Joana Santos Lima da Silva
Mestre em Conservação e Restauro

Ângelo de Sousa's photographic and film collection: strategies for the preservation of colour slide-based artworks

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Orientador: Professora Doutora Ana Maria Martelo Ramos, Professora Associada, Faculdade de Ciências e Tecnologia - Universidade NOVA de Lisboa, Caparica, Portugal.

Co-orientador: Professor Doutor Bertrand Lavédrine, Diretor, Centre de Recherche sur la Conservation, Paris, França.

Doutora María Jésus Ávila, Coordenadora, Centro de Artes Visuales Fundacíon Helga de Alvear, Cáceres, Espanha.

Júri:

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Prof. Doutora Lúcia Gualdina Marques de Almeida da Silva Matos
Prof. Doutora Ana Maria Martelo Ramos

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To my family

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Publications

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Abstract

The Portuguese artist Ângelo de Sousa (1938-2011) produced noteworthy work in photography and experimental film. However, a lack of in-depth studies focusing on the use of these media by the artist is acknowledged. Thus, his work has been studied, particularly through unpublished documentation found in the artist's house and in public archives, bringing new insights into his production. Despite the delay in the artistic context felt in Portugal in the post-modern period, Ângelo de Sousa produce photographic and film work perfectly in line with that of other international artists. The slide-based artwork *Slides de Cavalete* (1978-1979), constructed with the additive synthesis of colours, stands out as an example of the inventiveness achieved by the artist with these media. The production process behind *Slides de Cavalete* has been studied and reproduced, allowing for a thorough understanding of the work and contributing to the definition of its significance.

The photographs and films have been gathered together in his house. Since typologies, quantities and condition of the materials were unknown, a survey was carried out to enhance knowledge of the collection and to define preservation priorities. Accordingly, 35 mm chromogenic reversal films (slides), used to produce almost all his photographic colour work, was highlighted as the set in highest risk due to colour change detected in one third of these materials. Thereby, slide-based artworks by Ângelo de Sousa were studied in further detail.

The display options undertaken by the artist during his lifetime have been investigated, in order to guide the decision-making process regarding the exhibition and preservation of his slide-based artworks. *Slides de Cavalete* was selected as a case study, and the history of its exhibition was assessed by searching for documentation and interviewing people. Thus, it is understood that the work was first presented projected on a canvas over an easel, in 1979. Since the artist's death, the work has been presented without this setup, and recently, as a digital projection. An exhibition was conducted at FCT NOVA, to test the variability of the work displayed with a digital and a slide projector. Based on a questionnaire, a clear preference for the slide projection was acknowledged. Thus, guidelines for the exhibition of *Slides de Cavalete* are defined, following its first presentation.

Considering that chromogenic reversal films are highly susceptible to colour change and that there is still much to know about these materials, their molecular characterization and degradation has been studied. Different pathways to characterize chromogenic dyes are suggested based on chromatographic and spectroscopic techniques. Additionally, a methodology to accurately monitor colour change in these materials has been defined, based on samples artificially aged at different temperatures (50, 60, 70 and 80˚C) and relative humidity (40% and 60%). The samples were assessed using spectrophotometry with optical fibre probes in the ultraviolet-visible range. From the spectral data, intensity maximums, CIE L*a*b* coordinates and the total colour variation (ΔE*) have been determined. Optical microscopy and digitization have also proven useful for degradation assessment on these materials.

Keywords: Ângelo de Sousa; *Slides de Cavalete* (1978-1979); 35 mm chromogenic reversal films; slide-based artworks; exhibition; display; chromogenic dyes; monitoring; colour change; UV-vis spectrophotometry.

Resumo

Ângelo de Sousa (1938-2011) produziu uma obra notável em fotografia e filme experimental. Contudo, uma falta de estudos aprofundados focados nestes meios expressivos foi identificada. Por este motivo, o trabalho do artista foi estudado, maioritariamente, através de documentação inédita encontrada em sua casa e em arquivos de acesso público permitindo trazer novas perspetivas sobre a sua obra. Apesar do atraso sentido no contexto artístico português no período pós-moderno, Ângelo de Sousa desenvolveu o seu trabalho fotográfico e fílmico em linha com o de outros artistas internacionais. A obra *Slides de Cavalete* (1978-1979), construída através da síntese aditiva das cores, ilustra admiravelmente a criatividade alcançada pelo artista com estes suportes. O processo de produção desta obra foi estudado e reproduzido, permitindo um conhecimento mais profundo sobre a mesma e contribuindo para a definição da sua significância.

As fotografias e filmes do artista encontram-se guardadas em sua casa. Uma vez que a tipologia, quantidades e estado de conservação dos materiais era desconhecida, foi realizado um levantamento de forma a aumentar o conhecimento sobre a coleção e definir prioridades a nível da sua preservação. Assim, os diapositivos cromogéneos com formato 35 mm (slides), usados para produzir a quase totalidade da sua obra fotográfica a cores, foram sinalizados como o conjunto em maior risco devido à alteração de cor detetada em cerca de um terço destes materiais. Assim, algumas das suas obras com suporte em slide foram estudadas em detalhe.

As opções tomadas pelo artista relativas à exposição da sua obra foram investigadas, de forma a sustentar a tomada de decisão sobre a apresentação de obras com suporte em slide. A obra *Slides de Cavalete* foi selecionada como um caso de estudo e a história da sua exposição foi estudada através de pesquisa documental e realização de entrevistas. Desta forma, percebeu-se que a obra foi exposta pela primeira vez em 1979 projetada numa tela colocada sobre um cavalete. Desde a morte de Ângelo de Sousa, a obra tem sido apresentada sem a utilização destes dispositivos, e recentemente, através de uma projeção digital. De forma a testar a variação da obra mostrada com um projetor digital e com um projetor de slides, foi realizada uma exposição na FCT NOVA. Com base num questionário realizado neste contexto, percebeu-se que a grande maioria dos visitantes preferiu a apresentação da obra com projetor de slides. Apresentam-se, assim, diretrizes para a exposição da obra tendo por base a sua primeira apresentação.

Considerando que os diapositivos cromogéneos são altamente suscetíveis à alteração de cor e que existe ainda muito para descobrir acerca destes materiais, a sua caracterização molecular e degradação foram estudadas. Diferentes formas de identificar corantes cromogéneos foram propostas com base em técnicas cromatográficas e espectroscópicas. Adicionalmente, foi definida uma metodologia para monitorizar precisamente a alteração de cor nestes materiais com base em amostras artificialmente envelhecidas a diferentes temperaturas (50, 60, 70 e 80˚C) e humidade relativa (40 e 60%). As amostras foram seguidas através de espectrofotometria com fibras óticas, na gama do ultravioleta-visível. Através da análise espectral, determinaram-se máximos de absorvância, coordenadas CIE L*a*b* e a variação total de cor (ΔE*). A microscopia ótica e a digitalização também revelaram elevado potencial para o seguimento da deterioração nestes materiais.

Palavras-chave: Ângelo de Sousa; *Slides de Cavalete* (1978-1979); diapositivos cromogéneos 35 mm; slides; exposição; corantes cromogéneos; monitorização; alteração de cor; espectrofotometria UV-vis.

Table of contents

List of figures

List of tables

Notations and abbreviations

E_a	activation energy
ANSI	American National Standards Institute
ATR	attenuated total reflectance
B	blue
CA	cellulose acetate
CDA	cellulose diacetate
CTA	cellulose triacetate
CAM	Centro de Arte Moderna, Fundação Calouste Gulbenkian
CAC-MNSR	Centro de Arte Contemporânea, Museu Nacional Soares dos Reis
CD	compact disc
C	cyan
CMY	cyan, magenta and yellow colours
DCR	Department of Conservation and Restoration
DIR	development-inhibitor releasing couplers
D.O.P.	developing-out-papers
DSC	differential scanning calorimetry
DVD	digital video disc
Mini DV	digital video (S-size)
DVCAM	digital video (Sony)
ESI	Electrospray ionization
T_f	final temperature
t_f	final time
EMC	equilibrium moisture content
FBAUP	Faculdade de Belas Artes, Universidade do Porto
FTIR	Fourier-transformed infrared spectroscopy
A	frequency factor
RXP	Fuji Fujichrome Provia 400X Professional
FCG	Fundação Calouste Gulbenkian
T_g	glass transition temperature
G	green
Hi8	high-band Video8
HPLC-DAD	high-performance liquid chromatography - diode array detector
HPLC-MS	high-performance liquid chromatography - mass spectrometry
IR	infrared
T_i	initial temperature
t_i	initial time
ICC	International Color Consortium
ISO	International Standard Organization
JND	just noticeable difference
ET	Kodak Ektachrome 160T
EPT	Kodak Ektachrome 160T Professional

M___ magenta
m/z___ mass-to-charge ratio
λ_{max}___ maximum wavelength
MeOH___ methanol
d_{min}___ minimum density
N___ neutral grey
NEÂdS___ Núcleo de Estudos Ângelo de Sousa
OM___ optical microscopy
PE___ polyethylene
PMMA___ poly(methyl methacrylate)
PS___ polystyrene
QDI___ quinonediimine
k___ rate constant
R___ red
RGB___ red, green and blue colours
RH___ relative humidity
R_f___ retardation value
R_t___ retention time
T_{room}___ room temperature
SQDI___ semi quinonediimine
TIFF___ tagged image file format
T___ temperature
TGA___ thermogravimetric analysis
TLC___ thin-layer chromatography
t___ time
ΔE^*___ total colour variation
UV___ ultraviolet
UV-vis___ ultraviolet-visible
FCT NOVA___ Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia
VHS___ video home system
v___ volume
wt___ water content
λ___ wavelength
W___ white
WWII___ World War II
Y___ yellow

The maximum effect with minimum resources. Or: the maximum efficacy with minimum effort. Or, yet: the maximum presence with minimum shouting.

Ângelo de Sousa in *Ângelo: Pinturas dos Anos 60*, Lisbon: Galeria Valentim de Carvalho, 1985.

Chapter 1

Scope and outline of the dissertation

1.1. Background of the research project

Ângelo de Sousa (1938-2011) has been considered one of the most important Portuguese contemporary artists. In accordance with Bernardo Pinto de Almeida[1] (2016, 228):

> "He was a unique, complete artist, like few others. One of the few whose work reached the level of being able to be shown anywhere in the world, coinciding, happily and precisely, with his time in history. He influenced his contemporaries and many others who came after, both formally and through his attitude, even when this was not immediately obvious."

During his life, Ângelo de Sousa was mainly recognized for his work in painting, drawing and sculpture, although he also developed a notable oeuvre in photography and film since the 1960s up to his last years of artistic production. He left thousands of unseen works, including photographs, and also several experimental films. As explained by Sérgio Mah[2] (2017, 12):

> "His work in photography and film was not a by-product or occasional distraction from his main creative output; instead, it played a central and propelling role at the heart of his artistic practice and imagination."

The slide-based artwork *Slides de Cavalete* (1978-1979), composed of one hundred chromogenic reversal films constructed with the additive synthesis of colours, stands-out as a wonderful example of the inventiveness achieved by the artist with these media (Fig. 1.1).

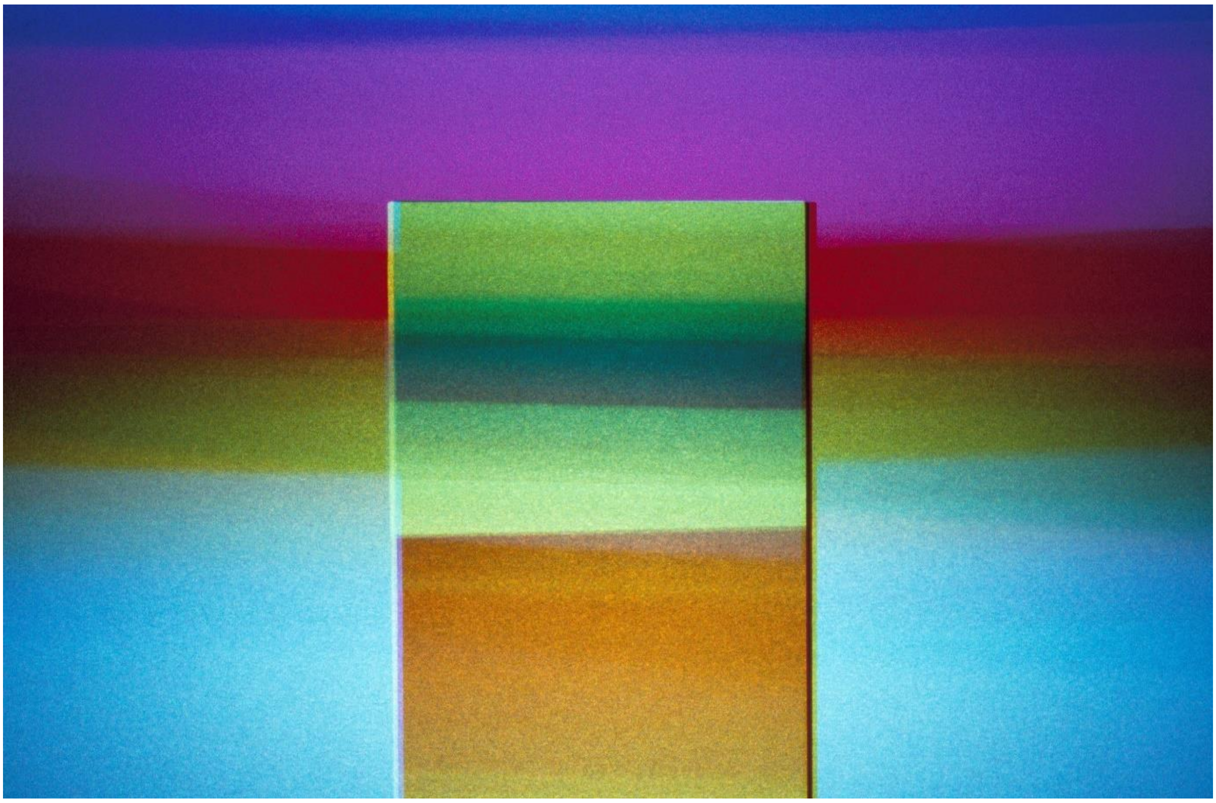

Figure 1.1 - Ângelo de Sousa, *Slides de Cavalete* (1978-1979), 35 mm chromogenic reversal films with cellulose acetate base.

[1] Bernardo Pinto de Almeida is a professor at Faculdade de Belas Artes, Universidade do Porto (Porto, Portugal) and a connoisseur of the artist's work. Since the 1980s, Almeida has been publishing writings dedicated to the artist's production.

[2] Sérgio Mah, professor and curator, is currently the theorist who has been most devoted to the study of Ângelo de Sousa's photographic work.

Despite the importance of these media in his artistic creation, only a few photographs and films were exhibited until 2001. The exhibition *Sem Prata* (2001) held at Fundação de Serralves (Porto, Portugal), was entirely dedicated to the photographic and film work by Ângelo de Sousa, and the first to display a representative set of these supports. Also, for the first time, consistent information about this production was collected and published within the framework of that exhibition. In the last few years, there has been a growing interest in his photographs and experimental films. Consequently, this parcel of the artist's production has been gaining in importance, contributing to (re)affirm the consistency and uniqueness of his overall work. In this regard, the exhibition *Encontros com as Formas* (2014) and the publication *Cadernos de Imagens* (2017), both from the authorship of Sérgio Mah, can be highlighted.

After Ângelo de Sousa's death, his son, Miguel de Sousa, inherited a significant part of his work, which includes paintings, drawings, metal and plastic sculptures, photographs and films. This vast collection has been gathered in the artist's house at Foz (Porto, Portugal). The Department of Conservation and Restoration (DCR) from Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia (FCT NOVA) and the artist´s heir have established a protocol entitled *Ângelo de Sousa´s Collection: Documenting, Cataloguing and Conserving to a better Knowledge and Use*. This partnership was born from the ambition to organize, preserve and disclose the global collection, which includes not only the artworks, but also documentation related to the artist´s production, materials and library, which all together allow for a complete assessment of the artist work. In 2015, the non-profit association Núcleo de Estudos Ângelo de Sousa (NEÂdS) was created to find the means to achieve these same goals. From this background, the present dissertation started to be developed focusing on the study of the photographic and film collection by Ângelo de Sousa[3].

1.2. Scope of the work

The primary purpose of this research was to contribute to the preservation of Ângelo de Sousa's photographic and film collection. To do so, the present study was supported on both social and natural sciences. In what concerns the conservation of modern and contemporary art, the need for multiple disciplines (conservation and restoration, conservation science, art history, philosophy, among others) to achieve a proper interpretation and intervention in the artworks (Hummelen and Sillé 2005, 10) was recognized already in the 1990s (Macedo 2008, 39). The meanings explored by modern and contemporary artists in their creations, as well as the materials used for their production, includes a diversity and complexity of possibilities inexistent in traditional art. Thus, in order to select the better solutions for the preservation of modern and contemporary artworks, both the definition of its significance and material composition should be pursued (Sillé 2005, 14). Accordingly, a transdisciplinary approach was adopted within the framework of this study to accomplish the established goal.

[3] As positive outputs from this partnership, two PhD thesis are being developed focusing on Ângelo de Sousa's works: the present dissertation and the study by Sara Babo, focusing on his poly(methyl methacrylate) sculptures. A Master's dissertation entirely dedicated to the polystyrene sculptures *Pequenas Esculturas* (1975) was also presented by Milton Raimundo in 2016. The painting coating from the same artwork was also one of the case studies from the Master's thesis by Artur Neves, defended in 2017.

Prior to this research, knowledge about this parcel of the artist's collection was scarce. Although some experts, such as art historians and curators[4], had been looking at Ângelo de Sousa's photographs and films (mostly to produce exhibitions), no information related to the typology and condition of these materials had been collected and systematized. Therefore, as a first and demanding approach to the collection, both the archive and the materials were assessed. After surveying the collection, conservation priorities could be established. It was understood that the colour images produced by the artist, which represents almost a half of his photographic production, were mostly captured in 35 mm chromogenic reversal films (slides). Moreover, visible colour change and/or fading was detected in more than one third of the slides. However, in works in which the content of the image is not an evident reproduction of the world, such as *Slides de Cavalete*, it is difficult to understand if dye fading and/or change in colour balance are occurring and, if so, to what extent. Thus, it is likely that some works present colour change without being noticed. Considering this alarming scenario, this dissertation strived to propose strategies for the proper preservation of the slide-based artworks by Ângelo de Sousa, focusing on both immaterial and material issues.

Although a growing interest in Ângelo de Sousa's work had been acknowledged, a lack of in-depth studies dedicated to the exploitation of these media by the artist, and relating all the documentation left by the artist (library, notebooks, sketches, materials, equipment, among others) with his photographs and experimental films, was recognized throughout this investigation. Therefore, some artworks were studied through published and unpublished documentation found in Portuguese archives and in Ângelo de Sousa's house, and through the data collected during the conducted survey. Even so, the present research did not have the ambition to contribute to a historiography of the use of these media by the artist under study. In the present study, special attention was paid to works in which the artist explored colour as a means of expression. Some of these works, such as *Slides de Cavalete*, proved to be truly original and ingenious by showing the mastery of the artist over the photographic medium and colour manipulation. Considering that colour change was detected in a significant number of Ângelo de Sousa's colour images, the risk of losing value is high. Thus, for a better understanding of the meaning of some case studies and of the impact of colour change, the production process of *Slides de Cavalete* (and other works produced within the same framework) was for the first time investigated and reproduced.

Slide-based artworks can be classed as time-based media art since they have duration as a dimension. Contrarily to 'conventional' art, these types of works only exist when exhibited, and therefore, have an intangible and temporary nature (Laurenson 2011, 36). These characteristics make slide-based artworks challenging for conservators. As Tina Weidner[5] (2012a) has stressed, the main fragility of slide art relies on its media technologies dependence, raising problems regarding its long-term preservation and display. Since the original slides should not be displayed due to the aggressive conditions to which they would be subjected (light, heat, dust), the installation of a slide-based artwork is dependent on the ability to replicate the 35 mm slides. Exhibition copies might be produced by replicating the technology of the originals (duplicates) or converting into another technology, such as digital (Weidner 2012a). For these reasons, while taking the decisions regarding the installation, the originally used technology might be disregarded. Now that Ângelo de Sousa's photographs and films

[4] For instance Sérgio Mah (independent curator), Jacinto Lageira (curator at Fundação Calouste Gulbenkian, Paris), Mário Valente (assistant curator at Colecção Caixa Geral de Depósitos, Lisbon), among others.

[5] Tina Weidner developed a research project at the Tate dedicated to the preservation of slide-based artworks (*Dying Technologies: the end of 35 mm slide transparencies*), having made an important state-of-the-art study regarding the chromogenic reversal films' technology and the available possibilities for the display of these works.

have been exhibited more often and without the presence of the artist, what can be done to ensure that his slide-based artwork being properly presented? What can be done to preserve the artworks' significance during its presentation? Focusing on these questions, an investigation was carried out with the aim of substantiating the decision-making process concerning the presentation of Ângelo de Sousa's slide-based artwork. Since there are no universal solutions and each work must be analysed individually (Berndes 2005, 167), only one work could be deeply examined within the timeframe of this study. Being one of the most interesting photographic works by Ângelo de Sousa (Mah 2014, 23), *Slides de Cavalete* was studied in further detail and guidelines for the exhibition of this work were proposed.

Although in the last decades significant improvements have been achieved in the stability of chromogenic products, these materials are intrinsically vulnerable to chemical degradation, having poor long-term stability. Chromogenic dyes are highly susceptible to oxidation and hydrolysis, both induced by light (light fading) and/or RH and T (dark fading) (Wilhelm and Brower 1993, 22). Continuous contact with environmental agents gradually disrupts the chromophore molecules, leading to the formation of colourless degradation products, responsible for the fading of the image (Reilly 1998, 9). Since the different dyes present in a chromogenic product have different molecular structures, these materials are prone to shift the original colour balance. Residual colour couplers are also vulnerable to oxidation, producing yellow stain (Bergthaller 2002c, 265). Accordingly, it is highly likely for a collection of chromogenic materials, such as the one under study, to present the aforementioned degradations. In order to preserve these materials, the recommendations are toward storing them under controlled environmental conditions (temperature – T, and relative humidity - RH) (Pénichon 2013, 205). Moreover, since the fading rate varies from material to material, chromogenic photographs should be monitored closely to detect any changes (Pénichon 2013, 204). However, during the present investigation, a gap of knowledge regarding chromogenic materials in general, and chromogenic reversal films specifically, was detected. Up to now, there are several references describing molecule structures, degradation pathways and preservation guidelines. Nonetheless, nowadays it is still difficult to answer to the following questions: Which dyes are present in a specific artwork and how long will they last? For how much time will we be able to see its colours in the proper balance, or was there any colour shift already? Thus, within the framework of this dissertation, the identification and characterization of chromogenic dyes was pursued by compiling several analytical techniques. Promising results were achieved with this approach, opening new paths for the understanding these materials. Yet, this was only a preliminary study and needs further development. Additionally, a methodology to accurately monitor colour change in chromogenic reversal films has been defined, based on reference samples conducted to artificial ageing. The ageing experiment was induced at different T and using samples with different water contents, allowing us to draw conclusions about the degradation of these materials and, consequently, about their preservation. This methodology can also be applied to other collections with similar characteristics.

Hence, the main research goals can be summarized as follows:

i) Description of the typology and condition of the photographic and film materials used by Ângelo de Sousa and definition of preservation priorities for the collection;
ii) Study of the photographic and film work by Ângelo de Sousa and his technique;
iii) Definition of guidelines for the exhibition of Ângelo de Sousa's slide-based artworks;
iv) Preliminary study into the characterization of chromogenic dyes;
v) Development of efficient methods for monitoring dye fading in chromogenic reversal films.

1.3. Outline of the thesis

In this first chapter, a brief description is made of the background from which this dissertation arose, an explanation of the main topics and goals explored in this research, and how the thesis is structured. The remaining chapters are organized as follows:

Chapter 2 – Introduction aims at providing the background knowledge for all the subjects discussed within the framework of this dissertation. This chapter starts with a section dedicated to the use of photography and experimental film by *neo avant-garde* artists, both in the international and national scene. The aim of this section is to frame Ângelo de Sousa in his period of production, helping to understand his photographic and film production. The following section presents the artist under study and his work, followed by an overview of the investigations focusing on his photographic and film work carried out until the present. The last section presents the state of the art regarding the preservation of slide-based materials, both considering their material and immaterial nature. A detailed description of chromogenic reversal film materials and technology is also provided for a better understanding of their composition and behaviour over time.

Chapter 3 - Assessing Ângelo de Sousa's photographic and film collection unveils the characteristics of Ângelo de Sousa's photographic and film collection. The history of the archive and environmental conditions of the storage room are first described. Then, the results from the survey conducted to the materials composing the archive are presented, allowing understanding of the typology, quantities, contents and conservation condition of the collection. From the obtained results, materials at risk were detected, as well as the collection fragilities and conservation priorities.

Chapter 4 - Contributions to a biography of Ângelo de Sousa's photographic and film work contributes to a broader overview of Ângelo de Sousa's photographic and film work. By taking some works as examples, this chapter shows the experimental character of the photographs and films produced by him, which was in line with the work produced by other international artists. Grounded on the additive and subtractive syntheses of colours, Ângelo de Sousa produced several innovative works in which he explored the idea of colour, namely *Slides de Cavalete*, among several others. For a deeper understanding of this work (and others), its production process was reproduced based on published and unpublished documentation found at the archive and this is presented in the chapter.

Chapter 5 - Discussing display options for slide-based artworks by Ângelo de Sousa proposes guidelines to assist the decision-making process concerning the preservation and display of slide-based artworks by Ângelo de Sousa. Considering the absence of the artist, this chapter sought to gather evidence on the choices made by him over time concerning the display of his photographs and films in general, and his slide-based artworks in particular. Since every work should be analysed as an individual case, *Slides de Cavalete* was studied in further detail. The display history of the artwork was accessed by looking for documentation related to its exhibition and by interviewing people who could have witnessed its presentation. Furthermore, an experimental study was conducted at the Library from the FCT NOVA, where *Slides de*

Cavalete was displayed with a digital projector and a conventional slide projector. The visitors of the exhibition were invited to fill out a questionnaire and to share their perception of the work under these two distinct scenarios of exhibition. The results of this investigation are presented in the last section of this chapter. Additionally, a digital restoration is proposed based on the studies conducted by Henry Wilhelm and Carol Brower (1993).

Chapter 6 - Launching new strategies for the preservation of chromogenic reversal films explores innovative approaches to the preservation of chromogenic reversal films. On the one hand, different pathways to characterize dyes from these materials were tested on samples found in Ângelo de Sousa's archive. Thus, procedures to identify chromogenic dyes were proposed based on the use of different analytical techniques, such as Thin-layer Chromatography (TLC), High-Performance Liquid Chromatography with Diode Array Detector (HPLC-DAD), High-Performance Liquid Chromatography-Mass Spectrometry (HPLC-MS), and Infrared and Raman Spectrometry. Moreover, this chapter presents accurate solutions for monitoring colour change in chromogenic reversal films, by using UV-vis spectrophotometry with optical probes and by calculating CIE L*a*b* coordinates. The methodology was validated in samples artificially aged (in one of the most common model of chromogenic reversal films used by Ângelo de Sousa), and subsequently applied to original artworks from the collection under study. Other techniques such as optical microscopy and digitization proved to be useful in the assessment of colour change in chromogenic materials.

Chapter 7 - Concluding remarks and future work summarizes the main findings and results discussed within this thesis, and makes suggestions for future research lines on the study of Ângelo de Sousa's collection and on the conservation of slide-based materials.

Chapter 2

Introduction

2.1. Photography, experimental film and the *neo avant-garde*: an overview

This section presents an overview of the production of photography and experimental film in the post-war art period (from the mid-1950s), both in the international context and in Portugal. The appropriation of photography and film by artists in this time is briefly exposed. Special emphasis is given to artists who worked with these media in an experimental condition, such as Ângelo de Sousa did. The Portuguese context, being defined by a specific political, cultural, economic and social background, shows its singularities in the use of photography and film, in which Ângelo de Sousa took part as a key personality.

The aim of this section is to frame the artist under study in his period of production, helping to understand his photographic and film production. This investigation was the starting point for a deeper research, presented in chapter 4. The Portuguese artistic panorama and cultural activities occurring in that period were also important to produce the research developed in chapter 5.

2.1.1. International Context

2.1.1.1. Photography

At the time of its origins in 1839, photography was identified as a mirror of reality. During that time, a positivist mentality was asserting in Western societies and photography was largely legitimated by the scientific field due to its technical and automatic nature. Also, in art, photography was associated with a mimetic language and with the faithful representation of the reality. Consequently, other art forms, such as painting, gradually freed themselves from the ambition of naturalistic representation. The culmination of this liberation has been reached in Modernist Art (Mah 2003, 17-18).

This objectivist perspective was felt in photography up to the mid-20th century, creating a distinction between the artistic value of photography and that from the traditional fine arts. However, it is pertinent to recall the importance of the *avant-garde* artists from the 1920s, who allowed for the creation of breaking points and for the development of new perspectives in photography, namely through the exploitation of optical devices and the photochemical manipulation of films (Garrel 1992, 2). Photograms, for instance, were used as a way of subverting the photographic image, through the devaluation of the photographic camera and valorisation of the photograph as a photosensitive media. The *rayographs* from Man Ray (1890-1976)[1] are known examples (Fig. 2.1, left). Another example of photographic emulsion manipulation was the controlled overexposure, also explored by Man Ray in his *solarizations*. Photomontages, negative prints, and the combination of photography with both typography and graphic design were other forms of experimentation used by the *avant-garde* artists as a way of revolutionizing the existing visual language and transforming the modern world (Phillips 1994, 66-68). As a result, abstracting arrangements with the frequent subtraction of figuration can be found (Squiers 2013, 24).

[1] Man Ray is an American artist established in France, who has been associated to the Dadaist and Surrealist movements. Ray is well known for his photographs, although he worked with several materials. *Rayograph* was the designation attributed to his photographs without a camera (Rexer 2013, 83).

Other personalities contributed to the definition of photography as an autonomous artistic medium. Among them, the work of both Alfred Stieglitz (1864-1946)[2] and László Moholy-Nagy (1895-1946)[3] should be stressed. Stieglitz sought to aestheticize the photographic image. Moholy-Nagy defined a perceptive revolution or a *new vision*, based on the photographic image and on the phenomenon of light (Fig. 2.1, right). This *new vision* was also shared internationally by other well-known artists such as Alexander Rodchenko (1891-1956)[4].

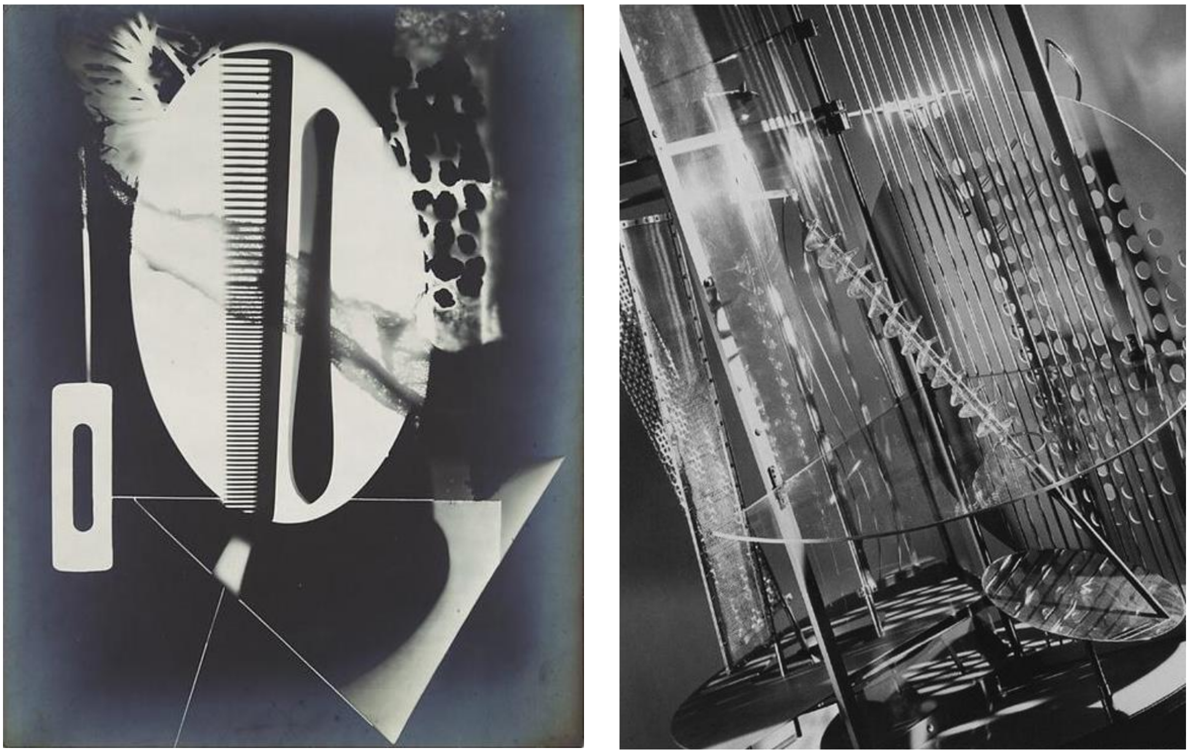

Figure 2.1 - Examples of *avant-garde* contributions to photography as an independent medium; **Left:** Man Ray, *Rayograph [Comb, Straight Razor Blade, Needle and Other Forms]* (1922), gelatine silver print, 22.2 x 16.9 cm. MoMA collection; **Right:** László Moholy-Nagy, *A Lightplay: Black White Gray* (c. 1926), gelatine silver print, 37.4 x 27.4 cm. MoMA collection.

Despite the importance of these approaches, they were not sufficiently strong to release photography from the stigma of the realism (Mah 2003, 18-19). Only in the mid-1950s, in the post-war

[2] Alfred Stielglitz was an American photographer who promoted photography as a fine art. Both his work and activities distinguished him. He organized several exhibitions, he founded the *Photo-Secession* group, and was the editor of the journal *Camera Work*. He was one of the most influential people of the Pictoralism movement, although his work was later influenced both by Cubism and straight photography (Mah 2003, 19).

[3] Lászlo Moholy-Nagy was a Hungarian artist. Vanguardist and experimentalist he used new industrial techniques, such as photography and film, as media with a particular expressive power and as the primary vehicle for the modern consciousness. He believed that the technique could capture the world in a unique and different way from the human eye. He valorized these media as fine arts. His ideas were summarized in his book *The New Vision, from Material to Architecture* (1938). His participation in the education of Bauhaus relied on Constructivism principles (Fiedler 2006, 15).

[4] Alexander Rodchenko was a Russian artist who worked in several fields, such as painting, sculpture, graphic design and photography. He was one of the main figures behind Constructivism in Moscow. As Moholy-Nagy, he believed that photography could be the ideal medium for the definition of a *new vision* in a new technological era, proper for a revolutionary society (Phillips 1994, 82).

context and with both the resumption of cultural exchange and proliferation of mass media, was a favourable scenario for a non-traditional approach to audio-visual media installed (Garrel 1992, 2).

From the 1960s onwards, essays on semiology and ideological criticism multiplied. This enabled the creation of new and different visions about the values of the image, contributing to the legitimacy of the photographic medium. Also, the growing interest of artists in psychology allowed for the valorisation of author subjectivity and the reinforcement of individual expression, which was being affirmed during that period. This view was especially important for the photographic media, to both define the role of the author as a determining factor in the development of the image, and to disregard the still existing idea of an automatic technique (Mah 2003, 21).

During the 1960s, as an influence of the breakthroughs achieved at the beginning of the century, artists began to question the role of art and the artist in a more incisive way. Also, they started to deconstruct the prevailing idea of a work of art. In this context, new media of expression, such as installation, performance and audio-visual, were often used by artists as a way of challenging and rethinking traditional disciplines (Wandschneider 1999, 29). Quoting the American critic and curator Lyle Rexer (2013, 133): "If modernist photography could be summed up in the world *investigative*, then the photographic tenor of the 1960s could be likewise captured by the word *subversive*". This subversive attitude, which lasted until the 1990s, was felt not only in photography but also in cinema (as discussed later), as well as in the fine arts world (Rexer 2013, 134).

Some *neo avant-garde* artists[5] adopted photography and film as privileged media of expression, contributing to the dissemination of these supports into contemporary art (Squiers 2013, 9), and favouring their assimilation in museums and art galleries (Mah 2015, 28). According to Rexer (2013, 137), Pop Art and Minimalism were particularly important movements to photography because they opened new possibilities. Pop art artists made an appropriation of photographic images and juxtaposed them to other expressive media. In this way, they reduced them to a common denominator, the final work, in which the question of photograph authorship was diluted. Thus, they questioned the importance of the artist's subjectivity and transformed photography into both a cultural object, whose meaning is constructed by the observer, and a physical object, exploited by its technical/aesthetical qualities. Alongside with appropriation, other procedures such as serialization, overlapping, and montage also opened multiple paths between the relationship of painting and photography. Robert Rauschenberg (1925-2008)[6] and his emblematic *combines* made from the turn of the 1950s to 1960s were examples of this transfer of unconventional materials (including photographs) to painting and sculpture (Fig. 2.2, left) (Rexer 2013, 136-137). Andy Warhol (1928-1987)[7], in his famous series of paintings *Marilyn* (1963), representing one of the greatest mass culture icons, simulated, through repetition, film sequencing and the mechanical reproduction of the photographic medium (Magalhães 2015a, 103). Additionally, due to its technical specificities, photography was a medium that perfectly fitted the needs of Minimalism and Conceptual art. On the one hand, photography has a repetitive capacity, derived from its technical reproducibility and mechanical nature. On the other hand, it has an

[5] The term refers to a loose grouping of North American and Western European artists emerging in the post-war period, who revised some of the historical *avant-garde* proposals (Foster 1994, 5).
[6] Robert Rauschenberg was an American artist who worked with several media (painting, sculpture, graphical arts, photography, etc.). He is known for his *combines*, which had significant repercussions on the artists of his time, particularly artists from the Pop Art movement (Rexer 2013, 137).
[7] Andy Warhol stands out in life for his work and for keeping a great artistic community around him. He is one of the best-known artists who used photography and film in the early 1960s. His film production became known for his popularity and for the high number of films that he produced (Magalhães 2015a, 100).

undefined character, derived from its capacity of creating illusory effects. Thus, photography was adopted as a form of compositional simplification. Within this context, the photographer Ray K. Metzker (1931-2014) started to create his *composites* in the 1960s by juxtaposing images extracted from different frames, captured in the same sequence. These composite images, when presented as a set, loose their readability, acquiring an abstract nature (Fig. 2.2, right) (Rexer 2013, 137-139).

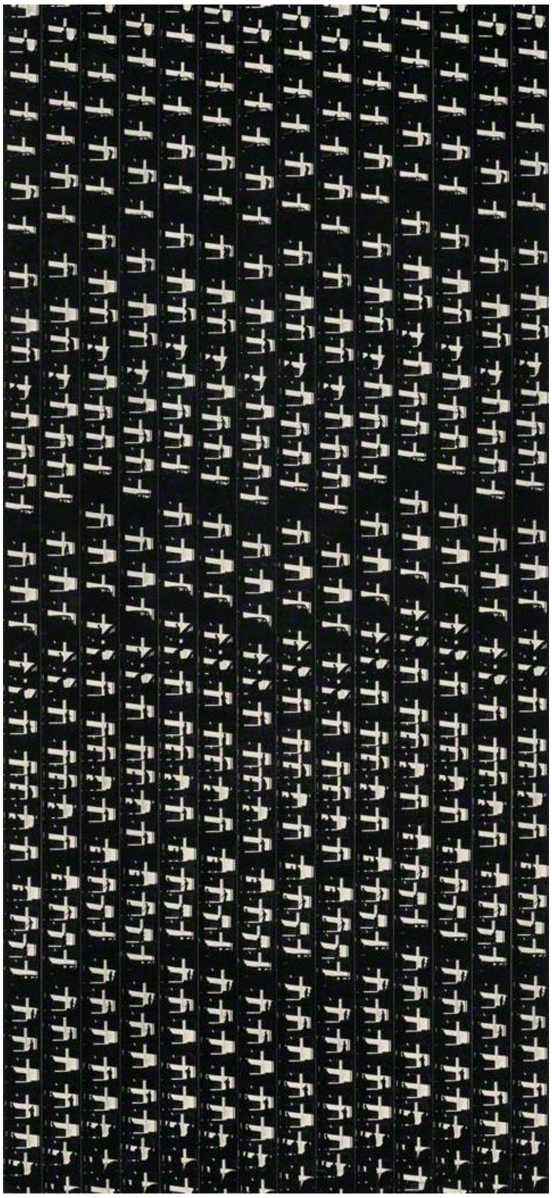

Figure 2.2 - Examples of artists' appropriation of photography; **Left:** Robert Rauschenberg, *Untitled* (c. 1954), combine: oil, pencil, crayon, paper, canvas, fabric, newspaper, photographs, wood, glass, mirror, tin, cork, and found painting with pair of painted leather shoes, dried grass, and Dominique hen on wood structure mounted on five casters, 219.7 x 94 x 66.7 cm. The Museum of Contemporary Art of Los Angeles collection; **Right:** Ray K. Metzker, *Composites: Parking Pavilion* (negatives, 1966; prints, 1982), gelatine silver print, 76 x 66 cm. The J. Paul Getty Museum collection.

All these contributions allowed photography to gradually free itself from the idea of a faithful representation of reality, to which it was associated since its inception. At the same time, photography was able to surpass its conventional limits and to define its own autonomous language, now supported by solid theoretical bases (Poivret 2010, 39).

According to Michel Poivret (2010, 68), a dichotomy was observed in the use of audio-visual media from the 1970s onwards. Sometimes it was used as a way of questioning the meaning of art, and sometimes as an exploitation of the photographic nature and materiality (Poivret 2010, 68). The conceptual and material recognition of these media, respectively, multiplied their use and allowed them to achieve a wider recognition, comparable to other art forms (Garrel 1992, 4-5).

Experimental photography, influenced by the historical *avant-garde* (from the beginning of the 20th century), focused on the identity and essence of the photographic medium (Poivret 2010, 39-40). Most of the experimental proposals came from artists who were not exclusively photographers, and that through their unconventional approach to the medium, were able to explore its material specificities (Squiers 2013, 13). Contrary to conceptual artists, who dematerialized the image, experimentalist artists supported their works in the exploitation of the materiality, often as a form of conquering identity and/or as a mean of abstraction. By working on the physical and chemical characteristics of the supports, they managed to reinvent light, colour, and composition (Squiers 2013, 9). In this context, the combination of mechanical processes with the manual intervention was frequent, as well as the mixing of images with different techniques (similar to what was done within Pop Art) (Squiers 2013, 13). The American artist James Welling (1951) sought to explore the technical components of photography, by transforming the materiality of the medium into the content of his images (Poivret 2010, 58). For instance, in his work *2-29 I (B15)* (1980) (Fig. 2.3, left) the artist explored light and its reflection on matter, enhancing its ability to outline the objects. Therefore, he produced a series of images with an abstract nature (Rogers 2000, 71). Frequently, the public has an active and leading role in the observation of the experimentalist proposals. Some artists have particularly explored the vision phenomenology by seeking the trigger of sensations and/or by establishing a relationship between the subject and the artwork (Poivret 2010, 56-57). For instance, the German artist Sigmar Polke (1941-2010), since the 1960s, explored photography to develop images that test the unconscious by stimulating the observer's psychotropics (Poivret 2010, 56). He also investigated the invisible and the unpredictable, namely by overlapping images and manipulating emulsions during processing to produce defects and create perceptually complex images (Fig. 2.3, right) (Squiers 2013, 15-16). In Polke's works, the various materials and overlapped layers composing the final image are often visible, revealing the artist's physical intervention on the object (Garrel 1992, 26).

Figure 2.3 - Examples of artworks by artists working the materiality of photography; **Left:** James Welling, *2-29 I (B15)* (1980), gelatine silver contact print, 8.9 x 10.2 cm. Artist collection; **Right:** Sigmar Polke, *Untitled (Mariette Althaus)* (c. 1973), gelatine silver print, 18 x 24 cm. Artist collection.

Many other artists whose influence extends to the present, such as Lucas Samaras (1936), Gerhard Richter (1932), and Floris Neusüss (1937), among others, can be named for their experimental proposals and for opening new paths for photography. However, their work is not explored here, since it surpasses the goal of this dissertation.

2.1.1.2. Experimental Film

As defended by the theorist Alan Leonard Rees (Rees 2011), some filmmakers chose to use the laboratory as a creative tool, giving rise to the so-called experimental film[8]. The experimental film appeared during the first *avant-garde* of the 20th century (van Ingen 2012, 19-20), and unlike photography, it was born dissociated from the realism culture.

The modernist artists found in film a new medium convenient to their *avant-garde* experiences. Futurists, for instance, made a manifesto claiming cinema to be synthetic, dynamic and free. Dadaists, in turn, used experimental film as a means for contestation (Rees 2009a, 31). Some artists also used experimental film as a sensory experience in which they could explore pure graphic abstraction, and through which they could often link music and colour[9]. Others, influenced by the work of Moholy-Nagy and the optical vision of the Cubist movement, sought to explore the specific properties of the medium in an analytical way to propose a new vision of reality. On this last subject, names such as the Dadaists Hans Richter (1888-1976) (Fig. 2.4) and Viking Eggeling (1880-1925)[10], and the Cubist Fernand Léger (1881-1955)[11] can be named (Rees 2009a, 28).

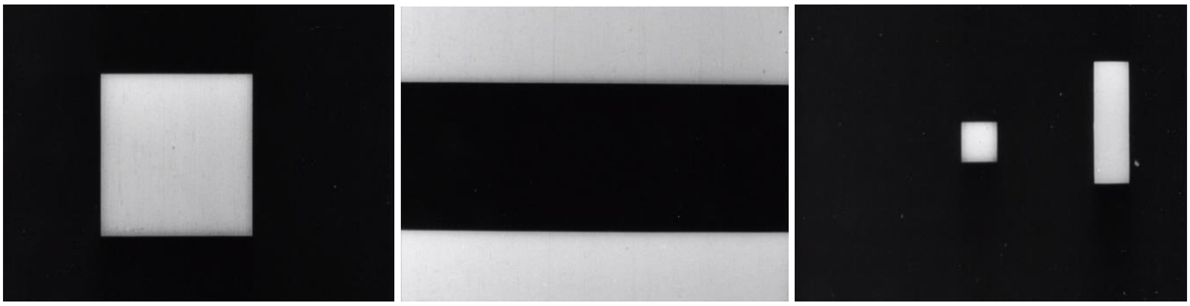

Figure 2.4 - Hans Richter, *Rythms 21* (1921-1924), three frames from the black-and-white 35 mm film. MoMA collection.

[8] Experimental film or *avant-garde* film is a type of cinema made on the margins of the film industry, often on an artisanal basis, and presenting a different structure and narrative than conventional cinema. The 16 mm and 8 mm film were the preferred format for this type of film. Later, new media, such as video, also started to be used (Rees 2011).

[9] This type of film was sometimes called synesthetic art, by connecting vision and hearing, so that the two senses could stimulate each other (Rees 2009a, 28).

[10] Hans Richter was an artist mostly known for his paintings, but he also produced an extensive body of work on film. He created abstract films such as *Rhytms* (1921). Viking Eggeling, also a painter, produced some experimental films like *Diagonal Symphony* (1921-1924). Artists of the same circle were part of the German absolute film movement, along with Walther Ruttman (1887-1941). This movement proposed the absence of the camera to create films without any representational referent, by manually introducing forms made of papers or paints (Elder 2008, 4-5).

[11] Fernand Léger was a French artist, mainly known for his paintings. In 1924 he made the *Ballet Mecânique*, one of the key films from Cubist cinema (Rees 2009a, 30).

According to Rees (2009a, 42), the first experimental films were produced within the context of the artistic movements of that time. However, despite being used as a means of rupture with the existing artistic practices, they were not strong enough to create independent movements. Nevertheless, these films had a significant impact on the artists of the following generations. Their influence was both felt as conceptual and formal counter-reactions, and as the adoption of similar aesthetic solutions. For instance, in the late 1920s, the Surrealists (influenced by Freudian theories) made films in which they created complex connections between images and subject, exploring the illusion enabled by the movement dimension, to represent unconscious states. The well-known film *Un Chien Andalou* (1929) by Luis Buñuel (1900-1983) and Salvador Dali (1904-1989) is one example (Rees 2009a, 31). Len Lye (1901-1980), on the other hand, began to make painted animations in transparent films during the 1930s and to explore the technology of some colour processes such as *Gasparcolor*[12], through the manipulation of the coloured emulsion layers (Rees 2009a, 42).

As reported by the artist and professor Sami van Ingen (2012, 22), in the late 1950s, and for the first time, filmmakers began to claim experimental film as a new and independent medium, even within the cinema. Therefore, experimental film started to be seen as an alternative to painting, sculpture, and other traditional supports, and not as an extension of them. Artists sought to move away from conventional cinema narratives by turning their films into autonomous aesthetic-perceptual experiences, and by opening doors for new generations of artists who consciously start working on the plasticity of film (van Ingen 2012, 22).

During WWII, many European artists such as Fernand Léger, Hans Richter, and Len Lye, among others, took refuge in the United States of America. According to Rees (2009b, 48), this generated a multicultural and very fertile artistic environment around filmmakers, in which the desire to escape from commercial cinema was shared. Within this context, two distinct paths of experimental film production started to grow. The first, headed by Maya Deren (1917-1961)[13], recovered the narrative feature of the *avant-garde* and created the *Psychodrama* style. The second, influenced by the abstract experimental films from Germany, merged the abstractionism with music and/or with the spontaneous appreciation of chance from the Dadaists and gave rise to the *Action Film* (Rees 2009b, 48).

As stated by Rees (2009b, 57), the late 1950s were marked by the contestation to the institutionalization of art by experimental filmmakers. Consequently, experimental film was marginalized and went underground. During that period, several stylizations began to appear, namely the *Metric film*[14] and the *Formal Film*[15] (Fig. 2.5). Other artists, such as Michael Snow (1929), worked on the experience and manipulation of time as a specificity proper from the film support (Rees 2009b, 57).

[12] Colour motion picture film system developed in 1933 by the Hungarian chemist Bela Gaspar (1898-1973). *Gasparcolor* films are composed of a subtractive three-colour process on a single film strip (Pénichon 2013, 206).

[13] Maya Deren was a Ukrainian filmmaker, activist and art critic. She initiated the *Psychodrama* style with the film *Meshes of the Afternoon* (1943), made in partnership with her husband. This style is characterized by a symbolic expressionism and by the valorization of the psyche (Rees 2009b, 48).

[14] *Metric film* is a genre of experimental film that adopts a specific discourse, such as the combination of static scenes, technical effects (e.g. flicker and loop) and/or collages between disjointed scenes. This allowed it to establish relationships between the various elements of the film in a minimalist language. The films by Peter Kubelka (1934) can be named as examples of this genre (Rees 2009b, 52).

[15] *Formal film* is characterized by the valorization of the film's materiality. Examples of this genre are the films by Stan Brahkage (1933-2003). Stan Brahkage, an American experimental filmmaker, explored the optical devices, the printing processes, and the surface of the films, acting directly on them with his hands or by using tools, and creating films strongly marked by an abstract expressionism (Rees 2009b, 55).

It is also relevant mentioning the importance of Jonas Mekas (1922)[16], whose performance supported the flourishing of the experimental film in New York's artistic environment. He was the founder of the magazine *Film Culture* in 1954 and of the *Anthology Film Archive* in 1969, a venue dedicated entirely to the study and exhibition of experimental film (Rees 2009b, 52).

Figure 2.5 - *Formal film*; **Left:** Stan Brakhage working on a movie film (Chodorov 2012).
Right: Stan Brakhage, *The Dante Quartet* (1987), one frame from the 16 mm chromogenic film. LUX collection.

Andy Warhol was one of the main characters in the art scene from the 1960s, and also in the experimental film scene. In his early films, he introduced the idea of immobility both by using repetitive actions in loop and by slowing down the projection speed in long-lived sequences (Magalhães 2015a, 104). His films gradually gained a greater complexity, also conferred by using multiple screens for projection and multiple projections on the same screen. According to the study conducted by Andreia Magalhães (2015a, 106-107), *Chelsea Girls* (1966) was the most successful experimental film to date, narrowing the gap between underground and commercial cinema.

From the 1960s onwards, some artists have also started to use more recent technologies to express themselves, such as video. However, according to Pedro Ferreira (2013, 33-34), those artists did not actually create radical visual reforms. Instead, they recycled the *avant-garde* styles adapting them to the preoccupations of their period.

The video, being composed of electronic signals, presents formal specificities that are distinct from analogue film, namely its immediate relationship with television (direct transmissions). On the other hand, its typology is more compatible and oriented to exhibition spaces, where monitors acquire a sculptural or performative feature. These characteristics enabled the artists to aspire to different conceptual and formal issues by using video. Therefore, video became an autonomous medium, appreciated and diffused by cultural institutions (Rees 2011, 16). Between 1960 and 1990, there was a gradual expansion of video art, which fitted perfectly both the purposes of provocation and questioning of the artistic object. Some artists adopted video as a social documentary, others transported it to their installations and performances (Ferreira 2013, 33).

[16] Jonas Mekas is a Lithuanian artist who emigrated to Brooklyn in 1944 with his brother Adolfas, with whom he actively participated in the dissemination and development of experimental film. His work is mainly characterized by the *cinema of mistakes*, and the vibrant films-poems, which portray casual moments/revelations of his daily life (Rees 2009b, 52).

2.1.2. National Context

In Portugal, during the dictatorial regime known as *Estado Novo* (1933-1974), photography was very much attached to the 'salons' aesthetic[17]. As defended by the artist and theorist António Sena (1998, 272-277), the photographic images created during that period tendentially presented an impervious discourse with a neorealist character and lack of formal dynamism.

Nevertheless, there were individual proposals by photographers such as Gérard Castello-Lopes (1925-2011), Jorge Guerra (1939), Costa Martins (1922-1996) and Vitor Palla (1922-2006), among others, who allowed for the introduction of novelties in the predominant discourse, namely in what concerns the exploitation of photographic technique (framing, contrast, lighting, etc.) (Sena 1998, 272-277).

Figure 2.6 - Fernando Lemos, *eu* (1949-1952), gelatine silver print (D.O.P.), 45 x 45 cm. Museu de Arte Contemporânea do Chiado collection.

The Portuguese artist Fernando Lemos (1926) was particularly important for the modernization of photography in Portugal, even though he only briefly contacted with this medium (1949-1952) and spent most of his life in Brazil. At the beginning of his artistic career, Lemos was associated with the surrealists Marcelino Vespeira (1925-2002) and Fernando Azevedo (1923-2002) (Serén 2002, 14-15). During that period, he took full advantage of the photographic technique to perform surreal spaces, which show some similarities with Man Ray's work (Herkenhoff 2004, 15). Starting from fortuitous images of the reality, Lemos used multiple exposures or later manipulations to move away from the reality (Fig. 2.6). The resulting images show a certain degree of unpredictability through which the artist seeks to surprise himself (Ávila 2001, 140-141). In other of his works, the artist used staged photographs in order to create Freudian environments where reality is replaced by the unconscious and dreams (Ávila 2001, 140-141). As stated by Maria do Carmo Serén (2009, 39), his vision, totally innovative in Portugal, influenced photographers of the next generation such as Jorge Molder (1947)[18] and Paulo Nozolino (1955). However, his work and the work of the above-mentioned photographers had a limited impact at the time, in both the artistic community and at the centre of traditional photography (Prata 2008, 95).

[17] The *salons* were events supported by *Estado Novo*, namely the *Salões Nacionais de Arte Fotográfica* (1932-1937) and later the *Salões Internacionais de Arte Fotográfica*. These *salons* typically did not encourage innovation in photographic production (Sena 1998, 12).

[18] Jorge Molder is a key figure in Portuguese photography. He was always independent and detached from the dominant practices. His photographs, sometimes linked to literature, explore the interaction of light with objects, emphasizing theirs shapes and volumes (Sena 1998, 318). Some of his photographs, very theatrical, acquire an introspective intensity (Prata 2008, 68-72).

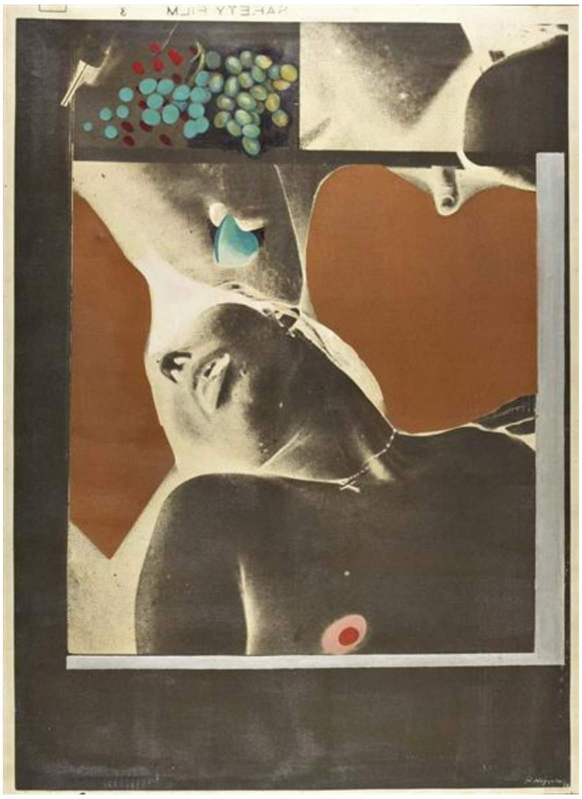

Figure 2.7 - Sá Nogueira, *Erotropo* (1970), acrylic and photography on canvas, 77 x 121 cm. Artist collection.

Based on the research conducted by María Jesús Ávila (1998, 24), the first association of photography with the traditional fine arts in the Portuguese context was made by the artist Lourdes Castro (1930) in 1962, within her series *Sombras*. At the end of the decade, certain artists such as Sá Nogueira (1921-2002), Luís Noronha da Costa (1942), and Cruz-Filipe (1934), to name a few, systematically transposed photography into the field of fine arts, as a way of reinventing the traditional media. For instance, Sá Nogueira, since 1969, influenced by Pop Art and particularly by Hamilton, developed his first series using photography: *Erotropos* and *Shunga*. In these series, he used pornographic images taken from magazines, which he photographed and impressed directly on the canvas, which he later painted (Ávila 1998, 24-26) (Fig. 2.7).

According to the curator Delfim Sardo, the path of photography expansion into the traditional fine arts also occurred through engraving, since both media became attractive for artists who seek to explore the serial and repetitive character offered by these techniques (Sardo 2015, 11).

Apart from brief experiences, which can be accessed by analysing some scripts and frames from surrealistic films (Ávila 2001, 69-71), it was only in the 1960s that a few artists started looking for film supports (especially amateur formats such as 8 mm or 16 mm) as a place for their experimentation. In general, these experimentations appeared as an extension of their visual artworks (Guarda 2008, 41-42)[19]. In accordance with the study conducted by Andreia Magalhães (2015a, 245-246), Ernesto Manuel Geraldes de Melo e Castro (1932), commonly known as E. M. Melo e Castro, was possibly the first artist to integrate film in his artistic production through the practices of *experimental poetry*[20]. His first film was *Lírica do Objecto*, in 1958.

With the end of the dictatorial regime in 1974 and the later admission of the country into the European Union (in the 1980s), there was a period of political and social turmoil in Portugal. This context was naturally reflected in the artistic field, and artists started to question and (re)think their possibilities (Nogueira 2013, 11). In general, the artists sought to break with the normalization of the previous years to return to subjectivity and redefine their creative language, even though, sometimes, in an unstructured way (Prata 2008, 59).

The growing interest in photography and film by artists contributed to the adoption of solutions with great plasticity when working with these media and to the recognition of photography and film in

[19] In the late 1970s, artists also began using video as a support for their expression, often in relation with performances. However, in that period, there were no artists working systematically with the medium. Instead, it was only in the mid-1990s that video flourished in tune with the country's economic and cultural growth (Guarda 2008, 41-42).

[20] The Portuguese artistic movement founded in the early 1960s by Ana Hatherly and other artists. It was initially a literary movement, guided by an *avant-garde* and experimental attitude (Magalhães 2015a, 246).

Portuguese art (Prata 2008, 43). By integrating photography into their artistic practices, and quoting Emília Tavares (2015, 21), "they deprive it of its object character and aesthetic status to use it as meaning, speech, series, displacement, performative document or even anti-painting"[21], contributing to a new understanding of the photographic image. Ângelo de Sousa, Ernesto de Sousa (1921-1988), Alberto Carneiro (1937-2017), Julião Sarmento (1948), Helena Almeida (1934-2018), Eduardo Nery (1938-2013), Lourdes Castro, René Bértholo (1935-2005), Fernando Calhau (1948-2002), Ana Hatherly (1929) and E. M. Melo e Castro were some of these protagonists (Guarda 2008, 41-42). In general, artists working with film were also working with photography (Magalhães 2015a, 243).

The group IF[22], founded in 1976, was responsible for a practice of documentary photography with a humanistic character and a critical realism, following both Costa Martins' and Vitor Palla's aesthetics. Group IF's proposal for the renewal of the photographic language, admittedly opposed to that of the plastic arts artists who made use of audio-visual media, also helped to free photography from the speech of the *salons* to which it was still associated (Tavares 2015, 22-23).

In accordance with the study conducted by Rui Prata (2008, 57), there was no open background of art critics in that period. However, a new generation of these professionals, from which Ernesto de Sousa[23] should be highlighted, started to develop a greater reflection on the role and value of audio-visual media, allowing for the projection of some works with photographic and film supports (Prata 2008, 57). As defended by João Pinharanda (1988, 7-8), through the rapprochement of theoretical reflection and artistic practice, and through the questioning about the relationships between artwork, artist and public, *neo avant-garde* discourses started to emerge. Consequently, as in other European countries, artists sought to abolish the boundaries between different artistic fields (Pinharanda 1988, 7-8).

However, António Sena (1998, 322) defended that even though some institutional and individual or collective efforts by artists and critics were present, there was no solid basis for a new discourse to flourish. Regarding exhibition, a lack of programmatic criteria prevailed until the 1980s, probably due to a lack of models. In fact, the dissemination of international art was still limited (Sena 1998, 322). Consequently, there was almost an exclusive display of traditional artworks to the detriment of more radical and problematizing productions. This exclusion included performance, installation, photography and experimental film (Pinharanda 1988, 7).

Nevertheless, some important institutions such as Fundação Calouste Gulbenkian (FCG) (Lisbon), Sociedade Nacional de Belas Artes (Lisbon), Centro de Arte Contemporânea from Museu Nacional Soares dos Reis (CAC-MNSR) (Porto) and Cooperativa Árvore (Porto) gradually started to organize exhibitions with photography and film. Additionally, new private spaces such as galleries opened, for instance, Cooperativa Diferença in Lisbon and Galeria Módulo in Porto, and exhibitions focusing on or including photography and film started to multiply at the end of the 1970s. Sometimes, traditional photographers and plastic artists using these photographic and film media were put into dialogue. The exhibition entitled *Fotografia na Arte Moderna Portuguesa,* organized by Fernando Pernes

[21] Translation by the author of this dissertation.

[22] Group IF: *Ideias* (ideas) e *Formas* (forms). João Paulo Sotto Mayor, José Carlos Príncipe, José C. Marafona, Luís Seixas Abrunhosa Vasconcelos, Manuel Magalhães, António Drummond and Luís Abrunhosa, were part of the group (http://apphotographia.blogspot.pt/2007/06/blog-post_7306.html; accessed on 18/09/2018).

[23] Ernesto de Sousa was an artist who continuously worked with photography and film and contributed to the redefinition of visual culture in Portugal. In 1977, he organized the emblematic exhibition *Alternativa Zero*, which he used as a public manifestation from the *avant-garde*. The zero symbolized the erasing of what was keeping artists in a language of the past, enabling a renewed future. He was also the founder of the *cineclubista* movement in Portugal (Sousa 1997, 235). Thus, he was a fundamental critic in the Portuguese *neo avant-garde* art scene.

in 1977[24] at CAC-MNSR was an example of that (Prata 2008, 54-57). The development of some exhibitions illustrating the use of photography in the plastic arts, such as the exhibition *18x18 - Nova Fotografia*, held both at CAC-MNSR and Cooperativa Grafil (Lisbon) in 1978, are also worth mentioning (Sardo 2017, 16)[25]. This exhibition gave rise to a manifesto text by Ernesto de Sousa on the nature of photography (Tavares 2015, 22). The first screening entirely dedicated to experimental film was made in 1978, also at CAC-MNSR allowing the disclosure of some *avant-garde* films never seen in Portugal before (Sousa 2001, 48). The exhibition in 1979 entitled *A Fotografia como Arte / A Arte como Fotografia*[26], should also be mentioned. Within this exhibition, both artists using photography as a mean of expression and international photographers with a recognized work were represented (Sena 1998, 316).

Another important event was the cycle *Encontros de Fotografia de Coimbra*, with its first edition in 1980. This cycle, despite some financial precariousness, brought together national and international artists, and was a place for photographic reflection, which encouraged other meetings of that kind[27] (Prata 2008, 60).

In the late 1970s, a larger circulation of photography and foreign photographers started, especially from Magnum[28]. As stated by Prata (2008, 38), those lately influenced some Portuguese photographers of that period. In that context, some itinerant exhibitions were organized (Prata 2008, 38).

Regarding personal contributions, Jorge Molder and Paulo Nozolino[29] should be stressed as two photographers who developed a renewed language between the end of the 1970s and the beginning of the 1980s. According to Prata (2008, 43), the plastic solutions adopted by them marked a turning point in Portuguese photography. Although they have very distinctive languages, a coherence in their path can be observed, namely the search for a subjective expression born from their individual imaginary (Prata 2008, 43). *Nova Fotografia* (New Photography) was the name used by some authors to define the photography from that period, expressing a rupture with previous predominant tendencies (Prata 2008, 38).

With few exceptions, as is the case of Ângelo de Sousa (later discussed within this dissertation), most *neo avant-garde* artists made use of photography and film in a conceptual way, taking advantage of the meaning and symbology of the image. Helena Almeida, for instance, worked with photography

[24] The exhibition in which some photographers linked to Surrealism and plastic artists participated, such as Fernando Lemos, Eduardo Nery, Alberto Carneiro, Noronha da Costa, Helena Almeida, Álvaro Lapa e Ângelo de Sousa (Serén 2009, 46).

[25] Ângelo de Sousa participated in that exhibition.

[26] This roaming exhibition took place at CAC-MNSR (Porto), at Edifício Chiado (Coimbra) and at FCG (Lisbon). The exhibition was organized by the German photographer Floris Nëususs. Alberto Carneiro, Fernando Calhau, Helena Almeida, Julião Sarmento and Ângelo de Sousa were some of the artists who participated in the exhibition (Sena 1998, 316).

[27] In the late 1980s some other similar events took place, such as *Encontros da Imagem de Braga* (1987), *Fotoporto* (1988), *Bienal de Vila Franca de Xira* (1989), among others (Prata 2008, 60). Ângelo de Sousa participated in all these events.

[28] First photography cooperative, founded in 1947 in Paris by photographers such as Robert Capa, Henri Cartier-Bresson, George Rodger, William Vandivert, among others. The cooperative was used as a support for photographers, namely photojournalists (http://www.magnumphotos.com/).

[29] Paulo Nozolino is frequently associated to Magnum photographers (Serén 2009, 50). His photography is intimist, like a visual diary that transpires his preoccupations with the world surrounding him. His images have a characteristic tension and dramatic intensity, conferred by the aesthetic options chosen by him: very dark and grainy (Prata 2008, 73-75).

since the 1970s, presenting work with a great formal and conceptual unity. Her photographic images, often presenting additional plastic interventions (painted, drawn, sewn, etc.), are staged and reveal a metaphorical intellectualism (Fig. 2.8) (Serén 2009, 57). By inhabiting her images, she defined a plastic space, where her continued self-representation was used as an instrument for the direct transmission of her message. Helena Almeida also worked with film, using the same type of aesthetic solutions used in her photographs (Prata 2008, 44-45).

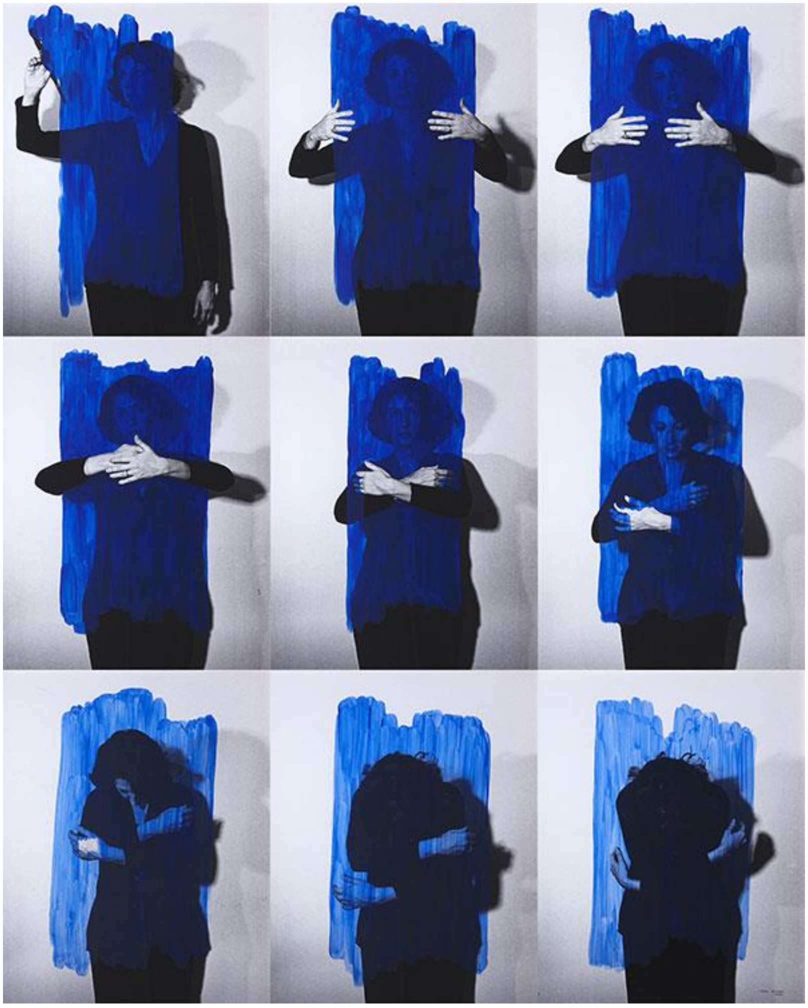

Figure 2.8 - Helena Almeida, *Pintura Habitada* (1975), gelatine silver prints (D.O.P.), 60 x 40cm. Artist collection.

Julião Sarmento, with his *micro-ficções suspensas* (suspended micro-fictions), Fernando Calhau with his structuralist films, and E. M. Melo e Castro with his visual poetry, are all examples of artists who used film to develop conceptual works (Guarda 2008, 47).

Sporadically, and particularly since the late 1980s, some photographers carried out some works of a more plastic or experimental character. Examples of such artists are Cristovão Dias (1931), Fernando Almeida, Carlos Costa (1954), Sérgio Eloy (1956), Luísa Ferreira (1961), Fernando Curado Matos (1953), Aurélio Veloso (1952), among others (Azevedo 1994). Ana Haterly (1929-2015)[30], although better

[30] In 1976-1977, Ana Haterly began lecturing, giving classes on *Cinema/Diaporam*' at *AR.CO* (Magalhães 2015a, 295). In the same school, she also performed some experimental film experiences with her students within the course *Curso de Cinema de Animação* (Animation Film Course), between 1978 and 1979.

known for her film *Revolução* (1975) or for her performances, made some experimental films during the film course she attended at the *London Film School* in the early 1970s. These works were animated films produced without the use of the camera, and with direct intervention on the film (16 mm and 35 mm), such as scraping and drawing of geometric shapes (Magalhães 2015a, 294-297). However, during the trigger of the *neo avant-garde* period, only a few authors established a more intimate and constant relationship with the materiality of the photographic medium.

Eduardo Nery (1938-2013), an artist trained in painting and often associated with Op art, was one of the authors who appropriated the materiality of the media for his aesthetic research. His photographic work begun in the mid-1950s is an example of that experimentation. Eduardo Nery worked the perceptual illusion, with the camera being his instrument of investigation and reflection. He often sought to explore the problems of light, space and image (Sousa 1990, 13-14). According to his words (1981):

> "One of the aspects that has been attracting me the most in photography is its capacity to abstract a particular motif without completely losing the relationship with the figurative structure that characterized it at the moment of the image capture. In this situation, the partial blurring, the dispersion of white light in the colours of the spectrum, and the unfolding or translation of the subject in a succession of parallel planes can be found"[31].

One notorious case of this relationship with materiality is the series *Espaço, Luz, Cor* (1980), in which the artist explored the technical specificities of the medium to construct images that sought a redefinition of light/colour and space (Fig. 2.9, left).


Figure 2.9 - Experimental use of photography by Portuguese artists. **Left**: Eduardo Nery, photograph[32] from the series *Espaço, Luz, Sombra* (1980-1981). Artist collection; **Right:** José M. Rodrigues, *Amsterdam* (1986), gelatine silver print (D.O.P.), 23.5 x 22.7 cm. Artist collection.

The work by the photographer José M. Rodrigues (1951) is also worth mentioning. Although he lived outside the country from 1968 to 1993 and was not in Portugal during the redefinition period of

[31] Translation from the author of this dissertation.
[32] No technical information regarding the photographic materials employed was found.

art and photography, he was one of the most influential names of Portuguese *neo avant-garde*. He studied photography in the Netherlands and contacted with several protagonists of the European *avant-garde* artistic movements. He was one of the co-founders of Perspektief[33]. Therefore, he collected a wide variety of influences from the German Fotoarte to Conceptual art, without forgetting the experimental cinema and the performing arts, which can be seen in his works (Oliveira 2008, 72). In his work *Fotograma* (1973), José M. Rodrigues took up the experiences of the *avant-garde* artists from the 1920s like Man Ray, and those of other artists from his time, namely Floris Neusüss (Oliveira 2008, 76). However, despite his sporadic experimental production, it is in the conceptual that he found the way to express the freedom of his creative act. In the documentary *Entre Imagens 03/13ª: José M. Rodrigues* (Mah 2013a), he explains that he used photography in his series *Amsterdam* (1986) to produce multiple exposures because it allowed him to perform his photographs and put in question his freedom as a creative artist (Fig. 2.9, right).

Due to the experimental character of the works he developed, Ângelo de Sousa was one of the main figures associated to the changes felt in Portuguese art in the late 1960s. A brief description of the artist and an introduction to his artistic production in made in the next section.

[33] Perspektief was an association founded in 1979, in Rotterdam, with the aim of developing *creative photography*, totally uncompromised and free. In 1980, the association opened a gallery and launched a magazine. José M. Rodrigues was responsible for the programming of the gallery (Calado 1999, 15).

2.2. Ângelo de Sousa

2.2.1. The artist and his work

Ângelo de Sousa (1938-2011) (Fig. 2.10) was born in Maputo, Mozambique. In 1955, he settled in Porto, Portugal, the city where he lived and worked for his entire life. He frequented the painting course at Faculdade de Belas Artes, Universidade do Porto (FBAUP) in Porto, Portugal (1955-1963), graduating with the maximum grade of 20/20. Based on this academic merit, he and another three colleagues created the group *Os Quatro Vintes* (The Four Twenties). From 1963 up to his retirement as a full professor in 2000, he kept lecturing at FBAUP (Fernandes and Wandschneider 2001, 271).

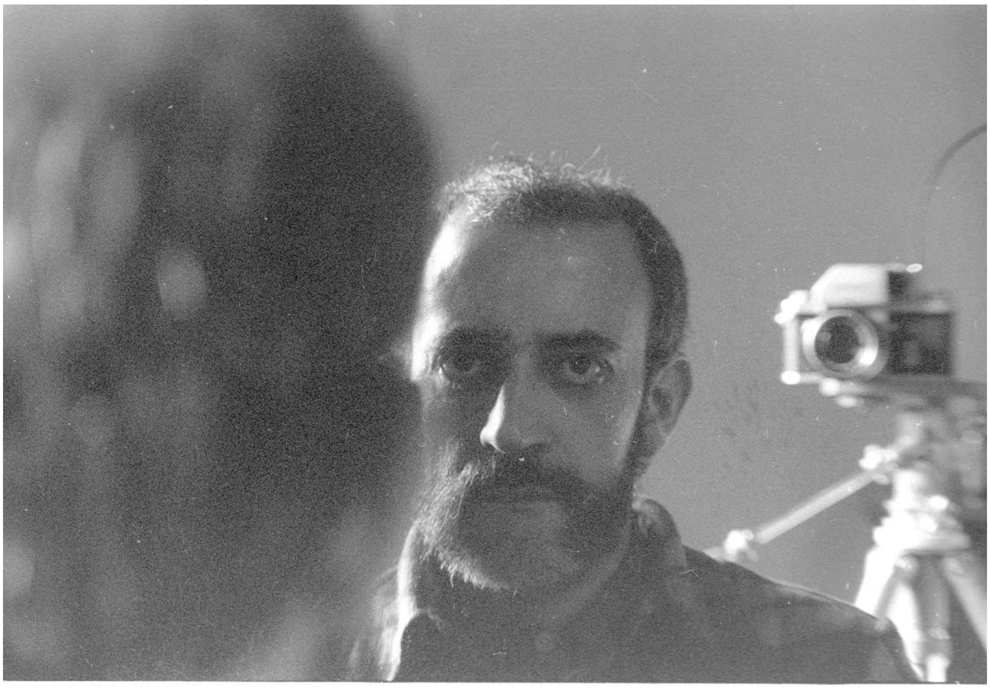

Figure 2.10 - Ângelo de Sousa, *Auto-retracto* (1977), 35 mm black-and-white negative with cellulose acetate base. Artist collection.

Between 1967 and 1968, he spent a year in London at Saint Martin's School of Fine Art with a grant from the British Council, working also for about a month at the Slade School of Art[34].

His first exhibition was in 1959, at Galeria Divulgação (Porto), together with the renowned Portuguese artist José de Almada Negreiros (1893-1970)[35]. This exhibition, part of a cycle of exhibitions proposed by the architect Pulido Valente, aimed at showing together an established artist and an artist starting his career. Ever since, Ângelo de Sousa was part of several individual and collective exhibitions, both in Portugal and abroad. In fact, the artist participated in several events that marked the Portuguese art, especially in the 1970s, 1980s and 1990s, such as *Alternativa Zero* at Galeria Nacional de Arte Moderna (Lisbon) in 1977, *Inauguração do Centro de Arte Moderna* at FCG and *Depois do Modernismo*

[34] Ângelo 1993: Uma antológica, ed. Miguel von Hafe Pérez and Maria Ramos, 120. Porto: Fundação de Serralves.

[35] The Portuguese architect Pulido Valente proposed a cycle of exhibitions putting together an established artist and another one starting his career. José de Almada Negreiros, one of the most celebrated artists at that time, and Ângelo de Sousa were chosen for the first (and only) session.

at Sociedade Nacional de Belas Artes (Lisbon) in 1983, *Um Olhar sobre a Arte Contemporânea Portuguesa* at Fundação de Serralves in 1988, and *Circa 1968* at Museu de Arte Contemporânea de Serralves (Porto) in 1999, among others. A few retrospective exhibitions can also be highlighted: *Ângelo 1993: Uma antológica* and *Sem Prata* at Fundação de Serralves, in 1993 and 2001, respectively, *Desenho* and *Ângelo de Sousa, Escultura* at Centro de Arte Moderna (CAM) from FCG in 2003 and 2006, respectively.

During his life, Ângelo de Sousa was awarded with several prizes, among them the International Award (ex-aequo) at the *XIII São Paulo Biennal* (São Paulo, Brazil) in 1975, the 1st Prize (ex-aequo) at the *1st Contemporary Art Exhibition* at MNSR (Porto) in 1985, the *Painting Award* from the *3rd Visual Arts Exhibition* at FCG in 1986, the *EDP Painting Award* in 2000, the *Calouste Gulbenkian Art Award* in 2007, and the *Amadeo de Souza Cardoso Award (Lifetime Achievement Category)* in 2007 (Almeida 2016, 300).

Currently, his work can be found in several private collections, as well as in the most important museums of contemporary art in Portugal, such as the Museu de Arte Contemporânea from Fundação de Serralves (Porto), Colecção Moderna from FCG (Lisbon), Museu Colecção Berardo from Centro Cultural de Belém (Lisbon) and Museu Nacional de Arte Contemporânea do Chiado (Lisbon).

Ângelo de Sousa used different means of expression during his life: drawing, painting, sculpture, engraving, serigraphy (screen printing), photography, film and installation. He also worked in scenography at the beginning of his career and made projects for the public space. Yet, his work is characterized by some constant elements: tendency towards simplification or elimination of figuration, economy of means and forms, accurate use of colour, and use of series as a mean of experimenting with some variations about the same theme or idea (Almeida 2016). As stated by Bernardo Pinto de Almeida[36] (Almeida 2018), there is an identical principle underlying the whole work of Ângelo de Sousa. The various media he explored interconnect with each other. For both the graphic simplicity and the use of similar shapes, his painting has a great affinity with his drawing (Wandschneider 1999b, 48). Similarly, photographs and films reflect the drawings, but also the paintings and the sculptures. Frequently, the artist worked on the same idea, transposing it from material to material, and there is now no way to know where the idea was first born (Almeida 2018). Quoting Almeida (1992, 16):

> "This dimension allows us, in a retroactive way, to understand that the underlying project of Ângelo de Sousa's work contained a kind of global meaning whose principle could be briefly described as the possibility of defining a body, both conceptual and plastic, granting us the chance to rehearse it in different support forms".

Being an artist with an experimental attitude and a man of science, Ângelo de Sousa explored the different materials with a deep knowledge of their properties (Ferreira 2011, 130). By observing his artworks, it is possible to see how he took full advantage of the supports, exploring their own specificities and characteristics. Still, he was not restrained by the media. On the contrary, as stated by Bernardo Pinto de Almeida (Almeida 2018), he sought to freely explore what each material could bring to his artistic process. This attitude led him to explore all the materials with the same interest and dedication (Almeida 2018). As José Gil[37] explains, Ângelo de Sousa belongs to the breed of experimenters (Gil 1993, 139-142):

[36] Bernardo Pinto de Almeida is a professor at FBAUP and a connoisseur of the artist's work.
[37] José Gil is a Portuguese philosopher who has been writing about Ângelo de Sousa, especially about his paintings and drawings.

> "One of the consequences of this freedom is the difficulty in classifying his work: it is neither abstract nor figurative, nor minimalist, nor conceptual, nor object art nor installation - or is it all of this put together? His images remain indifferent to these categories. As if they were superior to the question of representation".

Since the beginning of Ângelo de Sousa's artistic production, drawing was part of his routine (Wandschneider 1999b, 46). Unlike paintings and sculptures, the drawings had a great proximity to the gesture and, therefore, they were a tool for capturing the intensities of the motifs. The large quantities and the repetition, as a consequence of the experimentation process, worked as a way to fix his ideas (Almeida 2016, 161).

Regarding his paintings, he started working with oil, casein and wax (encaustic) as binders (Ferreira 2012, 29). In these first paintings, Ângelo de Sousa repeatedly used the same perceptible figures (plants, trees, horses, flowers, houses, etc.) to explore visual ideas (Almeida 1992, 6) (Fig. 2.11, left). After that, he started using other media such as vinyl and acrylic paints as well as off-set inks (easier to work, drying faster) (Ferreira 2012, 134), and his painting became gradually more abstracted. In the beginning of the 1970s, he started working on one of his most emblematic series. The 'monochromatic' series, as it was called by Almeida (1985), is a complex work of coloured backgrounds cut by thin lines (Fig. 2.11, right). From the 1990s, the forms gained a higher independence and colours became plainer, acquiring a different volumetry. In this series of paintings, each one is numbered and dated, as a registration or a noted idea (Fig. 2.12) (Almeida 2016, 161).

Also in his sculptures, different materials were employed, from traditional (stainless steel, iron, silver, stone, etc.) to new materials such as plastics (poly(methyl methacrylate) - PMMA, polystyrene - PS, etc.). During the 1960-1970s, he made several series starting from two-dimensional plates that he cut and folded to produce tri-dimensional objects. Following the same idea, the different materials lead to distinct results according to its specificity (Fig. 2.13) (Faria 2006b, 159-160). The sculptures were frequently tested in models produced in small dimensions. Some of these models were only transformed at full size for the exhibition at CAM from FCG (Lisbon) in 2006 (Pinto 2012, 15), and others took enormous proportions when incorporated in the public space (Fig. 2.14).

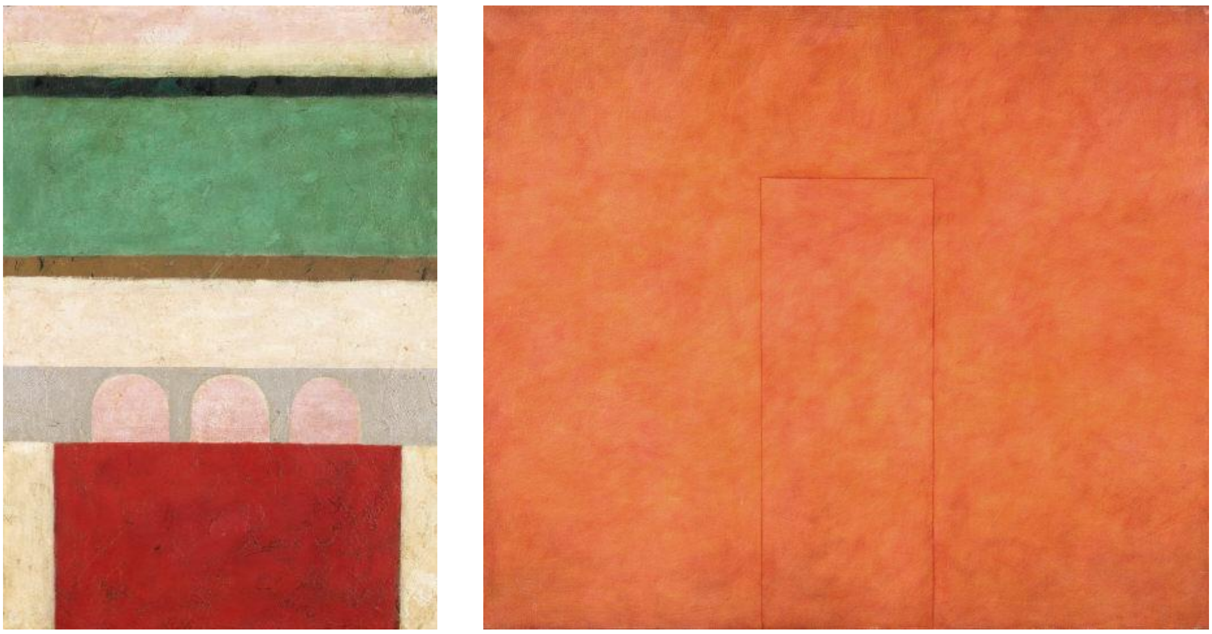

Figure 2.11 - Left: Paintings by Ângelo de Sousa. *Pintura* (1964), oil and gypsum on hardboard, 100 x 70 cm. Artist collection. **Right:** *Pintura* (1974), acrylic painting, 169.5 x 199 cm. Fundação Calouste Gulbenkian collection.

Figure 2.12 - Ângelo de Sousa, *Pintura* (1974), acrylic painting, 169.5 x 199 cm. Fundação Calouste Gulbenkian collection.

Figure 2.13 - Sculptures by Ângelo de Sousa. **Left:** *Escultura* (1966), steel painted with enamel paint, 36 x 67 x 31 cm. Fundação Calouste Gulbenkian collection; **Right:** *Sem título* (1965), poly(methyl methacrylate), 53.6 x 29 x 27.5 cm. Fundação Calouste Gulbenkian collection.

Figure 2.14 - Ângelo de Sousa, *Sem título* (2006), painted iron.

Some of his sculptures have the dimension of an installation, by taking control of the exhibition space and adapting themselves to the architecture, or by appealing to the spectator's participation (Figs. 2.15 and 2.16) (Faria 2006b, 160). Other two examples of installations are *Sem título [Envolvimento numa sala fechada]* (1997), presented in the exhibition *Alternativa Zero* (1977) held at Galeria Nacional de Arte Moderna (Lisbon), and *Uma Visita* at *Alfândega do Porto* (1993).

Both the paintings and the sculptures, although sometimes apparently simple, are commonly the result of a controlled and rigorous work[38] (Almeida 2016, 175).

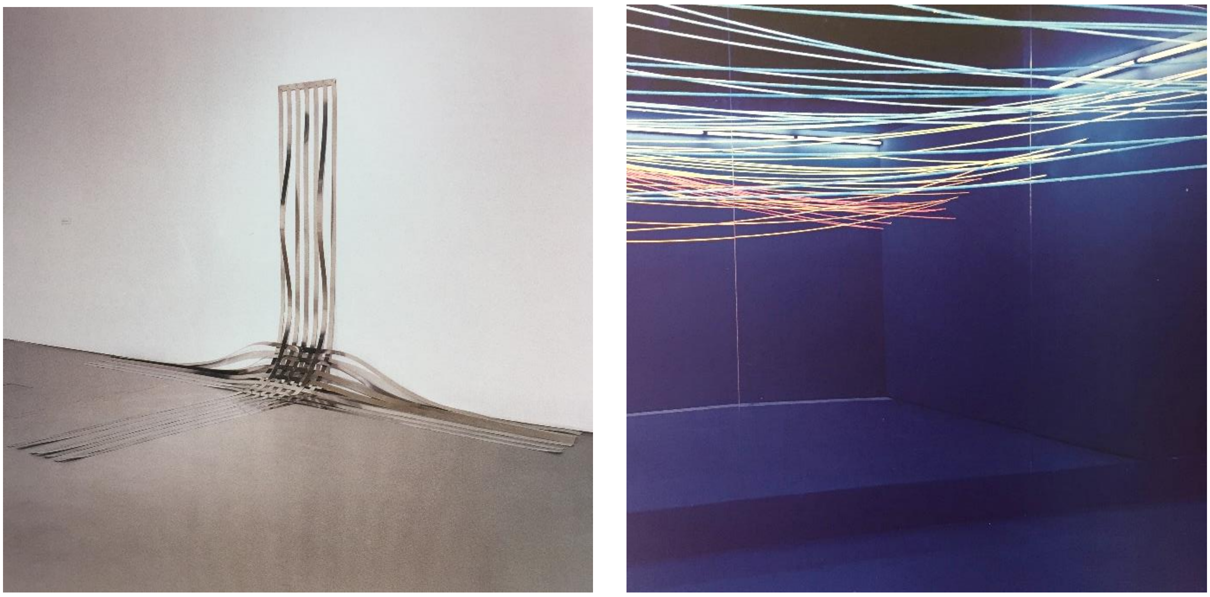

Figure 2.15 - Sculptures/installations by Ângelo de Sousa. **Left:** *Sem título* (1975), stainless steel strips, 200 x 430 x 200 cm. Fundação Calouste Gulbenkian collection; **Right:** *Cat's cradle* (1969/2006), mirror, cotton rope, fluorescent light and UV light, variable size. Artist collection.

Figure 2.16 - Ângelo de Sousa, *Um jardim catóptrico (Teuseus)* (2002), corten steel and mirrors (11 elements), 234 x 41 x 41 cm. Fundação de Serralves collection.

[38] According to several oral testimonies, Ângelo de Sousa destroyed hundreds of works that did not meet his expectations.

During his life, Ângelo de Sousa was specially recognized for his work in painting, sculpture and drawing. However, he also produced a noteworthy work in photography and experimental film, which has been recently gaining considerable importance. Since the mid-1960s, he developed a close and daily working relationship with these media. He was constantly capturing the different things that would cross his view within his daily life. Supporting this assertion is the oral testimony of his son, Miguel de Sousa, who told that his father was never leaving the house without a camera and at least a spare pair of rolls (Sousa 2014). The size of his archive can also prove it (see chapter 3). He used to take so many pictures that the photographic camera could be considered as an of extension of his vision. With video, he developed a similar relationship (Sousa 2014). He also had a great interest in cinema, a fact that can be assessed by reading some interviews (Sousa 2001, 44-45).

According to Almeida (2018), Ângelo de Sousa was one of the first Portuguese artists to make use of these media, being perfectly in line with what other international *neo avant-garde* artists were doing. Back in 1976, he chose to present the work *A mão esquerda (1ª série)* (1975), a diaporama composed of a series of macroscopic images of his hand, at the *Biennale di Venezia*, one of the most important international art exhibitions (Fig. 2.17). Due to his original and pioneer appropriation of photographic and film supports, he has been an influence on the following generations of artists in Portugal making use of these media[39] (Almeida 2018).

Through an in-depth analysis of some of is photographic and film works, a contribution to understand the role of Ângelo de Sousa on the development of the audio-visual artistic production in the Portuguese panorama is presented in chapter 4.

Figure 2.17 - Ângelo de Sousa, *A mão esquerda (1ª serie)* (1975),
35 mm chromogenic reversal film with cellulose acetate base. Artist collection.

[39] Also, through his position as a teacher, Ângelo de Sousa contacted with many students. Some of these future artists were somehow influenced by him (Almeida 2018).

2.2.2. Dissemination of the artist's photographic and film work

Even though photography and film occupied a significant part of Ângelo de Sousa's life and artistic production, it was only in 2001 that an exhibition entirely dedicated to this parcel of his work was planned. The exhibition, held at Museu de Arte Contemporânea, Fundação de Serralves (Porto), was entitled *Sem Prata*[40]. Twenty-three films and videos and three hundred and seventy-four photographs were displayed. For the first time, on that occasion, information about his photography and film was systematized and published, within the exhibition's catalogue. The catalogue contains an interview with the artist called *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa*, conducted by João Fernandes and Miguel Wandschneider, the curators of the exhibition (Sousa 2001). This interview has been considered a valuable source of information, being continually quoted within texts devoted to this part of the artist's work. In the same way, this interview was a fundamental reference within the framework of this dissertation.

Nonetheless, other important theoretical contributions to the understanding of Ângelo de Sousa's photography and experimental film work were published prior to this exhibition. The curator Miguel Wandschneider worked with Ângelo de Sousa before 2001, namely for the exhibition *Circa 68* (1999) and the project *SlowMotion* (2000). *Circa 68* was the opening exhibition of the Museu de Arte Contemporânea from Fundação de Serralves, bringing together works by Portuguese and foreign artists from the post-war period, and evidencing the experimental languages from that time. Several films by Ângelo de Sousa were exhibited on that occasion (appendix IV, Table IV.1). Within the exhibition catalogue, there is a text written by Wandschneider, *A lenta e difícil afirmação da vanguarda num contexto em mudança* (Wandschneider 1999), reflecting on the Portuguese panorama in the *neo avant-garde* period. *SlowMotion* was carried out at *Escola Superior de Artes e Design das Caldas da Rainha* (Caldas da Rainha) and FCG (Lisbon), and directed by Wandschneider. The project focused on the use of film and video by Portuguese artists, with Ângelo de Sousa being one of the protagonists. A handout with a short text explaining the presented films was distributed during the sessions.

Bernardo Pinto de Almeida is one of the main figures who has been developing a critical reflection on Ângelo de Sousa's work in general, including on his photography and film. Some of his texts arose within the context of exhibitions, such as *O rosto da máscara: auto-representação na arte portuguesa* (1994), *Fotoporto: Mês da Fotografia* (1988), *Ângelo 1993: Uma antológica* (1993). There are two publications from his authorship dedicated to Ângelo de Sousa's artistic work: *Ângelo de Sousa* (Almeida 1985) and *Ângelo de Sousa, Lógica da percepção* (Almeida 2016). In this last, Almeida placed the different media explored by Ângelo de Sousa in dialogue. The essay *As Imagens e as Coisas* (Almeida 2002), a compilation of short texts dedicated to the exploitation of the photographic image, should also be highlighted.

Fernando Pernes, as the director of CAC and then the first director of Fundação de Serralves, was an important actor for the development of photography and film in the Portuguese *neo avant-garde* context. He was responsible for emblematic exhibitions, such as *A Fotografia na Arte Moderna Portuguesa* (1977), *18x18 - Nova Fotografia* (1978), *A Fotografia como Arte / A Arte como Fotografia* (1979), in which Ângelo de Sousa participated. Therefore, he wrote several texts related to that topic, namely in the exhibitions' catalogues. For the retrospective exhibition dedicated to the artist under

[40] Until this exhibition, Ângelo de Sousa only participated in collective exhibitions and only a few photographic and film works were presented. More information related to the exhibitions is presented in chapter 5.

study, *Ângelo 1993: Uma antológica* (Pernes 1993), organized at CAC, he wrote *Ângelo, entre a alegria e a melancholia.*

Also, José Gil made several critical reflections within the context of the exhibitions, available in the respective catalogues. *O experimentador do acaso* in *Ângelo 1993: Uma antológica* (Gil 1993) and *O plano flutuante* in *Transcrições e Orquestrações: desenhos de Ângelo de Sousa* (Gil 2003) are two relevant examples. Recently he published the book *Poderes da Pintura*[41] entirely dedicated to Ângelo de Sousa's work.

Other people could also be referred to, such as Nuno Faria, Paula Pinto, Filomena Serra, Leonor Nazaré and Lúcia Matos, as authors who have occasionally written about Ângelo de Sousa's work, frequently establishing parallels between the different means of expression used by him, namely photography and film.

Since 2014, Ângelo de Sousa's photographic and film work has been gaining in importance. One reason for this growing recognition might be related to the creation of the association *Núcleo de Estudos Ângelo de Sousa* (NeÂDS)[42], formally constituted in July 2014. As previously mentioned in chapter 1, NeÂDS's mission is to preserve and disseminate the artist's work, nationally and worldwide. As a result, the work by Ângelo de Sousa, especially his photographs and films, has since been subjected to a series of publications and exhibitions. Some examples of this positive outcome are the opening of four exhibitions between 2014 and 2017 and the production of two publications, contributing to the dissemination of his work and to a holistic view of the artist's creations. The exhibition *Encontros com as Formas,* held at Galeria Fundação EDP (Porto) in 2014, and curated by Sérgio Mah, is one example. The exhibition was the first, after *Sem Prata* in 2001, entirely dedicated to Ângelo de Sousa's photography and film. In this exhibition, both previously shown and never-seen images were displayed. The catalogue contains a critical reflection by the curator (Mah 2014). Sérgio Mah, professor and curator, is currently the theorist who has been most devoted to the study of Ângelo de Sousa's photography and film. In 2017, he launched the publication *Cadernos de Imagens*, a limited edition composed of eight notebooks. In this publication, the photographic work by Ângelo de Sousa is presented in series made between 1968 and 2006. Some of the images had never been shown before. This initiative was in accordance with Ângelo de Sousa's willingness to publish books with his photographs, as confirmed by certain documentation found in the archive[43]. The exhibition *La Couleur et le Grain Noir des Choses,* held at FCG (delegation of Paris, France) in 2017 and curated by Jacinto Lageira, is another example that fulfilled the aims of NEÂdS by internationalizing Ângelo de Sousa's

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[41] Gil, J. 2015. *Poderes da Pintura*. Lisbon: Relógio D'Água.

[42] NEÂdS was created by its son and heir, Miguel de Sousa, also the director of NEÂdS; António de Almeida is the head of the board of founders; Luis Braga da Cruz is leading the general assembly; and António Lobo Xavier is directing the fiscal council. The association is also composed of several founding members, both individual personalities (Artur Santos Silva, Eduardo Souto de Moura, Jorge Molder, among others) and institutions (Faculdade de Ciências e Tecnologia from Universidade Nova de Lisboa e Fundação de Serralves).

[43] A file called *Mão* was found in Ângelo de Sousa's archive. In there, some documentation was grouped under the name *Projectos de Livros* (book projects). According to a draft for a letter to the publishing company *Assirio e Alvim* (dated July 1997), he wanted to publish five books, three books with photographs and two books with drawings. Regarding the first, one would be called *A Mão*, and would contain photograph of his hand produced between 1975 and 1977 (both black-and-white and colour photograps). Another would be dedicated to *Rua da Alegria*, with black-and-white photographs. The content of the last was left open. The draft contains some specifications by the author, such as image number, format, type of publication, among others. In another text by the author, some notes concerning the financial viability of the project can be found. For instance, he considered publishing a special edition with better quality photographs for the book *Mão*.

work. Jacinto Lageira sought to display a representative sample of the artist's work, and as a result, photography and film were prominent. Finally, the exhibition entitled *O Fotógrafo Acidental - Serialismo e Experimentação em Portugal, 1968-1980*, held at Culturgest (Lisbon) in 2017, and curated by Delfim Sardo, is also an example, even though other artists were represented. In this case, Ângelo de Sousa’s photographic work was highlighted among the photographic practice within the visual arts. The exhibition catalogue includes two essays, one by Delfim Sardo and another by Sérgio Mah. Also in 2017, a selection of films and photographs by the artist were presented in the exhibition *Potência e Adversidade, Arte da America Latina nas Colecções em Portugal* (2017) curated by Marta Mestre and held at Museu da Cidade (Lisbon).

Despite the growing dissemination and increasing reflection about this part of Ângelo de Sousa’s work, his photographic and film production has still not been systematically and globally analysed, remaining quite unexplored. For that reason, the photographs and films gathered in his archive have been assessed within the framework of this dissertation, with the goal to collect relevant information about contents, typology, as well as conservation condition of the collection. The results from the conducted survey are presented in chapter 3. In turn, chapter 4 is entirely focused on the artist’s photographic and film work. From a thorough assessment of both primary and secondary sources found both in the artist’s house and in public archives, chapter 4 launches new contributions for the understanding of this part of Ângelo de Sousa’s production, being of the novelties brought forth by this investigation.

2.3. Chromogenic reversal films: state of the art

During the assessment conducted to the photographic and film collection by Ângelo de Sousa (presented in chapter 3), it was found that 35 mm chromogenic reversal films with mounting (slides), were one of the most representative type of photographic materials used by the artist. Also, it was concluded that 35 mm chromogenic reversal films are the set at highest risk due to visible signs of colour change in a considerable number of specimens. Consequently, the need for an in-depth study focusing on that set became imminent.

The conservation of this type of photograph can raise problems related both to material and immaterial issues. On the one hand, chromogenic materials will, sooner or later, present colour fading and changes in colour balance, either induced by light and/or temperature (T) and/or relative humidity (RH). In some cases, colour change might take serious proportions and put at risk the useful lifetime of the works. On the other hand, when mounted, they can be projected and displayed in exhibitions. Due to the chemical instability of the originals, copies must be created for display. During this process, the presentation of the slide-based materials might be done by maintaining or changing the original technology of the work. Depending on the significance of the work, shifting the technology can raise problems related to its identity. With the aim of defining innovative and effective strategies to preserve the slides from the collection under study, current knowledge about chromogenic reversal films was reviewed and is presented in the following sections.

2.3.1. Slide-based artworks

Chromogenic reversal films are first-generation positive transparencies. During processing, the negative image registered in-camera is reversed into a positive image. This means that the final image, visible through transmitted light, is a direct representation of the original scene. The word 'slide' is a common way to describe a chromogenic reversal film cased inside a mounting. The mount is used to allow the projection of the transparency.

> "In most Romance languages 'slide' is translated as diapositive: dia [Gr.] (through, between). Transparent breaks down into 'trans' [Lat.] (beyond, across) and 'parere' [Lat.] (to appear, be visible, be seen, etc.). All three terms: slide, transparency and dia describe an ephemeral presence, a state in which a picture is formed, lasts and disappears."
>
> Weidner 2012b

At the beginning of chromogenic photography, slides were quite expensive (Weidner 2012a), especially in countries such as Portugal, where the materials had to be sent to other countries to be processed. However, the processing gradually became more affordable, due to technical improvements and the expansion of the so-called mini-labs (Weidner 2012a). In the 1960s, the use of 35 mm slides was common[44], although chromogenic negatives and prints had much higher success (Wilhelm and Brower 1993, 19-20). Nevertheless, colour slides were widely used in photojournalism, fine arts, for

[44] Film stocks are available in a few standardized formats, compatible to specific equipment. 35 mm film was first used in 1892 by William Dickson (1860-1935) and Thomas Edison (1847-1931). Since its standardization, 35 mm gauge became the most commonly used format in still photography and motion pictures (The Preservation Film Guide 2004, 6-7).

commercial applications such as advertising, fashion and industry, and also in academia to present images (Wilhelm and Brower 1993, 20). As described in section 2.1, during the 1960s, artists were gradually getting interested in audio-visual supports as new media of expression, especially in amateur formats, and chromogenic reversal films were no exception (Weidner 2012a). Ângelo de Sousa is an example of a Portuguese artist who made use of slide-based materials in his artistic production, as was illustrated within the exhibition *O Fotógrafo Acidental - Serialismo e experimentação em Portugal, 1968-1980* held at Culturgest in 2017 (Fig. 2.18).

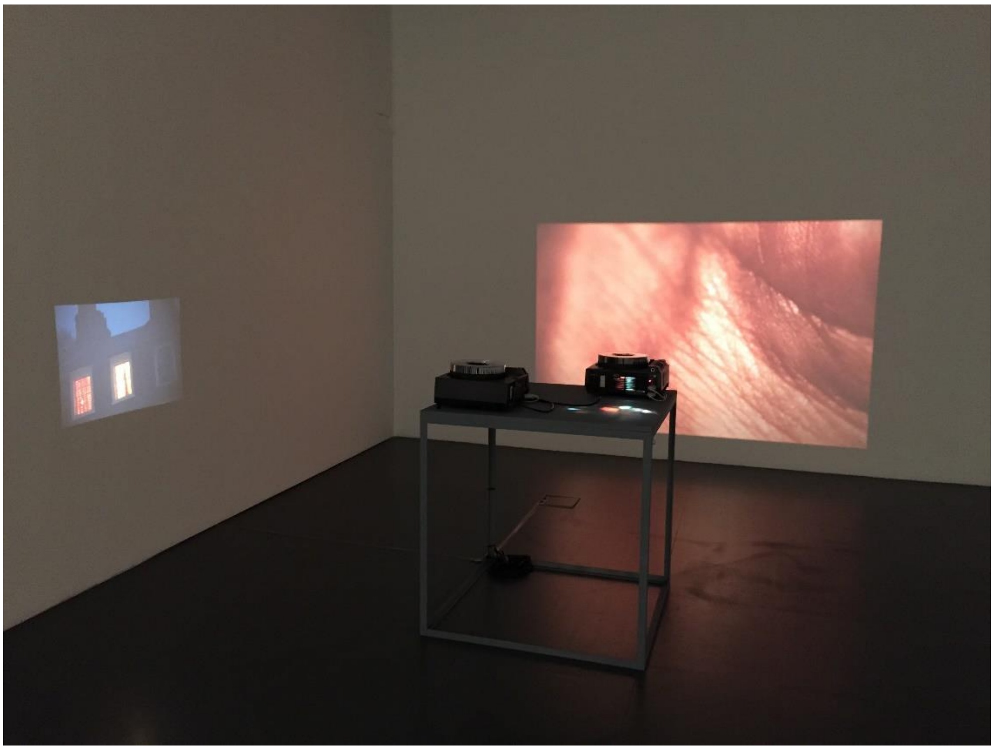


Figure 2.18 - Slide-based artworks by Ângelo de Sousa projected in the exhibition *O Fotógrafo Acidental - Serialismo e Experimentação em Portugal, 1968-1980* at Culturgest (Lisbon) in 2017.

Artists adopted 35 mm colour slides because it was an accessible and easy to use material, and/or because of its aesthetic qualities (Weidner 2012a). Slides produced a high-resolution image with good detail and precise colour reproduction, representing a unique material to easily create high-quality and cheap images (Pénichon 2013, 164). These matrices could be both projected in quite a large-scale without losing quality, and/or printed, namely by using silver dye-bleach technology which produced images with high contrast and saturated colours (Pavão 1997, 61). Some artists were particularly interested in the slides projector dependence and in the installation character of the work induced, for instance, by the sculptural and sound features of the slide projector, among others (Weidner 2012a). However, although slide-based artworks were meant to be projected, chromogenic reversal films were not built to be continuously projected, such as in an exhibition context (Gordon 2012). Chromogenic dyes are chemically unstable (see detailed information in the next section), especially when submitted to extreme conditions, such as the ones occurring during projection (light and high T)[45]. According to Henry Wilhelm and Carol Brower (1993, 211-212), light (not T) is the primary cause of fading during projection. Nonetheless, T can increase light fading. Quoting Henry Wilhelm and Carol Brower (1993, 211):

> "Projecting a 35 mm color slide exposes the image to a concentrated beam of extremely intense light - a Kodak Ektagraphic III projector equipped with the standard 300 watts EXR quartz lamp has a light level at the film plane of over one million lux (…) which is equivalent to about ten times the illumination intensity of direct outdoor sunlight".

It is important to keep in mind that a chromogenic reversal film is a unique one-of-a-kind photograph (Wilhelm and Bower, 211), and, therefore, original artworks should not be projected.

Slide-based works can be classed as time-based media[46] art since they have duration as a dimension and are dependent on technology. Time-based media art (video, film, computer-based art, among others) is typically complex, immersive, and performative. In general, time-based media needs to be installed to be experienced and a display equipment to be observed. Sara Gordon (2012), time-based media coordinator at the Hirshhorn Museum and Sculpture Garden of the Smithsonian Institution, describes slide art as *unique* because, in addition to the necessary equipment to complete the artwork, a specific sequence and time is required to display the medium. From this point of view, slide-based artworks are completely different from film, in which time is expressed in the medium itself (Gordon 2012) and can be considered a hybrid medium, somewhere in between still photography and cinema (Weidner 2012b). As installation art (Laurenson 2011, 36), time-based media works only exists when exhibited, and therefore have an intangible and temporary nature.

Due to its multi-dimensional character, slide-based artworks are challenging to conservators. Nonetheless, most references concerning slides were written by archive specialists, or similar institutions, focusing essentially on the materiality and degradation of chromogenic reversal films, as is described in the following sections. However, when the conservator deals with time-based media artworks, other issues related to immaterial matters arise, requiring specific expertise. As the head of Collection Care Research at the Tate, Pip Laurenson stated (2011, 39), part of the difference between an archival chromogenic reversal film and a slide-based artwork is that the significance of the medium goes beyond its role as a carrier for an image. As concerns with the specificity of conservation of contemporary art have only emerged in the late 1990s (Macedo 2008, 39), up to the moment, there are only a few conservators specialized in this relatively new field.

Some projects focusing on specific topics of conservation of contemporary art have been developed since the 1990s (Macedo 2008, 39). Some of the most important ones are summarized next. In 1997, one of the most emblematic projects for the conservation of modern and contemporary art, *Modern Art: Who Cares?*, was held by the Foundation for the Conservation of Modern Art and The Netherlands Institute for Cultural Heritage (Amsterdam, The Netherlands)[47]. The project gave rise to an

[45] According to studies conducted by Henry Wilhelm and Carol Brower (1993, 216), chromogenic reversal films can be projected between 20 and 50 minutes, depending on the type of film and projector light, before fading is visually observable

[46] Time-based media is the terminology commonly used in conservation, mainly in England (led by Tate) and the United States.

[47] The success of the first project gave rise to the symposium *Contemporary Art: Who Cares?* in 2010. This project was also at the origin of the International Network for the Conservation of Contemporary Art (INCCA), founded in 1999.

international symposium and a publication[48]. Based on ten pilot objects, several authors contributed to the presentation of decision-making models for data and condition registration, with the aim of structuring the conservation process. Two years later, the conference *Mortality Immortality? The Legacy of 20th-Century Art* was held at the Getty Center (Los Angeles, United States of America), putting different professionals with different backgrounds (from conservators to artists, art historians, scientists, and philosophers) in dialogue. These dialogues (some published[49]) illustrated the urgency of a holistic approach to the conservation of contemporary art. These were two pioneering initiatives that launched new strategies for this field. The *Variable Media Initiative* arose in 1999 from the Guggenheim Museum (New York, United States of America) and, two years later, the research *Variable Media Network* was created. The project focused on the preservation of works that have a performative and/or ephemeral nature, whether due to the chemical and physical instability of the materials used or to the use of immaterial technologies, such as electronic and digital. Some information about this subject can be found online[50], including a publication[51]. *Inside Installations: Preservation and Presentation of Installation Art*, organized by the International Network for the Conservation of Contemporary Art (INCCA) and created within *PRACTICs*[52], took place between 2004 and 2007. This was a large-scale collaborative project that joined together museums and other cultural institutions in Europe. The project was exclusively dedicated to the preservation and exhibition of installation art, which frequently has time-based media elements to be considered, such as slide projections. There is a publication summarising part of the knowledge produced during the project, available online[53].

Specifically concerning time-based media art, four initiatives can be highlighted in the context of this work: *Matters in Media Art*, *Capturing Unstable Media*, *DOCAM Research Alliance* and *TechFocus II: Caring for Film and Slide Art*. *Matters in Media Art* is a work in progress collaborative project between the Museum of Modern Art (MoMA) (New York, United States of America), the San Francisco Museum of Modern Art (San Francisco, United States of America) and the Tate Gallery (London, United Kingdom), which started in 2005. The aim of the project is to develop good-practice guidelines for the conservation of media art, namely in the acquisition and documentation of the artworks. A set of questions supporting decision-making processes regarding the preservation and exhibition of time-based media works was defined. On the website[54], it is possible to find various resources, namely the structure of a condition report for the evaluation of slide-based artworks. In 2003, the research project *Capturing Unstable Media* was created, conducted by V2_Institute for the Unstable Media (Rotterdam, The Netherlands). The project was specifically focused on the documentation and preservation of electronic

[48] *Modern Art - Who Cares? An interdisciplinary research project and an international symposium on the conservation of modern and contemporary art*, ed. Ijsbrand Hummelen and Dionne Sillé. London: Archetype Publications.
[49] *Mortality Immortality? The Legacy of 20th-Century Art*, ed. Miguel Angel Corzo. Los Angeles: The Getty Conservation Institute.
[50] www.variablemedia.net/ (accessed on 15/08/2018.
[51] *Permanence Through Change: The Variable Media Approach*, published by the Guggenheim Museum and the Daniel Langlois Foundation.
[52] PRACTICs is an acronym for Practices, Research, Access, Collaboration, Teaching in Conservation of contemporary art, an international project on contemporary art conservation led by the Cultural Heritage Agency of The Netherlands.
[53] *Inside Installation: Theory and Practice in the Care of Complex Artworks,* ed. Tajta Scholte and Glenn Warton. Amsterdam: Amsterdam University Press. Website: *Inside Installation: Theory and Practice in the Care of Complex Artworks,* ed. Tajta Scholte and Glenn Warton, 35-42. Amsterdam: Amsterdam University Press. Website: http://www.nimk.nl/eng/inside-installations (accessed on 15/08/2018).
[54] http://mattersinmediaart.org/ (accessed on 15/08/2018).

art and based on the findings from two case studies. Within the project, good-practice recommendations were formulated, which can be found online[55]. In 2005, the *DOCAM Research Alliance* was launched by the Daniel Langlois Foundation for Art, Science and Technology. The project included the analysis of several case studies from Canadian institutions holding contemporary art. For five years, several seminars and summits were held in various locations in Canada. As an output of the project, a cataloguing guide and a conservation guide were created and spread online[56], as well as other interesting resources. Specific recommendations for the preservation of slide-based works are available too. *TechFocus* is a series of workshops organized by the American Institute for Conservation's Electronic Media Group of the American Institute for Conservation of Historic and Artistic Works (AIC). *TechFocus II: Caring for Film and Slide Art* occurred in 2012 at the Hirshhorn Museum and Sculpture Garden from the Smithsonian Institution (Washington DC, United States of America). The aim of the event was to inform museum professionals about the specific technology of film and slide-based artworks, as well as to disclose current procedures for the acquisition, preservation and display of these works. Unfortunately, no online publication has resulted from this initiative, although some of the talks are available online[57]. To the best of our knowledge, this was the first event specifically dedicated to slide-based artworks. The conservators Barbara Sommermeyer and Claartje van Haaften, developed a three-years (2015-2018) research project at the Hamburger Kunsthalle on the preservation and installation of slide-based artworks in their collection. In 2016, they published a paper where they present some case studies and the different solutions encountered, considering the significance of the different components of those works (Sommermeyer and van Haaften 2016). A German-language workshop was also organized within the framework of the project, in January 2018.

All these contributions led to the definition of guidelines for an improved approach to the conservation of time-based media art, helping conservators in the decision-making process. It is now consensual that, before any decision, it is necessary to define a theoretical framework that captures the variable nature of the artwork. There are no universal solutions, and each work should be analysed individually, on a case-by-case basis (Berndes 2005, 167). The concept, appearance and experience of the work must be understood in-depth, in order to promote its proper preservation, display and communication (Noordegraaf 2013a, 14). Documentation is the key for safeguarding the integrity of a time-based media artwork (Depocas n.d. a) and is the basis for responsible decisions about the conservation strategy (Berndes 2005, 166-167). Documentation should be diverse, to capture the non-tangible aspects of the artworks (Macedo 2008, 301). Since time-based media works are prone to change and adaptation, both physical components, including information about the medium itself and the display equipment, and conceptual components of the work, such as the artist's intent, must be described. Moreover, the relationship between the components must be established to determine the identity of the artwork and the significance of the installation (Laurenson 2005, 1). After a thorough examination of the artwork, the information collected by the conservator can be expanded through the collaboration with other professionals, such as curators, art-historians and scientists, who can enlighten issues related to their speciality (Sommermeyer 2012, 144). When the artist is alive, which is frequent when dealing with contemporary art, interviewing the artist can also enrich the knowledge acquired by the conservator. Artists can frequently contribute to decision-making, bringing some fundamental

[55] http://v2.nl/archive/works/capturing-unstable-media (accessed on 15/08/2018).
[56] http://www.docam.ca/ (accessed on 15/08/2018).
[57] http://resources.conservation-us.org/techfocus/techfocus-ii-caring-for-film-and-slide-art-tw/ (accessed on 15/08/2018).

information especially regarding the creation, production, materials, intention and presentation of the artwork (Chiantore and Rava 2012, 17).

In terms of institutional contributions to time-based media conservation, it is important to highlight the work developed at the Tate. Pip Laurenson has been part of some of the projects mentioned before, as well as others, and published several important works, some of them referenced within this PhD thesis. Between 2011 and 2012, the researcher Tina Weidner developed the project *Dying technologies: the end of 35 mm slide transparencies* in the same institution (Weidner 2012a). Due to the gradual substitution of analogue photography by digital photography, nowadays there are only a few brands producing reversal films, and only reduce-type emulsions are still commercially available. Additionally, in 2009 Fuji discontinued the production of 35 mm duplication slides, followed by Kodak in 2010 (Weidner 2012e). Considering this background, she developed a unique project that focused on the future of 35 mm slide-based artworks, after discontinuation of duplication slide film and related technologies. The findings from the project are openly presented on the Tate's website, where it is also possible to find display specifications for slide-based artworks from the Tate's collection. Weidner also published a paper summarizing the findings of the project (Weidner 2013).

As Weidner pointed out (2012c), the main fragility of slide art relies on its media technologies dependence, which is constantly menaced by obsolescence, raising problems regarding its long-term preservation and display. Slide-based artworks are threatened both by the obsolescence of the exhibition copies and equipment. Since originals should not be displayed, the installation of an artwork is dependent on the ability to replicate 35 mm slides (Weidner 2012c). Before the discontinuation of duplication slide stock, the recommended procedure for institutions was to obtain master copies of the works during the acquisition process and to make display copies using duplication slides. Therefore, while the artwork and/or the duplication master is safely stored in cold storage, exhibition duplication sets can be made to assure the display of the artwork (Depocas n.d. b). Along with the duplication slides, the production of the projectors and spare parts are frequently discontinued, and the continuity of the display equipment is dependent on the occasional market. Thus, the installation of a slide-based work is also dependent on the availability of a projector and on specialists with knowledge on how to maintain or repair the equipment (Weidner 2012c). The availability of a budget to pay for all these services can also be an issue. As reinforced by Tina Weidner (2012a):

> "with the demise of the photographic skills needed to duplicate slides, along with the discontinuation of slide stock and the end of the manufacture of slide projectors and related equipment, our ability to continue to display and enjoy these works in the future is brought into question".

It is currently necessary to find viable options that maintain the aesthetic qualities of the slides and ensure the preservation of the essence of the original work when exhibited (Noordegraaf 2013b, 287). During the project conducted at the Tate, Tina Weidner made a survey of the alternatives to 35 mm duplication slides using digital intermediates to print into the still-available chromogenic film, such as sheet film, motion picture reversal or print stock and microfilm (Weidner 2012f). Jeffrey Warda, senior paper and photograph conservator at the Guggenheim Museum, and Doug Munson, director of the company Chicago Albumen Works, have established a collaboration for the creation of exhibition copies for slide works. For that purpose, they used a light valve technology (LVT) film recorders to print on sheet film. Their work was presented at *TechFocus II: Caring for Film and Slide Art* (Warda and Munson 2012). Other possibilities for the replication of slide-based artworks are its complete conversion into a digital experience, by displaying the digital copy in a digital projection (Depocas n.d. a).

While some artists used 35 mm slides for its aesthetic and specific characteristics, others only used it due to its availability and facility of use. Thus, it is important to understand what the relationship of the artist with this specific material was, to understand if the replacement of the original medium and/or projector might or might not be a significant issue (Noordegraaf 2013b, 286-287). According to Tina Weidner (2012h), independently of the meaning attributed to the work, alternative modes for display will have to be found because, one day it will eventually no longer be possible to use the original technology. Therefore, it is urgent to find alternatives to translate the analogue technology into digital technology, while it is still possible to compare them in the most accurate and viable way. Quoting Tina Weidner (2012c):

> "How to negotiate the future of these works in cases where no satisfactory alternative means of display can be found is largely unknown territory".

Based on the current procedures for the preservation and presentation of time-based media art, display options for slide-based artworks by Ângelo de Sousa are discussed in chapter 5.

2.3.2. The background of chromogenic photography

The invention of colour photography is closely linked with the history of colour theories. Some of these theories were the inspiration for solving technical problems pursuing colour photography well into the 20th century (Coote 1993, 14-21). Therefore, a brief description of the theories behind colour production and perception is exposed further in this section.

Since the beginning of the 17th century, the development of a unified theory of colour and light started to be drawn (Gage 1993, 153). Aristotle (c. 330 BC) had already established a parallel between light and colour, as he believed that each colour was the result of a black-and-white mixture in different proportions. In the 1660s, the English physicist and mathematician Isaac Newton (1642-1727) began a series of experiments with sunlight and prisms. He demonstrated that white light was composed of seven visible colours with different wavelengths - red, orange, yellow, green, blue, indigo and violet – by showing that each one of those colours were no further decomposable, and that their addition (with a second prism) would produce white. Thus, Newton published his colour theory in the *Philosophical Transactions of the Royal Society* in 1670, proposing a new sequence of colours corresponding to the visible spectrum and, in which, black-and-white were not contemplated. The colours of his chromatic sequence were gradually accepted as the basic colours (Pastoureau 2010, 4).

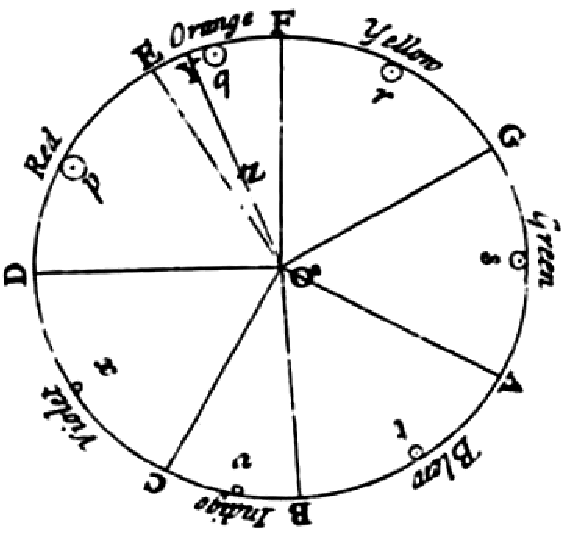


Figure 2.19 - Colour circle of Isaac Newton shown in *Optiks*[41].

In 1704, he wrote *Optiks*, systematizing his ideas and leaving a legacy that is still used today. Before *Optiks*, other studies and diagrams of

[58] https://commons.wikimedia.org/wiki/File:Newton%27s_colour_circle.png.

colour representation had already been made; however, these diagrams did not show a circular relationship between colours, as in Fig. 2.19. Newton was the pioneer in the description of hue (pure colours or basic colours that are expressed in the circle) as a dimension of colour. He also established a relationship of distances between colours that was based on a higher or lower colour intensity, and with that, he defined the idea of colour saturation. Moreover, he gave the first steps into colour complementarity research. These concepts were developed by other authors in the following century, and his ideas were the springboard to launch new questions about concepts such as colour contrast and harmony, which prevailed during most of the 19th century (Gage 1999, 15).

Newton laid the path for others to experiment with colour in a scientific manner. On the one hand, his work led to breakthroughs in optics, physics, chemistry, and perception. On the other hand, artists, who sought at this time theoretical bases for the application of colour in their works, were able to study it in a more theoretically and structured way (Pastoureau 2010, 4).

The British physicist Thomas Young (1773-1829), recognized as the founder of optical physiology, applied Newton's findings to the studies of visual perception and, at the end of the 18th century, he discovered that colours are perceived by fibrous nerves in the brain attached to receivers, which are sensitive to only one of three colours: red, green or purple. With this discovery, he described the trichromacy of vision that characterizes the spectral discrimination of the human eye (Gerritsen 1984, 112). Moreover, he took the first steps towards the definition of both additive and subtractive syntheses (Fig. 2.20) (Gerritsen 1984, 112). However, it was the German physicist Hermann von Helmholtz (1821-1894) who disseminated these concepts (Kemp 1990, 262).

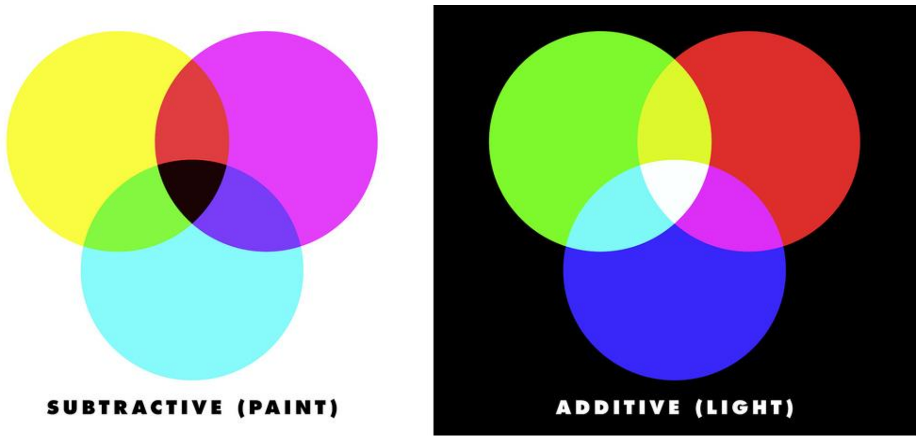


Figure 2.20 - Subtractive (matter) and additive (light) mixture[59].

Helmholtz was mainly concerned with the colour scheme description. Starting from the accepted and contemporaneously used trichromacy, he believed that it should be possible to conceive an ideal triangle, in which any mixture of the colours from the spectrum could be located. To this end, he related his research to the experience of painters, and published a table of mixtures that became part of some French painting books between 1860-1870 (Gage 1999, 212-213). In his *Manual of Psychological Optics* (1856), Helmholtz merged two triangles whose corners were determined in each case by the two possible combinations of the three basic colours: the first triangle, with red, green, and blue (RGB) corners, and the second triangle with cyan, magenta and yellow (CMY) (Fig. 2.21). From this,

[59] https://www.flickr.com/photos/thecampbells/7156774539 (accessed on 06/08/2018).

Helmholtz was able to explain the difference between the colours of the spectrum described by Newton - whose mixture is made additively and whose sum is white, from the colours of the pigments - whose mixture is subtracted and whose sum is black. In addition, and by analogy to music, Helmholtz perceived the difficulty of the human eye to perceive small variations of hue, saturation and luminosity, three concepts that were defined by him and that are still in use (Baumann n.d.).

In 1860, the British physicist and mathematician James Clerck Maxwell (1831-1879), wrote *Theory of Colour Vision,* presenting a method for colour quantification and measure (Pastoureau 2010, 7). Based on blindness, Maxwell was the first to see the potentialities of Thomas Young's findings and to solve the problem of colour perception (Pastoureau 2010, 7). After discovering equations that allowed for the identification of colours, he systematized the resulting combinations into a triangle similar to the one defined by Helmholtz (Fig. 2.21). Based on his findings, each colour mixture would fall on a line connecting to the different vertices of the triangle, which are the primary colours. In other words, from these principal components, all colours of the spectrum could be obtained, if the light stimulus was added or subtracted. His experiences have been validated by quantifying data, and by testing on people. Thus, by means of his triangle, Maxwell established a precise geometric relation between colours. In this triangle, he also located a white dot that allowed him, like Helmholtz, to specify the three variables that characterise colour: hue, tone and shadow (Baumann n.d.).

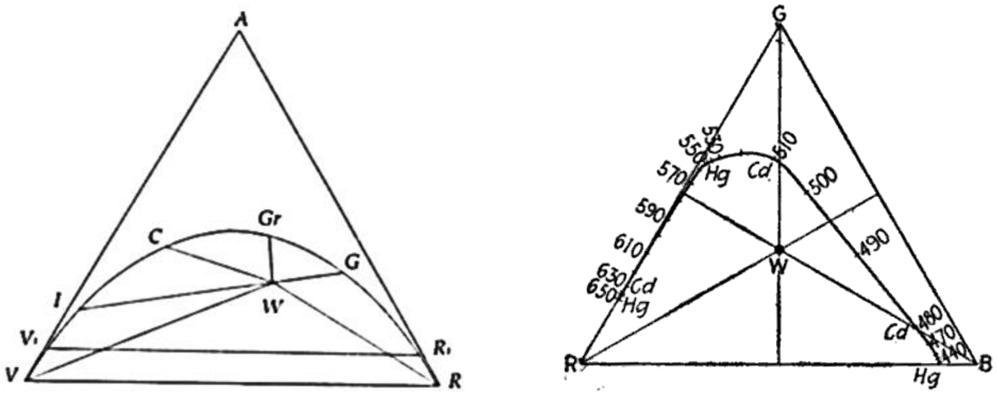


Figure 2.21 - Important colour diagrams for the definition of colour mixture.
Left: Helmholtz's triangle[60]; **Right:** Maxwell's triangle[61].

On 17 May 1861, Maxwell presented the first colour photograph in a public session at the *Royal Institution* in London to demonstrate the concept of additive mixing. This photograph was obtained by using three black-and-white negatives, captured through RGB liquid filters. During the presentation, positives obtained from the negatives were used to project, through the same filters, a superimposition of images, which looked like a colour reproduction of the reality (Fig. 2.22). Despite some technical problems now understood[62], Maxwell's presentation was a success (Kemp 1990, 320-321). The demonstration proved that the colour separation principle was the key for the development of colour photography. With a few exceptions (ex: Lipmann plate), photographic colour processes have been designed based on both additive and subtractive colour mixing (Pénichon 2013, 114).

[60] https://www.colorsystem.com/wp-content/uploads/20hel/03hel.jpg (accessed on 06/08/2018).
[61] https://commons.wikimedia.org/wiki/File:Maxwell_color_Triangle_Luckiesh_1921.png (accessed on 06/08/2018).
[62] At that time, sensitising dyes (explain further in this section) had not been invented yet.

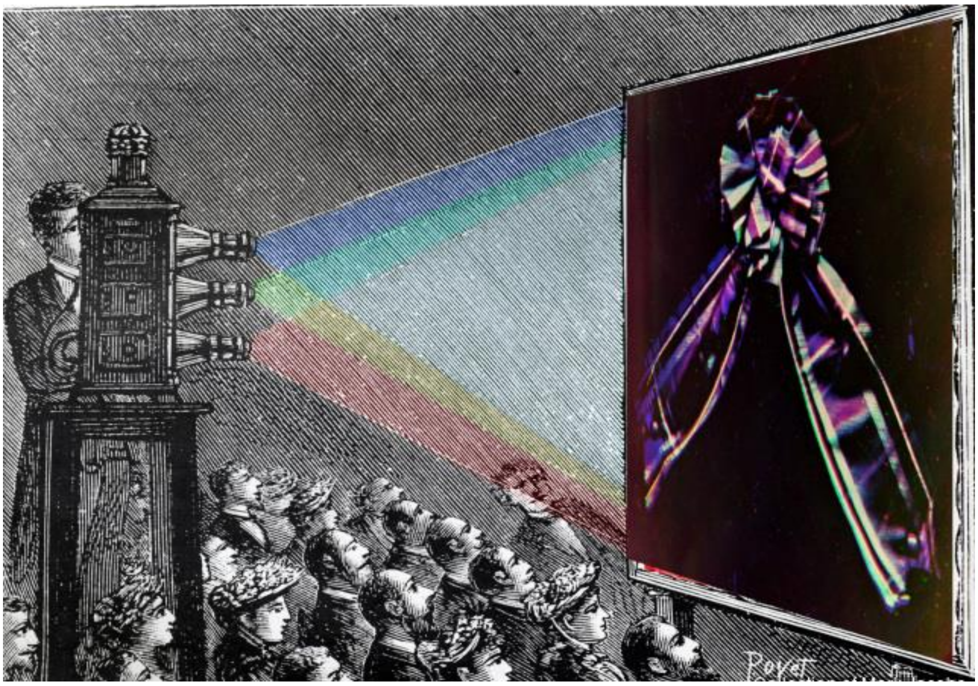


Figure 2.22 - Public presentation of the first colour photograph by Maxwell in 1861[63].

In 1869, two French inventors, Charles Cros (1842-1888) and Louis Ducos du Hauron (1837-1920), proposed the same solution for the production of colour photographic prints. Inspired by Maxwell's discoveries, they started by producing three separation negatives captured through RGB filters. Then, they prepared a positive image from each separation negative, which was tinted with the respective RGB complementary colour. At the end of the process, the three tinted positive images were superimposed on a paper support to produce a colour print. Influenced by the painters' primary colours, instead of using CMY they used B, R and Y colours, leading to prints with a lack of colour accuracy (Gerritsen 1984, 111-113). Years later, Ducos du Hauron proposed another alternative to the acquisition of colour images. Instead of producing separation negatives, he started to use only one colour filter composed of a screen made of thin lines or mosaics with the three primary additive colours. This idea would be appropriated by Auguste (1862-1954) and Louis Lumière (1864-1948)[64] in 1903, who transformed Ducos du Hauron's idea into the first successful colour photographic process: the Autochrome (Gerritsen 1984, 111-113). However, it was only in 1935 with the invention of Kodachrome (1935-2009) by Kodak, the first dye coupling or chromogenic process[65], that colour photography gained significant expression (Bergthaller 2002a, 154). Chromogenic photography, grounded in the colour separation principle to reproduce colours of an original scene, uses a tri-pack with superimposed layers sensitive to R, G or B light. The final image is a sum of three image layers, which are dyed C, M and Y, respectively, during the processing (Roosen, Staes and Verbrugghe 1973, 227). In subtractive colour photography, in general, if all three layers present their maximal dye intensity, all incident light is absorbed, and the perceived image is black. On the contrary, if all three layers present the minimum dye intensity, all the light is reflected or transmitted, and the perceived image is white. In theory, by

[63] https://sechtl-vosecek.ucw.cz/en/images/autochromy/big/projection-maxwell.jpg (accessed on 06/08/2018).
[64] The Lumière brothers are known for launching the foundation of a photographic industry in France. Louis Lumière was also a key figure in the invention of cinema (Lavédrine and Gandolfo 2013, 1).
[65] Both terms are used to describe this type of colour photography. Within this dissertation, the most popular term was adopted: chromogenic.

properly combining the subtractive coloured layers, all colours can be reproduced (Roosen, Staes and Verbrugghe 1973, 227). The fact that chromogenic photography, a fully industrialized process (no need for separating and assembling layers manually), provided good quality images at an accessible price, was the key for its success (Rauch 1973, 209). Moreover, the chromogenic process was available in a wide range of materials, such as motion picture films, photographic negatives, prints and transparencies (reversal films), and in different formats too (professional and amateur) (Reilly 1998, 6). Other subtractive methods developed by the photographic and cinematographic industry, achieved some success. Dye transfer, mostly known for its application in Technicolor films from the 1920s onwards (Coote 1993, 131), and silver dye bleach, commonly named Cibachrome or Ilfordchrome after the companies that produced those materials (Coote 1993, 183), are two examples of popular processes. However, it was through chromogenic processes that colour photography grew as never before. The introduction of Kodacolor in 1941, the first chromogenic negative-print system, and of the Kodak Instamatic Camera in 1963, represent two landmarks in the history of colour photography (Pénichon 2013, 160). The success of chromogenic materials led to the colour photography era, starting in the 1960s (after the industry rebuilt itself from WWII), when the use of colour photographs surpassed that of black-and-white. Ever since, inestimable amounts of colour photographs have been produced (Pénichon 2013, 160). By 2002, traditional photography begun to decline with the start of the new digital era (Wilhelm 2002, 14). Nevertheless, at the present, chromogenic photographs represent a significant part of the cultural heritage worldwide (Wilhelm and Brower 1993, 625).

2.3.3. Technology

“Few common commercial products are as chemically complex as photographic films”.

E. Steven Brandt (1989, 391)

There were several agents leading to the development of chromogenic photography. In 1907, the German chemist Benno von Homolka (1860-1925) discovered that it was possible to generate colour images, based on certain colourless compounds - colour couplers - that were able to react with developing agents, after being oxidized by their reaction with silver salts, to produce dyes (Pénichon 2013, 162) (Fig. 2.23). In 1911, another German chemist, Rudolph Fischer (1881-1957), made a patent based on the work started by Homolka, and proposed a multi-layered system (tri-pack) with the primary subtractive colours to produce a colour film. Although he was able to predict the future of colour photography, Fischer could not prevent colour couplers from wandering between the different emulsion layers[66] (Coote 1993, 137).

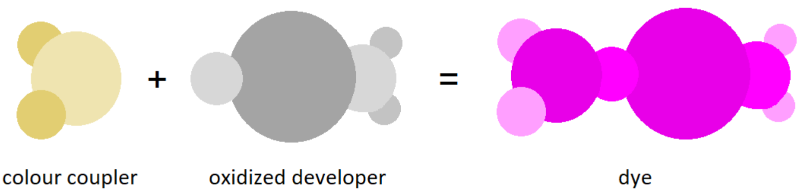


Figure 2.23 - Schematic representation of a chromogenic dye formation.

[66] In photography, an emulsion is a layer composed of an imaging material and a binding agent.

A few years later, two musicians passionate by photography, Leopold Godowsky (1870-1938) and Leopold Mannes (1988-1964) started to work on Fischer patents. After being hired by Kodak, in 1935, they solved the problems encountered by Fischer and launched Kodachrome[67], the first chromogenic product (Coote 1993, 138). Kodachrome was based on diffusible colour couplers that were introduced, separately, into the respective emulsion layers during development (added dye couplers) (Pénichon 2013, 162). Therefore, the first Kodachrome had an intricate, expensive and time-consuming processing, in which twenty-eight different baths were required to process the film (Pénichon 2013, 163). This processing, known as controlled diffusion bleach method, was substituted in 1938 by the selective re-exposure method, leading to a rather simplified processing[68]. Yet, the new processing still had a complex technology, making it impossible for the user to process the film (Wilhelm and Brower 1993, 20-21). This formula remained almost unchanged until the discontinuation of Kodachrome in 2009 (Pénichon 2013, 163). In 1936, the Agfa chemists Wilhelm Schneider (1900-1980) and Gustav Willmanns (1881-1965), introduced a chromogenic product (also a reversal film) with a different technology: Agfacolor Neu. The essential novelty of Agfa Neu was that non-diffusible colour couplers with long aliphatic chains were employed to avoid dyes from spreading into other layers. Hence, the colour couplers could be introduced in the emulsion during manufacture (integrated dye couplers) (Rauch 1973, 221). This allowed for a much simpler processing than that of Kodachrome, since only one colour developing bath was required to produce dyes in all three layers of the film simultaneously (Rauch 1973, 220). In 1938, Agfa-Ansco Company launched Ansco Color Film, the first chromogenic material that could be processed by users (Pénichon 2013, 164). After a few years, Agfa patents expired and other photographic companies, namely Kodak and Fuji, started to use products with integrated dye couplers (Pénichon 2013, 169). Ektachrome and Fujichrome, respectively, are two examples of reversal films with that technology. Since the chromogenic reversal films selected for an in-depth research within the framework of this dissertation are from the integrated dye couplers type, only these materials are described in the further sections.

There are two important references focusing on chromogenic photography. The first is from Peter Bergthaller (2002a-c), a former researcher from Agfa, and the second from Shinsaku Fujita (2004), from Fuji. These publications provide detailed information about the chromogenic processing, the characteristics of different colour couplers' classes and their functional groups, as well as the stability of the final dyes, among other technical issues. Both references were fundamental for the understanding of the materials under study. Within this context, the paper by the independent chemists Ronald D. Theys and George Sosnovsky (1997) are also worth mentioning. Unfortunately, as stated by Theys and Sosnovsky (1997, 83), most information about colour photography is the propriety of the industry and is classified. Moreover, as recognized by Berghtaller (2002a, 155) and confirmed by the author of this dissertation, the number of colour couplers' patents released over time is massive, and therefore, almost inscrutable. In the book by Jerome Katz and Sydney Fogel (1971), professor at the Rochester Institute of Technology and industry consultant, respectively, a list of patented couplers

[67] The commercial name Kodachrome is associated to a special type of chromogenic product with a specific processing. The first Kodachrome was first launched as a 16 mm reversal motion picture film, although it was later produced in other formats.

[68] Kodachrome processing has been largely described by the photograph conservator Pénichon (2013, 182-183). Sylvie Pénichon's (2013) book was a valuable reference for the development of this dissertation, being dedicated to the different colour photographic processes, their history, their technology, their material composition and their forms of degradation.

produced until that time can be found. The chemist Edwin Mutter (1967) also compiled a similar list (published in German only). Nevertheless, only a reduced number of the patented colour couplers has been employed in commercially available chromogenic materials (Wilhelm and Brower 1993, 22).

2.3.3.1. Image formation

To give a general overview of the material composition and stratigraphic layers of chromogenic reversal film with integrated dye couplers, each component is briefly described in this section (Fig 2.24). The chemical reactions that occur throughout processing and leading to the image formation are also explained.

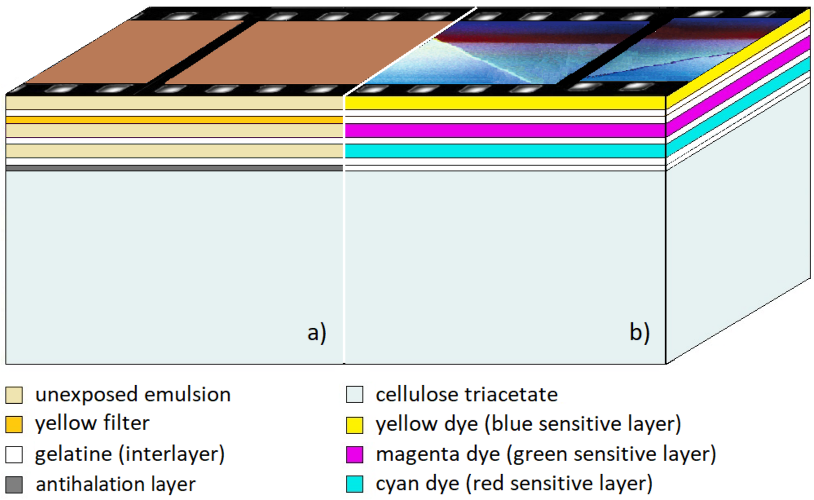


Figure 2.24 - Overview of a common cross-section from a 35 mm chromogenic reversal film (not to scale); a) before processing, b) after processing.

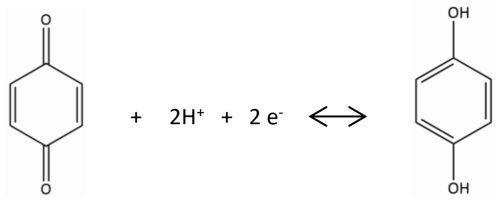
A photographic material can be divided into two parts: emulsion layer/s (imaging material + binding agent) and base. From the 1880s onwards, and due to its characteristics, the use of gelatine in photographic emulsions as a binding agent was widespread (Schrieber and Gareis 2007, 6). Its transparency and swelling proprieties (necessary for the processing), made it ideal for use in photography. The photographic gelatine manufacture is carried out by alkali pre-treatment (type-B gelatine) from bone and skin collagen (Abrusci et al. 2004, 537). Among others, gelatine allows for the acceleration of the processing time, for the stabilization of the silver halides and for a controlled growing of the imaging materials during development (Schrieber and Gareis 2007, 260-261). In chromogenic films, each colour emulsion layer has a thickness between 5 µm and 10 µm (Di Pietro 2007, 180). The superimposed emulsion layers are coated on a base that confers stability to the global structure. Both polyester and cellulose acetate (CA) have been used as a base for chromogenic reversal films (Pénichon 2013, 186). Although polyester started to substitute cellulose triacetate (CTA) supports in the 1960s, the latter has been maintained for motion-picture film (in-camera) because of its greater flexibility (Lavédrine 2003, 21-23). In the same way, 35 mm chromogenic reversal films are commonly CTA based (Horvarth 1987, 9; Vitale 2009, 5). According to the consulted technical data sheets made available by manufacturers, in this type of material the base has a thickness of around 120-130 µm.

Before processing, each emulsion layer is composed within the gelatine binder of colour couplers, silver halides (normally silver bromide) and sensitizing dyes. In 1873, the German photo-chemist Hermann Wilhelm Vogel (1834-1898) discovered that certain dyes, when in contact with silver halides could extend the sensitivity of the latter, only sensitive to wavelengths below 450 nm (Waller, Hinz and Filosa 2000, 61). Ever since, sensitizing dyes have been employed in the emulsion layers of photographic materials to make them absorb light at the desired wavelength, namely in the G and R region (Fujita 2004, 111). Commonly, sensitizing dyes from modern photography belong to the cyanine and merocyanine families (Hunger 2004, 509). During manufacture, the sensitizing dyes are mixed with the silver salts, remaining adsorbed on their surface. After exposure to light, the excited sensitizing dyes transfer an electron into the conduction band of the silver halides, becoming a radical cation. The transferred electron is then trapped into the silver halide and forms the latent image, and the radical cation is neutralized by a bromide anion (Fujita 2004, 119). Hence, silver halides can capture photons with energies that are outside their natural range (Brandt 1989, 391). According to the literature, in chromogenic reversal films, the first (top) layer is only sensitive to B light (400-500 nm), the following one to G (500-600 nm) and the last one to R (600-700 nm) (Pénichon 2013, 187)[69]. After processing, the sensitive layers reproduce the complementary colours in order to replicate the colours of the original scene, based on its three colour components: the B sensitive layer reproduces the Y elements of the picture, the G sensitive layer reproduces the M, and the R sensitive layer reproduces the C (Current 1987, 100). More than one layer for each colour might be used, in order to optimize the tint and sharpness of the final image (Bello 1973, 268). Since silver halides absorb in the B region of the visible spectrum, a yellow filter is placed below the B sensitive layer to absorb the B light and avoid its transmission to the layers below (Fujita 2004, 137). In 35 mm chromogenic reversal films, an anti-halation layer is placed underneath the emulsion layers, before the CTA base. This layer, made of silver or a mordanted dye within a gelatine binder, prevents light scattering produced by reflection from the transparent support (Waller, Hinz and Filosa 2000, 62). The remaining layers are auxiliary and protective. Frequently, a gelatine layer is coated on the top of the film for protection of the image (Bello 1973, 268). Contrary to other formats, the presence of a backing layer is not desirable in 35 mm films and for making slides (Current 1987, 115). Gelatine interlayers are employed to prevent dye dispersion (Bello 1973, 268). Additionally, white couplers and scavengers can be introduced into the gelatine interlayers as barrier agents to prevent colour mixing (Bergthaller 2002b, 223). Other compounds, such as antioxidants and UV absorbers, have also been incorporated into the emulsion layers (Theys and Sosnovsky 1997, 99) or coating layers (Pénichon 2013, 187) to prevent dyes from degrading.

Image formation begins with the exposure of the film to light. During exposure, R, G and B lights are selectively absorbed by the respective sensitive layer. The film must then be processed to develop the captured image. Chromogenic processing is composed of several steps. Since 1976 until the present, E-6 processing, developed by Kodak[70], has been used to develop chromogenic reversal films with integrated dye couplers (Pénichon 2013, 320)[71]. While chromogenic negatives and prints only need colour development, reversal films require a previous step with black-and-white development that enables it to convert the captured negative image into a positive image (Fujita 2004, 163). Taking as an example a chromogenic reversal film exposed to pure red, after the exposure of the film, the following steps occur within the emulsion layers (a summary of the processing steps is illustrated in Figure 2.25):

[69] This specific order was applied in chromogenic reversal films to improve image sharpness (Bello 1973, 276).
[70] The equivalent processing from Fuji is called CR-56.
[71] Before E-6, other processes were employed for the same materials. Covering the period under study, E-3 was introduced in the 1950s and E-4 in 1974 (Pénichon 2014, 320).

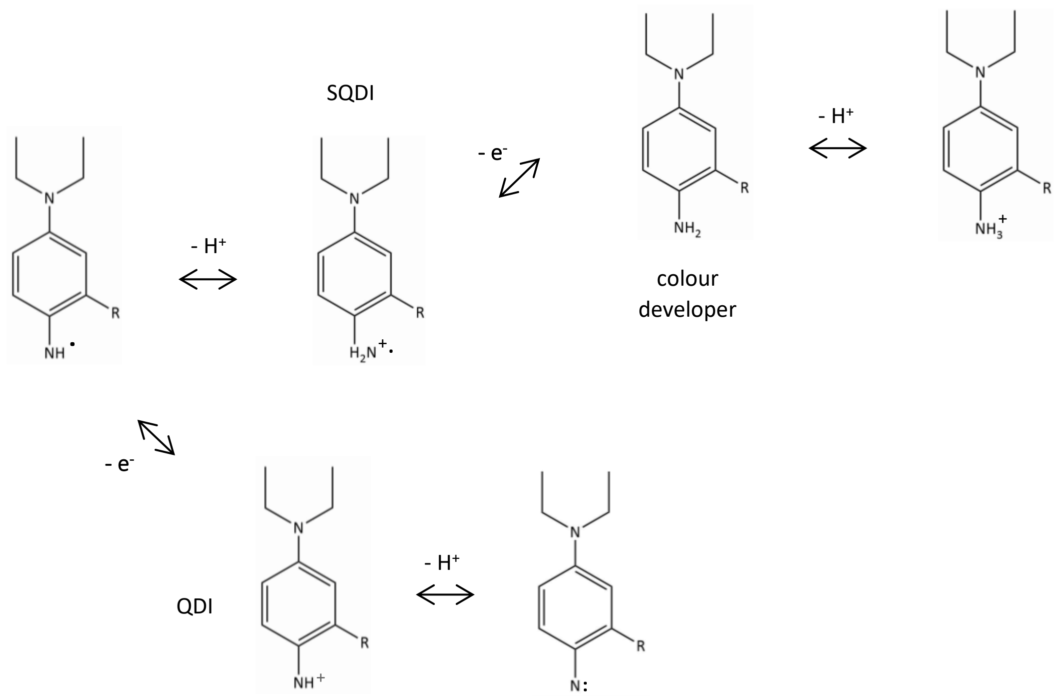
i) Silver halides development - Redox reaction (favourable in an alkaline environment) in which the silver ions are reduced and the developing agent (ex: hydroquinone) is oxidized. Within the developing aqueous solution, the surface of the crystals where latent image was formed during exposure works as an electrode between the developing agent and the silver halides, favouring electronic exchanges in the areas exposed to light (Melo 1987, 161);



$$Ag^{+} + e^{-} \leftrightarrow Ag^{0}$$

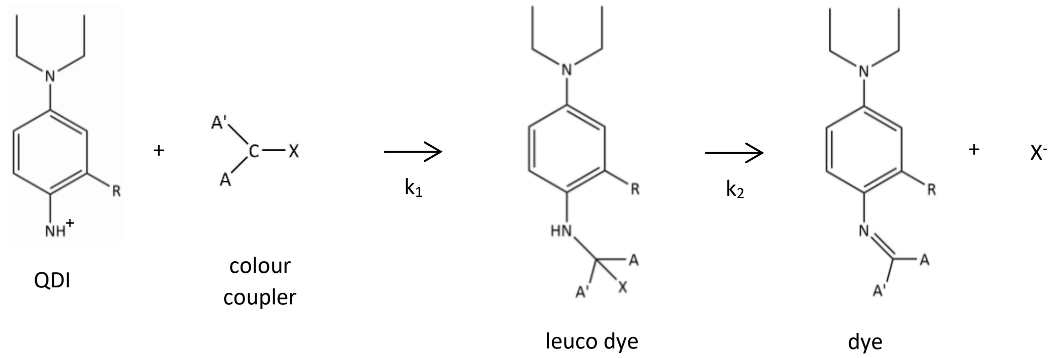
ii) Inversion - The film is exposed to white light to revert the negative image produced in-camera into a positive image[72] (Pénichon 2013, 160). By re-exposing the film to light, a latent image is formed in the areas unexposed at first (Pénichon 2013, 185-186). In this example, latent image is generated in both B and G sensitive layers, as described in i);

iii) Colour development - A colour developing solution containing *p*-phenylenediamine is used to reduce the sensitized silver salts (in this example, from the B and G sensitive layers). The oxidized developer, quinonediimine (QDI), is an active coupling agent (electrophile) and is the result of the protonation and redox equilibria between the colour developer and the silver halides. Semiquinonediimine (QDI) is an intermediate specie and a potentially active coupling agent (Bergthaller 2002a, 160).



[72] Alternatively, the film can be subjected to chemical fogging (Pénichon 2013, 160).

Colour couplers contain acidic hydrogens, which become ionized in the alkaline developer solution. The produced coupler anion reacts with QDI at sites with a greater positive charge, leading to the formation of a leuco dye. The continuous reaction with QDI will promote the creation of a conjugated system with an imine bond[73] (Kahn 2004, 4). In the present example, Y and M couplers [74] from B and G sensitive layers, respectively, lead to the formation of Y and M dyes. Spherical dye clouds[75], with about 1.5-6 µm, are produced in the vicinity of the developed silver grains (Vitale 2007, 6-7). The density of the dye corresponds to the density of the developed silver (Wilhelm and Brower 1993, 21);



iv) Bleaching - At the end of the processing, the metallic silver is bleached out. The bleaching process converts the metallic silver into ionic silver by using an oxidizing agent. The oxidizing agent is used in the presence of a halide salt, which in turn reacts with the ionic silver to form a silver halide (Kahn 2004, 8);

$$Ag^0 + Fe(CN)_6^{3-} \longrightarrow Ag^+ + Fe(CN)_6^{4-}$$
$$Ag^+ + Br^- \longrightarrow AgBr$$

v) Fixing - The silver halides are removed from the emulsion by using a typical fixing solution, such as a thiosulfate (Kahn 2004, 9).

vi) Washing - A final wash eliminates all the residues from the processing. At the end of the processing, only dye clouds and the unprocessed colour coupler (residual colour couplers, in this example from the B sensitive layer), are left. Sensitizing dyes and dyes from the yellow filter and anti-halation layers are also removed (Waller, Hinz and Filosa 2000, 63).

Several colour developers have been used over time. Within the E-6 processing, both CD-3 and CD-4 compounds have been employed as developing agents (Fig. 2.26) (Bergthaller 2002a, 158). CD-3 produces dyes with more brilliant hues, and normally with higher chemical stability than CD-4. CD-4 has a higher developing power, and so, it is used when photographic speed and development efficiency are required (Bergthaller 2002a, 159).

[73] The coupling reaction system is extremely complex and has a heterogeneous character (Bergthaller 2002a, 157).
[74] Note that although colour couplers are colourless, they are called CMY couplers in the literature, since they are meant to produce that colour at the end of the processing.
[75] Although chromogenic dyes are referenced in the bibliography as dyes, they can be considered organic pigments since they are insoluble in the gelatine binder.

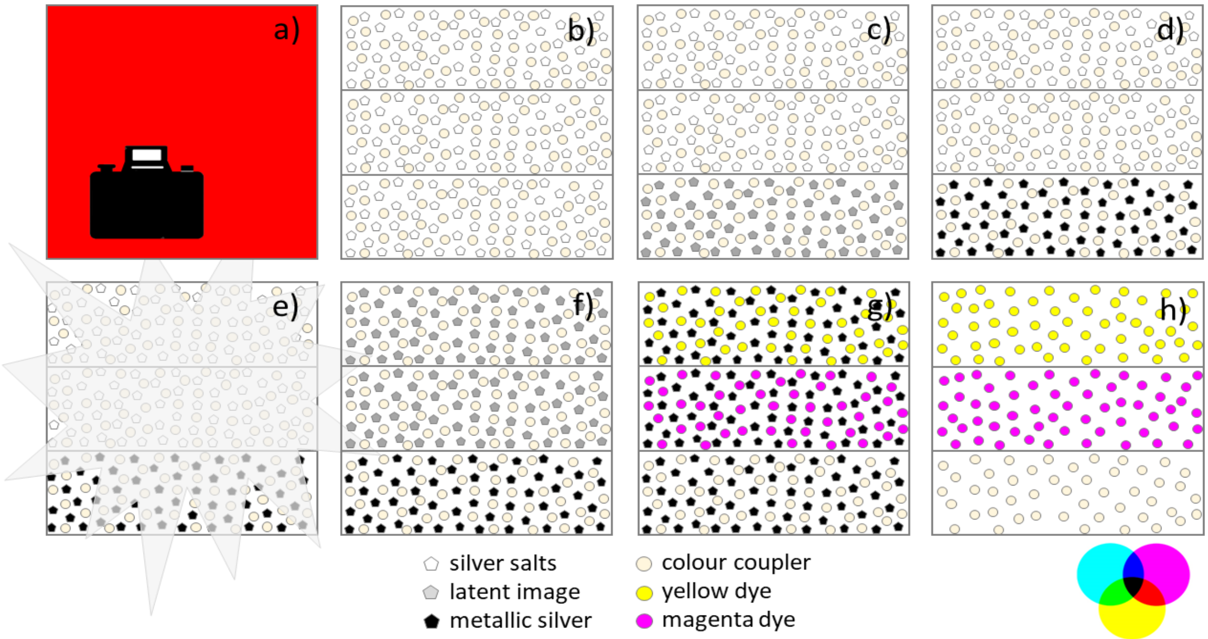
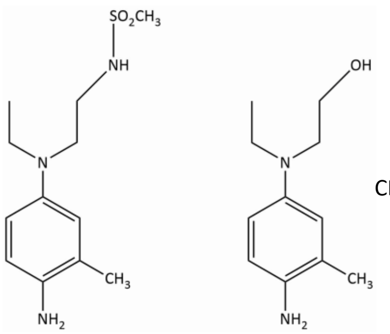


Figure 2.25 - Example of the E-6 processing of a chromogenic reversal film (based on Pénichon 2013, 185-186) exposed to R light: a) exposure of the film to R, b) emulsion layers before exposure; c) latent image formation on the R sensitive layer, d) development of the silver halides, e) exposure to white light to revert the image, f) latent image formation on the B and G sensitive layers, g) development of the silver halides and colour couplers, f) removal of the metallic silver. From b) to h) only a simplified cross-section of the emulsion layers is represented.

CD-3



CD-4

Figure 2.26 - Molecular structure of the colour developers used in E-6 processing (based on Bergthaller 2002a, 158).

2.3.3.2. Colour couplers and chromogenic dyes

The existing literature is essentially focused on the chemistry of colour couplers, and not on the final product, the dye. For that reason, the following review mainly addresses colour couplers.

Colour couplers are generally divided into two categories - two- or four-equivalent couplers - according to the number of electrons required to produce a dye molecule during processing. Two-equivalent couplers need one mol of developer oxidation product (two electrons) and four-equivalent couplers need two mol of developer oxidation product (four electrons) (Bergthaller 2002a, 161-162).

Different functional groups can be attached to the colour coupler nucleus to improve its features. Ballasting groups are usually employed to prevent dyes from wandering from one layer to another (Fujita 2004, 143). Considering the two moieties, colour coupler and oxidized developer, as well as ballasting groups, chromogenic dyes are in general long chain molecules. Leaving groups[76], also known as coupling-off groups, are molecular fragments added in two-equivalent couplers to optimize the coupling rate and promote the direct formation of the chromophore (Fujita 2004, 167). Both ballasting and leaving groups can be responsible for improving other photographic functions (Bergthaller 2002c, 234).

Among the non-diffusible couplers applied in integrated dye coupler type of materials, three categories of couplers have been used: i) hydrophilic, ii) oil protected, and iii) polymer protected (Fujita 2004, 143-145). Hydrophilic couplers were employed in the first products developed by Agfa to surpass the problems encountered by Fischer. Their hydrophilicity is based on groups such as sulphonic or carboxylic acids. Ballast groups with long aliphatic chains were used in this type of coupler, to increase the molecular weight and avoid spreading. However, those groups also turned the dispersion of the couplers into the emulsion layers more difficult. To overcome this problem, amphiphilic compounds were added to the molecule allowing it to behave as a micelle (Fujita 2004, 143). Oil protected couplers were first applied in Kodacolor (1942) and have been widely used ever since. These couplers are based on lipophilic ballast groups. Thus, the couplers can be dispersed in the emulsion layers as fine oil droplets, by means of oil derivates such as tricresyl phosphate or butyl phthalate (Fujita 2004, 144-145). Polymer protected couplers, based on the incorporation of a coupling nucleus into a polymeric structure instead of an oil, have also been employed. Hydrophobic compounds within loadable polymer particles, such as latexes, are common (Fujita 2004, 145). Latex type couplers, introduced by Fuji, enabled the production of much smaller particles, and therefore, the intensification of coupler concentration, which in turn allowed for the reduction of the layer thickness[77] (Pénichon 2013, 177). Both Kodak and Fuji, as well as other manufacturers, replaced the hydrophilic technology by oil or polymer encapsulated couplers (Wilhelm and Brower 1993, 21).

Development-inhibitor releasing (DIR) couplers[78] were introduced at the end of the 1960s, with the aim of restraining the size of the silver cluster during colour development. Thus, it was possible to enhance colour saturation and sharpness, and to reduce the graininess of the final image (Bergthaller 2002c, 235). However, DIR couplers could not be used in chromogenic reversal films, due to the reversal processes. To overcome this issue, DIR hydroquinones have been designed to be applied in the first black-and-white developing bath. Fuji has placed several products on the market using DIR hydroquinones, such as Velvia (1990), Provia (1994) and Astia (1997) (Fujita 2004, 311).

Although each manufacturer employed its own colour couplers, all the industry worked with materials with similar structures (Reilly 1998, 3). The most important classes of Y couplers are pivaloylacetanilide and benzoylacetanilide. Historically, benzoylacetanilides are the Y couplers *par excellence* due to their high tinctorial strength. Pivaloyacetanilides, introduced by Kodak in the 1960s, were appreciated for their low cost and simple access, as well as for the stability of the resulting dye (Bergthaller 2002a, 171). More recently, other classes of couplers have been employed, such as cycloalkanoylacetanilides and malonanilides (Bergthaller 2002a, 172). The first was patented by Fuji in 1993, as a new type of Y coupler, with much better stability and higher tinctorial strength (Bergthaller 2002a, 172). M couplers are normally heteroaromatic compounds; the major classes are pyrazolones

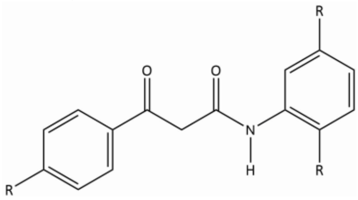
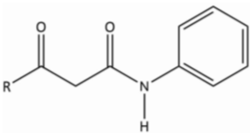
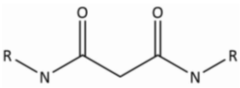
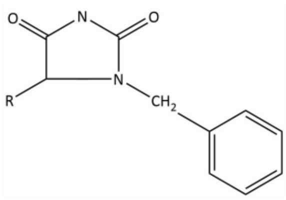
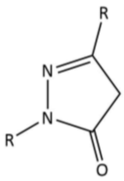
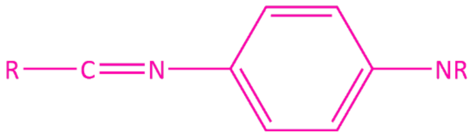
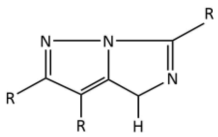
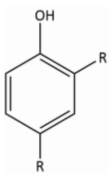
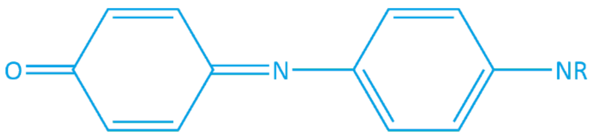
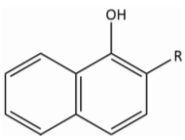
[76] During the coupling reaction, an heterolytic bond cleavage occurs in the colour coupler and the leaving group departs with a pair of electrons.
[77] The thinner the emulsion layers the less the light scattering, and therefore, the sharper the final image (Pénichon 2013, 177).
[78] Couplers having certain leaving groups, such as aromatic or heteroaromatic leaving groups, which are able to split-off during development and act as development inhibitors (Bergthaller 2002c, 235).

and pyrazoloazoles. Until 1980, pyrazolones were the M couplers of choice. The 3-acylaminopyrazolones, discovered in the 1940s, were mostly used in in-camera films such as negatives, reversal films and motion picture films, at least up to 1988, because of their image quality (Di Pietro 2007, 184). In the 2000s, the use of pyrazolotriazoles of the pyrazolo[5,1-c](1,2,4)triazole and pyrazolo[1,5-b](1,2,4)triazole types was widespread, due to the high quality of hues produced by the correspondent dye (Bergthaller 2002b, 188). Most C couplers are substituted phenols or naphthols (Bergthaller 2002b, 187). The use of 2,5-diacylaminophenols in reversal films, disclosed by Kodak, was generalized for more than twenty years (Bergthaller 2002b, 205). Nevertheless, heterocyclic compounds have also been used (Fujita 2004, 168). Polyazapentalenes, such as pyrrolo[1,2-b](1,2,4-triazoles), are examples of this type of coupler, with very good tinctorial strength and absorption (Bergthaller 2002b, 187). Other classes of all three colour couplers have been produced.

In general, the dyes resulting from the reaction of M and Y couplers with the developing agent are from the azomethine family, while those resulting from C couplers are from the indoaniline family (Rauch 1973, 212). Schiff base is one of the most important functional groups present in the three dyes, which is associated to the imine bond created between the molecule of the colour coupler and that of the activated colour developer. The Schiff base is an essential link in the conjugated system, being responsible for the absorption of the dye and therefore for its colour (Jesper 2015, 16). The most significant classes of couplers and the corresponding dye are summarized in Table 2.1. Figure 2.27 show a schematic representation of the formation of Y, M and C dyes.

The accuracy of the dyes' hue (absorption) and its long-term stability have been the two most important characteristics sought by the industry. These two technical features led to continuous improvements in the chromogenic system (Fujita 2004, 168). The precise structure of the final dyes present in a chromogenic material depends on the type of colour coupler and its functional groups, and on the developing agent used to process the film (Di Pietro 2007, 180). Consequently, a vast quantity of dyes with slight variations in specific functional groups can be found (Reilly 1998, 3-4). Over time, the composition of developing agents (Bergthaller 2002a, 159) and especially of colour couplers (Di Pietro 2007, 180) has undergone many changes (Reilly 1998, 3-4). According to the type of material (negative, print, reversal film), different couplers have been shaped (Reilly 1998, 3). Moreover, due to the constant evolution on coupler technology, manufacturers often changed the couplers at use, normally without any announcement (Reilly 1998, 3) and so, different couplers have been applied in different stocks as well (Di Pietro 2007, 180). Unfortunately, up to now, as far as it could be concluded from the conducted research, there is no way of knowing which colour couplers have been employed in which products based on the available literature.

Table 2.1 – Molecular structure of the main classes of colour couplers employed in chromogenic photography, and respective family of dye produced during development

<table>
<tr><th>Colour Coupler (class)</th><th>Dye (family)</th></tr>
<tr><td>Benzoylacetanilides
</td><td rowspan="4">Azomethine
</td></tr>
<tr><td>Pivaloylacetanilides
</td></tr>
<tr><td>Malondiamides
</td></tr>
<tr><td>Cycloalkanoylacetanilides
</td></tr>
<tr><td>Pyrazolones
</td><td rowspan="2">Azomethine
</td></tr>
<tr><td>Pyrazoloazoles
</td></tr>
<tr><td>Substituted phenols
</td><td rowspan="2">Indoaniline
</td></tr>
<tr><td>Substituted naphthols
</td></tr>
</table>

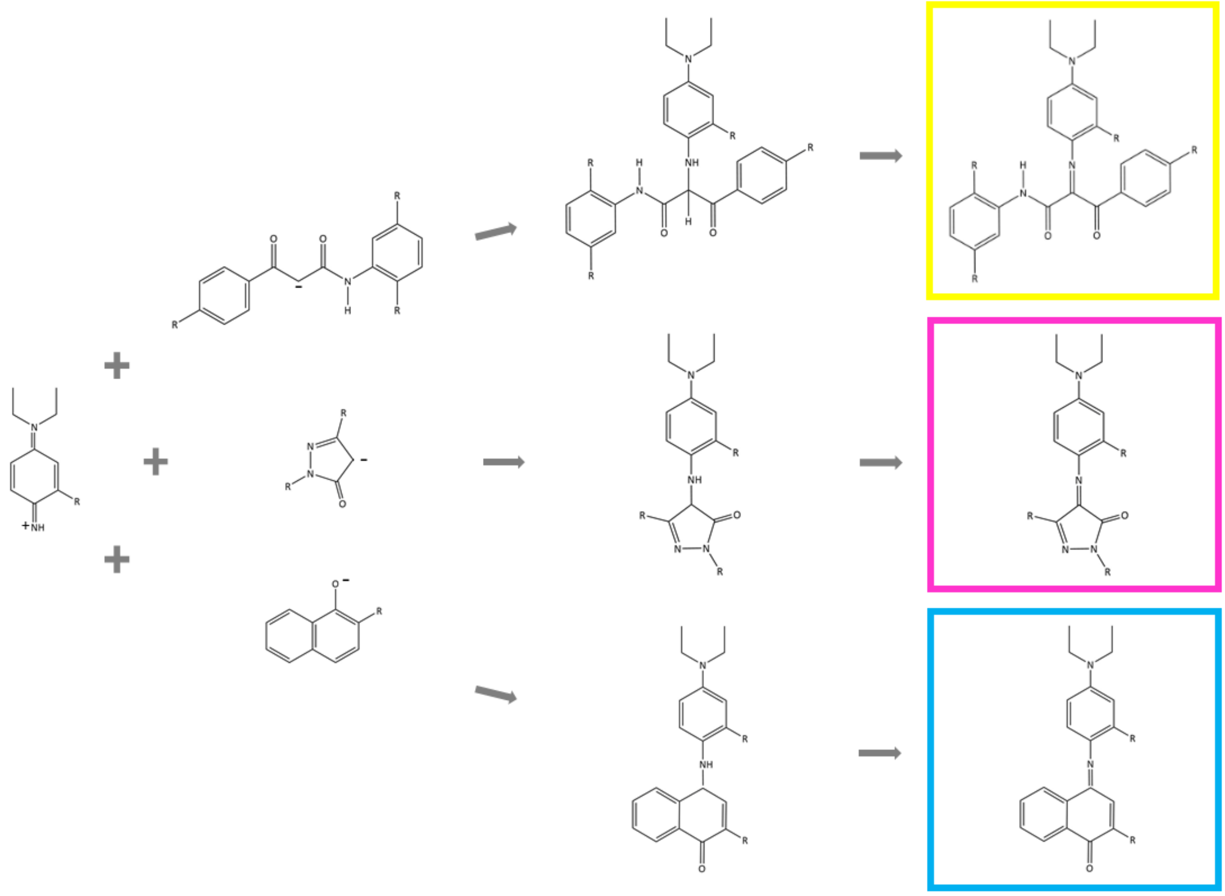


Figure 2.27 – Schematic representation of yellow, magenta and cyan dyes, resulting from the coupling reaction with a benzoylacetanilide, pyrazolone and substituted naphthol type of colour coupler, respectively (based on Guida and Raber 1975, 626).

2.3.4. Degradation

The first generation of chromogenic materials with integrated dye couplers were chemically very unstable. With the early signs of colour change, consumers denounced the poor quality of the products, pressuring the industry to improve their pattern of quality (Wilhelm and Brower 1993, 34-35). This drove Kodak, Fuji, Agfa, among other industries, to test the stability of their products on a regular basis.

From the late 1970s, chromogenic materials were induced to artificial ageing tests, under different T (at constant RH), following the Arrhenius method (Reilly 1998, 4-5). Unfortunately, although some companies often released the results of those tests, Kodak mainly kept them secret (Wilhelm and Brower 1993, 24). Nonetheless, some have been published, such as those from the following authors: Peter Adelstein, C. Loren Graham and Lloyd West (1970), Robert Tuite (1979), and Charleton C. Bard, George W. Larson, Howell Hammond and Clarence Packard (1980). These experiments led to a deeper knowledge on the deterioration mechanisms associated with chromogenic dyes, contributing to great improvements in the stability of these materials, from the 1980s onwards (modern materials) (Reilly 1998, 5). Over time, the existing couplers have been upgraded and new classes of colour couplers have been launched (Bergthaller 2002c, 265).

Even so, chromogenic dyes are intrinsically vulnerable to degradation, having poor long-term stability (Theys and Sosnovsky 1997, 99). Therefore, chromogenic materials raise problems associated first with dye degradation rather than with the base (Wilhelm and Brower 1993, 177). Chromogenic dyes are highly susceptible to oxidation and hydrolysis, both induced by light (light fading) and/or RH and T (dark fading) (Wilhelm and Brower 1993, 22). Continuous contact with environmental agents gradually disrupts the chromophore molecules, leading to the formation of colourless degradation products, responsible for the fading of the image (Reilly 1998, 9). Since the three dyes present in a film have a different molecular structure, they also have a different degradation rate. Therefore, these materials are prone to shift the original colour balance. Residual colour couplers from the integrated dye coupler type are also vulnerable to oxidation, producing yellowish species (yellow stain) (Bergthaller 2002c, 265). This is especially visible in the highlight areas of the image (Wilhelm and Brower 1993, 22), where residual colour couplers are present in higher quantity[79] (Tuite 1979, 477). Furthermore, the interaction between residual colour couplers (nucleophiles) and dyes (electrophiles) can accelerate dye fading (Bergthaller 2002c, 265). Improper processing can also decrease dye stability and/or enhance staining levels (Wilhelm and Brower 1993, 63). It is generally recognized that 30% density loss and 15% shift in colour balance are the values from which degradation is discernible (Lavédrine 2003, 12).

Colour photographs are normally less susceptible to air pollutants than black-and-white photographs (Reilly 1998, 14). However, some acidic vapours might also accelerate dye fading (Reilly 1998, 15). Based on the PhD thesis by Ann Fenech (2011, 176), acetic acid (released from CTA base in decay, among others), is the pollutant that causes the highest rate of dye degradation in chromogenic prints, being one of the most common acids presents in storage facilities with archival materials.

According to Sylvie Pénichon (2013, 188), mould growth is one of the most common types of degradation emerging in chromogenic reversal films. Based on the study conducted by Miguel Lourenço and José Paulo Sampaio (2007, 30), colour materials are more vulnerable to fungi than black-and-white materials.

Over the years, it has been demonstrated that degradation products generated by dark and light fading can be different, since the two degradation courses might lead to different disruptions of the chromophores (Bergthaller 2002c, 265). The same film can be very unstable when exposed to light and quite stable in the dark. For instance, M dyes are normally the most susceptible to light fading and the most stable to dark fading (Wilhelm and Brower 1993, 165). Also, Kodachrome is known for its very good dark fading stability[80] and for its very poor projector fading stability (Wilhelm and Brower 1993, 176).

In general, it can be stated that the higher the T and RH, the higher the fading rate (Tuite 1979, 99). One of the main degradation pathways arising in the dark is induced by hydrolysis, by means of the gelatine from the emulsion layers that absorbs the atmospheric water (Reilly 1998, 11). Hydrolysis is accelerated by T and extreme pH values (Jacobson 2000, 373). The hydrolysis of the Schiff base can lead to reverse reactions of dye formation (Jesper 2015, 16). However, according to Peter Bergthaller (2002c, 266), the degradation mechanisms associated with the hydrolysis of chromogenic dyes are not yet completely understood. Nevertheless, he proposed a generic degradation pathway for the detachment of the developer fragment from the dye in the presence of RH (Bergthaller 2002c, 266). The degradation process can be triggered by a sequence of single-electron or proton transfer to the imine bond, as shown in Figure 2.28. According to the independent researchers Henry Wilhelm and Carol Brower (1993, 163), dark fading stability of modern materials is mainly determined by T due to its influence on the fading rate. As explained by the Image Permanence Institute (IPI) researcher James Reilly (1998, 11), the higher

[79] Residual colour couplers are present in inverse proportion to the amount of dye formed (Tuite 1979, 477).
[80] Since Kodachrome does not contain integrated dye couplers, this type of film does not present yellow stain (Wilhelm and Brower 1993, 176).

the T, the higher the probability of breaking a molecular bond spontaneously, which causes a structural rearrangement. And, at room T, there is enough heat energy to promote rearrangement in most chromogenic dyes (Reilly 1998, 11).

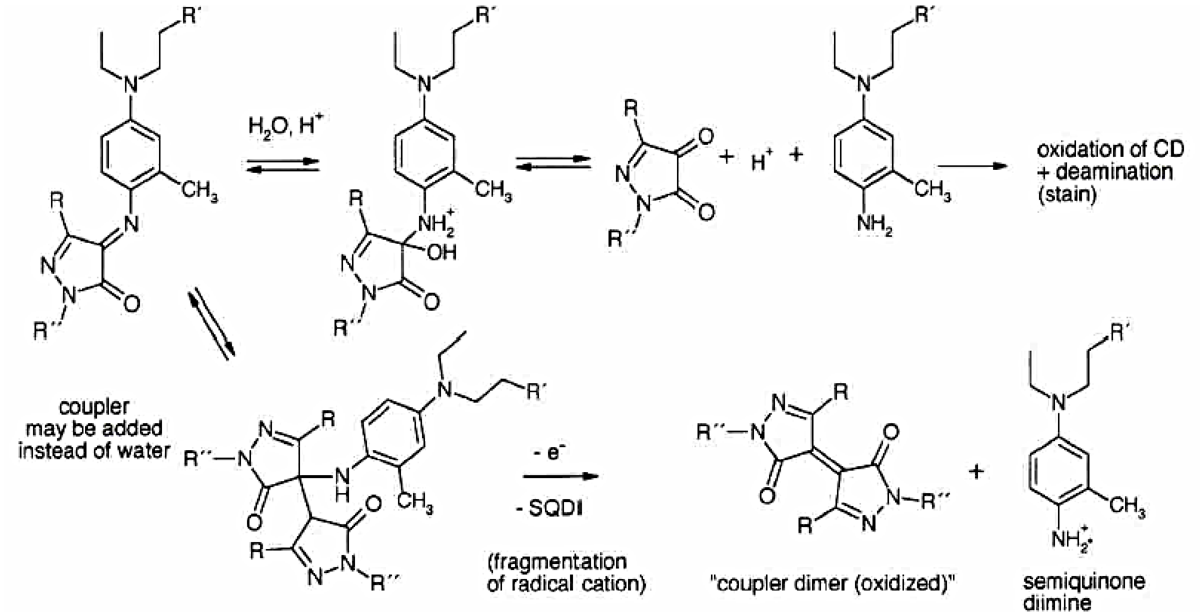


Figure 2.28 - Hypothetical dark fading reaction, based on the hydrolysis of a chromogenic dye derived from a pyrazolone coupler (Bergthaller 2002c, 266).

Dark fading normally leads to colour shift and loss of density, homogeneously spread over the image. The production of yellow stain, mostly located in the low-density areas of the image, also contributes to the discolouration of the films (Wilhelm and Brower 1993, 164-165). Y dye is normally more susceptible to dark fading than the C and M dyes (Tuite 1979, 479). Still, certain C dyes are also vulnerable to dark fading (Theys and Sosnovsky 1997, 100). The first generation of Ektachromes (previous to E-6 processing) have extremely poor dark fading stability (Wilhelm and Brower 1993, 165), showing a characteristic shift to magenta/reddish due to severe C and Y dye loss (Wilhelm and Brower 1993, 26).

The exposure of chromogenic materials to light is irreversible and cumulative (Pénichon 2013, 203). Photochemical degradation implies the absorption of light by the dye molecules, promoting them to a higher energy-excited state (singlet and triplet excited states). Both intensity and wavelength distribution of light are important factors in photodegradation. The resulting excited molecules are prone to react with atmospheric oxygen, leading to the production of undesirable degradation products (Theys and Sosnovsky 1997, 99). The excited states of indoaniline and azomethine dyes have, in general, very short average lifetimes. These dyes act as efficient physical quenchers for singlet oxygen ($^1\Delta$). Light fading in the presence of molecular oxygen can occur by direct addition of the excited dye to singlet oxygen or by single-electron transfer. The produced $^{\cdot}O\text{-}O^{-}$ ion is relatively long lived and is a very effective oxidant, triggering a series of reactions. On the other hand, residual colour couplers might be responsible for chain reactions with reactive radicals (Bergthaller 2002c, 267). Bergthaller (2002c, 267) also proposed a reaction scheme for both these degradation pathways, presented in Figure 2.29 and Figure 2.29. The photochemical reaction cascade usually ends up with the deactivation of the reactive radicals and long-lived excited species (Bergthaller 2002c, 267).

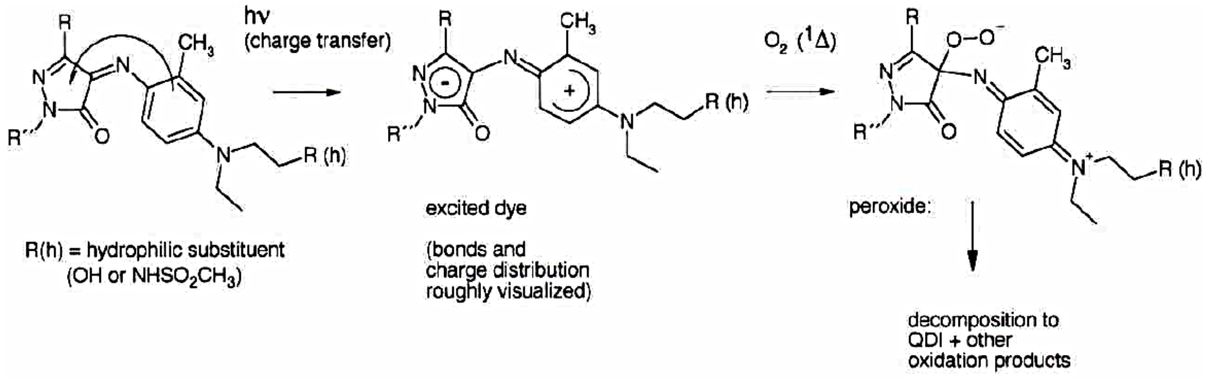


Figure 2.29 - Hypothetical light fading reaction, based on the photooxidation of an azomethine dye derived from a pyrazolone coupler (Bergthaller 2002c, 267).

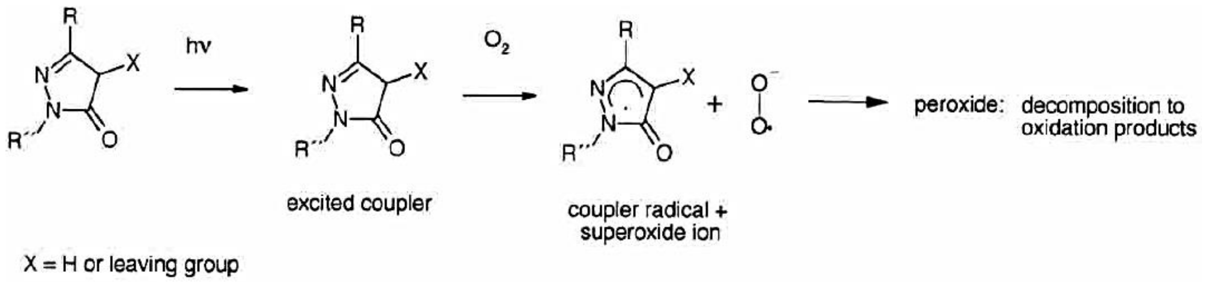


Figure 2.29 - Hypothetical light fading reaction, based on the reaction of an azomethine dye derived from a pyrazolone coupler with a residual colour coupler (Bergthaller 2002c, 268).

As previously mentioned, stabilizers and antioxidants have been added to the emulsions to prevent dye degradation, by deactivating excited molecules generated over time (Bergthaller 2002c, 268-271). To the greatest extent, light fading leads to loss of density, mainly located in the lower density areas of the image. In modern materials, stain formation induced by light is less significant than staining produced in the dark (Wilhelm and Brower 1993, 164). Nevertheless, every light-faded material is a product of light fading and dark fading (Tuite 1979, 475). C dyes are normally considered the most stable to light (Theys and Sosnovsky 1997, 100).

Y dyes have been judged more prone to hydrolysis than to photodegradation (Reilly 1998, 12). According to the artificial ageing experiments conducted by James Reilly (1998, 2), in all tested products Y was the limiting dye. Typically, hydrolytic reactions associated to Y dyes can occur both in acidic and alkaline environments (Tuite 1979, 481-482). As mentioned before, pivaloylacetanilide couplers are more stable than benzoylacetanilides, previously used (Di Pietro 2007, 180). Pivaloylacetanilides with sulphonamide groups, instead of the commonly used carboxylates, greatly improved the lifespan of Y dyes (Theys and Sosnovsky 1997, 100). Later, cycloalkanoylacetanilides couplers achieved even better stability (Bergthaller 2002a, 172). Early M dyes were prone to react with residual colour couplers by forming colourless degradation products (Tuite 1979, 479). This problem was solved by using aldehydes in the final processing bath (Theys and Sosnovsky 1997, 99). Azomethine dyes resulting from pyrazolone M couplers are normally unstable. For instance, 3-acylaminopyrazolones are sensitive to aerial oxygen. On the contrary, azomethine dyes from pyrazolotriazole M couplers are quite stable, being resistant to yellow stain, light and dark fading. Because of the continuous improvements on M couplers, none of the Kodak chromogenic products post-1979 are M dye-limited for dark stability (Di Pietro 2007, 184). C dyes from both phenol and naphthol classes of couplers have been subjected to continuous stability improvements (Di Pietro 2007, 185). The most common degradation associated to C dye is its fading by reduction of the dye in the presence of residual couplers and subsequent formation of a colourless leuco dye (Theys and Sosnovsky 1997, 100). Moreover, C dyes were noted to be particularly sensitive in the presence of reducing agents such as residual thiosulphate (fixing agent) (Bergthaller 2002c, 265). This problem was overcome by changing both the colour-developing agent from CD-2 to CD-3, and the dye structure, namely by using phenol-type couplers with an amide group in the 2.5 position of the ring (Theys and Sosnovsky 1997, 101).

2.3.5. Preservation

As previously mentioned, from earliest times, it was noticed that chromogenic materials were impermanent. If in some art fields the *patina* resulting from the natural ageing is well accepted, in colour photographs, dye fading and shift in colour balance are not easily tolerated. As defended by Kayley Vernallis (1999, 470), this might be due to the fact that these degradations occurred within a very short timeframe, and therefore, could not be experienced as a historical or aesthetic quality. According to James Reilly (1998, 4), in the 1960s and 1970s, museums avoided acquiring colour photographs due to their short lifespan. Quoting Henry Wilhelm and Carol Brower (1993, 33): "the prevailing view among most museum curators and archivists was that 'all color fades' and nothing could be done to stop it". As a result, several conferences were organized by museum staff during the 1970s and 1980s, gathering photographers, conservators, archivists and industry researchers, to discuss the preservation of colour photographs[81]. In Europe, the symposium *The Conservation of Colour Photographic Records*, held at the Victoria and Albert Museum in 1973, was the first event dedicated to the conservation of colour photographs. In 1975, the *Colloquium on the Collection and Preservation of Colour Photographs*, held at the George Eastman House, was the first in the United States of America (Wilhelm and Brower 1993, 31). This last was marked by strong critics towards the industry, its secrecy policies and the poor quality of the products (Wilhelm and Brower 1993, 32). It is also worth mentioning the contribution of the filmmaker Martin Scorsese, who was able to create a successful campaign in 1980 pressuring Kodak and other companies to disclose the stability tests of their current products and to launch improved motion picture films with higher stability (Wilhelm and Brower 1993, 34-35). In 1978, the annual meeting from the Society of the Photographic Scientists and Engineers made a special session dedicated to the stability and preservation of photographic materials. Robert Tuite, a Kodak researcher, presented the results from accelerated ageing tests performed at the company on their chromogenic products. For the first time, scientific research made on the degradation mechanisms affecting photographic colour materials was discussed openly with the industry (Wilhelm and Brower 1993, 33-34).

The main conclusions and actions arising from those meetings were the adoption of preservation policies for existing materials (Wilhelm and Brower 1993, 33-34). From the first abovementioned meeting until today, the recommendations are towards storing all types of chromogenic photographs under controlled environmental conditions, i.e., under low T and RH. Thus, it is possible to control their heat energy and water content, respectively (Table 2.2). In this respect, there has been no major scientific breakthroughs in the last decades. Additionally, it has been recommended that institutions collect a reserve print along with the original print during the acquisition

[81] Henry Wilhelm and Carol Brower (1993, 31-37) made a survey of the important conferences dedicated to the preservation of colour photographic materials, which took place before their book was released.

process. When kept in cold storage, the reserve print can work as a backup to the original artwork (Kennedy, Reiss and Sanderson 2016, 92).

Table 2.2 - International Standards Organization (ISO) recommendations for storage of chromogenic films (Pénichon 2013, 205)

RH (%)	T (˚C)
50	- 10
40	- 3
30	2

Generically, the lower the T and RH, the higher the lifespan of a chromogenic material (Reilly 1998, 11). Based on the study undertaken by James Reilly (1998) at IPI, it is possible to have an idea of the gain on the lifetime of these materials by decreasing T and RH within certain security parameters (namely drying limits, particularly from the gelatine) (Fig. 2.31). Decreasing those values will also reduce the risk of biological contamination (Lavédrine 2003, 133).

Temperature	20% RH	30% RH	40% RH	50% RH	60% RH	70% RH	80% RH
30 F/-1 C	8000	3500	1500	800	600	450	350
35 F/2 C	4500	2000	1000	600	350	300	250
40 F/4 C	3000	1500	700	350	250	200	175
45 F/7 C	1750	900	450	250	175	125	100
50 F/10 C	1000	600	300	175	125	90	80
55 F/13 C	700	350	200	125	80	60	50
60 F/16 C	450	250	125	80	60	45	35
65 F/18 C	300	150	90	50	40	30	25
70 F/21 C	180	100	60	40	25	20	18
75 F/24 C	125	70	40	25	19	15	12
80 F/27 C	80	50	30	19	14	11	9
85 F/29 C	50	30	20	13	10	8	6
90 F/32 C	35	20	14	10	7	6	5
95 F/35 C	25	15	10	7	5	4	3
100 F/38 C	15	11	7	5	4	3	2
105 F/41 C	10	7	5	4	3	2	2
110 F/43 C	7	5	4	3	2	2	1
115 F/46 C	5	4	3	2	2	1	1
120 F/49 C	3	3	2	1	1	1	1

Figure 2.30 - Results of research conducted by James Reilly at the IPI on chromogenic materials;
Time (in years) to reach 30% density loss in materials stored in the dark at the specified T and RH (Reilly 1998, 20).

There are different ways to achieve low T and RH values. According to the size of the collection and financial resources of the institutions, cold storage vaults might be built, or domestic frost-free refrigerators or freezers might be used. For the first solution, the photographic materials can be conditioned in appropriate enclosures and arranged in shelves inside the vault. Regarding the last solution, the recommended RH values might be difficult to achieve inside refrigerators or freezers (Lavédrine 2003, 61). If so, the materials (or the enclosures) can be stored either inside vapour-proof sealed packaging or polyethylene (PE) bags with moisture buffering (ex: silica gel, cardboard, etc.) (Wilhelm and Brower 1993, 658). Mark H. McCormick-Goodhart (1994, 2) suggests adding a critical moisture detector inside PE bags. Sealing the materials inside vapour-proof packages also provides a protection against air pollutants (Wilhelm and Brower 1993, 702). However, since those packages are aluminium based (effective moisture barrier), the materials cannot be observed and properly monitored without opening the packaging (McCormick-Goodhart 1994, 1). Yet, in both cases, the photographs will be protected against excessive RH and fluctuations (Lavédrine 2003, 62).

Besides proper storage, an important way to preserve the content of chromogenic reversal films is by proceeding with their duplication and/or digitization. The sooner this process is achieved, the closer the registered image will be to the originally captured image. On the one hand, making copies available will reduce handling of the originals, which is especially important if they are to be kept in cold storage. According to the study conducted by James Reilly (1998), the combined permanence of colour photographic materials in a controlled storage and in a non-controlled space such as a working area, can drastically reduce their overall life expectancy. For instance, if a chromogenic photograph is kept in storage at T=4˚C and RH=40%, its expected lifetime is about 700 years. If the photograph is removed from storage into a working space (T=24˚C and RH=60%) for a period of 30 days per year, its lifetime will be reduced to 175 years. The greater the difference between the storage and the working area conditions, the greater this discrepancy will be (Reilly 1998, 21). On the other hand, fading and changing in colour balance from chromogenic materials is irreversible, and there is no way to chemically revert the dye degradation process. However, colour corrections can be applied during the duplication process, or by manipulating the digital image. Still, it is important to keep in mind that these are very delicate operations, that need to be applied in a way that ensures the faithfulness to the original image (Reilly 1998, 45).

When the permanence of a specific chromogenic photograph is to be known, the material or an equivalent (same brand and model) can be induced to artificial ageing in order to estimate its lifespan (Lavédrine 2003, 33). Since 1969, the American National Standards Institute (ANSI), in collaboration with an interdisciplinary team composed of people responsible for cultural institutions, conservators, industry researchers, among others, started to develop standards for testing the stability of different colour photographic materials. In 1990, the first standard was greatly improved, and more accurate testing conditions were defined for both dark and light fading. This standard and similar (namely from the International Standards Organization (ISO)) received wide application by manufacturers, independent laboratories, researchers and conservators (Wilhelm and Brower, 65-66). The last update to this document is dated from 2006 (ISO 18909:2006(E)). According to those guidelines, during the artificial ageing test, changes in dye density are monitored in neutral areas and areas with primary subtractive colours, with known densities. To do so, the samples are previously exposed to light filtered through an appropriate filter. The optical density[82] of the step-wedges is measured with a densitometer.

Institutions have also been studying the light stability of chromogenic prints by using the micro-fading test[83]. This test is normally applied to predict the result of exhibition and to assist display decisions. Examples of institutions using this method are the Metropolitan Museum (New York), the

[82] Optical density is related to the propagation of light through a material. When a dye fades its optical density decreases (ISO 18909:2006(E)).

[83] The micro-fading test is an accelerated method that uses a fibre optics reflectance spectroscopic setup in which a very small area of the surface of an object is slightly faded using high-intensity infrared and ultraviolet light. Therefore, colour change can be calculated from spectral change in real time (https://www.microfading.com/microfading-faq.html; accessed on 15/08/2018).

Getty Conservation Institute (Los Angeles), the Smithsonian Museum (Washington), the National Gallery of Victoria (Melbourne), the Library and Archives Canada (Wellington), the M+ Museum for Visual Culture (Hong Kong), among others.

Henry Wilhelm was a pioneer advocate for the preservation of colour photographs, having been involved in most of the aforementioned events. Wilhelm has been dedicating his lifetime investigation to the stability of colour photographs, having created his own company (Wilhelm Imaging Research) devoted to that purpose[84]. In his book (Wilhelm and Brower 1993), often referenced within the framework of this dissertation, he presented a comparative study on the dark and light stability of different colour materials, namely chromogenic reversal films with different brands and models available until that time. The work published by James Reilly (1998) led to the definition of guidelines for the preservation of chromogenic materials. Ann Fenech has recently published some articles, within the framework of her PhD thesis, focusing on the lifetime of chromogenic colour prints in the archival context. For such purpose, she defined a statistic model to calculate the extent of degradation on chromogenic prints, based on a multi-parametric change function (T+RH+acetic acid) (Fenech et al. 2010, Fenech, Fearn and Strlic 2010, Fenech 2011, Fenech et al. 2012).

Due to the characteristic instability of chromogenic dyes, monitoring dye fading should be made periodically to assess colour change (Wilhelm and Brower 1993, 243). A few years ago, the use of densitometers to follow dye fading was widespread (Robert, West and Hubbell, 1967; Adelstein, Graham and West, 1970; Tuite, 1979; Bard, Larson, Hammond and Packard, 1980; Lavédrine, Trannois and Flieder, 1986; Wilhelm 1993; Reilly, 1998). Densitometry is recommended by ANSI and ISO to assess the optical density of the chromogenic dyes individually. Although there is simplicity and effectiveness in the use of a densitometer to assess dye fading, this technique has some limitations when compared with others and is becoming obsolete. Recently, certain authors have been using colourimeters to monitor image stability in chromogenic prints by following CIE L*a*b* coordinates (McCormick-Goodhart and Wilhelm, 2004; Mason, 2007; Veselý, Dzik and Káčerová, 2010; Fenech, 2011; Sanderson, 2013). Likewise, UV-vis spectrophotometry was applied to study the light stability of autochromes (Casella, Tsukada, Kennedy, 2011). However, recent studies focusing specifically on the degradation of chromogenic reversal films and their colour monitoring are still lacking. Therefore, new methodologies for monitoring colour change in chromogenic reversal films were tested. The results of this study are presented in chapter 6 and are of the main novelties brought by this dissertation.

Rudolf Gschwind, retired Professor from Basel University, has been studying effective ways to digitally restore colour photographs (Gschwind, 1989; Frey, Gschwind and Reilly, 1995; Gschwind, Frey and Rosenthaler, 1995; Rosenthaler and Gschwind, 2001). To do so, Gschwind digitized chromogenic materials with a CCD-array camera equipt with broad-band filters, which allows for channel separation according to the absorption wavelengths of the three dyes, and therefore monitors their optical density. Based on artificial ageing tests conducted on chromogenic materials, Gschwind was able to develop mathematical fading models for known materials. However, the developed methodology is not applicable to materials for which the degradation pathway is unknown. Giorgio Trumpy[85] and Rudolf

[84] The results of his research are regularly published on the company website: http://www.wilhelm-research.com/

[85] Giorgio Trumpy is currently a researcher in Barbara Flueckiger's research project - ERC Advanced Grant FilmColors - from Basel University. The main objective of the project is to trace relationships between the technology and aesthetics of colour motion picture films, based on an interdisciplinary approach. These insights are being applied to the digitization and restoration of historical films. Trumpy is working on spectral analysis of historical film images, aimed at creating an identification tool for colour film stocks and improving current scanning technologies (http://www.research-projects.uzh.ch/media/pdf/p21207.pdf; accessed on 15/08/2018).

Gschwind (2014) are also trying to assign characteristic absorbance bands, in the near-infrared (NIR) and visible (vis) ranges of the electromagnetic spectrum, to specific products. The collected spectral data is supposed to integrate an already existing database with historical data on chromogenic films (ex: edge marking, imprinting, barcodes, etc.), which together works as a comprehensive identification tool (Gschwind, Zbinden, Trumpy and Delaney 2017). They also used Principal Component Analysis (PCA) to obtained analytic densities (single dye spectra) from integral densities (sum of the three dyes obtained by collecting spectral measurements). Before 1973, Noburu Ohta (1973), from Fuji Research Laboratories, also used PCA for the same purpose.

In 2004, an interesting project[86] was begun by the conservation scientist Giovanna Di Pietro on the identification of chromogenic dyes from motion picture films. The results of the investigation were later published in a paper (Di Pietro 2007). Identification is the first step to a complete understanding of a material. By knowing the molecular structure of a material, it is possible to predict its degradation pathway and estimate a better solution for its long-term preservation, for instance by inducing reproductions (mock-ups) into artificial ageing. This procedure is commonly followed within other conservation areas. In the course of the research project, Di Pietro was able to separate chromogenic dyes with Thin Layer Chromatography (TLC) and High-Performance Liquid Chromatography (HPLC). She also analysed them individually with Raman Spectroscopy, without much success, and with Fourier Transform Infrared Spectroscopy (FTIR), wherewith some sensitivity of the technique was observed. Unfortunately, these first promising experimental results were not continued. Anthony Bristow, from the Research and Development Department of Kodak, also made separation and identification of dyes from chromogenic photographs by using Solid Phase Extraction-Fourier Transform-Raman spectroscopy (Bristow, Coubariaux, Sewell and Strawn, 1998), and Capillary Electrochromatography (Bristow and Bumfrey, 2002). He achieved identification creating a usable database (not accessible to the public). However, a sustainable methodology to identify dyes present in a specific chromogenic product is still not available today. Considering this scenario, the characterization of chromogenic reversal films was pursued by using analytical techniques. The results of this preliminary study are described in chapter 6.

[86] This Australian project was a partnership between the University of Canberra and cultural institutions such as the National Archives of Australia, the National Museum of Australia and the National Film and Sound Archive (http://afcarchive.screenaustralia.gov.au/newsandevents/at_archive/preservation/colour_dye/newspage_201.aspx; accessed on 15/08/2018).

Chapter 3

Assessing Ângelo de Sousa's photographic and film collection

3.1. Preamble

As previously mentioned, Ângelo de Sousa produced a vast quantity of photographs and several experimental films during his life. These have been gathered together in the artist's house since he moved there, in the begging of the 1970s, and remain at the present (approximately) as left by him. Prior to the present research, there was a general lack of knowledge about the composition of this estate, since the collection had never been assessed, and consequently, no information had been systematized. Thus, there was no idea about either the objects' typologies and quantities or their conservation condition. Accordingly, apart from the photographs and films displayed in exhibitions and some digitisations produced during the artist's life, there was no record about the subjects explored by the artist with these media.

Taking this background into account, performing a survey was considered a necessary and priority approach to enhance the knowledge about the collection and propose the best preservation strategies for the photographs and films by Ângelo de Sousa. During a period of approximately three months, information about the typology of the photographs and films, number of objects, conservation condition of the materials, as well as contents of the images and production time was gathered (among others). The collected information was recorded in an Microsoft Office Access® database designed for the purpose and considering the current archival procedures.

During the assessment of the collection, the artist's personal documentation related to the production of these media present at the archive was analysed. Additionally, the organization of the collection and the information contained in and the materials and their original containers was observed, in order to trace Ângelo de Sousa's way of working.

The environmental conditions of the archive were evaluated considering the materials composing the collection. To do so, the relative humidity (RH) and temperature (T) of the storage space were monitored and registered during the time-frame of this dissertation using a datalogger. By gathering this information, it was possible to estimate the conditions to which the materials have been subjected over time.

Based on the conducted investigation (survey to the photographic and film materials and assessment of the storage room), it was aimed at detecting materials at risk, defining the collection fragilities, and though, the conservation priorities.

Within the outline of this chapter, the artist's son, Miguel de Sousa, was interviewed in order to collect his testimony about the history of the collection. The interview conducted with Ângelo de Sousa by the curators of the exhibition *Sem Prata* (2001), was also a very important source of information, complementing the data collected during the present research.

This chapter is divided in two main sections. Section 3.2 is dedicated to the description of the archive, its history and the environmental conditions of the storage space. Section 3.3 is dedicated to the assessment of the photographic and film materials. From this, it was possible to launch the research lines of this dissertation. The main goals of this chapter are summarized in Figure 3.1.

Part of the content of this chapter was presented in a national and in an international conference:

<u>Silva, J.</u>, Ferreira, J. L., Lavédrine, B., Ramos, A. M. 2015. Preservation of an Artist's Legacy: Ângelo de Sousa´s Photographic and Filmic Collection. Poster presentation at *SOIMA 2015 International Conference: Unlocking Sound and Image Heritage*, 3 – 4 September, Royal Flemish Academy of Belgium for Science and the Arts, Brussels, Belgium.

Silva, J., Ramos, A. M. 2014. Cellulose Acetate in Ângelo de Sousa´s Photographic Collection. Oral communication at *Encontros DigitFUP*, 15 December, Arquivo Histórico Ultramarino, Instituto de Investigação Científica e Tropical, Lisbon, Portugal.

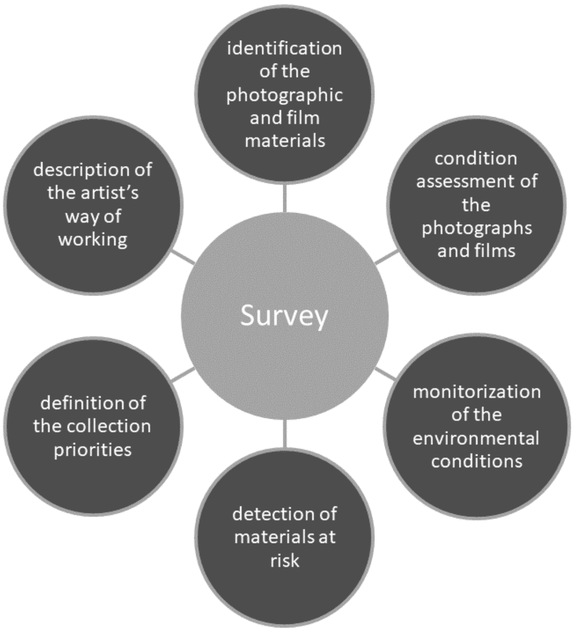


Figure 3.1 - Scheme of the main objectives adopted for the development of the contents presented in chapter 3.

3.2. The archive: photographic and film collection

3.2.1. The past and the future of the artist's global collection

The artist's house can be separated into two different areas, the atelier, where the artist worked, and the residence, where the artist lived (Fig. 3.2). His artworks have been mainly assembled in the atelier area. Besides the artworks, it was possible to find several valuable sources of information, such as personal documentation and materials related to his artistic production, as well as his library. In addition to this house, Ângelo de Sousa started to work in an apartment nearby, in 2001, where some remnants of his latest production (especially painting) can be found.

Figure 3.2 - Ângelo de Sousa's house in Foz (Porto); on the left side is the atelier and on the right side the residence, here separated by a red mark.

One of the main goals of the partnership NEÂdS/DCR, is to transform the house (atelier area) into several controlled storage facilities according to the specificities of the materials, and from this goal, to preserve the collection all together under suitable T and RH conditions. This space is intended to be, simultaneously, a place for the study and fruition of Ângelo de Sousa's work. A simplified plan for the atelier area, which aims at maintaining the original floor plant, is presented in Figure 3.3.

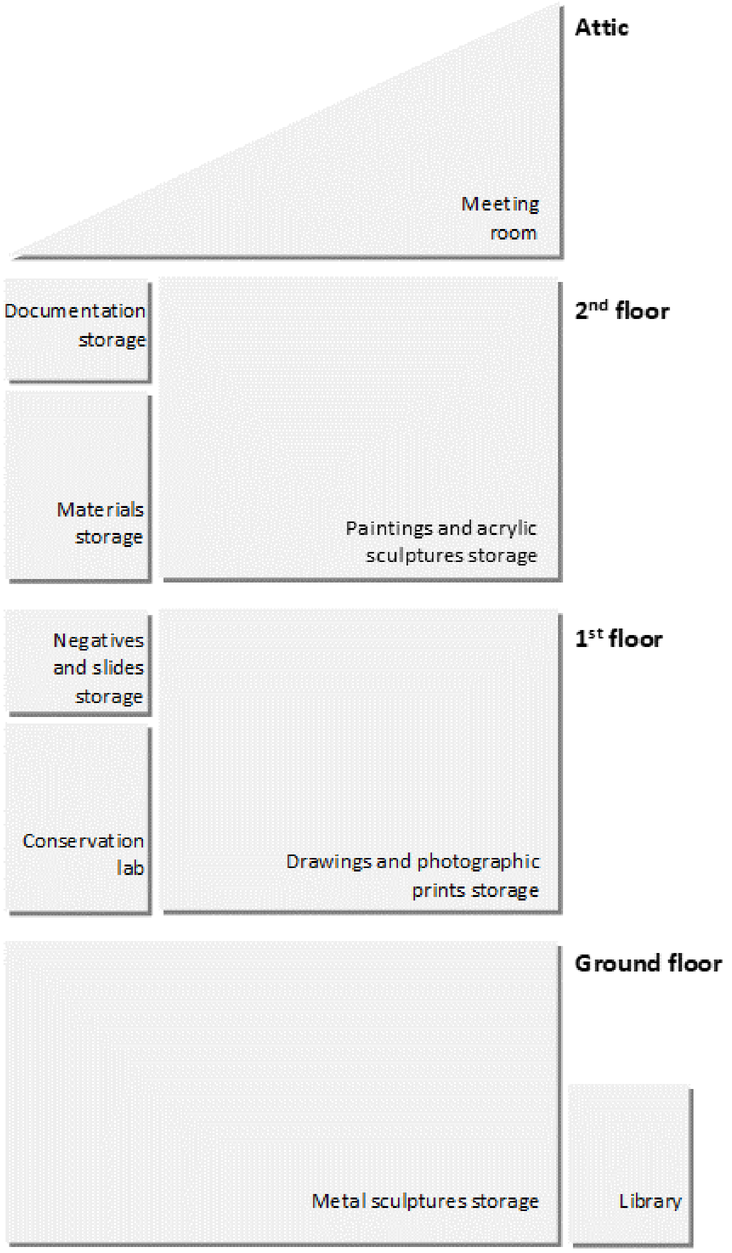


Figure 3.3 - Plan for the adaptation of the atelier area (image by Joana Lia Ferreira).

3.2.2. Assessment of the storage space

During his life, Ângelo de Sousa produced and accumulated a considerable number of films, and especially photographs. This can be immediately assessed when visiting the artist's house. The photographic and film collection (materials and equipment) has been mainly assembled in a same room (Fig. 3.3, 'Negatives and slide storage'), with the exception of the negatives that were found in the floor below (Fig. 3.3, 'Conservation lab'). The photographs and films are currently archived in the original packaging, arranged in metal and wooden bookcases with open shelves. Some photographs, mostly prints displayed in exhibitions, are held at the apartment.

After the exhibition *Sem Prata* (2001) at Fundação de Serralves (Porto), Ângelo de Sousa hired Paula Pinto[1] as an assistant to work with him on the photographs. Pinto accompanied him for about a year and returned in 2010 to continue the work started in 2001[2]. According to Miguel de Sousa (Sousa 2014), the assistant's work consisted of the digitization of a selection of black-and-white photographs for the series of publications that the artist wanted to do and for exhibitions (namely *Sem Prata*). After the artist's death, Pinto continued to work on the archive, surveying the collection until the 2012 (Sousa 2014). By observing the archive, it was possible to conclude that the assistant conditioned part of the photographic collection into a new packaging and developed a thematical organization. She also numbered and made a preliminary inventory for some selected photographs. Apart from this work, everything has been kept in the original packaging, as left by the artist.

Based on the photographic registration of the artist's house[3] undertaken immediately before Ângelo de Sousa's death, it was possible to have an idea of the archive at that time (Fig. 3.4). After Ângelo de Sousa's death, metal shelves were added to the room to organize the materials. A dehumidifier was also placed in the storage room to decrease the RH[4].

In 2014, in the beginning of the present study, the archive was untidy and in need of cleaning. Therefore, as a starting point, the room was cleaned and straightened[5]. This task helped to identify the materials at risk and from that preventive measures were undertaken to stabilize the photographs, films and equipment[6] (Fig. 3.5). As previously mentioned, the collection was almost entirely grouped in the same room, but there were some dispersed objects found in several places in the house and apartment. For security reasons (to avoid any losses) and environmental control, all the photographic and film materials were gathered in the same room.

Since August 2015, both T and RH had been monitored with a datalogger. The measurements collected during the year 2016 are shown in Figure 3.6. The average T measured during 2016 was 19.9˚C ± 4.2 ˚C and the average RH was 50.7% ± 6.4%. According to the recommended values for photographic collections (Table 3.1), these values are not ideal. High T and RH values tendentially accelerate the degradation rate (chemical and physical) and can produce an environment resonant to the proliferation of microorganisms (Lavédrine 2003, 84). The same recommendations can be applied to film collections based on the material equivalence.

[1] Paula Pinto was part of the research team from that exhibition.

[2] Information kindly provided by Paula Pinto in an email. Paula Pinto declined the invitation to be interviewed by the author of this dissertation.

[3] These pictures were made by Lúcia Matos, associate professor at ESBAD.

[4] This was made by Ângelo de Sousa's son, around 2012 (Sousa 2014).

[5] This task was carried out with the collaboration of a student from the DCR, Daniel Mendes, from the second-year class *Cuidar de Coleções I* (Bachelor's degree), in the 2015 interim period. The room and walls were vacuumed and washed. The shelves were cleaned with a dampened cotton cloth, and the boxes containing photographic and film materials dusted with a dry cloth. The original order and sequence were maintained so that no contextual information was lost.

[6] For instance, photographic materials without any protection, were gathered in an acid-free cardboard storage box, between conservation paper sheets. Loose envelopes and materials were placed in conservation storage boxes, and bigger materials, such has the envelopes where the original 8 mm films are kept, were placed inside a polyethylene box. Heavy and fragile materials, such as photographic and film equipment, were wrapped with polyethylene foam, after being cleaned with a soft brush, and were placed in the lower shelves to avoid physical damage and to facilitate manipulation.

Figure 3.4 - General views of the storage in December 2010 (Photographs by João Lima).

Figure 3.5 - General views of the storage. **Top:** before the assessment, in January 2014; **Bottom:** after the assessment, in January 2015, carried out during this investigation.

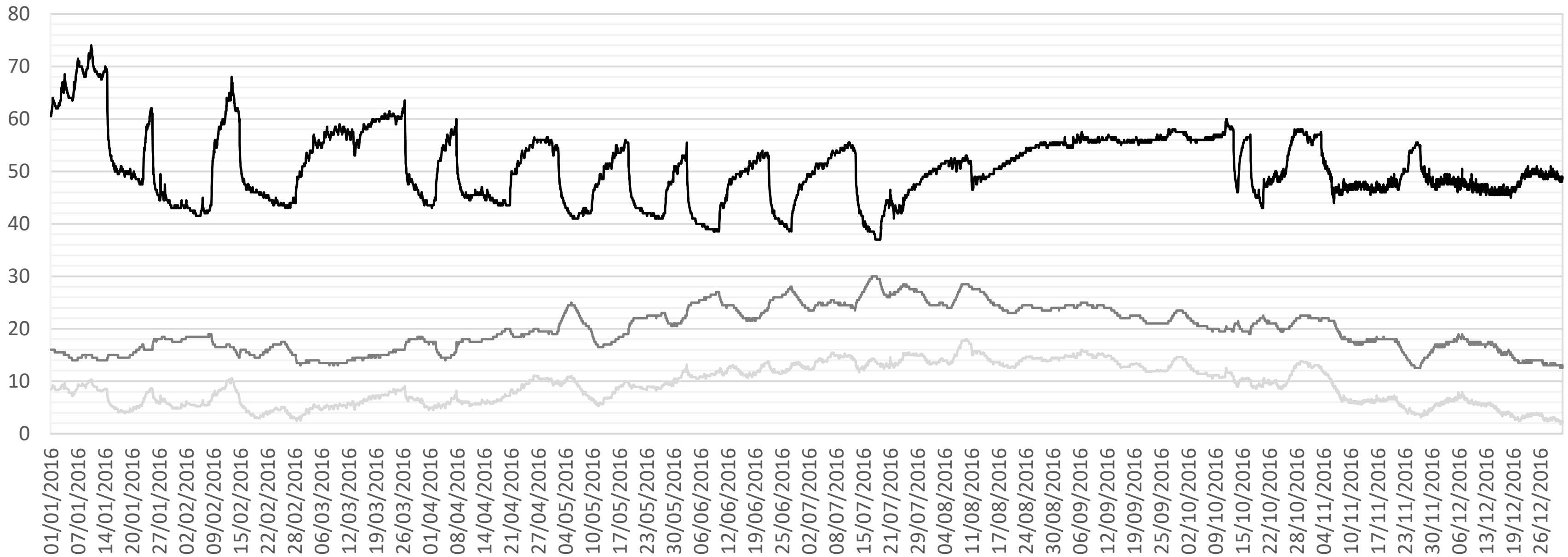


Figure 3.6 - Relative humidity (black line), temperature (dark grey line) and dew point (light grey line) measured in the photographic and film archive. The measurements were collected every hour during the year 2016.

Table 3.1 - Recommended T and RH values for photographic collections, based on Bertrand Lavédrine (Lavédrine 2003, 89)

Image	Base	Photographic process	T_{max} (°C)	RH_{max} (%)
Black-and-white	glass	silver gelatine negatives/positives	18	30 - 40
	paper	silver gelatine prints	18	30 - 50
	cellulose nitrate, cellulose acetate	silver gelatine negatives/positives	7 5 2	20 - 30 20 - 40 20 - 50
	polyester	silver gelatine negatives/positives	21	30 - 50
Colour	paper	silver dye bleach prints, dye diffusion prints, chromogenic prints	18	30 - 50
	cellulose acetate, polyester	chromogenic reversal films, chromogenic negatives	2 -3 -10	20 - 30 20 - 40 20 - 50

According to Bertand Lavédrine (2003, 88), it might be difficult to define the correct RH value for a mixed photographic collection, such as the one under study. Since the house was not designed to be an archive, and it is in a site with a moderate and humid climate (nearby the river mouth and sea), the collected values are not surprizing.

By observing Figure 3.6, it is possible to detect high and sudden fluctuations throughout the year. The maximum T value, 30˚C, was measured on 18 July 2016 (summer), and the minimum T value, 12.5˚C, on 26 November 2016 (winter). Regarding the RH, the maximum value, 74%, was measured on 10 January 2016 (winter), and the minimum value, 37%, on 18 July 2016. Not coincidentally, 18 July was the warmest and driest day measured in the year. The sudden fluctuations are probably related to the functioning period of the dehumidifier (RH climbs associated with the turning off and falls with the turning on). Since the dehumidifier is not connected to a sewer, it must be emptied when the reservoir is full of water, otherwise it automatically turns off. Since there is no one permanently working at the archive, it is possible that the equipment did not work continuously during all the year.

Four different samples of measurements collected during the first week and day of January (winter), April (spring), July (summer) and October (autumn) 2016, were observed (see graphics in appendix II, Fig. II.1 and II.2) to analyse the periods of fluctuations in further detail. A summary of the results is presented in Table 3.2.

Table 3.2 - Temperature and relative humidity fluctuations during the first week and day of January (winter), April (spring), July (summer) and October (autumn) 2016

Month	Maximum fluctuations			
	T (°c) in one week	T (°c) in one day	RH (%) in one week	RH (%) in one day
January	↓ 1.5	0	↑ 10	↑ 2
April	↓ 3	↓ 0.5	↑ 15	0
July	↑ 1	↓ 0.5	↑ 6	↑ 1.5
October	↓ 3.5	↓ 0.5	↓ 2	↓ 0.5

According to Bertrand Lavédrine (2003, 89), ±4°C should be the maximum T fluctuations, and ±5% should be followed for RH fluctuations over a twenty-four-hour period to avoid putting the photographic materials at risk. Nonetheless, ±10% RH fluctuation is considered as a minimal risk and ±20% a slight risk (Lavédrine 2003, 90). Although the annual T and RH fluctuations might be high, based on Table 3.2, the fluctuations over a day are ideal during all four seasons, and the fluctuations measured over a week are not worrisome. Still, the absolute values are higher than the recommended values, especially for sensitive materials such as cellulose ester-based materials and colour films (Table 3.1). Decreasing both T and RH can greatly increase the life expectancy of the materials. For instance, decreasing T from 20°C to 10°C increases the lifetime of a colour film by about three times, and a cellulose acetate (CA) film by almost four times (Lavédrine 2003, 95). Therefore, the obtained results reinforce the need to place the photographic and film materials under controlled T and RH.

3.3. Materials survey

Ângelo de Sousa's curiosity and awareness about the materials he used has already been documented, namely within the framework of the PhD thesis by Joana Ferreira (2011). Ferreira interviewed the artist and questioned him about the composition of some of the materials he used in specific artworks, which he was able to describe in great detail. Ângelo de Sousa also used to add a label to the back of his paintings, with a precise description of the materials employed for its execution (support, preparation, paint layers and additional layers) (Ferreira 2011, 130). In his archive, there is a file with ageing tests conducted by him on different sorts of materials, showing his interest for the materials' stability (Fig. 3.7). According to Ferreira (Ferreira 2011, 133), he placed the materials under a glass, in a precise slope in relation to the sun, during the summer months. By consulting the file, it is possible to observe that he carried out tests on several types of colour photographs[7], during the summer of 2004. Other examples of his interest in the materials' stability can be found in his archive[8].

As previously mentioned, prior to this research, there was no systematic study focusing on the typology and condition of the materials composing the photographic and film collection of Ângelo de Sousa. Therefore, to gather information related to the different objects composing the archive, a broad survey covering photographs, films, as well as duplications and digitisations, and equipment, was undertaken. Surveying a collection can be seen as a primary preservation strategy. On the one hand, it allows for the assessment of the organizational content of the collection, and on the other hand, for its physical content. Regarding the last, the survey makes possible to identify and quantify the materials, as well as assessing its conservation condition (Casella 2007, 1). Gathering this information supports the decision-making process and provides grounded evidence that helps to establish conservation priorities (Johansen and Braae 2002, 92).

Essentially due to the large number of objects, typical for a photographic collection, it is common to adopt archival methodology to process this type of collection. According to the General International Standard Archival Description (ISAD(G)), it is recommended to number each unit of material that will be described (Boadas, Casellas and Suquet 2001, 183-184). The higher the quantity and quality of information collected during the survey, the more insightful the survey can be (Ritzenthaler et. al. 2006, 134). Thereby, although time-consuming, it was decided to describe each original container[9] and to count every photographic and film object. Each original container with photographic or film materials was numbered, using a sequential numbering. Such numbering enabled the systematization of the information in a database (Pavão 1997, 271). The defined numbering functioned as a topographic inventory, which allows for the location of the containers. By recording this information, the original organization was documented before the collection is treated and conditioned

[7] i) digital print on Kodak Professional Digital Paper from 2001, ii) red and black off-set print, iii) silver dye beach print (Cibachrome) from 1978, iv) chromogenic print on Kodak Rapid photographic paper from 2000, v) chromogenic print on Kodak Professional photographic paper from 2001, vi) chromogenic reversal film, Kodak from 2002, vii) digital print on Fujifilm Archive Papers Supreme paper, viii) digital print on Kodak Photo Perfect Paper, ix) three digital prints on Sony Print Paper from 1998, x) dye diffusion print (Polaroid) from 1998, and xi) digital print from 1998. In all cases, fading, changing in colour balance and yellow stain can be observed.

[8] For instance, in the file called *Mão* found in his archive, Ângelo de Sousa wrote the note "the most stable of all papers" related to the duplication paper that should be used for the duplication of the work *Mão esquerda* (1976) (see appendix IV, Figure IV.1).

[9] The Society of American Archivists (SAA) Glossary defines 'container' as "n. ~ A package or housing used to hold materials; a receptacle".

in the future storage[10]. By using this methodology, the intellectual integrity of the collection can be safeguarded (Ritzenthaler et. al. 2006, 134). The adopted procedure ensured the assessment of the overall collection.

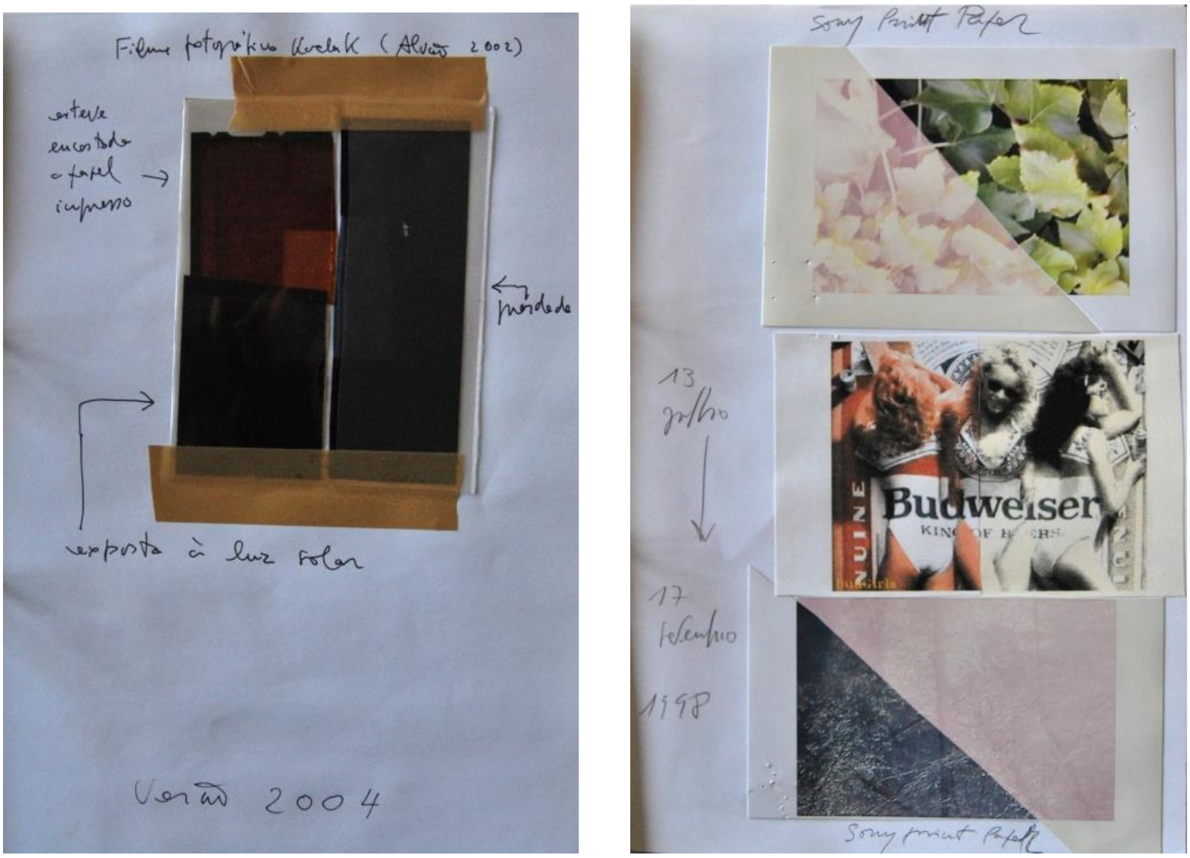


Figure 3.7 - Examples of ageing tests conducted by Ângelo de Sousa to photographic materials.

The collected information was recorded in a Microsoft Office Access® database[11], using two related tables: i) original container, and ii) object[12] (more information about the description fields can be found in appendix II, Table II.1 and II.2). The second table, linked to the first one, refers to the photographic or film objects inside the container. For each identified type of photograph and film (different process and format)[13], an entry was created, which means that for each entry in the 'container' table there might be several entrees of an 'object'. Some of the results obtained from the survey are presented further on in this section. Information concerning the artist's equipment was also collected in a Microsoft Office Access database, adapting the description fields to the nature of the materials. In both cases, attention was paid to the use of a pre-established key-words so that the

[10] As a normal procedure, when a photographic collection is treated, the materials are conditioned according to their composition and format, to safeguard the materials in adequate storage conditions and optimize the storage space (Pavão 1997, 266-267).
[11] Microsoft Office 2014.
[12] The Society of American Archivists (SAA) Glossary defines 'object' as "n. ~ 1. An item that is tangible, especially one with significant depth relative to its height and width; an artefact or specimen".
[13] The photographic or film process was identified by observation and by consideration of the production period. The polyester film base was identified using cross-polarized filters by eye.

information can be easily found. The results from the survey to the equipment are presented in chapter 4, Fig. 4.5.

The database was the key to systematize and characterize the materials from the collection, being a powerful tool for data processing and statistical treatment. The database can also be used by other researchers studying Ângelo de Sousa's work. Since the collection is being currently sought by art historians and curators, it allows for a more complete overview of the collection content. Additionally, access via the database will reduce handling of the originals.

3.3.1. Photographs

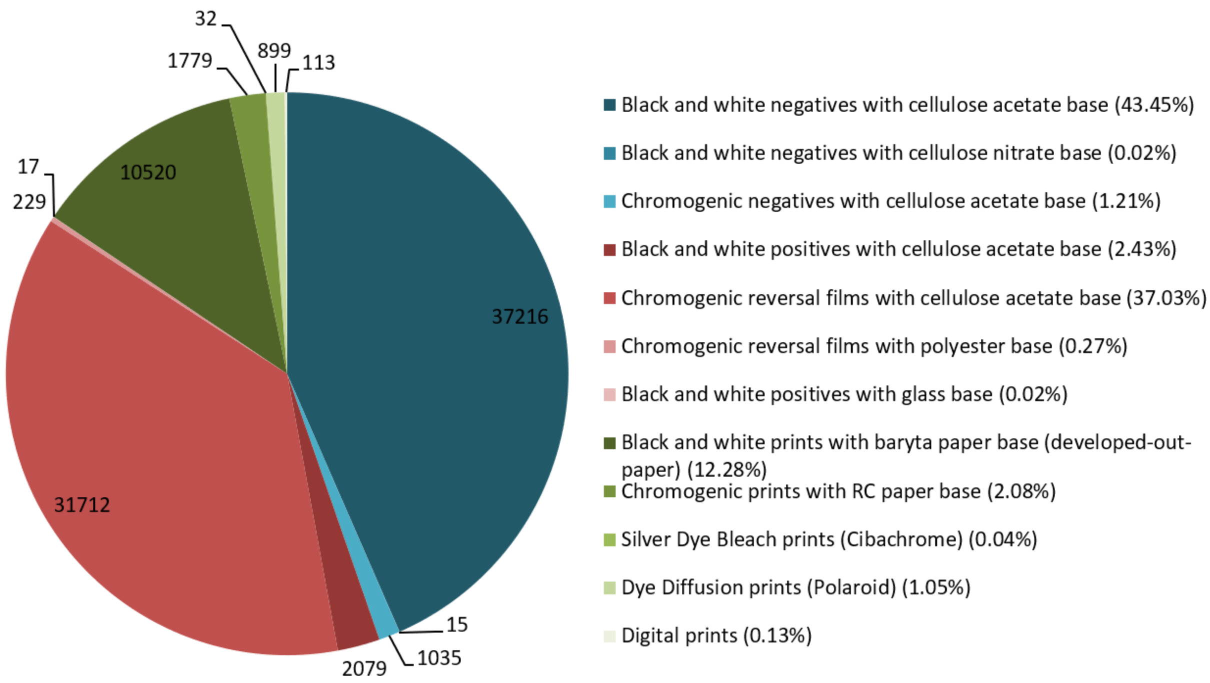


Figure 3.8 - Types and quantities of the photographic materials found in Ângelo de Sousa's archive. The three main groups of materials are highlighted: negatives (blues), positive transparencies (red) and prints (green).

After surveying the collection, it is possible to state that Ângelo de Sousa's photographic collection is composed of 85646 objects, which can be divided in three main groups (Fig. 3.8): i) 44.7% of negatives (blue), ii) 39.7% of positive transparencies (red), and iii) 15.6% of prints (green).

During his photographic production the artist used both black-and-white and colour materials (Fig. 3.9). Based on the obtained results, it can be concluded that Ângelo de Sousa chose to work with a limited range of materials. Regarding his black-and-white production, he mainly employed 35 mm black-and-white negatives with CA base, which he used to make enlargements using 18x24 cm black-and-white developing-out-prints with baryta paper (D.O.P). The great majority of the colour set is composed of 35 mm chromogenic reversal films with CA base, mainly with mountings (slides) (see more information about the formats in appendix II, Fig. II.3 to II.8). According to the conducted survey, it is possible to conclude that only a small quantity of colour negatives was produced. Therefore, almost all colour production by Ângelo de Sousa was based on positive images. Those three main groups of materials are presented in detail, further in this section.

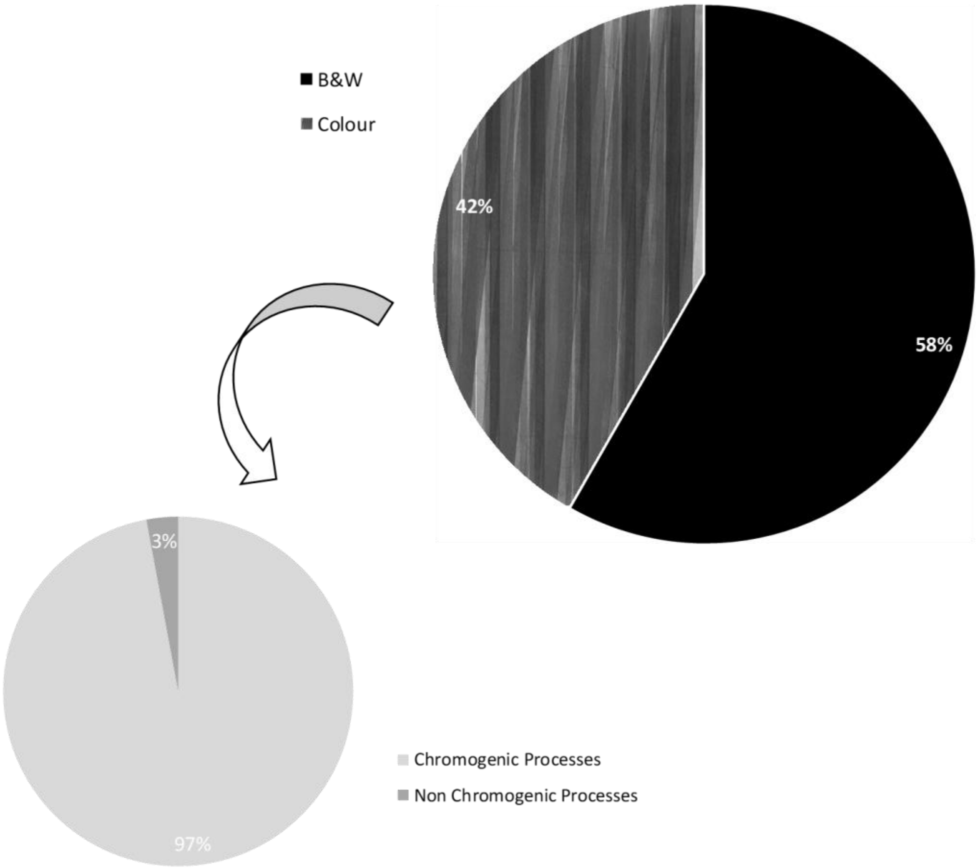


Figure 3.9 - Black-and-white vs colour photography.
As shown, 97% of colour photography is based on chromogenic processes.

Although the collection has been kept in inadequate climate conditions, as described in the previous section, the photographic collection has been considered in a fair condition (Fig. 3.10). This evaluation was made based on the condition grades described by Luís Pavão, which are presented in appendix II, Table II.3[14]. Even though 84% of the collection is composed of CA based materials (Fig. 3.11), no vinegar syndrome was detected[15]. Despite the awareness of the artist for the stability of the materials, most of them have an unstable nature, especially the ester-cellulose based and the chromogenic materials. Although no vinegar odour was felt, the acetic acid released by the CA supports was measured. Based on the current procedures used for assessing the condition of photographic and film archives with CA materials (Bigourdain 2002, 104), the acetic acid released by the different groups of CA-based materials from the collection were evaluated using AD-strips[16] (three samples by group).

[14] The table with the condition grades produced by Luís Pavão is not published. However, over the years, it was spread within Portuguese institutions holding photographic collections (namely through the courses held at Luís Pavão Limitada).
[15] Typical degradation of cellulose acetate materials, which occurs with the hydrolysis of the plastic support. The first characteristic pathology is usually the vinegar odour (acetic acid) (Reilly 1993, 13).
[16] Product developed by the Image Permanence Institute (IPI). The strips have an acid-base indicator, which reacts with the acetic acid released by the cellulose acetate base. The strip changes colour according to the quantity of detected acid, within a four levels scale (appendix II, Fig. II.10). Therefore, it provides an indirect method for verifying the conservation condition of the films (Bigourdain 2002, 104). The strips were left in contact with the negatives during the time recommended in the AD-strip manual.

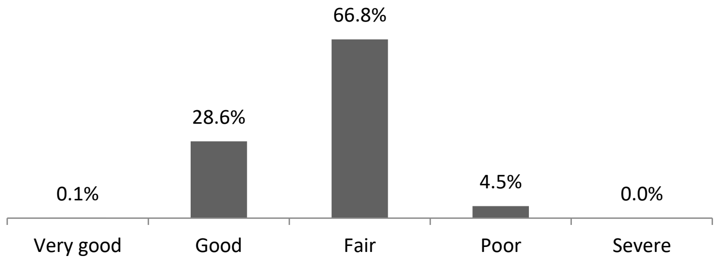


Figure 3.10 - Conservation condition of the overall photographic collection.

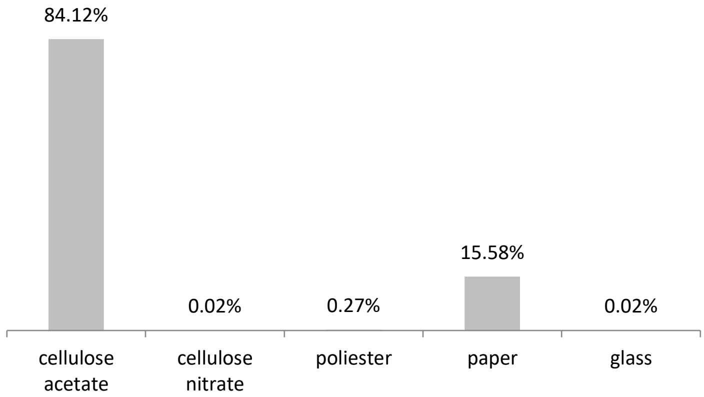
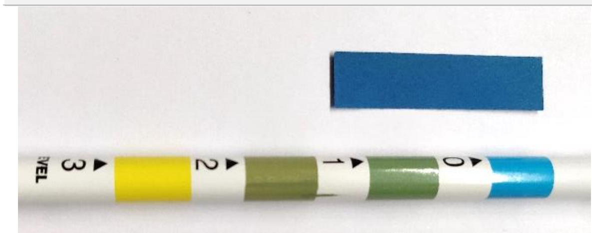
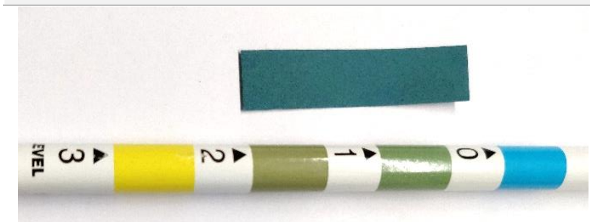


Figure 3.11 - Typology of the supports from the photographic materials.

The AD-strips were placed inside three envelopes containing black-and-white negatives with CA base[17] and three boxes containing chromogenic reversal films with CA base[18]. Assuming that most of the photographs have been subjected to the same environmental conditions, the obtained results might be transposable to the same types of materials present in the collection. The sampling was selected from the earlier series of negatives and slides, that should also be the most aged and deteriorated samples. The obtained results are presented in Table 3.3. Regarding the black-and-white negatives, two AD-strips were associated with level 0 - good condition, no deterioration - and one strip with a level between 0 and 1 - good to fair condition, deterioration starting. Regarding the chromogenic reversal films, all strips were associated with a level between 0 and 1. Although the level 1 of deterioration has not yet been reached, at least in the analysed samples, it can be concluded that the deterioration has already started in some negatives and slides. These results reinforced the urgency to find the means to transfer the collection into a storage with controlled T and RH. When reaching the autocatalytic point (level 1.5), the degradation rate becomes exponential and difficult to control. Therefore, it is highly recommended to store CA based materials under desirable environmental conditions before reaching that point, in order to extend their useful life span (Bigourdain 2002, 104).

[17] Negatives inside the original installation envelopes 817, 818 and 819. The negatives are from 1980.
[18] Slides inside the original installation boxes 653, 656 and 669. The negatives are from 1994, 1998, 1982, respectively.

Table 3.3 - Results obtained from the AD-strip testing for the black-and-white negatives and chromogenic reversal films with cellulose acetate base

black-and-white negatives	comments
	2 strips were associated with level 0 (good condition); 1 strip was associated with a level between 0 (good condition) and 1 (fair to good condition);
chromogenic reversal films	comments
	All strips were associated with a level between 0 (good condition) and 1 (fair to good condition);

3.3.1.1. Black-and-white photography

Ângelo de Sousa essentially made his black-and-white production using negatives with the widespread 35 mm format. When returning from London in 1968, he built his own darkroom[19], allowing him to develop the negatives and to make prints. Thereby, his first black-and-white photographs are dated from the end of the 1960s. In the mid-1980s he stopped the black-and-white production to work with colour photography (Sousa 2001, 47).

Ângelo de Sousa divided his black-and-white production into three main groups (Sousa 2001, 12-13):

i) *Umanistas* (Umanists, purposely without an 'h' as a reference to the Italian neo-realist cinema) are documentary images that make a visual anthropology of Porto's life;
ii) *Abstractas* (Abstracts), created from the activity of street photography, combine the randomness of his daily experience with his photographic vision;
iii) *Criança* (Child), photographs of his son up to adolescence.

As explained by the artist himself (Sousa 2001, 13), these groups allowed him to organize the photographic collection (labelling the images was not his main purpose). Although Ângelo de Sousa stated that the photographs were not organized (Sousa 2001, 13), and, although the archive was untidy, there is a defined order associated with the set of black-and-white photography. This order makes it possible to understand his working process and reflects a methodical character.

As described by the artist (Sousa 2001, 12), given that he photographed compulsively, it was common for him to accumulate several rolls that he would process at once. After developing a roll, he would cut it into strips and make contact prints (D.O.P., 18x24 cm). The negative strips from the same

[19] The darkroom was made in a bathroom on the ground floor of the residence area. Ângelo de Sousa also considered making a darkroom in the room where the photographic and film collections are gathered. The darkroom was dismantled when Ângelo de Sousa was still alive (Sousa 2014).

roll were placed inside an envelope, which was numbered with a sequential and chronological order[20]. Ângelo de Sousa wrote the same numbers on the envelope, contact sheet and, if existing, on the prints, establishing a relation between negatives and prints. Some envelopes contain notes by the artist, with technical information, for instance. The envelopes were finally archived inside a box (Fig. 3.12).

Figure 3.12 - Black-and-white negatives. **Top (left):** box with a set of envelopes; **Top (right)**: detail from the numbering marked on the envelope; **Bottom:** 35 mm roll of black-and-white negative with cellulose acetate base cut into strips.

[20] The first series of envelopes is numbered from 1 to 40, differently from the rest of the series. All the other series are numbered as follows: 2-1 to 2-50, 3-1 to 3-50, etc. The last envelope is 20-44.

The type of films[21] used by Ângelo de Sousa was registered on the database. According to the collected data, it might be concluded that the artist mainly used Ilford 35 mm black-and-white negatives, especially Ilford HP (Hypersensitive Panchromatic)[22] and FP (Finegrain Panchromatic)[23] films. The obtained results reinforce that the artist chose to work with a specific and small group of materials (Fig. 3.13).

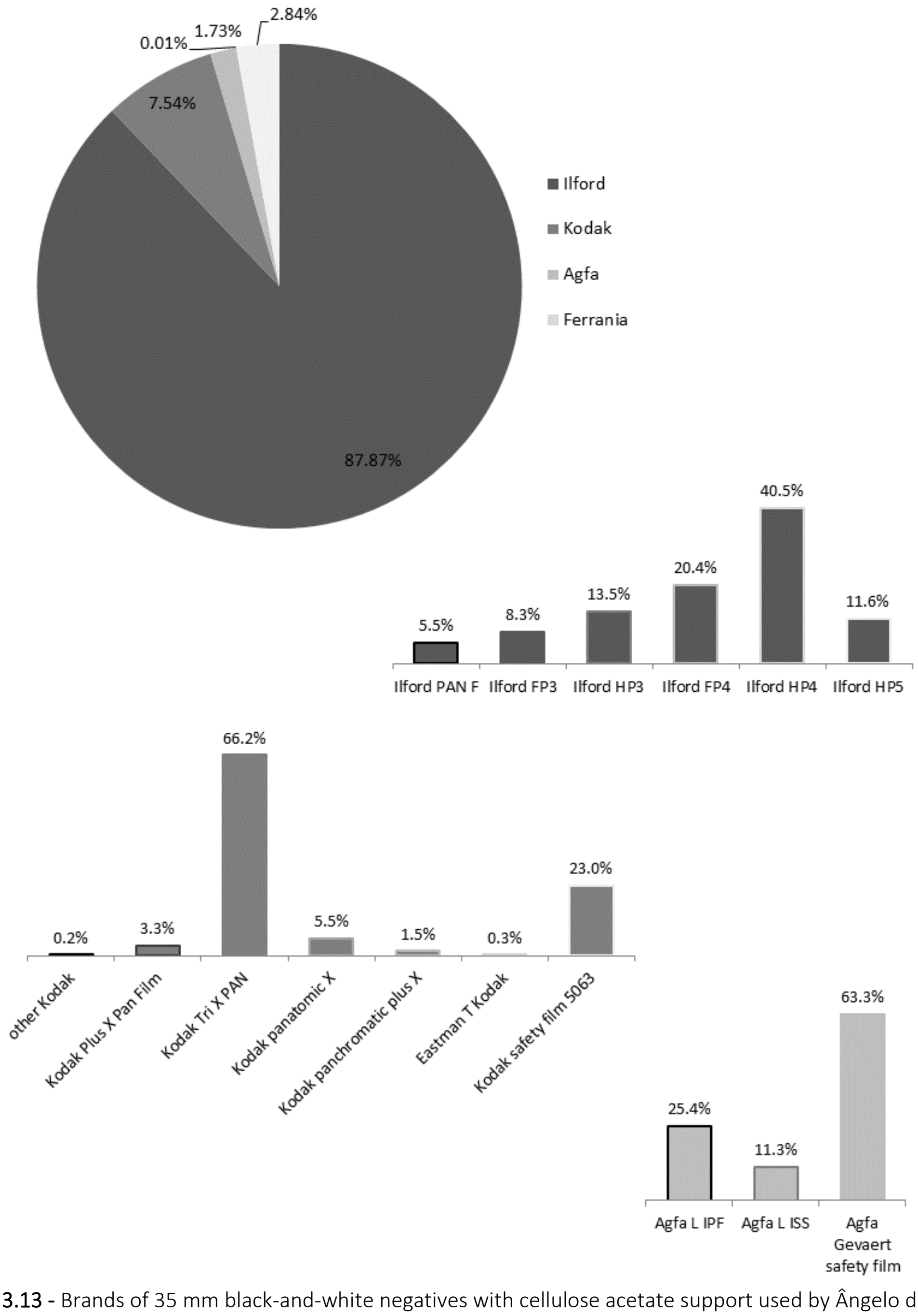


Figure 3.13 - Brands of 35 mm black-and-white negatives with cellulose acetate support used by Ângelo de Sousa.

[21] The edge marking prepared during manufacture and developed during the processing is an important feature that allows for a simple identification of the film type.

[22] Medium contrast, all-purpose black-and-white film. Ideal for action, documentary and available light photography (https://www.ilfordphoto.com/hp5-135; accessed on 18/09/2018).

[23] All-purpose black-and-white film with fine grain, medium contrast and outstanding sharpness. Ideal for most shooting scenarios in good light conditions (https://www.ilfordphoto.com/fp4-135; accessed on 18/09/2018).

According to the evaluation of the conservation condition conducted during the survey, most of the negatives show dust, fingerprints, and slight abrasion (Fig. 3.15). The manipulation of the negatives resulting from the artist's work might be the cause of their current condition. In addition to these physical deteriorations, some of the negatives possibly show signs of microbiological contamination[24] and present chemical deterioration, such as silver mirroring. Nevertheless, 98% of the negatives were considered in fair condition (Fig. 3.14). Although no alarming signs of vinegar syndrome were detected, considering that CA based negatives require very low RH and T conditions (Table 3.1), it is of the upmost importance to transfer them into a controlled storage to ensure their long-term stability.

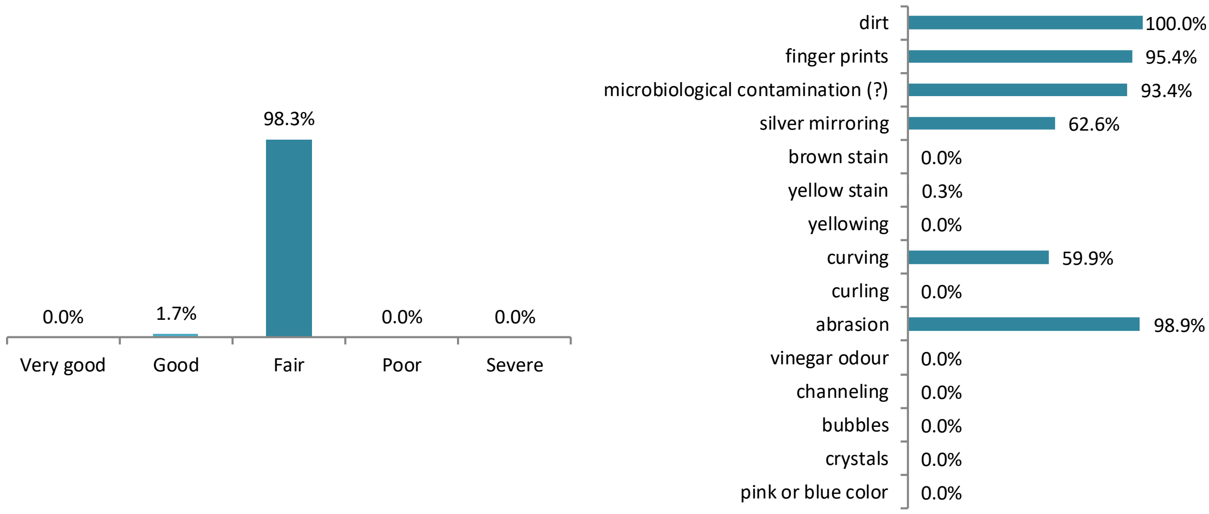


Figure 3.14 - Conservation condition of the 37175 black-and-white negatives with cellulose acetate base with 35 mm (99,89% of the black-and-white negatives). **Left:** general evaluation; **Right**: type of damage and frequency (%).

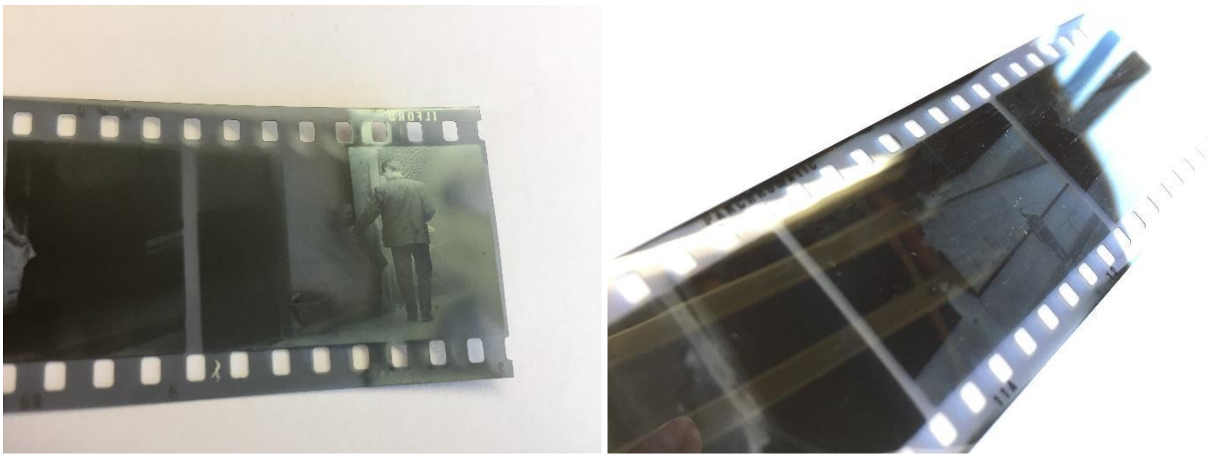


Figure 3.15 - Degradations observed in 35 mm black-and-white negatives with cellulose acetate base.
Left: silver mirroring; **Right**: dust and abrasion.

The negatives are a fundamental material testimony to the appreciation of the overall black-and-white photographic production by Ângelo de Sousa, since they represent the in-camera/first-generation images. Only a few of those images were printed. The contact prints are also interesting

[24] This evaluation was only based a macroscopic observation. The effective presence of fungi was not confirmed.

documents of Ângelo de Sousa's production, since they are evidence of his working process. The contact prints often present notes and schemes by the artist, for instance, showing his preferences about framings or images excluded by him, among others (Fig. 3.16).

Figure 3.16 - Examples of notations made by Ângelo de Sousa in a contact sheet (detail).

Figure 3.17 - Contact prints. **Left:** File 4 with contact prints; **Right:** Contact prints from the series 4 cut into strips and glued to a paper sheet.

In the beginning of his production, he cut the contact sheets into strips, similarly to the negatives, and glued them on paper sheets. He gathered the sheets in files arranged by series[25], numbered and organized with the same order of the negatives. From series 6 onwards, he started to keep the contact sheet entire, arranged inside photographic paper boxes, following the same organization of the previous series. Each contact print contains information about the negatives from which it was made (place, date, film brand) (Fig. 3.17).

From time to time, Ângelo de Sousa was going to his archive to work on the contact prints. After observing them (sometimes only a few months after its development), he would make prints from the negatives (black-and-white prints with baryta paper, 18x24 cm). He used to print a selection of images to see them enlarged (Sousa 2001, 12). According to himself (Sousa 2001, 14), these intermediary working prints were frequently developed without too much care. Those with which he was satisfied, would be printed cautiously leaving a white margin, to distinguish them from the testing (Sousa 2001, 14) (Fig. 3.18). The images he wanted to print and repeat, would be marked on the contact sheet (Sousa 2001, 24). Hence, those prints represent the vision and the choices made by Ângelo de Sousa over his black-and-white photographic work.

Figure 3.18 - Black-and-white prints with baryta paper (D.O.P) 18x24 cm inside a box.
The print on the top of the box has white margins, meaning that it was part of a selection made by Ângelo de Sousa.

The prints were gathered inside photographic paper boxes, organized according to the three main groups previously mentioned: i) *Umanistas*, ii) *Abstractas*, iii) *Criança* (Sousa 2001, 12-13). The boxes were identified with 'U', 'A' or 'C', respectively. Thus, the prints do not present a chronological organization. Some boxes were marked as having interesting material. Some also present a red- and/or green-painted strip or a round sticker with the same colours. Those colours might have a relation with those used for the notations in the contact prints, although no trends could be established.

[25] For instance, file 2 contains contact sheet from 2-1 to 2-50, file 3 contact sheet from 3-1 to 3-50, etc.

The D.O.P brands were also collected, even though a significant amount of prints did not present any information related to the brand, making the results inconclusive.

Regarding the conservation condition, the D.O.P were considered in fair condition. This grade was especially due to the fact that most of the prints show curling, probably due to the stacking inside the boxes and to the high RH values and fluctuations felt in the archive. The prints also present slight yellowing of the paper support. Additionally, a considerable amount of them show dust, finger prints and slight abrasion (Figs. 3.19 and 3.20).

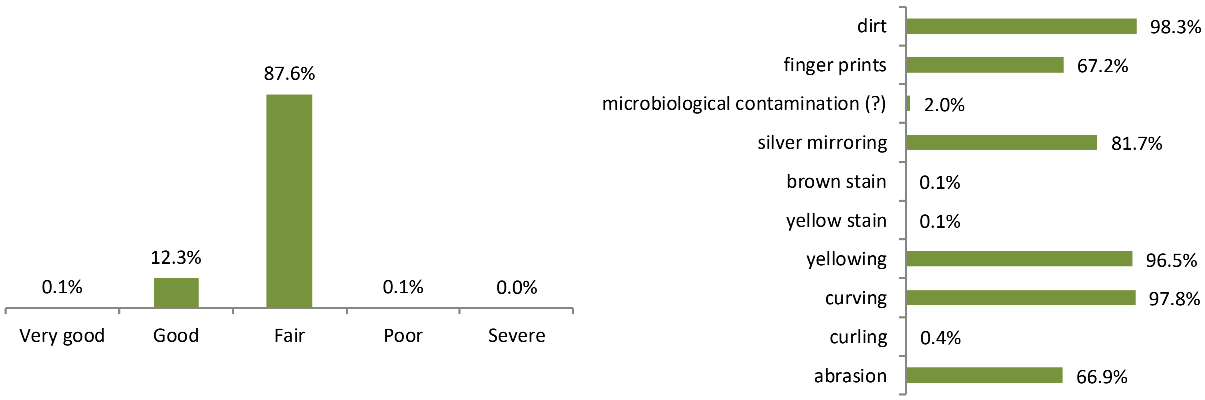


Figure 3.19 - Conservation condition of the 9555 black-and-white prints with baryta paper (D.O.P) with 18x24 cm (90.83% of the D.O.P). **Left:** general evaluation; **Right**: type of damage and frequency (%).

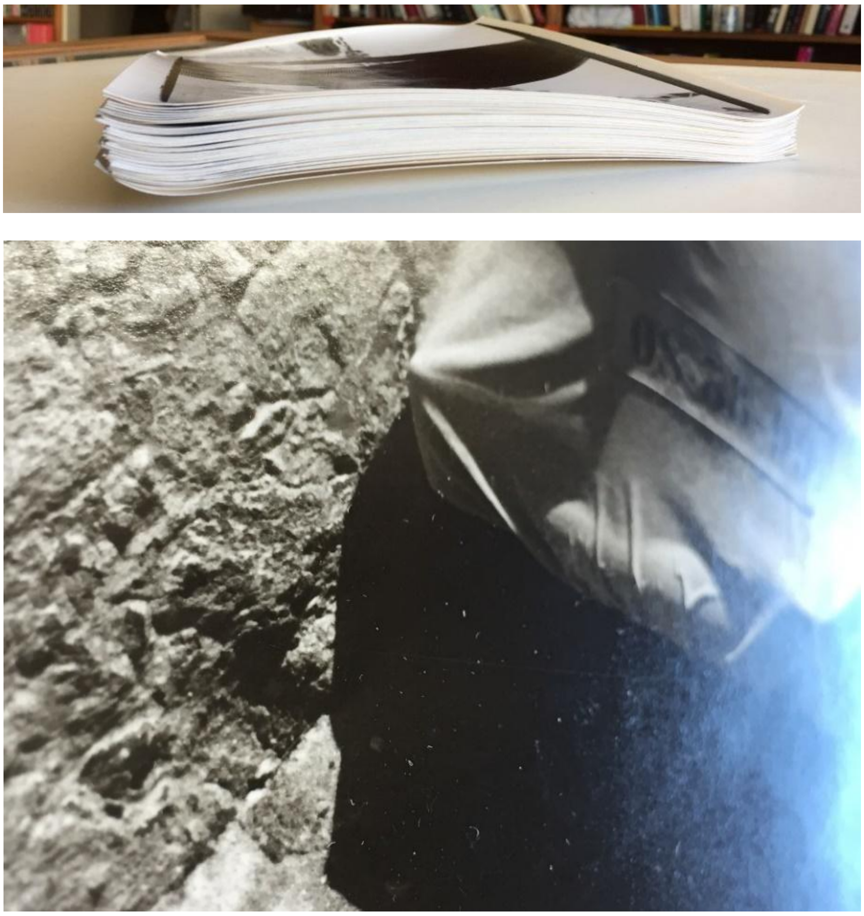


Figure 3.20 - Examples of degradations observed in black-and-white prints with baryta paper (D.O.P). **Top:** curling; **Bottom**: dust and silver mirroring.

3.3.1.2. Colour Photography

Ângelo de Sousa started his photographic production in the mid-1960s by using 35 mm chromogenic reversal films. During the time of his fellowship in London (1967-1968), he found the means to test the medium and produced several images. Nevertheless, when returning to Portugal, due to the high cost of colour slides at the time, he started to work with black-and-white photography. Until the late 1980s, chromogenic reversal films were mostly employed for reproduction of his other works (paintings, sculptures, drawings, etc.). In the 1980s, he returned to colour slides, having developed a massive production until his death (Sousa 2001, 47).

Probably because of chromogenic processing being much more expensive and complex than the black-and-white processing, the artist used commercial laboratories for its development (Sousa 2014)[26]. According to his son (Sousa 2014), after receiving the slides, he would see them with a slide viewer and archive those he wanted to keep and would throw out those he did not appreciate (similarly to what he did with the drawings). From time to time, he was making projections at home with friends (Sousa 2001, 11).

Differently from the black-and-white photography, there are no evident traces of the artist's choices over his slides. Although he used silver dye-bleach prints (Cibachrome) to print some slides, only a few prints were found in his archive (Fig. 3.7). Thus, there was less manipulation over these images (no image adjustments, no framing, no repetitions, etc.). Still, it is possible to have an idea of the artist's choices, for instance based on past exhibitions (see appendix IV, Table IV.1).

The colour photography set has no discernible organization. The colour slides are conditioned inside their original commercial boxes and there is no original numbering associated with the boxes. Nevertheless, they present some notations, such as date, place, topics, film type, and/or others. Some slides also contain notations on the mountings (Fig. 3.21).

Figure 3.21 - Example of slide box showing notations by Ângelo de Sousa.

[26] In Portugal back to the 1970s, chromogenic reversal films could only be processed in Lisbon, which would take a week (Sousa 2001, 19). Later, it was possible to process them in Porto. Ângelo de Sousa used to process the films in the city center at *Fernando Fraga*, and years after at *Centro Comercial da Foz* (see more information in appendix III) (Sousa 2014).

Contrary to the black-and-white negatives, Ângelo de Sousa used several brands and models of slides during his production, although he essentially worked with Fuji and Kodak (Fig. 3.22). This could be possibly linked to the recognized instability of the first generation of chromogenic products (see chapter 2, section 2.3.3) which was gradually improved. In the 1980s, more stable products were shaped, and in the 1990s Fujichrome were proclaimed as the most stable chromogenic reversal films (Wilhelm and Brower 1993, 3). Information related to the different types of chromogenic reversal films used by the artist was gathered (see appendix II, Table II.4).

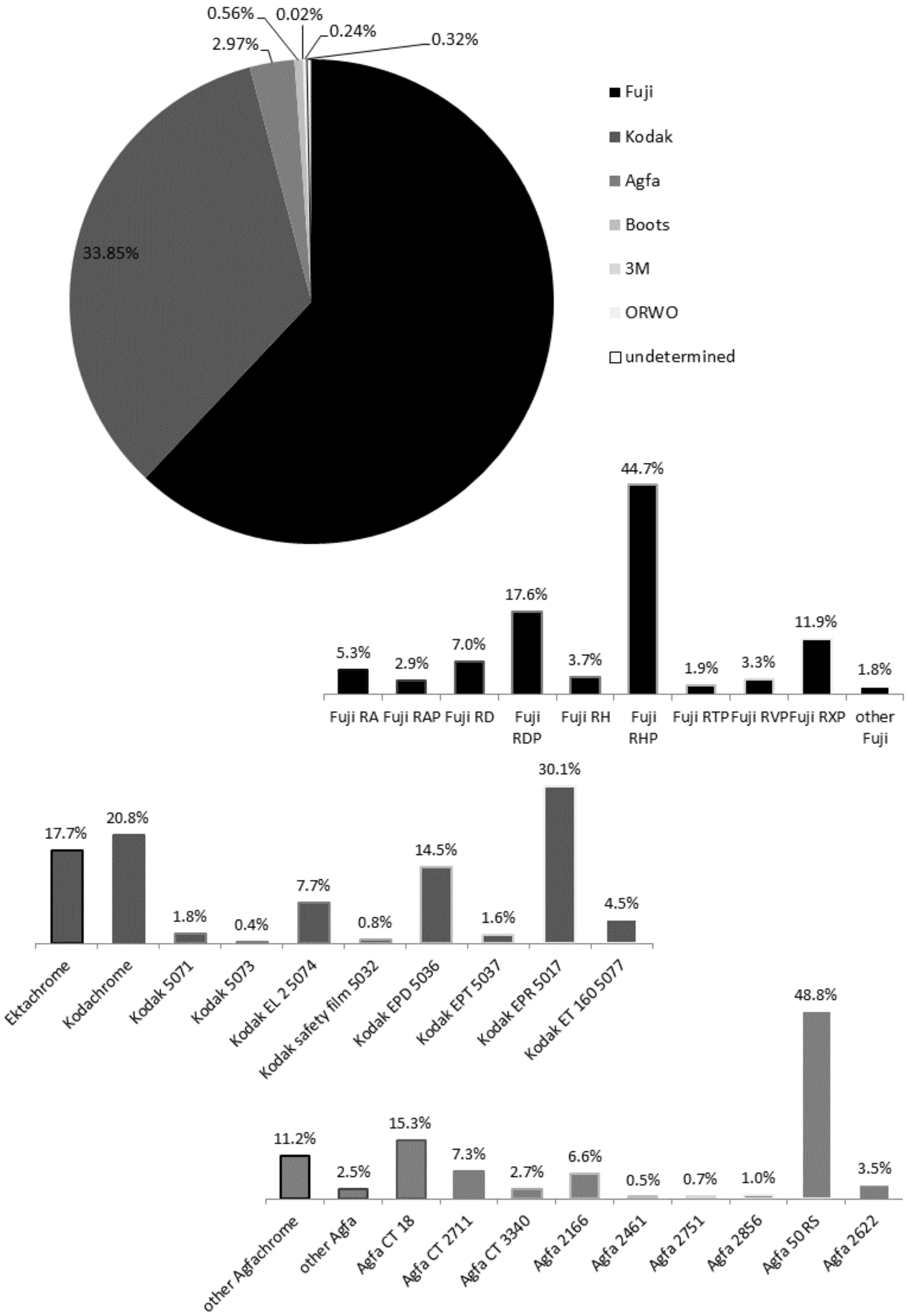


Figure 3.22 - Brands of 35 mm chromogenic reversal films with cellulose acetate support used by Ângelo de Sousa.

The reduced manipulation of this set of materials is probably responsible for 63% of the slides being considered in good condition. In general, the chromogenic reversal films only show slight dust. A few slides present finger prints and little abrasion. However, almost 37% of the chromogenic reversal films were considered in fair or poor condition, which was mainly assigned to changes in colour balance and/or fading[27] (Fig. 3.23).

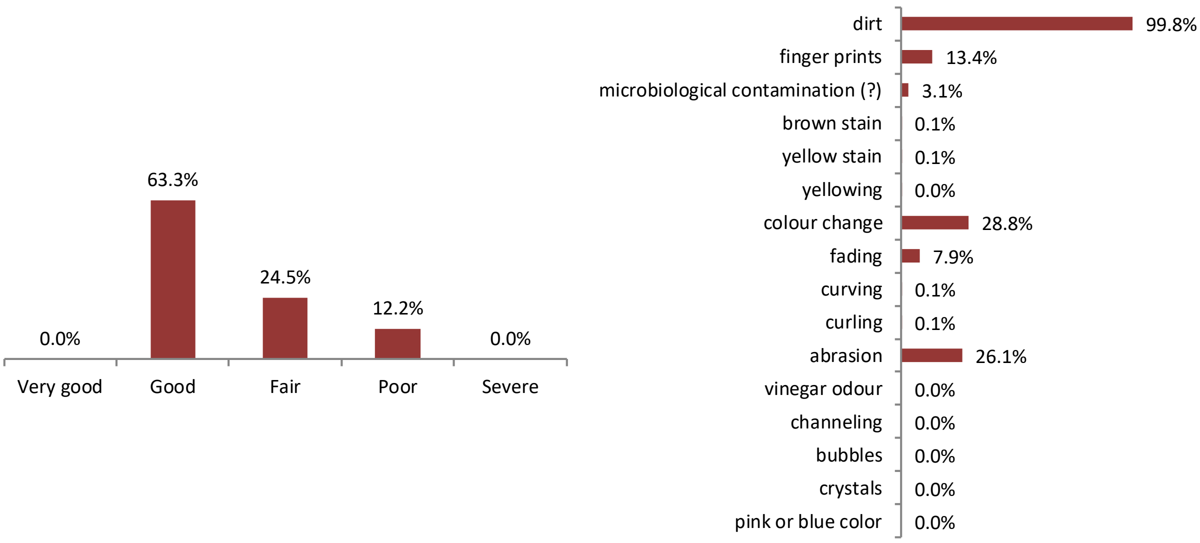


Figure 3.23 - Conservation condition of the 31582 chromogenic reversal films with cellulose acetate base with 35 mm (99.29% of the chromogenic reversal films). **Left:** general evaluation; **Right**: type of damage and frequency (%).

An attempt to relate the observed colour change with the different brands and models of 35 mm chromogenic reversal films employed by Ângelo de Sousa was pursued (Fig. 3.24). To do so, the percentage fading and/or changing in colour balance per models/brands was calculated based on the results from the survey recorded on the database. As expected, both by the quality and ageing time, most of the older slides present more problems associated to dye fading and changing in colour balance than the more recent ones. Several Ektachromes and Kodachromes from the 1960s and 1970s are examples of that. Most of the slides from Agfa, Boots, 3M and ORWO, also from his early production, present signs of dye degradation. Some of the colour changes can be easily recognized and associated with specific brands, showing that each film has a different degradation pathway. The most representative examples of that are presented in Table 3.4. Fuji was assessed as the most stable brand in the artist's collection, although he started to use this brand mainly from the late 1980s onwards.

The colour change detected in the chromogenic reversal films was considered alarming. However, bearing in mind that, up to now, the slides have been kept far beyond the recommended environmental conditions (Table 3.1), the obtained results are not surprising. Since chromogenic materials are the photographic materials requiring lower T and RH conditions, controlling these parameters is mandatory for the long-term stability of these objects.

Apart from the chromogenic colour materials, Ângelo de Sousa also made some dye diffusion prints (Polaroids) and a few silver dye bleach prints (Cibachromes). Fortunately, probably due to their chemical stability superiority (Pénichon 2013, 231, 273), they do not present any alarming degradation signs.

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[27] Only cases in which these degradations were clearly discernible with the naked eye were considered in the database.

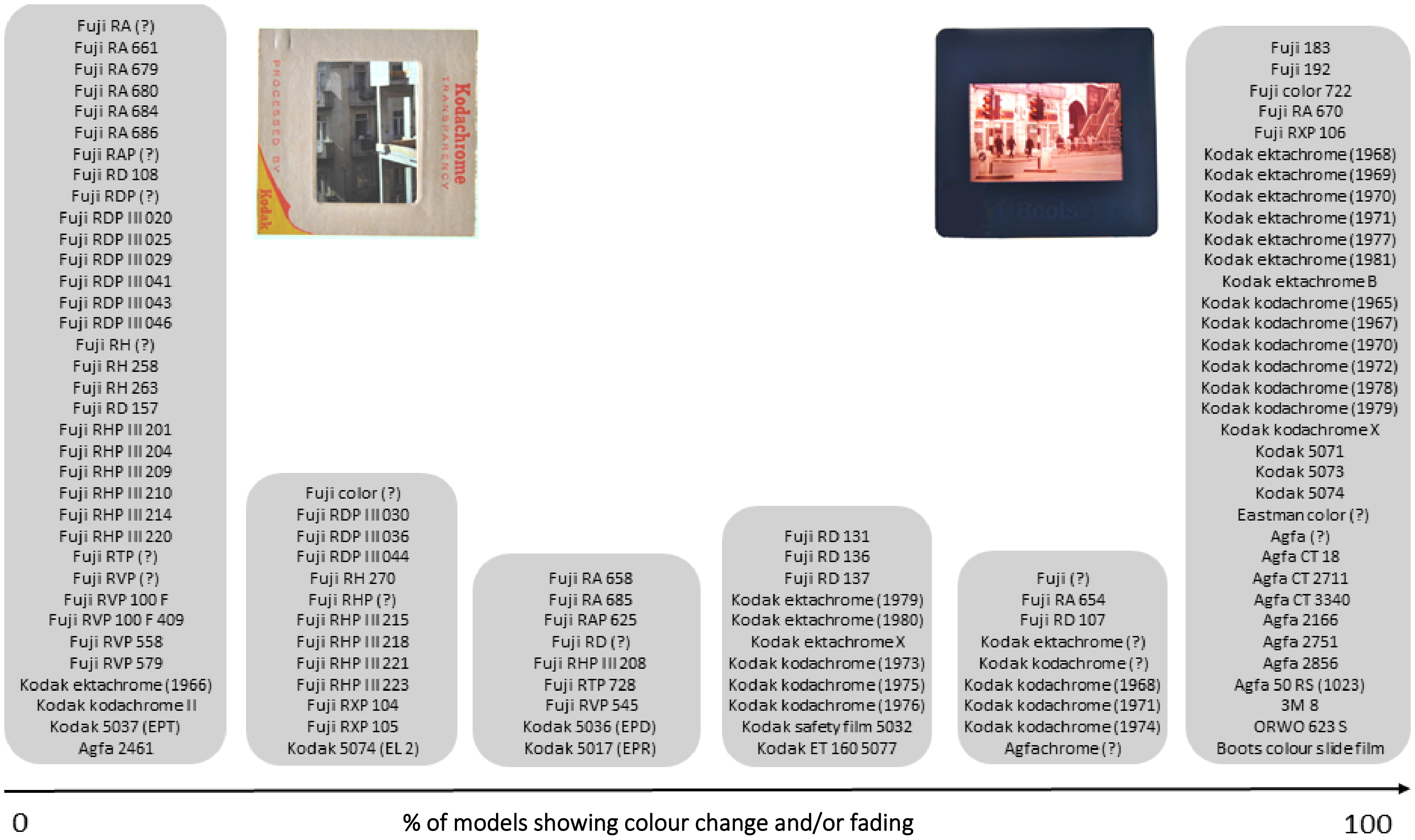
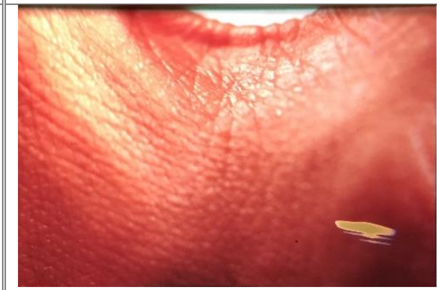
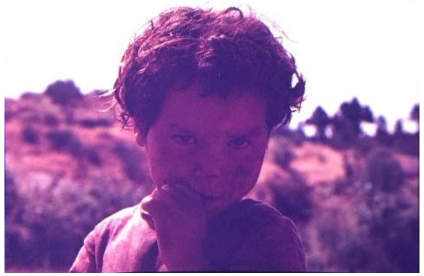
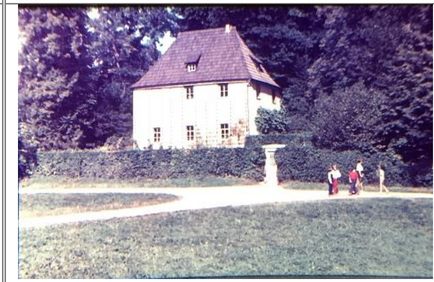


Figure 3.24 - Percentage (%) of slides showing colour change per models/brands of 35 mm chromogenic reversal films with cellulose acetate base (from 1965 to 2009). The insets show examples of slides without (image on the left) and with (image on the right) visual colour change.

Table 3.4 - Brands and models used by Ângelo de Sousa with characteristic fading and/or colour deviation

image	model and production	colour deviation	image	model and production	colour deviation
	Agfa 50 RS	purple/blue		Fuji 192	brownish/orange
	Agfa CT 18	blue/purple		Fuji color	purple
	Boots colour slide film	orange		Orwo	purple
	Kodak Ektachrome X	brownish		3M 8	(blurring)

3.3.2. Films

The film collection is composed of 212 objects, and two main groups can be distinguished: i) analogue films, and ii) videos (Fig. 3.25). Due to technical limitations, only the physical objects (and not the films themselves) have been described within the framework of the present survey.

Figure 3.25 - Examples of films from the film collection;
Left: 8 mm chromogenic reversal film with cellulose acetate base reel; **Right:** Mini-DV video tape.

Regarding the analogue films, the whole set is composed of 125 reels of 8 mm chromogenic reversal films with CA base. Concerning the videos, 87 magnetic tapes were counted in his archive. Within the video set, different formats were identified (Fig. 3.26). However, some formats were only used for duplication, such as VHS and Betacam. Those formats can also contain other types of filmed material, not from Ângelo de Sousa' s authorship. Therefore, only Hi8 (8 mm), Mini DV 1"4 and DVCAM Digital 1/4" were used as video support for the artist's production. Once again, it might be concluded that Ângelo de Sousa chose to work with a limited range of materials. Both analogue films and videos are in colours.

His analogue films were produced within a short time frame: from 1968 until the late 1970s. After shooting, the films would be processed in commercial laboratories for their development[28]. For their observation, the artist would need to project them. According to the interview *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa* (Sousa 2001, 11), and similarly with the slides, the artist also did some projections of his films with close friends. In 1994, he bought a video camera although he only started his video production in 1998 (Sousa 2001, 50). The videos are composed of a magnetic tape, which does not require chemical processing. Therefore, since the images could be viewed in the instant they were taken, working with video would have rather simplified the artist's working process.

The brands used by Ângelo de Sousa for his film production were registered. Regarding his analogue film production, a few different types of films were identified and are presented in Figure 3.27. Concerning the videos, he exclusively used Sony Hi8 videos, and used Sony, TDK and Fuji for MiniDV and DVCAM Digital.

[28] According to Ângelo de Sousa (Sousa 2001, 33), the films would be sent to Spain or France to be processed.

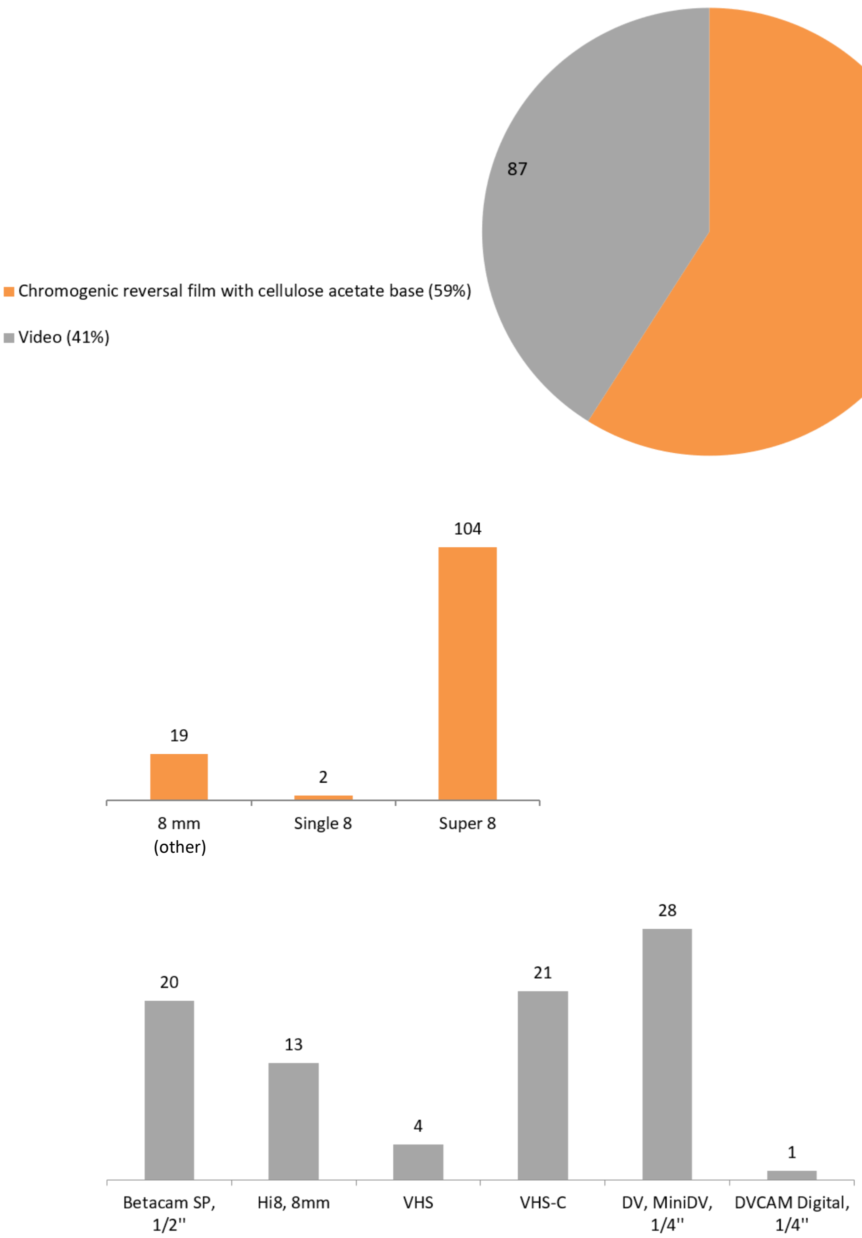


Figure 3.26 - Types and quantities of film materials found in Ângelo de Sousa’s archive. The two main groups of materials are highlighted: analogue film (orange) and videos (grey).

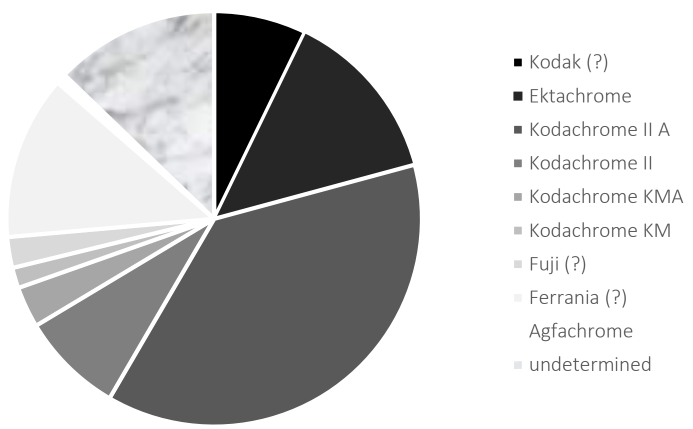
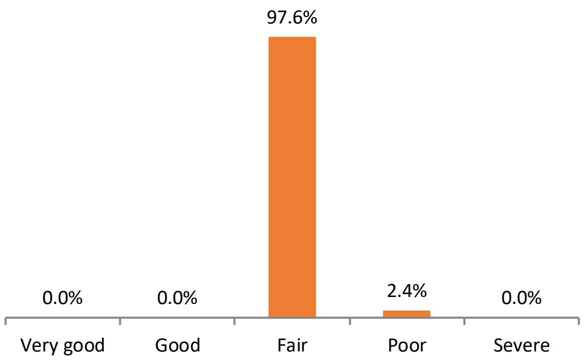


Figure 3.27 - Brands of 8 mm chromogenic reversal films with cellulose acetate support found in Ângelo de Sousa’s archive.

As in his colour photography, the films do not show any perceptible organization. Some 8 mm reels were kept inside envelopes; others have no packaging. The video tapes were maintained inside their commercial boxes. The films were normally identified with their title or a descriptive designation and are sometimes dated. Each reel or tape normally contains more than one film. As with his colour photography, it is only possible to deduce Ângelo de Sousa's choices over his film production based on the films presented in exhibitions (see appendix IV, Table IV.1). In his archive, there is a file with typed texts and two notebooks containing scripts and ideas for the films.

Almost 98 % of the analogue films were considered in fair condition (Fig. 3.28). This condition grade can be assigned to dust, apparently a slight microbiological contamination[29], abrasion and occasionally some curling and physical deformation, such as creasing (Fig. 3.29).



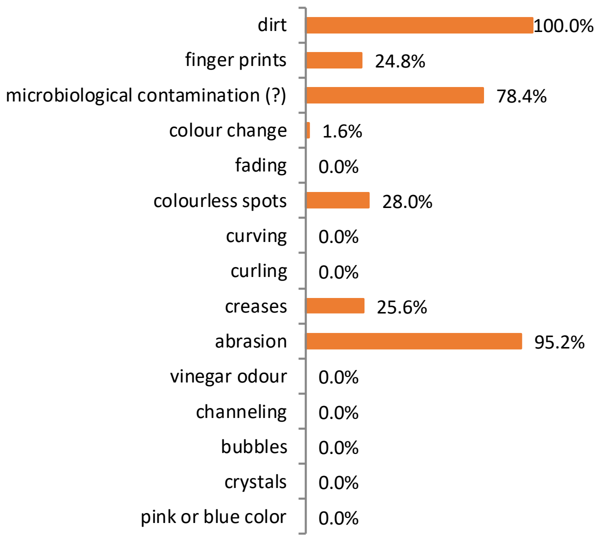


Figure 3.28 - Conservation condition of the 125 reels of 8 mm chromogenic reversal films with cellulose acetate base. **Left:** general evaluation; **Right**: type of damage and frequency (%).

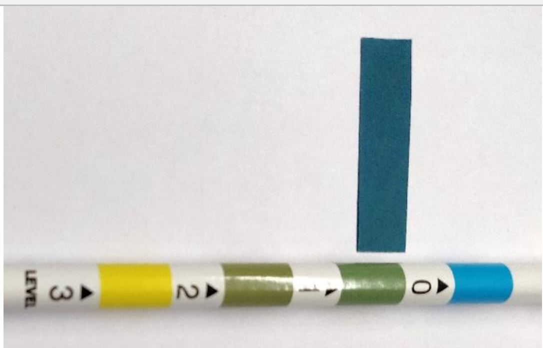
Figure 3.29 - Degradations observed in an 8 mm chromogenic reversal film: dust and abrasion.

[29] This evaluation was only based a macroscopic observation. The effective presence of fungi was not confirmed.

However, having no winding table, the examination of the films was not accurate. The evaluation of the analogue films was based on the observation of the first photograms of the films. Considering that these films are chromogenic materials from the late 1960s and 1970s, it would have been expected that, like the slides, the films exhibit changes in colour balance and/or fading. Nevertheless, within the conducted evaluation, those type of degradations were not detected.

Although all the analogue films have a CA base, no signs of vinegar syndrome were detected during the assessment of the films[30]. Nonetheless, and similarly with the photographic set, the acetic acid content of the films[31] was assessed by using AD-strips. The strips were placed inside three reels containing chromogenic reversal films. The results from the assessment are presented in Table 3.5. Along with the negatives and slides, the AD-strips were associated with a level between 0 - good condition - and 1 - good to fair condition. Thus, it can be concluded that the deterioration of the analogue films has started.

Table 3.5 - Results obtained from the AD-strip testing for the analogue film with cellulose acetate base

films	comments
	Strips were associated with a level between 0 (good condition) and 1 (fair to good condition);

41% of the videos were considered to be in good condition, and 57% in fair condition, essentially assigned to dust, curving and creasing (Fig. 3.30 and 3.31). A magnetic tape is composed of a base film (polyester from the 1960 onwards) and a magnetic layer[32]. A small number of video tapes present white stains, which could be related to lubricants from the composition of the magnetic tape. Some lubricants tend to exudate and crystallize on the tape surface (van Bogart 1995, 4). Although only a few tapes presented that degradation, and no sticky tape[33] was recognized, this might be an alarming signal. Additionally, similarly with the analogue films, the evaluation of the videos was only based on the observation of the tape exposed outside the cassette, and therefore other video tapes might be suffering from that problem without it being noticed.

[30] No vinegar odour was detected.

[31] Films inside the original installation envelopes 5021, 5022, 5023. Only the film in the original installation 5021 is dated (1974). Nevertheless, as previously mentioned, the films were all produced between 1968 and the 1970s.

[32] The magnetic tape is made of a pigment, a binder and other additives such as lubricants. Chromium dioxide is used as a pigment in medium to high-grade audio tape and some high-grade VHS/Beta video tape, and metal particulate is used in high-grade audio and 8 mm video tape (van Bogart 1995, 1). From 1960s onwards, the binder is normally a polyester-based polymer (van Bogart 1995, 8).

[33] Typical degradation of magnetic tapes. As the deterioration of the magnetic tape progresses, molecular chain scission of the polymeric support occurs and the binder proprieties are gradually lost. This process can lead to softening, brittleness, loss of cohesion, and the formation of sticky products. The tape may become unplayable (Bigourdain et al. 2006, 6).

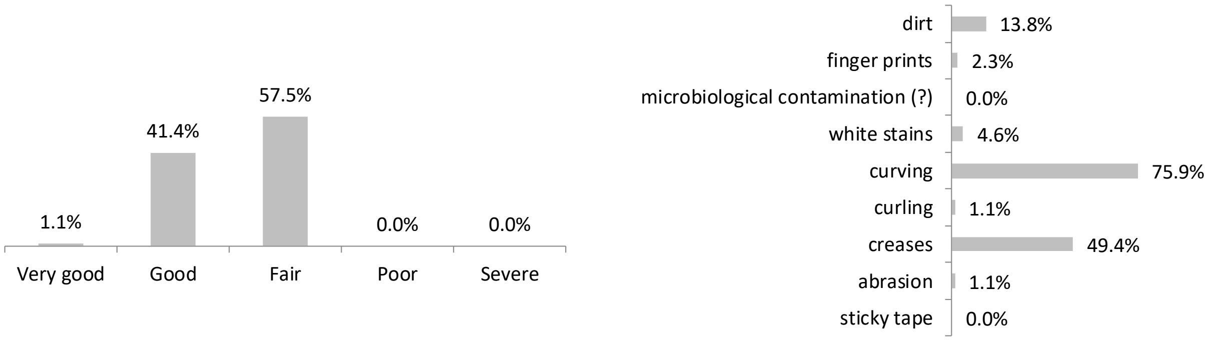


Figure 3.30 - Conservation condition of the 87 video tapes.
Left: general evaluation; **Right**: type of damage and frequency (%).

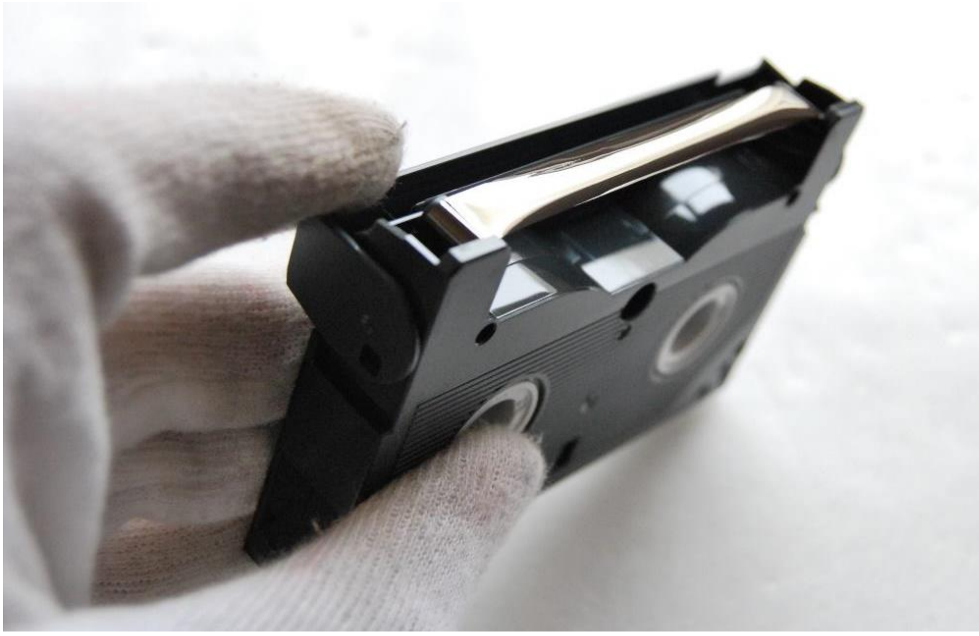


Figure 3.31 - Degradation observed in a video tape: curving.

The stability of magnetic tape is strongly influenced by the storage environment. T and RH promote its deterioration. In the same way, these factors accelerate colour dye fading and CA deterioration in the analogue films[34] (Bigourdain et al. 2006, 7-8). Therefore, similarly with the photographic collection, it is urgent to transfer the film collection into a climate-controlled space to properly preserve the overall collection.

3.3.3. Digitisations and duplications

As already mentioned, Ângelo de Sousa wanted to publish a series of books with photographs of his authorship. Within this context, some digitisations were performed at his atelier in the 2000s using a scanner[35]. Additionally, some digitisations were made within the framework of exhibitions. Other

[34] ISO 18923: 2000—*Imaging materials—Polyester-base magnetic tape—Storage practices,* recommends a temperature range between 11°C and 23°C and a related range of RH levels between 20% and 50%.
[35] Canon 4400 F.

digitisations, both from his authorial and documental photography (namely slides of his paintings, sculptures and drawings created in the 1960s to 1980s) were made elsewhere[36]. A total of 4587 black-and-white and 2979 colour images were digitized, which represents 12% of the black-and-white and 9% of colour photographs. The digital files have, in general, a good quality. These have been exclusively kept in CDs or DVDs, and, unfortunately, some of them are now corrupted[37]. Considering the instability of these supports (Byers 2003, 1-5), the digital files were transferred into external discs, as an immediate preventive measure. Nevertheless, it is fundamental to implement a migration policy to ensure the continuity of the digital reproductions.

Regarding the film collection, a great number of films have been migrated into other media, and in some cases, in more than one format. When Ângelo de Sousa's analogue films started to be exhibited more often, they were transcribed into video to be displayed. The analogue films were firstly converted into Betacam in 1995[38], which were in turn digitized in 2001[39]. Some telecines were also made in 2011[40]. Later, a set of analogue films was sent to Germany to be digitized (Sousa 2014). A few copies of his photographs and films were made for the exhibition *Sem Prata*, in 2001, and subjected to colour adjustments. This process was followed by the artist (Sousa 2001, 15). Currently, there are digital copies from some of his films at Fundação Calouste Gulbenkian (FCG), at Centro de Arte e Comunicação Visual *(ar.co)*, and at Fundação de Serralves (Sousa 2014). Nevertheless, the percentage of copied films remains unknown, since the total number of films has not been assessed up to the moment.

Despite the growing dissemination and reflection about Ângelo de Sousa's photographic and film work, a substantial part of his photographs and films remains unrevealed. With exception of the publication *Cadernos de Imagens* and of the exhibition *Encontros com as Formas* (2014) edited and curated by Sergio Mah (chapter 2, section 2.1.2), respectively, the current contributions have been based on the already available and digitized images. Those images represent a selection by Ângelo de Sousa of his work. Nonetheless, it is known that the artist used to throw away works with which he was not satisfied. This happened with drawings, photographs, and probably other media, according to several interviews. For instance, in the interview "*A Felicidade no Gatilho": Entrevista a Ângelo de Sousa*, the artist said (Sousa 2001, 47):

> "In London I was able to buy lots of rolls of slides, that it took only a day to develop. I brought back from there lots of boxes of slides, which I threw out some ten to fifteen years ago, when I had a clear out once. I only kept a dozen".

In his archive, it was found a set of about a thousand slides that were kept huddled inside a plastic bag, entitled '*lixo'* (garbage). Therefore, at least based on the percentages of digitalized photographs, it might be concluded that there is still much more to explore and discover about this parcel of the artist's production.

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[36] André Pregneitzer was responsible for the digitization of a part of Ângelo de Sousa's photographs. He generated TIFF images with 45 to 50 MB.

[37] CDs and DVDs are not suitable for long term archival use. Disks have a plastic and metal layered structure. The information, which is stored on optical disks in form of pits, is susceptible to total loss if chemical or physical damage occurs on the material (Byers 2003, 1-5).

[38] In *Associação de Produtores Independentes de Audiovisuais - APIARTE* (Portuguese association of independent audiovisual producers). The work was made by Mário Moutinho.

[39] Within the framework of the exhibition *Sem Prata*.

[40] Process of transferring motion picture film into video in a colour suite. The telecine was directed by Amarante Abramovitchy.

3.4. Conclusions

This chapter aimed at developing a global overview of Ângelo de Sousa's photographic and film collection. After surveying both photographic and film materials present at the archive it was possible to understand that the collection is composed of 85646 photographs and 212 cartridges of films. Based on the obtained results, it was concluded that Ângelo de Sousa chose to work with a limited range of photographic and film materials.

The photographic collection is composed of a variety of objects, but the artist basically developed his production based on three main groups: i) 35 mm black-and-white negatives with CA base, and ii) 18x24 cm black-and-white developing-out-prints with baryta paper (D.O.P), for his black-and-white production, and iii) 35 mm chromogenic reversal films with CA base (slides), for his colour production. The negatives were used to produce contact prints, which in turn allowed for the selection of the images to print. 98.3% of the negatives were considered in fair condition, assigned to manipulation (dust and abrasion) but also to silver mirroring, slight curling and possibly microbiological contamination. 87.6% of the prints were considered in fair condition, mainly due to yellowing and physical deformation. Regarding the colour set, the slides were only used to produce a few prints (Cibachromes). Thus, the slides do not present much signs of usage. However, 24.5% were considered in fair condition and 12.2% in poor condition, assigned to dye fading and shift in colour balance.

The film collection comprises both analogue and video supports, all colour films. The whole set of analogue films is composed of 8 mm chromogenic reversal films with CA base. Concerning the videos, Hi8 (8 mm), Mini DV 1"4 and DVCAM Digital 1/4" were used. 97.6% of the films were classed in fair condition, presenting some dirt, abrasion, and possibility microbiological contamination. The videos were mostly considered in fair/good condition.

After surveying the materials, Ângelo de Sousa's working methodology was made clear. This is especially true for the photographic negatives and prints, in which the contact sheets were a fundamental work tool for image selection and production. The notations left by the artist in these objects are insightful of his choices over his black-and-white photographic production. In the same way, by observing the collection, and especially this same set of materials in which he developed a numbering system, it was possible to behold the artist's organization.

Although some films have been transcribed into other formats, especially the analogue films, only a small percentage of photographs has been digitized. Therefore, it can be concluded that a substantial part of his photographs and films remains unknown and needs to be digitised.

After assessing the storage space where the photographs and films have been gathered, it can be concluded that the environmental conditions recommended for the materials composing the collection are not being reached. The T and RH measured in the archive since 2014 pointed out to values above what is desirable, putting at risk the overall collection. Considering that a significant percentage of the collection is made of CA based and chromogenic materials, as well as video tapes, its reconditioning under controlled T and RH is a pressing task.

The conducted survey allowed us to define the collection fragilities. From the overall collection, 35 mm chromogenic reversal films with CA base were considered the set at higher risk. More than one third of these materials present discernible colour change which was considered alarming. Moreover, along with black-and-white negatives with 35 mm CA base, the slides are the most representative photographic process used by the artist, deserving special attention.

Chapter 4

Contributions to a biography of Ângelo de Sousa’s photographic and film work

4.1. Preamble

As first mentioned in chapter 2, a limited number of references addressing the photographic and film work produced by Ângelo de Sousa was acknowledge. This might be a consequence of these media having had less visibility than others explored by him, such as painting and sculpture, especially in the past. Although some authors have been recently searching his photographs and films, namely to produce exhibitions, in-depth research studies focusing on these media are still lacking. Nevertheless, certain authors such as Bernardo Pinto de Almeida (Almeida 2018), pointed out that Ângelo de Sousa was one of the first Portuguese artists to work with these supports as an artistic expressive tool. Pursuing this premise, the goal of this chapter is to contribute to a comprehensive understanding of the use of photography and experimental film by the artist under study.

With this aim in mind, his photographs and films were studied through available published documentation, but mostly through unpublished primary sources found in the artist's archive and public Portuguese archives, such as Fundação Calouste Gulbenkian's (FCG). Regarding the artist's archive, personal documentation related to the production of his artworks (such as letters, notebooks and sketches) as well as the artist's materials, equipment and library were accessed. Additionally, during the literature review conducted within chapter 2, Bernardo Pinto de Almeida and Miguel Wandschneider were considered as key personalities, who worked with and have written about the artist. Therefore, both were formally interviewed in order to register their perception about this parcel of the artist production.

The research presented in this chapter sought to develop certain identified trendlines in the artist production, such as expressive freedom, technical and material experimentation, serial, aesthetic simplification, and conscient use of colour. Considering the results of the investigation described in chapter 3 (35 mm chromogenic reversal films were used to produced almost the overall set of colour photographs and that one third of these slides have shown visible colour change), special attention was paid to the last topic, in order to understand if some of his slide-based artworks could be at risk of losing value associated to colour change. Some of his photographs and experimental films were examined and related with documental information. Comparisons between paintings, drawings, sculptures, photographs and experimental films were highlighted throughout this chapter. An attempt to show the harmony of Ângelo de Sousa's work with the work of other established international *neo avant-garde* artists was made as well. Additionally, for a better understanding of some of the works in which the artist explored the idea of colour, notably *Slides de Cavalete* (1978-1979) and the untitled work (colourful hand shadows) (1979) made within the framework of the first, their production process was reproduced based on documentation found in the artist's archive.

This chapter was divided in two main sections. Section 4.2 makes an overview of the overall photographic and film work by the artist. Section 4.3 focuses on the colour exploitation by the artist, in his work in general, and especially by means of the photographic medium. The methodology adopted for the development of this chapter is outlined in Figure 4.1.

Part of the content of this chapter was presented in a national conference:

<u>Silva, J.</u>, Ferreira, J. L., Ramos, A. M. 2015. Slides de Cavalete by Ângelo de Sousa: constructing colour with additive synthesis. Poster presentation at *Noite da Luz da FCT*, 8 June, Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia, Monte da Caparica, Portugal.

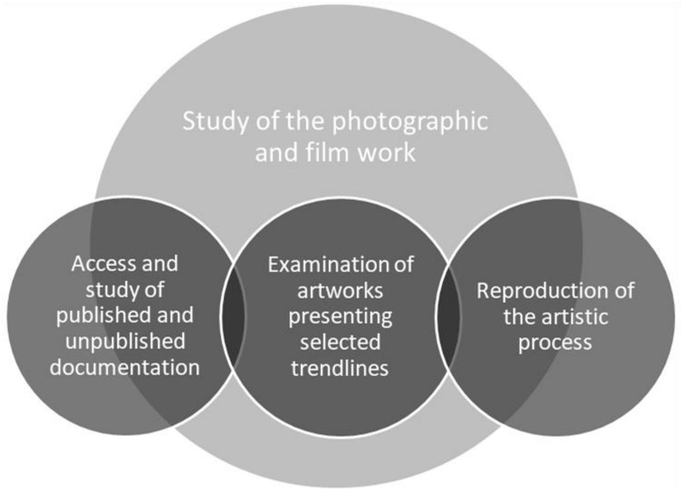


Figure 4.1 - Scheme of the main goal (light grey) and chosen methodology (dark grey) adopted for the development of chapter 4.

4.2. Ângelo de Sousa's experimentation with photography and film

The work by Ângelo de Sousa is characterized by an expressive freedom. His projects were normally associated with experimentation, arising or evolving as a reaction to materiality (Sousa 2001, 34-35). As stated by the artist (Almeida 1993a, 23):

> "(…) it's the material that creates response, that is the result of a mediate accumulation process of, a process of evolution".

Ângelo de Sousa had a special interest in the exploitation of new materials. In the report that he wrote to FCG[1] in 1965, he explains, referring to polyvinyl acetate paints:

> "(…) I should add that the use of these materials also served myself as an essay, since they do not belong to the extensive list of traditional painting materials. They have, however, different properties and qualities, and for that reason I was interested in their investigation."[2]

or, referring to the sculptures:

> "I would like to (...) continue to experiment with materials that have just been created, such as different types of synthetic resins, thermosetting and thermoplastic, polyester (reinforced with glass fibres) and acrylic, respectively"[3].

When the *neo avant-garde* artists started to value audio-visual supports as media for expression worldwide, Ângelo de Sousa also began his photographic and film production. This beginning corresponded to the period immediately prior to his academic formation in London (1967-68), where he had the opportunity to acquire photographic equipment, his first movie camera, and to deepen his knowledge with technical bibliography (Mah 2014, 20). Although his contact with international photography and experimental film in the 1960s and 1970s was short and sporadic[4], he produced work of great originality.

As in other media that he explored, the artist attributed an experimental character to his photographic and film work. As Michel Poivret (2010, 56) stressed out, photography (perhaps more than film, as it consists of a sequence of frames which produces a narrative), is a privileged medium for the exploitation of conscious states, as it allows for the materialization, in images, of irrational phenomena coming from experimentation. In other words, photography, because of its immediate and automatic nature, enables the achievement of the creative process, spontaneously, in a unique way. Another symptom of Ângelo de Sousa's experimentalism is the significant number of photographs (see chapter 3), drawings, sculptures, and paintings produced by him.

In London, the artist started taking photographs more frequently. He began by developing his photographic work in colour, but later, on his return to Portugal, he initiated his black-and-white production. From the 1980s onwards, at the same time he left black-and-white photography, the colour

[1] *Subsídio material e atelier* (material allowance and atelier), grant awarded by the Fine Arts Service from Fundação Calouste Gulbenkian.
[2] Translation by the author of this dissertation.
[3] Translation by the author of this dissertation.
[4] During his stay in London, Ângelo de Sousa had the opportunity to watch several experimental films at the *National Film Theatre*, some of which would only be available a decade later in Portugal (Sousa 2001, 45-48).

work started to become increasingly important. From this set, the so-called *Epifanias* (Epiphanies)[5] stand out; those images, similarly with the *Abstractas*, are purely experimental and have a self-sufficient nature (Sousa 2001, 47-48) (Fig. 4.2).

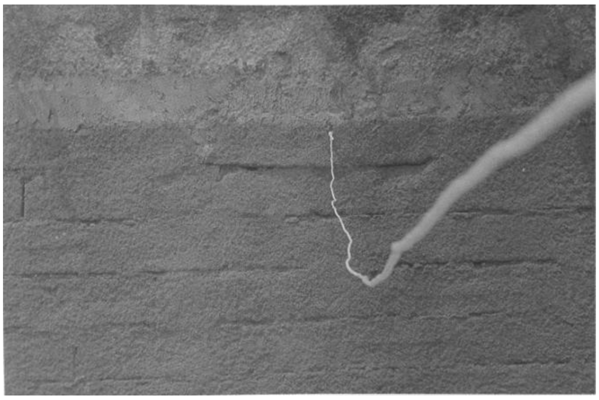



Figure 4.2 - *Abstractas* photographs by Ângelo de Sousa. **Left:** *Sem título* (1982), 35 mm black-and-white negative with cellulose acetate base; **Right**: *A corda* (1976), 35 mm black-and-white negative with cellulose acetate base. Artist collection.

Regarding his films, the first years of his production, starting in London in 1968 and ending in the late 1970s, proved to be quite fruitful. His first movies were all shot in 8 mm film (see chapter 3, Fig. 3.26). Although the artist acquired some editing tools (Fig. 4.5), his films were typically made without interruptions or cuts, and the *montages* were made during the shooting. Therefore, most of his films are the immediate product of his shootings (Sousa 2001, 36)[6]. According to a report sent by Ângelo de Sousa to FCG in 1976[7], it is possible to conclude that he considered using sound films, but due to some technical problems (namely, the malfunction of his sound projector), he ended up by quitting the idea. Only in the 1990s, after almost a decade without producing any films because of technical problems, Ângelo de Sousa started to shoot on video, during the exhibition of his installation at *Alfândega do Porto*[8] (Sousa 2001, 50).

Ângelo de Sousa developed his film work disengaged from a conventional narrative. According to his own words (Sousa 2001, 45):

> "When I bought my first film camera, in London, it never crossed my mind to make an in-depth film with a story. In London, I followed various film cycles at the National Film Theatre, where, besides a whole host of films that weren't being shown in Portugal at that time, I saw quite a lot of experimental cinema - American, German and Austrian; I saw films by people such as Stan Brakhage, Kenneth Anger, Warhol, as well as some films by Vienna Actionists. If I hadn't been convinced that it was possible to make films without a story, perhaps these films would have served as an incentive for me to cast aside any doubts in this respect".

[5] As they were called in the exhibition *Sem Prata* (2001).
[6] The film *Uma escultura* (1972), produced during an exhibition at the Sociedade Nacional de Belas Artes, in May of that year, is an exception. This film was previously planned and assembled after the shooting, according to the script (Magalhães 2015a, 286).
[7] *Subsídio de investigação, artes plásticas e comunicação visual* (research, plastic arts and visual communication funding), grant awarded by the Fine Arts Service from Fundação Calouste Gulbenkian.
[8] Within the framework of the *2as Jornadas de Arte Contemporânea*, in 1993, Ângelo de Sousa made an installation in the cellars of the Port Customs (Porto): *Uma visita, instalação com espelhos* (Sousa 2001, 50).

Besides his authorial work, which represents the largest portion of his photographic and film collection, the artist also used these media to document his paintings, sculptures and drawings. In the 1960s, he photographed his remaining work, especially by using colour slides, although he also used black-and-white negatives. Later, he hired people to do this task. In the 2000s, he started to register his work using polaroids (Sousa 2014). The same happened with film. *Desenhos 62-72* (1972), *Uma Escultura* (1972) and *Quadrum Abril* (1975), are some examples whose subject is his remaining artistic work. Although having a documental character, these films are, as the other films, a product of the artist's creation. According to Andreia Magalhães (2015a, 286), *Uma Escultura* (1972) is one of the most impressive films by Ângelo de Sousa. This is the only film in which Ângelo de Sousa followed a precise script. To accomplish his idea, he shot eight reels and edited them manually (Magalhães 2015a, 286).

Based on the conducted research, it was understood that ideas for some of his films and photographs were previously sketched. This can be assessed by observing the documentation present in his archive, in various notebooks[9] and scripts for films (Fig. 4.3). In the abovementioned report sent to FCG, he frequently described ideas for films and photographs. However, he also complained about not having time to produce all the work he wanted to, basically due to his onerous position in the direction of the University (which he did not appreciated) along with his professorship. Nonetheless, some of his plans were achieved, although others never came to be materialized.

In any case, his films emerged as a narrative of the unconscious, freedom and joy (Sousa 2001, 33-34). His films, often characterized by vibrant colours, arose as spontaneous witnesses of his daily life, similarly with what happens in Jonas Mekas's films. During this investigation, it was possible to conclude that a large part of Ângelo de Sousa's films, as well as his *Abstractas* and *Epifanias* photographs, came up as fortunate appearances or discoveries from visually challenging motifs that he wanted to capture or that caught his attention. As in a visual dialogue, he sought to record the briefness of certain moments, or the particularity of certain motifs that arose in his everyday life. The same motifs as those photographed (trees, plants, houses, among others) are also often found in his early paintings or drawings. As described by Fernando Pernes (1993, 9) (referring to his paintings and drawings), through the images created by Ângelo de Sousa, we are frequently transposed into an imaginary of shapes resultant from almost unrecognizable objects, such as in an abstractionist process. Thus, the artist transformed the images into a formal exercise, praising the capacity of photography to transform the objects from reality into motifs with an abstracting content. Confined to the frame of the photograph, the motifs acquire a visual weight that transcends their original nature, being transformed into another thing. Through this process of image reinvention, Ângelo de Sousa leads us to discover pure shapes, straight or curved lines, intersected or overlapped. When observing his overall *oeuvre*, these same shapes can be frequently found in the different media explored by the artist. For instance, in the photograph *Céu* (1979-1997) (Fig. 2.14), and in the film *Chão de Cimento Abstracto* (1973) (Fig. 4.4), the same crossed lines can be found, which in turn are repeated in his paintings. According to José Gil (2003, 34):

[9] In his archive there are notebooks with notes about Ângelo de Sousa's ideas to produce paintings, sculptures, drawings, photographs and films. Some ideas are illustrated with instant prints (polaroids). Other types of notes can also be found, such as technical information about a process, or a reference to a book, or just a sentence that he recorded. In the later notebooks, *collages* from newspapers can also be found. In total, there are 20 notebooks, numbered and dated (the first booklet started on the 22nd November 1958 and the last finished on the 27th May 2006). Notes about photography and specially film can be found in most notebooks. Apparently, before Ângelo de Sousa started his film production, he was already sketching ideas for films. The first idea for a film is dated back to 17th February, 1959. Regarding photography, the first written idea only emerges in 1967.

"(...) a large part of the painter's work can be considered as an immense rhizomatic proliferation: the drawings connect with each other, and with the sculptures, with the paintings, by suggestion and action of rhizomes, of appendices, of current escape lines with virtual points"[10].

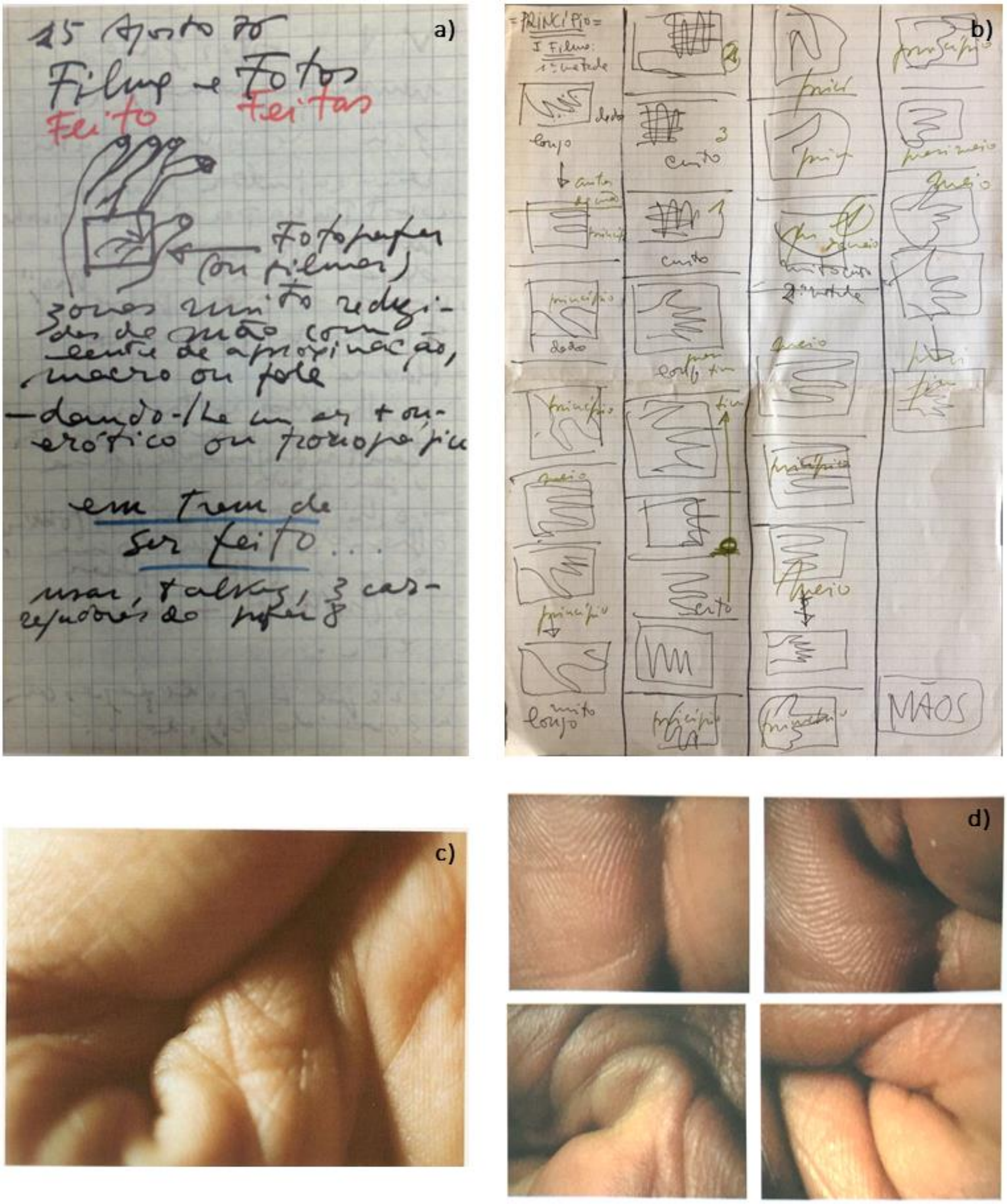


Figure 4.3 - Artwork and respective documentation found within the framework of this dissertation: a) page from notebook nº 13 showing the idea about capturing the hand with a macro lens, to produce a photographic and/or film work, b) paper sheet from the file *Filmes* showing sketches of the script for the first film, *A mão* (1976), c) Ângelo de Sousa, *A mão esquerda (1ª serie)* (1975), one 35 mm chromogenic reversal film with cellulose acetate base, d) Ângelo de Sousa, *A mão* (1976), four frames of the 8 mm chromogenic reversal film. Artist collection.

[10] Translation by the author of this dissertation.

Figure 4.4 - Relationships found between artworks from Ângelo de Sousa; **Top**: *Céu* (1979-1997), 35 mm chromogenic reversal film with cellulose acetate base; **Bottom**: *Chão de Cimento Abstracto* (1973), three frames of the 8 mm chromogenic reversal film. Artist collection.

In this way, Ângelo de Sousa invites us to stop and spend some time looking at images of common objects which, due to their ubiquity, are almost imperceptible to us. In these images, his intuition about the relationships established between the different formal components of the created composition is revealed.

The *Epifanias*, photographs or films, can also result into a series, i.e., to a multiplication of images about the same motif during a trigger-happiness moment, sometimes repeated apart at times. Photography is the ideal medium for a serial. Through repetition and sequencing, the creative process can evolve, detaching itself from the idea of a finished work (Sardo 2017, 18-19). Like in his drawings, the photographs could function as a sketch, totally free (Molder 2003, 12-13). The repetition, as an exercise for the photographic eye, allows for testing the composition possibilities and limits. This exercise can be seen as a research process, in which Ângelo de Sousa sought for aesthetic inventiveness.

Many of his films were born from this context, notably the series of films *Chão*. The first one, *Chão (1ª experiência)* (1972), fortuitously, unleashed the development of further films (Sousa 2001, 34), more planned and gradually more abstract.

Both in his films and photographs, Ângelo de Sousa explored the technical capacities of equipment to extend his creative opportunities, namely by using different cameras and lenses, but also by looking for equipment with a high amplitude of possibilities (Sousa 2001, 38)[11]. During the survey conducted on the materials present in the artist's archive, different movie cameras were counted, as well as several photographic cameras, lenses, and filters, among others (Fig. 4.5). Quoting Ângelo de Sousa, "The technical possibilities are very helpful and suggestive of different ways of making films" (Sousa 2001, 38). Additionally, these solutions allowed him to enhance the ability of these media to generate economic visual effects (Fig. 4.6, top). The camera can capture moments visually identical but temporarily different. The various works produced by him with multiple exposures, both in film and photography, are examples of that. Multiple exposures make it possible to complicate the narrative sequence and play with the possibility of producing unlikely phenomena of appearance. The essence of photography was also exploited by Ângelo de Sousa, for instance, through long exposures to light.

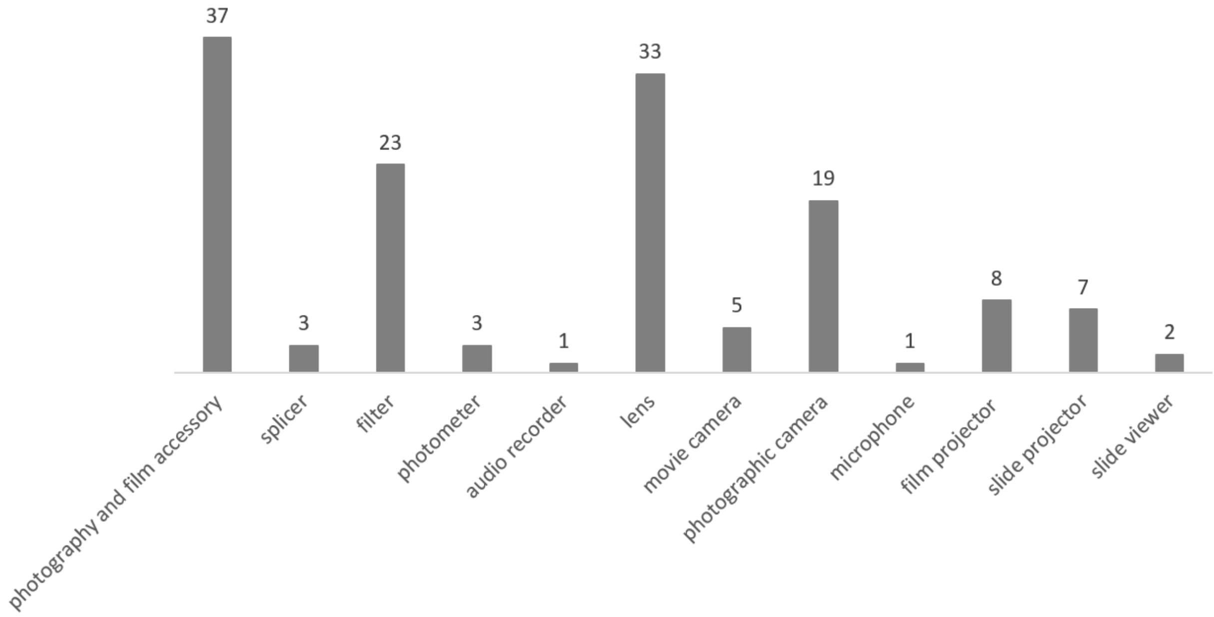


Figure 4.5 - Typology and quantities of photographic and film equipment found in Ângelo de Sousa's archive during this investigation. A total of 126 objects were found.

In a film, the dimension of movement is added, derived from the articulation of the image with time. By acknowledging the potential of the film support, Ângelo de Sousa manipulated the speed of both the image capture (between three and 64 frames per second) and its projection (Sousa 2001, 38-40), allowing him to create interesting optical variations. In his series of films *Chão*, after testing several

[11] His first video camera, bought during his internship in London, was an Ilford Elmo C300. This camera allowed him to produce multiple exposures by rewinding the film. In 1970, he bought a Beaulieu, which expanded his possibilities. With this camera, it was possible to change the objectives and lenses, as well as to use a greater amplitude of shooting speeds (Sousa 2001, 39-40).

projections, slower or faster, clear or blurred, the artist enjoyed its slow projection at 5 seconds, in which the film became a sort of slideshow (Sousa 2001, 55).

His black-and-white self-portraits from the 1960s were also produced in this context. Like other *neo avant-garde* artists, Ângelo de Sousa valued his self-representation as a mean of experimentation, using the distortion of his face through optical devices like lenses that defocused, deformed or disfigured his image (Sousa 2001, 20). In his self-portraits from the 1960s, he used a Hologon camera with a 120-degrees aperture that allowed him to deform the image while keeping it focused. In those from the early 1970s, he used a 20-mm lens, and in his mid-1990s self-portraits he used a panoramic lens that allowed for, in both cases, the deformation of the image (Fig. 4.6) (Sousa 2001, 20).

Figure 4.6 - Self-portraits by Ângelo de Sousa; **Top:** *Auto-retrato* (1972), 35 mm black-and-white negative with cellulose acetate base; **Bottom**: *Auto-retrato* (1995), 35 mm chromogenic reversal film with cellulose acetate base. Artist collection.

To dissociate himself from the traditional ideas of self-representation, the artist transformed the self-portrait into a spontaneous and momentary act. As stated by Bernardo Pinto de Almeida (2002, 181-185), differently from a mask which is a rigid representation of a feeling, these distortions present a succession of states of consciousness that are transformed from capture to capture. The series, multiplying deformed visions of his face, allowed for the performance of a diversity of hypothetical representations of himself (or someone else) (Almeida 2018). In some cases, the fragmented depiction of his face was achieved by giving emphasis to certain areas of the face, leading to its transfiguration in a quasi-caricatural process. In other cases, as in the colour self-portraits mentioned above (Fig. 4.6), there is a dilution of the face with loss of contour, which eventually becomes a misshapen mass in which the original referent is loss.

Another type of self-representation worked by Ângelo de Sousa was the shadow, which appears in several photographs and films to mark his presence on the image and to present the author of the work. The film *Chão (1ª experiência)*, in which Ângelo de Sousa describes the shadow as the artist's 'ex-machina': "(…) the artist who steps out of the machine and appears in order to finish the film off, to bring it to its final end" (Sousa 2001, 22), is an example.

One more recurring motif in his photographs and films is his hand (Figs. 4.3 and 4.7): "Close at hand, I had a docile model available to my left hand; the right hand turned on the camera" (Sousa 2000, 3). The hand, right under his eyes and always within reach, functioned sometimes as an instrument for testing. For instance, in the transition from film to video, the hand served as a model for comparing the technical possibilities of the two technologies (Sousa 2001, 50-51). It turned out to be the most exposed and revisited subject in Ângelo de Sousa's work (see more information in chapter 5), as he found in his hand an original and unexplored motif (Sousa 2000, 3). The first work produced under this subject was *A mão esquerda (1ª série)* (1975)[12], a work made in colour slides with his macro lens acquired in 1975. It was followed by the series *Mão esquerda* (1976), in black-and-white photographic film (Fig. 4.7), and by the films *A mão* (1976) (Fig. 4.3). When he showed the first series to his friends, very enlarged images of specific parts of his hand (1 or 2cm^2), they reacted with some strangeness (Sousa 2001, 130). The loss of the referent due to the clipping of the framework and the abolition of the natural scale, led to the metamorphosis of the hand. The successive images of the skin of the hand suggests fragments of the skin on a naked body. The enlargement, like a *trompe l'oeil*, might produce perceptual conflicts by creating a reality that is beyond the reach of the human eye. Macrophotography was often explored throughout Ângelo de Sousa's work. The enlargement allows the observation of what naked eyes cannot see: the smallest fingerprints, the topography of the skin, the fluff of a plant, the irregularities of apparently flat surfaces, etc. In some cases, when the motifs are extracted from their context, they become almost unrecognizable, dissociating themselves from figuration and from the faithful representation of reality (Sousa 2000, 3). Thus, surprises may come from the decontextualization of the objects, and from a deformed scale, which promotes an abstract visual experience. The images dissolved from their own identity value, come to exist only with their formal and pictorial presence. In this process of abstraction, the spectator can be transported to a world of pure shapes, in a reduction to the essential. Once more, these forms are repeated in other works, reminding us of his drawings, paintings, sculptures, and even other photographic and/or film images.

According to the documentation found in Ângelo de Sousa's archive during this investigation, it was understood that the artist wanted to publish a book with photographs of the hand. Thus, he compiled information related to the subject in a file entitled *Mão*. In this file, there are photocopies of dictionaries with the meaning and symbology of the word "hand" and some derivatives such as "to hand", "hands down" (in english) and "*main*" (in french). A poem by Francis Ponge entitled *Première Ébauche d'une Main* can also be found. Furthermore, there is a handwritten text with indications for the production of the second series of the work, *A mão esquerda (2ª série)* (1977) (such as the type of slide film and the photographic paper for the prints), as well as for the duplication of the work *Mão*

[12] There are two series from this work. The first (1975) corresponds to a set of slides made over time, with different conditions (films, exposure, lighting, etc.). *A mão esquerda (2ª série)* (1977) is a repetition of the first series, made for the exhibition *Biennale di Venezia* in 1978, with controlled conditions to avoid colour discrepancies. Years later, Ângelo de Sousa understood that there was no colour shifts in the first series after all (Sousa 2001, 22-23).

esquerda (1976). The file also contains schemes for the cover of the book, and indications related to the page size, paper thickness, layout, among others (see appendix IV, section IV.1).

Figure 4.7 - Ângelo de Sousa, *Mão esquerda* (1976), 35 mm black-and-white negative with cellulose acetate base. Artist collection.

4.3. Colour images by Ângelo de Sousa

In the beginning of the 20th century, artists sought inspiration in several areas adopting, for instance, experimental procedures analogous to those of psychology (Gage 1999, 250-253). Like Wassily Kandinsky (1866-1944) and Piet Mondrian (1872-1944), who developed some of their work based on the psychological effects of colour, artists from the *op art* and *colour field* did the same in the 1950s. Their concerns are well described in the *Interaction of Colors* of 1963, by the Bauhaus painter and professor, Josef Albers (1888-1976) (Gage 1999, 16-17). Many artists, namely from Abstractionism, were informed about the various colour systems, allowing them to substantiate their expressive language. However, according to John Gage, the modern artists were not particularly concerned with the study of colour perception. It was mainly the concept of colour symbolism that was addressed, to sustain the issues associated with abstraction. For instance, Kandinsky considered that blue was an important colour because it was the colour of spirituality and the colour of men, while yellow symbolized the feminine, and red the material, which should surpass the others (Gage 1999, 246-248). Even though there was the inauguration of more refined lines of expression and simplified spaces, with some exceptions, these new expressions were not theoretically supported by colour, as probably expected. In fact, during the 20th century, only a few studies regarding colour were published or written. The primary colour scheme was perhaps the most present colour debate during this period, even though no consensus prevailed. Nevertheless, the Bauhaus played a key role in the definition of colour during this time, where the work of Josef Albers was particularly important (Gage 1999, 50).

Based on Ângelo de Sousa's interviews and the variety and quality of his personal library[13], the erudition of the artist is undeniable. The technical investigation enabled him to have an in-depth knowledge of the media and supports with which he worked with (Gil 1993, 14). As stated by himself (2001, 48-49):

> "(...) the subconscious is very important, but it needs to be fed information". This solid knowledge is visible in his works, which often transpires the complexity of an experimentalist. Still, this might not always [be] perceptible to a more distracted observer.

Among the various interests and subjects deepened by Ângelo de Sousa, it was possible to conclude from this investigation that the mechanisms of perception were a topic that aroused his attention for many years, leading him to research about light and colour (Fig. 4.8). From 1965 onwards, Ângelo de Sousa began to use colour in a very conscious way, namely in his paintings. According to José Augusto França (1985, 32), the use of colour allowed him to justify and model both the compositional systematization and simplification. Thus, colour served as a tool for deconstruction, enabling the creation of harmonious and autonomous pictorial spaces free from traditional representation (França 1985, 32).

[13] According to a survey carried out by Gabriela Sotto Mayor in 2006, on Ângelo de Sousa's photo library, there are 2335 books. In his general library there are also technical books, books related to fine arts (painting, sculpture, etc.) and architecture, and other books focused on subjects such as colour and perception. Notations by Ângelo de Sousa are often found in his books. In addition to his library, several technical photography and film magazines can also be found, especially French and American, which proves that Ângelo de Sousa was aware of what was being published abroad. Some examples are: *Chasseur d´Images*, *Réponse Photo, American Photo, Popular Photography, Photography Directory and Buying Guide, Photo Reporter, Practical Photography, 35 mm Photography, Photocinéma, Camera, Photo Ciné Revue, What Video*, among others.

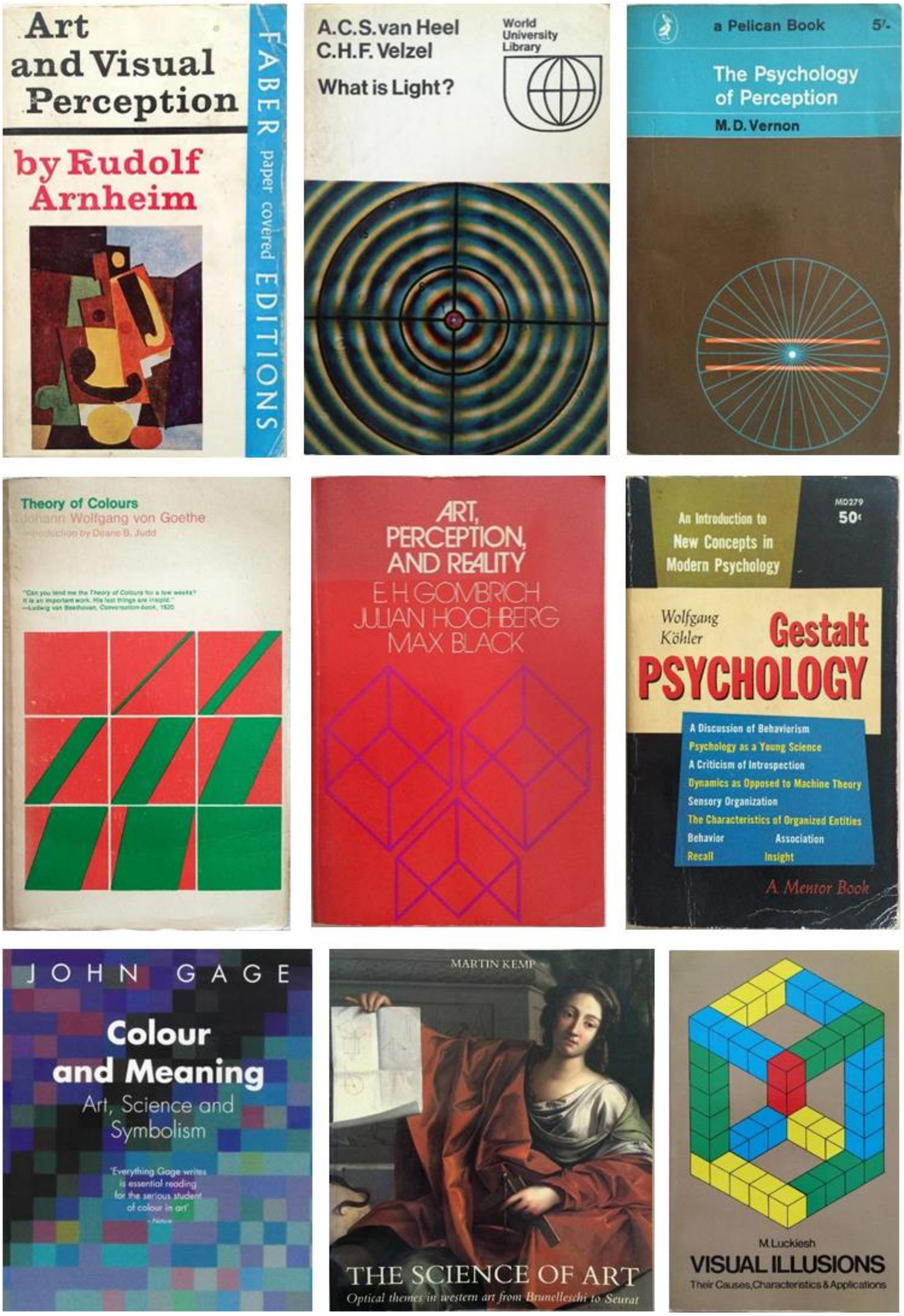


Figure 4.8 - Examples of book covers related to colour and perception found in Ângelo de Sousa's personal library.

As stated by José Gil (1993, 15-16), colour is the movement of his work, defining form, space and light:

> "Ângelo de Sousa, throughout his life, did no more than conceive sets of movements of colour: he is a coloureographer. A drunken painter, colour addict: a chromoman"[14].

However, unlike the abstractionists, Ângelo de Sousa had no ambition to find any absolute truth or any order of things. On the contrary, as stated by Bernardo Pinto de Almeida (1985, 27-28), he sought the greatness of simplicity and the natural harmony of things. Like the artists of the Middle Ages (for whom the artist under study revealed his interest (Almeida 1993a, 27)), who were devoid of preoccupations of mimetic representation because they sought only to transmit the divine message through symbology, he also took full advantage of colour as a form of expressive freedom.

Although conscious of the colour theories, he did not adopt any of them, perhaps because, like Josef Albers, Ângelo de Sousa thought they had a limiting and closed side. Therefore, it was in the genesis of colour theory - additive and subtractive synthesis - that he found the tools to construct his narrative. Since the 1960s, he chose to favour three colours (and also black) to obtain 'maximum effect': magenta, yellow, cyan. These colours were used by the artist in his drawings (coloured pencil) and paintings (off-set inks and acrylic paints) (Almeida 1985, 68). During one of the interviews conducted within the framework of the dissertation by Joana Ferreira, the artist explained (Ferreira 2013, 314):

> "Since I was poor and also because of different habits that I have, maybe from the high school scientific education, I already knew how to do tetrachromy or trichromy and I thought I was being stupid, buying so many colours, buying some dubious pigments and mixing polyvinyl with this or that, if there are offset pigments that should serve. I spoke with a gentleman who got me a tin can of 1 kg of cyan for offset, a tin can of magenta, a tin can of yellow, a tin can of white, a tin can of black and a can of medium; the black I used very little, I still must have it, the white I never used. (...) at that time I started to work only with offset paints, primary colours and this lasted for many years ..." [15]

According to a report sent to FCG in 1965[16], studied in this research, Ângelo de Sousa had some ambition to disseminate his way of painting, namely to his students:

> "It seems to me that this is a process that deserves to be more fully studied with a view to a possible normalization of the colours used in the artistic painting (instead of having, as still happens today, heterogeneous materials, physically and chemically, designated by traditional names, possibly, but in general, fantasist and that only disorient a painter that is beginning). (...) It seems to me that this would be an experiment to try, the one of reducing the multitude of resources that they think to be able to lay hands (with great disorientation) [the students], in a narrower range, standardized in their characteristics and behaviours; I have been informed that such attempts are being made in German schools, but, unfortunately, without further details rather than those contained in what I have just mentioned"[17].

In the early 1970s, he began to paint the so-called 'monochromatic' paintings, to which he dedicated a few years, starting with the 'black series', as named by Bernardo Pinto de Almeida (1985,

[14] Translation by the author of this dissertation.
[15] Translation by the author of this dissertation.
[16] *Subsídio material e atelier* (material allowance and atelier), grant awarded by the Fine Arts Service from Fundação Calouste Gulbenkian.
[17] Translation by the author of this dissertation.

31), and whites (creating strong contrasts that recall the legacy of Chevreul), and then exploring other colours (Fig. 4.9). Despite of the monochrome appearance, these paintings are composed of multiple layers of the three primary subtractive colours, in higher or fewer number, more diluted or less diluted, until 'nothing else can fit' (Almeida 1993a, 28). Through the overlapping of layers, the artist constructed several complex structures of colour.

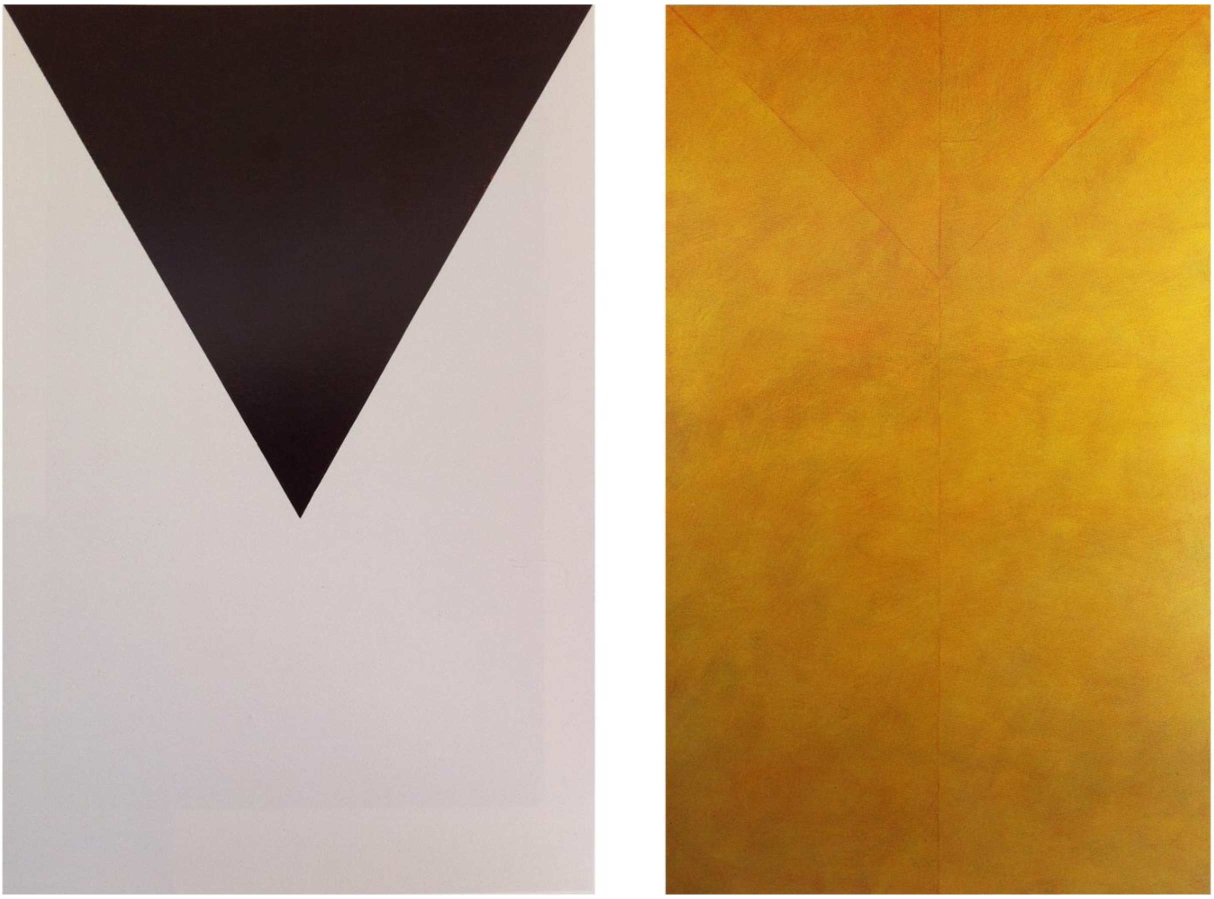


Figure 4.9 - 'Monochromatic' paintings by Ângelo de Sousa; **Left:** *Sem título* (1972), acrylic paint on canvas, 194 x 130 cm. Fundação de Serralves collection; **Right:** *Sem título* (1974), acrylic paint on canvas, 200 x 125 cm. Artist collection.

Since he did not appreciate the characteristics of oil as a vehicle for painting (Ferreira 2012, 134), Ângelo de Sousa explored new technical possibilities similar to the American artists of the 1950s and 1960s, notably Morris Louis and Mark Rothko, who used synthetic paints that allowed greater transparency of the layers (Gage 1993, 254). The superimposition of transparent layers allowed for the achievement of colours with great deepness (Berns 2016, 138). These layers functioned as filters that, when overlapped, allowed several colours up to the total elimination of incident light (black) to be obtained.

Regarding his photographic work, it can be stated that through colour manipulation, Ângelo de Sousa produced works with great interest. A few years after starting the 'monochromatic' series of paintings, he produced the slide-based artwork *Slides de Cavalete*[18] (1978-1979). According to Sérgio Mah (2014, 23), this is one of most original photographic works by the artist. From this premise and

[18] Translation: easel slides.

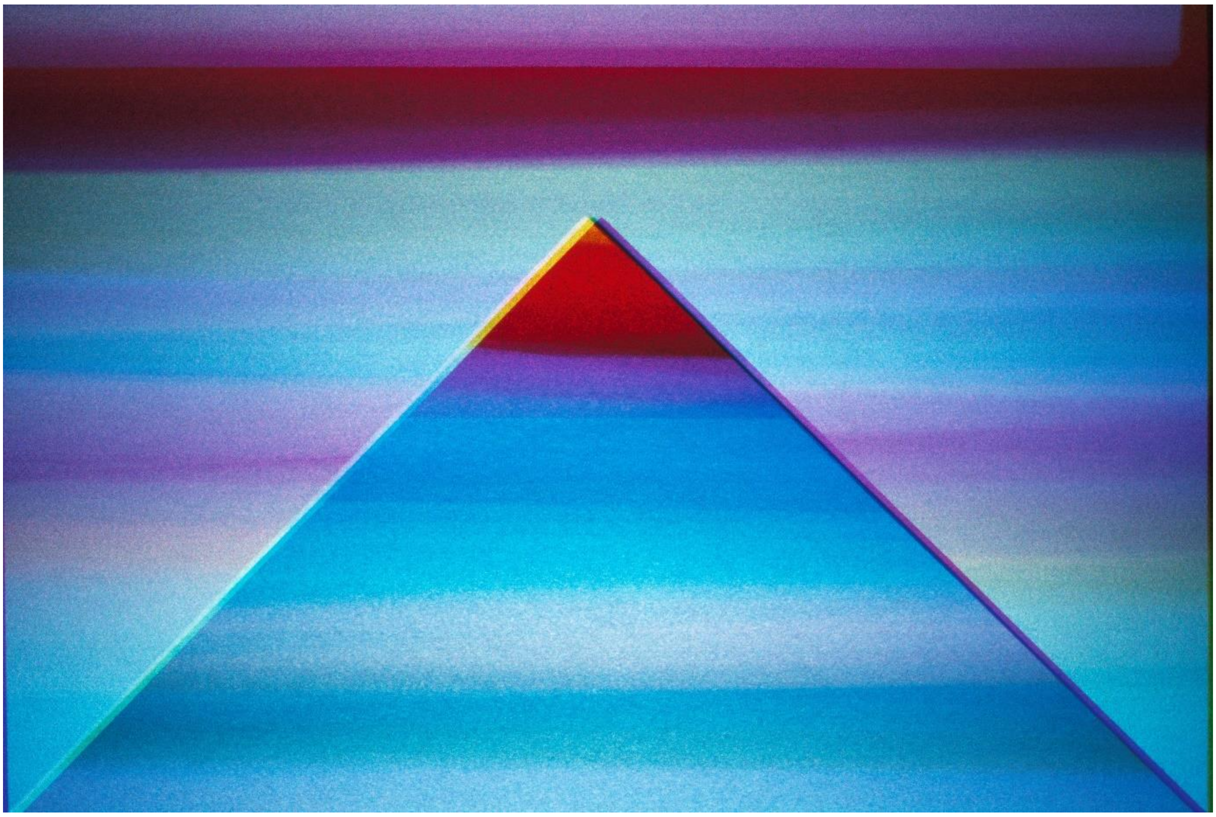
considering the abstract nature of the images composing *Slides de Cavalete*, this was the central artwork studied throughout the framework of this dissertation.

Already acquainted with the subtractive synthesis (used in his drawings and paintings), the artist decided to work with additive synthesis (Sousa 2001, 18), by combining coloured lights. His film *Sombra de Trepadeira* (1974) (Fig. 4.10), produced prior to *Slides de Cavalete* (1978-1979), is, to the better of our knowledge, the first work in which the artist explored the idea of additive colour mixing. In this film, he shot a hanging plant on a whitewashed wall, successively illuminated by R, G and B lights (Sousa 2001, 94). The Single 8 mm film allowed him to rewind the reel and shoot multiple times over the same frames. Thereby, he obtained "a relatively naturalistic representation except for the shadows that exhibit a colouring (...) unexpected" [19].

Figure 4.10 - Ângelo de Sousa, *Sombra de Trepadeira* (1974), three frames from the 8 mm chromogenic reversal film with cellulose acetate base. Artist collection.

Just a few years later, he started *Slides de Cavalete* (Fig. 4.11). Focusing on the etymology of photography, he sought to explore the essence of the medium by creating images the vehicle of which was not ink, as in his paintings, but light. Thus, he reached impressive coloured screens, reminiscent of watercolours. The images from *Slides de Cavalete*, either by its conception and form, have perceptible similarities with paintings, in particular with the 'monochromatic' paintings, something to which perhaps Ângelo de Sousa wanted to allude by calling the work 'easel paintings' (Mah 2014, 23)[20]. However, this parallelism does not seem to have any intention of reducing photography in relation to painting; on the contrary, it suggests the opposite. As Helena Almeida, although in a very different way, Ângelo de Sousa used the photographic medium as a means and system of representation, exploring its possibilities of approaching to or conversion into painting. Slides, unlike paintings, due to their projection dependence, allowed him to present a series of images in the same place, following a timeline.

[19] Quotation from the report written by Ângelo de Sousa in November 1976 under the grant *Subsídio de investigação, artes plásticas e comunicação visual* (research, plastic arts and visual communication funding), awarded by the Fine Arts Service from Fundação Calouste Gulbenkian (translation by the author of this dissertation). In the same report, he refers to other plans he had to produce other films in which he would replicate the same idea but using the human figure for instance. In his notebooks, sketches for other films and photographs can also be found, some dated before the execution of these works, in which he intended to test the overlapping of primary or secondary colours.
[20] In 1978-1979, Ângelo de Sousa was still working on his 'monochromatic' paintings.



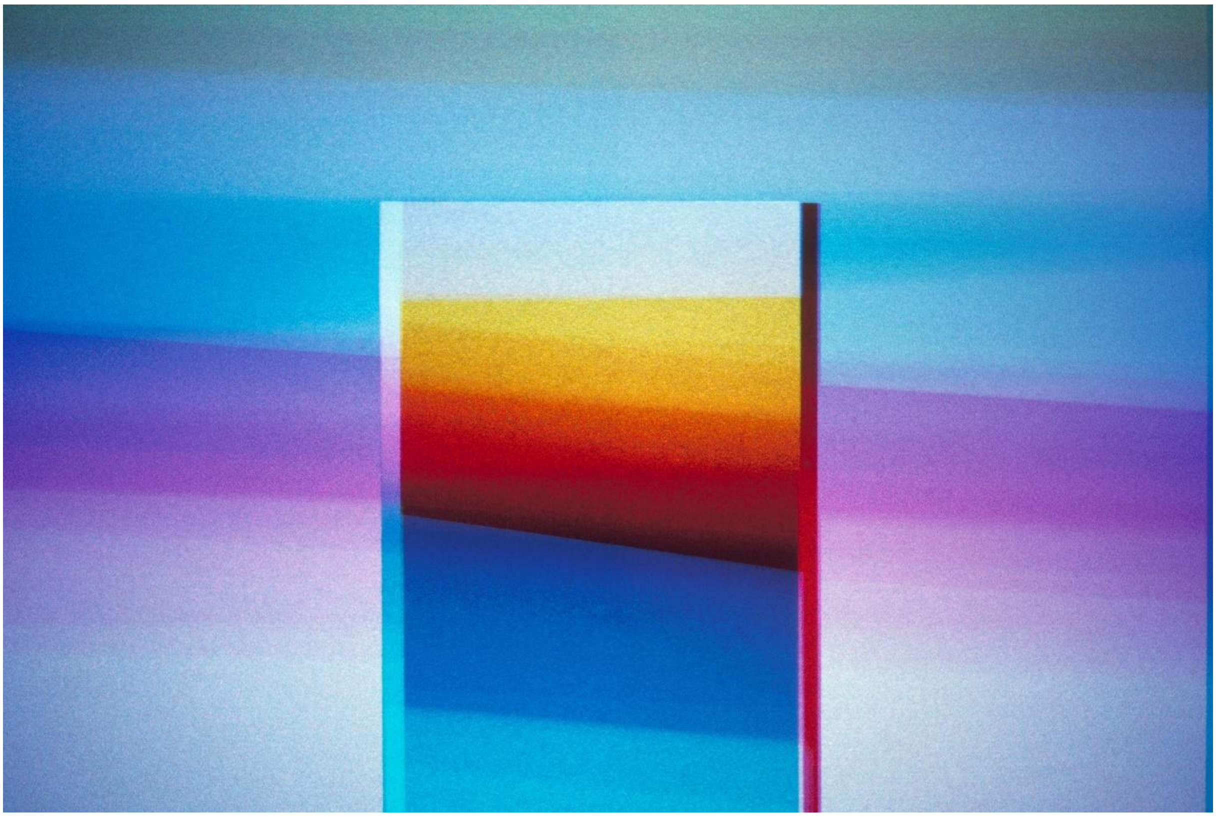


Figure 4.11 - Ângelo de Sousa, *Slides de Cavalete* (1978-1979), 35 mm chromogenic reversal films with cellulose acetate base; **Top:** Example of a slide from Part I; **Bottom:** Example of a slide from Part II. Artist collection.

The diaporama is composed of a set of one hundred colour slides, to be presented with a specific order (the slides are numbered). The total set of images composing the slide-based artwork is presented in appendix I, Fig. I.1. *Slides de Cavalete* begins with eight introductory slides: PHOTOGRAPHS | PHOTOGRAPHS (SLIDES) | OF SOME PAINTINGS, IMAGINED AND INEXISTENT | (EXCEPTING IN THE SLIDES THEMSELVES, PROJECTED) | [spacer] | THEY COULD BE CALLED… | … EASEL SLIDES? | [spacer][21]. The two spacers (dark images with texture, without text) introduce a break in the reading of the text. The text slides are made of black-and-white negative film. The introduction is followed by the images constructed with the additive synthesis. This set is composed of two parts: a triangle (Part I) and a rectangle (Part II) (Fig. 4.11), both shapes having the same proportion (appendix I, Fig. I.12). The artist ended the work as he began it, with slides containing typed text: THE END | FOR NOW. | ÂNGELO DE SOUSA 1978-1979[22]. In both introduction and conclusion, his characteristic sense of humour can be felt[23].

The work was first presented by Ângelo de Sousa in the exhibition *A Fotografia como Arte / A Arte como Fotografia* in 1979, under the title *Fotografias (slides) de algumas pinturas imaginadas e inexistentes (excepto nos próprios slides projectados)*[24]. According to Paula Pinto (2014, 185), *Slides de Cavalete* was conceived to be presented in that exhibition. Based on the dated documentation left by the artist, the work was being produced until just before the opening of the exhibition (March 1979).

During the present research, a file entitled *Slides*, containing the registration of the production process of the work *Slides de Cavalete*, was found in his archive. On the first page, dated from 1988[25] and signed, he briefly describes the process and the materials he used, explaining that preliminary tests were necessary to master the issues of filtering, exposure times, film characteristics, etc. (Fig. 4.12). Additionally, in the same file, more information can be found: i) typed texts (that appear at the beginning and at the end of the work), ii) hypotheses for the script (actually not the final script), iii) information about the conducted tests (carried out between 11th February and 4th March, 1979) and some examples of the resulting slides, iv) schemes and notes mentioning the equipment necessary to produce the slides and their precise position, v) shape proportions, and vi) sketches explaining how to obtain the desired luminous gradations. Thus, it can be concluded that *Slides de Cavalete* resulted from extensive planning and experimentation. Additionally, based on the documentation found and on the test slides that remain in his archive (about 260 slides), it is possible to conclude that other compositions were tested, with different shapes and contrasts. Hence, the diaporama would have been the outcome of a selection of images chosen from the obtained results. From these experiences, other ideas and works with the additive synthesis have also resulted, namely the series of coloured hand shadows from the same period, discussed further on in this section. Detailed information about the documentation left by the artist is gathered in appendix I, section I.2. The thorough analysis of this documentation was the basis for the comprehension of the images composing *Slides de Cavalete*. Nevertheless, reproducing the production process was essential for a complete understanding of the artwork. Only after this practical experience, was it possible to understand certain subtilties required to obtain the colour gradations, which were not explicit in the documentation left by the artist. Moreover, this task allowed for the recognition of the difficulty and complexity of the execution process.

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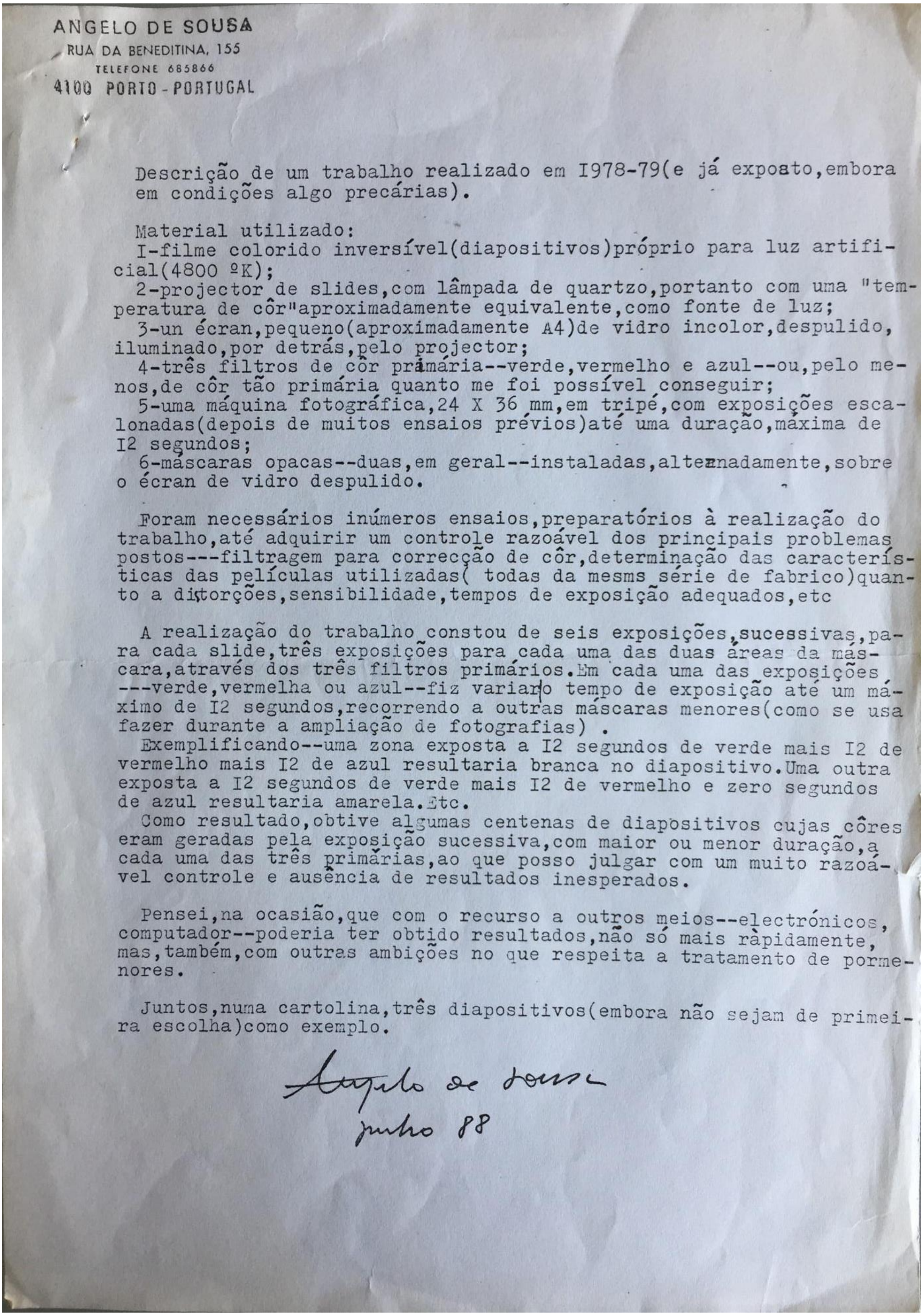
[21] Translation by the author of this dissertation.
[22] Translation by the author of this dissertation.
[23] These slides are 35mm negatives and not chromogenic reversal films.
[24] Photographs (slides) of some imagined and non-existent paintings (except in the projected slides themselves). Translation by the author of this dissertation.
[25] This letter was possibly written for the exhibition *Fotoporto: Mês da Fotografia* (1988) where the work was displayed.



ANGELO DE SOUSA
RUA DA BENEDITINA, 155
TELEFONE 685866
4100 PORTO - PORTUGAL

Descrição de um trabalho realizado em I978-79(e já exposto,embora em condições algo precárias).

Material utilizado:
I-filme colorido inversível(diapositivos)próprio para luz artificial(4800 ºK);
2-projector de slides,com lâmpada de quartzo,portanto com uma "temperatura de côr"aproximadamente equivalente,como fonte de luz;
3-un écran,pequeno(aproximadamente A4)de vidro incolor,despulido, iluminado,por detrás,pelo projector;
4-três filtros de côr primária--verde,vermelho e azul--ou,pelo menos,de côr tão primária quanto me foi possível conseguir;
5-uma máquina fotográfica,24 X 36 mm,em tripé,com exposições escalonadas(depois de muitos ensaios prévios)até uma duração,máxima de I2 segundos;
6-máscaras opacas--duas,em geral--instaladas,alternadamente,sobre o écran de vidro despulido.

Foram necessários inúmeros ensaios,preparatórios à realização do trabalho,até adquirir um controle razoável dos principais problemas postos---filtragem para correcção de côr,determinação das características das películas utilizadas(todas da mesms série de fabrico)quanto a distorções,sensibilidade,tempos de exposição adequados,etc

A realização do trabalho constou de seis exposições,sucessivas,para cada slide,três exposições para cada uma das duas áreas da máscara,através dos três filtros primários.Em cada uma das exposições ---verde,vermelha ou azul--fiz variar o tempo de exposição até um máximo de I2 segundos,recorrendo a outras máscaras menores(como se usa fazer durante a ampliação de fotografias) .
Exemplificando--uma zona exposta a I2 segundos de verde mais I2 de vermelho mais I2 de azul resultaria branca no diapositivo.Uma outra exposta a I2 segundos de verde mais I2 de vermelho e zero segundos de azul resultaria amarela.Etc.
Como resultado,obtive algumas centenas de diapositivos cujas côres eram geradas pela exposição sucessiva,com maior ou menor duração,a cada uma das três primárias,ao que posso julgar com um muito razoável controle e ausência de resultados inesperados.

Pensei,na ocasião,que com o recurso a outros meios--electrónicos, computador--poderia ter obtido resultados,não só mais ràpidamente, mas,também,com outras ambições no que respeita a tratamento de pormenores.

Juntos,numa cartolina,três diapositivos(embora não sejam de primeira escolha)como exemplo.

Angelo de Sousa
Junho 88

Figure 4.12 - Sheet from the file entitled *Slides*, where the artist briefly describes the production method of the work *Slides de Cavalete* (1978-1979).

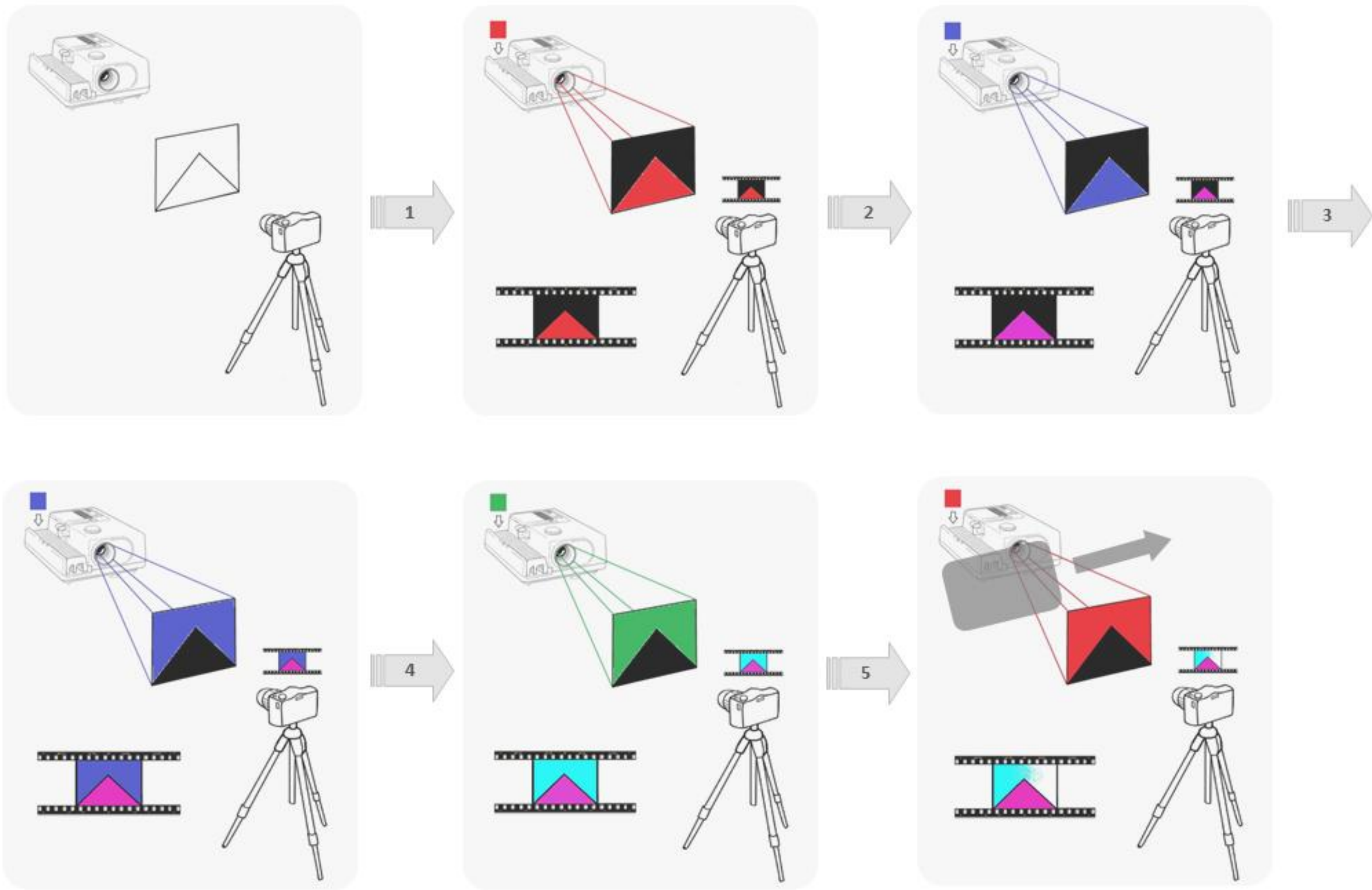


Figure 4.13 - Illustrative scheme of the production process of *Slides de Cavalete* (1978-1979), based on the documentation studied in the course of this investigation and on conducted reproductions.

Based on the performed research, it is now possible to propose how the work *Slides de Cavalete* was produced, hereafter described and outlined in Figure 4.13:

i) a slide projector was used to project R, G and B lights on two frosted glass panes (with about the A4 format), by using filters with these colours, as primary as possible;
ii) a cardboard mask was fixed between the glass panes to alternately block the light in the shape or in the background, to expose the two areas separately at different times;
iii) the camera, placed behind the glass, successively captured multiple exposures of R, G and B lights (three for the shape and three for the background);
iv) secondary masks were used to block the light in selected areas to obtain colour gradations;
v) the coloured lights were captured on chromogenic reversal film, each frame (slide) being composed of six exposures (three for the shape and three for the background);

This way, the artist sought to achieve the 'maximum effect' without overexposure. For instance, by successively projecting each coloured light for the same proportion of time, through multiple exposures in the same frame, pure white could be obtained. If he played with different proportions of the three filters, which he controlled by using opaque masks (hands or objects) to reduce light exposure in certain areas, he would obtain different tones and gradations. By obeying to the principle of additive mixing (see chapter 2, Fig. 2.19) and according to his words, he would be able to predict the result of the sum of the primary colours (Sousa 2001, 18-19). In theory, given that a colour slide is a three-colour process, at each capture of an additive primary light only one of the stratigraphic layers was sensitized, a fact that Ângelo de Sousa was undoubtedly aware of [26].

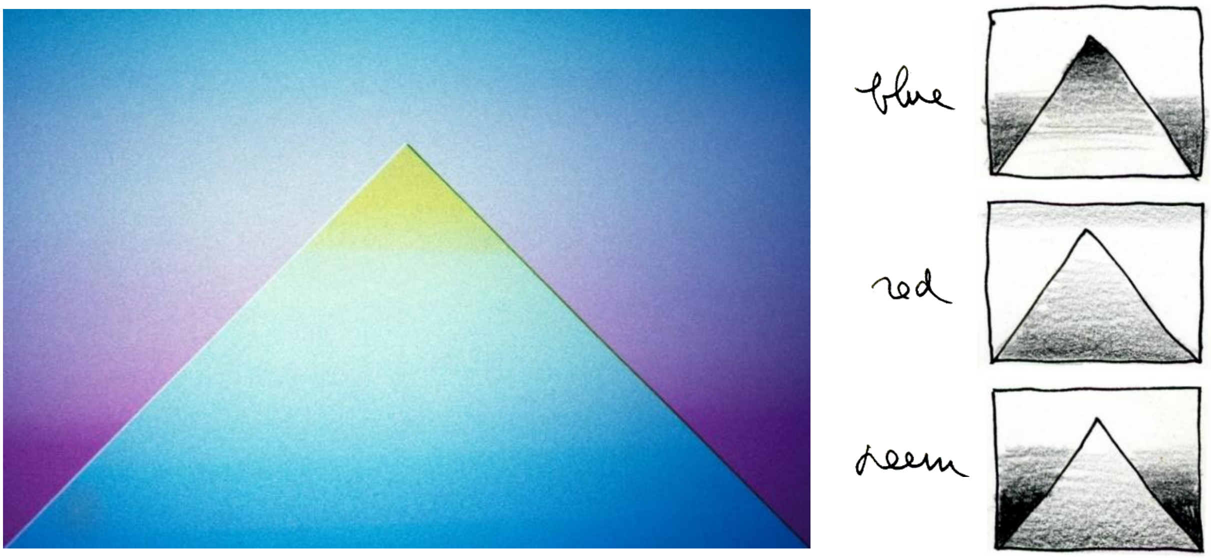


Figure 4.14 - Match between sketch (nº22) and slide from the work *Slides de Cavalete* (1978-1979), discovered during this investigation.

[26] The chromogenic processes consist of three layers of emulsion superimposed with subtractive primary colours: yellow, magenta and cyan, which allow the reproduction of all colours of the spectrum. The yellow layer is only sensitive to blue, the magenta layer to green, and the cyan layer to red (see chapter 2, section 2.3.3).

The production process was described by the artist as very simple and quite predictable, but with a certain degree of randomness, which he controlled through experimentation. Nevertheless, it is difficult to assign the sketches made by him, in which he drew the gradations applied to each slide, to the obtained results (the slides). This might reinforce the premise that i) there was a certain unpredictability associated with this complex process, ii) a great number of slides were produced without previous sketching, or iii) there is some documentation lacking. An example of match between sketch and slide is presented in Figure 4.14.

Like Josef Albers in his series *Study for Homage to the Square* (Fig. 4.15), Ângelo de Sousa explored the relationship between colours in *Slides de Cavalete*. In this celebrated series by Albers (started in 1949 and created until just before his death in 1976), he made thousands of oil paintings where he combined various colour relationships. Albers devoted much of his life to the study of colour, focusing on the construction of pictorial space and colour volume (Gage 1993, 264). For Albers, a colour can never be perceived as it is, physically, but converted into something relative. Therefore, for him, colour depends on both external and internal factors: external - juxtaposition and neighbourhood, and internal - depending on colour amount and density, among other characteristics. This variability characterizes colour but also gives it an illusory side (Rosenthal 2006, 22-23). Each painting is composed of three or four squares, one inside the other, and adjusted with a certain proportion that gives a non-static dimension to the complete set. Colours are the only element varying, and, according to their juxtaposition, they create different harmonies and dissonances. Each colour has its own characteristic and a certain weight in the complete set. Thus, the effect produced by the perception of the whole must be higher than the effect perceived by the exclusive nominal colour (Rosenthal 2006, 18-20).

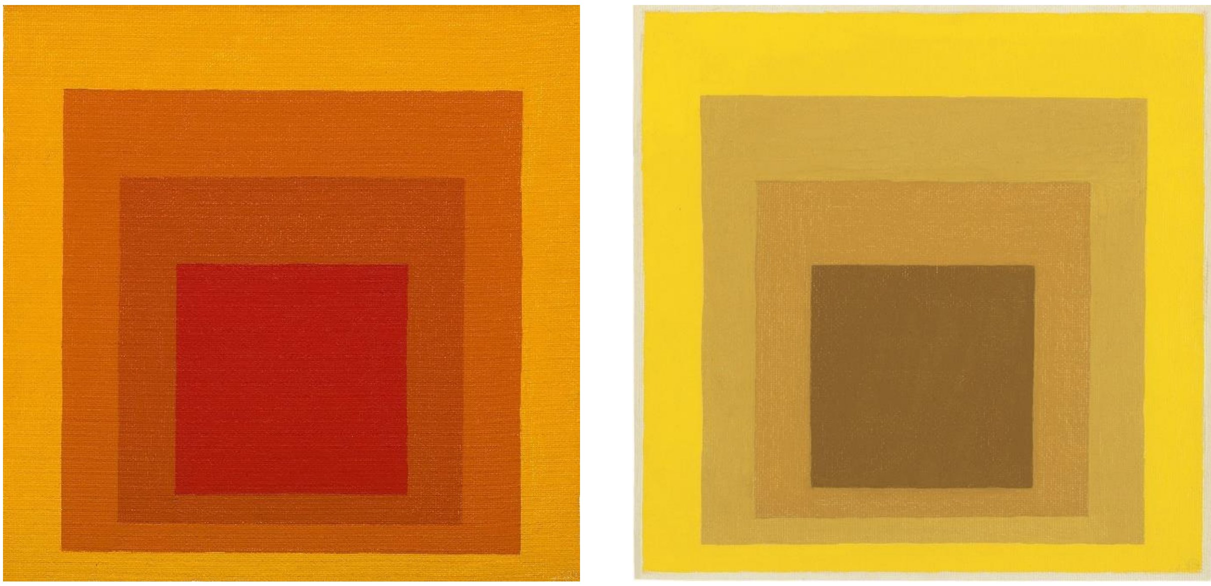


Figure 4.15 - Josef Albers, *Study for Homage to the Square* (1964). **Left:** acrylic on hardboard, 40.2 x 40.2 cm. Solomon R. Guggenheim Museum collection. **Right:** oil on hardboard, 40.6 x 40.6 cm. Museo de Arte Contemporáneo de Buenos Aires collection.

In *Slides de Cavalete*, Ângelo de Sousa combined the dimension of texture offered by colour gradations (which was not so explored by Albers) in two distinct forms, the triangle and the rectangle.

Unlike Albers, who used plain colours (Rosenthal 2006, 19), he worked the mixture of colours[27]. As with his 'monochromatic' paintings, he defined a shape and a background that he worked with as independent pictorial spaces (see entire work in appendix I, Fig. I.1). These spaces acquired different depths depending on their tonal and textural heterogeneity, creating an illusion of perspective or three-dimensionality. Like some of his drawings, the lines of the triangle or rectangle define atmospheric zones, rather than geometric shapes. According to the produced combinations, each image may offer more fluid or more striking, more static or more dynamic, more two-dimensional or more three-dimensional atmospheres. As in the Albers' series *Study for Homage to the Square*, the different slides from *Slides de Cavalete* act distinctly on us. The sequence of the projection confers a narrativity of sensations. Such as in his 'monochromatic' paintings, the chromatic gradations of *Slides de Cavalete* subtly reveal the chromatic complexity of the image through the creation of rhythms and contrasts created by the overlapped layers. This optical game, when discovered, strengthens the relationship between the work and the spectator. Therefore, this artwork admirably illustrates the aesthetic simplification and simultaneous complexity of the production process, noticeable over Ângelo de Sousa's whole artistic production.

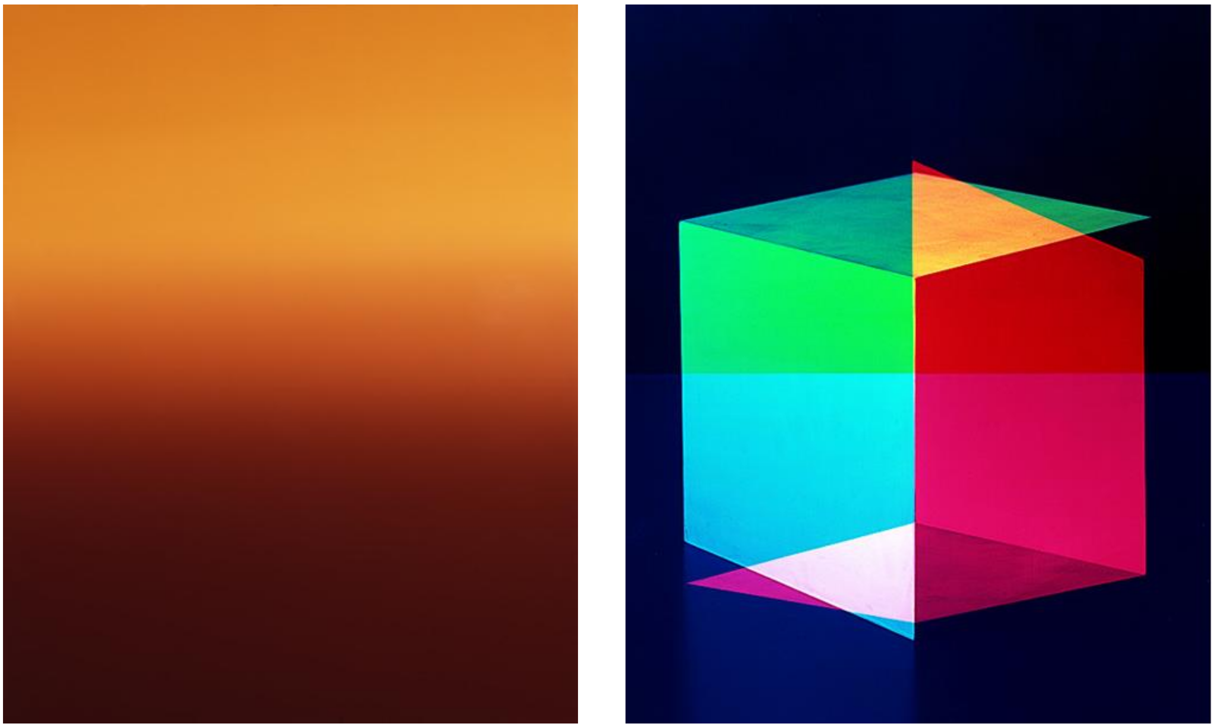


Figure 4.16 - Example of works from artists exploring colour through photography; **Left:** James Welling, *Untitled* (1998-2003) from the series *Degrades*, chromogenic print[28]. Artist collection; **Right:** Jessica Eaton, *cfaal 109* (2011) from the series *Cubes for Josef Albers and Lewitt,* pigment print, 101.6 x 81.3 cm. Private collection.

Colour has been a recurrent reason to explore the materiality of photographic supports. For instance, James Welling in *Degrades* (Fig. 4.16, left) explored a similar idea to the one used in *Slides de*

[27] In some of his paintings from the 1960s, such as in *Grande Geométrico* (1967), and in some of his later works, Ângelo de Sousa worked on the relationship between plain colours, particularly in the paintings exhibited in 2001, at the Galeria Quadrado Azul (Nazaré 2005, 8).
[28] No information related to the dimension was found.

Cavalete. The series *Degrades*, started in 1986, is composed of chromogenic photographic papers exposed to different wavelengths using different filters in distinct areas. During the exposure time, the prints were moved to create smooth colour gradations. Among other works in which he explored coloured lights, Welling did *Hexachromes* in 2006 and *Glass House* in 2006-2009, in which he made six exposures of a cactus, using RGB and CMY filters (Squiers 2013, 20-21). More recently, Jessica Eaton took multiple exposures of a white cube calibrated to the primary colours to produce *Cubes for Josef Albers and LeWitt* (2011) (Fig. 4.16, right) (Cotton 2014, 233). In this way, she created the feeling of colours disintegrated from the form, exploring concepts such as the possibility of manipulating time, space and perception, also addressed by Ângelo de Sousa in *Slides de Cavalete* and other works previously and further discussed in this section. In the Portuguese context, the series *Espaço, Luz, Sombra* (1980-1981) by Eduardo Nery can be named. Also, José Luís Neto (1966) sought to work both primary and secondary colours to honour the chromogenic photographic process, namely in *BRGYCM* (1993). This work is composed of six chromogenic reversal films printed on a photographic paper; the three primary colours and the three secondary colours translate the technology from which they are composed of.

Years after the production of *Slides de Cavalete*, Ângelo de Sousa exploited again the additive primary colours in a work that promoted a *dejá vu* sensation by using the same motifs and forms used in *Slides de Cavalete* and some 'monochromatic' paintings. The sculpture, first produced in 1986, is composed of three suspended pieces of PMMA sheets with the additive primary colours (Fig. 4.17). This work appeals to the spectator's participation in a performative journey, since according to the angle through which it is observed, a different object can be perceived. At a specific angle, the sculpture ironically loses its three-dimensionality to become a plane of pure colours and acquires the dimension of an image. From all the other points of view, the sculpture dematerializes or multiplies itself in several forms (Faria 2006). This kinetic relationship between the artwork and the spectator had already been explored in other works by Ângelo de Sousa, namely in the 'monochromatic' paintings. Also, it transports the spectator to the idea of the invisible, to what cannot be immediately seen (Serra 2004, 308).

Figure 4.17 - Ângelo de Sousa, *Sem título* (1986/2006), poly(methyl methacrylate), variable dimensions. Artist collection.

The fragmentation of the image leads us to other photographic works. Within the context of experimentation occurring during the production of *Slides de Cavalete*, the artist produced other interesting images, namely the colourful hand shadows[29] (Fig. 4.18). This series of shadows was never exhibited during the artist's life. As was previously mentioned in this chapter, the hand was a frequent motive in Ângelo de Sousa's work, especially in his photographic work. In this work, the hand served once again to explore technical features, more specifically, issues related to the additive mixture of colours.

Since only a few references to images of hands were found in the file *Slides* (see appendix I, Figs. I.13 and I.14), the way this work was produced has only been unveiled by carrying out a reproduction of the production process (see appendix I, section I.3). Based on the documentation found in the artist's archive and in the reproductions carried out during this investigation (using the same methodology adopted for the understanding of the work *Slides de Cavalete*), it was possible to collect some information related to the production process of this work, as shown in Fig. 4.19.

As far as it can be understood, Ângelo de Sousa used the same type of procedure employed to produce the work *Slides de Cavalete*, namely in what concerned the necessary equipment and its arrangement. He would have used a slide projector as a light source and placed the colour filters inside the projector, to project primary coloured lights onto a frosted glass. Then, the glass would have been photographed by making multiple exposures in the same frame, in order to capture each colour projection separately. However, in this case, instead of applying black cardboards to create a shape and a background, Ângelo de Sousa would have placed his hand between the projector and the glass and captured successive silhouettes of the hand while changing its position.

Considering the theory of additive synthesis and the result of overlapped shadows represented in some of these images, he apparently resorted not only to three primary colour light sources (RGB) but also, in some cases, to secondary light sources colours (CMY). Considering the documentation from the file *Slides* and the filters found in the artist's archive, he would have made several tests, namely with filters R, G, B, C, M and Y (see appendix I, Figs. I.6 to I.8). In the areas of shadow produced by the hand (when placing it in front of the glass) the coloured light was blocked, also preventing the exposure of the film. After the capture of the three additive primary colours, a mixture of coloured shades was produced.

Based on the image presented in Fig. 4.18 (top), produced through multiple exposures of the additive primary colours, the following can be discerned:

i) the yellow shadow is produced by blocking the blue light (red and green lights converge to produce yellow);
ii) the magenta shadow is produced by blocking the green light;
iii) the cyan shadow is produced by blocking the red light;
iv) the red and blue colours are then produced by the additional blocking of blue and red, respectively, where the light blockage overlaps;
v) when all lights are blocked by the shadows of the hand, black is formed (total absence of light exposure);
vi) finally, the background appears white as the sum of all lights.

By carefully analysing Figure 4.18 (top), it is possible to conclude that six exposures were performed, two per filter.

[29] This name was adopted by the author of this dissertation to identify this untitled work within the text.

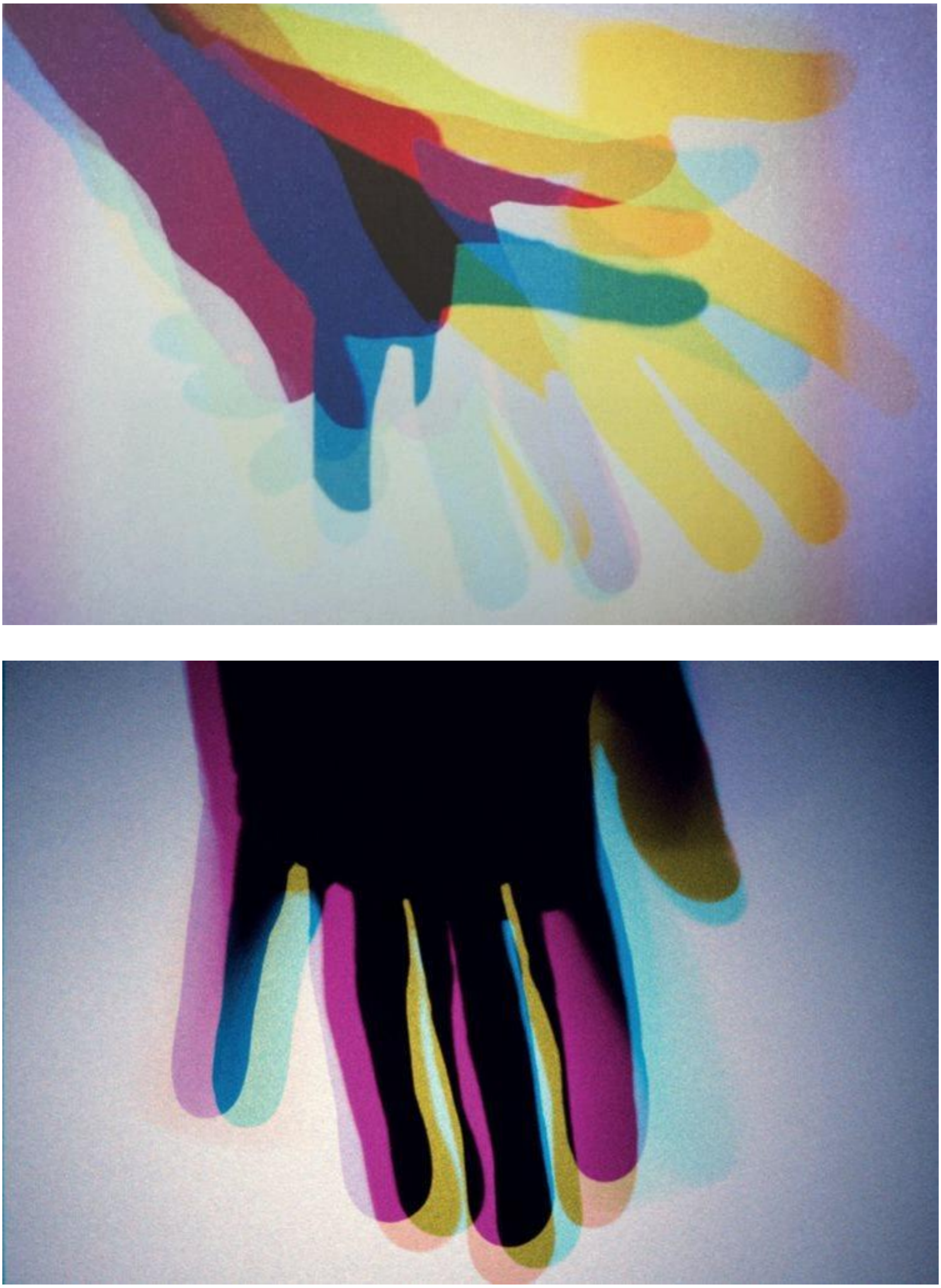


Figure 4.18 - Ângelo de Sousa, untitled [colourful hand shadows] (1979), 35 mm chromogenic reversal films with cellulose acetate base. Artist collection.

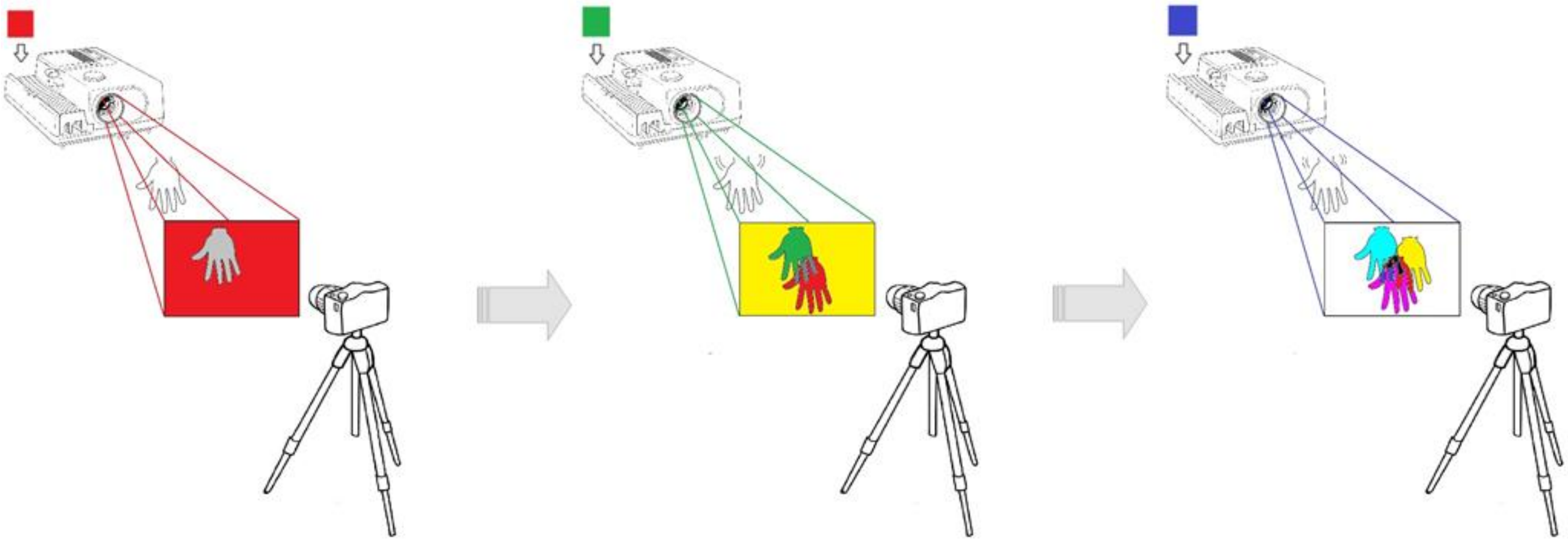


Figure 4.19 - Illustrative scheme of the production process of the untitled work [colourful hand shadows] made in 1979, based on the documentation studied in the course of this investigation and the conducted reproductions.

To produce the slide shown in Figure 4.18 (bottom), Ângelo de Sousa apparently used the secondary additive colours (CMY)[30] as light sources. A process similar to the one described above could have been used, however, giving rise to a mixture of secondary colours (violet, orange and aqua-green) in the overlapping areas. In this case, only three exposures seem to have been performed.

Other works by Ângelo de Sousa exploring both colour and light are the series of films *Op*. In the first film, *Op* (1968), he decided to project combinations of *moiré* patterns[31] with subtractive primary colours and black on different supports (paper, carpet or translucent white plastic), which recalls the works by Carlos Cruz-Diez. Cruz-Diez is one of the main figures from the kinetic and op art movements, whose work was centred on colour perception. His works are conceived around colour as an autonomous reality (Barrett 1970, 162-163) and his theories lay on four chromatic conditions: subtractive, additive, inductive and reflected (Fig. 4.20) (Barrett 1970, 93). In his turn, Ângelo de Sousa created coloured undulating backgrounds by displacing filters against each other, testing their optical power and their interaction with the film support (Sousa 2001, 127). In some of the *Op* series of films, he also used his hand in different planes of projection, dissolving the shadow in luminous colour patterns (Fig. 4.21) (Serra 2004, 302-303). Here, vibrant primary colours resemble his painting *Finger Painting* (1972). Could this series have inspired this painting?

Figure 4.20 - Carlos Cruz-Diez, *Couleur Additive. Édition Denise René n.3* (1971), 75 x 75 cm[32]. Artist Collection.

[30] In the slide mounting, the inscriptions "ciba yel-mag-cyan" were found (see appendix I, Fig. I.13).

[31] A *moiré* is a pattern created by overlapping two or more periodic structures with solid and open regions. As a result, a strange visual effect is generated ('shock-waves') (Barrett 1970, 65-66).

[32] No information related to the materials/technique was found.

Figure 4.21 - *Moiré* patterns in Ângelo de Sousa's work; **Top**: *Moiré* patterns found in the Ângelo de Sousa's archive; **Bottom:** Ângelo de Sousa, *Mão* (1968), three frames from the 8 mm chromogenic reversal film with cellulose acetate base. Artist collection.

There is an interesting series for the exploitation of materiality, which is a set of three slides with no date, no title, and no reference left by the artist. In these works, Ângelo de Sousa took full advantage of the chromogenic reversal films by scratching them. To produce these works, he used sub-exposed (black) and over-exposed (transparent) slides. On the black slides, he tested the three-colour process emulsion, by exploring the contrast between black (three layers of emulsion), transparent (all layers scraped to the support) and cyan (by scraping the two surface layers - yellow and magenta) (Fig. 4.22). In these works, Ângelo de Sousa exploited the technical components of the chromogenic reversal films in a controlled and meticulous way, showing his knowledge of the medium. By trespassing the materiality of slides (scraping), he was able to play with the microscopic layers of the emulsion. This physical manipulation led him to obtain a minimalist optical effect, the final image being the result of his activity.

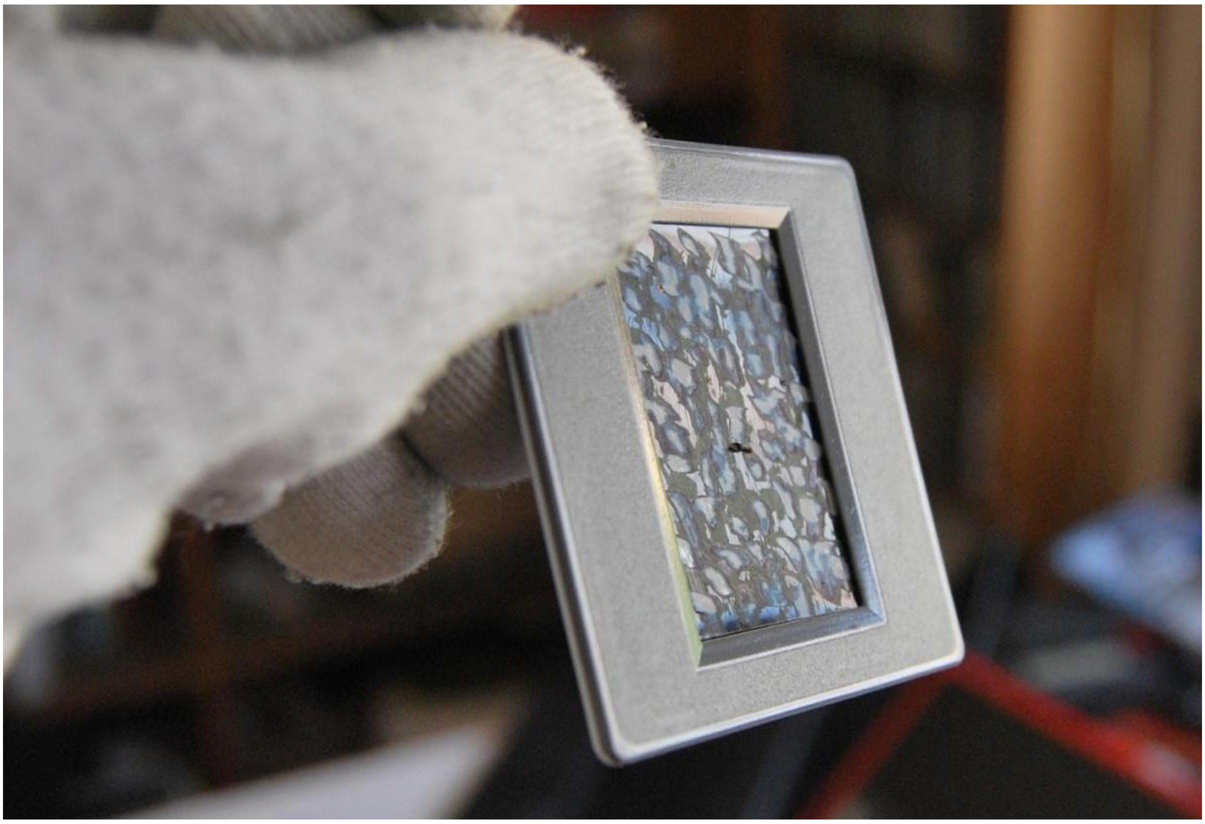


Figure 4.22 - Ângelo de Sousa, untitled, undated, scraped 35 mm chromogenic reversal film with cellulose acetate base. Artist collection.

The work *Gelatin Photographs* (1977-1980) by James Welling or the film *Free Radicals* (1958) by Len Lye (among several others), show a similar process. Both artists have scratched and/or applied pictorial layers over the emulsions of the film. These solutions, recurrent at the beginning of the experimental cinema, were also researched by Ângelo de Sousa, as for instance, in the abovementioned case or in the set of painted slides without title or date (Fig. 4.23 and 4.24). The last is a set of commercial slides that were painted with translucent inks with the subtractive primary colours and black, over images illustrating magnified microorganisms. These images show geometric forms with an abstract character, which were explored by Ângelo de Sousa. Some of the paintings follow the faint moth of the photographed subjects, others use the photographic support as a vehicle for the projection of pure colours. Hand-coloured film strips were also found in Ângelo de Sousa's archive, leading us to think that the artist performed similar experiences with film (Fig. 4.25).

Figure 4.23 - Ângelo de Sousa, untitled, undated, painted 35 mm chromogenic reversal film with cellulose acetate base. Artist collection.

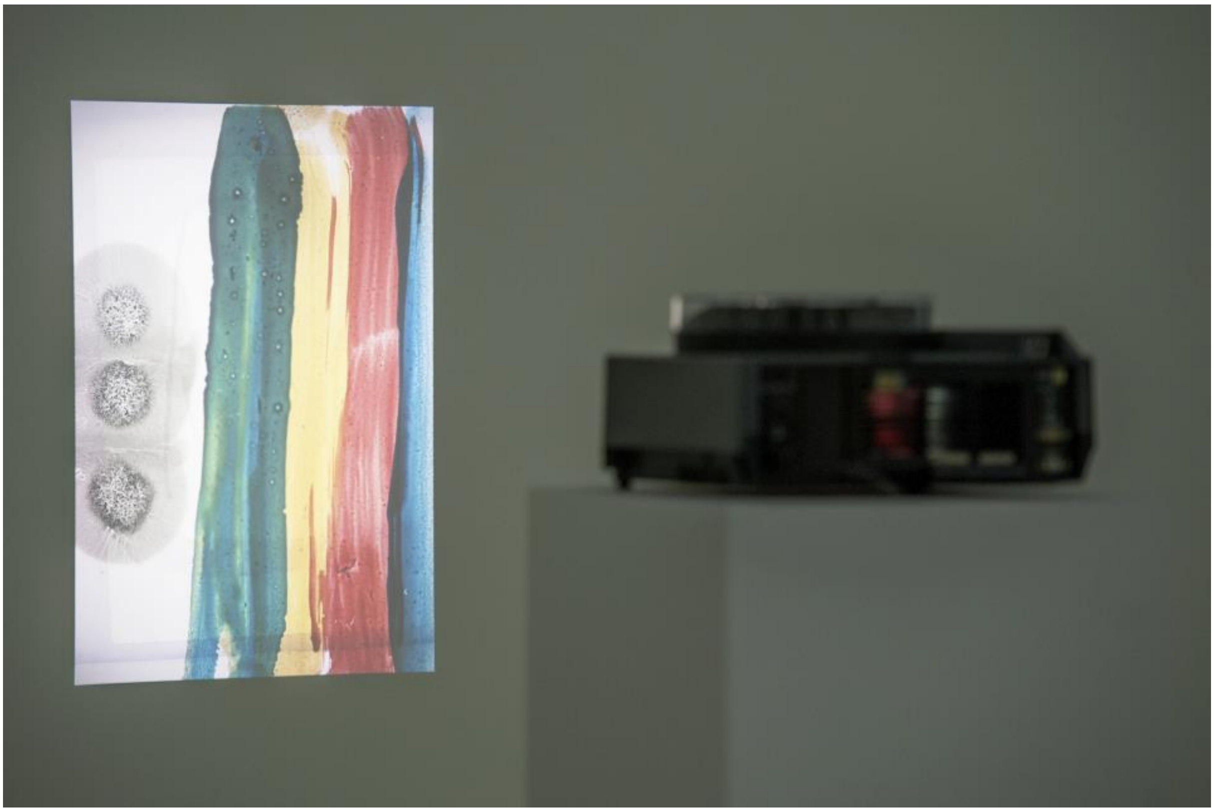


Figure 4.24 - Ângelo de Sousa, untitled, undated, painted 35 mm chromogenic reversal film with cellulose acetate base, projected in the exhibition *Encontros com as Formas* at Galeria Fundação EDP*,* Porto (2014). Artist collection.

Figure 4.25 - Painted film strips found at Ângelo de Sousa's archive. Artist collection.

The series of films *Marmeleiro* (1974) is another interesting example of colour exploitation (Fig. 4.26). In these films, Ângelo de Sousa tried to manipulate the light entering through the optical devices in order to obtain colourful effects. This was carried out by following the principle of light refraction as described by Newton. To this end, he placed a biconvex meniscus of five dioptres, installed in the bellows of his Beaulieu camera and in the place of the lens[33]. From this, he was able to play with the focal length and to create images ranging from unfocused to relatively clear. To control the level of light entering in the camera, he cut circular masks in black cardboard showing different perforations (Fig. 4.27). This allowed him to achieve "(…) different effects on the arrangement of coloured fringes or irisations (…)" (Sousa 2001, 78-79).

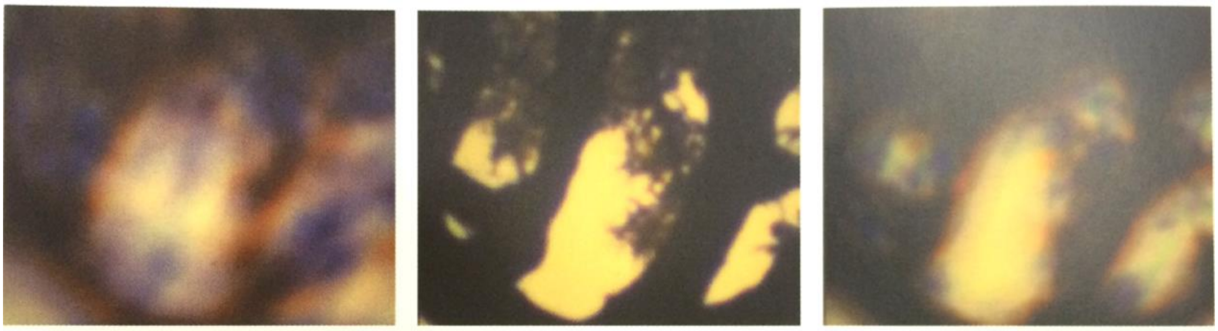


Figure 4.26 - Ângelo de Sousa, *Marmeleiro* (1974), three frames from the 8 mm chromogenic reversal film with cellulose acetate base. Artist collection.

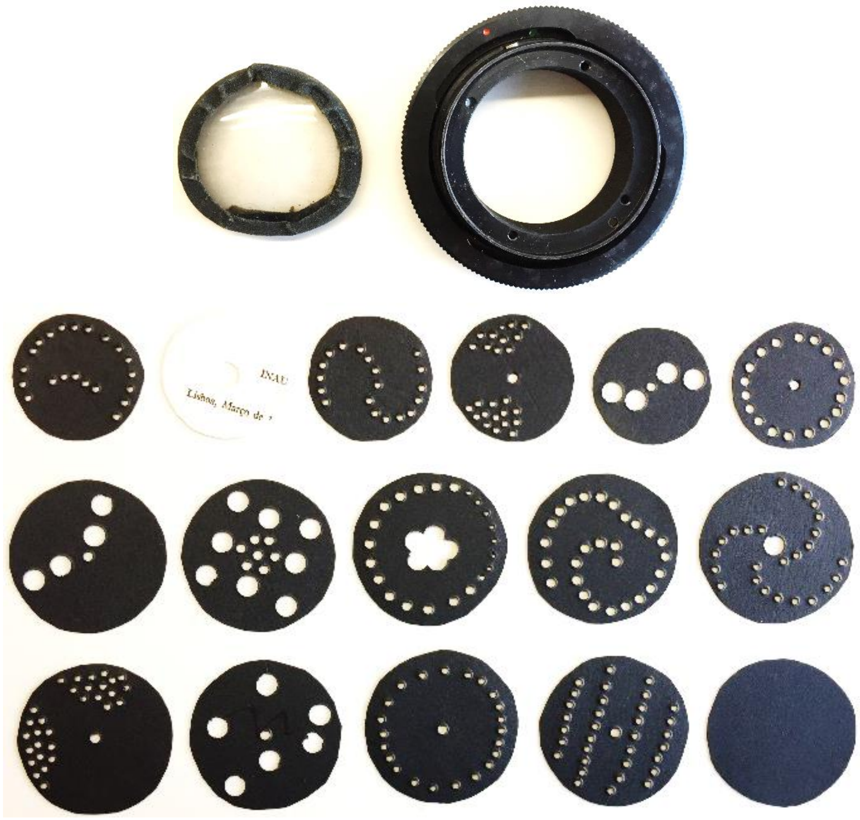


Figure 4.27 - Accessories used to produce the series *Marmeleiro* by Ângelo de Sousa, found in the artist's archive.
Top: Biconvex meniscus and adapter for the camera;
Bottom: Examples of cardboard masks made by Ângelo de Sousa to control the light entrance.

[33] As previously mentioned, this camera allowed him to change the objectives and lenses, as well as to use a greater amplitude of filming speeds.

The point of departure of the series of films *Marmeleiro* was a fragment of the quince tree, which was a motif to create chromatic effects with an abstracting nature standing out from the object (sometimes recognizable, sometimes completely blurred). A few years later, he also made a series of colour slides that captured isolated instants, according to the same methodology (Fig. 4.28). The use of light refraction as a physical effect for colour exploitation is also present in other photographic works by Ângelo de Sousa in which he used hair, soap bubbles, oil puddles, among other things.

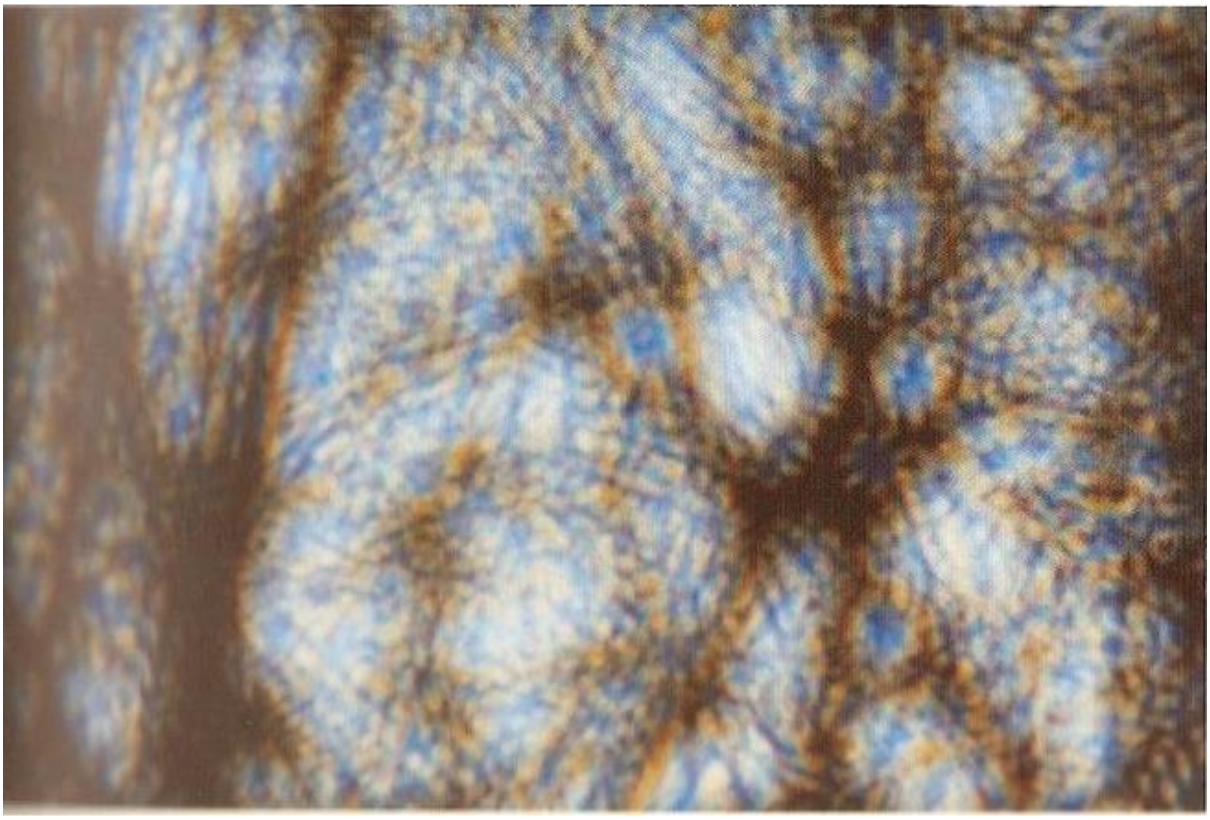


Figure 4.28 - Ângelo de Sousa, *Árvores desfocadas (sabugueiro 2)* (1979), 35 mm chromogenic reversal film with cellulose acetate base. Artist collection.

4.4. Conclusions

This chapter aimed at contributing to the understanding of Ângelo de Sousa's photographic and film work. To achieve this goal, published and unpublished documentation, from FCG's archive and found in the artist's archive, were studied. Additionally, his library, equipment and other materials related to the production of these media, were analysed. All these stood out as powerful sources of information for the in-depth study about Ângelo de Sousa's photographic and film production. By interconnecting these sources with the images produced by the artist under study, it was possible to launch new perspectives about his work.

As in other media explored by the artist, Ângelo de Sousa attributed an experimental character to his photographic and film work. This experimental character can be verified by observing some cross traits in his work, such as the expressive freedom, the exploitation of the equipment devices and his serial production. The photographs and experimental films presented throughout this chapter (among others that remained to be cited), illustrate the originality that Ângelo de Sousa achieved with these media. Through these images, his knowledge and interest about the technology and materiality of the photographic medium was highlighted. The selected images reflect the artist's unique and coherent language among the various medium he used to express himself. Also, these artworks show how the specificity of the supports can transform an idea, by moulding and reshaping it according to the characteristics of the materials. Thus, the pioneering place that Ângelo de Sousa occupied in the renewal of the Portuguese experimental proposals has been illustrated. Moreover, by establishing comparisons between Ângelo de Sousa and international artists from the same period of production, it was possible to grasp that he was in line with *neo avant-garde* proposals.

During the conducted research, it was understood that additive and subtractive syntheses served as a theoretical basis for the elaboration of a large number of artworks produced by Ângelo de Sousa. Interested and informed about colour theories and perception, he consciously explored colour as a means of expression. Since the 1960s, he decided to foster the primary colours to achieve the *maximum effect with minimum resources*: CMY, when using substance, such as paints, and RGB, when using light as a source for image formation. Regarding his photographic and film work, it can be stated that through colour Ângelo de Sousa produced works of great interest. The slide-based artwork *Slides de Cavalete* (1978-1979), composed of one hundred chromogenic reversal films to be projected as an ensemble, proved to be truly original and ingenious by showing the mastery of the artist over those media and colour manipulation. After thoroughly studying the documentation left by the artist related to the production of this work, and after several attempts to reproduce some of the slides composing *Slides de Cavalete*, the production process of the work was traced. In order to construct each one of the slides composing the work, the artist projected white light from a slide projector through filters with the additive colours, over a frosted glass screen covered with masks with the desired shapes. By successively projecting RGB lights in shorter or longer times, which he controlled by using opaque secondary masks to reduce light exposure in selected areas, and by capturing on the same frame a superimposition of the lights, he would obtain outstanding colour gradations. Each slide from *Slides de Cavalete* is a composed of six exposure, three (R+G+B) for the background and three (R+G+B) for the shape. Considering the high number of test slides produced within the outline of this work and the extensive documentation found in the archive, it is possible to conclude that *Slides de Cavalete* is the output of a wide and planned experimentation. The series of colourful and shadows, are examples of test slides. According to the reproductions carried out by the author of this dissertation, the production process of both works is similar. Based on conducted study, it is now possible to provide a more accurate characterization of these artworks. This knowledge added valuable information to the significance of the objects.

Chapter 5

Discussing display options for slide-based artworks by Ângelo de Sousa

5.1) Preamble

Based on the condition assessment of the photographs and films of Ângelo de Sousa presented in chapter 3, 35 mm chromogenic reversal films with CA base represent about 37% of the photographic collection. From these, 97% are 35 mm with mounting (slides) (see appendix II, Fig. II.6). Along with the set of 35 mm black-and-white negatives with CA base (43% of the photographic collection), these were the most representative materials employed by the artist. In this chapter, display options for works with slide supports were studied.

The display of slide-based artworks is one of the biggest challenges in the preservation of this type of materials. Quoting Peter Galassi (1999, 82): "(…) there is an inherent conflict between the desire to display pictures - to see them - and the desire to preserve them". As explained in Chapter 2, time-based media works, in general, only truly exist when installed, and their installation implies a reconfiguration and adaptation to the exhibition space (Laurenson 2011, 36). This characteristic contributes an intangible and temporary dimension to this type of works, which is usually undefined because the artists did not normally consider it when they conceived the artwork (Laurenson 2011, 36). Since the original chromogenic reversal films cannot be projected in a slide projector due to the aggressive conditions to which they would be subjected, exhibition copies must be generated to present the works. These copies might be produced by replicating the technology of the originals or might be converted into another technology, such as digital. Additionally, both duplication slides and slide projectors are constantly menaced by obsolescence, making it difficult to reproduce the original presentation. For these reasons, while taking the decisions regarding the installation, the originally used technology is frequently replaced.

Within contemporary art, in particular time-based media art and other works that lack fixity, the inevitability of change has been widely discussed and is well accepted today, for the sake of the continuity and presentation of the works. The possibility of adapting variable artworks through the collaboration between the artist, curators, conservators and other technicians, is now a current procedure for international cultural institutions (Warton 2016, 33). In this context, as stressed out by the conservator Manon D'haenens (2016, 51), the role of the conservator has been the management and transmission of change. But what happens in the absence of the artist and of his guidelines regarding the creation and production of the artwork?

During the present investigation, a lack of documentation related to display options undertaken by Ângelo de Sousa was acknowledged. Therefore, the exhibition history of his photographs and experimental films was studied, through published and unpublished documentation, and is outlined in section 5.2. Additionally, during the interviews conducted within the framework of this dissertation, Bernardo Pinto de Almeida and Miguel Wandschneider were questioned about the display of time-based media works by the artist under study. Based on the conducted research and following the current procedures, general guidelines for the exhibition of his slide-based artworks are discussed in section 5.3.

Nevertheless, when it is time for installation, each work must be considered and studied as an individual case (Berndes 2005, 167). Thus, the work *Slides de Cavalete* (1978-1979) was investigated in further detail. The production process behind the artwork was researched based on documentation found in the artist's archive, as well as in reproductions. Those findings are presented in chapter 4. Furthermore, the display history of the artwork was accessed, by seeking documentation related to its exhibition and by interviewing people who could have witnessed its presentation. The conducted research was very helpful in tracing the artists' intention and defining the significance of *Slides de*

Cavalete. The discussion about the authenticity of the work was not explored, since it would imply the definition of the concept. Considering the extensive debate about authenticity related to art/artworks, this reflexion was considered out of the scope this dissertation.

All the gathered information guided the final proposal for the preservation and display of the artwork under study, which is presented in this chapter and summarized in appendix VII. Finally, the proposed guidelines were tested in an exhibition/experimental study held at the Library from Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia (FCT NOVA). During a week, the work was displayed with a digital projector and a conventional slide projector. The public was invited to fill out a questionnaire and to share their perception of the work under these two distinct scenarios of exhibition. The results of the investigation are also presented in this chapter.

The methodology adopted for this research is summarized in Figure 5.1.

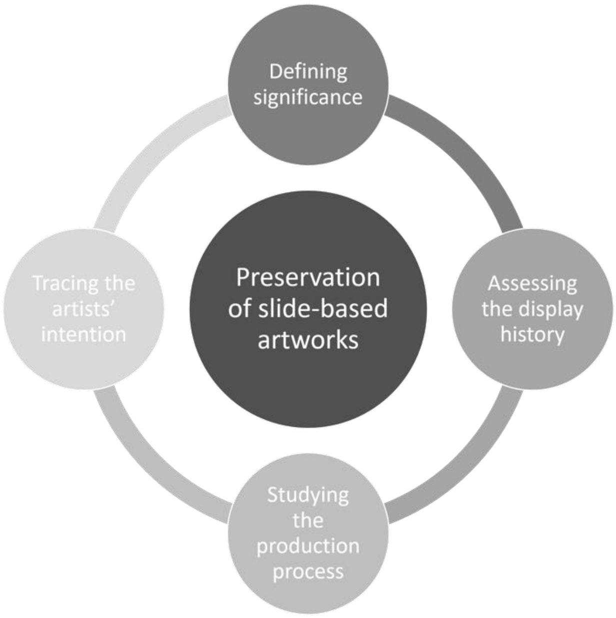


Figure 5.1 - Summary of the objectives and methodology adopted for the development of chapter 5.

Part of the content of this chapter has been submitted to a peer-reviewed journal:

Silva, J., Ferreira, J. L., Ávila, M. J., Ramos, A. M. 2019. The past and the future display of the slide-based artwork Slides de cavalete (1978-1979) by Ângelo de Sousa. *In Revista de História da Arte 14 – The Exhibition: Histories, Practices and Politics*. Lisbon: Instituto de História da Arte; accepted.

5.2. History of the exhibitions of Ângelo de Sousa's photographs and films

The first presentation entirely dedicated to Ângelo de Sousa's photographic and film work took place in 2001, in the exhibition *Sem Prata* (Porto, Portugal). This was a unique opportunity for the curators, João Fernandes and Miguel Wandschneider, to work with the photographs and films by the artist with his participation in the process. The interview *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa*, published in the catalogue, was a valuable reference for the development of this section. It allowed to gather information concerning display options undertaken by the artist, regarding his photographs and films, and particularly, his slide-based artworks. Therefore, some passages of the interview are transcribed and/or described within this text. Furthermore, Bernardo Pinto de Almeida and Wandschneider have been interviewed within the framework of this study, as testimonies of people who followed Ângelo de Sousa's photographic and film production and exhibition.

As previously mentioned, photography was part of Ângelo de Sousa's daily life. However, this part of his work did not have the same visibility as other means of expression also used by the artist. When questioned about the few exhibitions with his photographic and film work, he answered as follows (Sousa 2001, 11):

> "If things are going to work, they require certain material and psychological circumstances, objective and subjective conditions, as people used to say. And neither the objective nor the subjective conditions existed for showing the films and photographs. I believe that the possible is a decisive factor in everything that we do, regardless of what we want, and that the possible also conditions what we actually want. Perhaps I can best sum this up by saying, in a very Portuguese sort of way, that there have never been any infrastructures where they might be shown."

As explained in chapter 2, during the 1980s, some exhibitions focusing on the use of photography and film by artists exploring their specific aesthetic characteristics were organized. However, there was no institutional structure to sustain *neo avant-garde* proposals with these (and other) new media. As pointed out by Delfim Sardo (2015, 16), only during the 1990s, with the arising of important institutions such as Museu de Arte Contemporânea from Fundação de Serralves (Porto), Fundação Caixa Geral de Depósitos - Culturgest and Centro Cultural de Belém (Lisbon), among others, was a significant openness of the museology felt. Consequently, this scenario conditioned the exhibition of photographic and film works, particularly those with novel approaches to those media (Sardo 2015, 16).

Perhaps only for circumstantial and practical reasons, and since his painting and sculptural works were already appreciated at that time, Ângelo de Sousa opted to invest mainly in the exhibition of these artworks. Also, perhaps because some of his photographic works were poorly received when shown[1], he chose to reserve them mainly for his private life. Furthermore, according to his own words, Ângelo de Sousa did not have the need to show his work or did not work to show it, as he did not feel the need to receive other people's opinion. He worked for his fulfilment, and he was satisfied with his photographic and film work (Sousa 2001, 25). It is also possible that his continuous production led to an accumulation, harder and harder to work with, which might have constrained his dedication. According

[1] Namely of work *Slides de Cavalete* (1978-1979) in the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979), as previously explained in chapter 2 (section 2.2.2). Ângelo de Sousa also noted that when showing the work *A mão esquerda (2ª série)* (1977), he did not felt any enthusiastic reception (Sousa 2000, 4-5).

to the report sent to Fundação Calouste Gulbenkian (FCG) in 1977[2], he stated that he needed to "straighten a few years of photography"[3], which would require time, time that he did not have due to his obligations at the University. Nevertheless, a few exhibitions with a selection of photographs and films did take place, and some of his photographs and films were displayed during his life, as presented in appendix IV, Table IV.1[4]. Indeed, Ângelo de Sousa participated in some of the most relevant exhibitions showing the photographic and film work of artists at the end of the 1970s, such as *A Fotografia na Arte Moderna Portuguesa* (1977) and *A Fotografia como Arte / A Arte como Fotografia* (1979). He was also part of several exhibitions focusing on audio-visual supports in general, that became more and more frequent from the 1980s onwards.

The information collected to build Table IV.1 was based on published documentary sources, which are essentially exhibition catalogues, flyers and brochures. According to Sardo (2015, 13), the non-existence of an organized and structured museology in Portugal until the late 1980s led to a generalized lack of documentation regarding exhibitions. This fact was also recognized during the work developed by Rita Macedo, which included interviews with directors and curators from museums (Macedo 2008, 301). In the absence of the artist, all types of available sources concerning the exhibition of his artworks can help in the decision-making processes (Wegen 2005, 206). As Ângelo de Sousa is no longer available to interview, the history of his exhibitions became one of the unique sources for the understanding of the artist's intention. As stated by Julia Noordegraaf (2013b, 286), the exhibition of a work in different places and times might also provide a reference for future display.

By observing Table IV.1, it is possible to see that the both *A mão esquerda (1ª série)* (1975) and *A mão esquerda (2ª série)* (1977), were the most presented photographic works of the artist. According to himself (Sousa 2001, 23):

> "That has to do with the so-called strategy of the dog marking out his territory. It seemed so evident to me that someone would very soon remember to make photographs of their hands that I, like a dog that marks the trees that it walks past, decided to say that I had already done so. That was why I presented them at the Venice Biennial as early as 1978."

Based on the carried-out investigation, Ângelo de Sousa took different options over time concerning the display of his works. The analogue films, which started to be presented with a certain frequency since the exhibition *Ângelo 1993: Uma antológica*, were transcribed in 1995 to VHS and displayed as a video projection. In 2001, the videos were converted onto DVD for their exhibition in *Sem Prata* (Wandschneider 2018). Regarding black-and-white photography (presented only a few times in the first decades of his production), he used silver gelatine prints, normally printed by himself, and then in *Sem Prata*, he opted for displaying digital prints. Colour slides were presented either in projections or printed, both using silver dye bleach (Cibachrome) or digital technology. It is also possible to observe different choices for the presentation of the same artwork. For instance, the work *A mão esquerda (1ª série)* was first projected in the exhibition *A Fotografia na Arte Moderna Portuguesa* (1977), and then, since 1978, *A mão esquerda (2ª série)* (1975) was printed in Cibachrome. Also, the sizes of the prints changed; first the work was presented in 18x24 cm format, and since the exhibition *Fotografia* (2000), in 60x90 cm. In 2003, he decided to project the work again in the exhibition *Sem Limites* (2003). As far

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[2] *Subsídio de investigação, artes plásticas e comunicação visual* (research, plastic arts and visual communication funding) awarded by the Fine Arts Service from Fundação Calouste Gulbenkian.

[3] Translation by the author of this dissertation.

[4] Although very important to the development of this section, Table IV.1 is presented in an appendix because of its large size.

as it can be understood from the information contained in the catalogues and, according to Bernardo Pinto de Almeida (2018), it was a contemporaneous procedure to display original slides in the exhibitions until recently.

Although an exhibition catalogue might be a precious document (often the only documentation remaining from an exhibition), the accessed catalogues revealed the lack of valuable information. For instance, in *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa*, Ângelo de Sousa explained that the slide-based artwork *A mão esquerda (1ª série)* (1975) and *A mão esquerda (2ª série)* (1977), and the film *A mão* (1976) had previously been projected on a white canvas (Sousa 2001, 43):

> "The lines of the hand, both in films and in photographs, are not very different from the lines of the apparently monochromatic painting. For me, these films and photographs work like paintings. It's not by chance that I projected them onto a white canvas that has roughly the same size as a painting".

However, this information was never mentioned in the respective catalogues. Furthermore, the techniques and materials of the artworks are usually poorly (and sometimes badly) explained, especially for photographic works. The original photographic process is rarely described, and only the presented process is specified. If the subtitle 'inkjet print' is presented *tout court*, incorrect assumptions might be taken. For instance, it could be assumed that Ângelo de Sousa photographed with a digital camera, or that the original image was a chromogenic negative. Although, as it is possible to conclude from the survey conducted within the framework of this study and presented in chapter 3, basically all colour photography by Ângelo de Sousa was made with chromogenic reversal films, and he did not use digital cameras to photograph. Curiously, more attention is paid to films, and information regarding both the original process and the process presented in the exhibition are usually described. However, the options undertaken during the curatorial process are rarely described. When the display options are different from the ones made by the artist during his life, and no considerations regarding the reason behind the option adopted are presented nor additional documentation gathered, this can lead to misinterpretations of the artworks.

While reading interviews with Ângelo de Sousa, such as *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa*, it is possible to understand that during his life he actively participated in his exhibitions' conception. As confirmed by Almeida (2018), the artist gave the upmost importance to what was presented and how it was presented. He always looked for the most precise condition to communicate his work. For instance, when the artist decided to present digital images at *Sem Prata*, he only selected images that could 'fit' that technology (Almeida 2018). As far as it can be understood, after the artist's death, the decision-making process regarding the exhibition of his artworks relies essentially on curators' opinions. However, in an ideal scenario, due to the multi-dimensional nature of time-based media, the exhibition process should be defined not only by the artist and the curator, but also by other professionals with different expertise, namely by conservators, to ensure that the continuity of the artworks relies on what might be called its significance. As defended by Joanna Philips (2015, 168-169), the lack of an interdisciplinary approach can lead to an incomplete understanding of the artworks. According to Barbara Sommermeyer (2011, 145), the role of a curator is to understand and interpret the work created by the artist, recognizing its relevance by placing the work in context, and presenting it to the public. From the point of view of Tânia Alegria (2013, 15), the curator has been the exhibition creator since the 1960s, the person who defines the exhibition concept. Suzanne Keene (2001, 27) argued that "curating an exhibition has become a glamorous and high-profile thing to do". Being the author of the exhibition, the success of the exhibition is the recognition of the curator's work, and this can influence his or her actions and decisions (Sommermeyer 2011, 145). On the contrary, the main responsibility attributed to the conservator[5] has been the conservation and restoration of the artwork material. However, as defended by Sommermeyer (2011, 145), the mission of a conservator is to preserve both the material and the immaterial integrity of the artwork. To reach this goal, the conservator needs to recognize the information that the artwork and its context provides and detect any discrepancy that might lead to an incorrect interpretation of the artwork (Sommermeyer 2011, 145). Since the remit of the conservator is above all with the artwork, he or she can be considered the professional who can act most independently in the decision-making about the preservation and exhibition of an artwork (Sommermeyer 2011, 146). Despite the efforts made internationally during the 21st century, namely by the *International Council of Museums*, *Committee for Conservation* (ICOM-CC), the *European Confederation of Conservator-Restorers* (ECCO) and the *European Network for Conservation-Restoration Education* (ENCoRE), to recognize the importance of the conservator's role (Casanova 2011, 2-3), Portugal still shows a lack of professionals working as staff members of institutions trained in conservation, close to other professionals of the cultural heritage, such as art historians, curators, etc. According to the study conducted by Francisca Figueira (2015, 48-49), only scarce supervision is provided by conservators within museums or other cultural heritage institutions. Furthermore, based on Lúcia Matos' point of view (2015, 53), cultural heritage professionals still must adapt to the new challenges posed by contemporary art, and particularly by time-based media art (Matos 2015, 53). According to Andreia Magalhães (2015b, 70), Portuguese institutions frequently have an incomplete understanding of time-based media works for which they are responsible. Consequently, deficient strategies for their management, documentation, preservation and exhibition are undertaken (Magalhães 2015b, 70). The fact that an association is responsible for taking care of Ângelo de Sousa's work, can also contribute to insufficient financial resources, and consequently, a lack of interdisciplinary approaches to the collection. So far, NEÂdS has been self-financed and has no staff permanently working on the collection. As Sommermeyer explained (2011, 145-146), referring to estate associations with similar characteristics:

> "A main concern is that the deceased artists should not be forgotten; on the contrary, their fame should be increased. This is one of the reasons why exhibition projects are strongly supported by foundations, even if they are a risk to the artworks. And it's no surprise either, that foundations prefer deteriorating artworks to remain as long as possible, even as they vanish into oblivion".

Considering this background, it is urgent to establish guidelines for the exhibition of Ângelo de Sousa's photographic and film works. Ensuring the proper communication of the works, is a way to guarantee that its significance is well preserved. Therefore, a contribution to the definition of guiding rules for the display of slide-based artworks by the artist is presented in the following section.

[5] The term 'conservator' is used by the author of this dissertation, as having the same meaning as 'conservator-restorer'.

5.3. Exhibition of slide-based artworks by Ângelo de Sousa

5.3.1. Defining guidelines for the exhibition of Ângelo de Sousa's slide-based artworks

5.3.1.1. Documentation

As described in chapter 2, there is a consensus that documentation is a fundamental tool for the understanding and preservation of time-based media works, helping to construct a comprehensive biography of the works. Prior to any operation related to the exhibition of a slide-based artwork, the meaning of the work must be traced for a responsible decision-making process. Relevant information for the definition of the artworks' meaning must be registered, such as the materials employed, the artist's working method, the production process and the artist's intention (Berndes 2005, 166-167), as well as the history of the artwork and lifecycle of exhibitions (Wijers 2013, 238). Documentation produced by the artist in the production process can be a valuable source of information. For instance, the analysis of the documents from the file *Slides* found in Ângelo de Sousa's archive relating to the work *Slides de Cavalete* (1978-1979) was fundamental to achieve a deeper understanding of that work. It is also important to document the most appropriate ways of installing a slide-based artwork, which includes not only technical issues related to the artwork itself (image carrier, display equipment, etc.) but also intangible issues related to the exhibition space (spatial layout, projection sizes, equipment location, etc.). Additionally, the time characteristics, typical of time-based media art and determinant for the spectator experience, should also be documented (Matos 2015, 52). However, as Joanna Philips underlines (2015, 169): "not every exhibition space or budget allows for an ideal realization of an artwork's concept and specifications". Similarly to an installation that needs to be adapted to a specific space (Sommermeyer 2011, 145), unintended changes will occur when installing a slide based-artwork. The curator Jon Ippolito (2001) argued that even if the exhibition of a work implies deviation from the original artists' intention, it is sometimes the only way for the work to survive. According to Rebecca Gordon (2014, 97), a certain amount of variation does not necessarily interfere with the significance of the artwork. However, how the decision-making process is affecting the artwork must be documented too. Change should be recorded considering all the parameters involved in the installation of the slide-based artwork, as well as the reasons for the change (Philips 2015, 171-172). These discrepancies should also be somehow transmitted to the public who experience the artwork.

Although the importance of the documentation for the preservation of modern and contemporary art has been widely discussed by the international community (see chapter 2, section 2.3.5), this working methodology has not yet been adapted by Portuguese cultural institutions in a systematic way, possibly due to the lack of conservators in these organizations (Figueira 2015, 48-49).

5.3.1.2. Presentation

Like other time-based media works, slide-based artworks are vulnerable to two types of change. On the one hand, the chemical instability of chromogenic reversal films causes the need for the originals to be transferred to another medium in order to be displayed. On the other hand, they can easily be detached from the conditions and technologies of their original display. Additionally, both image carrier (slides) and display equipment (projector) are highly prone to obsolescence, favouring the distance between the exhibition of the work at its time of conception, and exhibition of the work reinstalled at the present time (Laurenson 2011, 35).

Besides the issues related to the technology of the exhibition copies and display equipment, when a slide-based artwork is installed at the exhibition site, it must be adapted to the space (Philips 2015, 169). Different factors such as room size and illumination, the area and surface characteristics of the projection (roughness, colour, etc.), among others, might influence its perception and should therefore be judiciously selected.

Media migration?

As explained in chapters 2 and 4, Ângelo de Sousa sought to explore the materials from his time, exploiting the materiality of all media which he tested and worked with. Therefore, it can be said that materials, in general, have a significance in the artist's works, carrying their own meaning. According to the survey conducted on the collection and presented in chapter 3, about 89% of his colour photographs are chromogenic reversal films (mostly with mountings). Since the artist scarcely used other colour photographic processes, it can be stated that slide technology is fundamental in his work.

Although Ângelo de Sousa worked a great deal with slide technology and chose to specifically exhibit some of his works using slide projectors, he also displayed slide-based artworks (sometimes even the same work) as printed photographs framed and hung on the gallery wall. For instance, in the exhibition *Sem Prata* about half of the slide-based works were presented in projection (the originals), and the other half in digital prints (inkjet prints), showing his openness to medium variation (Fig. 5.2).

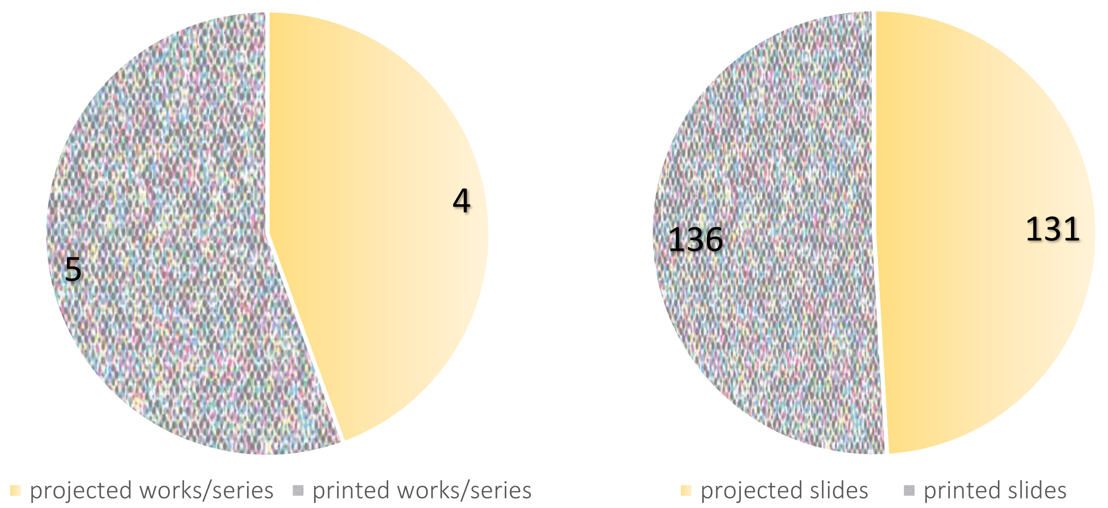

Figure 5.2 - Number of works/series (graphic on the left) and the corresponding number of slides (graphic on the right) projected or printed for display in the exhibition *Sem Prata* at Museu de Arte Contemporânea from Fundação de Serralves (2001).

Bernardo Pinto de Almeida thinks that the reason for these differences might simply be linked to the aesthetic character of the image (Almeida 2018). If in one case a slide should be displayed by projection, in others, it should be presented printed with a specific technology. Therefore, if one artwork was firstly displayed with one technology, it could later be transferred to another one, more recent, where the image 'fits' as well (or even better) (Almeida 2018). Also, Miguel Wandschneider (2018) explained that while some images could be projected in sequence, i.e. in a slide projection, due to the coherence between them, others could not, due to their autonomy. Additionally, as Ângelo de Sousa was very cautious with the materials (Ferreira 2011, 133), he could have been concerned with the durability of the artworks, after successive projections, and so opted to print them.

When questioned about how he came to the idea of replacing the original photographic and film processes by digital printing for the exhibition *Sem Prata*, Ângelo de Sousa explained (2001, 14):

> "(…) we began talking about this exhibition sometime around Christmas 1999. But, last spring, Manuel Ulisses from [Galeria] Quadrado Azul came round to my house and, during our conversation, he asked me how far I'd got with the exhibition. By that time, I should already have begun working on it, but I was putting it off, because I knew it would give me a huge amount of work and take enormous amounts of time. My intention was to choose the pearls from amongst my treasures, then make 400 or 500 good enlargements and then, finally, choose 80 or 100. In the middle of our conversation, I remembered the photographs that I had made for the [Teatro] Rivoli, printed with inkjet after they had been digitized, and I had the idea that I wouldn't make any enlargements on photographic paper. I immediately noted down the title for the exhibition: 'sem prata', 'sin plata', 'without silver', and so on…"

During the interview *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa* (Sousa 2001, 14), the curators made him see that the digital format was also a useful tool for image correction, such as abrasion and staining (negatives) and colour adjustments (slides), that otherwise, according to himself, could not have been displayed (Sousa 2001, 14-15).

Similarly, several of his films were transcribed into VHS and converted to digital for display in the same exhibition. These options were made both for financial and practical reasons, due to the great number of selected films for the exhibition and long duration of the exhibition (four months) (Wandschneider 2018). When asked if he was sorry about the films not being displayed in the original format, Ângelo de Sousa explained that, although the difference between video and 8 mm chromogenic reversal film was significant, Super 8 projectors have the disadvantage of producing a small image projection, besides the difficulty of producing a duplication with good colour reproduction (Sousa 2001, 16). Probably at that time, museum staff, or other laboratories with which they worked, were not prepared to do proper duplications. It would be interesting to know what would be Ângelo de Sousa's opinion if good duplications would have been made. The interviewers referred to the current practice of displaying celluloid copies projected in loop, to which the artist answered (Sousa 2001, 16-18):

> "(…) As far as I am concerned, what matters is the image. How it's made is my business. I don't understand much about the subject, but probably even more would be lost in the transcription into film… I think that it's much more economical, requires much less work and is more reliable to make the colour correction with the computer instead of using filters and emulsions. At most, I could project the originals twenty, thirty, or forty times if the machine was a very good one, until an enormous scratch would begin to appear, as happened last year when we were watching the papyrus film, or else until the machine started to chew up the film. The original would be shown until it committed hara-kiri and ceased to exist. That would be a possibility."

Apparently, Ângelo de Sousa was, at least in 2001, quite open to the idea of migrating the original supports to another type of support, since it was, to his knowledge, the most reliable way to do it. However, he did not affirm that they should all be converted into recent technologies. The artist probably made what interested him or could be done in that specific context. What he did not made, is not necessarily deprived of value.

In the absence of the artist and due to lack of documentation related to the decision-making process of previous exhibitions, when we are today confronted with the exhibition of Ângelo de Sousa's slide-based artworks several questions can be raised:

- What would be Ângelo de Sousa's opinion about the display of his artworks at present?
- How would he think at the time of the artworks production?
- Should the comments made in a specific context and period be the gauge for decision-making today? Is the interview from the exhibition *Sem Prata* enough to assume that Ângelo de Sousa would prefer to exhibit his photographic and filmic work using digital media?
- Most importantly, what should be preserved, the image or the total experience of a slide-based artwork?

As the curator D. H. van Wegen (2005, 207) argued, the responsibility of a conservator is with the artwork, and not with the artist. An artwork is an historical object, somehow independent of the artist, and the interpretation of contemporary art is not the artist's job (Wegen 2005, 206-207). According to the conservator Barbara Sommermeyer (2011, 143-144) "The conservator is responsible for the maintenance of the historicity and the zeitgeist of the work". Within the practice of conservation of contemporary art, the artist is called to participate in the decision-making process and constitute a source of information about the work and the creative process. However, as stated by Sommermeyer (2011, 150), the artwork itself should be the central source of information. The artist often desires to update the artwork, which is a controversial option that can go against the conservator's point-of-view. Furthermore, it might be difficult for an artist to develop a rational distance from a work made years ago (Sommermeyer 2011, 146). Additionally, as noted by the conservator Cristina Oliveira (2016, 219) during her investigation on the conservation of installation art, the artist's intention is not permanent. Frequently, the participation of the artist in the re-installation of the artwork might lead to significant alterations. This is why the opinion of the artist about a work made in the past should be discerned from his supposed original intent (Stigter 2016, 174). Additionally, the concept of the work can sometimes be better understood by the audience when displayed with its original materials, helping to place the work back in its time (Stigter 2016, 175). Quoting the conservator Sanneke Stigter (2016, 175): "not only a change in the physical artwork causes shift in experience, the change in time does too, having ushered in a complete new visual culture". In Pip Laurenson's opinion (2005, 2), the role of a conservator is to understand what might constitute an authentic installation and ensure that this demanding goal is achieved. This is especially truth in the absence of the artist. Therefore, the conservator (along with other heritage professionals and other individuals responsible for the works), is responsible for the identification and maintenance of the significance of the artworks, so that future generations can enjoy their fullness.

In this dissertation, it is argued that the solution that better allows for the maintenance of both the original technology and presentation of Ângelo de Sousa's slide-based artworks should, in general, be pursued.

In contrast to Ângelo de Sousa's films, from which he made duplication masters and copies to present the works, there are no available copies of his slide-based artworks. Therefore, first-generation duplication slides copied from the original slides, at least from the most important slide-based works by the artist, should be done to ensure the preservation and display of the works with the original technology, for as long as possible (Weidner 2012d). Ideally, at least two duplication master sets should be produced: i) a reference copy set, defining a faithful representation of the artwork at present, and ii) a duplication master set, from which exhibition copies are to be done. A third restored version of a duplication master set can also be produced. Issues associated with colour change of the originals can be partially overcome during the duplication process by using colour filtration. Nevertheless, experience and knowledge must be acquired before being able to correctly use colour filtration settings (Weidner 2012e). Thus, restored exhibition copies could be produced to be displayed. In the absence of the artist, this duplication master set should only be done if proper restoration can be achieved. Otherwise, only exhibition copies based on the reference copy set should be displayed. A summary of the copy sets is presented in Figure 5.3.

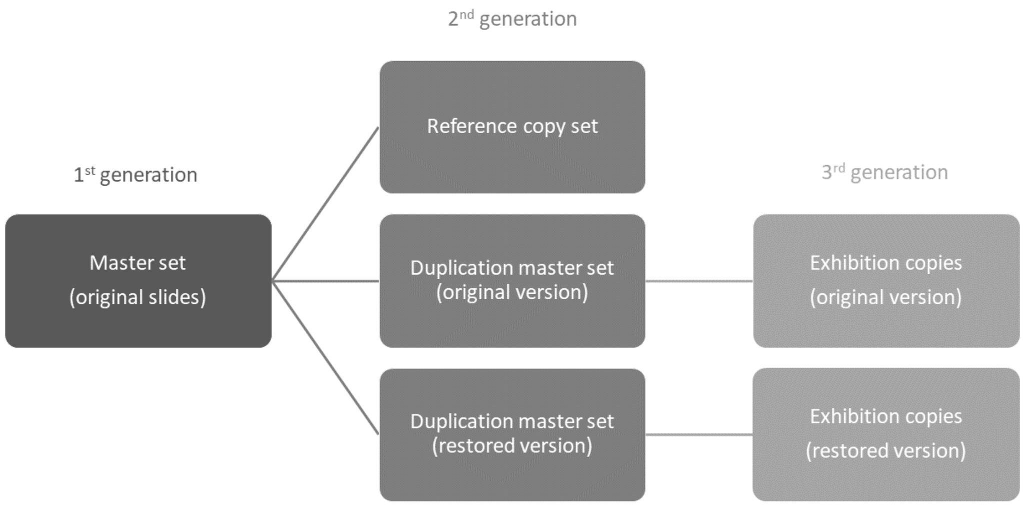

Figure 5.3 - Generations of slides needed to assure the preservation and exhibition of slide-based artworks. The 1st generation has the best quality image, followed by the 2nd and 3rd, respectively (adapted from Warda and Munson 2012).

Nevertheless, as mentioned before, Ângelo de Sousa also exhibited slide-based artworks using Cibachrome and digital prints. Therefore, these options might also be considered as a solution for display, especially when already used by the artist in the past. Also, if only a small quantity of slides is to be displayed, it can be easier to show prints instead of a slide projection; or if very different images are to be presented, a slide projection can be an inappropriate option. Most importantly, each work should be individually analysed on a case-by-case basis (Berndes 2005, 167). Additionally, the undertaken decisions must be substantiated and documented. The options should also be available to the public, who should be informed about the original technology.

Analogue vs Digital duplication

Since duplication slides were completely discontinued in 2010, alternatives had to be found to ensure the creation of duplication master sets. Unfortunately, the available films for duplication do not have the ideal emulsions for copying as duplication films had (low contrast film and very fine grain/very low ISO to capture detail), making difficult the production of an accurate duplication. Additionally, some information of the original image can be loss during the duplication process. Furthermore, a certain amount of variability in the results is almost inevitable due to the chemical dependence of the process (even if the processing baths are monitored and renewed to increase the stability and reproducibility of the processing) (Weidner 2012e). Nevertheless, by using chromogenic reversal films for the creation of a duplication master set, it is possible to maintain the image characteristics and the aesthetic content of the original work.

Besides obsolescence problems related to duplication slides, it is nowadays difficult to find photographic laboratories that duplicate slide. Similarly, there are only a few laboratories that process chromogenic reversal films, and those that still maintain the business only work with small quantities of materials[6], which normally means that the quality of the processing materials is less rigorous (Weidner 2012). Duplication sets are, as the originals, prone to fading, and the aggressive conditions of the exhibition (light, heat, dust) force the frequent substitution of the exhibition copy sets (Noordegraaf 2013b, 287). These sets must be changed on average every six weeks, meaning that a large number of slides needs to be provided for the exhibition of every slide-based work (Weidner 2012a). Moreover, it should be considered that the original slides, master duplication sets and reference copy sets, must be kept in cold storage to prevent colour change and ensure their accurateness. Last, but not least, the high cost of duplication must be considered.

Instead of analogue duplication, digital duplication can be considered as a solution. This implies digitizing the slides and flash the digital file into a chromogenic reversal film (Depocas n.d. b). Generating a digital intermediate might be advantageous since it can be more easily manipulated than a chromogenic reversal film. For instance, colour adjustments can be applied to the digital image before printing, simplifying the colour correction process. Nonetheless, the use of digital intermediates also entails some consequences, namely deviation from the original technology. A digital image is an image electronically captured using light and converted into a numeric representation. Thus, when using a digital copy, certain characteristics of the original technology are lost (Saba 2013, 101). Additionally, digitization is a demanding process and must be carried out in a rigorous way (similarly to other conservation treatments). Moreover, the data must be migrated and reformatted in short intervals, now and again, demanding the implementation of a preservation policy for the digital archive. This makes the costs for data retention more expensive than sometimes assumed (Lavezzo et al. 2015, 173). Furthermore, while digital data are prone to total loss, a physical support is prone to a gradual loss (Sommermeyer and van Haaften, 220-221). For all these reasons, the future availability of the digital data is still quite uncertain (Lavezzo et al. 2015, 173). It seems however inevitable that, sooner or later, digitization makes part of the preservation and exhibition process of slide-based artworks. Quoting Barbara Sommermeyer and Claartje van Haaften (2016, 226):

> "On the assumption that digital technology will probably completely overtake analogue slide technology, we must continue to develop a conscious awareness of what will be lost in the process, in order to formulate precise decisions".

According to the study conducted by Haida Liang, Pip Laurenson and David Saunders (2004), in a partnership between the Tate and the National Gallery (London), digital duplication of slide-based artworks has led to accurate copies. Thus, as this solution allows for the maintenance of the original physical support, it can be considered a good alternative to analogue duplication (Weidner 2012f). The currently available options for media migration of slide-based artworks were reviewed and are presented in Table 5.1.

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[6] In the Portuguese main cities, the following photographic laboratories processing chromogenic reversal films were identified: *Fine Print*, *Colorfoto* and *Gamut* in Lisbon, and *Sempre ID* and *ONELAB PRO* in Porto. Fine Print and Gamut also make duplication of slides.

Table 5.1 - Summary of the available options for media migration of slide-based artworks and projection and comments on its pros and cons

Media migration	Pros and cons
Analogue duplication: duplication with commercially available chromogenic reversal films (Weidner 2012e);	Pros: reflects the imaging techniques of the time, maintains the aesthetic content of the originals; Cons: degradation of the exhibition copies during projection, obsolescence problems, difficult to do colour adjustments (filters), requires trained staff, expensive;
Digital duplication: digitization (high definition) + printing with light valve technology (LVT), cathode ray tube or laser film recorders into available chromogenic reversal films (Weidner 2012f);	Pros: easier to print the digital image, easier colour adjustments; Cons: degradation of the exhibition copies during projection, loss of some characteristics of the original image, obsolescence problems, expensive;
Digital duplication: digitization (high definition) + printing (high resolution) + photographing with commercially available chromogenic reversal films (Lavezzo et al. 2015, 172);	Pros: easier to print the digital image, easier colour adjustments, inexpensive; Cons: degradation of the exhibition copies during projection, loss of the characteristic information from the originals with the digital conversion and printing, loose image quality;
Digital migration: digitization (high definition) (Sommermeyer and van Haaften, 222);	Pros: easier to print the digital image, easier colour adjustments, no need of exhibition copies, fast process, inexpensive; Cons: loss of the characteristic information from the originals with the digital conversion, total deviation from the original technology;

Projection	Pros and cons
The same projector used by the artist (Laurenson 2005, 2);	Pros: maintain the exact technology; Cons: obsolescence problems, requires trained staff;
Different slide projector (Wijers 2013, 238);	Pros: maintain the technology; Cons: can raise obsolescence problems, requires trained staff;
Digital projector (Sommermeyer and van Haaften, 222);	Pros: can be seen as an easy way of installing the works (wrongly), less expensive; Cons: deviation from the original technology

Projection

Besides the carrier of the image, the display equipment and conditions of display can raise issues related to the identity of slide-based artworks. As supported by specialists in this field, the reception of a work is highly dependent on the way it is presented (Szmelter 2011, 121).

In a report sent by Ângelo de Sousa to FCG[7] in November 1976, during the time he was producing the first series of the work *A mão esquerda (1ª série)* (1975), he stated:

> "it's a series which I called 'Mão' and that will constitute a collection to be shown in those projectors with circular tray (…)[8]".

To the best of our knowledge, this makes the only available source created during a work's production where Ângelo de Sousa expresses his desires on how to display his photographs and films. Also concerning the same work, as previously mentioned, he also specified that he used to project it on a white canvas with "roughly the same size as a painting" (Sousa 2001, 43). Beside these references related to the installation of *A mão esquerda (1ª série)*, a letter concerning the display of the work *Slides de Cavalete* (1978-1979) was found and will be presented further in this section. Based on the scarcely available documentation, the artist did not seem to have produced his works for display in a specific type of projector. Additionally, none of the projectors found in the artist's archive have a circular tray (caroussel), proper for display in an exhibition. Ângelo de Sousa (similarly with other artists) was probably using the slide projectors available at the institutions hosting the exhibitions.

Projectors are mass-produced equipment, and consequently, are not valued for uniqueness. Therefore, they can be replaced for an equivalent with discernible change (Laurenson 2005, 2). According to Gaby Wijers (2013, 238), there is a consensus that in most cases the display equipment can be upgraded. Nevertheless, proper equipment is crucial for the presentation success. Different display equipment's can produce different images; not only the projector itself but also its spare parts, such as lamps and lenses (Warda and Munson 2012). The available options for projection are presented in Table 5.1.

Due to the obsolescence of the slide projectors and spare parts, the continuity of the display equipment is dependent on the availability of the projector and on specialists with the knowledge on how to maintain and repair the equipment (Weidner 2012c)[9]. Despite these difficulties, the substitution of the slide projector by a digital projector might modify the landscape, and consequently, the experience of the artwork. First, the physical/sculptural effect of analogue and digital projectors is different (Lavezzo et al. 2015, 170-171). Also, the digital projector suppresses the sound experience of the slide projector mechanism passing the slides (Monteiro 2015, 175). Although it is possible to simulate the sound of the projector, this option would probably be too farfetched, considering the artist in question. According to Bernardo Pinto de Almeida (2018), Ângelo de Sousa appreciated the performative character that the slide projector conferred to an exhibition, since it would allow for the phenomena of appearance and disappearance of images. However, digital projectors obliterate this characteristic transition effect between images (Monteiro 2015, 175), although this feature can, to a

[7] *Subsídio de investigação, artes plásticas e comunicação visual* (research, plastic arts and visual communication funding), grant awarded by the Fine Arts Service from Fundação Calouste Gulbenkian.
[8] Translation by the author from this dissertation.
[9] One way of assuring the availability of the slide projector is to acquire and accumulate projectors for future presentations (Depocas n.d. b).

certain extent, be simulated. Additionally, digital projectors are often launched with better resolutions changing the visual appearance (dimension and quality of the projection) of the projected images (Monteiro 2015, 175). As pointed out by Barbara Sommermeyer and Claartje van Haaften (2016, 225), the light being projected through a chromogenic reversal film has a different appearance to a digital projection. From Ana Paula Monteiro's point of view (2015, 175), there is an atmosphere of imperfection produced by the analogue equipment and this aesthetic characteristic should also be offered to the public. Quoting Tina Weidner (2012b):

> "Whilst artists foreground the experience of the apparatus of slide technology to a greater or lesser degree, the position of the slide projector on a pedestal and the sound it creates when the slides change is tightly interwoven with our experience of these works. Though we appreciate that the equipment associated with slide technology possesses a sculptural presence, this is often entirely unintended and is simply a consequence of using this technology. Nevertheless, the carousel slide projector has become an iconic object and the distinction between the apparatus of 35 mm slide projection and a digital projection is therefore significant".

Although updating the display equipment for digital technology might be tempting these days, it entails some problems. It apparently streamlines the exhibition of the works (although special equipment and technicians are required for the accurateness of the projection), namely by reducing the costs and maintenance associated with slide exhibition copies. However, an accurate digital projection is, as slide projection, hard to achieve without proper equipment and technicians.

A summary of possible advantages and disadvantages of maintaining the original slide-based technology is presented in Figure 5.4.

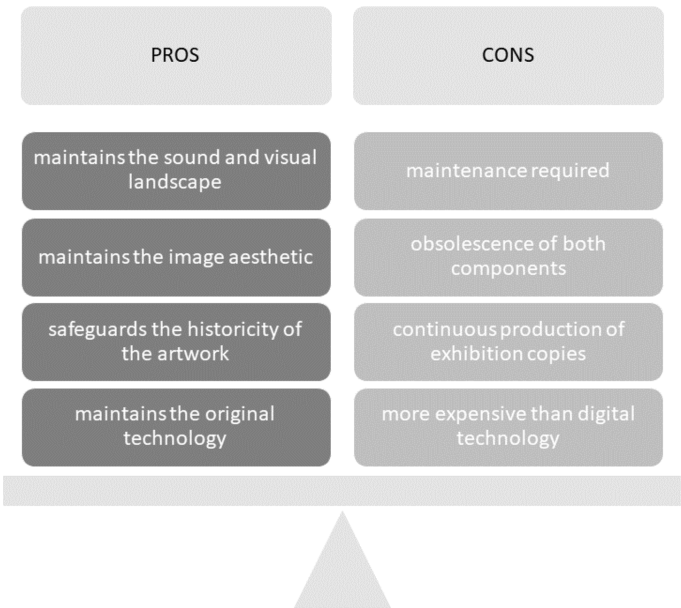


Figure 5.4 - Summary of possible pros and cons of maintaining the original slide-based technology.

5.3.2. Case study: *Slides de Cavalete* (1978-1979)

In this section, options for the exhibition of the slide-based artwork *Slides de Cavalete* (1978-1979) are discussed. The context, meaning and production process of the work have been investigated within the framework of this dissertation. The results of this research are presented in chapter 4 (section 4.3). Therefore, only a summary of the findings of this study are described in this section. In here, inspired by the significance guide designed by Roslyn Russell and Kylie Winkworth (2009), values have been attributed to the work under study to establish its significance. This evaluation was essential to define what to preserve and how to display the artwork.

Additionally, two different presentation scenarios for the artwork under study were tested and presented to the public during an exhibition/experimental study organized at the Library from the FCT NOVA. A questionnaire was made to the visitors, in order to record their perception of the work displayed within the two scenarios. The results from the questionnaires are presented and discussed further in this section.

5.3.2.1. Defining significance and tracing the display history of the work

Slides de Cavalete is composed of one hundred colour slides. Sérgio Mah (2014, 23) described the work as one of the most astonishing and prodigious photographic works by Ângelo de Sousa. Indeed, the artistic and aesthetic value of *Slides de Cavalete* is undeniable. In this work, the artist constructed a series of different luminous spaces by projecting additive colours and capturing successively, on the same frame, a superimposition of RGB lights. Using longer or shorter exposures, which he controlled by using masks to reduce the exposure to light in selected areas, he achieved outstanding tonal gradations obeying the principle of additive synthesis. The result is a series of abstracted images that confers a narrativity of sensations. *Slides de Cavalete* is a unique and irreproducible register of the artist's interaction/performance with light.

Taking into account the subject and production process of the artwork, it can be said that light and colour have important weight in its significance. As the colours of the film change over time, a gradual loss of information is expected to occur. As stated by Kayley Vernallis (1999, 462), since the meaning of a colour photograph is closely related to the information contained in the image carrier, a loss of information caused by dye degradation leads to a loss of meaning. The subtle colour gradations and colour harmony of *Slides de Cavalete* can be seriously menaced by dye fading (loss of detail) and colour shift, and put at risk the aesthetic value of the work (Vernallis 1999, 467). In other words, the significance of the work is menaced by the degradation of the film. Knowing that chromogenic reversal films are susceptible to both dark and light fading, and taking into account the history of the collection (chapter 3, section 3.2.2), it can be concluded that these slides suffer from colour change. Thus, two questions should be raised: Does *Slides de Cavalete* still maintain its aesthetic value and its artistic value although it had lost its original colours? Should the artwork be considered a total loss at some point?

The innovative solutions adopted for the conception of this workplace Ângelo de Sousa close to the international experimentalists from the *neo avant-garde* period. As discussed in chapter 4, Ângelo de Sousa was one of the main figures associated with the changes felt in Portuguese from the 1960s onwards. This was due both to his use of audio-visual supports and to the plastic solutions adopted by the artist when using this media. *Slides de Cavalete* is a pioneer testimony of the use of slide-based materials by Portuguese artists. Hence, it has an important historical character.

Additionally, although Ângelo de Sousa produced thousands of colour slides, only two sets were defined as a diaporama: *A mão esquerda (1ª série)* and *Slides de Cavalete*. Therefore, it can be stated that *Slides de Cavalete* was meant to be presented as a slide show, and the significance of the work can be linked not only to the image but also to the slide-based technology.

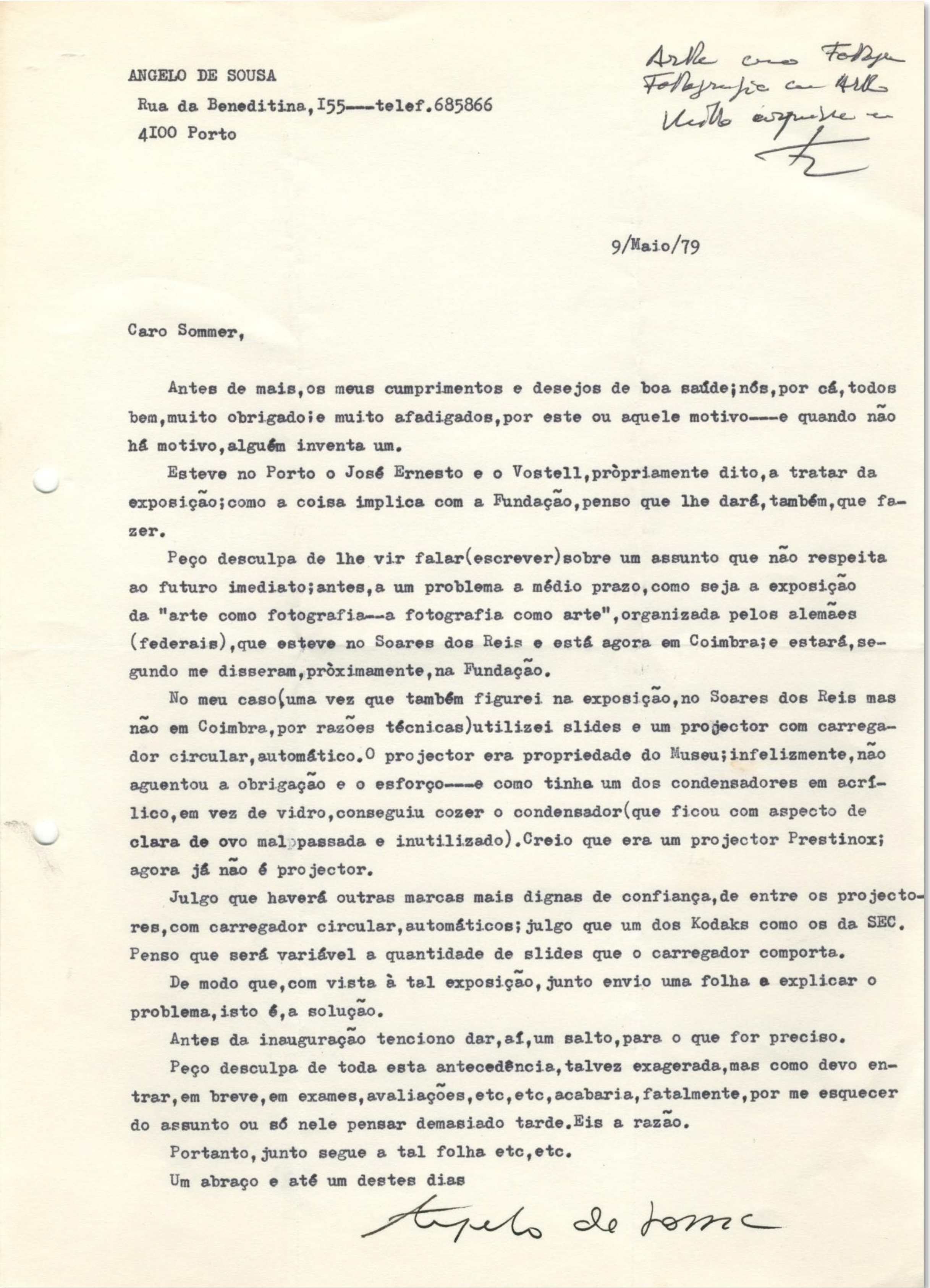
Although *Slides de Cavalete* is one of the most ingenious photographic works produced by Ângelo de Sousa, it was only presented in two exhibitions during Ângelo de Sousa's lifetime. The work was shown for the first time in the exhibition *A Fotografia como Arte / A Arte como Fotografia* in 1979, curated by Floris Neusüss[10]. As mentioned in chapter 4, *Slides de Cavalete* could have been conceived to be presented in that exhibition (Pinto 2014, 185). The work was presented under the title *Fotografias (slides) de algumas pinturas imaginadas e inexistentes (excepto nos próprios slides projectados)*[11]. Ângelo de Sousa reported that Floris Neusüss objected to the inclusion of his work in the exhibition (Sousa 2001, 19). Although Neusüss was an active agent in the international art scene having participated in the transformation of the artistic context at that time, and even though the exhibition was intended to show a more comprehensive view on the practice of photography, it is possible that the curator did not understand the work and irony of its title. Another possibility for the rejection could have been the look of the artwork as a provocation considering the scope of the exhibition, despite being a true homage to photography (as a unique medium enabling the exploitation and registration of light). According to Paula Pinto (Pinto 2014, 185), it was the direct allusion that the diaporama established with easel painting that prevented its comprehension. Despite this, the artwork was displayed, although badly projected and only until the projector ceased to function (Sousa 2001, 19-20). The exhibition was held in three different places: Centro de Arte Contemporânea from Museu Soares dos Reis (CAC-MNSR) (Porto), Edifício Chiado (Coimbra), and FCG (Lisbon).

The documentation related to the exhibition at FCG was accessed at the institution's archive, where a letter from Ângelo de Sousa was found (Figs. 5.5 and 5.6). Since the content of this letter is of the utmost relevance for the present work, the main ideas are summarized next[12]. According to that letter, the work wasn't displayed in Coimbra. The letter describes some details about the display conditions used in Porto. The artist wanted to maintain the setup for the exhibition in Lisbon, and therefore, he described all the necessary materials for the exhibition of the artwork. He explained that he used a slide projector, belonging to CAC-MNSR, with a circular tray and capacity for one hundred slides, which broke down during the exhibition. Therefore, he asked for an automatic projector with circular tray, safer than the one used in Porto, suggesting Kodak as the brand. He also referred to the fact that, although the work is composed of one hundred slides, if the capacity of the projector from the museum was smaller than the number of slides in the artwork, he could adjust the number of slides to be presented. Additionally, he requested an easel, ideally with a 19th century appearance and with a hand crank, and a white canvas (or at least something that resembles it) with 90 x 120 cm (or larger if within the same proportion), to project the slides onto its surface. At the end of the letter, there is a scheme for a projector, installed over a support that resembles a tripod or a bench, and a canvas over an easel.

[10] Floris Neusüss (1937) is a German artist who have been working with, writing and teaching about photography. In the 1970s he founded Kassel Foto Forum at the University of Arts in Kassel, for the exhibition of the photographic work developed by students. Neusüss consistently explored the photographic image without the use of a camera, producing numerous series of photograms. His series *Körperfotogramms* from the 1960s are examples of that (Squiers 2013, 25). He also worked with double-exposures, negative montages, among other experimental practices (n.a. 2012).

[11] *Photographs (slides) of some imagined and non-existent paintings (except in the projected slides themselves)*.

[12] No information related to the exhibition was found at the archive from MNSR.



ANGELO DE SOUSA
Rua da Beneditina,I55---telef.685866
4IOO Porto

Arte como Fotografia
Fotografia como Arte
Vostell exposição em

9/Maio/79

Caro Sommer,

Antes de mais,os meus cumprimentos e desejos de boa saúde;nós,por cá,todos bem,muito obrigado;e muito afadigados,por este ou aquele motivo---e quando não há motivo,alguém inventa um.

Esteve no Porto o José Ernesto e o Vostell,pròpriamente dito,a tratar da exposição;como a coisa implica com a Fundação,penso que lhe dará,também,que fazer.

Peço desculpa de lhe vir falar(escrever)sobre um assunto que não respeita ao futuro imediato;antes,a um problema a médio prazo,como seja a exposição da "arte como fotografia--a fotografia como arte",organizada pelos alemães (federais),que esteve no Soares dos Reis e está agora em Coimbra;e estará,segundo me disseram,pròximamente,na Fundação.

No meu caso(uma vez que também figurei na exposição,no Soares dos Reis mas não em Coimbra,por razões técnicas)utilizei slides e um projector com carregador circular,automático.O projector era propriedade do Museu;infelizmente,não aguentou a obrigação e o esforço---e como tinha um dos condensadores em acrílico,em vez de vidro,conseguiu cozer o condensador(que ficou com aspecto de clara de ovo mal passada e inutilizado).Creio que era um projector Prestinox; agora já não é projector.

Julgo que haverá outras marcas mais dignas de confiança,de entre os projectores,com carregador circular,automáticos;julgo que um dos Kodaks como os da SEC. Penso que será variável a quantidade de slides que o carregador comporta.

De modo que,com vista à tal exposição,junto envio uma folha a explicar o problema,isto é,a solução.

Antes da inauguração tenciono dar,aí,um salto,para o que for preciso.

Peço desculpa de toda esta antecedência,talvez exagerada,mas como devo entrar,em breve,em exames,avaliações,etc,etc,acabaria,fatalmente,por me esquecer do assunto ou só nele pensar demasiado tarde.Eis a razão.

Portanto,junto segue a tal folha etc,etc.

Um abraço e até um destes dias

Angelo de Sousa

Figure 5.5 - Documentation found at Fundação Calouste Gulbenkian's archive related to the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979) © Fundação Calouste Gulbenkian.

ANGELO DE SOUSA
Rua da Beneditina,I55---telef.685866
4I00 Porto

9/Maio/79

PARA A EXPOSIÇÃO--"A FOTOGRAFIA COMO ARTE-A ARTE COMO FOTOGRAFIA"

Material a utilizar(à semelhança do que foi feito a quando da exposição no Museu Nacional de Soares dos Reis,no Porto):

A-um projector de slides,automático,com carregador circular(com uma lâmpada sobresselente,ou duas,consoante a duração previsível da exposição).

--de que marca e tipo de projector se poderia dispor?os Kodak parecem ser bastante robustos e fiáveis;

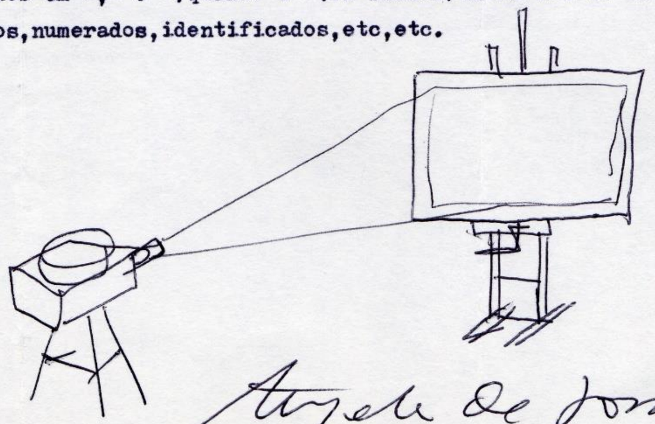
--para quantos slides(montados com vidros)seria o carregador circular?durante a exposição no Soares dos Reis,utilizei um carregador de I00 slides;julgo que os Kodak comportam 80 slides;consoante o tipo de carregador teria eu que adequar a colecção de slides a projectar.Isto é,conviria saber,com a possível antecedência,com o que haveria de contar.

B-um cavalete,dos do tipo de atelier,quanto mais século XIX melhor,e se tivesse uma manivela,então,seria o ideal.

C-uma tela branca,isto é,se possível,uma tela como as usadas para pintar quadros ou,pelo menos,com a aparência de uma;formato rectangular,disposto à largura,com as dimensões de I20 X 90 cm,aproximadamente;pode ser ainda maior mas dentro dessas proporções.

D-uma colecção de slides,no formato 24 X 36 mm(o mais usual),todos projectados "à largura",isto é,sendo a maior dimensão a horizontal;o número de slides a utilizar seria,como disse acima,condicionado pelas características do projector e do seu carregador circular.

Agradecia que fosse estudada a possibilidade de se arranjarem,em Lisboa,os artigos referidos em A,B e C;quanto a D(os slides)enviá-los-ia ou levá-los-ia comigo,ordenados,numerados,identificados,etc,etc.



Angelo de Sousa

Figure 5.6 - Documentation found at Fundação Calouste Gulbenkian's archive related to the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979) © Fundação Calouste Gulbenkian.

As far as it can be concluded from the letter found at FCG, the artist was worried enough with the display of the artwork under study, to write a letter to the institution where it was going to be displayed, describing in great detail all the devices necessary to its proper presentation. Unfortunately, none of this valuable information was described in the exhibition catalogue[13] (Fig. 5.8), and no more documentation related to the exhibition conditions was found.

Apparently, similarly to the slide-based artworks *A mão esquerda (1ª série)* (1975) and *A mão esquerda (2ª série)* (1977), and the film *A mão* (1976), Ângelo de Sousa wanted to allude to the resemblance of *Slides de* Cavalete with his 'monochromatic' series of paintings, equating the photographic medium to the paintings by placing it over an easel. Considering the art scene in Portugal at that time (Chapter 2) and the exhibition name[14], the artist seems to be mocking the questioning of photography as art (as it would be obvious for him).

The fact that the artist chose specific devices to be part of the display landscape, contributes an important sculptural character to the work. Thus, the FCG's letter allows, for the first time in the present, to consider that this work is composed of specific components besides the slide projection. With this discovery, the title and subtitle attributed to the work by the artist has taken on meaning. By using the subtitle, the artist possibly wanted to highlight the immaterial and throbbing features of the slide projection. Thus, the projected slides can be seen as 'some imagined and non-existent paintings', which are able to appear and disappear, and only exists during the projection time. In the exhibition's catalogue, the work is represented by a white rectangle (Fig. 5.7), enhancing the temporary nature of the work. By choosing this representation of the work, the artist was perhaps also playing with the fact that, during their production, the images only existed in the artist' s head (since the result would only be visible after its processing).

Slides de Cavalete was only re-exhibited almost ten years later, in *Fotoporto: Mês da Fotografia* (1988). The exhibition was held at Casa de Serralves (Porto) and curated by Fernando Pernes. Curiously, although Ângelo de Sousa once stated that "What matters is the image. How it's made is my business" (Sousa 2001, 16), on that occasion, Ângelo de Sousa apparently wrote a document explaining the production process of the artwork, which was found in his archive in the file *Slides*. Once again, he chose to present a representation of the work, now alluding to the production process. In the catalogue from the exhibition *Fotoporto: Mês da Fotografia*, the work is represented as a black-and-white scheme of three rectangles filled with diagonal lines. As a reference to the production process, the first rectangle was named "red", the second "green" and the last "blue" (Fig. 5.8). Perhaps the artist considered that the knowledge about the production process would enrich the comprehension and perception of the artwork.

Since Casa de Serralves does not have an organized archive, no documentation related to the exhibition was found[15]. As in the catalogue from the exhibition *A Fotografia como Arte / A Arte como Fotografia*, the catalogue from the exhibition *Fotoporto: Mês da Fotografia* does not contain any information related to the exhibition conditions[16]. Additionally, no information was found in interviews or other published sources.

[13] A Fotografia como Arte / A Arte como Fotografia, ed. Fernando Pernes. 1979. Lisbon: Fundação Calouste Gulbenkian.
[14] Photography as art, art as photography (translation by the author of this dissertation).
[15] This information was provided by Cristina Grande during a phone call. Although she was part of the exhibition staff, she did not remember that the work under study was displayed in that occasion.
[16] Fotoporto: Mês da Fotografia, ed. Fernando Pernes. 1998. Porto: Casa de Serralves.

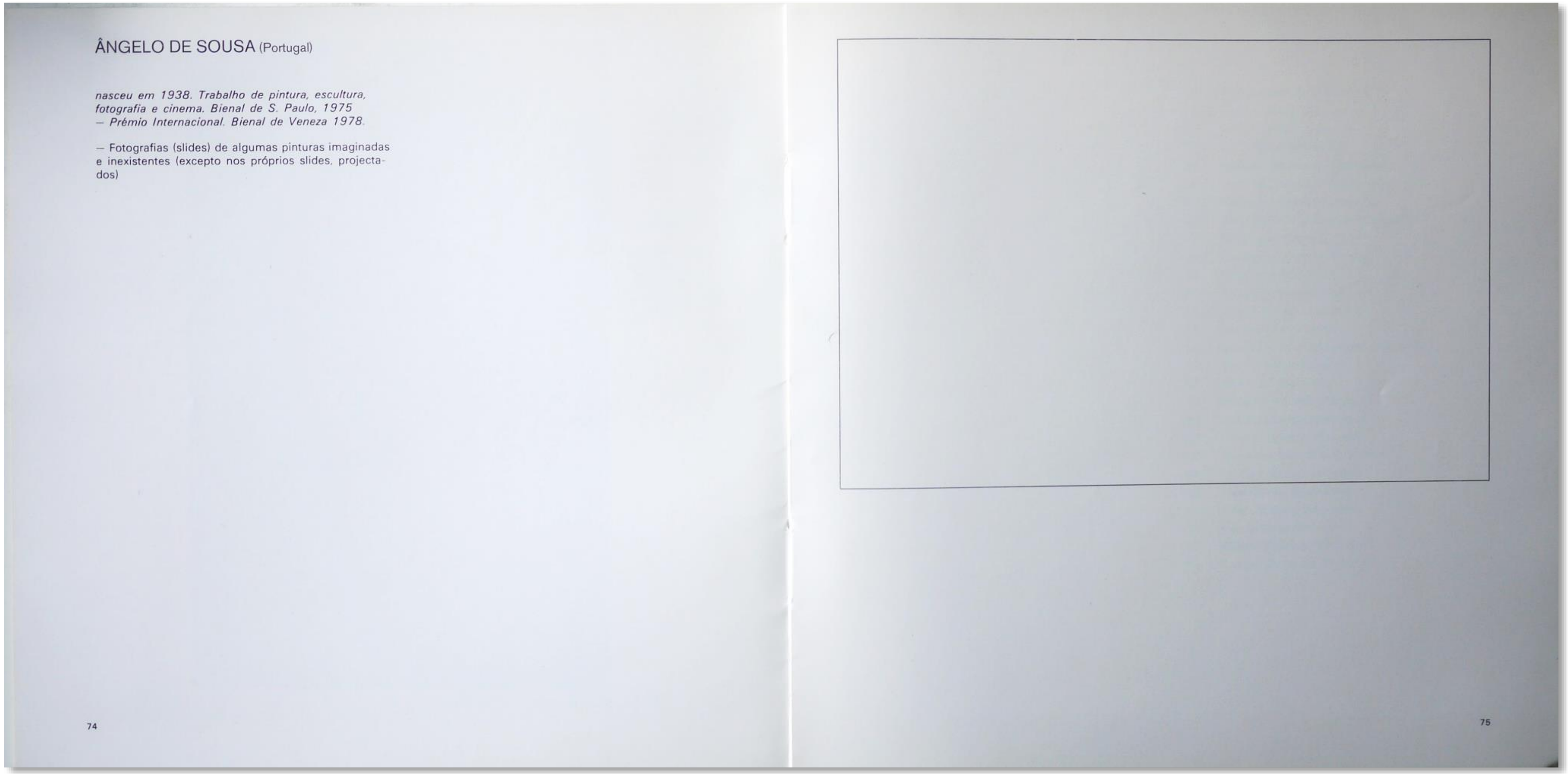


Figure 5.7 - Information related to *Slides de Cavalete* (1978-1979) contained in the catalogue from the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979).

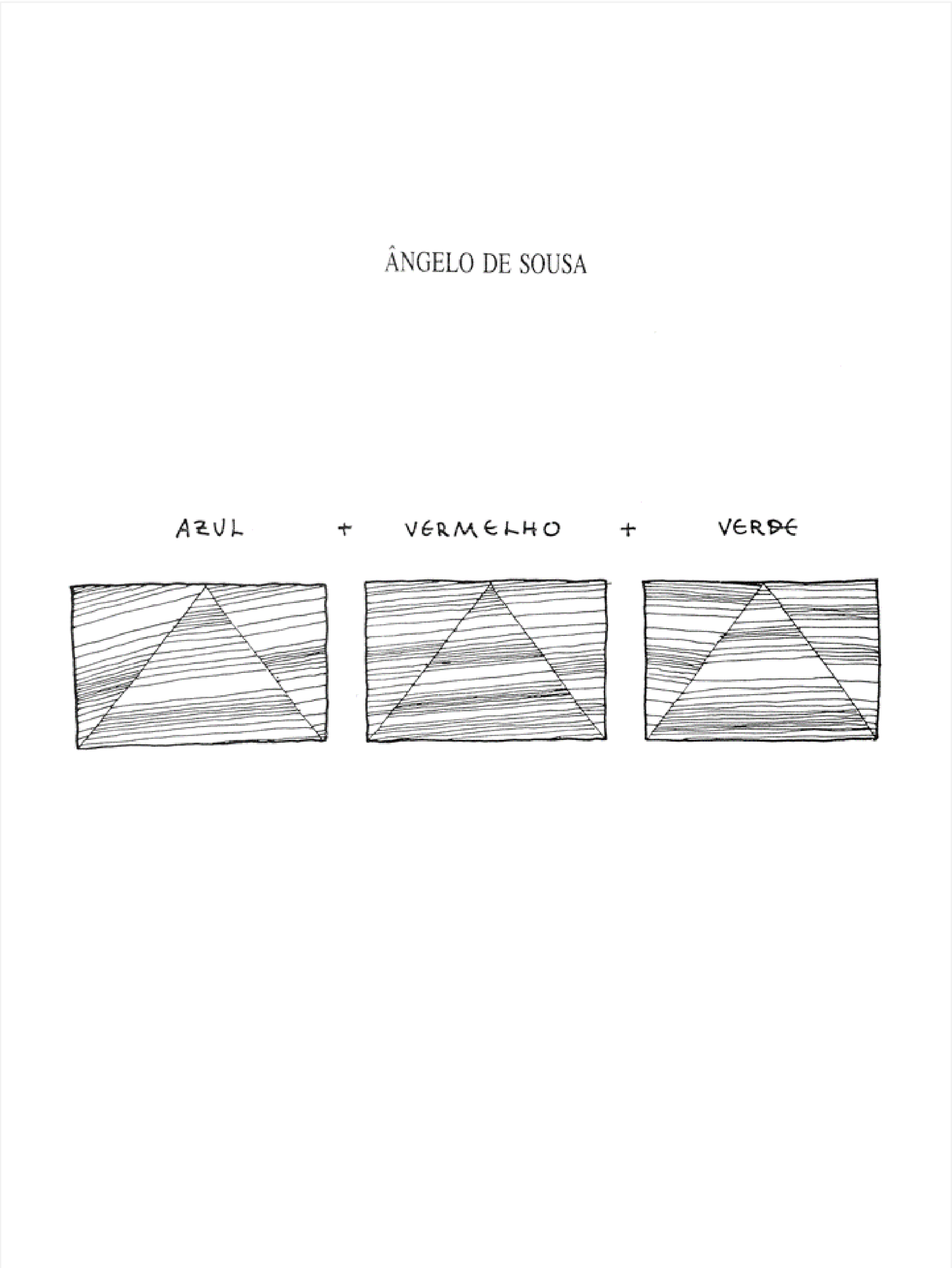


Figure 5.8 - Information related to *Slides de Cavalete* (1978-1979) contained in the catalogue from the exhibition *Fotoporto: Mês da Fotografia* (1988).

Thus, with the intention of gathering evidence on how the artwork was presented in the exhibition *Fotoporto: Mês da Fotografia*, Manuel Magalhães[17]and Bernardo Pinto de Almeida were interviewed about the display setup of the work on that occasion[18]. Both had been involved in the production of the exhibition. Additionally, the artist Julião Sarmento, who also participated in that exhibition, was questioned. Unfortunately, neither Magalhães or Almeida (2018) nor Sarmento, were able to remember how the work was presented on that occasion. Hence, and taking into account the lack of documentation related to that exhibition, it was not possible to trace how the work was presented in 1988.

As far as can be concluded, the original slides were displayed in both exhibitions. Therefore, in addition to dark fading caused by the permanence of the artwork in inadequate storage conditions, the slides surely suffer from light fading due to their projection in the two exhibitions.

After Ângelo de Sousa's death, *Slides de Cavalete* was presented in three exhibitions: *Encontros com as Formas* (2014) in Galeria Fundação EDP (Porto), curated by Sérgio Mah, *La Couleur et le Grain Noir des Choses* (2017) in FCG (Paris), curated by Jacinto Lageira, and *Potência e Adversidade, Arte da America Latina nas Colecções em Portugal* (2017) in Museu da Cidade (Lisbon), curated by Marta Mestre (Fig. 5.9). Additionally, on the 7th July 2018, the work was presented in a one-day session, within the framework of the *Jornadas Lúcidas 2 - Oporto*. This happening was organized by the Portuguese artist Alexandre Estrela at Casa dos Marinheiros Mercantes in Lisbon.

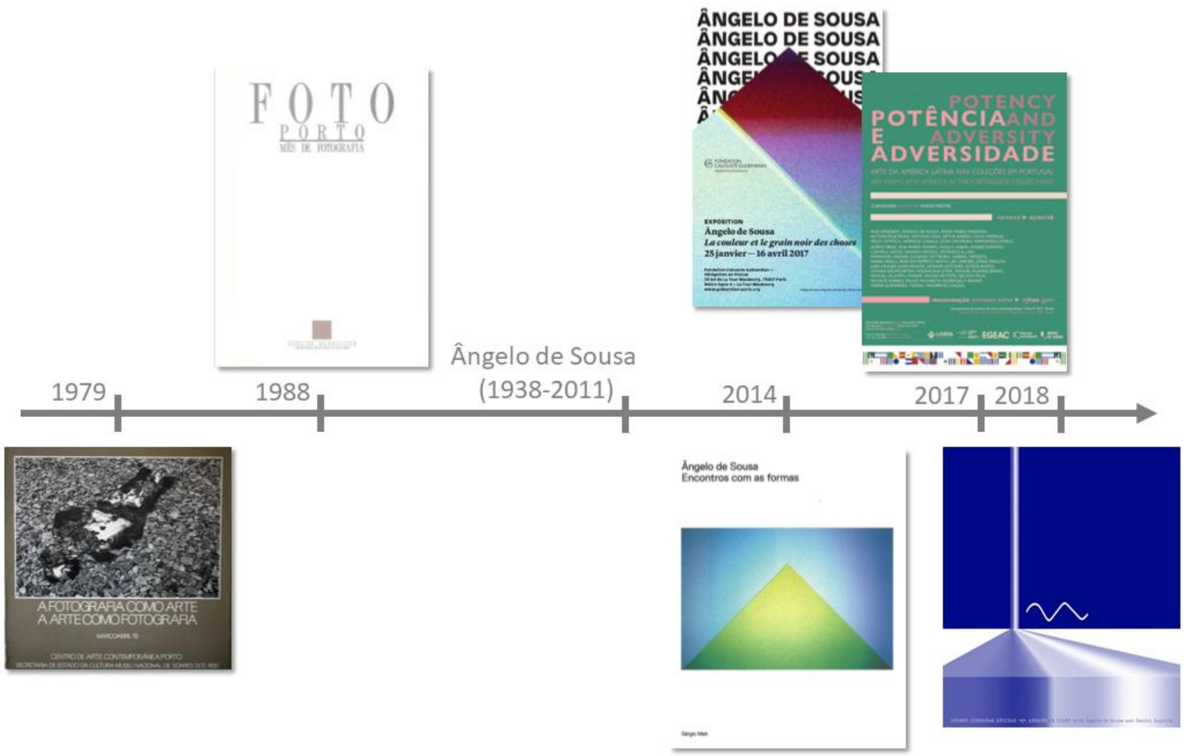


Figure 5.9 - Timeline of the exhibitions where *Slide de Cavalete* (1978-1979) was displayed.

[17] Architect and photographer who was part the group IF (see chapter 2, section 2.2.2). Manuel Magalhães was interviewed in an informal way, and therefore the interview was not recorded.
[18] The curator of the exhibition was Fernando Pernes (1936-2010), who left no data.

For the exhibition *Encontros com as Formas* (2014), Sérgio Mah made some tests by projecting the work with a digital projector and a slide projector. Mah concluded that the digital projection allowed for a better accuracy of colour reproduction, although the subtle variation between colours and their density could be better achieved with the slide projector[19]. Therefore, he opted for exhibiting a copy of the original slides in a slide projector. The one hundred slides were digitized in high definition and the digitisations were sent to London[20] to be exposed in chromogenic reversal film with a film recorder. The digital duplications were used as exhibition copies[21,22]. The artwork was displayed in a small dark room to provide an ideal environment for the contemplation of the work alone (Fig. 5.10)[23]. However, the first time the work was presented, the scenario was quite different. *A Fotografia como Arte / A Arte como Fotografia* was a collective exhibition and, as far as it can be concluded, Ângelo de Sousa shared the exhibition space with other artists. Moreover, a certain luminosity would be necessary to allow the proper observation of the sculptural components that are part of the artwork. The dimensions of the projection are unknown, although, based on photographic images, the proportion were maintained.

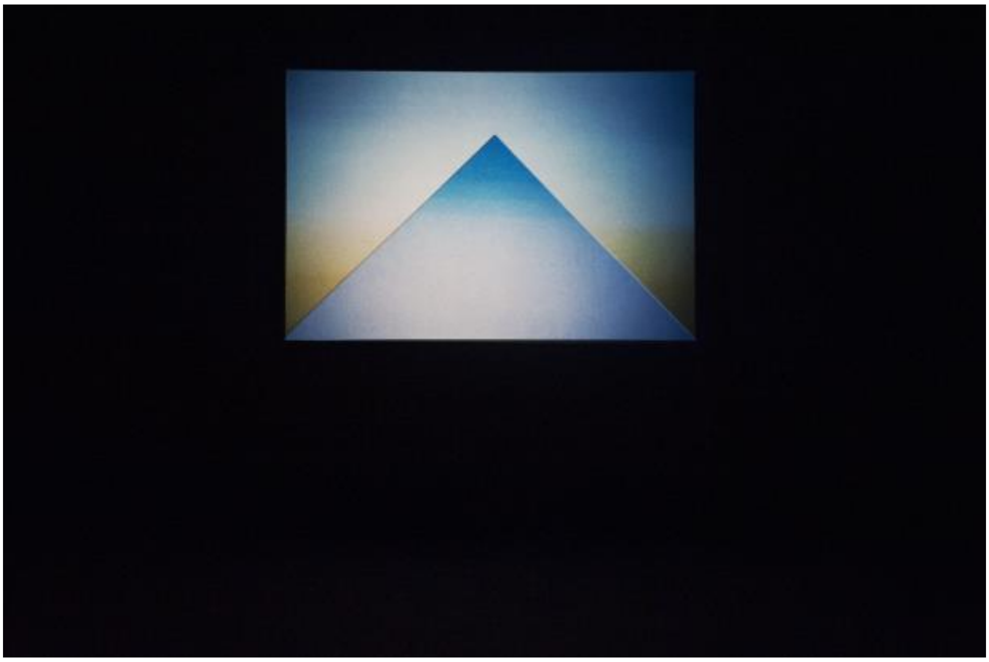


Figure 5.10 - View of the exhibition of the work *Slides de Cavalete* (1978-1979) in *Encontros com as Formas*, 2014[24].

[19] This information was kindly shared by Sérgio Mah during the round table organized within the exhibition/experimental laboratory organized at FCT NOVA (see section 5.3.2.3 from this chapter).
[20] To the company *Digital Slides*: https://www.digitalslides.co.uk/wp-2013/ (accessed on 18/09/2018).
[21] This information was kindly provided by André Cepeda, the technician responsible for the digitization process of *Slides de Cavalete* and other photographic works by Ângelo de Sousa. The digital images were subjected to colour matching in order to ensure their approximation to the originals (in the current condition).
[22] Unfortunately, during the digitization process, the slides containing text were reversed, and negative images of the originals were presented in the exhibition, as well as in the catalogue (white background with black lettering instead of a black background with white lettering).
[23] This information was kindly shared by Sérgio Mah during the round table organized within the exhibition/experimental laboratory organized at FCT NOVA (see section 5.3.2.3 from this chapter). Only scarce documentation from the exhibition setup can be found in the exhibition catalogue and in the few press releases from the time.
[24] https://makingarthappen.com/2014/04/16/encontros-com-as-formas-fotografias-e-filmes/ (accessed on 18/09/2018).

In the exhibition *La Couleur et le Grain Noir des Choses* (2017), the digital copies made for the exhibition in 2014 were presented in a digital projector, placed at the top of the entrance staircase[25]. The dimensions and proportions of the projection were not described nor documented, but they were surely, far above 90 x 120cm.

Likewise, in the most recent exhibition, *Potência e Adversidade, Arte da América Latina nas Colecções em Portugal*, similar options were undertaken. A DVD was made with three films and the work *Slides de Cavalete*, in order to be presented in a digital projector as a slideshow in a dark room (Fig. 5.11). According to Miguel de Sousa, the slides were passing too fast because of an incorrect DVD *montage*[26]. When the exhibition site was visited, the projection was not working and, according to the staff present there, the projector had been inoperative for almost a month. Thus, it was only possible to observe the room painted in black and with a white rectangle (75 x 100 cm) where the images should have been projected. This dimension was below the 90 x 120 cm described by Ângelo de Sousa in FCG's letter, although within the same proportions.

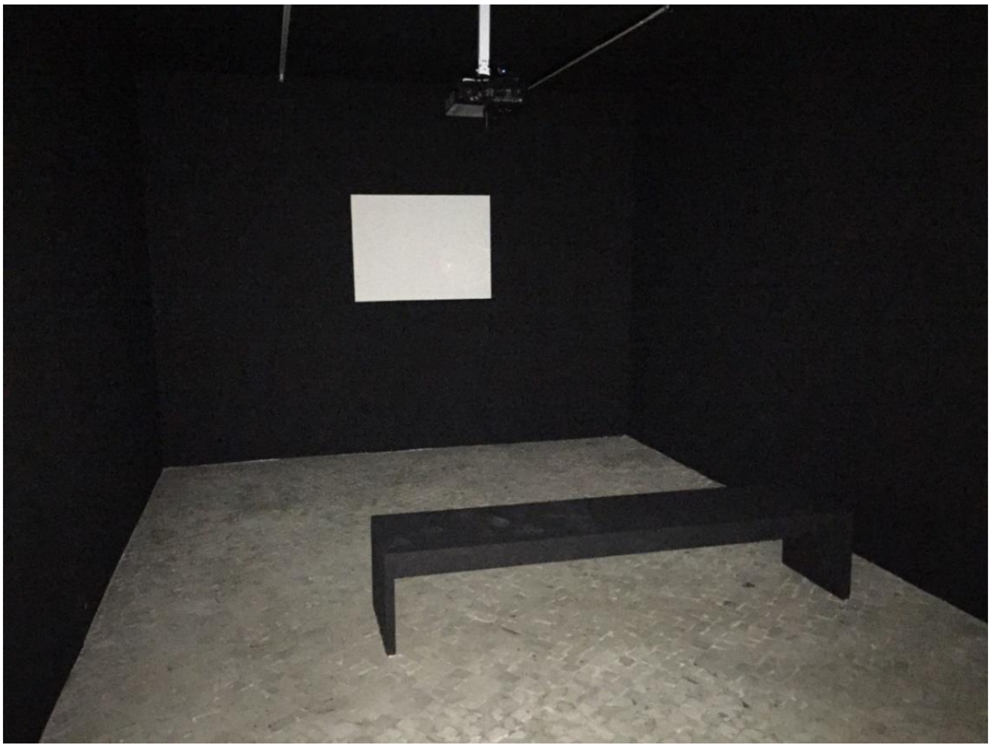


Figure 5.11 - View of the exhibition of the work *Slides de Cavalete* (1978-1979) in *Potência e Adversidade, Arte da America Latina nas Colecções em Portugal*, 2017.

After Ângelo de Sousa's death, different display options from those undertaken by the artist in the past can be observed, possibly due to absence of knowledge about the FCG documentation. In the one hand, the canvas and easel were subtracted. On the other hand, in the last two exhibitions, the slide projection was shifted to digital projection. Thus, over time, *Slides de Cavalete* [easel slides] has lost the easel and also the slides. The detachment from the first presentation might have led to a deviation the original intention of the artist. The public who visited the artwork in the last two

[25] *Idem* as [17].
[26] This situation was fixed after the inauguration at the request of Miguel de Sousa.

exhibitions, subsequently more subjective and with interpretative new elements, experienced a different version of *Slides de Cavalete*. Additionally, none of the curatorial options was justified and explicit for the visitor. As sustained by the conservator Sanneke Stiger (2016, 169), the clear communication of the material structure of the original artwork and its reinterpretation, is fundamental for a proper experience. Considering the new insights brought by the present investigation, it is believed that *Slides de Cavalete* should no longer be presented as a simple diaporama.

At *Jornadas Lúcidas 2 - Oporto*, the work *Nobody Here* (2009) by Daniel Lopatin was exhibited along with the artwork under study, in a session dedicated to additive light. The exhibition copies used were produced following the same methodology and using the same suppliers than for the exhibition *Encontros com as Formas*. The display options undertaken by Estrela were discussed with the author of this dissertation. The work was projected using a slide projector on a 4m width screen (Fig. 5.12). The projector only had the capacity for eighty slides, and therefore, Estrela made a selection of images to be presented[27]. This option was undertaken knowing that the artist had predicted this situation, as described in the documentation found at the FCG's archive related to the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979). Although some changes to the original presentation of the work were undertaken, the organization made available to the public a handout where the variations are described and the curatorial options justified (appendix IV, Figs. IV.8 and IV.9).

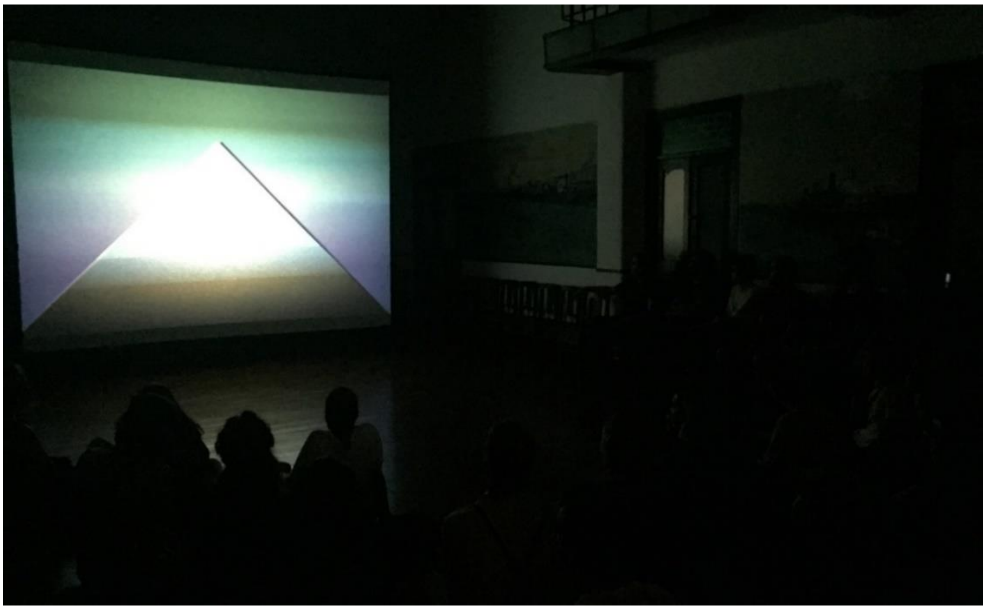


Figure 5.12 - Exhibition of the work *Slides de Cavalete* (1978-1979) in *Jornadas Lúcidas 2 - Oporto*, 2018.

5.3.2.2. Display proposal

Based on the results from the research conducted so far and considering the absence of the artist to guide the decision-making process about the exhibition of *Slides de Cavalete*, it is proposed to display the work according to its first public presentation in 1979. To the best of our knowledge, the

[27] According to the information kindly provided by Alexandre Estrela, the selection was made by Sérgio Mah and himself. The selection tried to maintain the coherence of the entire work, by selecting a representative set of images to be presented. The selection of slides is presented in the handout shared with the public, as shown in appendix IV, Fig. IV.9.

letter found at FCG and written by Ângelo de Sousa within the context of the exhibition *A Fotografia como Arte/A Arte como Fotografia* represents the only instructions left by the artist regarding the display of the work under study. Additionally, this approach ensures the maintenance of both the aesthetic and historicity of the work, which were considered part of its significance. Thus, the visitor may experience how the artwork was presented at the time of its conception. To do so, the following materials would be necessary (Fig. 5.13):

i) Number of necessary exhibition copy sets (according to the duration of the exhibition);
ii) Automatic carousel slide projector with capacity for one hundred slides;
According to the letter found at FCG's archive, Ângelo de Sousa was not very determined to use a specific projector. He only refers to Kodak as an apparently reliable brand. Nevertheless, according to the scheme presented in the same letter, the projector is part of the scene. On the documentation related to the production process of the artwork found in Ângelo de Sousa's archive (Fig. 4.11), he mentioned a quartz lamp for the production of the work. Similarly, the same type of lamp (or with equivalent spectral emission) could be used in the projection to avoid any interference with the colour of the images. Although carousels with capacity for eighty slides are more common than those with capacity for one hundred slides, the latter should be pursued (even if the artist acknowledged the possibility of adapting the artwork to the capacity of the carousel). Since Ângelo de Sousa is no longer available to carry out a selection of slides to be displayed, and did not leave any instructions regarding that matter, the selection might raise issues related to the identity of the artwork, as it would allow to produce multiple versions of the work.
iii) Bench/small table/plinth as support for the projector;
iv) Easel with a 19th century appearance and a hand crank;
v) White canvas with 90 x 120 cm (or larger if within the same proportion);
vi) Slightly dark room;
When a slide-based artwork is installed at the exhibition site, it must be adapted to the space (Philips 2015, 169). Different factors such as room size and illumination might influence its perception. Although no documentation was found referring to this issue, it was assumed that the room should not be completely dark so that the easel and canvas can be slightly visible. Though, the levels of luminosity should not be very high otherwise the colours of the slides might not be correctly perceived. Moreover, although the work has been displayed in a single room lately, nothing leads us to think that was the artist's choice. Although no graphic information was found regarding the display of *Slides de Cavalete* in 1979, based on the photographic documentation consulted at the FCG's archive, the exhibition space was shared with other artists' works.
vii) One last issue to be considered is the projection duration of each slide. Since no references were found related to that matter, some tests have been carried out in order to define a frame time. Based on those tests, it is advised to project each slide for a period of 8 to 12 seconds, which seemed the appropriate to fully appreciate each image.

Additionally, special attention should be paid to the subtitles, both on the exhibition site and in the catalogue. Information relating to the materials of the original artwork and exhibition copy should be described. In order to provide additional information to the visitor, a brochure could be made available at the exhibition site. This brochure should contain a brief context description, a short description of the production process, information about the conservation condition, and some clarification about curatorial options, especially if new elements were added. This data would help the public to understand the artwork. This same information should also be available in the exhibition catalogue.

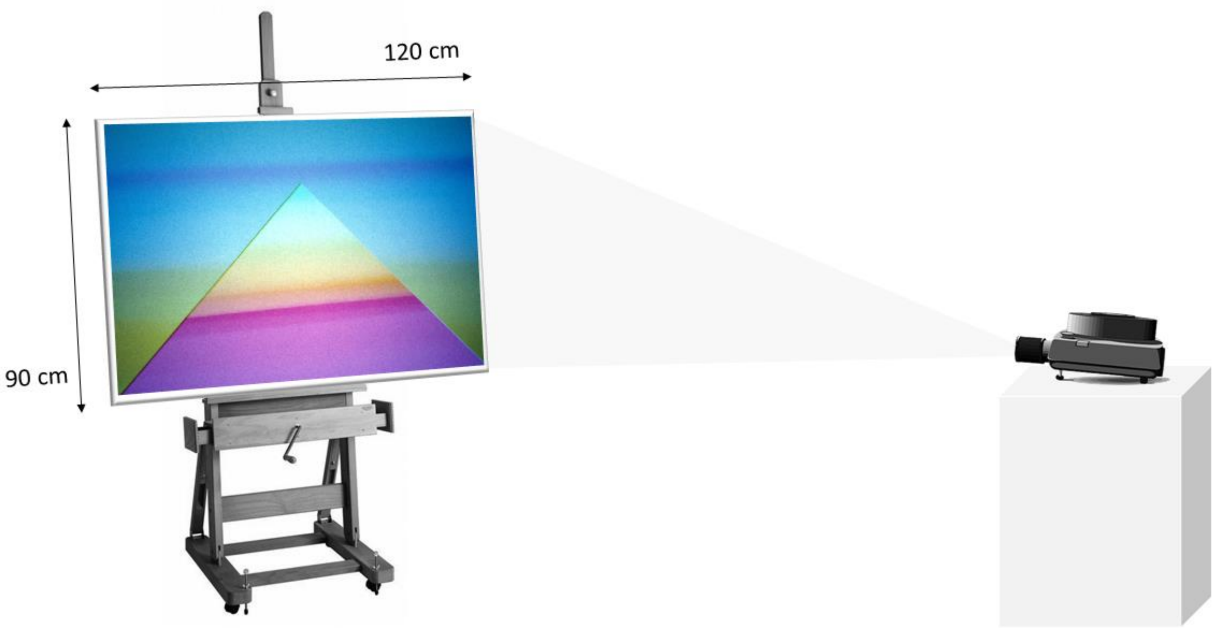


Figure 5.13 - Scheme representing the proposed setup for the exhibition of *Slides de Cavalete* (1978-1979).

A catalogue for the preservation and presentation of the artwork under study was created and is presented in appendix VII.

As explained in chapter 4, during the testing for the production of *Slides de Cavalete*, Ângelo de Sousa conducted several experiences to test the setup, the conditions, and the results that could be achieved by working with the additive mixture of colours. From these experiences, he chose the one hundred slides to be presented as *Slides de Cavalete*. The remaining test slides were never exhibited during the artist' s life. However, some of the results obtained from this experimentation are interesting images, such as the colourful hand shadows produced in 1979. In the artist's archive, eight images of hands constructed with additive synthesis were found. This series was presented after Ângelo de Sousa's death, in the exhibition *Encontros com as Formas* (2014) at Galeria Fundação EDP (Porto). Four 18x26 cm inkjet prints were displayed (Fig. 5.14).

Several questions arise when considering the exhibition of this series. However, two fundamental questions should be highlighted:

- Since the artist did not choose those images to be presented, should they ever be displayed? If so, how should they be presented to the public?
- Should this series be seen as an artwork or as a testing?

Unfortunately, up to now, not enough information has been collected to answer those questions based on evidence. Nevertheless, a few considerations are expressed next.

As explained in chapter 3, Ângelo de Sousa only used to keep the positive outcomes of his artistic production. Part of his working process consisted of making a selection among a set of works, and throwing away unwanted images (drawing, slides, among others) (Sousa 2014). Therefore, it can be stated that the artist chose to keep those test slides. Additionally, the fact that the artist did not displayed these images during his lifetime, does not mean that he thought that they should never be presented. Taking this into account, and assuming that this series can be displayed, their context of production should nevertheless be made clear to the visitor and that they were not selected by the author as a final work to be presented.

Figure 5.14 - Exhibition of the untitled work [colourful hand shadows] (1979) in *Encontros com as Formas*, 2014[28].

5.3.2.3. Experimental study at FCT NOVA

An experimental study was carried out, which consisted on the exhibition of the *Slides de Cavalete* within two scenarios of presentation: scenario A - digital projection, and scenario B - slide projection. The experimental study was organized at the Library from FCT NOVA[29], between the 23rd and 27th April 2018, according to the program summarized in Table 5.2. During the first and third days of the exhibition, the artwork was displayed using a digital projector, and on the second and fourth days, using a conventional slide projector (Fig. 5.15). In the first and last days of the exhibition, a workshop was offered with the intention of explaining the production process behind the artwork. Additionally, on the first day, three different seminars were held to present the artist and the artwork under study, its technology and its exhibition history to the public. On the last day, a roundtable was organized aimed at bringing together connoisseurs on Ângelo de Sousa photographic production. Sérgio Mah, Miguel Wandschneider and his son, Miguel de Sousa, were invited to discuss the problems associated with the exhibition of *Slides de Cavalete*.

[28] https://makingarthappen.com/2014/04/16/encontros-com-as-formas-fotografias-e-filmes/ (accessed on 18/09/2018).
[29] At *Sala Estúdio*.

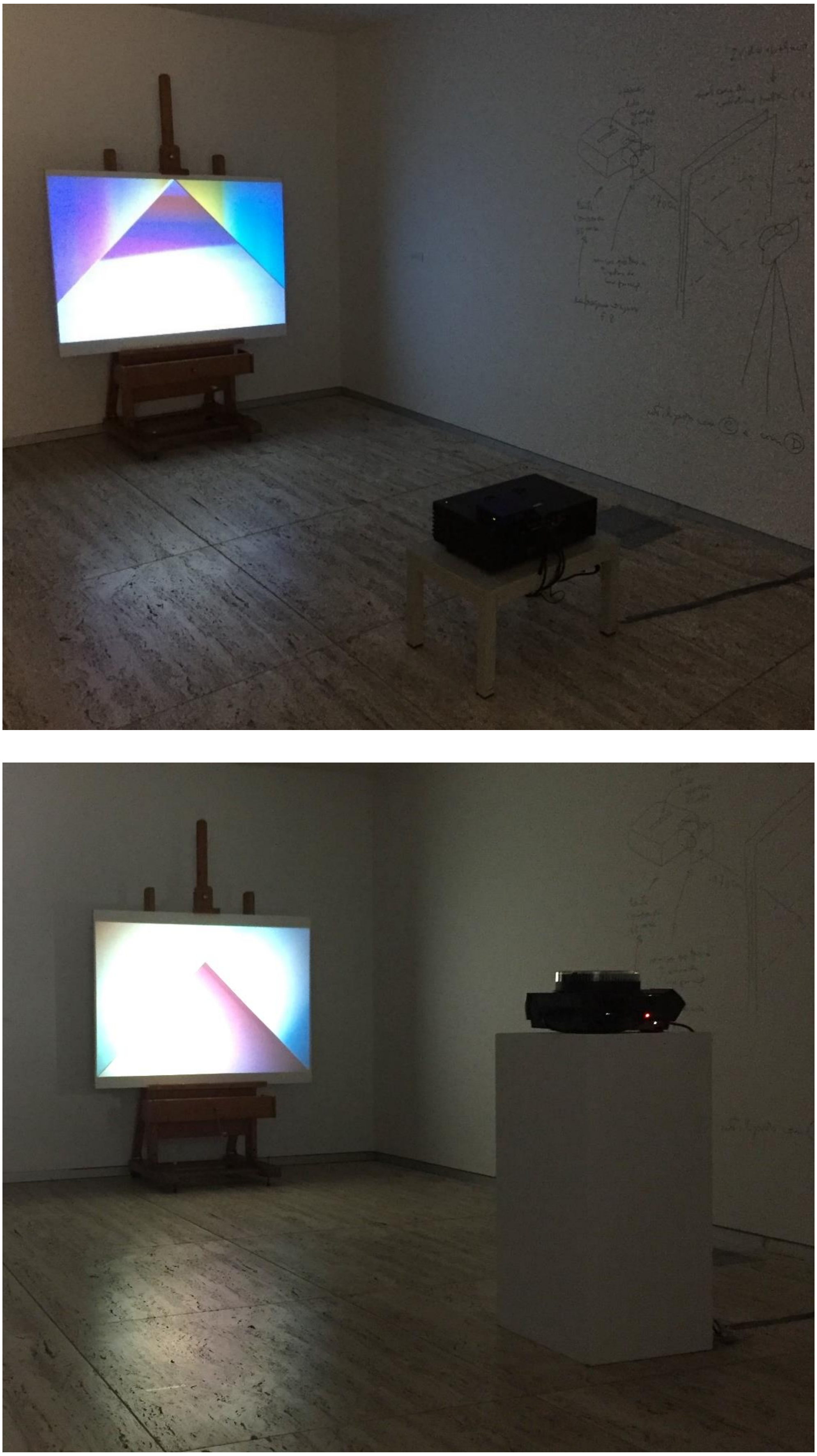


Figure 5.15 - Views of the work *Slides de Cavalete* (1978-1978) presented at *Sala Estúdio* (Library from FCT NOVA); Top: digital projection; Bottom: slide projection.

Table 5.2 - Schedule of the experimental study at FCT NOVA

1st day	2nd day		3rd day	4th day
Digital projector	Slide projector	closed	Digital projector	Slide projector
Opening Seminars Workshop Exhibition	Exhibition		Exhibition	Roundtable Workshop Exhibition

For the collection of information related to the exhibition, an *ad hoc* questionnaire was used. Methodological aspects of the study are described hereafter.

The target population was the public at large. However, an intentional sampling was completed by personally inviting some individuals, such as professionals from the conservation field outside the university, as well as professors and colleagues from the university (Department of Conservation and Restoration - DCR, and Chemistry). Additionally, the first year Master students from the DCR were formally invited to participate in the study. At the end, the sample consisted of thirty-nine persons (number of persons who observed the two scenarios of presentation and answered to the questionnaires)[30].

Regarding the exhibition of the work, during the mentioned days, *Slides de Cavalete* was continuously (in loop) presented from 9 am to 6 pm. The work was projected onto a white canvas mounted over an easel, according to its first presentation, as it was considered the best solution to preserve both the aesthetic and historicity of the work (as explained in the previous section). The canvas used to project the work, brought from Ângelo de Sousa's archive, was 96x128 cm and coated with a white preparation[31]. The easel had a 19th century appearance, as described by the artist in the documentation found at the FCG's archive. In both digital and slide projections, the work was presented in the same room with the same conditions. A plan of the room and disposition of the equipment is presented in Figure 5.16.

The illumination of the room was only provided by natural light coming from the entrance. In order to offer additional information about the artwork to the public, relevant materials used by the artist to produce the work and documentation were presented inside a showcase at the back of the room. The objects on display were: i) the file *Slides* with the text explaining how to produce the slides from *Slides de Cavalete;* ii) the RGB and other filters used to produce the work; iii) some tests (slides) produced within the experimentation for the production of the work; iv) the catalogue from the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979); v) a *facsimile* of the letter found at the FCG' s archive, explaining how he wanted to display the work in the 1979 exhibition. One of the schemes by Ângelo de Sousa (found in the file *Slides*) explaining the equipment and materials necessary for the execution of the slides was reproduced on one of the room walls (Fig. 5.17). Moreover, a brochure containing information mainly related to the production process was available for the visitors (see appendix IV, Figs. IV.10 and IV.11).

[30] The total number of visitors is unknown.
[31] The preparation was made by the artist or by his assistants.

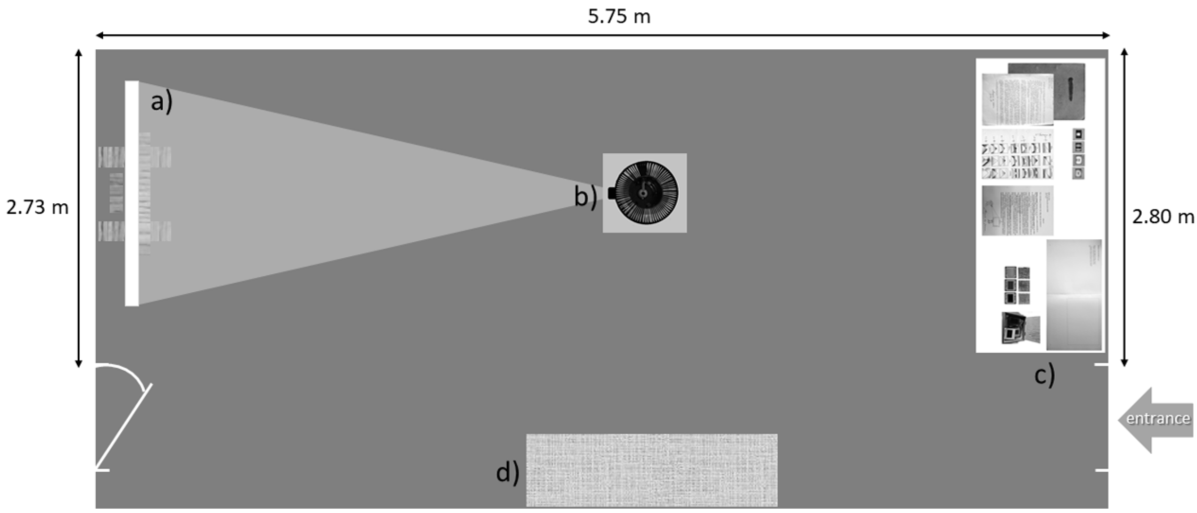


Figure 5.16 - Scheme of the exhibition setup at FCT NOVA (top view);
a) canvas over an easel; b) projector over a support; c) showcase; d) bench.

Figure 5.17 - View of the exhibition space at FCT NOVA, showing the reproduction of a diagrammatic projection scheme by Ângelo de Sousa on the wall and the showcase.

Regarding scenario A, a Panasonic PT-AE4000 was used to project digital images of the work[32]. Regarding scenario B, a set of exhibition copies was produced to be displayed in the slide projector. The copies were ordered from the same company and using the same methodology as in the exhibition

[32] Three different digital projectors were tested. Panasonic PT-AE4000 was the only one leading to good results, and thus, the one selected for the exhibition.

Encontros com as Formas (2014)[33]. Unfortunately, the obtained colours were not very accurate: the copies presented less vivid and darker colours than the original artwork. Nevertheless, these slides were presented at the exhibition. Colour accuracy was not easier to achieve with the digital projection; it was difficult to obtain a good reproduction of all the colours in the same image within the several modes and adjustments tested. The slides were projected with a Kodak EKTALITE 2000 slide projector. Since the carousel of the projector had only the capacity for eighty slides, a selection of the slides to be projected had to be made[34]. Although, as mentioned in the previous section, the work should be presented in a carousel with capacity for the one hundred slides, considering the availability of the equipment, and above all, the context of the exhibition (experimental study), the work was presented this way. Nevertheless, the images were judiciously selected, looking to maintain the proportion of images with triangular and rectangular shapes and the representativeness of images to be presented. This last task was quite difficult, especially for the second part of the work, since the images with rectangles have a higher chromatic complexity and, therefore, a higher variability from image to image. Although the global work could have been projected with the digital projector, it was decided to present the same images in both projections to avoid undesirable differences in the two scenarios of experimentation. Each slide was projected for 9 seconds before changing to the next one. Therefore, considering the passage between slides, about 14 minutes were necessary to see the overall work.

As previously mentioned, a questionnaire was designed within the outline of this experimental study to evaluate certain indicators. The questionnaire was composed of a total of nine questions, regarding: i) characterization of the participants (genre, nationality, age range, level of education, training area, profession, and frequency attending exhibitions), ii) attendance or not attendance at the workshop about Ângelo de Sousa and the production process of *Slides de Cavalete*, iii) perception of the aesthetic quality of the artwork itself, iv) perception of the quality of the projection. For the two last items, a Likert-type scale with four points was applied, as follows: iii) excellent quality, very good quality, mean quality, reduced quality, and iv) excellent ambience, very good ambiance, mean ambience, bad ambience. Within the research design, the independent variable 'attendance at the workshop' was intersubjective with the levels 'attend at the workshop' and 'did not attend at the workshop', and the variable 'projection technology' was intrasubject with the levels 'slide projection' and 'digital projection'. Eight dependent variables were considered, namely four variables for the perception of the aesthetic quality of the artwork (colour brightness, colour beauty, visual harmony and chromatic quality), and four variables for the perception of the projection quality (rhythm of the projection, sound of the projection, beauty of the projection, harmony between work and projection).

The two scenarios of exhibition were intentionally built with the same characteristics. However, due to technical limitations related to the display equipment, depending of the projector in use, a different support was employed in each case. In scenario A, the digital projector was placed over a small grey table. In scenario B, the slide projector was set over a white plinth. Any variations occurring between two scenarios were only related to the display equipment setup.

Thirty-nine participants visited the two scenarios, within the frame time available for each type of presentation. After the observation of the artwork, the same questionnaire with the same questions

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[33] The same digitisations made for that exhibition were exposed with a film recorder in chromogenic reversal film. The original TIFF files are 16 bit/channel and in AdobeRGB(1998) colour space. These files were compared with the original slides and seem visually quite similar in colour when viewed in a calibrated light box slide viewer. The screen of the computer and light box were both calibrated at T=5100K for comparison. The printing was made by the company *Digital Slides*: https://www.digitalslides.co.uk/wp-2013/ (accessed on 18/09/2018).
[34] Removed slides: 5, 8, 14, 17, 19, 32, 36, 40, 41, 46, 51, 53, 57, 59, 64, 69, 76, 91, 93 and 95.

was distributed to visitors, who immediately filled out the form. To avoid influencing the respondents, the visitors were not in possession of additional information concerning the aims of the study. Moreover, the questionnaires were anonymous. This approach was followed to guarantee the homogeneity of the data and reliability of the results. The obtained answers were processed using statistical software[35].

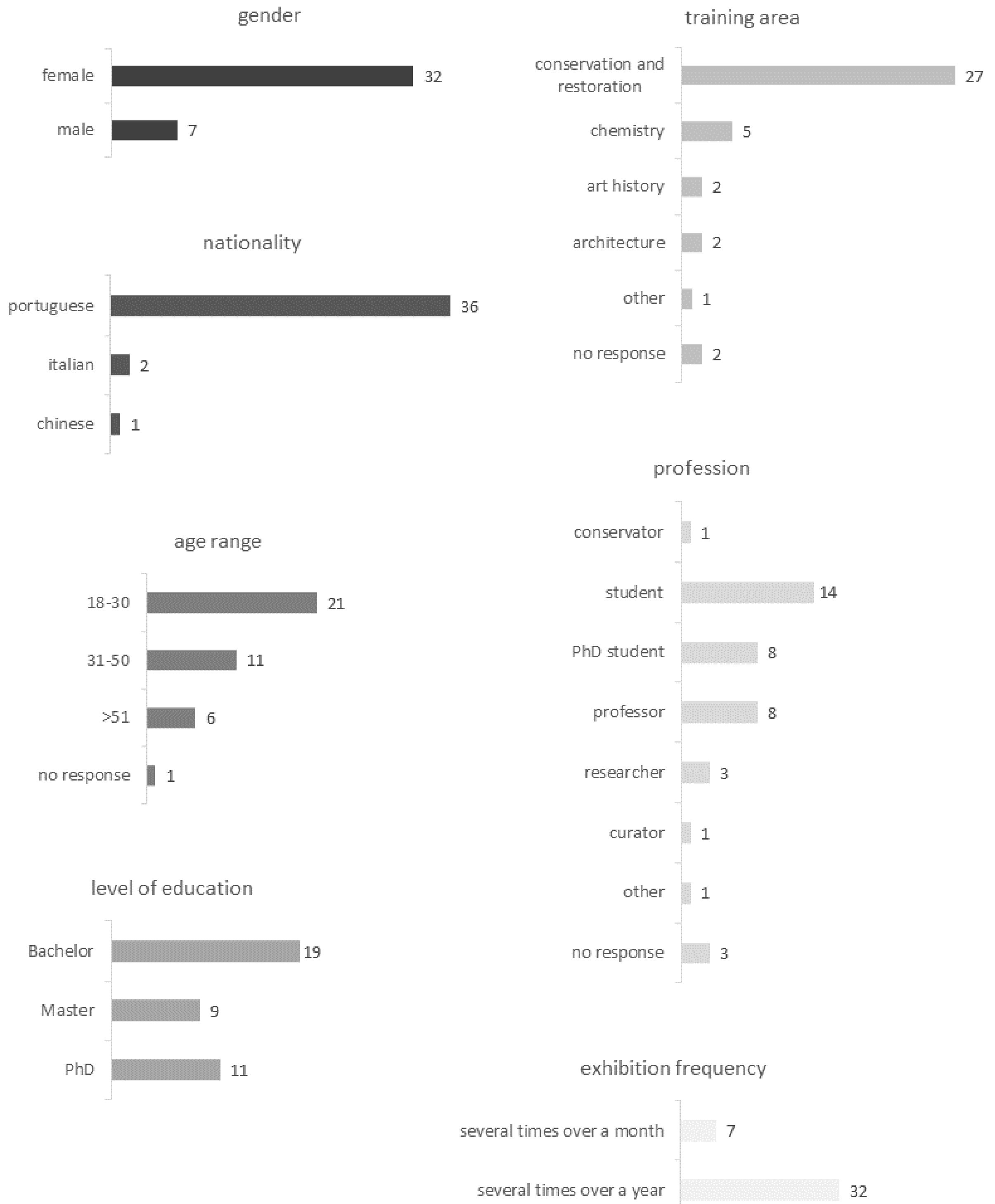

Figure 5.18 - Frequency (number) of the responses regarding the characterization of the 39 people who answered the two questionnaires.

[35] Wizard.

The characterization of the questioned people is presented in Figure 5.18. Most people who participated in the study are Portuguese. The age range of the majority of the respondents is less than thirty-one years old. The great majority are from the conservation field, either conservators or (mainly) students. As a consequence, a considerable number of respondents are female. The respondents are people who visit exhibitions with a certain frequency. All questionnaires were filled by persons with high education.

An attempt to correlate the characterization of the respondents with the obtained results was made. However, no statistically relevant relationships could be established. The results obtained by comparing the two scenarios of experimentation against the evaluation criteria i) image quality and beauty, and ii) global scenario/installation, are summarized in Figures 5.19 and 5.20. When comparing the two scenarios of experimentation, within the various parameters, a significant difference can be observed by applying the Wilcoxon signed rank test[36] ($p<0.001$). In a general overview, the respondents had a better appreciation to the experience of the artwork presented with the slide projector than with the digital projector. Regarding the image quality and beauty, most of the respondents classified the several variables of the digital projection as having good quality, with the slide projection as having excellent quality. Regarding the slide projection, the variable 'colour beauty' can be highlighted, having 85% of the respondents classifying it with excellent quality. The 'colour brightness' had the worse classification among the slide projection, with only 51% of the respondents considering it as having excellent quality. Nevertheless, this variable had a far better classification than it had with the digital projection. In general, the evaluation of the digital projection is more distributed amongst all variables (values spread between excellent and mean quality), than it is for the slide projection.

Regarding the global scenario/installation, the same tendency was observed in a more discernible way. In the slide projection, all variables were classified above 70% as having excellent ambience. Thus, there was a very clear positive appreciation of the global scenario/installation for the slide projection. In the classification of the digital projection, the opposite can be observed. The evaluation is distributed between excellent and bad ambience. The variable 'harmony between work and projection' in the slide projection can be underlined since 95% of the population classified it as having excellent ambience. This classification contrasts highly with the classification of the same parameter in the digital projection, in which only 23% of the respondents considered it as having excellent ambience and 10% considered it had a bad ambience. Regarding the variable 'sound of the projection', 29% of the respondents considered that in the digital projection there was a bad ambience, whereas in the slide projection 78% considered that there was an excellent ambience. Nevertheless, this parameter was quite ambiguous for a certain number of people, since the sound was non-existent in the digital projection. This fact is reflected in the percentage of respondents that did not classify this variable (10.3% missing). Similarly, it can be concluded that certain people also had difficulty to classify the variable 'beauty of the projection', since 5.1% of the population did not respond.

[36] Nonparametric test for matched or paired data. It is based on the average difference of scores, considering both the sign and the magnitude of the observed differences (Marshall n.d., 22).

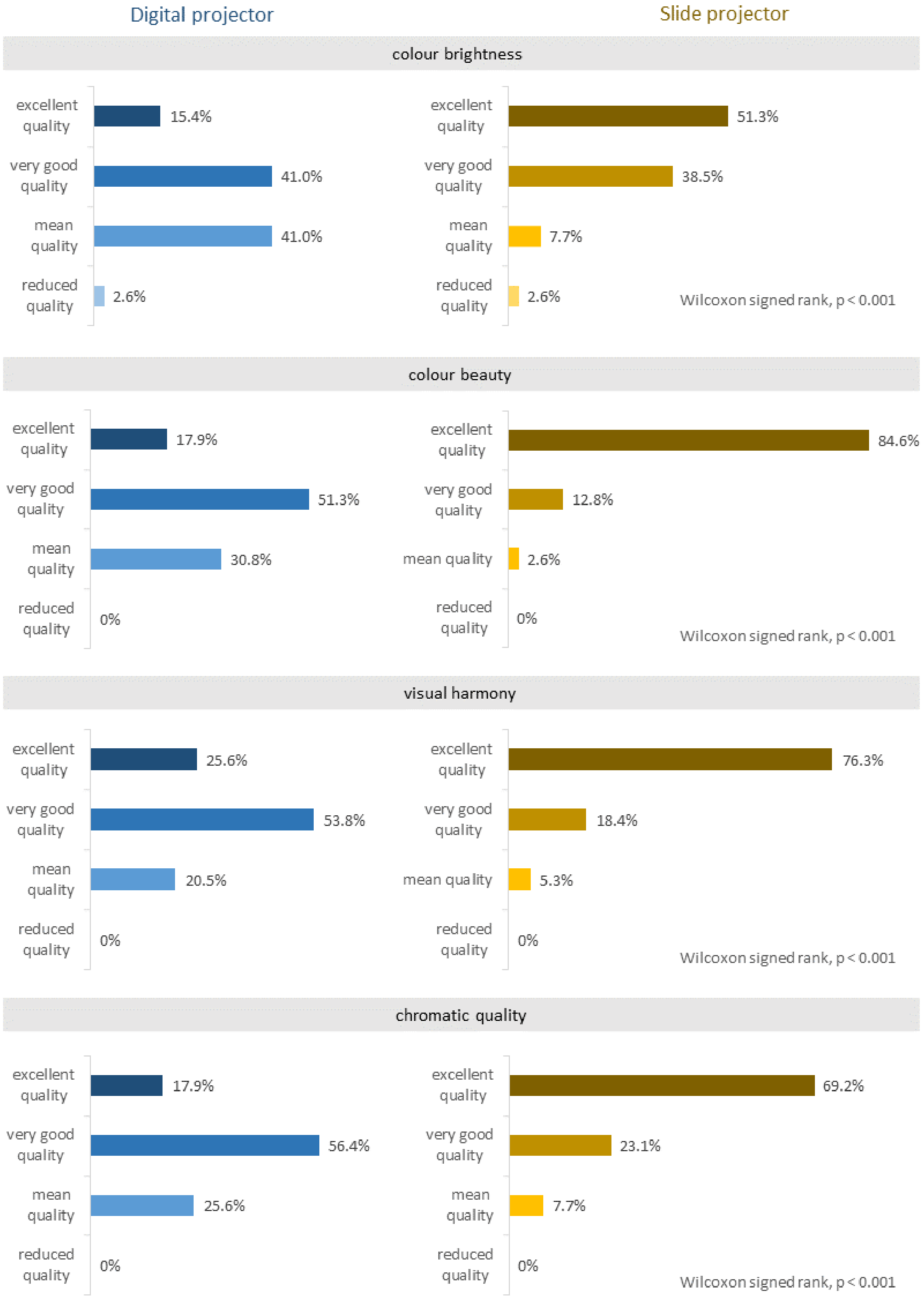

Figure 5.19 - Frequency (%) of responses to questions regarding the image quality and beauty (total of 39). Graphics in blue represents the digital projector; graphics in yellow the conventional slide projector.

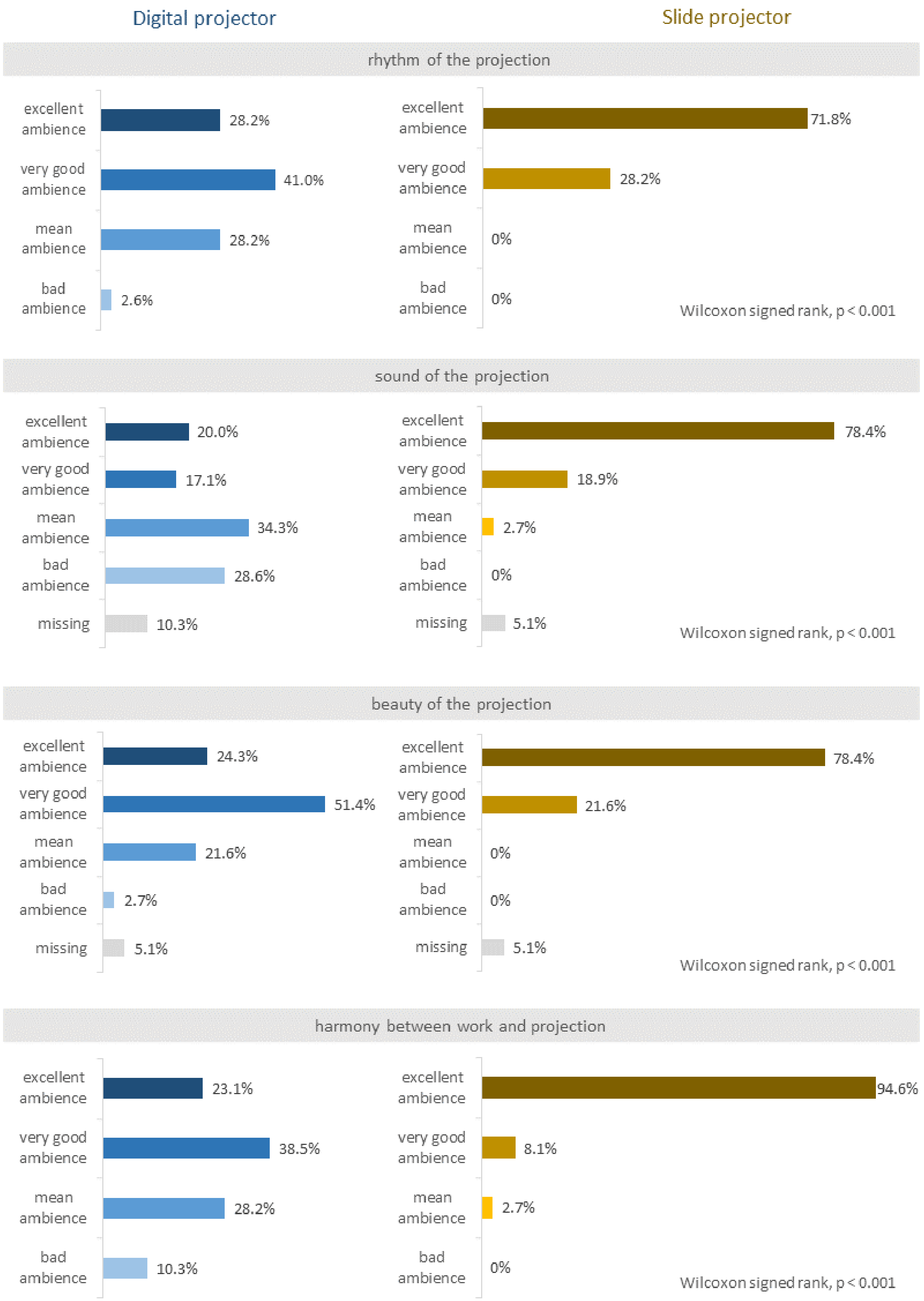

Figure 5.20 - Frequency (%) of responses to questions regarding aspects of the global scenario/installation (total of 39). Graphics in blue represents the digital projector; graphics in yellow the conventional slide projector.

The impact of the third variable, the attendance or not to the workshop in the perception of the artwork, was studied by applying the Kolmogorov-Smirnov[37] statistic to each scenario of presentation and parameter of evaluation. The results are presented in appendix IV, Figs. IV.16 and IV.17. In general, it can be stated that the attendance or not to the workshop had no statistical relevance in how respondents evaluated the various parameters. This finding might indicate that, independently of the visitor being informed about the production process of the artwork, they still prefer it presented with the slide projector.

In addition to the statistical treatment of the questionnaires, sixteen oral testimonies (41% of the respondents) were collected to enrich the obtained data. From these sixteen collected testimonies, eleven people clearly showed their preference for the slide projection, which is in line with the results obtained from the questionnaires. A few individuals stated that the work does not make sense presented with the digital technology, especially if projected on a canvas over an easel. Some people also mentioned the importance of the slide projector, as a testimony to the production process. Thus, the removal of the slide projector from the presentation of the artwork would mean the removal of a significant part of the work. Following the same idea, some people also referred to the importance of the original technology in the historicity of the work. Additionally, some persons raised the importance of the slide projector for the maintenance of the materiality of the work. A slide projection is produced by the passage of light through a chromogenic reversal film, which is matter, although a digital projection is based on the emission of light, which has a different appearance. One person also stated that the digital projector somehow removes the installation character of the artwork. Nevertheless, some people considered that the use of a digital projector to present the artwork is a fairly acceptable possibility. Some people stated that Ângelo de Sousa would have been amenable to the mutation of the work into digital. Regarding the perception of the image in both scenarios of experimentation, in a general way, people preferred the quality and beauty of the image projected with the slide projector. Three people noted that the most important issue to consider in the evaluation of the artwork is the image quality. Several people mentioned, as positive outputs, that the slide projection produced an image with more granularity, with hotter hue, and less plane and homogeneous when compared with the digital projection. Some people also highlighted the fact that a higher depth of the images was achieved with the slide projection (conferred by the darkness of the corners), which was lost in the digital projection. The sound of the projection was a variable often mentioned in the oral testimonies. Two people noted that the sound from the slide projector could be somehow disturbing, distracting the attention from the image itself. In one testimony, it was noted that the absence of sound could lead to a sort of a sublime state during the observation of the sequence of the images. However, the majority of people considered the presence of the sound, so characteristic of the slide projector, as an important factor, conferring a narrativity to the artwork and capturing the visitor’s attention. The rhythm of the slide projection, induced by the passage of the slides, was also mentioned as a positive issue that would create the feeling of a sequence or a narrative. One person referred to digital projection looking faster than the slide projection, possibly due to a more sudden and unforeseen transition between images.

Besides the oral testimonies, the author of this dissertation also observed people and took notes of the relevant information that arose from conversations between visitors during the exhibition time. From this intervention, it deserves to be stated that several students had never seen a slide projector before that exhibition. Some did not even understand, at first, if the artwork was being displayed with

[37] Nonparametric test used to compare two samples and detect non-normality. It is based on the distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution (Marshall n.d., 12).

a digital or a slide projector. When some of the students saw the slide projector, they were very enthusiastic about it. This leads to the conclusion that the subtraction of the original technology might make especially significant consequences for the future (and even current) generations. Even if it is explicit to the public that the original technology was slides and slide projection, most (younger) people who do not know what a slide projector is, might not be able to comprehend what it means since that technology is no longer part of their life experience.

It is important to reinforce that the described information was obtained from questionnaires and oral testimonies made to a very specific population. As previously mentioned, most of the people who visited the exhibition were from the conservation field. Normally, conservators are trained to observe and study the materiality of objects. Therefore, this characteristic almost certainly influenced their perception of the artwork under study. Nevertheless, people from other training fields were also part of the population who answered the questionnaires and shared their experience of the work within the two scenarios. Moreover, according to the statistical treatments applied to the obtained data, no special trends could be established for the different professions or training areas of the respondents.

As previously mentioned, in the 4th day of exhibition, a roundtable was organized with experts in Ângelo de Sousa's work: Sérgio Mah, Miguel Wandschneider and Miguel de Sousa. During the public session, different subjects were approached related to the artist's photographic production in general, based on the personal experience of each one of the participants. Regarding *Slides de Cavalete*, the discussion was mainly focused on the paradigm analogue vs digital. Sérgio Mah shared the testing performed within the framework of the exhibition *Encontros com as Formas* (2014), previously described on this section. All agreed that the slide projection should be pursued when displaying the artwork. Less was said about the sculptural relevance of the work and the documentation found in FCG's archive. Nevertheless, during the day, the author of this dissertation was able to speak with the guests. Neither Miguel de Sousa nor Sérgio Mah have taken a demarcated stance about the display of the work. On the contrary, Miguel Wandschneider stated that the work does not have to be presented with the canvas over an easel. In his opinion, this would make the work dated. Moreover, he felt like it was redundant, considering the title of the work.

5.2.3.4. Digital restoration

As defended by Kayley Vernallis (1999, 461), some types of degradations leading to loss of information can somehow be compensated by the human brain. For instance, a scratch or even a small lacuna, can mentally be filled based on the uninjured adjacent areas. However, when severe colour change occurs in a photograph (which normally is uniformly spread on the overall image) there is no way to proceed in the same way (Vernallis 1999, 461). In a typical colour photograph, that reflects the reality as we see it, a shift in colour balance might lead to a significant loss of meaning. Nevertheless, as defended by different authors (Wilhelm and Brower 1993, 89; Vernallis 1999, 469-470), the degradation of certain colours is more tolerable than others. Normally, familiar colours (colours we are used to recognise), such as the colour of the skin or the blue sky, are less suitable to diverge. According to the study conducted by Clare Richardson and David Saunders (2013, 185), changes in abstract images are considered more acceptable than in other types of images. The tolerance in colour shift is also much smaller with prints viewed in normal surrounding, than in projected images viewed in a dark atmosphere (Tuite 1979, 476). Nevertheless, in works such as *Slides de Cavalete*, in which the artistic intention relies unequivocally on colour exploitation, the expressive qualities can be highly sensitive to colour change and dye fading.

Considering this scenario and the framework of this dissertation, a contribution to the approximation of the original colours from *Slides de Cavalete* was considered necessary and a demanding task. Nevertheless, colour corrections should only be done with substantiated data (especially in the absence of the artist), otherwise false adjustments might occur and disrupt the aesthetic value of the artwork. In the interview *"A Felicidade no Gatilho": Entrevista a Ângelo de Sousa* (Sousa 2001, 15), Ângelo de Sousa reported that for the production of the exhibition *Sem Prata*, 2% to 8% of M was removed from the majority of the digital images obtained from the slides. When the image is a representation of the natural world, it might be quite straightforward to know which direction colour deviation is taking. However, in images with no references to the natural world, such as the work under study, colour correction is a very delicate issue. Thus, all the information collected during the present study was considered before proposing any colour correction.

As described in chapter 3, the photographic and film collection by Ângelo de Sousa has been kept under T and RH values above the recommendations, and the work *Slides de Cavalete* is no exception. In general, all chromogenic dyes are highly susceptible to hydrolysis and oxidation under these conditions (dark fading). Since some dyes are chemically more stable than others, the fading rate is different from dye to dye. Moreover, residual colour couplers from materials of the incorporated dye coupler type, are also susceptible to degradation, leading to a yellowing of the emulsion (yellow stain). Therefore, these materials are prone to present dye fading and changing in colour balance (Bergthaller 2002c, 265). According to the conducted investigation previously presented in this chapter, the original slides from *Slides de Cavalete* were projected in at least two exhibitions. Based on the studies carried out by Henry Wilhelm and Carol Brower (1993, 216), chromogenic reversal films can be projected between 20 to 50 minutes, depending on the type of film and projector light, before objectionable fading is discernible. Light fading can lead to the same type of degradation as produced by dark fading. However, if in the dark fading loss of density is normally homogeneously spread over the image, in light fading the image is more affected in the highlights or low-density areas (Wilhelm and Brower 1993, 221). Considering that *Slides de Cavalete* suffers both from dark fading and light fading, and although it might be difficult to predict the exact amount of change induced by these two courses of degradation, a digital approximation to the original colours was attempted. The proposed digital restoration was based on published research made by Henry Wilhelm and Carol Brower (1993) between the 1980s and 1990s. During that period, the authors tested several chromogenic reversal films contemporary to the work *Slides de Cavalete*, and, specifically, the film used by Ângelo de Sousa to produce this work - Kodak Ektachrome 160T Professional.

According to the accelerated aging tests conducted by Henry Wilhelm and Carol Brower (1993, 176)[38], the major change occurring in Ektachrome films (Process E-6 films) stored in the dark, was the development of high levels of yellow stain. Based on the same studies, the Y dye from Ektachrome 160T Professional films, proved to be the most unstable of the three dyes present in the film. It was estimated that 105 years would be necessary to reach a 20% loss of Y dye (limiting dye) if that film was stored in the dark at 24˚C and 40% RH (Wilhelm and Brower 1993, 203). On the contrary, M dye was considered the most stable to dark fading (Wilhelm and Brower 1993, 223). Regarding light fading, according to the tests conducted by the authors[39], the least stable dye in Ektachrome films (in general) is the M, followed

[38] Artificial ageing tests induced at 62˚C and 45% (Wilhelm and Brower 1993, 193).
[39] Artificial ageing tests induced by projecting slides (open frame mounts) in a slide projector (GE type EXR Lamp) on high lamp position (Wilhelm and Brower 1993, 215).

by the C, with the Y the most stable dye. Thus, a projector faded Ektachrome normally presents a colour shift toward green, due to the disproportionate disappearance of the M dye[40], mainly visible in the highlights (Wilhelm and Brower 1993, 222-223) (Fig. 5.21). Unfortunately, no light fading tests were published by Wilhelm and Brower specifically for Ektachrome 160T Professional films, and therefore the degradation of Ektachrome in general was considered. Thus, these two degradation pathways, for dark and light fading, were taken as a reference for the present study.

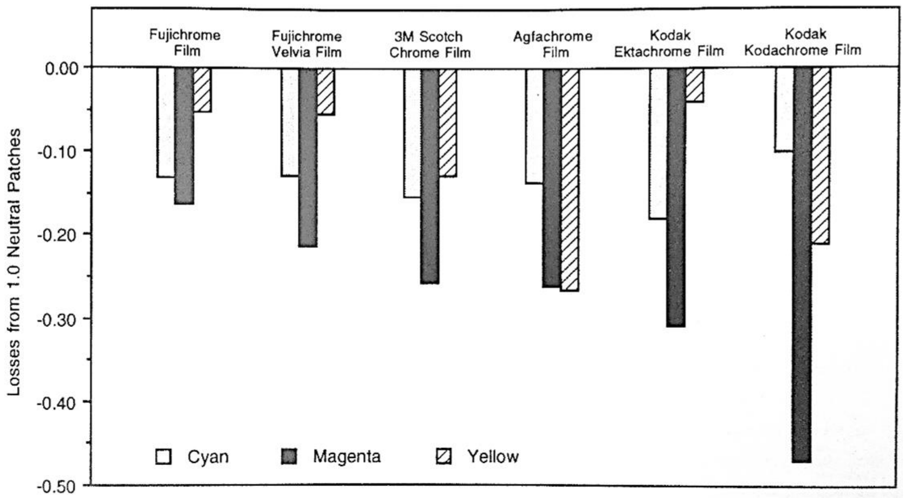

Figure 5.21 - Fading of different chromogenic reversal films, including Ektachrome, following C, M and Y dyes in 1.0 neutral patches (Wilhelm and Brower 1993, 214).

The digital restoration process was made in a computer with a screen with an AdobeRGB(1998) colour space (screen and display card: 10 bit color depth) and calibrated, to allow the proper observation of the image colours[41]. The high-resolution digitisations made from *Slides de Cavalete* for the exhibition *Encontros com as Formas* (2014) were treated by using the software Adobe Photoshop. Two treatment layers were generated: i) to recover the dark fading, ii) to recover the light fading. In both cases, linear corrections were applied to the RGB curves. Since C, M and Y dyes are complementary to RGB colours, respectively, RGB coordinates can be used to describe the behaviour of the dyes. Being this relation inversely proportional, a decrease in dye concentration means a positive variation in the respective coordinate and an increase in dye concentration means a negative variation (Fenech 2011, 97-98). Thus, the corrections were applied as follows: i) R(-6), G(0), and B(-7) (Fig. 5.22), ii) R(-6), G(-10), and B(-2) (Fig. 5.23). These values were based on Henry Wilhelm and Carol Brower's studies, considering the fading rate of the C, M and Y dyes, previously described. The two layers were than applied to the digital files (TIFF format) as Photoshop action. Assuming that all images suffered from the same amount of change induced by thermal and photo degradation, the same action was applied to all images composing the work under study.

The obtained results were quite satisfactory. In general, it can be stated that, after treatment, the images look less Y, as expected. On the one hand, the highlight areas (white) became whiter. On the other hand, the primary colours (RGB) and secondary colours (CMY) became purer. Additionally, in some slides, it is possible to observe that colour gradations became richer. This might be due to the fact that

[40] C and Y dye remain in the emulsion layers, and according to the subtractive mixture, their sum is green colour.
[41] X-Rite colour calibration tool (colourimeter).

a dominant colour resulting from degradation was masking the original colours and interfering with the perception of the work. The applied corrections were minor, in order not to exceed a realistic amount of change that otherwise would lead to illusory colour adjustments. As desired, only a subtle change can be observed between the original and the restored digital images. It is possible that better results could have been reached if deeper colour adjustments were made. However, since it is very difficult to know the precise amount of change suffered by the slides, and because of the abstract nature of the image, it was decided to limit the digital restoration to an approximation of the original colours. Two examples of the obtained results are presented in Figure 5.24.

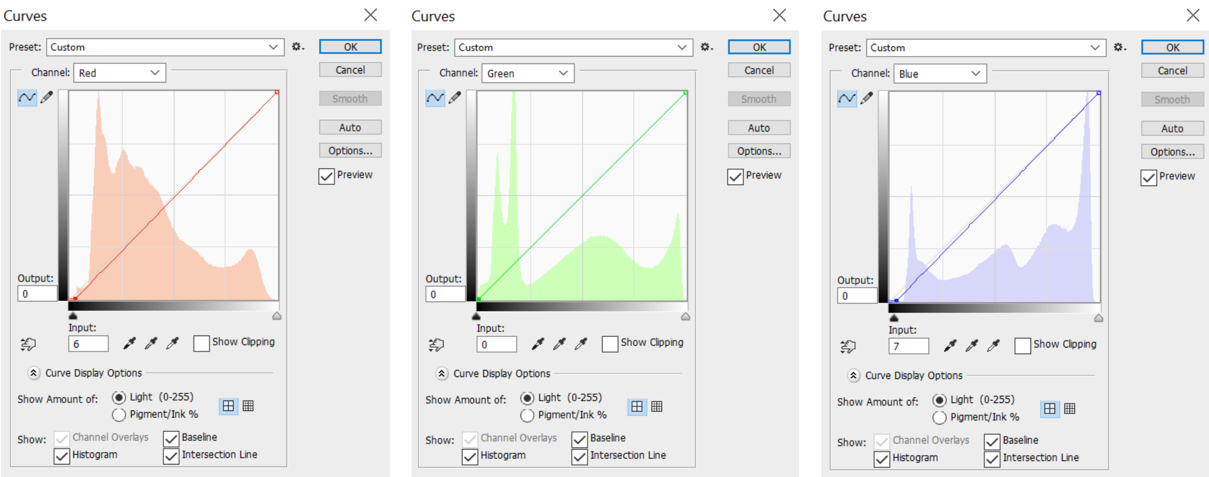

Figure 5.22 - Linear corrections applied for the R, G and B channels to recover dark fading applied to the digitisations of the work *Slides de Cavalete* (1978-1979).

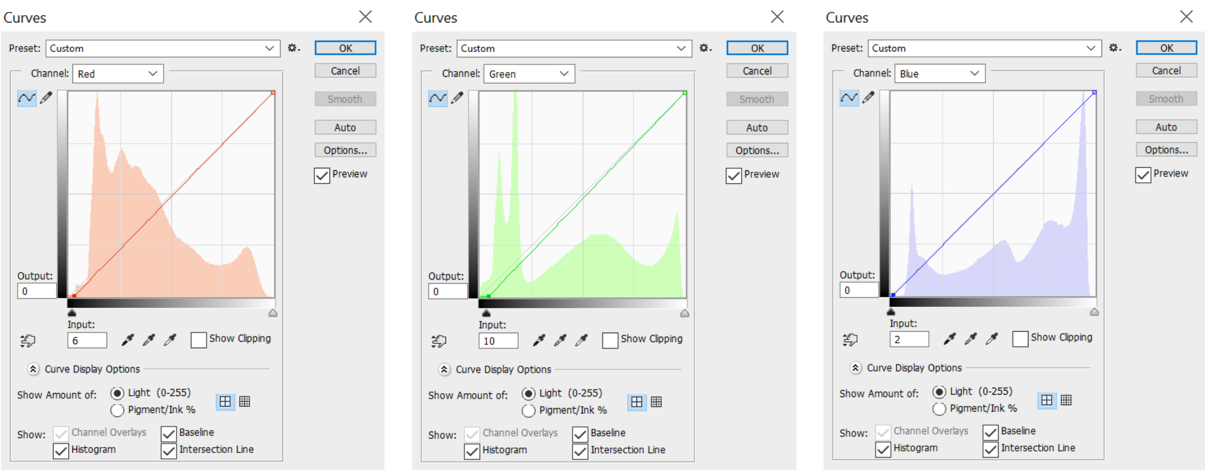

Figure 5.23 - Linear corrections applied for the R, G and B channels to recover light fading applied to the digitisations of the work *Slides de Cavalete* (1978-1979).

Thus, more tests should be done before assuming this approach as a good digital restoration. If so, the developed treatment can be applied before printing exhibition copies. This treatment is especially useful when using digital duplication. Yet, the obtained results can also be used to guide colour corrections applied during the duplication process or the projection of the work.

Before digital restoration After digital restoration

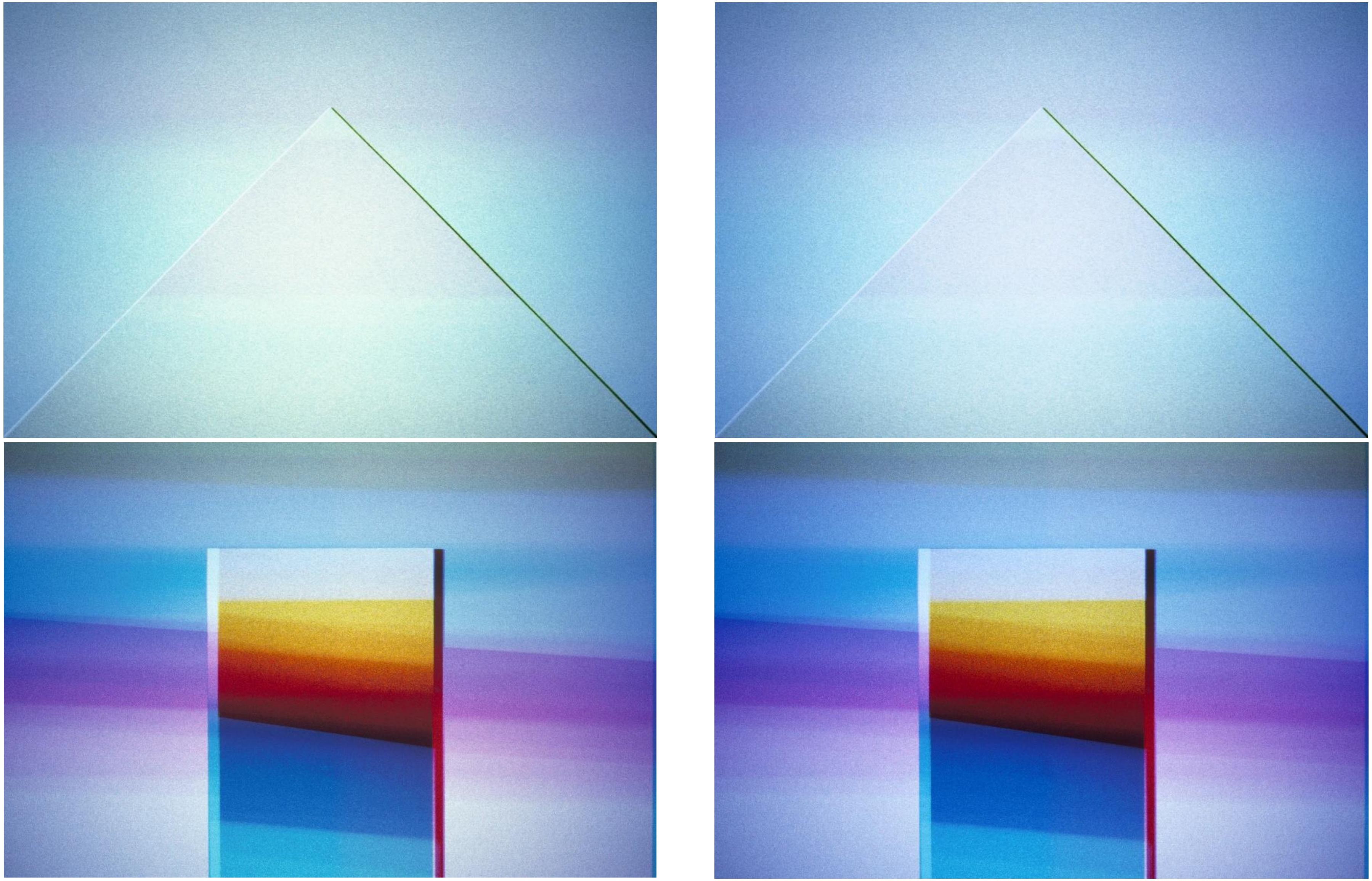

Figure 5.24 - Two examples of images from *Slides de Cavalete* (1978-1979), before (right) and after (left) digital treatment

5.4. Conclusions

Although during his life Ângelo de Sousa was mainly recognized for his painting, sculpture and drawing artistic production, he did present some of his films and photographs in exhibitions held in Portugal and abroad. In fact, the artist participated in some of the most important exhibitions dedicated to the use of audio-visual supports both by artists and photographer performed in Portugal at the end of the 1970s and in the 1980s, such as *A Fotografia na Arte Moderna Portuguesa* (1977) and *A Fotografia como Arte / A Arte como Fotografia* (1979). In 1976, he presented the work *A mão esquerda (1ª série)* (1975), at the *Biennale di Venezia*, one of the most iconic international art exhibitions. However, only scarce information remains from those exhibitions, and thus, most of the undertaken display options are not documented. Considering this knowledge gap, a contribution to a comprehensive history of the exhibitions with photographs and films by the artist was made in section 5.2 of this chapter. For such a purpose, published and unpublished sources of information found in Portuguese archives, such as the FCG's archive, have been studied. Additionally, several persons were interviewed to produce new sources of information. The collected data has been summarized in this chapter, aiming at providing a base to substantiate the decision-making process about the future exhibition of Ângelo de Sousa's photographs and films, particularly his slide-based artworks.

Although Ângelo de Sousa did show some openness to the migration of the original photographic and film supports to more recent technologies, chromogenic reversal films are one of the most representative photographic materials used by the artist. As was explained in chapters 2 and 4, the artist sought to explore the materiality of all means of expression with which he worked. Additionally, he made a pioneering use of these materials, which are important testimonies of the experiences made by artists with audio-visual supports in the *neo avant-garde* period in Portugal. Therefore, in general, the maintenance of the original technology should be pursued, especially if it was the solution adopted by the artist or if no references were left by him. Either by analogue or digital duplication, the generation of copies made by using chromogenic reversal film should be performed as soon as possible to ensure the continuity of the original technology.

Since each work should be addressed individually, *Slides de Cavalete* was used as a case study for an in-depth research, considering the importance of the work and its sudden frequent exhibition. This research brought new insights into the interpretation of the artwork under study. During the conducted research, it was understood that Ângelo de Sousa first presented the artwork projected on a canvas placed over an easel (being the projector part of the scene), at the exhibition *A Fotografia como Arte / A Arte como Fotografia* in 1979. This information was found in a letter sent by the artist to the FCG, in which he clearly explains how he wanted to display the artwork in that exhibition. This finding led us to unveil the important sculptural character of this artwork that had been subtracted over time. Since the artist's death, the work has been presented without the canvas and the easel. Moreover, in the last two exhibitions in 2017, it was presented as a digital projection. Unfortunately, it is possible to observe a gradual deviation from the first presentation of the artwork, which, without any communication to the audience, might have led to a misunderstanding of the work. Guidelines for the presentation of *Slides de Cavalete* are proposed in this chapter, aiming at providing a possibility for future generations to enjoy the artwork as it was first imagined by the artist at the time of its conception. Thus, the results from the conducted research can now be considered in future exhibitions.

In order to test the variability of the work projected with a digital projector and a slide projector, an exhibition/experimental study was organized at the Library from the FCT NOVA. For one week, the visitors were invited to see the work displayed with the two projections. To capture the perception of the public about the work presented under these two distinct scenarios of presentation, the visitors were invited to fill out a questionnaire. The results obtained from the questionnaires were very explicit and demonstrated that the respondents clearly preferred the experience of the artwork presented with the slide projector than with the digital projector. However, it is important to stress that the great majority of the respondents were from the conservation field, which might have weighted the obtained results. Thus, it would be interesting to replicate the experimental laboratory in other institutions, and to verify if a trend can really be established with certainty.

Lastly, an attempt to recover the original colours of the artwork under study was made. To do so, a digital restoration was applied to high-resolution digital files, by generating two recovering layers: one for the dark fading and another one for the light fading. The digital adjustments were based on the studies conducted by Henry Wilhelm and Carol Brower (1993). The digital restoration was limited to a slight approximation to the original colours to avoid skewed treatments. More testings are now required, so that the most accurate treatment can be applied to the slides from *Slides de Cavalete*. Digital restoration should also be designed taking into account the characteristics of the duplication film, to overcome colour deviations produced during the recreation of the work.

Chapter 6

Launching new strategies for the preservation of chromogenic reversal films

6.1. Preamble

After surveying Ângelo de Sousa's photographic and film collection (chapter 3), it was possible to conclude that 35 mm chromogenic reversal films are one of the most representative materials with which the artist chose to work. Unfortunately, about 37% of these materials now show visible colour change and/or dye fading. In 2001, within the framework of the exhibition *Sem Prata*, the artist already noted that almost all digitized slides had about 2% to 8% of excessive magenta (Sousa, 14-15). As described in chapter 2, the different dyes in a chromogenic product fade at different rates and, simultaneously, other degradation mechanisms might lead to the staining of the emulsion. During the study of the artist's photographic and film work (chapter 4), it was understood that additive and subtractive syntheses of colours served as a theoretical basis for the elaboration of a considerable number of his artworks. Some of these, namely the slide-based artwork *Slides de Cavalete* (1978-1979), proved to be truly ingenious, showing the mastery of the artist over the medium and colour manipulation. As explained in chapter 5, in works such as *Slides de Cavalete*, colour change might lead to particularly serious consequences and constrain the perception of the original work. Additionally, in works of an abstract nature, it might be difficult to understand if dye fading and/or shift in colour balance are occurring, and, if so, to what extent, making the problem even more complicated.

From this background arose the necessity to accurately document colour change in Ângelo de Sousa' slides. However, as discussed in chapter 2, when surveying the state-of-the-art of knowledge about chromogenic reversal films, a lack of recent studies focusing on the degradation of these materials and their colour monitoring was acknowledged.

The susceptibility of an artwork to degradation is highly dependent on the chemical nature of the materials composing the object. As stated by Oscar Chiantore and Antonio Rava (2012, 16), the conservator needs to know the artwork in-depth before taking any decision concerning its preservation. To do so, it is necessary to identify the material composition and to gather detailed information about its change over time (Chiantore and Rava 2012, 16). The more information about the materials the conservator collects, the better their condition can be accessed, and long-term predictions extrapolated. Unfortunately, in contemporary materials, the precise composition of the materials constituting an artwork can be difficult to determine, and therefore, the ageing pathway of the work cannot be accurately traced (Berndes 2005, 167). Particularly concerning chromogenic materials, up to the moment, there is no available methodology to identify the chromogenic dyes from a specific product. The current procedure to study this type of materials is to submit reference material samples (with the same brand and model as the work under study) to artificial ageing, in order to follow dye fading. However, chromogenic photographs are industrial products, which have been progressively upgraded. For that reason, it is nowadays difficult to find a product equivalent to the one used in the past. In addition, the batches of chromogenic materials become discontinued in a short timeframe. Thus, unless the initial condition of the artwork was documented (which is not common), there is no way to estimate how a specific chromogenic artwork has changed, making difficult to predict how vulnerable are its colours. One of the possible solutions to overcome this issue might be found in the study of the history of the chromogenic dyes over time and in its molecular characterization.

From this premise, a research study was carried out within the framework of this dissertation, focusing on the characterization of chromogenic dyes. Based on the isolation of the different dyes composing a chromogenic material, several procedures were proposed with the attempt to molecularly describe the dyes found in chromogenic reversal films. To do so, different analytical techniques, such as Thin-layer Chromatography (TLC), High-Performance Liquid Chromatography with Diode Array Detector

(HPLC-DAD) and linked to Mass Spectrometry (HPLC-MS), and Infrared and Raman Spectroscopies, were used. The results of this investigation are presented in section 6.3 of this chapter. Considering the state-of-the-art knowledge on the characterization of chromogenic dyes, section 6.3 only ambitioned to offer a contribution to this unexplored topic.

Additionally, this chapter aimed at developing a methodology to accurately describe and monitor both dye fading and shift in colour balance in chromogenic reversal films. Densitometers have been widely used to monitor dye fading in colour photographic materials, by both the photographic industry and conservation fields. However, this technique has some limitations and is becoming obsolete. Additionally, the instability of the measuring devices can put at risk the validity of the measurements, especially during long-term tests[1]. Therefore, UV-vis spectrophotometry with optical probes was used to analyse chromogenic reversal films upon ageing in alternative to densitometry. This is a non-destructive technique that allows both spectral and colourimetric analysis. By using optical fibre probes, reduced areas of the image can be analysed, which was considered a valuable contribution for the analysis of 35 mm films. Optical microscopy and digitization were also used as tools to assist the assessment of colour change in the artificially aged samples. The results of this study are presented in section 6.4.

Both subjects explored in this chapter have been developed with a view to their applicability in other collections with chromogenic reversal films besides the one under study.

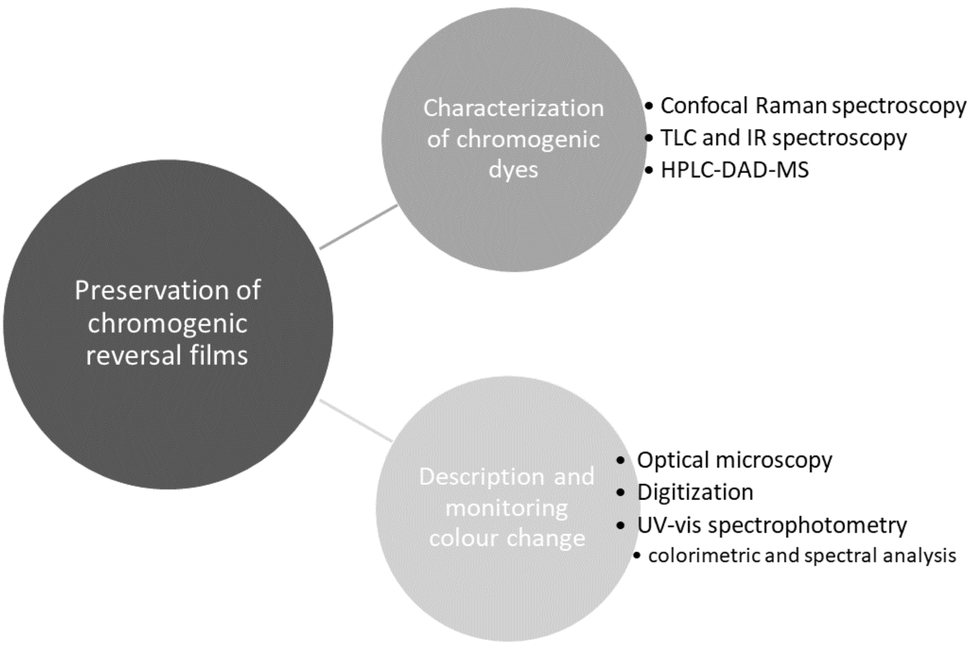

Figure 6.1 - Summary of the objectives and methodology adopted for the development of chapter 6.

Part of the content of this chapter was presented in two international conferences (one giving rise to a peer-reviewed paper):

Silva, J., Laia, C. A. T., Parola, A. J., Ferreira, J. L., Lavédrine, B., Ramos, A. M. 2017. New approaches for monitoring dye fading in chromogenic reversal films: UV-Vis spectrophotometry and digitization. *In*

[1] ISO 18909:2006(E), 3.

ICOM-CC 18th Triennial Conference, Preprints, Copenhagen, 4-8 September, ed. J. Bridgland, art. 1403. Paris: International Council of Museums.

Silva, J., Ferreira, J. L., Lavédrine, B., Ramos, A. M. 2016. Cellulose acetate based chromogenic reversal films: The case study of Ângelo de Sousa's photographic collection. Oral communication at *Plastics Associated with Photographic Materials*, The Foundation of the American Institute for Conservation of Historic and Artistic Works in collaboration with the Center for Creative Photography, 14 - 18 March, Tucson, Arizona, United States of America.

6.2. Case studies

In order to develop a thorough research strategy into the characterization of chromogenic dyes, and define new techniques to accurately assess colour change in 35 mm chromogenic reversal films, two case studies were selected:

i) Kodak Ektachrome 160T Professional (EPT);
ii) Fuji Fujichrome Provia 400X Professional (RXP).

Both films are from the integrated dye couplers type. Some technical information related to each film is described next. To confirm the structure and materials composing each chromogenic reversal film, the materials were analysed using different techniques. Cross sections were collected from both types of films, before and after processing. The collected samples were observed under the optical microscope (OM) (see appendix VI, section VI.1, VI.2 and VI.3 for detailed information about sample preparation and observation under the OM). Moreover, the identification of the film bases was made using Attenuated Total Reflection (ATR) infrared spectroscopy (IR).

6.2.1. Case study I: Kodak Ektachrome 160T Professional (EPT)

As previously mentioned, *Slides de Cavalete* (1978-1979) is one of the most original photographic works produced by Ângelo de Sousa (chapter 4). Knowing that chromogenic reversal films are highly susceptible to dark and light fading (chapter 2), that the work has been gathered in inadequate environmental conditions for about forty years (chapter 3), and that the original slides have been projected in two exhibitions at least (chapter 5), visible colour change would be expected. According to the study by Henry Wilhelm and Carol Brower (1993, 662), Ektachrome films (Process E-6) in general, are expected to take about 75 years to present 'just noticeable' fading[2], when stored at 27.5˚C and 40% RH. The same type of film should only be projected for 2 hours and 40 min before reaching perceptible colour change[3] (Wilhelm and Brower 1993, 215). Therefore, considering the background of *Slides de Cavalete*, it can be stated that this artwork surely presents colour degradation. However, due to the abstract nature of the images from *Slides de Cavalete*, colour change was not straightforward to observe. Accordingly, this artwork was selected as a case study for further research.

Two different chromogenic reversal films were used to produce *Slides de Cavalete*: Kodak Ektachrome 160T Professional (EPT) and Kodak Ektachrome 160T (ET)[4]. Ektachrome 160T Professional was produced between 1976 and 2007; this film has the code EPT and the emulsion number 5037 (Pénichon 2013, 300). Ektachrome 160T was produced between 1977 and 1996, under the film code ET and emulsion number 5077 (Pénichon 2013, 300). After 1976, Ektachrome films were processed using E-6 chemistry (Pénichon 2013, 320). A technical data sheet for EPT dated from 2007 was found and is presented in appendix VI, section VI.9. However, considering the evolution of chromogenic photography (chapter 2), it is highly likely that the product has changed over time. No cross-section is represented in the data sheet.

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[2] Time required for the least stable image dye to fade 10% from an original density of 1.0 (Wilhelm and Brower 1993, 662).
[3] Accumulated times of intermittent projection in a Kodak Ektagraphic III Projector to reach limits of density loss or shift in colour balance (Wilhelm and Brower 1993, 215).
[4] This was understood after observing the edge marking of each chromogenic reversal film composing the artwork.

A film tip and an unprocessed 35 mm film of EPT were found at the artists' archive, allowing us to conduct a series of analyses to this type of film without having to rely on the original slides (Fig. 6.2). Both samples were undated. Nevertheless, according to the data collected during the survey carried out within the present investigation, besides for the production of *Slides de Cavalete* (and other slides produced within the framework of that work), the artist scarcely used this type of film. This could be because EPT had a very specific emulsion designed for exposure with tungsten illumination (3200 K)[5]. Although no dating could be established for the few remaining EPT slides found in the collection, the original containers were gathered with the set of older chromogenic reversal films, inside old-fashion commercial boxes. Therefore, it was assumed that both film tip and unprocessed roll would be representative of the films used to produce *Slides de Cavelete*.

Figure 6.2 - Ektachrome 160T Professional (EPT) found in Ângelo de Sousa's archive. **Left:** unprocessed roll; **Right:** sample used for the investigation carried out within the framework of this dissertation (film tip).

Cross-sections were collected from the EPT samples found at the archive and observed under the OM. Based on the microscopy images, the film presents a typical structure. Before processing, the film is composed of: i) a protective layer on the top of the emulsion layer, ii) three sensitive coloured layers (RGB), iii) a yellow filter, and iv) an anti-halation layer upon the film base (Fig. 6.3). After processing, the film contains: ii) a protective layer, i) three coloured layers, Y (top), M (middle) and C (near the base), and iii) interlayers separating the coloured layers (Fig. 6.4). By observing the images obtained with the OM, it can be concluded that the film has a thickness of about 130 µm. The film base was identified with ATR as being cellulose triacetate (CTA), presenting the characteristic absorption bands of this material (see Fig. 6.9 and Table 6.7).

[5] Technical data sheet from Kodak Ektachrome 160T Professional Film / EPT (appendix VI, section VI.9).

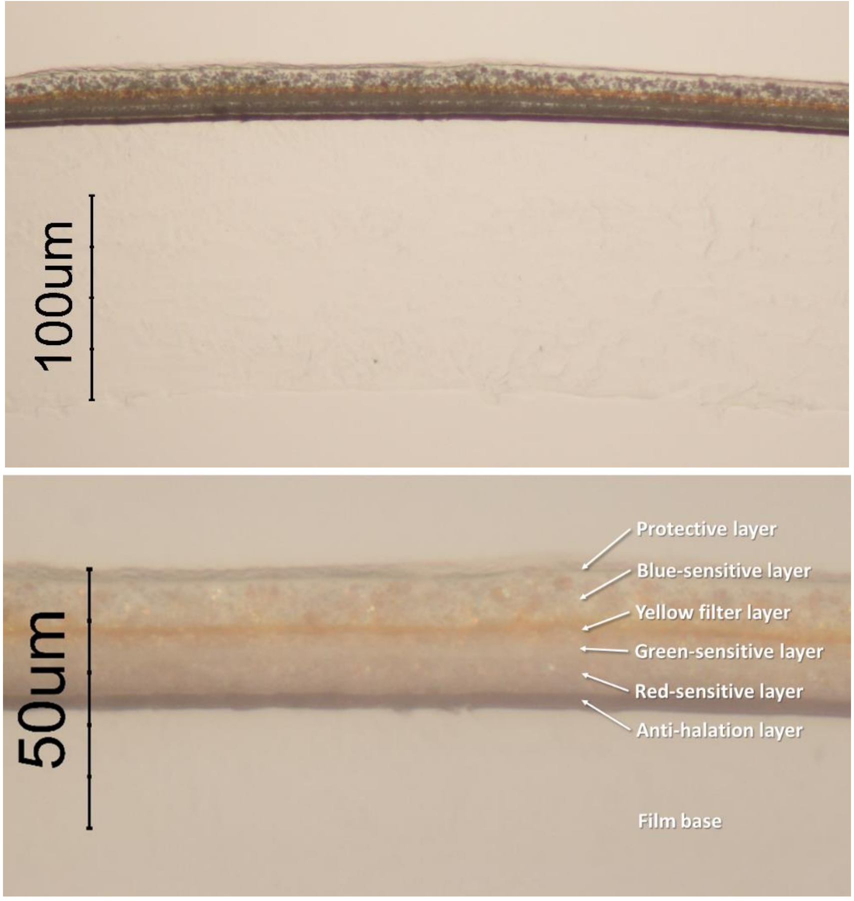


Figure 6.3 - Microscopy image of a cross-section from Ektachrome 160T Professional (EPT) before processing.

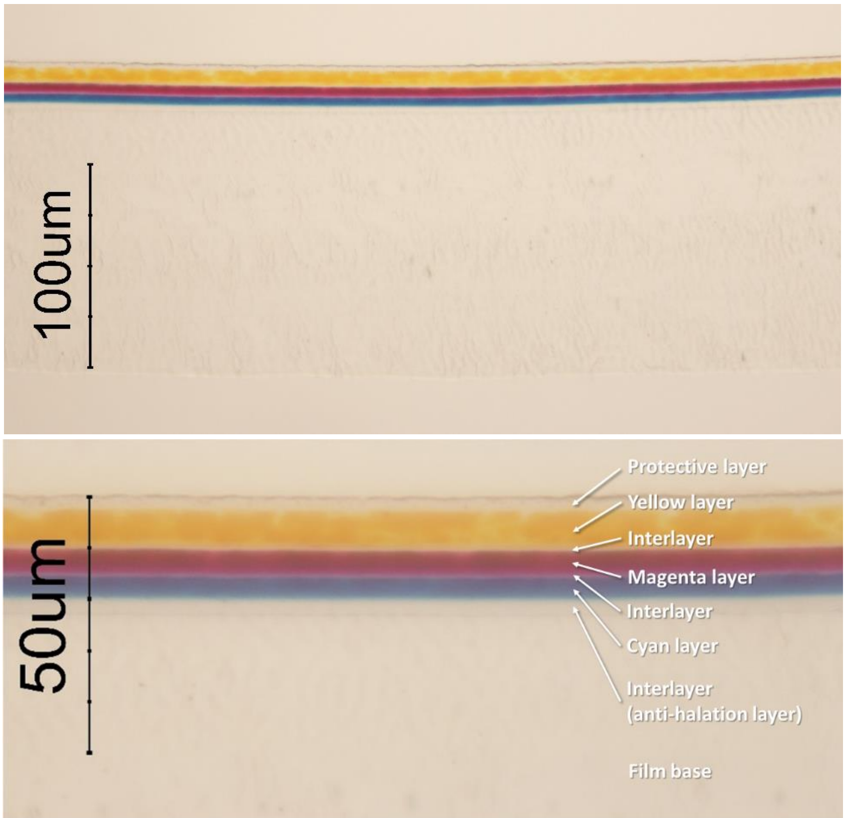


Figure 6.4 - Microscopy image of a cross-section from Ektachrome 160T Professional (EPT) after processing.

6.2.2. Case study II: Fuji Fujichrome Provia 400X Professional (RXP)

Although it is still possible to find unprocessed EPT and ET from the same production time of *Slides de Cavalete*, those films have now expired[6]. Thus, a different type of film was chosen to produce enough samples to develop a methodology to accurately monitor colour change in chromogenic reversal films. A set of thirteen unexposed Fujichrome Provia 400X Professional (RXP) films was found at Ângelo de Sousa’s archive (Fig. 6.5). Based on the survey conducted on the artist’s photographic collection, this type of film was found to be the third most abundant model of chromogenic reversal films used by him (chapter 3). Although the shelf-life of the RXP films expired in 2009, considering their representativeness and availability, seven of those films were used to carry out the artificial ageing tests.

Figure 6.5 - Fujichrome Provia 400X Professional (RXP) found in Ângelo de Sousa’s archive.
Left: unprocessed roll; **Right:** commercial box where the expiration date is visible (red circle).

Fujichrome Provia 400X Professional is currently discontinued, and no references were found to understand the timeframe during which it was produced. This film was manufactured under the film code RXP and emulsion number and emulsion number starting in 101 (this number increased with the year of production). In the artist’s collection, RXP films with emulsion numbers of 104, 105 and 106 were found. The films used for the present study have the emulsion number 104. RXP is an E-6 processing film. The (undated) data sheet from the manufacturer with technical information related to this film, can be consulted in appendix VI, section VI.9.

In the data sheet, a schematic cross section of the film is represented (Fig. 6.6). The microscopy images collected from the cross sections of RXP films, before and after processing, are presented in Figure 6.7 and 6.8, respectively. By comparing the technical data from the manufacturer and the images obtained with the OM, there are some discrepancies. The film is composed of i) three sensitive layers, B (top), G (middle) and R (near the base), ii) a protective layer on the top of the emulsion layer, and iii) an anti-halation layer upon the film base. However, although the colour-correction layer described in the data sheet might be distinguishable in the microscopy images, the one between the G and B sensitive layers is not perceptible. Moreover, in the microscopy images, an interlayer between the G and R sensitive layers, which is not marked in the scheme from the manufacturer, seems to be present

[6] Several rolls were purchase on E-Bay by the author of this dissertation. After exposure and processing, the films only presented a slightly visible image.

(also visible in the film after processing). On the contrary, the interlayers indicated by the manufacturer (resulting from colour-correction and yellow filter layers after processing) are not visible in the microscopy images. The film base was identified with ATR as being CTA (as suggested by the manufacturer), showing a spectrum very similar to that of EPT film (Fig. 6.9). Also, the thickness of the base seems to correspond: 127 µm.

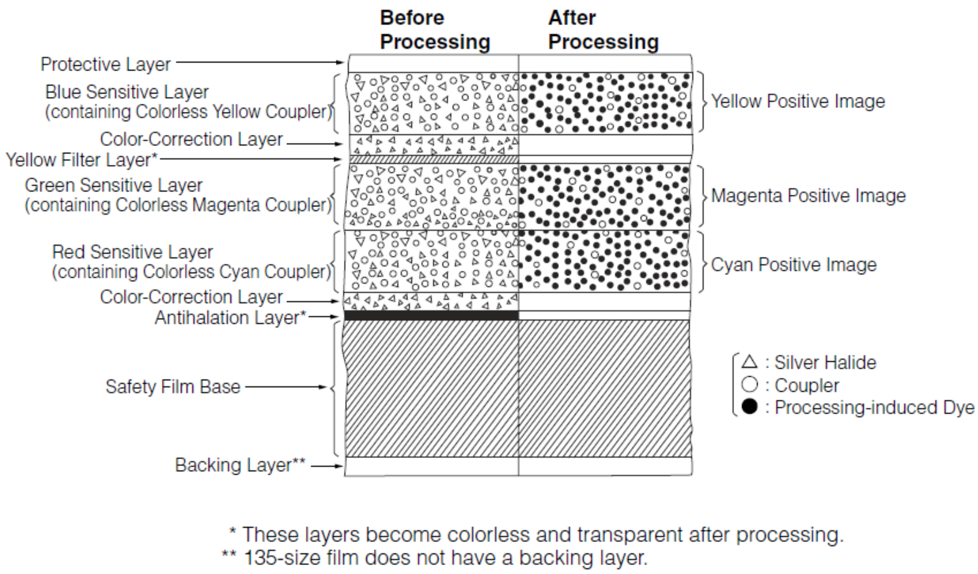


Figure 6.6 - Schematic cross-section of Fujichrome Provia 400X Professional (RXP) (data sheet from the manufacturer).

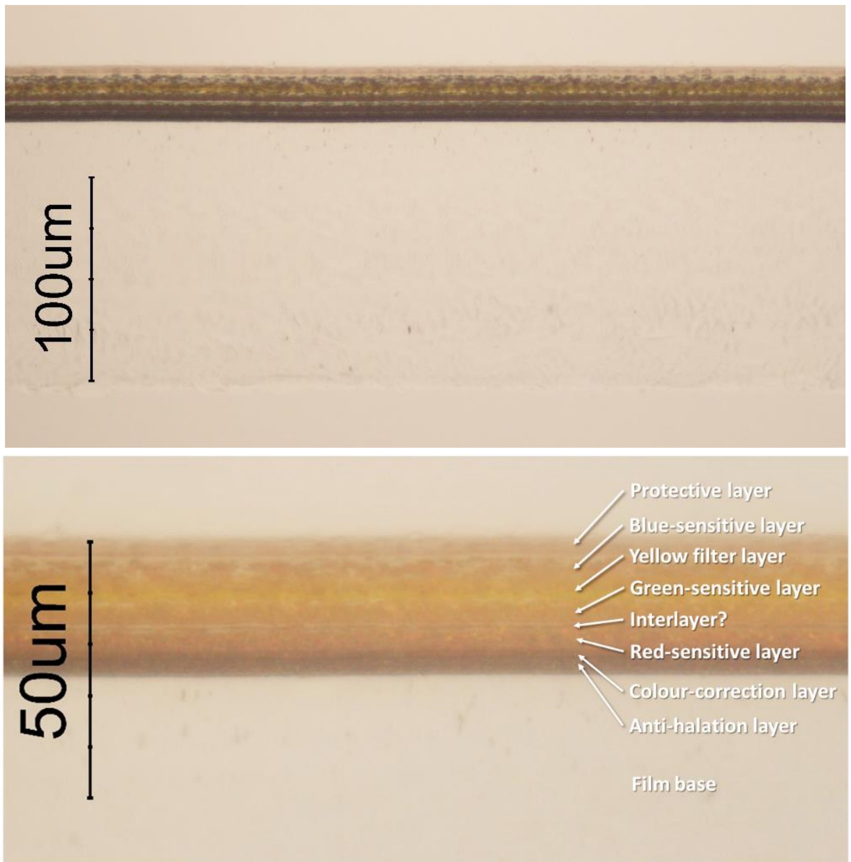


Figure 6.7 - Microscopy image of a cross-section from Fujichrome Provia 400X Professional (RXP) before processing.

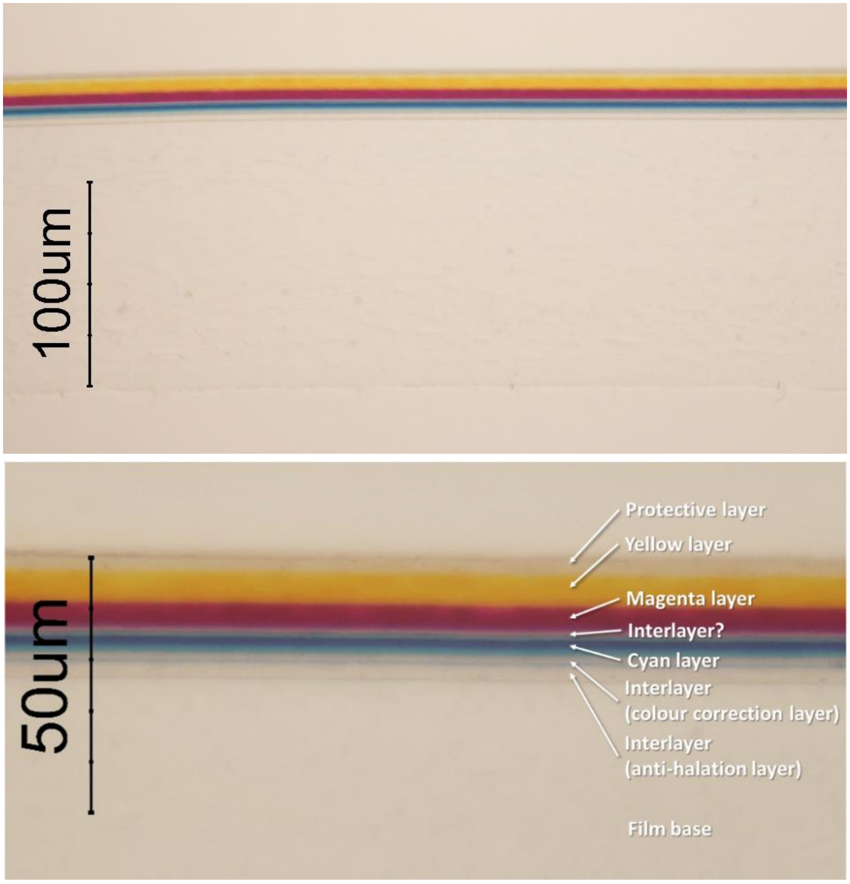


Figure 6.8 - Microscopy image of a cross-section from Fujichrome Provia 400X Professional (RXP) after processing.

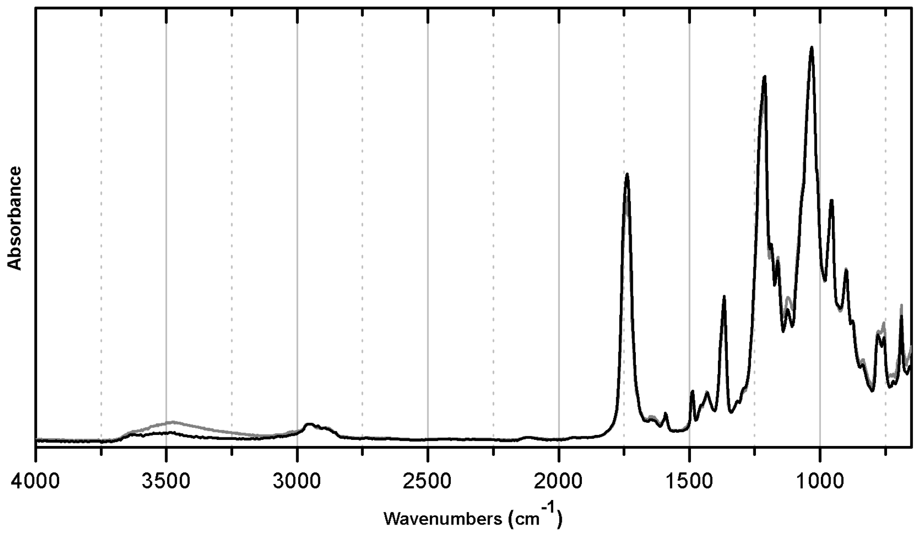


Figure 6.9 - Infrared spectra from Ektachrome 160T Professional (grey line) and Fujichrome Provia 400 X Professional (black line) cellulose triacetate base.

6.3. Preliminary study into the characterization of chromogenic dyes

6.3.1. Methodology

In order to gather information about the molecular structure of Ângelo de Sousa's slide-based artworks, different procedures to characterize chromogenic dyes present in reversal films have been tested. To do so, EPT and RXP samples were analysed using different analytical techniques, for the separation and examination of the dyes present in each product:

i) Confocal Raman spectroscopy
ii) Thin-layer Chromatography (TLC) and Infrared (IR) spectroscopy
iii) High Performance Liquid Chromatography (HPLC) linked to Diode Array Detector (DAD) and Mass Spectrometry (MS)

The pursued methodology sought to test the efficiency of some of the most commonly analytical techniques used in the study of cultural heritage. Additionally, non- or micro-invasive techniques were also explored, to avoid putting at risk the integrity of the works. This study was inspired by the work developed by Giovanna Di Pietro (2007) and Ann Fenech (2011).

As previously mentioned, chromogenic reversal films are layered materials in which the different coloured layers are stacked together (multi-pack). In chromogenic reversal films, due to the inversion of the image during processing, the borders of the films are black, i.e., the emulsion layer have high concentration of Y, M and C dyes. Thus, these areas can be used for analysis without compromising the image. As a first approach to the characterization of chromogenic dyes, the emulsion layers of EPT and RXP films were micro-sampled under a stereomicroscope in order to acquire samples of Y, M and C emulsion, separately. The collected micro-samples were analysed using confocal Raman spectroscopy, since it allows to detect molecular characteristic vibrational modes and considering its recognized ability to detect synthetic organic pigments (Scherrer et al. 2009, 519). By using confocal Raman micro-spectroscopy, the samples can be observed under the microscope and analysed in the desired areas (with circa 5 µm). Several tests were also performed by directly analysing the stratigraphic layers of the films and in cross-section from the samples. Considering the lack of literature focusing on the use of Raman spectroscopy in chromogenic dyes, an attempt to assign characteristic vibrational modes to the obtained results was made, based on reference books of Raman spectroscopy and published studies conducted to synthetic organic pigments (in particular azo dyes) with this technique. For detailed information about the performed Raman analysis, see appendix V, section V.1.

The films under study were also analysed by means of chromatographic techniques in order to separate the dyes from the sample. To do so, a method to extract the dyes from the gelatine layers was developed, adapted from the available bibliography (Di Pietro 2007, Fenech 2011) (see detailed information about the extraction in appendix V, section V.2). The dyes extracted from EPT and RXP films were then separated by: i) Thin-layer Chromatography (TLC), and ii) High Performance Liquid Chromatography (HPLC).

TLC allows for the separation of different compounds present in a mixture, based on the different migration of the components along the TLC plate. The distance travelled by the components is referred to as a retardation value (R_f) (Spangenberg, Poole and Weins 2011, 13-14). R_f values for each dye of both EPT and RXP chromogenic reversal films were calculated from the travelled distances observed at the end of the experiment. Every compound has a specific Rf value for a specific eluent and TLC stationary phase, and therefore can provide corroborative evidence of the identity of a compound.

Since different dyes travel at different distances in the TLC plate, this technique can be used to compare samples, by conducting the experiment under the same conditions (Wall 2000, 2619). Accordingly, this technique allows for the individual characterization of chromogenic dyes (Di Pietro 2007, 187). Silica TLC sheets were used for the separation of the dyes present in both EPT and RXP samples and comparison between the two products. The isolated dyes can therefore be scraped-off the plate and re-dissolved in an appropriate solvent for further analysis. In the present study, the dyes were analysed with IR spectroscopy (see detailed information about the procedure in appendix V, section V.4). While a vibrational mode is Raman-active when there is change in polarizability, a vibrational mode is IR-active when there is a change in the molecular dipole moment. In general, it can be stated that antisymmetric vibrational modes and vibrations due to polar groups are more likely to show strong IR absorption, while symmetric vibrational modes are likely to be strong in Raman (Lin-Vien et. al 1991, 4). Therefore, these techniques are frequently complementary. Knowing that IR spectroscopy is, as Raman spectroscopy, commonly used for the study of the dyes, additional information about the structures of the dyes was intended to be gathered with this technique.

HPLC coupled to a Diode Array Detector (DAD) was also used to separate the dyes from the films under study. This technique can provide information about the dyes of a specific product by unveiling its characteristic spectral absorbance in the UV-vis. Such as in TLC analysis, the retention time (R_t) associated with each dye in the HPLC system gives important information about the dyes. By comparing the separation of different samples acquired by the same equipment in the same conditions, it is possible to relate the dyes of different products. The same methodology developed for the separation of the dyes using HPLC-DAD was used for the analysis of the samples with HPLC coupled to Mass Spectrometry (MS). MS is a powerful technique that can ultimately provide a structural identity of the individual components with high molecular specificity and detection sensitivity. For detailed information about the performed HPLC analysis, consult appendix V, section V.5.

6.3.2. Separation and examination of chromogenic dyes from the emulsion layers

6.3.2.1. Analysis of micro samples using Raman spectroscopy

Both EPT and RXP samples were analysed using confocal Raman spectroscopy. The results presented further on this section were obtained from micro-samples (Fig. 6.10).

Since the analysis of the protective layer (gelatine) did not present any signal, and each coloured layer presented a different spectrum, the obtained Raman spectra can be assigned to the dyes and/or colour couplers present in the emulsion. The main limitation observed during the analysis carried out with this technique, was the presence of some fluorescence in all the collected spectra, probably arising from the gelatine binder and/or impurities present in the emulsion layers (Bouchard et al. 2009, 29). The fluorescence partially overwhelmed the Raman vibrational bands from the compounds of interest. Nevertheless, with some persistence and experience, it was possible to maximize the Raman signal.

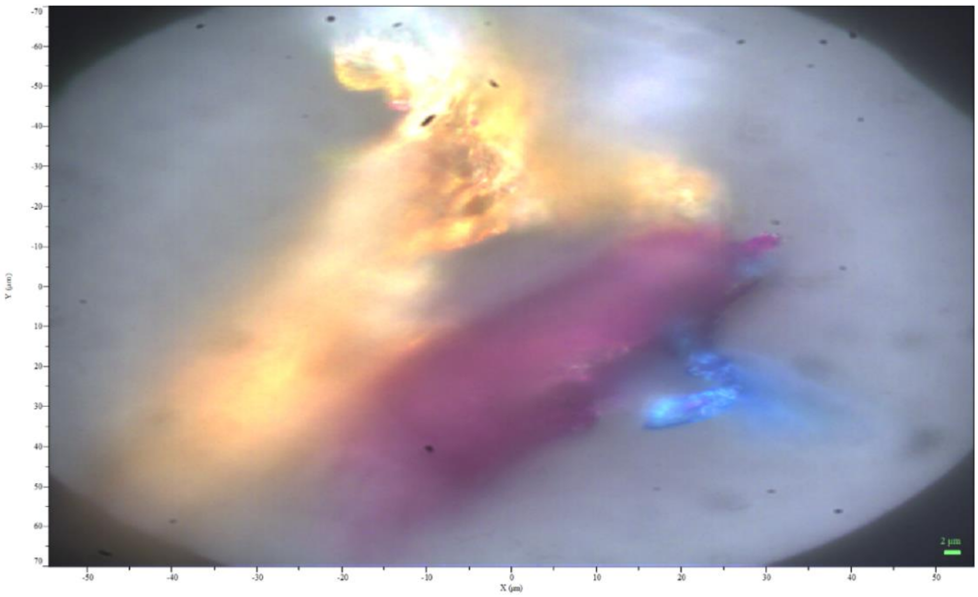


Figure 6.10 – Microscopy image of a micro-sample collected from Ektachrome 160T Professional (EPT) for analysis with Raman spectroscopy, where yellow, magenta and cyan layers are discernible.

Each dye of EPT and RXP samples presented a characteristic Raman spectrum (Fig. 6.11). Although it was not possible to assign the obtained spectra to classes of colour couplers due to the similarity of the dyes molecules and, especially, to the absence of databases, possible assignments of the obtained bands to fragments of molecules present in azomethine and indoaniline dyes in general are presented in Table 6.1. Both colour developer and coupler moieties, conjugated system, and ballasting groups (for instance long aliphatic chains) were considered. However, it should be stressed that the bands can shift in wavenumber and intensity according to the functional groups surrounding the bonds (Vandenabeele et al. 2000, 514). In general, at higher wavenumbers (1000-1800 cm^{-1}) C-H deformation, aromatic C-C and C=C, and C-N stretching vibrations can be observed (Vandenabeele et al. 2000, 513). C-C stretching and C-H deformation modes can be seen between 1500 and 900 cm^{-1} (Vandenabeele et al. 2000, 515). Since all chromogenic dyes are from the azomethine or indoaniline family, C=N vibration characteristic of Schiff bases would be expected near 1640 and 1625 cm^{-1} (Ropret, Centeno and Bukovec 2008, 494). According to Lin-Vien et. al (1991, 201), C=N in conjugation with C=C bond can be shifted towards ca. 1600-1650 cm^{-1}. This characteristic vibration was indeed observed in all spectra from both samples, with exception of the C dye from the RXP sample. Nevertheless, this spectrum is the one showing higher fluorescence, having possibly overcame this peak. The lower wavenumber region (200-1000 cm^{-1}) mainly corresponds to skeletal vibration and ring deformation of the molecules (Bouchard et al. 2009, 31). Thus, according to several publications, the last is the most relevant range for the identification of organic pigments (Scherrer et al. 2009, 519).

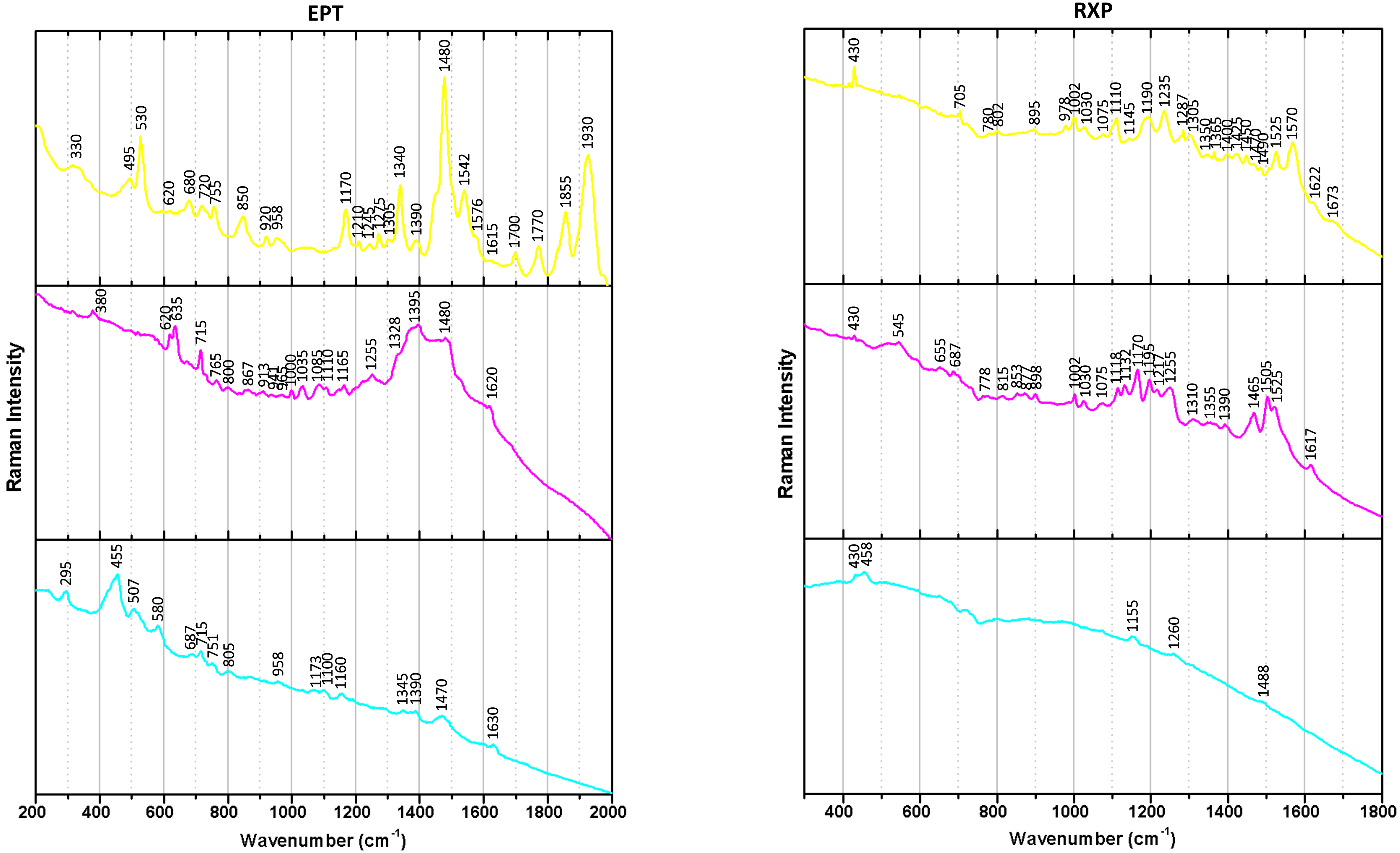


Figure 6.11 - Raman spectra of the yellow, magenta and cyan dyes from Ektachrome 160T Professional (EPT) (left) and Fujichrome Provia 400X Professional (RXP) (right).

Table 6.1 – Characteristic Raman vibrations possibly assignable to azomethine and indoaniline dyes

Wavenumber (cm^{-1})	Type of vibration	Assignment	Reference
ca. 1700 - 1800	C=O stretching	several structures	Lin-Vien et. al 1991
ca. 1700 - 1600	C=N and C=C stretching	several structures	Lin-Vien et. al 1991
ca. 1600 – 1650	C=N stretching	Schiff base	Lin-Vien et. al 1991
ca. 1600	ring vibration	aromatic compound	Bouchard et al. 2009
ca. 1630 - 1550	ring stretching	benzene derivatives	Lin-Vien et. al 1991
ca. 1535 - 1560	NO_2 asymmetric stretching	nitro alkanes	Lin-Vien et. al 1991
ca. 1490	ring vibration	azobenzene	Vandenabeele et al. 2000
ca. 1480 - 1470	OCH_2 and OCH_3 deformation	aliphatic ethers	Lin-Vien et. al 1991
ca. 1473 - 1446	CH_2 and CH_3 deformation	*n*-alkanes	Lin-Vien et. al 1991
ca. 1395 - 1345	NO_2 symmetric stretching	nitro alkanes	Lin-Vien et. al 1991
ca. 1385 - 1368	CH_3 symmetric deformation	*n*-alkanes	Lin-Vien et. al 1991
ca. 1370 - 1290	C-H deformations	aromatic compounds and aliphatic side-chains	Vandenabeele et al. 2000
ca. 1320 - 1360	NO_2 asymmetric stretching	aromatic compound	Vandenabeele et al. 2000
ca. 1310 - 1175	CH_2 twist and rock	*n*-alkanes	Lin-Vien et. al 1991
ca. 1305 - 1295	CH_2 in-plane twist	*n*-alkanes	Lin-Vien et. al 1991
ca. 1300	C-C stretching and C-H bending	azo compounds	Vandenabeele et al. 2000
ca. 1230 - 1200	ring vibration	para disubstituted benzenes	Lin-Vien et. al 1991
ca. 1200 and 1130	C-N stretching and bending	azo compounds	Vandenabeele et al. 2000
ca. 1175 and 1140	C-N stretching and bending	azo compounds	Vandenabeele et al. 2000
ca. 1150 – 950	C-C stretching	*n*-alkanes	Lin-Vien et. al 1991
ca. 1160	SO_2 symmetric stretching	SO_3^- groups	Vandenabeele et al. 2000
ca. 1060 - 1020	ring vibration	ortho disubstituted benzenes	Lin-Vien et. al 1991
ca. 1030 - 1015	in-plane CH deformation	monosubstituted benzene	Lin-Vien et. al 1991
ca. 1000		monosubstituted benzene	Vandenabeele et al. 2000
ca. 992	ring breathing	benzene	Lin-Vien et. al 1991
ca. 950		benzylamide	Vandenabeele et al. 2000
ca. 930 - 830	C-O-C symmetric stretching	aliphatic ethers	Lin-Vien et. al 1991
ca. 905 – 837	C-C skeletal stretching	*n*-alkanes	Lin-Vien et. al 1991
ca. 830 - 720		para disubstituted benzenes	Lin-Vien et. al 1991
ca. 825	NO_2 scissoring	aromatic compound	Vandenabeele et al. 2000
ca. 630 - 615	ring deformation	monosubstituted benzene	Lin-Vien et. al 1991
ca. 620	ring deformation	aromatic compound	Vandenabeele et al. 2000
ca. 450	C=O bending	several structures	Vandenabeele et al. 2000
ca. 425 - 150	chain expansion	*n*-alkanes	Lin-Vien et. al 1991
ca. 350	O-C-C in-plane rocking	several structures	Vandenabeele et al. 2000

6.3.2.2. Thin-layer chromatography for separation and further analysis

The dyes from both EPT and RXP chromogenic reversal films were successfully separated with silica TLC sheets. After making some tests, diethyl ether:ethyl acetate (90:10) was revealed to be a suitable mobile phase to develop the EPT sample, and ethyl acetate to elute the RXP sample (see more information in appendix V, section V.3). The fact that two different solutions had to be used for each sample, in order to achieve a proper separation of the dyes, immediately points out to chromogenic reversal films composed of different dyes. The results of the separation are presented in Table 6.2.

As can be observed in Table 6.2, the EPT sample presents three spots in the TLC sheet, which can clearly be associated to M, Y and C dyes, being R_f(M) < R_f (Y) < R_f (C). In a TLC sheet, the different compounds of the mixture travel at different rates based on their attraction to the stationary phase and solubility in the mobile phase (Strieger and Hill 1996, 5). In a normal phase silica plate (polar), the most polar compound has a stronger interaction with silica leading to a faster binding to the TLC sheet. On the contrary, the less polar compound moves along with the mobile phase up to the sheet (Strieger and Hill 1996, 26). Thus, it can be concluded that M is the most polar dye from the EPT sample, followed by Y and finally C dyes. Apart from M, Y and C dyes, a faint bluish grey spot is discernible under visible light. As suggested by Di Pietro (2007, 188), faint spots can be related to the ageing of the films that caused the breakdown of some dye molecules. Since the film under study should be dated from the end of the 1970s, this theory can be applied to the EPT sample. Considering the colour of the faint spot, it could be associated to the degradation of the C dye. The TLC sheets used in this study have a fluorescent indicator, making it possible to detect colourless compounds not noticeable under visible light[7]. By observing the obtained TLC sheet under UV-light, it can be concluded that the EPT film also contains colourless compounds, which were separated by the TLC plate. Those compounds can be associated to residual colour couplers and/or other components added to the photographic emulsion (Fenech 2009, 95-96), such as white couplers, scavengers, antioxidants and/or UV absorbers.

Regarding the results from the separation of the RXP chromogenic reversal film (Table 6.3), the TLC sheet also shows the separation of coloured components. In this case, one C, two M and one Y were separated, being R_f(C) < R_f (M1) < R_f (M2) < R_f(Y). Therefore, in this film, C is the most polar dye, followed by M and finally Y dyes. Since only one of each sensitive layer was detected in the cross-section observed under the OM, these results might indicate the presence of two different M dyes in the same G sensitive layer. According to several authors, more than one layer of the same sensitive colour has been used to improve colour accuracy; however, no references were found describing different dyes applied in the same sensitive layer. Alternatively, one of the M compounds might be associated to a degradation product of the M dye, leading to a sub-product with a different R_f (similarly with EPT sample). However, based on Di Pietro's study (2007, 188), aged films give rise to a second much fainter colour with the same hue, and in this case, two different Ms with similar intensity but different hues were obtained. The TLC sheet was also observed under UV light. As with the EPT sample, several colourless spots were detected.

In order to analyse the dyes from both EPT and RXP chromogenic reversal films, preparative TLC sheets were made. The isolated dyes were scraped from the sheet and diluted in ethyl acetate for further analysis (see detailed information in appendix V, section V.3). The obtained solutions were dried under a stream of nitrogen (Figs. 6.12 and 6.13).

The extract was then re-dissolved in ethanol and the dyes were individually analysed with IR spectroscopy, in order to gather more information about the molecules. The obtained spectra are presented in Figure 6.14. As with Raman spectroscopy, it was not possible to identify colour coupler classes, mainly due to the absence of databases. Nevertheless, the bands obtained in the FTIR spectra, from the EPT and RXP samples were assigned to characteristic functional groups from azomethine and indoaniline dyes.

[7] The separated compounds quench the fluorescence of the TLC sheet, appearing as a dark spot under UV-light.

Table 6.2 - Results from the TLC analysis conducted to Ektachrome 160T Professional (EPT)

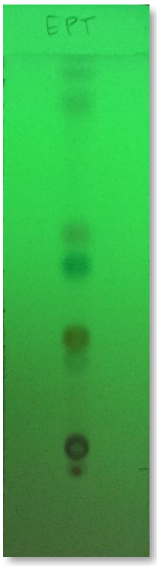
EPT		
TLC plate (under Vis light)	TLC plate (under UV light)	**Conditions**
		90:10 diethyl ether: ethyl acetate (v:v) **R_f value** ↑ Cyan dye - R_f = 0.50 Yellow dye - R_f = 0.31 Magenta dye - R_f = 0.05 **Comments** Vis-light: - The C, M, Y dyes were successfully separated - A bluish grey spot was also separated UV-light: - Colourless components are discernible

Table 6.3 - Results from the TLC analysis conducted to Fujichrome Provia 400X Professional (RXP)

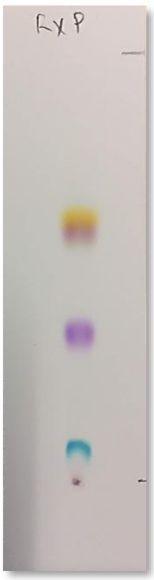
RXP		
TLC plate (under Vis light)	TLC plate (under UV light)	**Conditions**
		Ethyl acetate **R_f value** ↑ Yellow dye - R_f = 0.64 Magenta dye - R_f = 0.59 Magenta dye - R_f = 0.36 Cyan dye - R_f = 0.09 **Comments** Vis-light: - The different dyes were successfully separated - Two magenta spots are discernible UV-light: - Colourless components are discernible

Figure 6.12 - Isolation of Ektachrome 160T Professional (EPT) dyes from the TLC sheet. **Top:** extracted dyes in solution; **Bottom**: extracted dyes after drying in a round-bottom flask under nitrogen stream.

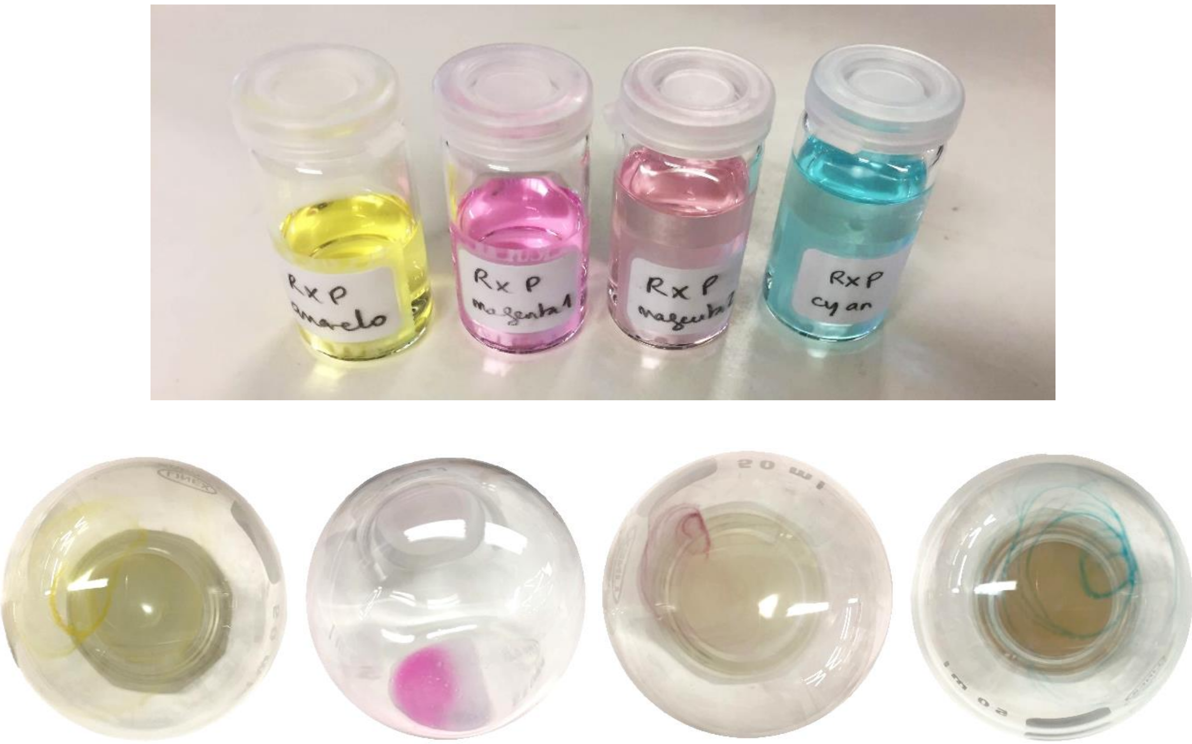
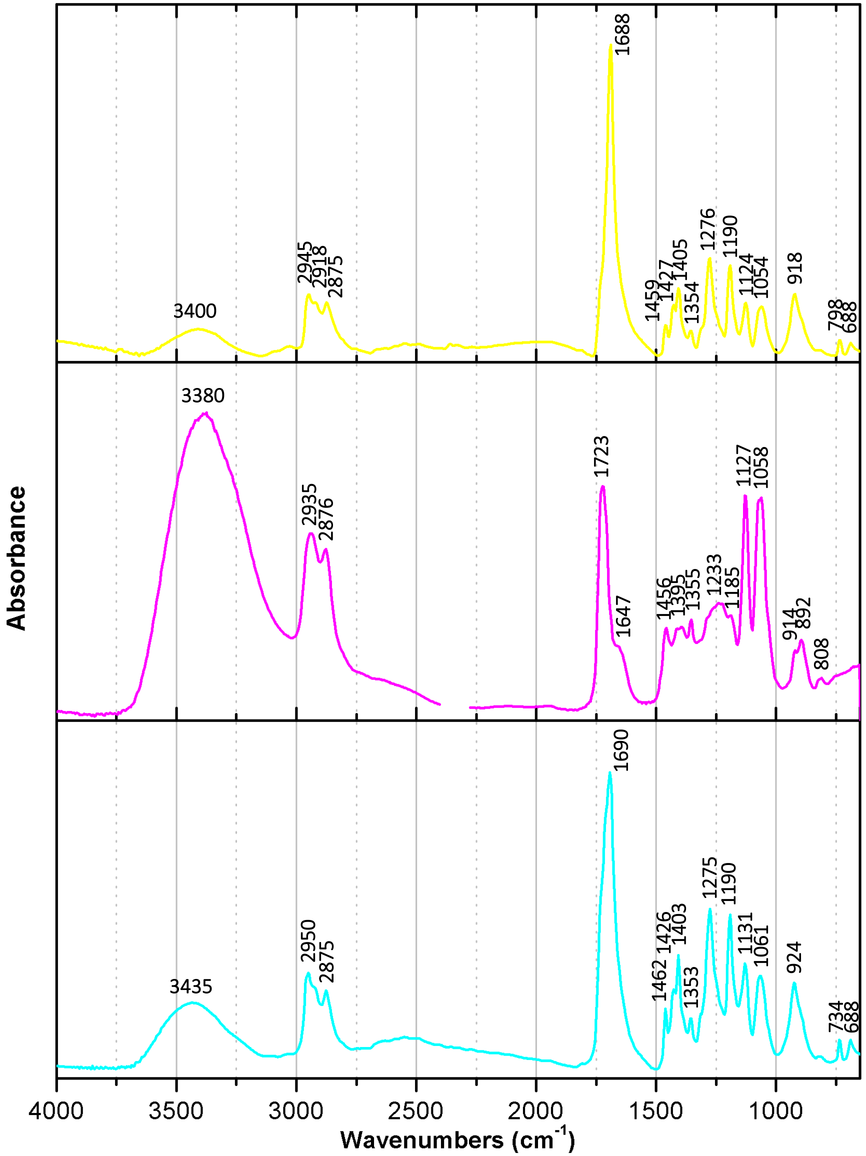


Figure 6.13 - Isolation of Fujichrome Provia 400X Professional (RXP) dyes from the TLC sheet. **Top:** extracted dyes in solution; **Bottom**: extracted dyes after drying in a round-bottom flask under nitrogen stream.



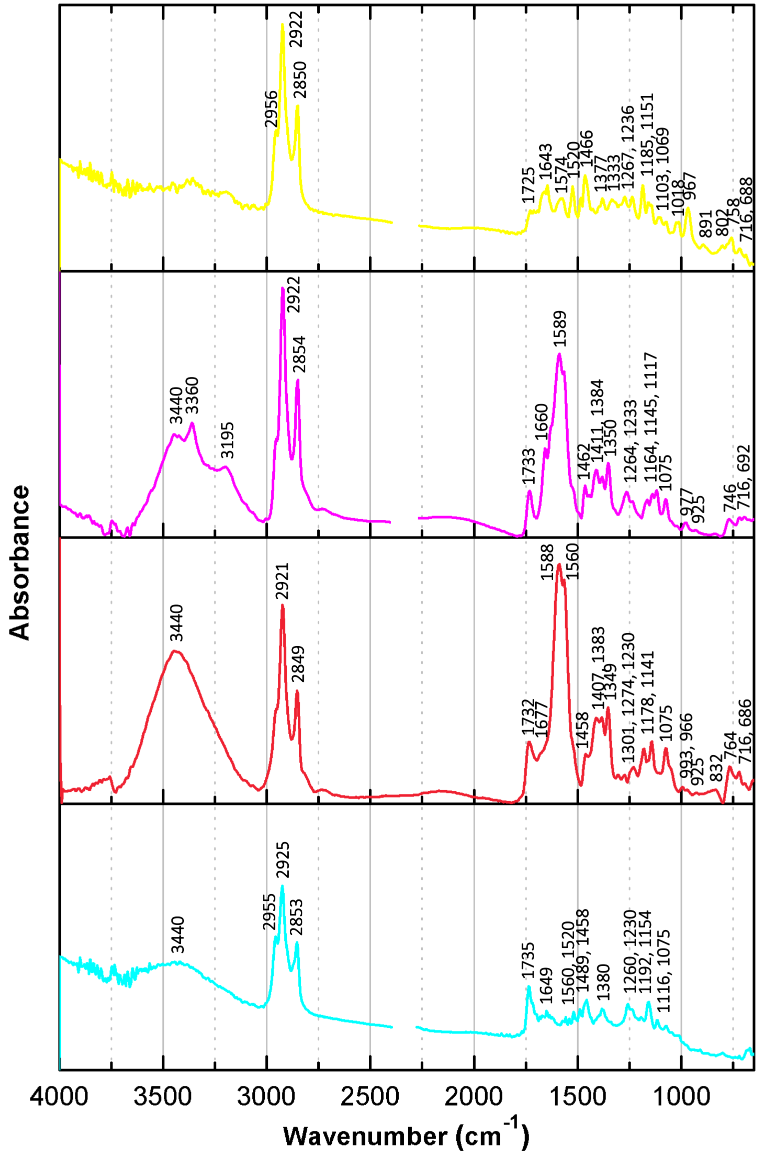


Figure 6.14 - Infrared spectra of the dyes from Ektachrome 160T Professional (EPT) (left) and Fujichrome Provia 400X Professional (RXP) (right).

IR spectroscopy is a highly effective technique to detect OH and NH stretching. Both these groups can be assigned to the obtained bands at ca. 3400 cm^{-1}. All dyes also present double or triple bands at ca. 2900-2800cm^{-}1. Methyl and methylene groups result in doublets slightly different frequencies, due to C-H stretching at ca. 2900-2800cm^{-1}. Triple bands in this same region can be derived from C-H stretching vibrations. Infrared spectroscopy is very sensitive to carbonyl species, producing sharp peaks in a broad range between 1900-1550 cm^{-1}. The imide bond (C=N), characteristic from azomethine and indoaniline dyes, is normally visible between 1690-1630 cm^{-1}. All dyes from both samples seem to present this band, although sometimes overlapping with C=O peak. Additionally, C=C stretching bands can normally be found between 1680 and 1600 cm^{-1}. The conjugation with other double bonds can decrease the frequency of these bands. Aromatic compounds normally present bands between 1620 and 1420 cm^{-1} and methyl and methylene groups between 1500-1250 cm^{-1}. Therefore, the bands found in those ranges could be assigned to these groups. At lower wavenumbers, C-O stretching vibrations (between 1300-750 cm^{-1}) and C-H wag (between 1000-600 cm^{-1}) can normally be observed (Larkin 2011, 124-133). The position of these bands is highly dependent on the proprieties of the substituents. The bands ranging from 900 to 500 cm^{-1} could also be assigned to O-H, N-H, NH_2 wag (Larkin 2011, 124-133). A summary of possible assignments for chromogenic dyes is presented in Table 6.4. In general, each dye, in both samples, seems to present a characteristic spectrum. Nevertheless, C and Y dyes from EPT samples present great similarities in the IR spectra. Moreover, it was difficult to acquire good spectra from the Y and C dyes of the RXP sample.

Table 6.4 – Characteristic IR vibrations possibly assignable to azomethine and indoaniline dyes (Larkin 2011 and Lin-Vien et. al 1991)

Wavenumber (cm^{-1})	Type of vibration	Assignment
ca. 3550 - 3230	O-H stretching	several structures
ca. 3550 - 3250	N-H stretching	several structures
ca. 3200 - 2980	C-H stretching	unsaturated hydrocarbons
ca. 2975 – 2950 ca. 2885 - 2865	C-H stretching	methyl groups
ca. 2835	C-H stretching	methoxy groups
ca. 2940 – 2915 ca. 2870 - 2840	C-H stretching	methylene groups
ca. 1900 - 1550	C=O stretching	several structures
ca. 1680 - 1600	C=C stretching	unsaturated hydrocarbons
ca. 1690 - 1630	C=N stretching	Schiff base
ca. 1580 – 1475 ca. 1390 - 1320	N=O stretching	aliphatic and aromatic groups
ca. 1400 – 1390 ca. 1410	N=O stretching	aromatic *cis* nitroso groups
ca. 1300 – 1250	N=O stretching	aromatic *trans* nitroso groups
ca. 1600 - 1580	ring quadrant stretching	aromatic compounds
ca. 1600 - 1500	ring stretching	heteroaromatic compounds
ca. 1500 - 1460	ring semi-circle stretching	aromatic compounds
ca. 1480 - 1430	CH_2 scissors deformation and CH_3 out-of-phase deformation	methyl and methylene groups
ca. 1378	CH_3 in-phase deformation	aliphatic groups
ca. 1300 – 750	C-O stretching	several structures
ca. 1000 - 600	C-H wag	several structures
ca. 900 - 700	C-H wag	aromatic compounds
ca. 900 - 500	X-H wag	several structures

6.3.2.3. *High performance liquid chromatography linked to diode array detection and mass spectrometry*

After testing several elution programs, the dyes from both EPT and RXP samples were separated with HPLC using a gradient composed of Millipore water/methanol (see more details about elution programs in appendix V, section V.5).

The retention times (R_t) and absorption maxima of the compounds separated with the HPLC system and analysed with DAD, respectively, are presented in Table 6.5.

Table 6.5 - Absorbance maximum (λ_{max}) and retention times (R_t) of dyes extracted from Ektachrome 160T Professional (EPT) and Fujichrome Provia 400X Professional (RXP)

	cyan		magenta		yellow	
	λ_{max} (nm)	R_t (min)	λ_{max} (nm)	R_t (min)	λ_{max} (nm)	R_t (min)
EPT	663	31.83	551	31.23	442	31.98
RXP	651	33.32	546 551	33.45 37.04	451	33.93

Regarding the EPT sample, all peaks of interest were separated. However, the three dyes were eluted at the end of the elution program (after 31 minutes), when only methanol was running in the HPLC system. Moreover, the R_t of the C and Y dyes are too close to each other, and there is a superimposition of the dye peaks, as presented in the chromatogram collected at 260 nm (Fig. 6.15). The faint bluish spot observed in the TLC sheet was not clearly identified with the HPLC analysis. Species absorbing in the UV region and non-absorbing in the visible region of the electromagnetic spectrum were detected. These components can consist of colour couplers and other components added to the photographic emulsion, such as already mentioned in the results obtained with TLC. M was the first dye to be eluted. Since a reversed-phase analytic column was used, it is expected that non-polar molecules tend to be retained in the column for a longer period of time, and polar molecules eluted faster. Within this system, non-polar molecules are eluted by lowering the polarity of the mobile phase. Thus, as already concluded from the TLC experiment, M dye, presenting the lower R_t, is the most polar dye from the EPT film, followed by C and Y dyes. However, possibly due to the inefficacy of the elution program, in the HPLC-DAD analysis the C dye was eluted before the Y dye (although almost simultaneously). Moreover, the eluents used for the two analysis (TLC and HPLC-DAD) were different and a straight comparison cannot be established. Nevertheless, it is possible to distinguish three absorption bands associated to each dye (Fig. 6.16). The M dye has an intense absorption in the G region (at 551 nm) and a less intense band in the B region (at circa 430 nm), as a shoulder on the shorter wavelength side of the principal absorption band. According to R. J. Berry (1998, 23), M dyes from the pyrazolone family have a characteristic double absorption band with similar shape, arising from two different electronic transitions. Thus, the M dye from the EPT film could be from that family. Pyrazolones were the M couplers of choice until the 1980s (Bergthaller 2002b, 188), in particular 3-acylaminopyrazolones were used in reversal films were used up to the end of the 1980s (Di Pietro 2007, 184). Considering that EPT was used to produce *Slides de Cavalete* in 1978-1979, this attribution is congruent. Unfortunately, azomethine dyes resulting from pyrazolone M couplers are normally unstable (Di Pietro 2007, 184). C and Y present a well-defined band in the R and B regions of the visible spectrum at 663 nm and 442 nm, respectively. However, due to the proximity of their R_t, a slight absorption in the R region of the Y spectrum can be observed (Fig. 6.16). Since this side absorption was not observed in the analysis performed with the HPLC-DAD-MS equipment, with which a better separation was achieved (see appendix V, section V.5), it can be asserted that it resulted from the superimposition of the C and Y peaks. No references were found concerning the characteristic absorption spectra of C and Y dyes from different families.

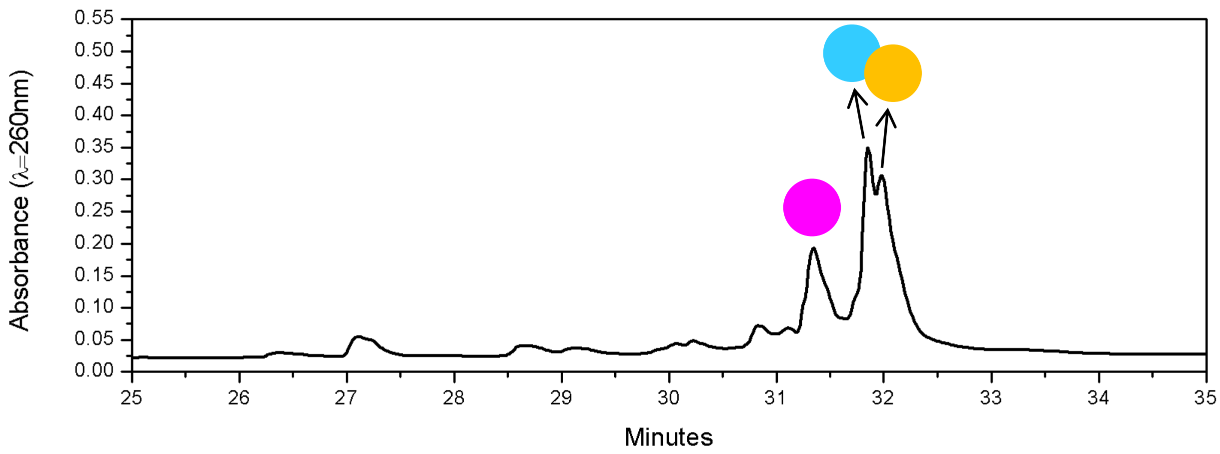


Figure 6.15 – HPLC-DAD chromatogram from Ektachrome 160T Professional (EPT) chromogenic reversal film acquired at 260 nm, where three different dyes can be identified (marked with a coloured circle).

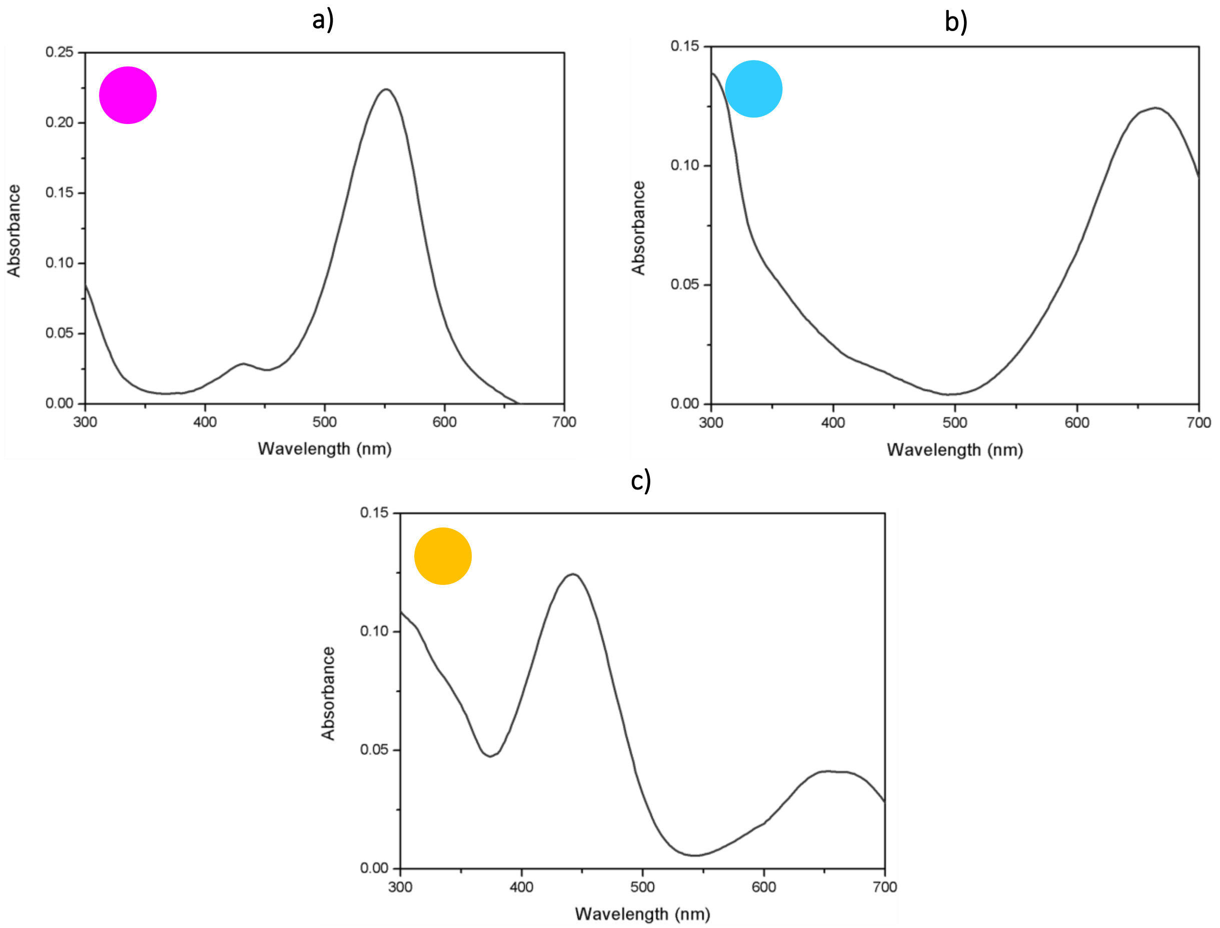


Figure 6.16 – Spectral absorbance of the individual dyes from Ektachrome 160T Professional (EPT) chromogenic reversal film separated with the HPLC-DAD analysis: a) magenta (λ_{max}=551 nm), b) cyan (λ_{max}=663 nm), and c) yellow (λ_{max}=442 nm).

The same types of results were achieved for the RXP sample. As with the TLC experiment, four different dyes were isolated. Although all peaks of interest were separated with the selected elution program, as with the EPT sample, all dyes were only eluted at the end of the run. In this case, the Y and M dyes were well isolated, but another M and the C dye were eluted very closely. Therefore, there is a partial superimposition of the Y and C dye peaks, as presented in the chromatogram collected at 260 nm (Fig. 6.17). C was the first dye to be eluted, immediately followed by one of the M dyes. Contrarily to the TLC separation, the HPLC experiment led to the separation of the Y before the second M dye. As with the EPT sample, several species absorbing in the UV region can also be distinguished in the chromatogram. The absorbance spectrum of each dye was recorded in the UV-vis region (Fig. 6.18). The C and Y dyes have well-defined absorption bands with maxima at 651 nm and 451 nm, respectively. These dyes present different absorption maxima and R_t comparing to EPT dyes with the same colours. The first M dye has an intense absorption at 546 nm, and a slight absorption in the R region, possibly due to the proximity of the R_t form the C and M dyes. The second M dye has a single absorption band at 551 nm, pointing out to a different M specie. Although the second magenta has an absorption maximum with the same wavelength of the M dye from the EPT sample, the spectra of the two compounds are clearly different. Considering that both M dyes from the RXP sample have a single absorption band, it can be concluded that they are not from the pyrazolone family. According to R. J. Berry (1998, 23), M dyes from the pyrazoloazole family have no secondary B absorption as pyrazolone dyes, having a sharp cut off on the long wavelength side resulting from a single electronic transition in the visible spectral region. Since in the 2000s, the use of pyrazoloazoles was widespread (Bergthaller 2002b, 188), it is likely that both M dyes from the RXP film are from that family.

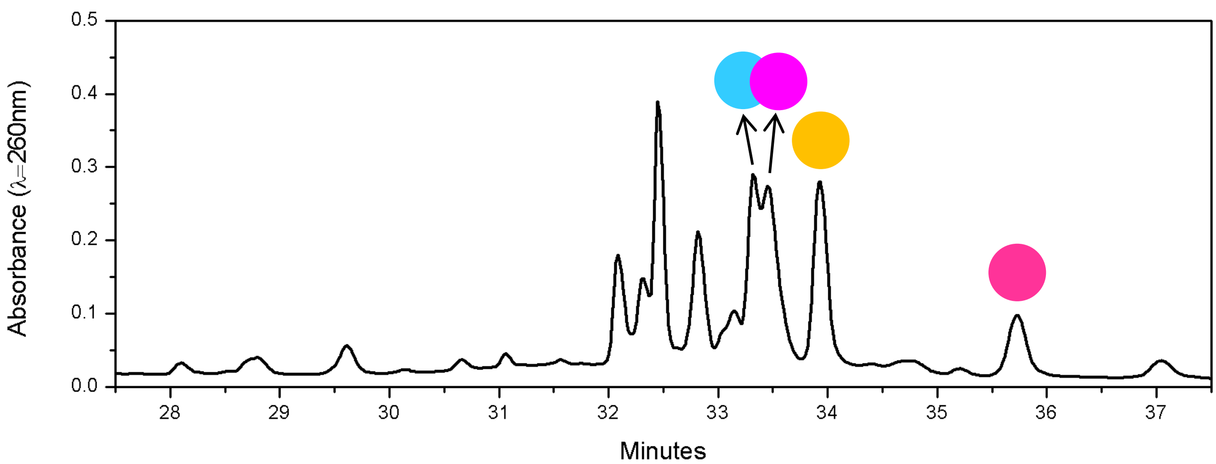


Figure 6.17 – HPLC-DAD chromatogram from the Fujichrome Provia 400X Professional (RXP) chromogenic reversal film acquired at 260 nm, where four different dyes can be identified (marked with a coloured circle).

In order to try to identify the three dyes separated by HPLC, the EPT sample was also analysed by HPLC-DAD-MS and by Liquid chromatography–high resolution mass spectrometry (LC-HRMS). The results were too difficult to interpret without a database, due to the complexity and variability of the chromogenic dyes (see results in appendix V, section V.5). Nevertheless, the separation provided by the HPLC-DAD-MS (a different equipment) was far more effective than the separation previously described in this section, and together with the HRMS/MS data, some information was obtained.

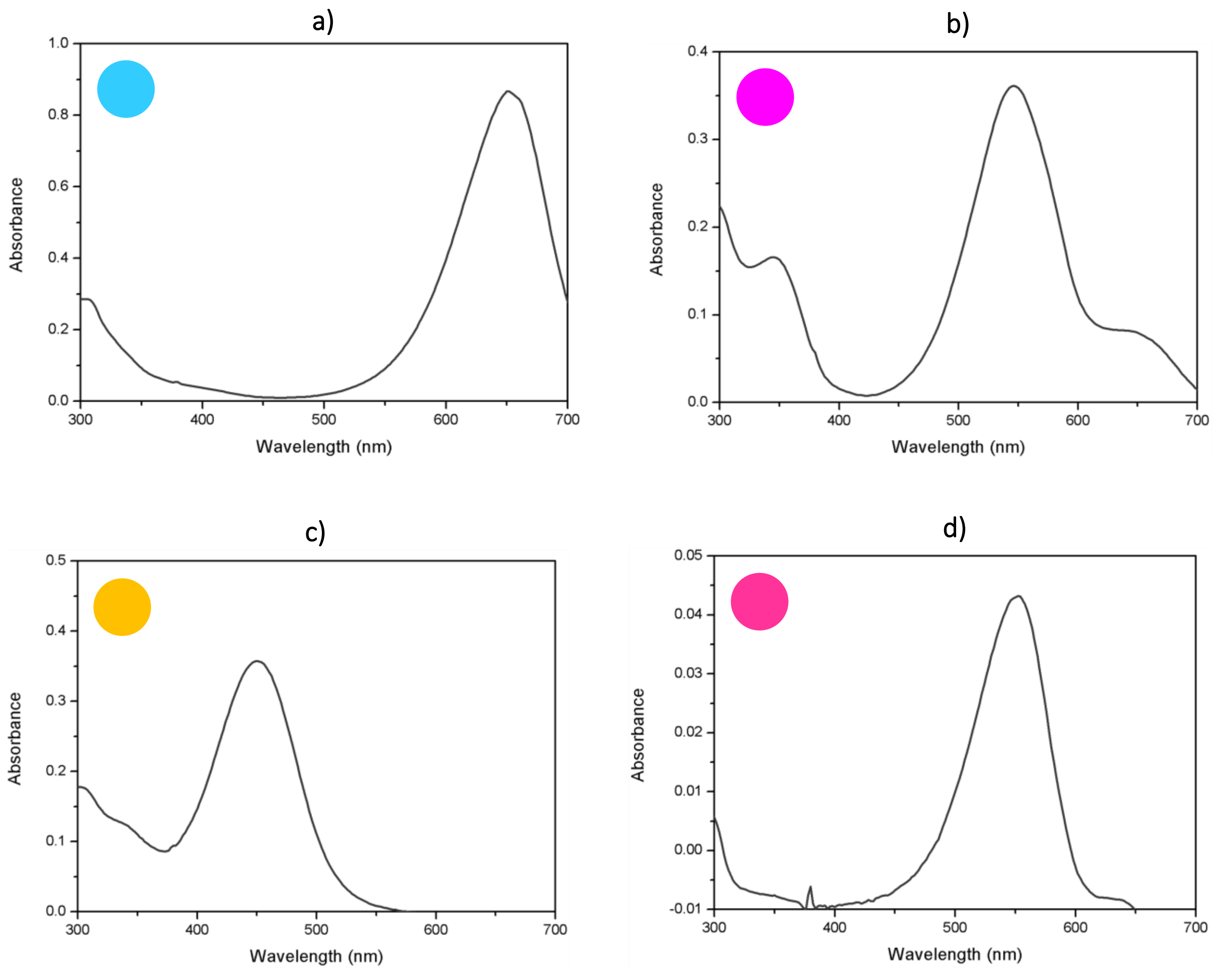


Figure 6.18 – Spectral absorbance of the individual dyes from Fujichrome Provia 400X Professional (RXP) chromogenic reversal film separated with the HPLC-DAD analysis: a) cyan (λ=651 nm), b) magenta (λ=546 nm), c) yellow (λ=451 nm), and d) magenta (λ=551 nm).

Accurate measurements of the protonated molecules obtained for the three main peaks identified by LC-DAD displaying maximum wavelengths values between 420 and 670 nm, were determined. The C dye (R_t = 23 min) can be attributed to a mono charged species with m/z 918.4059. The isotopic distribution and the tandem mass spectrum for this precursor ion clearly indicates that the colour coupler of this dye does not contain any chloride or bromide atom in this structure. On the other hand, the isotopic profiles of the accurate masses obtained for peaks at R_t = 21 and R_t = 22.7 min, attributed to M and Y dyes, respectively, indicate that the colour couplers associate with these dyes may have some chlorine atoms in their structures. The ion assigned to M dye displays a group of peaks with an accurate m/z 938.2999/940.295, having an isotopic distribution profile indicating the presence of three chlorine atoms in the structure. This result is supported by the fragmentation pattern observed in the tandem mass spectrum of this precursor ion. The Y dye peak with an accurate m/z 824.4213 displays an isotopic distribution profile fitting the presence of one chlorine atom in its structure. However, by relating the gathered information with the literature (Bergthaller 2002 and Fujita 2004), it was not possible to assign a class of colour coupler to the dyes from the EPT sample.

6.4. Following colour change in chromogenic reversal films

6.4.1. Methodology

An experimental study was designed with the aim of providing an accurate methodology to describe and monitor colour variation in this type of material. Fujichrome Provia 400X Professional films (RXP) were artificially aged to acquire samples with different degrees of degradation. Since most chromogenic reversal films from the artist's collection are more likely to present dark fading (from being kept under uncontrolled storage conditions) than light fading (only a few cases were projected in exhibitions, and the originals will no longer be projected), the samples were induced to thermal degradation.

After assessing the conditions in which artificial ageing tests of chromogenic materials have been conducted up to now (see appendix VI, section VI.1, Table VI.1), it was decided to follow the ISO 18909:2006(E)[8] recommendations. However, certain parameters from the standard were adapted to the framework of this study.

A set of 252 RXP slides with plastic mounting (polystyrene - PS) were aged under four T values: 50, 60, 70 and 80°C. The influence of RH in the ageing of the chromogenic reversal films was also evaluated by conducting the T tests in samples with different weight percentage of water content, for the sake of simplicity only indicated as wt.

The samples were aged using the sealed bag method. Since slide-based materials from Ângelo de Sousa collection have been kept closed inside their plastic commercial boxes, this method provides a good simulation of the conditions to which the materials have been exposed over time. Before ageing, the samples were kept inside desiccators with saturated salts for 14 days (time necessary to reach equilibrium moisture content – EMC) (Bigourdain, Adelstein and Reilly 1997, 198). Potassium carbonate was used to produce circa 40% (good practice RH conditions) and sodium bromide circa 60% of RH (value commonly measured in Ângelo de Sousa's photographic and filmic storage room), providing samples with an emulsion with a water content of circa 12.5% and 15%, respectively (Bigourdain, Adelstein and Reilly 1997, 196). The samples were then sealed inside polyethylene and aluminium bags. Finally, the bags were placed inside an oven at the desired T (see detailed information about sample preparation in appendix VI, section VI.2). According to ISO 18909:2006(E), the water content of the samples remains quite constant with this method, independently of the T to which they were artificially aged.

The ISO standard suggests the use of samples composed of images with pure C, M, Y and neutral patches, and with specific optical densities: minimum density areas (d_{min}) and density of 1 above d_{min}. Considering that the scope of this international standard is to measure dye fading of specific commercial products, the assessment of colour change in d_{min} areas is very useful since it allows to apply a correction and subtract the yellow stain produced by residual colour couplers upon ageing. Thus, the fading of each dye can be measured individually, without having the influence of yellow stain formation disturbing the results. However, the aim of the present research was to accurately monitor colour change in Ângelo de Sousa's slide-based artworks, defining a methodology that can be transferred to other collections with similar materials. As previously mentioned, yellow stain formation varies according to the

[8] ISO 18909:2006(E): Photography - Processed photographic colour films and paper prints - Methods for measuring image stability. This ISO standard can be used to obtain meaningful information about the long-term dark stability of colour photographs made with a specific product.

concentration of residual colour couplers left in the image, which is different from area to area of the image (inversely proportional to the concentration of dye formation in each layer). Hence, the type of image suggested by the standard is not in line with the goals of this dissertation. Thus, two different types of images were designed for the present study: i) a step-wedge with six coloured patches, 80% neutral grey (N80), 50% neutral grey (N50), 18% neutral grey (N18), Y, M and C, and ii) an image of the artwork *Slides de Cavalete* (slide 54) (Fig. 6.19). The first type of samples was selected to bring insights into the ageing process associated to specific colours and different densities of the image. The second type was intended to simulate the work *Slides de Cavalete,* and to understand the effectiveness of the method for the assessment of colour change in real artworks.

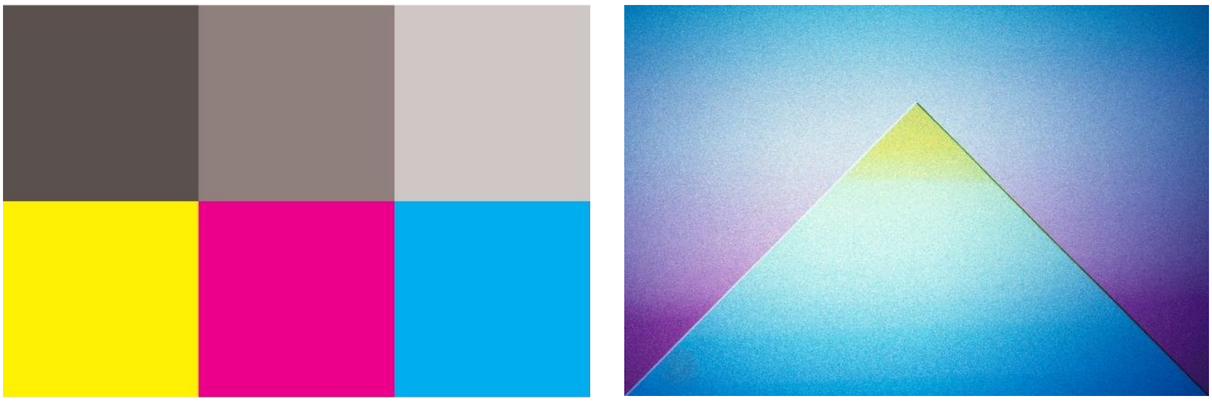


Figure 6.19 - Images designed for the artificial ageing tests conducted to Fujichrome Provia 400X Professional (RXP) films; **Left:** step-wedge image, **Right:** image of the artwork *Slides de Cavalete* (slide 54).

The RXP films found at Ângelo de Sousa's archive were exposed to the desired image (step-wedge or image of the artwork). After exposure, the films were processed using E-6 chemistry. For detailed information about the exposure and processing of the samples, consult appendix VI.2., section VI.2.

Sets of three samples (slides) were removed from the oven at different ageing times, as described in Table 6.6, to acquire samples with different degrees of degradation.

To test the proposed methodology before using Ângelo de Sousa's chromogenic reversal films, a set of commercial slides was previously exposed to artificial ageing, under the same two RH values at 80°C. The results of this preliminary artificial ageing experiment have been published elsewhere[9].

The samples were analysed upon ageing using different techniques, for the assessment of the deterioration of both the image and base:

i) Optical microscopy (OM)
ii) Digitization
iii) Attenuated total reflection (ATR) IR spectroscopy
iv) Ultraviolet and visible (UV-vis) spectrophotometry

[9] Silva, J., A.M. Ramos, J.L. Ferreira, C.A.T. Laia, A.J. Parola, and B. Lavédrine. 2017. New approaches for monitoring dye fading in chromogenic reversal films: UV-vis spectrophotometry and digitisation. In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4-8 September 2017,* ed. J. Bridgland, art. 1403. Paris: International Council of Museums.

Table 6.6 – Resumé of the samples and conditions used in the artificial ageing

Samples (designation) 		Ageing time (days)	Ageing conditions: water content (wt, %) temperature (T, ˚C)
sw 1, 2, 3	i 1, 2, 3	30	wt≈12.5 and T_{room}
sw 4, 5, 6	i 4, 5, 6	60	
sw 7, 8, 9	i 7, 8, 9	120	
sw 10, 11, 12	i 10, 11, 12	225	
sw 13, 14, 15	i 13, 14, 15	300	
sw 16, 17, 18	i 16, 17, 18	30	wt≈15 and T_{room}
sw 19, 20, 21	i 19, 20, 21	60	
sw 22, 23, 24	i 22, 23, 24	120	
sw 25, 26, 27	i 25, 26, 27	225	
sw 28, 29, 30	i 28, 29, 30	300	
sw 31, 32, 33	i 31, 32, 33	30	wt≈12.5 and T=50
sw 34, 35, 36	i 34, 35, 36	60	
sw 37, 38, 39	i 37, 38, 39	120	
sw 40, 41, 42	i 40, 41, 42	225	
sw 43, 44, 45	i 43, 44, 45	300	
sw 46, 47, 48	i 46, 47, 48	30	wt≈15 and T=50°C
sw 49, 50, 51	i 49, 50, 51	60	
sw 52, 53, 54	i 52, 53, 54	120	
sw 55, 56, 57	i 55, 56, 57	225	
sw 58, 59, 60	i 58, 59, 60	300	
sw 61, 62, 63	i 61, 62, 63	30	wt≈12.5 and T=60°C
sw 64, 65, 66	i 64, 65, 66	60	
sw 67, 68, 69	i 67, 68, 69	120	
sw 70, 71, 72	i 70, 71, 72	225	
sw 73, 74, 75	i 73, 74, 75	30	wt≈15 and T=60°C
sw 76, 77, 78	i 76, 77, 78	60	
sw 79, 80, 81	i 79, 80, 81	120	
sw 82, 83, 84	i 82, 83, 84	225	
sw 85, 86, 87	i 85, 86, 87	15	wt≈12.5 and T=70°C
sw 88, 89, 90	i 88, 89, 90	30	
sw 91, 92, 93	i 91, 92, 93	60	
sw 94, 95, 96	i 94, 95, 96	120	
sw 97, 98, 99	i 97, 98, 99	15	wt≈15 and T=70°C
sw 100, 101, 102	i 100, 101, 102	30	
sw 103, 104, 105	i 103, 104, 105	60	
sw 106, 107, 108	i 106, 107, 108	120	
sw 109, 110, 111	i 109, 110, 111	15	wt≈12.5 and T=80°C
sw 112, 113, 114	i 112, 113, 114	30	
sw 115, 116, 117	i 115, 116, 117	60	
sw 118, 119, 120	i 118, 119, 120	15	wt≈15 and T=80°C
sw 121, 122, 123	i 121, 122, 123	30	
sw 124, 125, 126	i 124, 125, 126	60	

Perceptible changes produced during the artificial tests were documented by scanning the samples before and after ageing. Additionally, superficial microscopic changes were evaluated by observing the samples under the OM. Cross-sections were also collected from the samples with the aim of relating the variations to specific layers of the film. For detailed information about digitization consult appendix VI.4., and about OM see appendix VI.3.

The emulsion (gelatine) and base (CTA) layers were assessed upon ageing by using ATR, in order to understand the contribution of these layers to colour change measured in the overall chromogenic reversal films (see more information about the ATR analysis in appendix VI.5).

The ISO 18909:2006(E) recommends measuring the optical density loss by using a densitometer to follow dye degradation. However, UV-vis spectrophotometry was chosen to assess colour change in the obtained artificially aged samples in a more insightful way. Measurements were done at specific and on small areas of the image (ϕ = ±1 mm) by using optical fibre probes. Every step-wedge sample was analysed in six spots (N80, N50, N18, Y, M and C patches) and image of the artwork sample in four different spots (M, C, W and Y areas). The absorbance spectra (obtained in transmittance) enabled following the degradation of the film in specific areas of the visible spectrum, namely at about 440 nm (absorption maximum of the Y dye), 560 nm (absorption maximum of the M dye) and 655 nm (absorption maximum of the C dye). See detailed information about the performed UV-vis analysis in appendix VI, section VI.6. The step-wedge samples aged at T=80°C were also assessed using a densitometer to compare the values obtained with this equipment and those obtained with the UV-vis spectrophotometer (see appendix VI, section VI.7). Additionally, the entire spectral data acquired with the UV-vis spectrophotometer was mathematically treated in order to calculate colorimetric data. CIE L*a*b* is a psychometric colorimetric system, which is based on the measurement of the colour stimuli and is used to compare colour differences between objects (Oleari 2016, 261). Thus, colour change can be expressed according to human perception (Oleari 2016, 280). CIE L*a*b* coordinates were obtained from the absorbance spectra by calculating the trichromatic values X, Y and Z, as described below (Costa et al. 2012, 5272):

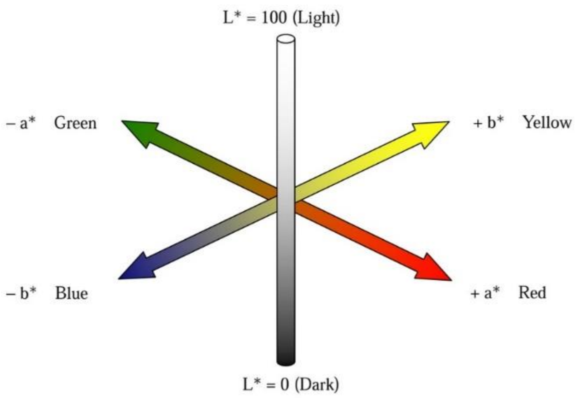


Figure 6.20 - Schematic representation of CIE L*a*b* colour space.

$$X = \sum E_i x_i T_i \qquad (1)$$

where E_i is the coefficient of the Standard Iluminant D65, x_i is the coefficient of the tristimulus value and T_i is the optical transmittance, for all wavelengths. These values can be converted into CIE L*a*b* coordinates (Fig. 6.20), according to the following equations (Costa et al. 2012, 5273):

$$L^* = 116 \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16 \qquad (2)$$

$$a^* = 500 \left[\left(\frac{X}{X_n}\right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}}\right] \qquad (3)$$

$$b^* = 200\left[\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n}\right)^{\frac{1}{3}}\right] \tag{4}$$

where X_n, Y_n and Z_n are the white colour values.

The variation of the CIE L*a*b* coordinates was analysed individually and as a whole, by calculating the total colour variation ΔE* (Costa et al. 2012, 5273):

$$\Delta E^* = \sqrt{(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2} \tag{5}$$

Although colour perception can change depending on the observer, on lighting conditions and on the represented scene (Richardson and Saunders 2013, 184), ΔE* ranging from 2 and 3 has been considered as a gauge above which just noticeable differences (JND) can be detected (Mahy et al. 1994). Thus, ΔE*=2.5 (average value) was established as a limiting value within the framework of this study.

Moreover, the quantification of the occurred degradation was endeavoured based on the conducted digitisations. To do so, RGB coordinates were calculated from the digital files (Adobe RGB 1998). According to Ann Fenech (2011, 97-98), the RGB colour space can be correlated with C, M and Y dyes from the samples due to their complementarities with the R, G and B coordinates, respectively. The computations described next were made with a program created in the open source language 'R'[10]. In order to assess colour variation, the digital images before and after ageing were compared pixel by pixel in the following way:

a) <u>RGB coordinates</u>
- For each pixel, the R value from the aged image was subtracted to the R value from the corresponding unaged image.
- The same process was applied to G and B values.
- For each R, G and B coordinates, all the computed values were added and divided by the total number of pixels. That is to say, the average value variation of each coordinate was computed.

b) <u>CIE L*a*b* coordinates</u>
- The RGB coordinates were converted to CIE L*a*b* coordinates using the software package "convertColor" (*R Documentation: Convert between Colour Spaces*).
- The average value variation was computed following the process of the RGB described previously.
- Additionally, ΔE* was calculated using equation (5).

After refining the methodology for monitoring colour change in chromogenic reversal films, a selection of slides composing the artwork *Slides de Cavalete* and some test slides produced within the outline of that work, were analysed using UV-vis spectrophotometry in order to document the current condition of the slides. Periodical analysis of the samples has been made to monitor colour change in these works (see appendix VI, section VI.6).

[10] The complete R code is presented in appendix VI, section VI.4, and on the following website: https://github.com/joanalimadasilva/RGB-and-CIELab-conversion/blob/master/convertRGB%26Lab%20with%20Delta.R

6.4.2. Assessing colour change in artificially aged RXP samples

6.4.2.1. Macroscopic and microscopic observation

At a macroscopic level, it was not possible to detect any visible changes on the images from the chromogenic reversal films induced by artificial ageing. However, the plastic mountings from the samples aged at T=70˚C and T=80˚C presented physical deformation (curling) after a few days of ageing. The infrared spectrum of the PS frame revealed the presence of butadiene (see appendix VI, section VI.5, Fig. 6.26). Polybutadiene has been commonly blended to PS to improve the qualities of the polymer (Shashoua 2008, 248). Styrene butadiene has also been employed as an additive to soften the PS polymer and increase its impact resistance (Murphy 2001, 192). Thus, the presence of butadiene might have contributed to a decrease in the glass transition (T_g)[11] of the material (pure PS has a T_g around 100˚C), leading to a change in the molecular conformation of the polymer when exposed to high T, such as the Ts used in the artificial ageing experiments.

In general, photographic materials tend to undergo dramatic changes at high T due to the physical properties of gelatine. Photographic gelatine changes from a glassy to a rubbery state when surpassing the T_g (Adelstein, Bigourdain and Reilly 1997, 196). Being a hygroscopic molecule, the T_g changes drastically according to the moisture content of the gelatine. While dry gelatine has a T_g value around 200˚C, when equilibrated to RH around 70-75% this value drops to T_{room} (McCormick-Goodhart 1996, 10). Therefore, the emulsion layer of the artificially aged samples was observed under the OM to detect any visible damage induced in the gelatine layers upon ageing. The microscopy images from the step-wedge and artwork samples, before and after 60 days of artificial ageing at T=80˚C and wt≈15%, are presented in Figures 6.21 and 6.22, respectively.

Fortunately, no discernible changes were observed regarding the general appearance of the gelatine (neither the protective layer, nor the emulsion layers). As can be seen in Figures 6.21 and 6.22, a few bubbles were present before ageing, which apparently remained within the same proportion after ageing. On the contrary, a clear change in colour can be observed upon ageing. After the ageing tests, the samples gained an orange tone in the overall image, pointing to the production of coloured degradation products. Dark fading normally leads to colour shift and loss of density, homogeneously spread over the image (Wilhelm and Brower 1993, 164). As previously mentioned, residual colour couplers present in the emulsion layers are vulnerable to oxidation, producing yellowish species (Bergthaller 2002c, 265). The same tendency was observed for all samples aged at different conditions, and for both types of samples (step-wedge and artwork image) (see appendix VI, section VI.3). Yet, this colour change was more visible for samples aged at T=70˚C and T=80˚C, which points to samples in a more advanced stage of degradation. These variations are especially visible in the neutral patches from the step-wedge samples, in particular N(18). The Y, M and C patches and the image of the artwork samples also show a highly perceptible colour change, which looks duller than the unaged references. Moreover, dye clouds from the aged samples seem to have spread upon ageing, looking blurred and less sharp. No differences between samples with wt≈12.5% and wt≈15% were observed under the microscope.

[11] Temperature at which an amorphous material (or semi crystalline materials with amorphous regions) begins to absorb energy.

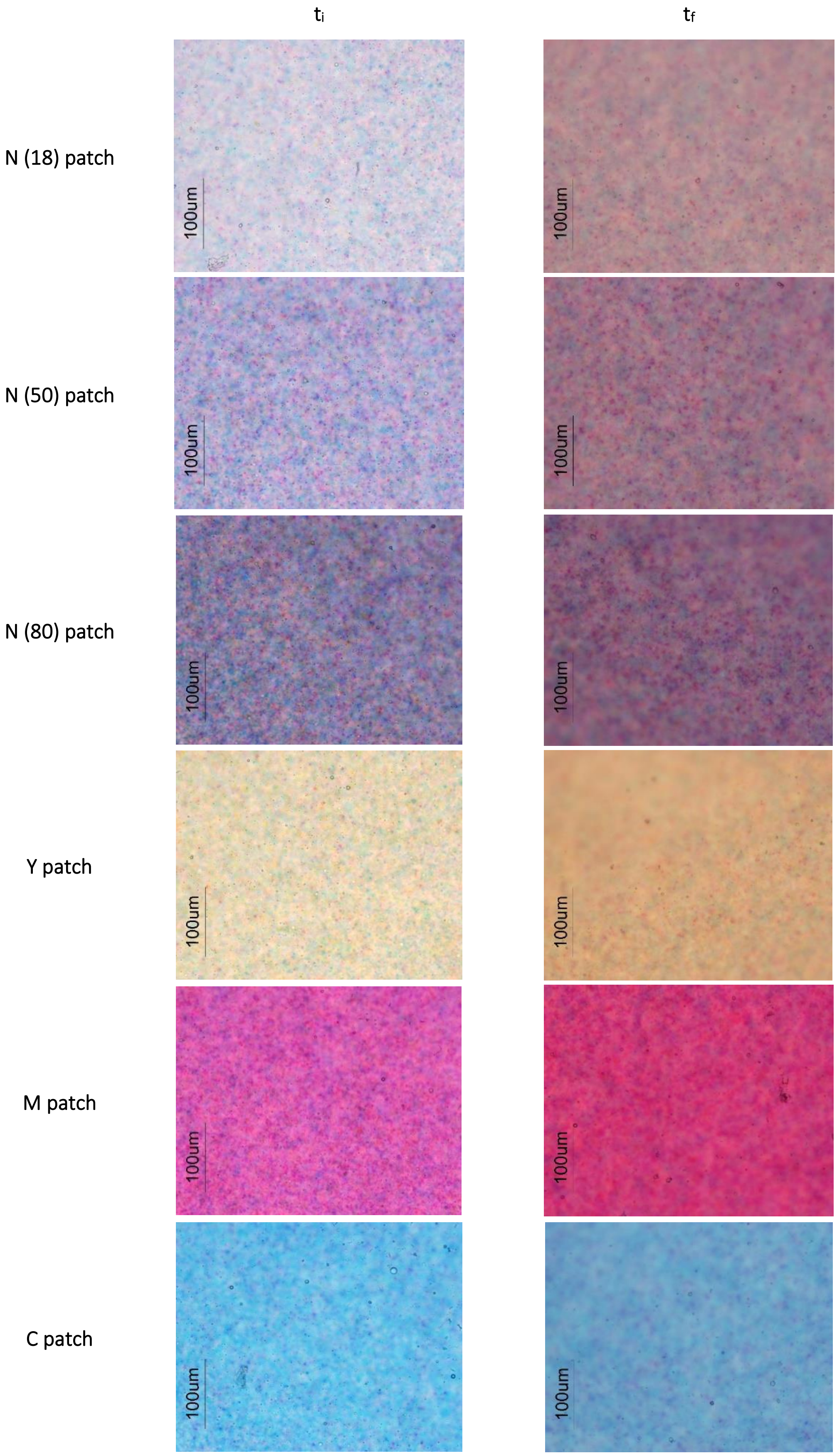


Figure 6.21 - Microscopy images of a step-wedge sample before (t_i) and after (t_f) 60 days of artificial ageing at T=80˚C and water content (wt)≈15%.

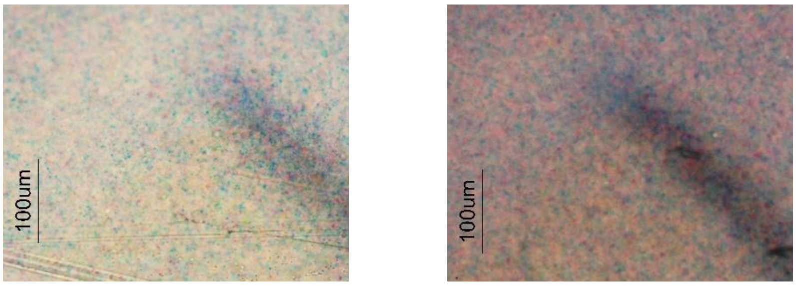


Figure 6.22 - Microscopy images of the artwork sample before (t_i) and after (t_f) 60 days of artificial ageing at T=80˚C and water content (wt)≈15%.

Cross sections were collected from the historical EPT film found in Ângelo de Sousa's archive (Fig. 6.23) and from the RXP samples with different degrees of degradation and were examined under the OM (Figs. 6.24 and 6.25). Regarding the artificially aged samples, no differences were observed within the emulsion layers under different lighting (see obtained images in appendix VI, section VI.3). On the contrary, a slight increment on the fluorescence of the CTA base was detected on aged samples. The samples show a weak fluorescence under blue-violet and ultraviolet excitation wavelengths, which tends to increase upon ageing (Figs. 6.24 and 6.25). This is especially visible in samples aged at wt≈15%, on the surface (top and bottom) of the films. In 1930, James McNally and Waldema Vanselow, from the Kodak Research Laboratories, noted that cellulose acetate (CA) presented strong fluorescence in the ultraviolet region (McNally and Vanselow 1930, 3846). According to the study conducted by those authors on CA films with different percentages of acetyl groups, as CTA is hydrolysed to cellulose diacetate (CDA) there is a slight increase in the fluoresce intensity of the films at $\lambda > 365$ nm (McNally and Vanselow 1930, 3851-3852). By observing the historical EPT film it is possible to see fluorescence in the overall CTA layer, corroborating the obtained results (Fig. 6.23).

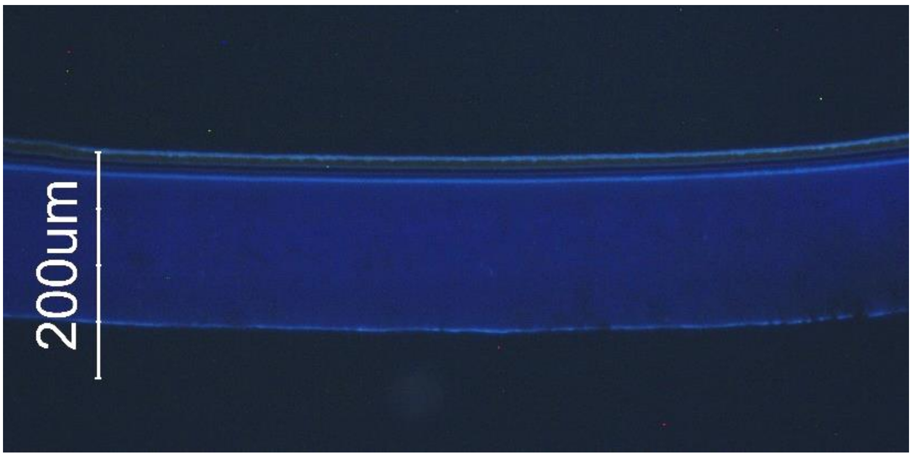


Figure 6.23 - Microscopy images of the cross-sections from the naturally aged Ektachrome 160T (EPT) film under ultraviolet light.

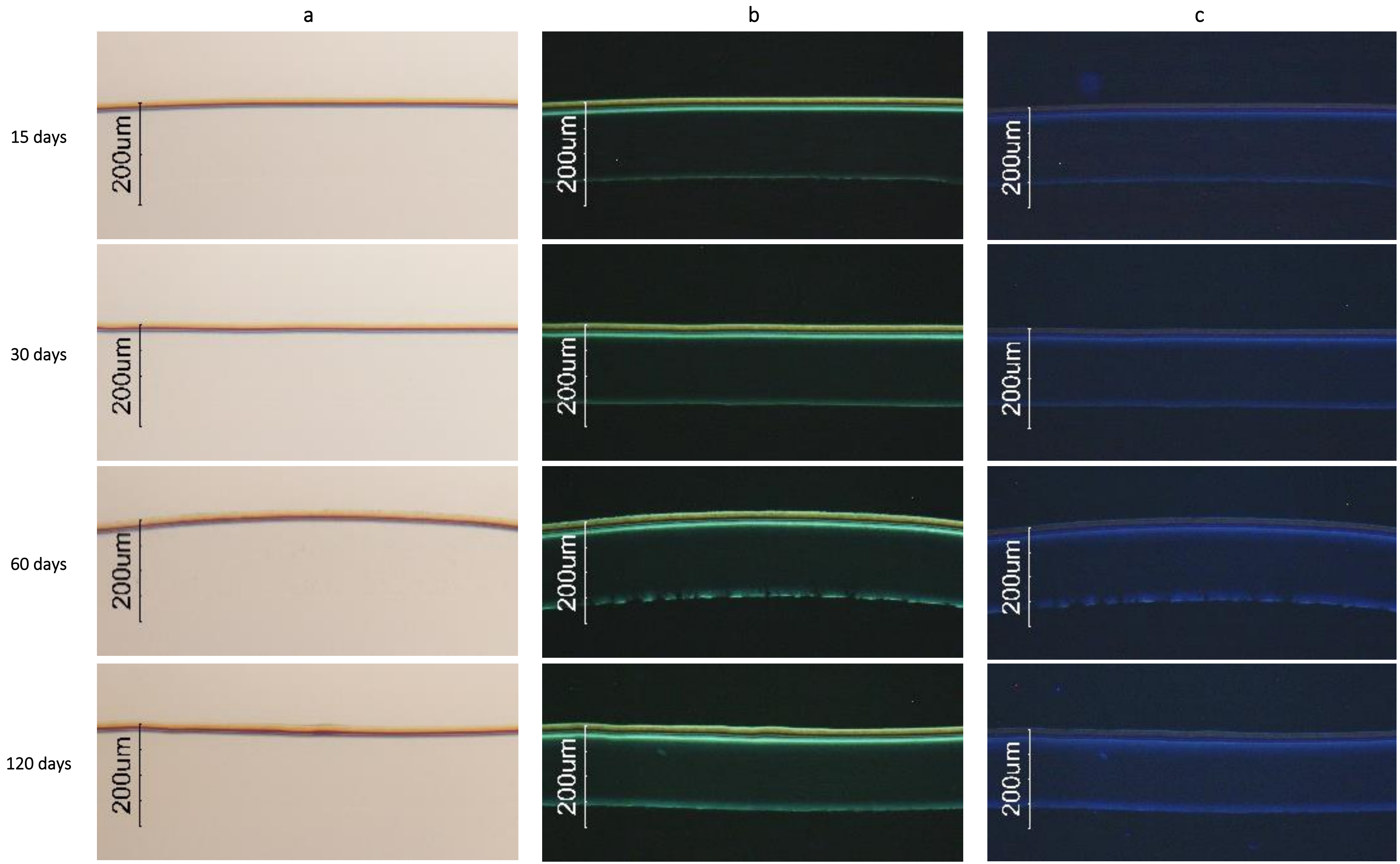


Figure 6.24 - Microscopy images of the cross-sections from samples after 15, 30, 60 and 120 days of artificial ageing at T=70˚C and water content (wt)≈12.5%, under a) reflected cross-polarised light, b) blue-violet light, and c) ultraviolet light.

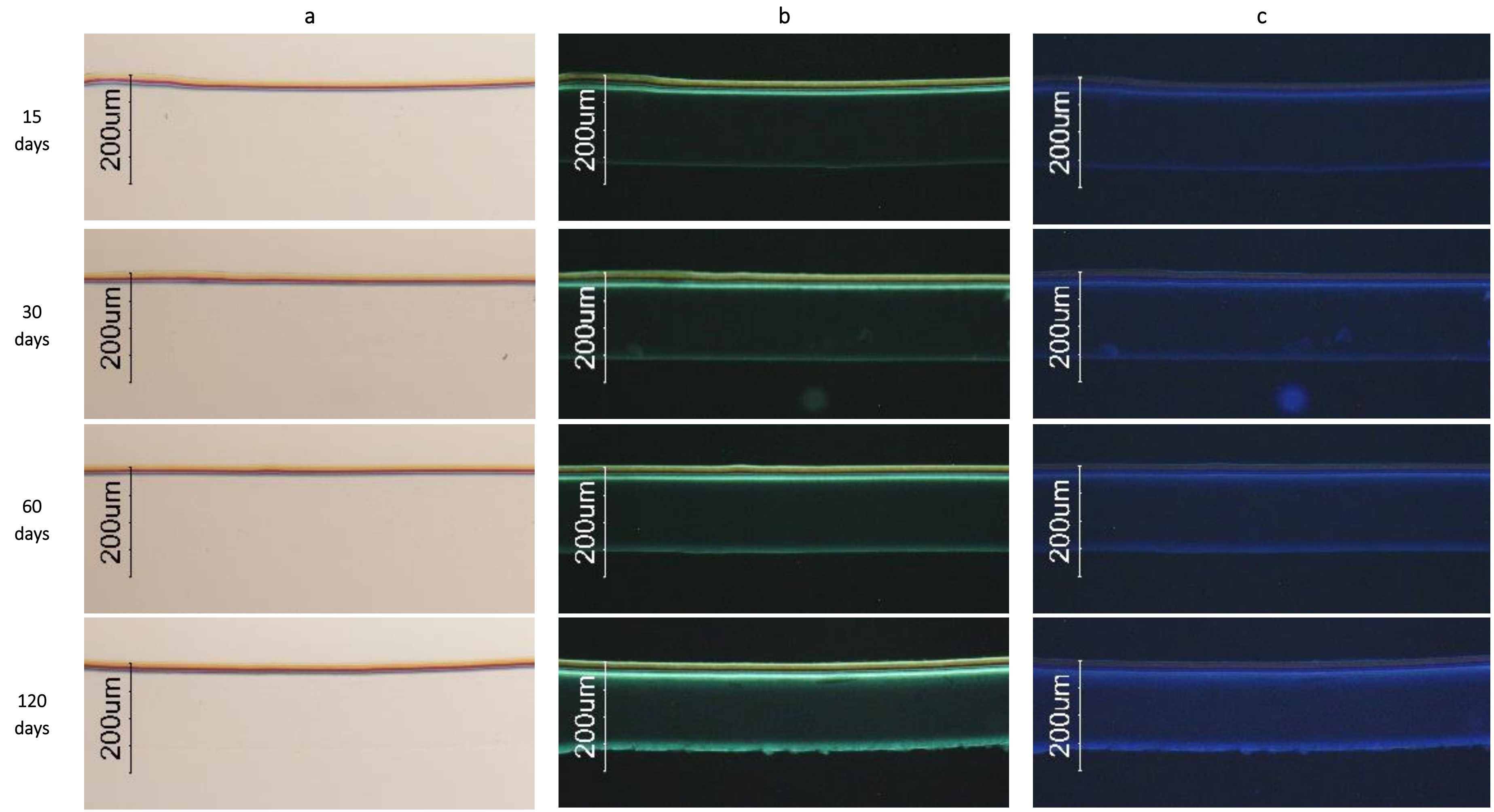


Figure 6.25 - Microscopy images of the cross-sections from samples after 15, 30, 60 and 120 days of artificial ageing at T=70˚C and water content (wt)≈15%, under a) reflected cross-polarised light, b) blue-violet light, and c) ultraviolet light.

6.4.2.2. *Digital documentation*

All samples induced to artificial ageing were digitized before and after ageing (see details about the digitization process in appendix VI, section VI.4). Due to technical constraints, it was not possible apply an ICC (International Color Consortium) profile to the obtained digital images. Nevertheless, the samples were digitized following the exact same parameters in a new scanner.

The digital images of the step-wedge and artwork image samples, before and after 60 days of artificial ageing at T=80˚C, are presented in Figures 6.26 and 6.27 (the remaining digital images can be consulted in appendix VI, section VI.4).

After ageing, an orange tone can be noted in the overall image, as previously observed in the microscopy images (previous section). This characteristic tone is more difficult to observe in the image of the artwork samples, which more likely seem to have lost the original blue hue, looking now more magenta and yellow than the samples before ageing. Additionally, yellow/orange linear marks can be observed in all images, both before and after the ageing experiment. This type of staining points to an improper processing. The samples were processed in one of the remaining laboratories still doing E-6 processing in Lisbon, and according to Tina Weidner (2012), it is common for this type of small laboratory to reduce the quality of processing due to low workload. As with the microscopy images, no clearly discernible variations could be established between samples with wt≈12.5% and wt≈15%.

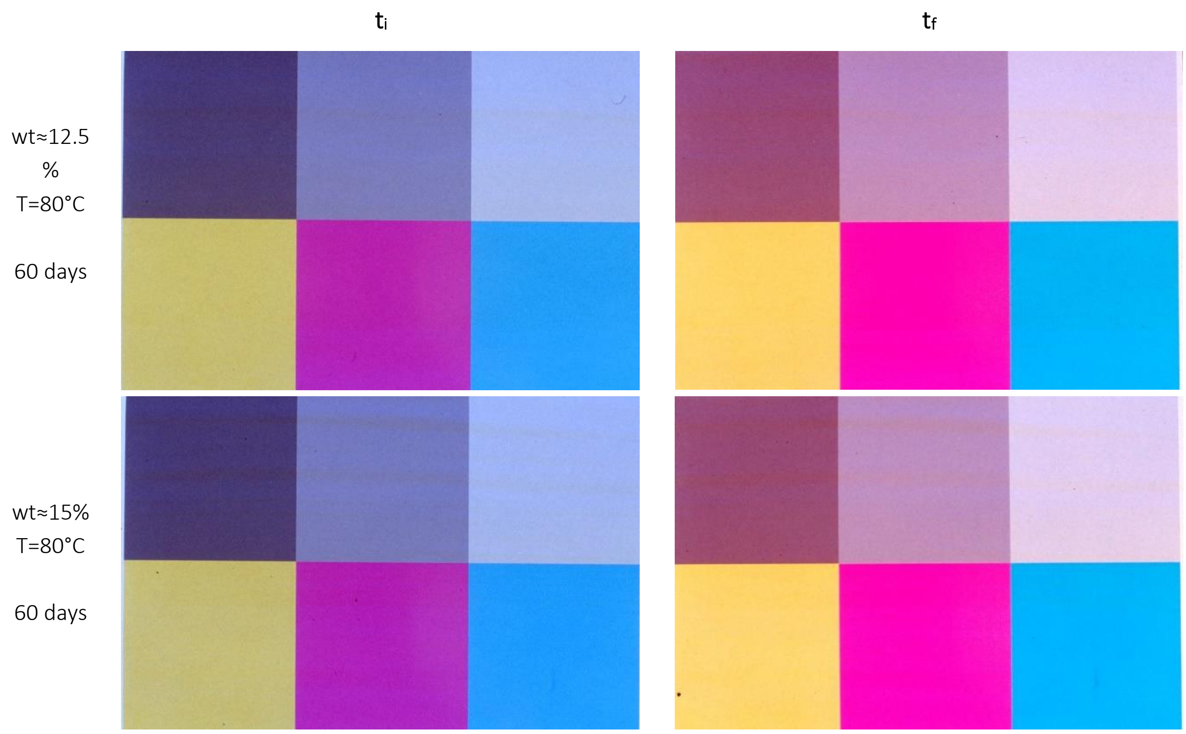


Figure 6.26 - Digital images of the step-wedge samples before (t_i) and after (t_f) 60 days of artificial ageing at T=80˚C and water content (wt)≈12.5%, and before and after 60 days of artificial ageing at T=80˚C and water content (wt)≈15%.

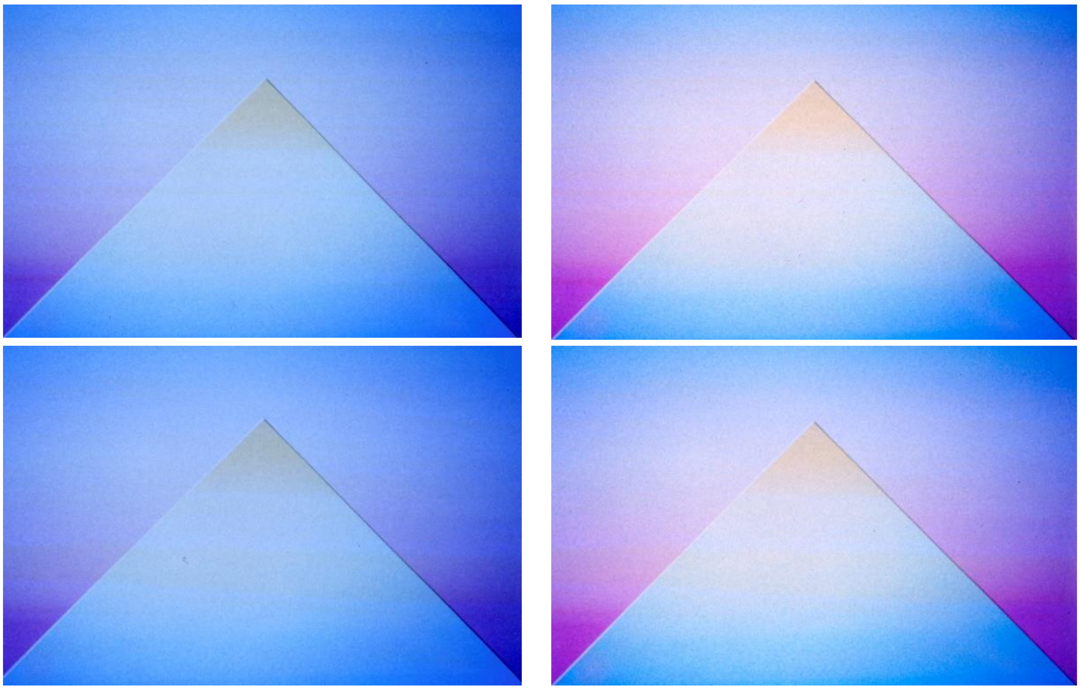


Figure 6.27 - Digital images of the artwork samples before (t_i) and after (t_f) 60 days of artificial ageing at T=80˚C and water content (wt)≈12.5%, and before and after 60 days of artificial ageing at T=80˚C and water content (wt)≈15%.

6.4.2.3. Base and emulsion characterization

The condition of the CTA base and gelatine emulsion layers from the RXP samples induced to artificial ageing was studied at a molecular level by using IR spectroscopy. To do so, ATR spectra were collected at the surface of the samples before and after ageing. The results obtained for samples aged at T=80˚C are shown from Figures 6.28 to 6.31. The same pattern of degradation was observed in the remaining tests conducted at T=50 ˚C, 60 ˚C and 70˚C (see appendix VI, section VI.5). In general, no significant changes were detected between samples with wt≈12.5% and wt≈15%.

CTA is a semi-synthetic polymer derived from cellulose, made of repetitive anhydroglucose units esterified with acetate groups (Shashoua 2008, 40-41). As mentioned in section 6.2, the CTA base for the RXP samples presents characteristic vibrations in the infrared region of the spectrum (Table 6.7). In addition to the absorption peaks associated to the CTA polymer, other peaks at 3070, 1590, 1490, 1430, 1185, 1160, 1125, 950, 900, 830, 770, 755, 690 cm^{-1} were identified. All these peaks have a clear match with triphenyl phosphate (TPP), pointing to a CTA base plasticized with this compound (see reference infrared spectrum of TPP in appendix VI, section VI.5, Fig. VI.25). TPP has been widely used as a flame retardant and plasticizer in CA since the 1940s (Shashoua 2008, 182). By observing Figures 6.28 and 6.29, slight differences can be observed in the spectra collected before and after artificial ageing. The primary degradation pathway associated with CTA is its deacetylation in contact with atmospheric water (especially for samples aged in the dark and without much contact with oxygen). This degradation, best known as vinegar syndrome, leads to the formation of acetic acid (Reilly 1993, 11). As the material deteriorates, there is a loss of acetate groups, which are substituted by hydroxyl groups. Accordingly, a reduction of the carbonyl (C=O) peak and an increase in the hydroxyl (OH) band is expected in the infrared spectrum (Littlejohn et al. 2013, 420). Additionally, the formation of chromophores such as carbonyl groups in the structure of the CTA, resulting from oxidation and hydrolysis, can lead to yellowing of the base (Shashoua 2008, 165). However, in all the collected spectra no significant changes could be assigned to those functional groups. Hence, no deacetylation nor evidence of yellowing of the CTA base could be detected. The major observed differences are located at wavelengths corresponding to the absorption of TPP. The loss of plasticizer, with its gradual migration to the surface of the film, is a usual degradation path associated with the degradation of CTA films, due to the chemical incompatibility of commonly used plasticizers with the CTA polymer (Reilly 1993, 12). The exudation of TPP from the base can also underpin the fluorescence detected on the surface of the films under the OM (previous section). According to Comelli et al. (2014, 359), the presence of aromatic fluorophores can cause the fluorescence emission of polymers. Moreover, the spectra collected in the middle and at the end of the ageing time are nearly overlapped, showing that plasticizer loss did not gradually arise upon ageing. Those results are not surprising, considering that TPP has a melting point of 48.5˚C, and that all ageing tests were conducted at T above 50˚C. Since TPP decomposes to phenol and diphenyl phosphate, the last being a strong acid (Shashoua 2008, 182), the degradation of this compound might possibly contribute to the fading rate of the dyes.

Table 6.7 - Characteristic absorptions in the infrared for cellulose acetate-based materials (Shashoua 2008, 256)

Wavenumber (cm^{-1})	Type of vibration	Assignment
3430	Stretching	OH…O
3000-2840	asymmetric and symmetric stretching	CH_2 and CH_3
1743	Stretching	C=O
1368	in-plane deformation	CH_3
1237	Stretching	C=O e C-O
1027	Stretching	C-O-C

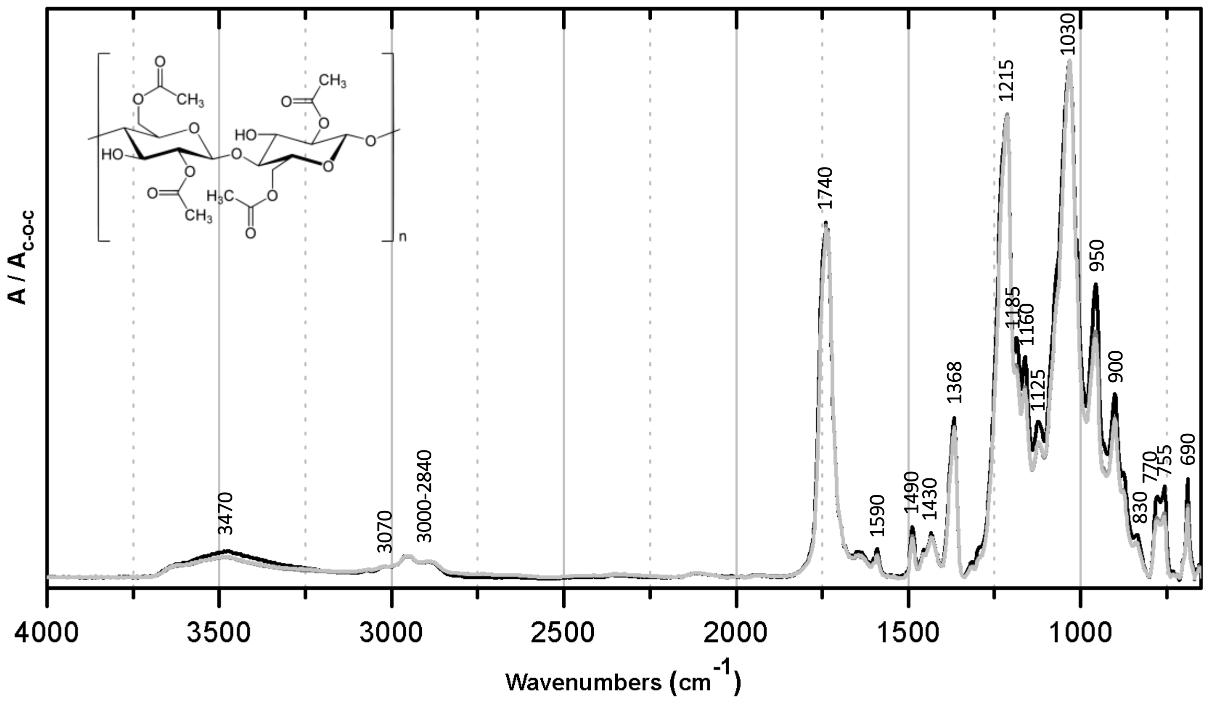


Figure 6.28 – Infrared spectra of the cellulose acetate base from samples before (black line), after 30 days (dark grey line) and 60 days (light grey line) of artificial ageing at T=80˚C and water content (wt)≈12.5%. The two spectra after ageing nearly overlap.

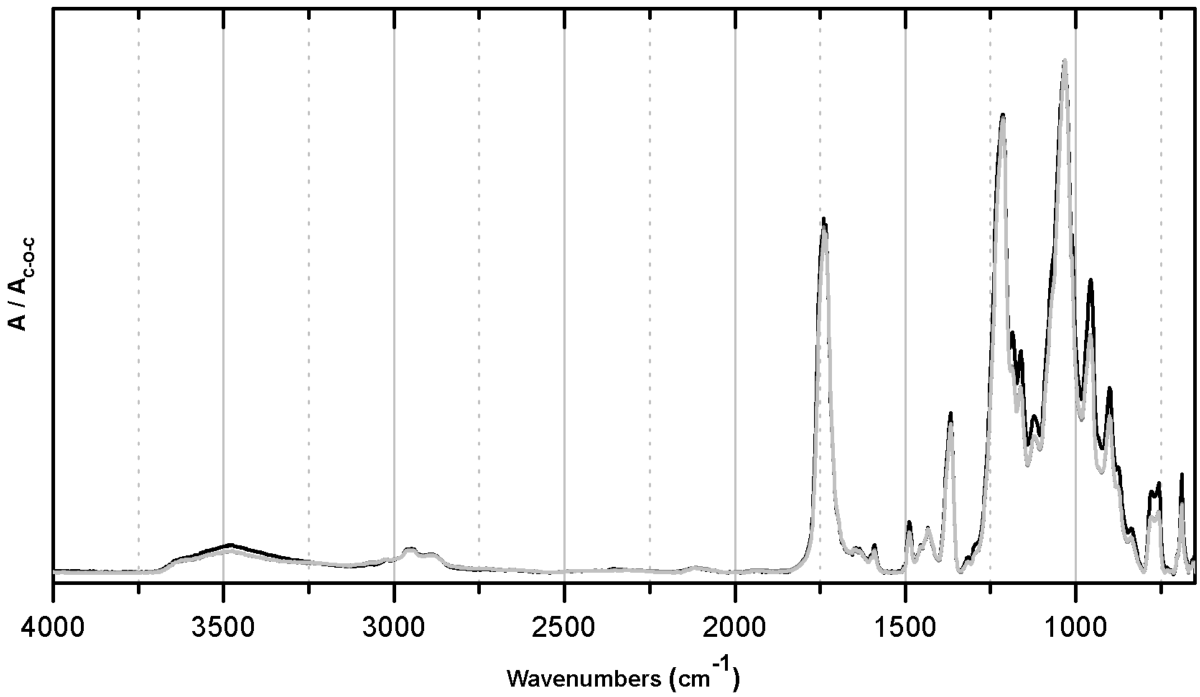


Figure 6.29 – Infrared spectra of the cellulose acetate base from samples before (black line), after 30 days (dark grey line) and 60 days (light grey line) of artificial ageing at T=80˚C and water content (wt)≈15%. The two spectra after ageing nearly overlap.

Gelatine is a proteinaceous material derived from collagen; it is polymer composed of long chains of amino acids joined through a peptide linkage. Obtained from the hydrolytic denaturation of collagen, gelatine has predominantly an amorphous structure (Abrusci et al. 2004, 537). The gelatine of the RXP samples shows typical vibrations in the infrared region of the spectrum, associated to the amide groups and peptide bonds (Table 6.8). Based on the consulted bibliography, the amide A band should be found at 3400 cm^{-1} instead of 3300 cm^{-1}, as observed in Figures 6.30 and 6.31. However, based on the study carried out by Jakir Hossan et al. (2014, 31), the N-H stretching can also be distributed at shorter wavelengths according to the degree of cross-linking of the gelatine. The same authors assigned the band at 2945 cm^{-1} to C-H stretching of the amide B (Jakir Hossan et al. 2014, 31). Peaks ranging from 1460 cm^{-1} to 1380 cm^{-1} can be attributed to the symmetric and asymmetric bending vibrations of methyl groups (Merina et al. 2017, 241). Although photographic gelatine is composed of highly purified proteins and has been considered chemically quite stable at T_{room} (Reilly 1986, 28), yellowing can occur as gelatine ages (Weaver 2008, 4). In aqueous environments, gelatine undergoes progressive hydrolytic degradation, lowering its molecular weight and consequently decreasing its physical properties (Abrusci et al. 2004, 538). In Figures 6.30 and 6.31, significant changes can be observed in the infrared spectra of the samples before and after artificial ageing, especially at wavelengths corresponding to the vibrations of amides A and B. By increasing the T of the gelatine, the rupture of interchain hydrogen bonding (denaturation) might be induced, increasing its amorphous structure (Samouillan et al. 2011, 232-233). As demonstrated by Jesper Stub Johnsen (1996, 558), when gelatine is placed at high T and RH, the structure of the gelatine changes and its melting point increases. The observed variation can also be caused by the exposure of gelatine to conditions exceeding its T_g (McCormick-Goodhart 1996, 10-11). Thus, the decrease observed at 3300 cm^{-1} and 2945 cm^{-1} can reveal a rearrangement of the gelatine structure and destruction of some bonds (such as hydrogen), and not necessarily a degradation pathway. Accordingly, based on the study conducted by Tomšová, Ďurovič and Drábková (2016, 4), the ratio between amide I and amide II was used to follow any degradation occurring in the gelatine emulsion. According to that study, an increase in the ratio between amide I and amide II points to the oxidation and/or hydrolytic cleavage of the gelatine (Tomšová, Ďurovič and Drábková 2016, 4). As a slight variation in this ratio can be observed, it can be concluded that the gelatine from the samples had started to deteriorate. As with the spectra from the CTA base, no significant differences could be established between the spectra collected in the middle and at the end of the ageing time. The question whether this degradation was enough to contribute to the discolouration of the emulsion layer remains to be answered.

Table 6.8 – Characteristic absorptions in the infrared for gelatine (Merina et al. 2017, 241)

Wavenumber (cm^{-1})	Type of vibration	Assignment
3433	NH and OH stretching	amide A
1630	C=O stretching	amide I
1565	CN stretching and NH bending	amide II
1240	C-N and N-H in-plane bending	amide III

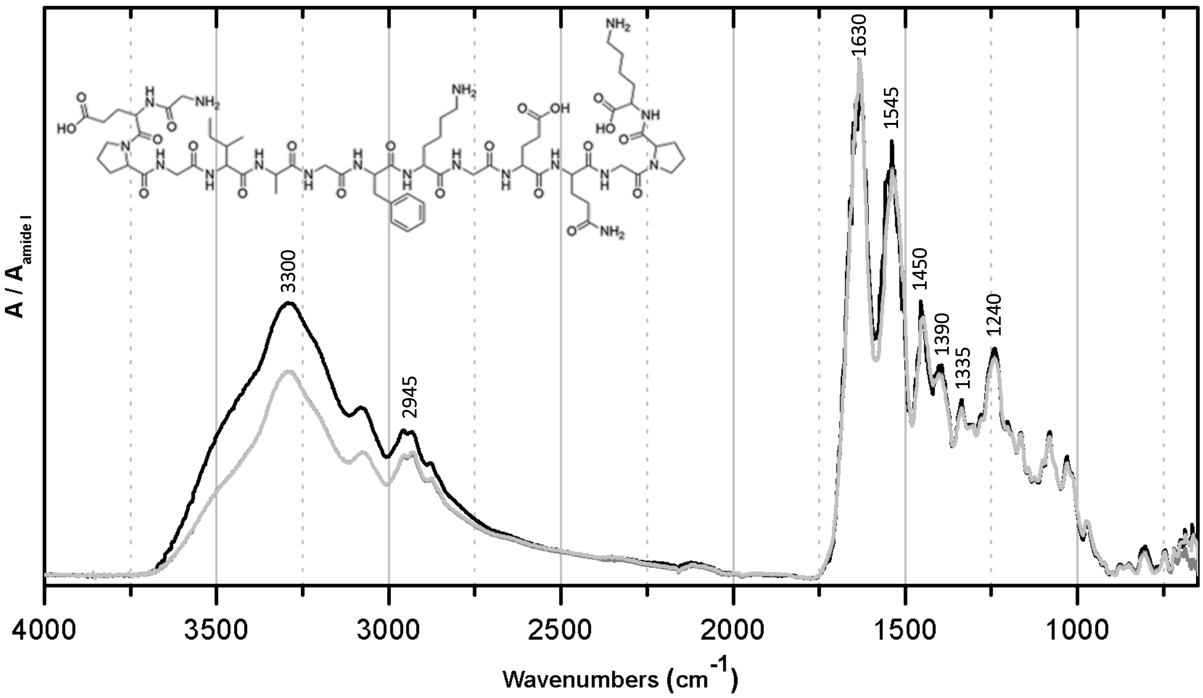


Figure 6.30 – Infrared spectra of the gelatine emulsion from samples before (black line), after 30 days (dark grey line) and 60 days (light grey line) of artificial ageing at T=80˚C and water content (wt)≈12.5%. The two spectra after ageing nearly overlap.

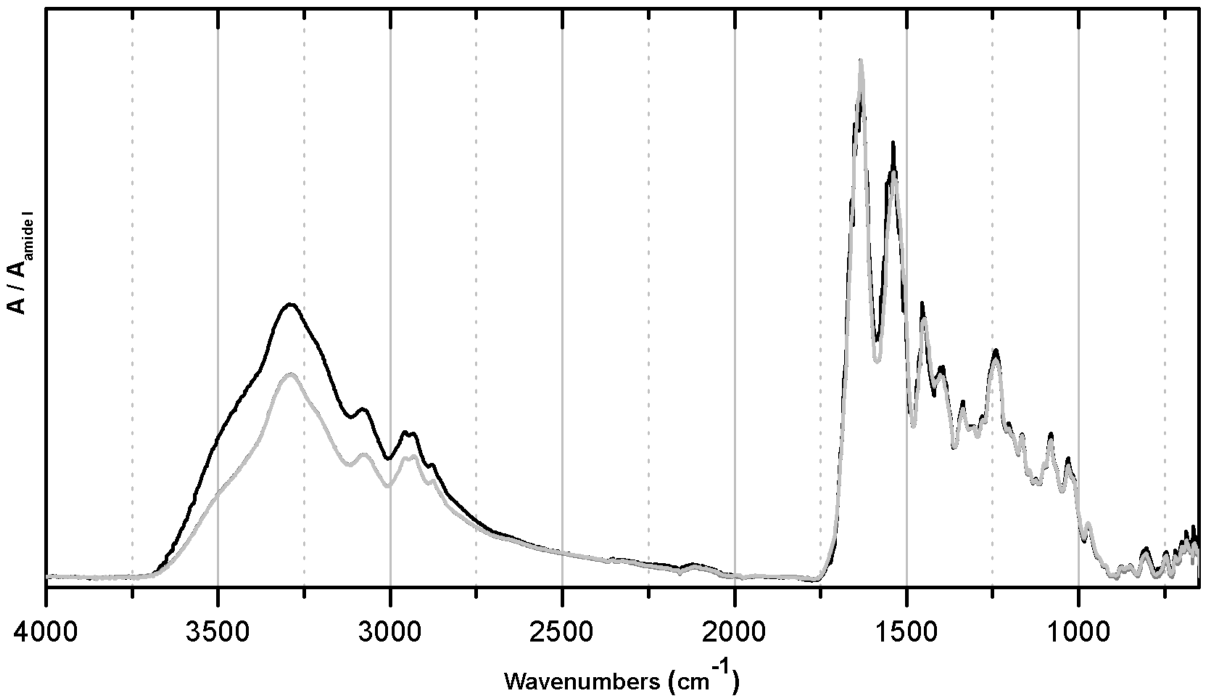


Figure 6.31 – Infrared spectra of the gelatine emulsion from samples before (black line), after 30 days (dark grey line) and 60 days (light grey line) of artificial ageing at T=80˚C and water content (wt)≈15%. The two spectra after ageing nearly overlap.

Within the present study, Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) were performed to the emulsion layer from the RXP samples, pre-conditioned at RH=40, 60% and 100%, in order to determine the T_g of the gelatine and to detect physical phenomena such as water desorption, respectively. However, the results from DSC were inconclusive (see results in appendix VI, section VI.8). Compared to the study performed by Mark H. McCormick-Goodhart (1996, 13), in all conditions at which the present ageing tests were conducted, the T_g was surpassed. However, according to Adelstein, Bigourdain and Reilly (1997), T_g is not a critical parameter, since the tests conducted both above and behind the T_g of gelatine maintained a linear correlation. Regarding TGA analysis, a visible decrease in weight loss of the gelatine was observed at about T=68˚C for samples pre-conditioned at RH=40%, and T=70˚C for samples pre-conditioned at 60%, whereas the gelatine sample pre-conditioned at RH=100% presented an immediate weight loss as the temperature increased, as can be seen in Table 6.9 (see thermograms in appendix VI, section VI.8). This weight loss has been related to loss of adsorbed (non-crystalline) and bounded (crystalline) water (Apostolov et al. 1998, Chuaynukul, Prodpran and Benjakul 2014). Based on the study conducted by Anton Apostolov et al. (1998, 469), the discrepancy observed between samples can be explained by the crystallized water (in higher amounts in samples with high moisture content) being released from the polymer matrix in a shorter interval, whereas the non-crystallized water (in higher amounts in samples with low moisture content) leaving the system gradually over a larger temperature range. After that interval, gelatine starts to decompose. This physical variation might lead to a differential behaviour of the samples aged at T=80˚C (samples aged at T=70˚C, right at the beginning of the water desorption phenomenon, do not seem to be so affected). Therefore, based on the present study, it is recommended not to perform artificial ageing tests at T > 68-70˚C, depending on the water content of the samples.

Table 6.9 – Transition temperatures from the TGA thermograms of gelatine pre-conditioned of RXP samples at different at RH=40, 60 and 100%

Pre-conditioning RH (%)	weight loss			
	T_i (˚C)	T_f (˚C)	T_i (˚C) degradation	T_f (˚C) degradation
40	69.5	143.2	164.5	non-defined
60	67.8	157.6	193.9	non-defined
100	T_{room}	123.9	222.2	non-defined

*6.4.2.4. UV-vis spectra and CIE L*a*b* coordinates for the description of colour change*

The spectral absorbance of all RXP samples was collected in the UV-vis region, before and after artificial ageing. The acquired spectra present three distinguishable bands with maximums at circa 441 nm, 558 nm and 657 nm, which can be assigned to the absorption of Y, M and C dyes, respectively. These represent the so-called integral densities of the chromogenic material. Figures 6.32 and 6.33 illustrate the integral intensities of the analysed areas in the step-wedge and artwork samples, respectively. Contrary to all the other analysed areas, C and M areas from the artwork samples show considerable variation from sample to sample. This was probably a consequence of an unfortunate selection of the area to be examined (in the interface between two totally different colours - the background and triangular shape), leading to a considerable error associated with the analysis of these two areas. Thus, henceforth, only the W and Y areas were considered for the artwork samples.

As expected, the three neutral areas of the step-wedge samples have similar spectra, showing significant absorption in the B, G and R regions. The intensities of the bands vary according to the density of the image, as follows: N(80) > N(50) > N(18). The absorption intensity is lower at 441 nm than at 558 nm and 657 nm, for all three neutral patches, possibly meaning that less Y than the remaining dyes was produced. Regarding the spectra of the Y, M and C patches, a prominent high absorption at 441 nm, 558 nm and 657 nm, respectively, can be distinguished. In the Y patch, the absorption of the band at 441 nm is less intense (≈1.4) than in the M and C patches (≈2.2). Although an attempt to produce patches with the primary colours was made, all the patches present absorptions (to a greater or lesser extent) in all three regions of the spectrum. Regarding the artwork samples, both Y and W areas of analysis present similar spectra. The major absorption intensities (≈1.4) are, in both cases, in the R region, followed by the absorption in the G region (≈1.2) and finally in B region (≈0.8).

Figures 6.32 and 6.33 also show the spectra of the different analysed areas of samples with wt≈15%, before and after 60 days of ageing at T=80°C. A slight (1-3 nm) but consistent shift to shorter wavelength (hypsochromic or blue shift) can be observed in the absorbance spectra after artificial ageing, for all three intensity maximums, possibly resulting from the interaction of the dyes with the environment. According to Berry (1998, 24), this might be a consequence of a widening of the HOMO-LUMO gap in the dye molecule resulting from the expansion of the quinone system.

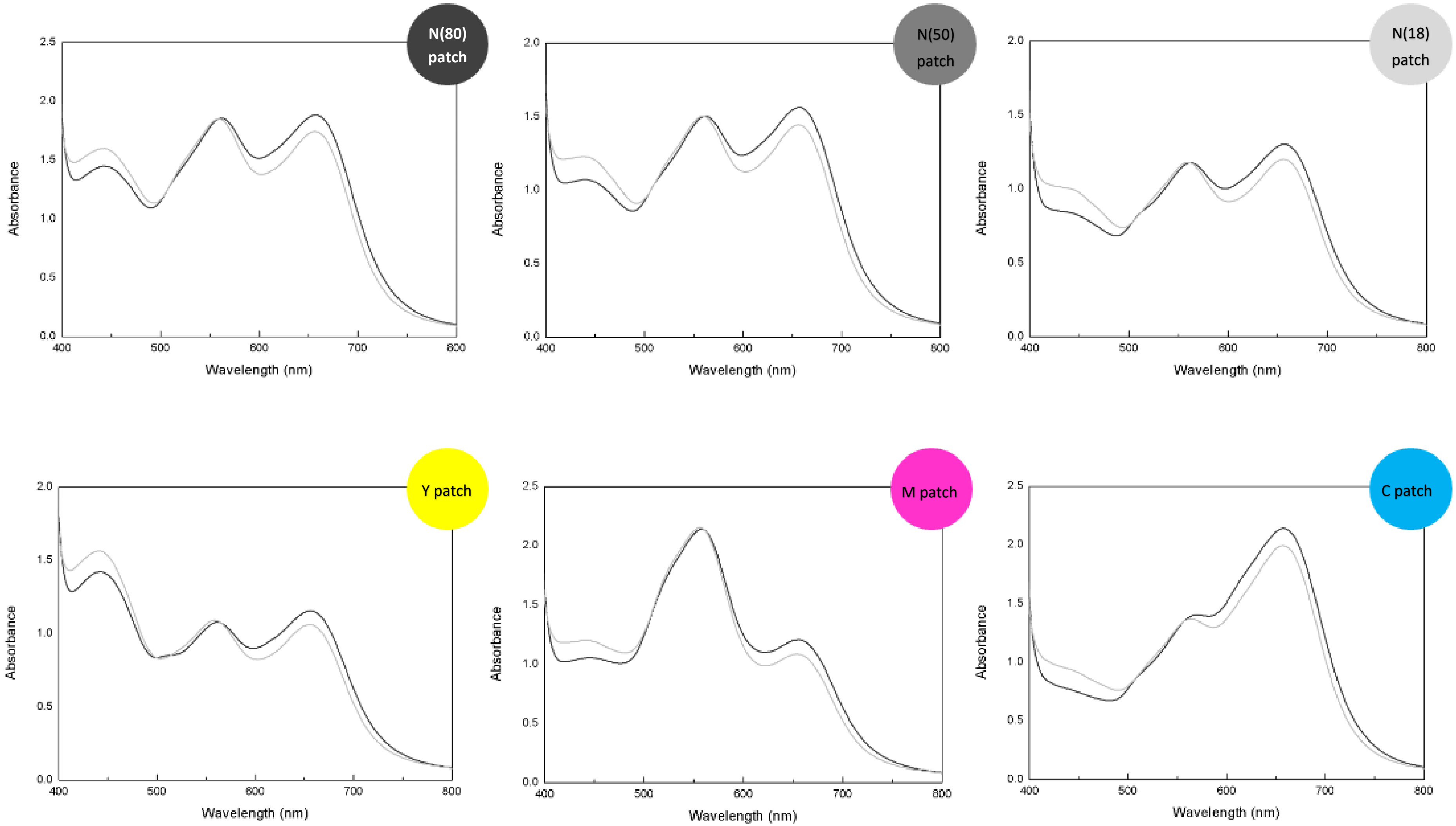


Figure 6.32 - Spectral absorbance of a sample before (dark grey line) and after (light grey line) 60 days at water content (wt)≈15% and T=80°C.

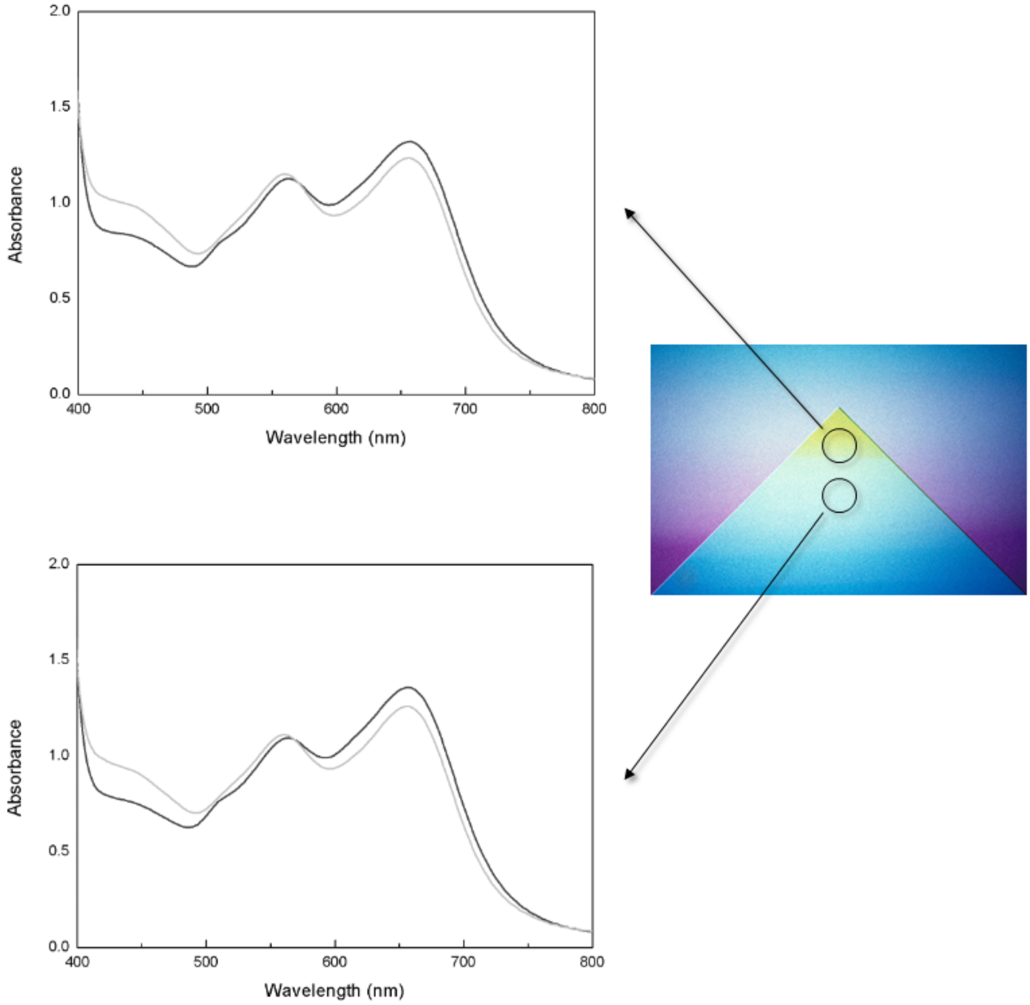


Figure 6.33 – Spectral absorbance of a sample before (dark grey line) and after (light grey line) 60 days at water content (wt)≈15% and T=80°C.

Although C, M and Y dyes have characteristic strong absorption bands in the R, G and B regions, respectively, as shown in the UV-vis spectra of each dye individually from the RXP sample acquired in the HPLC-DAD analysis (see section 6.3.2.3), the dyes also have slight side absorptions at other wavelengths. Thus, when observing the integral densities of a chromogenic photograph, a variation in the amount of one of the dyes of the mixture can result in a variation at all wavelengths (Evans, Hanson and Brewer 1953, 441). Nonetheless, the absorption intensity in the R, G and B regions of the spectra can be used to qualitatively assess the variations occurring in the samples.

According to the literature, from the three dyes, Y is the most susceptible to dark fading (Tuite 1979, 479; Reilly 1998, 12). In the studies conducted by James Reilly (1998, 2), Y proved to be the limiting dye in all tested products. Conversely, azomethine dyes from pyrazolotriazole M couplers, used in modern materials, are quite stable being resistant to yellow stain, light and dark fading (Di Pietro 2007, 184). C dyes resulting from both phenol and naphthol classes of couplers have been subjected to continuous improvements having achieved some chemical stability (Di Pietro 2007, 185). Nonetheless, the fading of C dyes can be accelerated by its reduction in the presence of residual couplers (Theys and Sosnovsky 1997, 100). However, regardless of the analysed area and ageing conditions, the samples artificially aged within the framework of this study show a different trend. After ageing, the following can be observed: i) an increase in the absorption intensity in the B region, ii) the G region remained on average approximately unchanged (although it increased in some cases and decreased in others), and iii) a decrease in the absorption intensity in the R region. These results confirm that apart from the expected fading of the dyes, coloured species were formed upon ageing, probably resulting from the degradation of residual colour couplers (Bergthaller 2002c, 265). In addition, since all stratigraphic layers of the film were analysed, there could be some contributions from other sources, such as the gelatine binder and/or the CTA base. However, only slight evidence of degradation was detected with the ATR analysis in those layers (section 6.4.2.1). Furthermore, according to Henry Wilhelm and Carol Brower (1993, 177), it is expected that the degradation of the chromogenic dyes starts long before that of the base.

The obtained results corroborate what was previously observed (microscopy and digital images): a reddish yellow (Y+M=R) tone was produced upon ageing. The degradation products are absorbing mostly in the B region of the spectrum, but also in the G region of the spectrum, masking the fading of both Y and M dyes, respectively. Therefore, from the obtained results, it is not possible to study the fading rate of these two dyes. On the contrary, the degradation products produced throughout ageing do not absorb in the R region of the spectrum. Thus, it is possible to assess, in a reliable way, the fading rate of the C dye.

Intensity maximums

In order to compare the results obtained through densitometry with those obtained through UV-vis spectrophotometry, the intensity maximums from the spectra collected with the last technique were recorded at 441 nm, 558 nm and 657 nm. The variation of the intensity maximums for samples aged at T=80°C is shown in Figures 6.34 and 6.36, for step-wedge and artwork samples, respectively (the results of the remaining ageing tests are presented in appendix VI, section VI.6.2.1). The step-wedge samples aged at T=80°C were also analysed with a densitometer and the optical density[12] variation was recorded (Fig. 6.35). As expected, both techniques led to similar results.

Based on Figures 6.34 and 6.36, it is possible to conclude that the previously observed variations (increase in the absorption intensity in the B region and decrease in the absorption intensity in the R region) are gradual. Regarding the variation in the G region, contrary to the B region where an increase can be noticed since the beginning of the ageing experiment, it is possible to observe an initial decrease (associated with the fading of the M dye) and a posterior increase in the intensity on that region upon ageing. This suggests that some degradation products, absorbing in the G region, are produced at a different stage of the degradation process. Contrary to what would be expected, when analysing the results obtained at different T, the influence of the RH is not clear. In other words, the samples aged at both RH present similar levels of degradation.

[12] Optical density can be considered the same as intensity maximum in the absorbance spectrum.

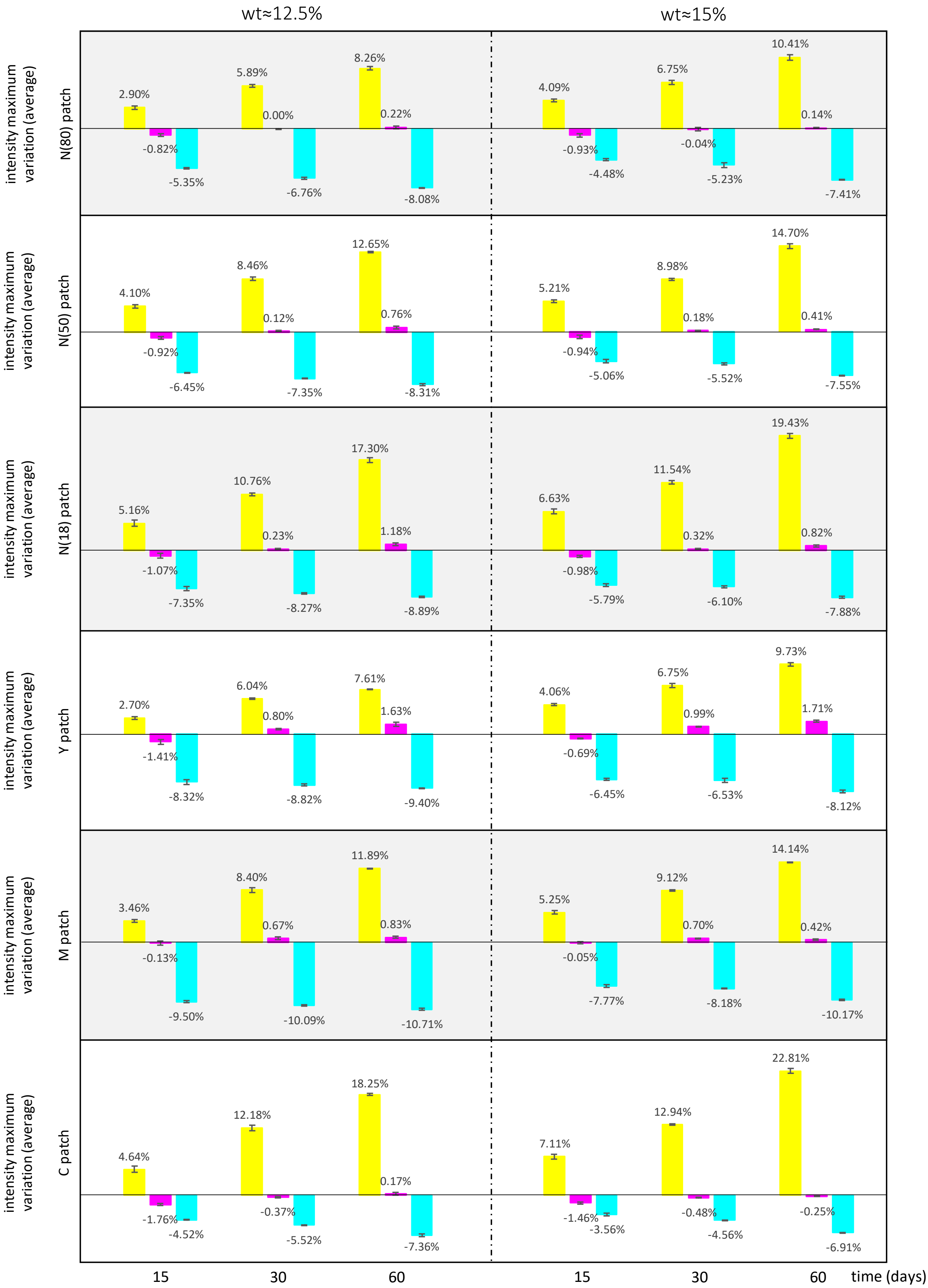


Figure 6.34 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the artwork samples before and after artificial ageing at T=80˚C.

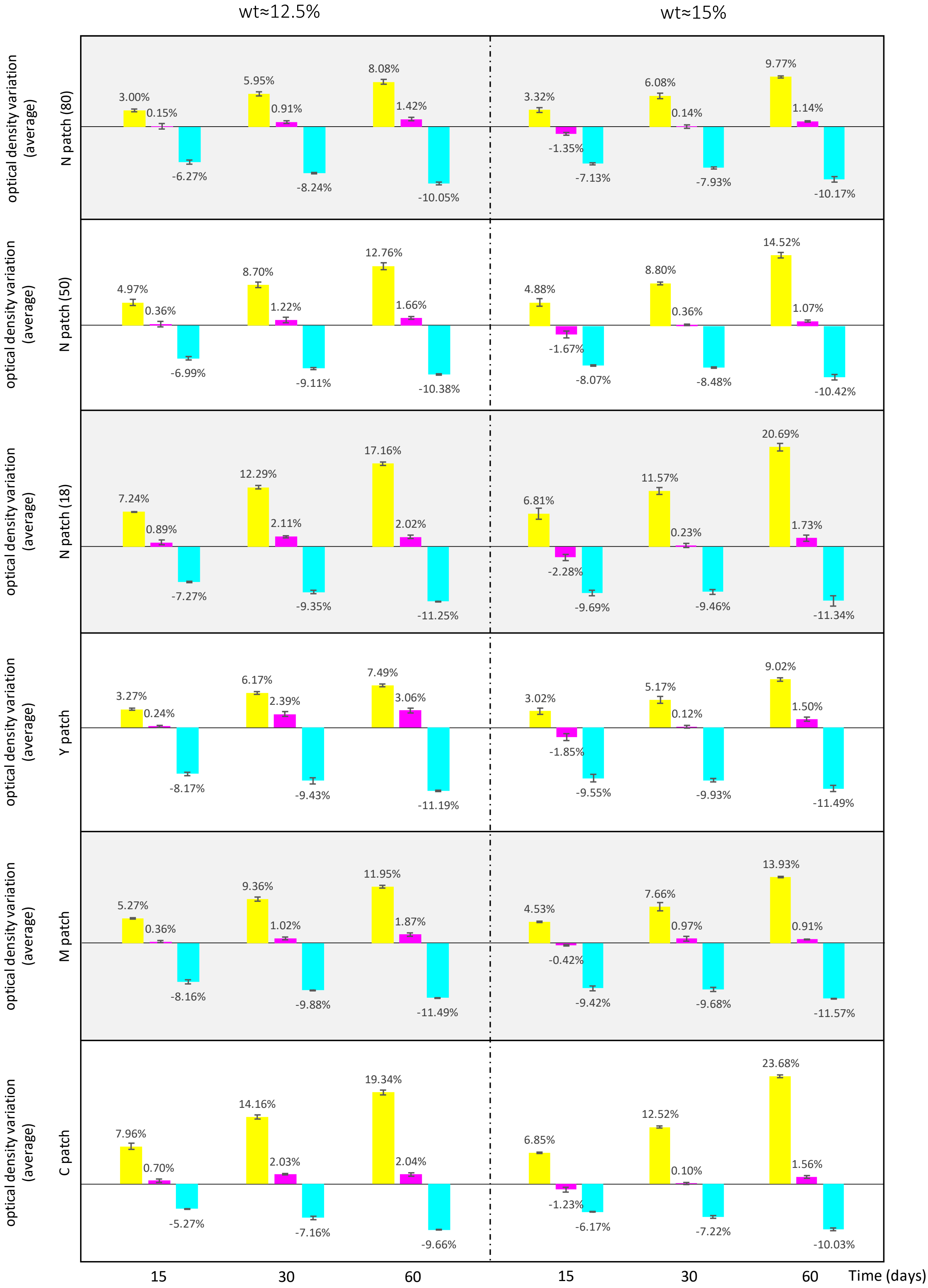


Figure 6.35 - Optical density variation (average %) on the red (cyan dye), green (magenta dye) and blue (yellow dye) regions, obtained from the densitometer measurements of the step-wedge samples before and after artificial ageing at T=80˚C.

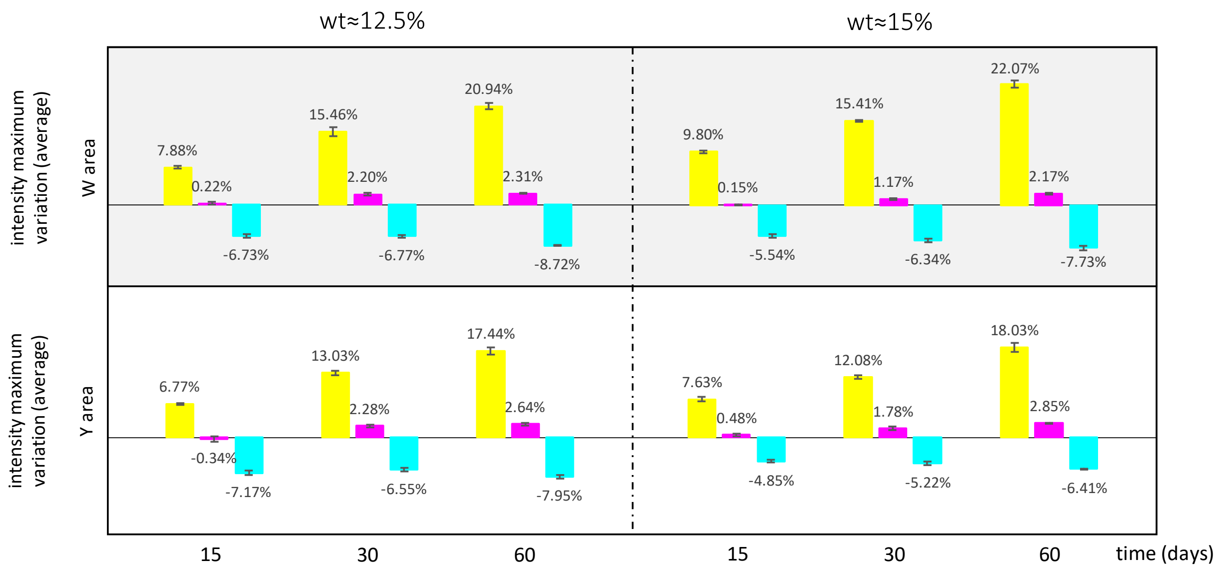


Figure 6.36 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the artwork samples before and after artificial ageing at T=80˚C.

The coloured species produced within these artificial ageing tests were much more pronounced than that of the preliminary test conducted within the framework of this study and published elsewhere[13]. This discrepancy might be a consequence of improper processing, and/or because RXP samples used for the artificial ageing experiments were out of time. As explained by Henry Wilhelm and Carol Brower (1993, 63), contaminated processing chemicals and/or inadequate replenisher or washing, as well as omission of the stabilizer bath, can adversely affect image stability by decreasing the permanence of the dyes and/or enhancing staining levels. On the other hand, the samples were aged by using the sealed bag method, and therefore, any degradation product produced during the experiment remained confined, possibly resulting in a catalytic effect in the degradation rate (Adelstein, Bigourdain and Reilly 1997, 203).

CIE L*a*b* coordinates

The colorimetric proprieties of the samples were also determined based on the overall spectrum collected for each sample (not exclusively based on the intensity maximums). CIE L*a*b* coordinates were calculated before and after ageing, in order to define a comprehensive overview of colour variation occurring in the samples. This type of valuable information could not have been determined from data provided by densitometers. By using the entire spectral data for the description of colour change, the issues previously discussed associated with integral densities when evaluating each dye individually, are no longer a problem. Thus, it is possible to have a more complete assessment of the samples, which is the goal of this study. The variations of the CIE L*a*b* coordinates in step-wedge and artwork samples aged at T=80°C are resumed in Figures 6.37 and 6.38, respectively. The results obtained in the remaining ageing tests are in accordance with those obtained at T=80°C (see appendix VI, section VI.6.2.2).

[13] Silva, J., A.M. Ramos, J.L. Ferreira, C.A.T. Laia, A.J. Parola, and B. Lavédrine. 2017. New approaches for monitoring dye fading in chromogenic reversal films: UV-vis spectrophotometry and digitisation. In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4-8 September 2017,* ed. J. Bridgland, art. 1403. Paris: International Council of Museums.

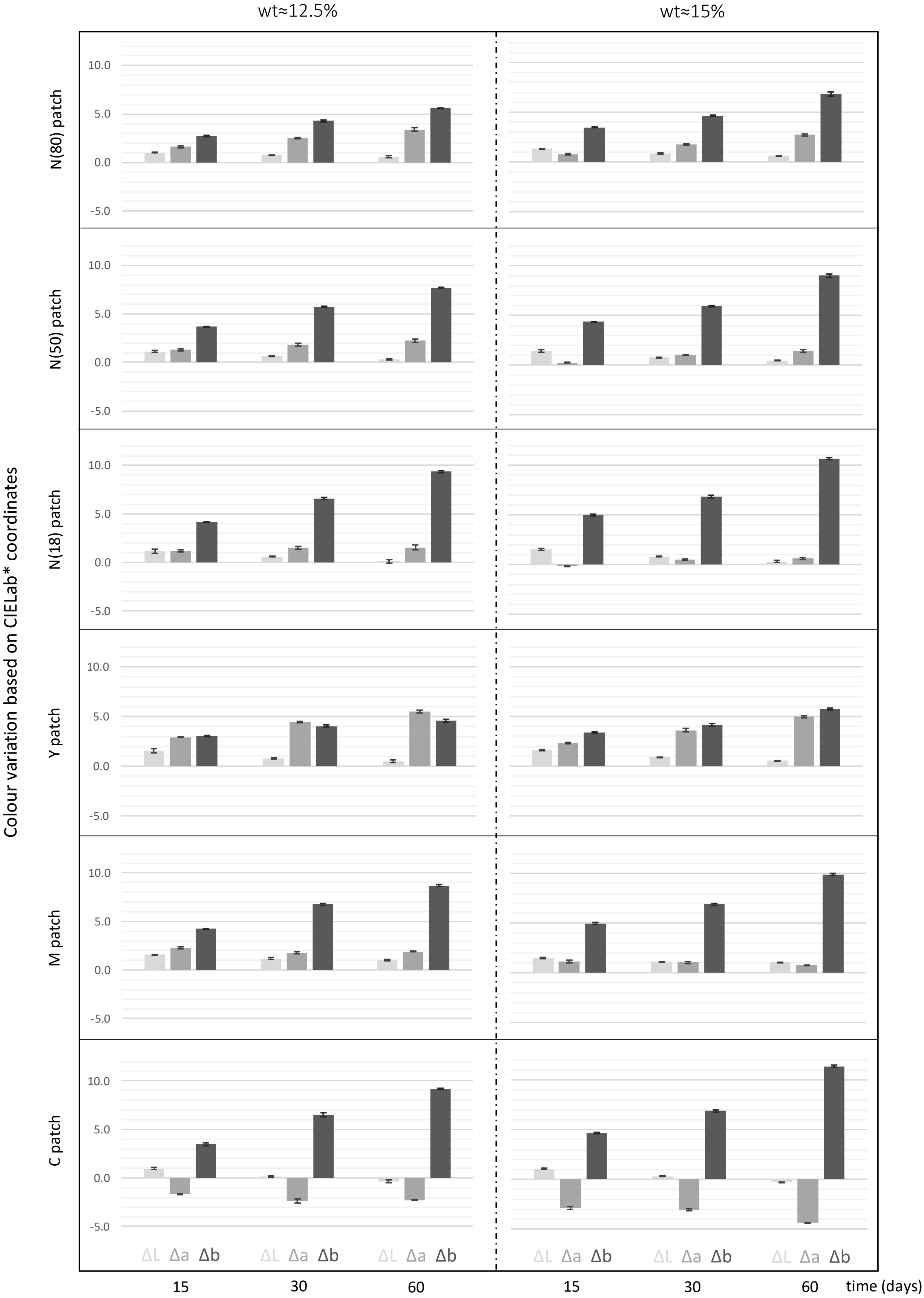


Figure 6.37 - Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the step-wedge samples, before and after artificial ageing at T=80˚C.

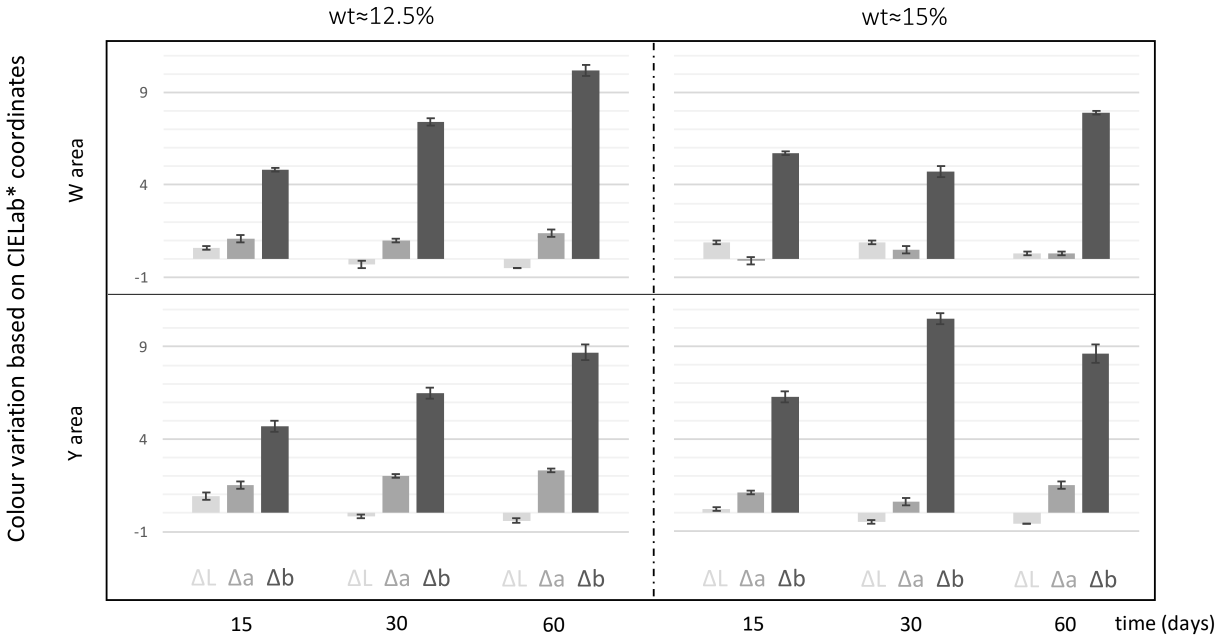


Figure 6.38 - Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the artwork samples, before and after artificial ageing at T=80˚C.

The behaviour of the samples upon ageing are implied in the variation of the CIE L*a*b* coordinates. In all analysed areas of both types of samples, regardless of ageing condition, there was an increase of all coordinates, with the exception of the C patch from the step-wedge samples. A positive variation on the L* axis means that more light is able to pass through the samples; a positive variation on the a* axis means that the samples are became redder (opposed to green); and a positive variation on the b* axis means that samples are became yellower (opposed to blue) upon ageing. The increment of L* can be assigned to dye fading and, consequently, more light passing through the sample and reaching the detector of the equipment. Although this increment was considered minor, it was a constant in all patches from the step-wedge samples. In some of the examined areas, there was an initial increment of L* followed by a reduction of this coordinate. This could be linked to the formation of degradation products absorbing in the visible region, in an advanced stage of the ageing process, which gradually mask dye fading. The tendency towards a slight increment of the a* value can be explained by the production of species absorbing in the G region of the spectrum. The C patch from the step-wedge samples is the only one to present a clear reduction of a*. This result can be a consequence of the formation of yellowish degradation products, which in this particular patch might have led to a greenish sensation (C+Y=G). A significant increment of b* was a trend observed in all areas of analysis upon ageing and can be assigned to both the production of yellowish degradation species and fading of the C dye.

CIE L*a*b* coordinates were also calculated from the digitized samples, by converting the RGB colour space assigned to the digital files into CIE L*a*b* colour space. To do so, the overall image of the samples before and after artificial ageing was considered, and the average variation of each CIE L*a*b* coordinate was calculated. The variations estimated for the samples artificially aged at T=80˚C are presented in Figure 6.39. The results obtained in the remaining ageing tests are shown in appendix VI, section VI.4 (Figs. VI.9 and VI.10). For both types of images an increment of all three coordinates can be observed. The major variation can be assigned to b*, followed by L* and finally by a*. The CIE L*a*b* coordinates calculated from the RGB values of the digital images are inflated comparing to the results obtained with the UV-vis spectrophotometer, particularly in what concerns the L* coordinate. Nevertheless, the general degradation pathway estimated with the data obtained from the scanner seems in accordance with colour change detected by the UV-vis spectrophotometer. No significant changes were noticed between samples with wt≈12.5% and wt≈15%. Curiously, in some cases, the variation of the CIE L*a*b* coordinates seem rather lower in samples with wt≈15%.

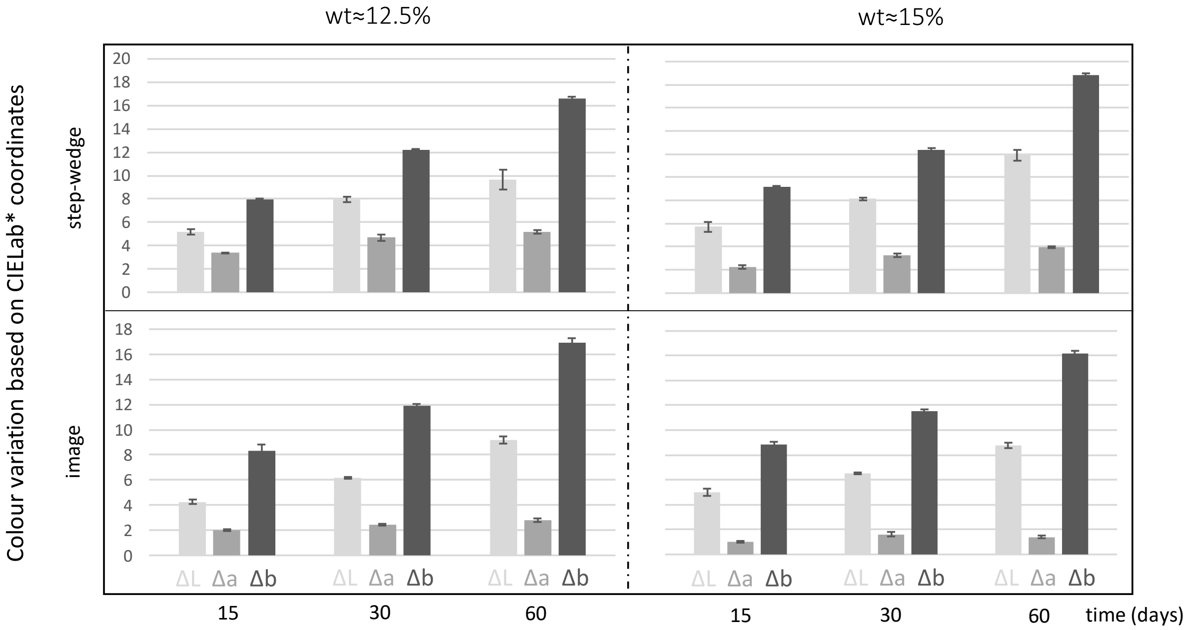


Figure 6.39 - Colour change variation based on CIE L*a*b* coordinates calculated from the RGB values of the overall digitised images, before and after artificial ageing at T=80˚C.

Total colour variation (ΔE^*)

The total colour variation (ΔE^*) was defined based on the CIE L*a*b* coordinates calculated from the UV-vis spectra of the samples upon ageing. This approach was very helpful in drawing conclusions about the different areas of analysis, which was a difficult task to do exclusively based on the maximum intensity variation or in the CIE L*a*b* coordinates individually. The calculated ΔE^* for each examined area from the step-wedge and artwork samples, before and after artificial ageing at T=80˚C are presented in Figures 6.40 and 6.41, respectively.

All samples present JND (ΔE^* > 2.5) immediately at the first ageing stop, and far above that value at the end of the ageing test. Regarding the step-wedge samples, as can be observed in Figure 6.40, ΔE^*(C) > ΔE^* (N18) > ΔE^* (M) > ΔE^* (N50) > ΔE^* (Y) > ΔE^* (N80). This means that colour change is not at all homogenous in the overall image. The disparity on the ΔE^* values measured in the different patches increases upon ageing. As expected, ΔE^* in the neutral areas of lower density (N18) is higher (ΔE^*=9.5 for samples with wt≈12.5% and ΔE^*=10.7 for samples with wt≈15%) than in areas of higher density (N80) (ΔE^*=6.6 for samples with wt≈12.5% and ΔE^*=7.4 for samples with wt≈15%). As previously mentioned, residual colour couplers are present in the image in inverse proportion of the amount of dye formed (Tuite 1979, 477). Therefore, as explained by Henry Wilhelm and Carol Brower (1993, 164-165), the production of yellow stain is mostly located in the low-density areas of the image. In what concerns the coloured patches, the C patch shows the higher ΔE^* (ΔE^*=9.6 for samples with wt≈12.5% and ΔE^*=12.2 for samples with wt≈15%), which can be assigned to both fading of the C dye and production of coloured reddish-yellow species. On the contrary, the colour shift produced in both Y and M patches, surely suffering from dye fading too, can, to a certain extent, be compensated by the production of yellowish and reddish degradation products at wavelengths corresponding to dye fading, respectively. Regarding the image of the artwork samples (Fig. 6.41), ΔE^* (W) > ΔE^* (Y). Since both areas have a similar density, this slight variation can be explained by the production of degradation products, more evident in the W area. However, the experiment carried out at T=70˚C led to slightly different results (see appendix VI, section VI.6, Figs. VI.43 and VI.44). In this test, ΔE^* (W) ≤ ΔE^* (Y), showing a slightly different and more disordered trend. No clear explanations could be found for this discrepancy.

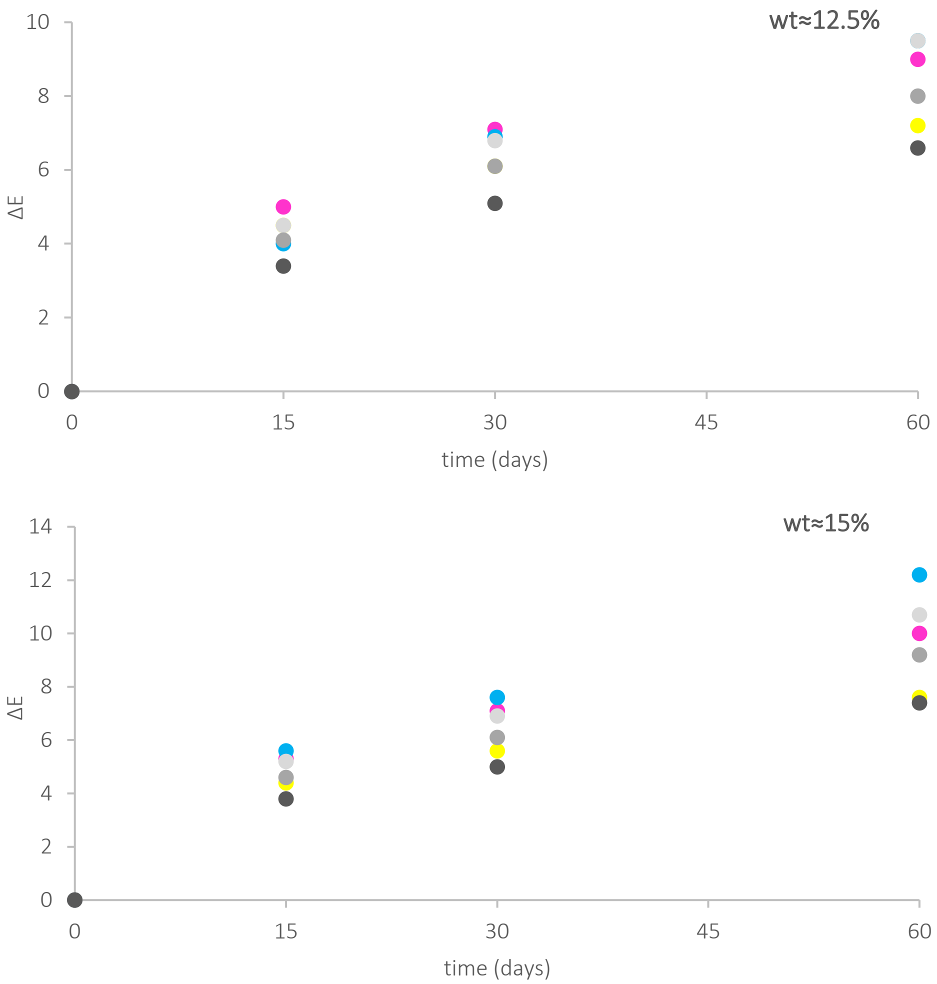


Figure 6.40 – Total colour change variation (ΔE^*) calculated from the CIE L*a*b* coordinates of the six patches from the step-wedge samples, at water content (wt)≈12.5% (top) and wt≈15% (bottom) upon ageing at T=80˚C. The standard deviation did not exceed ±0.2 for all the obtained values.

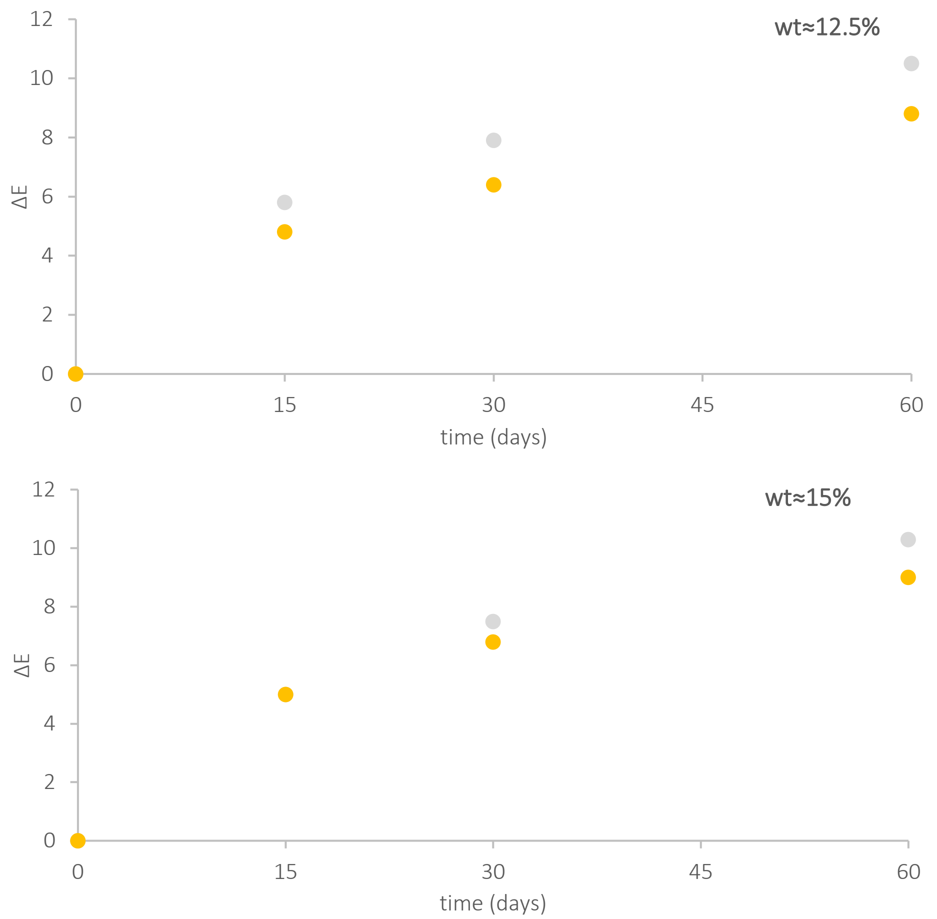


Figure 6.41 – Total colour change variation (ΔE^*) calculated from the CIE L*a*b* coordinates of the two areas of analysis from the artwork samples, at water content (wt)≈12.5% (top) and wt≈15% (bottom) upon ageing at T=80˚C. The standard deviation did not exceed ±0.3 for all the obtained values.

Corroborating the results obtained from the visual observation (optical microscopy and digitisations) and from the maximum intensities and CIE L*a*b* coordinates, no significant differences can be established between samples artificially with wt≈12.5% and wt≈15% (with exception of the ageing test conducted at T=80˚C for the step-wedge samples). Therefore, based on the conducted experiment, there is no clear benefit of reducing the environmental conditions from wt≈15% to wt≈12.5% for these materials. These results are in line with the testing made by other authors (Adelstein, Graham and West 1970, Wilhelm and Brower 1993, Reilly 1998). According to those authors, the rate of dark fading is a function of T, and to a lesser degree, of RH. Considering that under normal RH conditions, gelatine provides an aqueous substrate to the dyes present in the emulsion, it is not surprising that small variations in the RH can be considered almost negligible to dye degradation.

The ΔE^* was also estimated for the digital images, based on the variation of CIE L*a*b* coordinates upon ageing (obtained from the RGB values of the overall image). The obtained results are shown in Figures 6.42 and 6.43. When comparing ΔE^* calculated from the UV-vis spectra and from the digital images, the same tendency can be observed. Nevertheless, the data obtained for the digital images are much higher than those obtained with the UV-vis spectra. Moreover, the colour variation measured in samples aged at wt≈12.5% is slightly higher than those aged at wt≈15%.

The discrepancies noted between the data obtained with the UV-vis spectrophotometer and with the scanner can be explained by different factors. Firstly, as stated by Tina Weidner (2012g), the task of translating between the analogue and digital colour spaces is extremely complex, since each technology interprets colour differently. Scanners are typically three-channel devices that record the image based on RGB colours. Although RBG coordinates can be translated into tristimulus values (XYZ), which in turn, can be converted into CIE L*a*b* coordinates (Berns 2016, 164), scanners are restricted by colour gamut[14]. Within the present study, Adobe RGB (1998) was automatically assigned to the digitized images, and therefore, only a fraction of the range available within CIE L*a*b* colour space was recorded with the images. Hereby, certain colours could probably not be encoded accurately, giving rise to hue errors (Berns 2016, 172-176). In addition to technical issues related to the nature of the devices, the data analysis performed to the digitisations was applied to the overall image, while UV-vis analysis was restricted to a small area of the image. This difference in the methodology is certainly also responsible for differences in the results obtained from both techniques.

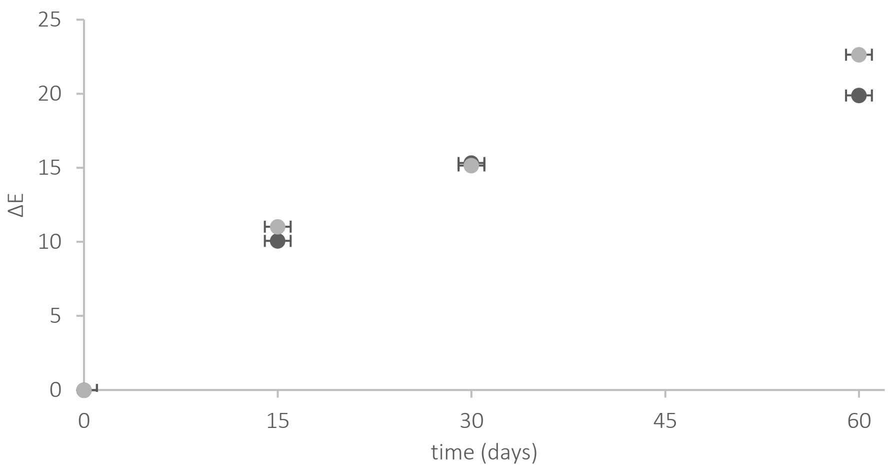


Figure 6.42 – Total colour change variation (ΔE^*) calculated from the CIE L*a*b* coordinates variation calculated from the digitized step-wedge samples (overall image), upon ageing at water content (wt)≈12.5% (black scores) and wt≈15% (grey scores), and T=80˚C.

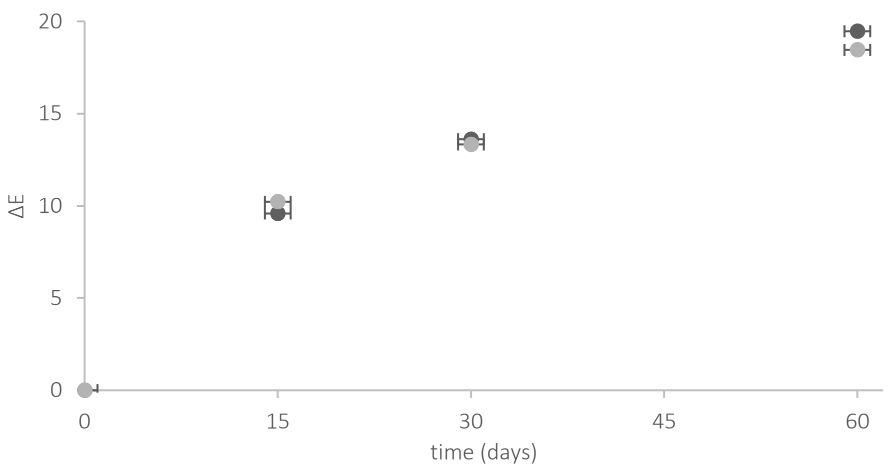


Figure 6.43 – Total colour change variation (ΔE^*) calculated from the CIE L*a*b* coordinates variation calculated from the digitized artwork samples (overall image), upon ageing at water content (wt)≈12.5% (black scores) and wt≈15% (grey scores) and T=80˚C.

[14] Range of colours that can be accurately represented by a certain device.

6.5. Conclusions

Within the present study, different spectroscopic and chromatographic techniques have been tested with the aim of outlining suitable procedures for the characterization of chromogenic dyes and paving the way for the molecular identification of dyes present in chromogenic reversal films (presented in section 6.3).

Raman spectroscopy has shown the ability to characterize chromogenic dyes. Micro-samples were collected from the borders of the chromogenic reversal films under study, in order to analyse C, M and Y emulsions separately. The dyes were also successfully analysed in cross-section, by examining layer by layer. In both cases, the confocal microscope of the equipment was used to select the desired coloured areas. The dyes from EPT and RXP samples produced different Raman spectra.

Chromatographic techniques also proved to be powerful tools to isolate and characterize chromogenic dyes. As a major disadvantage, all tested chromatographic techniques require the collection and destruction of a small sample. However, considering that the borders of chromogenic reversal films can be used to remove a sample without compromising the image, and that the analysis of one sample can bring insights into several works (of the same model/batch), collecting a sample can be easily justified. TLC has the advantage of giving immediate and easy to interpret information, by displaying coloured spots in the TLC sheet. By calculating the R_f of the separated dyes, additional information about the compounds under study was gathered. Knowing that every molecule has a specific R_f value for a specific solvent and solvent concentration, TLC analysis provides evidence of the identity of the compound. Additionally, the time and the cost associated to this type of analysis is substantially lower when compared with liquid chromatography. Most importantly, by using preparative TLC, the separated compounds can be isolated and used for further analysis. In the present study, the isolated dyes were characterized with IR spectroscopy. The collected IR spectra provided fingerprint spectra of C, M and Y dyes from EPT and RXP samples. HPLC has also been traced as a useful technique for the characterization of chromogenic dyes. As in TLC, the R_t associated to each dye in a specific HPLC equipment separated with a given elution program offers additional information about the molecules. Linked to DAD, the absorbance spectra of each dye can be observed. The shape and maximum of the absorbance spectrum of a dye in the visible region can provide a clue to differentiate and characterize the different samples. Based on the shape of the M dyes, it is proposed that M from EPT is from the pyrazolone family. The absorbance spectra collected in DAD also worked as background information for the analysis with MS. Thereby, the peaks of interest (dyes) were selected and analysed with MS. The isotopic profiles of the accurate masses attributed to M and Y dyes from the EPT film, respectively, indicate that the colour couplers associate with these dyes may have some chlorine atoms in their structures.

The main difficulties encountered within the investigation presented in section 6.3, was the inexistence of references to support the assignment of the obtained results to specific families of chromogenic dyes. Although the tested analytical techniques have shown promising results, building databases of chromogenic dyes for Raman and IR spectroscopies, as well as MS, is the key for the identification of these materials.

In section 6.4, new methodologies for monitoring colour change in slide-based artworks were pursued. The effectiveness of the use of UV-vis spectrophotometry with optical fibre probes was tested on artificially aged RXP chromogenic reversal films with two different water contents (wt≈12.5% and wt≈15%) under four T (50, 60, 70, 80˚C). Although the films showed an atypical degradation process (possibly due to the use of expired films and/or to unproper processing), UV-vis spectrophotometry proved to be a powerful analytical technique to describe colour variation in this type of material. By using optical fibre probes, small areas of analysis ($\phi = \pm 1$ mm) can be selected to follow the evolution of the colours. Nevertheless, preference should be given to homogenous areas, in order to ensure the reliability of the obtained results. Since colour variation is dependent on the image density, several spots with different densities were used for monitoring the samples, in order to gather a more complete assessment of the overall colour degradation.

The intensity maximums in the R, G and B region of the spectra were used to follow the evolution of the absorbance bands. A gradual increase in the absorption intensity in the B region, associated with the production of yellowish degradation products, and decrease in the absorption intensity in the R region, assigned to dye fading, was observed upon ageing. The variation in the G region presented an initial decrease, associated with the fading of the M dye, and a posterior increase in the intensity upon ageing, assigned to reddish degradation products. When comparing the results between UV-vis spectrophotometry and the densitometry, the obtained values were very similar. Nonetheless, contrary to densitometry, spectrophotometry allows for different types of data treatment based on the acquired spectra. Thus, CIE L*a*b* coordinates were determined by mathematically treating the overall spectra. In general, an increase of all coordinates was observed. The positive variation of L*, means that more light can pass through the samples upon ageing, due to dye fading. The positive variation of a* shows that samples are becoming redder, while the positive variation of b* points to samples becoming more yellow, due to the formation of degradation products. Nevertheless, the percentage of variation in all CIE L*a*b* coordinates is dependent of the analysed area. For instance, the C patch presented a reduction of a*, contrary to the other analysed areas. This means that a greenish patch was produced upon ageing, as a consequence of the formation of yellowish degradation products. Therefore, the description of CIE L*a*b* coordinates allowed for a more comprehensive understanding of the shift in colour balance, according to different areas of the image. Both intensity maximums and CIE L*a*b* coordinates can be used to substantiate the decision-making process about the digital or analogue restoration of the colours in slide-based artworks.

The total colour variation (ΔE^*) was also calculated based on CIE L*a*b* coordinates. Summing up the perceptible degradation in one value allowed for an easy understanding of colour change variation associated to different density areas of the image. Knowing that ΔE^*=2.5 has been considered to represent a JND, the determination of this parameter was very useful to recognize the real impact of colour change. Regarding the step-wedge samples, ΔE^*(C) > ΔE^* (N18) > ΔE^* (M) > ΔE^* (N50) > ΔE^* (Y) > ΔE^* (N80), and the artwork samples, ΔE^* (W) > ΔE^* (Y), showing that colour change is not at all homogenous. All samples presented JND (ΔE^* > 2.5) immediately at the first ageing stop, and far above that value at the end of the ageing test. ΔE^* in the neutral areas of lower density was higher than in areas of higher density, due to the lower content of residual colour couplers and higher dye concentration of the last. C patch have shown the higher ΔE^*, which can be assigned to both fading of the C dye and production of coloured reddish-yellow species. On the contrary, the colour shift produced in both Y and M patches (also presenting dye fading) can, to a certain extent, be compensated by the production of degradation products at wavelengths corresponding to dye fading.

Apart from UV-vis spectrophotometry, OM and digitization can also be considered suitable tools for the technical examination of chromogenic reversal films. By collecting microscopy and digital images of a chromogenic reversal film upon ageing (under the same conditions), it was possible to record the condition of the sample. Thus, an immediate visual information about colour change was gathered. In addition, digital images can provide interesting data about colour values. The RXP samples digitized before and after artificial ageing were compared pixel by pixel allowing extraction of the average variation of CIE L*a*b* coordinates and to calculate ΔE^*. Although inflated when compared with CIE L*a*b* coordinates by using the UV-vis spectra, the values determined based on the digital files pointed out the correct colour shift.

Based on the conducted artificial ageing tests, the variation on the water content of the samples (in a range between wt≈12.5% and wt≈15%), does not seem to play an important role in the degradation of chromogenic reversal films. According to those results, preference should be given to T control in Ângelo de Sousa's archive, in order to preserve his chromogenic reversal films.

After successfully testing the developed methodology, slide-based artwork by Ângelo de Sousa, such as Slide*s de Cavalete (197*8-1979) and a selection of slide tests produced within the framework of that work, started to be monitored by using this technique. The condition of these works is being accessed and registered on a regular basis, so that any changes can be detected. Up to now (after one year), no variations have been observed (see appendix VI, section VI.6.2.3).

Chapter 7

Concluding remarks

7.1. Major contributions

The work described in this thesis aimed at contributing to the study and preservation of the photographic and film collection of Ângelo de Sousa, in particular his slide-based artworks.

The literature review presented in Chapter 2 allows acknowledgement of the absence of in-depth studies focusing on this collection. However, in order to define better solutions for the preservation of Ângelo de Sousa's photographs and films, both their significance and material composition had to be known. Thus, this thesis brings for the first time an exhaustive study into this collection. Firstly, the history of the collection and environmental conditions of the archive were traced, allowing us to understand that his photographs and films have been gathered all together in the artist's house at Foz (Porto) since the beginning of the 1970s, under uncontrolled and inadequate environmental conditions. Although both T and RH have not shown worrisome fluctuations, the absolute values are higher than recommended in the literature, especially when considering sensitive materials such as cellulose ester-based and colour films. These results clearly demonstrate the urgency of moving the collection into a climate-controlled storage, in order to extend the life span of the objects. Based on a survey conducted to the materials, the detailed composition of the collection, hitherto unknown, was also disclosed. It is now known that the collection is composed of 85646 photographs and 212 reels or cassettes with films. Additionally, the survey led to the finding that Ângelo de Sousa chose to work with a limited range of materials. In what concerns his photographic production, he used negatives (44.7%), positive transparencies (39.7%) and prints (15.6%). Regarding the black-and-white set, he mainly employed 35 mm black-and-white negatives with CA base, which he used to make 18x24 cm black-and-white developing-out-prints. The great majority of the colour set is composed of 35 mm chromogenic reversal films with CA base with mountings (slides). From this set, he only printed a few Cibachrome prints. Regarding the films, two main groups were distinguished: 8 mm analogue films (59%) and videos (41%), both colour films. Although some experimental films have been transcribed into other formats, only a small percentage of photographs has been digitized. Considering that the collection is normally analysed focusing on the transcriptions and digitization's, it might be concluded that a substantial part of Ângelo de Sousa's collection remains unknown. The assessment of the condition of these materials revealed that, from the overall collection (considered in good/fair condition), 35 mm colour slides is the set at highest risk due to fading and colour shift observed in about one third of these materials. For that reason, slide-based artworks by Ângelo de Sousa were subjected to a thorough investigation focusing on the characterization of chromogenic dyes and monitoring of colour change. The photographic and film equipment was also surveyed, demonstrating the great number of cameras and other devices acquired by the artist to enhance his technical possibilities. Additionally, his personal documentation, library and other materials were examined, unveiling the artist's way of working. Several notebooks with ideas for photographs and films were found, dating back from the beginning to the end of his production, as well as some scripts for films.

As pointed-out by some authors such as Bernardo Pinto de Almeida, Ângelo de Sousa was one of the main figures associated with the changes felt in Portuguese art in the *neo avant-garde* period. This was partly due to his use of audio-visual supports and to the plastic solutions adopted by him when using these media. During the present study, a contribution to illustrate that premise has been made by highlighting the experimental character of some of his photographs and films. From the several ideas explored by the artist throughout his production, colour was an important one. Ângelo de Sousa made several works in which he consciously explored the subtractive and additive synthesis of colours as a means of expression. The artist developed a painting technique consisting of the overlapping of multiple layers with the primary subtractive colours, to achieve *the maximum effect with minimum resources*. His series of 'monochromatic' paintings, started in the 1970s, were produced this way. According to unpublished documentation found at Fundação Calouste Gulbenkian's archive (FCG), he inclusively sought to disseminate his way of painting through his students at the University. In what concerns photography and film, it can be stated that through colour he achieved exceptional originality. He produced works by using the mixture of additive primary colours, examples being the experimental film *Sombra de Trepadeira* (1974) and the slide-based artwork *Slides de Cavalete* (1978-1979). The last was considered one of the most impressive photographic works by Ângelo de Sousa and has been selected as a case study within this dissertation. For the first time, the work was studied based on documentation found at the artist's archive and on the reproduction of its production process. With this approach, it was possible to conclude that the work was produced by projecting white light from a slide projector through filters with the additive primary colours, and capturing successively, on the same frame, a superimposition of these lights. By using different proportions of the three filters, which he controlled by applying opaque masks to reduce light exposure in certain areas, he obtained different colour gradations. Thus, the images from *Slides de Cavalete*, either in its conception or form, show clear similarities with his 'monochromatic' paintings. Based on the examination of the documentation and test slides found at the archive, it is also possible to state that the work resulted from an extensive planning and experimentation. The knowledge acquired during this research process was of the utmost importance in tracing the artist's intention and defining the significance of *Slides de Cavalete*.

As previously mentioned, the condition of the slide-based artworks by Ângelo de Sousa was considered alarming. With the view of establishing the best preservation strategies for these materials, they were studied under two points-of-view: immaterial (installation and display) and material (assessing colour change).

Regarding the first, a survey of the exhibitions with photographs and films by the artist was carried out, to understand the options undertaken by him over time. Based on the conducted research, it is possible to conclude that, although the first exhibition entirely dedicated to his photographic and film work, *Sem Prata*, was held in 2001 at Fundação de Serralves, since the 1970s the artist presented some of these media in exhibitions both in Portugal and abroad. In fact, he participated in the iconic *Biennale di Venezia* in 1976 with the slide-based artwork *A mão esquerda (1ª série)* (1975), and in several important exhibitions dedicated to the use of audio-visual supports by artists and photographer performed in Portugal at the end of the 1970s and in the 1980s, such as *A Fotografia na Arte Moderna Portuguesa* (1977) and *A Fotografia como Arte / A Arte como Fotografia* (1979). Unfortunately, a lack of documentation relating to the exhibitions produced in Portugal has been detected, making it difficult to evaluate display options. Based on the available documentation and on the oral testimony of people interviewed within the framework of this dissertation (Almeida 2018 and Wandschneider 2018), it was possible to conclude that Ângelo de Sousa took different options concerning the presentation of his photographs and films in general, and his slide-based artworks in particular. Although the artist chose to exhibit some of his slide-based works using a slide projector, he also displayed them as prints, sometimes even the same work, showing his openness to medium variation. Nevertheless, according to the conducted investigation, both his photographic and film work proved to be important testimonies of the experiences made by a Portuguese artist in the *neo avant-garde* period. Accordingly, some of his slides might carry an important historic value, which can also be linked to the type of support used to produce the artworks at the time of their conception. In addition, as conclusion from the survey to the materials, it is now known that the artist scarcely used colour photographic processes other than slides. Therefore, it can be stated that this technology is fundamental in his work. Thus, in general, the maintenance of the original technology should be pursued within the decision-making process about the display of his slide-based artworks, especially if this was the solution adopted by the artist in life or if no references were left by him. Either by analogue or digital duplication, the generation of copies (master sets and exhibition copies) made with chromogenic reversal film should be performed, as soon as possible, to ensure the continuity of the original technology. The display of *Slides de Cavalete* was studied in further detail, and all the information collected throughout this dissertation has been used to substantiate the final proposal for the presentation and preservation of this work. During the artist's life, the work was shown in two exhibitions: *A Fotografia como Arte/A Arte como Fotografia* (1979) and *Fotoporto: Mês da Fotografia* (1988). Within the present investigation, a letter relating to the exhibition of the work in 1979, directed to FCG and written by the artist, has been accessed. In that letter, the artist described all the necessary materials for the presentation of the artwork: a slide projector with circular tray and capacity for one hundred slides, an easel (ideally with a 19^{th} century appearance and with a hand crank) and a white canvas with 90 x 120 cm (or larger if within the same proportion) to project the slides onto its surface. To the best of our knowledge, this letter represents the only instructions left by the artist regarding the display of *Slides de Cavalete*. Since 2014 (after the artist's death), *Slides de Cavalete* has been presented in four exhibitions; in all these exhibitions, the canvas and easel were subtracted from the display setup, and in two of them, the slide projection was shifted to digital. In order to test the variability of the work presented with slide projection and digital projection, an exhibition was conducted at the Library of FCT NOVA in 2018. During a week, visitors were invited to see the work presented under these two distinct scenarios of presentation and express their opinion in an *ad hoc* questionnaire. The results from the questionnaire, although mainly filled in by people from the conservation field, showed a clear preference for the slide projection. Thus, the conducted investigation has brought new insights into the display of *Slides de Cavalete*. For the first time in the present, this work has been considered to have an important sculptural character, that should be preserved in future presentations. Therefore, although it was not possible to unveil how the artwork was displayed in 1988, it is proposed to display the work in the future according to its first public presentation, in order to preserve both its aesthetic characteristics and historicity. Additionally, a digital restoration was proposed grounded on previous studies conducted by Henry Wilhelm and Carol Brower (1993) and is considering both light and dark fading suffered by the original slides. This restored version of the work might be used to produce improved digital duplications for exhibition.

Regarding the preservation of the colours in Ângelo de Sousa's slide-based artworks, two different approaches have been pursued, focusing on the characterization of dyes and monitoring of colour change. The results of this investigation are of the main innovations brought forth in this dissertation.

Although the identification of the dyes present in the analysed samples was not possible to achieve due to the absence of databases for these types of dyes, different procedures for the characterization of chromogenic dyes in reversal films were traced. Both chromatographic and spectroscopic techniques proved to be efficient for the classification of chromogenic dyes. Although Thin-layer Chromatography (TLC) and High-Performance Liquid Chromatography (HPLC) imply the removal of a small sample for analysis (which can, nevertheless, be obtained without compromising the image), these techniques can provide a proper separation of the dyes and inform about the composition of the isolated molecules when compiled with spectroscopic techniques or mass spectrometry (MS). Confocal Raman micro-spectroscopy, in particular, has shown promising results since it enables for the direct analysis of dyes (both in cross-sections or in micro-samples collected from the border of the films).

Moreover, a new methodology for monitoring colour change in chromogenic reversal films has been successfully developed, as an alternative to the traditional densitometry. UV-vis spectrophotometry with optical probes was used to follow dye fading and shift in colour balance in specific and small areas of the image. Contrary to densitometry, spectrophotometry provides absorbance spectra at desired spectral range. From the obtained spectra, the maxima intensity of the bands (same as optical density provided by densitometers) was assessed. Additionally, spectral data can be converted into the CIE L*a*b* colour space and colour change can be expressed according to human perception. Slide samples with different water content artificially aged at different T were used to test the methodology. CIE L*a*b* coordinates and the total colour variation (ΔE^*) were calculated, allowing assessment of colour variation in a more accurate and reliable way. According to the obtained results, the variation of water content ranging from wt≈12.5% and wt≈15% does not show much influence on the stability of the samples. These results are in accordance with the experiments made by other authors (Adelstein, Graham and West 1970, Wilhelm and Brower 1993, Reilly 1998), who concluded that dark fading is primarily a function of T. Although further testing is needed to confirm the influence of the water content on the degradation of chromogenic reversal films, the obtained results indicate that T is the most important parameter to control in Ângelo de Sousa's storage room. Intensity maximums and CIE L*a*b* coordinates can also serve as a basis for the restoration of colour change slide-based artworks. Although these values are particularly useful for digital restoration, they can also be used to assist and substantiate colour corrections applied during duplication. This study has also outlined optical microscopy and digitization as valuable tools for the assessment of colour change in chromogenic reversal films. Lastly, as a practical outcome of this investigation, slide-based artworks in the collection are now being monitored for change using the developed methodology.

7.2. Limitations and future research

Although the present study has contributed to the enhancement of knowledge about the photographic and film collection by Ângelo de Sousa, there is still much more to study and discover. Considering that the collection is in a privileged situation, gathered along with materials used by the artist, his library and personal documentation, among others, future research should focus on holistic approaches interconnecting different sources of information. Also, more attention should be paid to the photographs and films that have not yet been digitized or transcribed. The information collected during the survey, now gathered in a database, can be further explored by other researchers interested in the collection (for instance image content).

One of the gaps in the present study is the inaccurate assessment of the film condition. The evaluation of both analogue films and videos was based on the observation of the first photograms of the films and tapes exposed outside the cassette, respectively. Therefore, a proper examination and visualization of the films is needed. Additionally, during the timeframe of the dissertation, it was not possible to analyse the original titles of the films and have an estimation of the number of films produced by Ângelo de Sousa. The data collected within the conducted survey only refers to the number of physical objects.

In-depth studies focusing on the display history of slide-based artworks by Ângelo de Sousa should be continued, since each work must be considered as an individual case. Further answers are still needed for the proper exhibition of slides produced within the framework of *Slides de Cavalete*, such as the colourful hand shadows (1979). Substantiated solutions for the presentation of emblematic works, such as *A mão esquerda (1ª série)* (1975) and *A mão esquerda (2ª série)* (1977), should also be found to ensure a proper communication of these works in the future and the preservation of their significance.

Although a contribution to the characterization of chromogenic dyes has been launched by this dissertation, fundamental research still needs to be done. Firstly, as acknowledged by Giovanna Di Pietro (2006, 196), a timeline of the dyes used in chromogenic materials must be drawn. Although it is well recognized that some brands and models behave differently upon ageing, there is a knowledge gap regarding the history of the dyes employed by the photographic industries in their products. However, technological characteristics (dye molecules, additives, layers composition) are the basis for the understanding of the degradation in chromogenic materials. The major difficulty in achieving this goal arises from the secrecy surrounding the photographic and film industry. Even if questioned about discontinued products, industry staff offer great resistance to revealing the nature of the dyes. Efforts should be done to establish a dialogue with those agents and make them realize that this type of research should not be seen as threat. Some archives, such as Agfa-Gevaert's (Belgium), contain valuable and unexplored primary sources of information, which can also possibly contribute to this purpose. Although a very ambitious task, scrutinizing data from the patents launched by the industry might also shed some light onto the historical development of the dyes used in chromogenic materials. After gathering consistent information about chromogenic dyes, they can be characterized in terms of stability. Finally, it is necessary to produce databases of these materials, particularly based on analytical techniques currently used for the study of cultural heritage, such as infrared (IR) and Raman spectroscopies. From this starting point, flowcharts based on the absence or presence of distinctive IR or Raman can be created, allowing for the systematic identification of these dyes. Additionally, databases for MS could also be produced. Spectrophotometry can also be used in collecting spectral data from the UV-vis range and also in the NIR region.

Concerning the monitoring of chromogenic reversal films, an attempt should be made to improve the results obtained with the scanner. One of the major shortcomings of the present work, was the inability to assign an appropriate colour profile (i.e. ICC profile) to the digitized samples. Applying an ICC profile to images scanned upon ageing might be a way to refine these results. Additionally, films could be digitized with higher resolution, and, for instance, by using professional digital camera backs in medium or large format, as this procedure has shown the highest standards of quality. One of the advantages when using a digital back (instead of a scanner) is the greater control over the light source, which is a lightbox consisting of a photographic flash with a uniform and precise colour T (Weidner 2012f). This parameter can also be considered when converting the RGB colour space into CIE L*a*b* colour space. Alternatively, the use of multi- or hyperspectral cameras could be tested, as this would provide the spectral proprieties of the samples (Berns 2016, 164). Moreover, data treatment could be done considering small areas of the image, similarly with UV-vis spectrophotometry, in order to reduce the error associated with the treatment of the digital images. A calibration of the scanner devices based on UV-vis data could also be pursued, in order to improve the quality of the data extracted from digital computations. Hence, CIE L*a*b* coordinates from digital data could possibly be used, in a more reliable way, to follow colour change in chromogenic reversal films and as guidelines to apply colour corrections.

Additionally, the use of the absorbance spectra for the study of the degradation kinetic of chromogenic reversal films should be pursued. ΔE^* has already been tested for the development of predictive studies based on the Arrhenius equation by some authors (Bernval'd et al. 1993). Nevertheless, the viability of the use of this parameter still needs clarification. To do so, artificial ageing tests should be performed, ideally not exceeding T=70˚C (based on the results from the present investigation), in order to test the efficiency of this parameter for the study of chromogenic materials.

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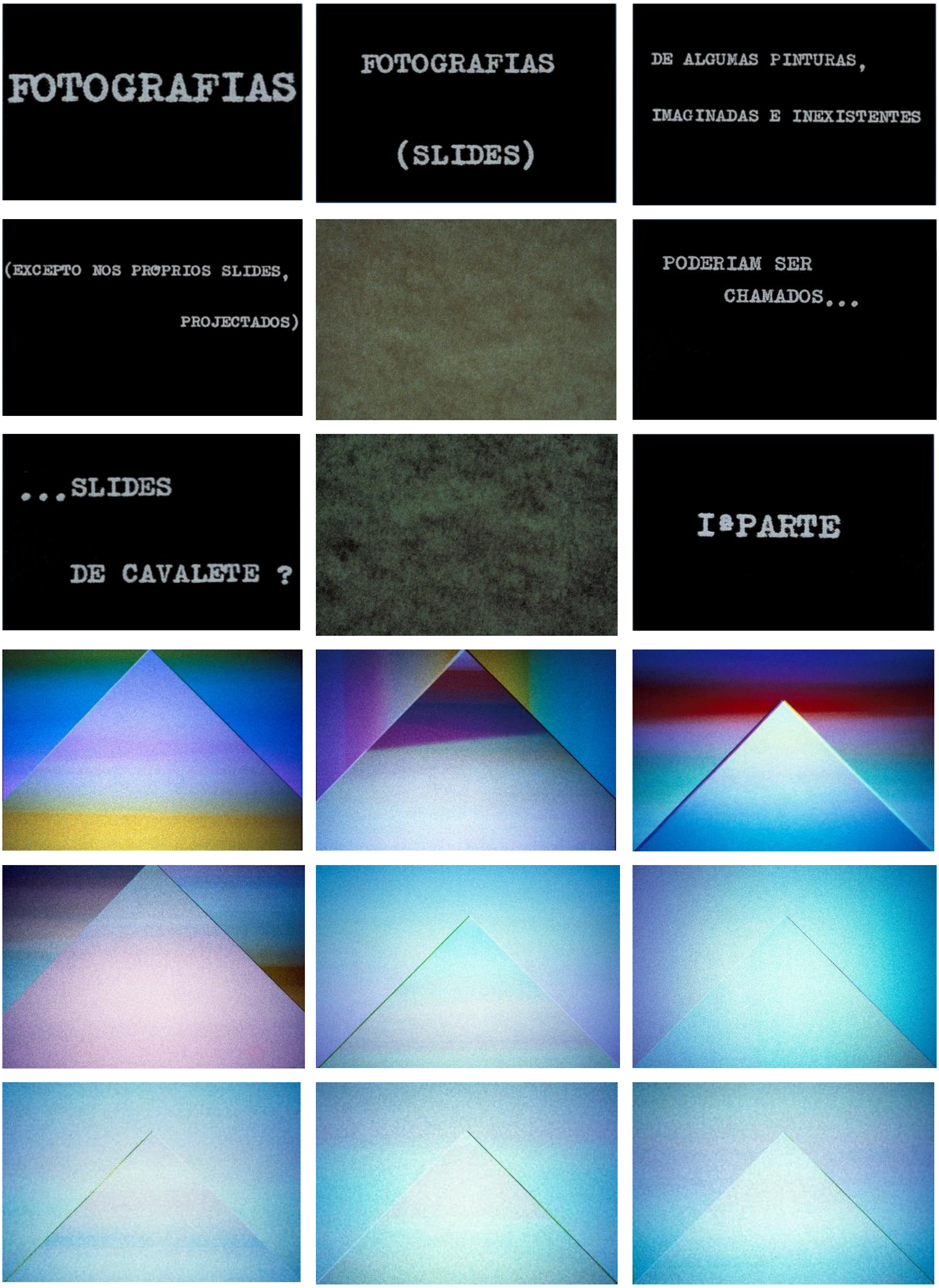
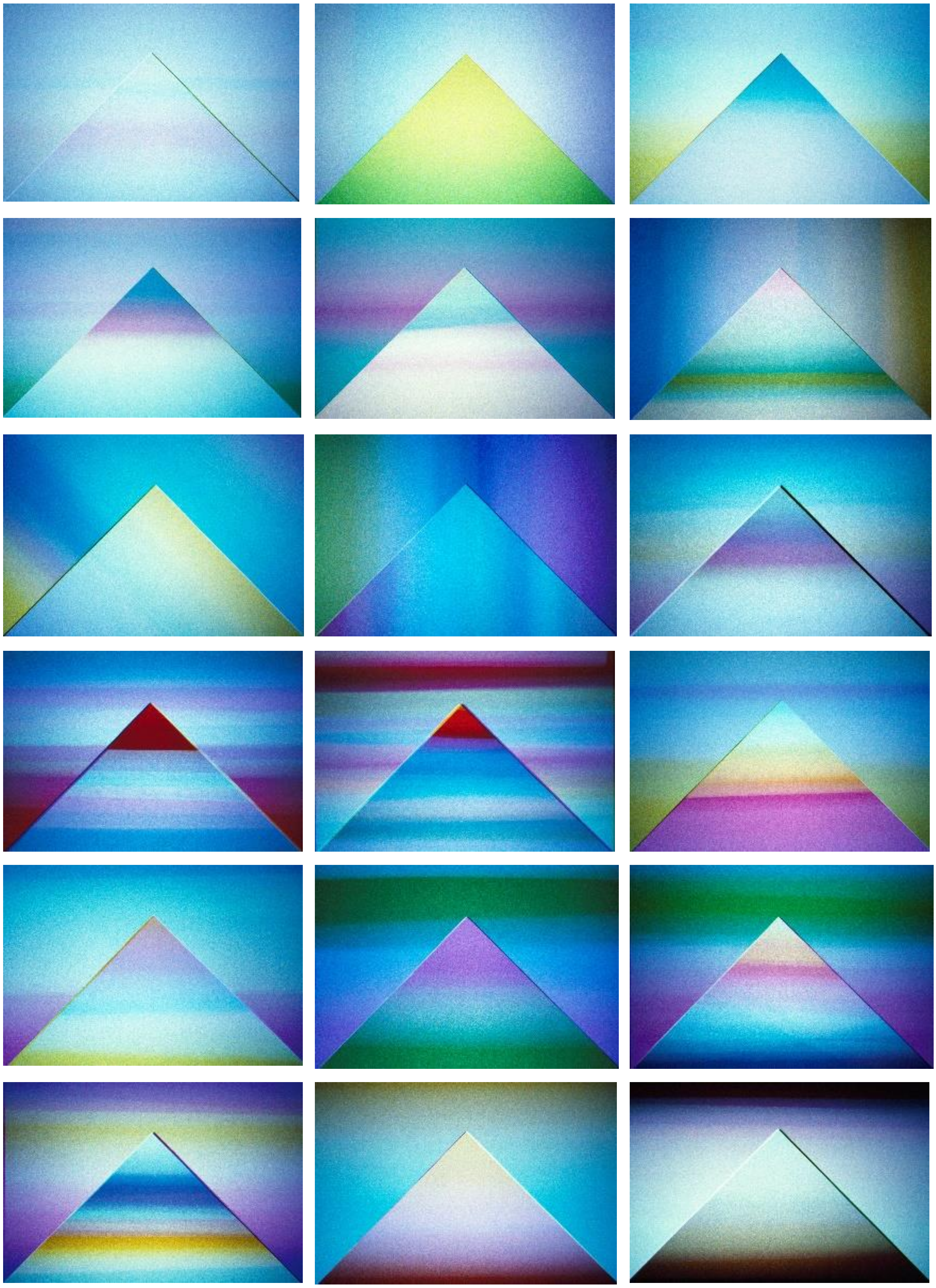
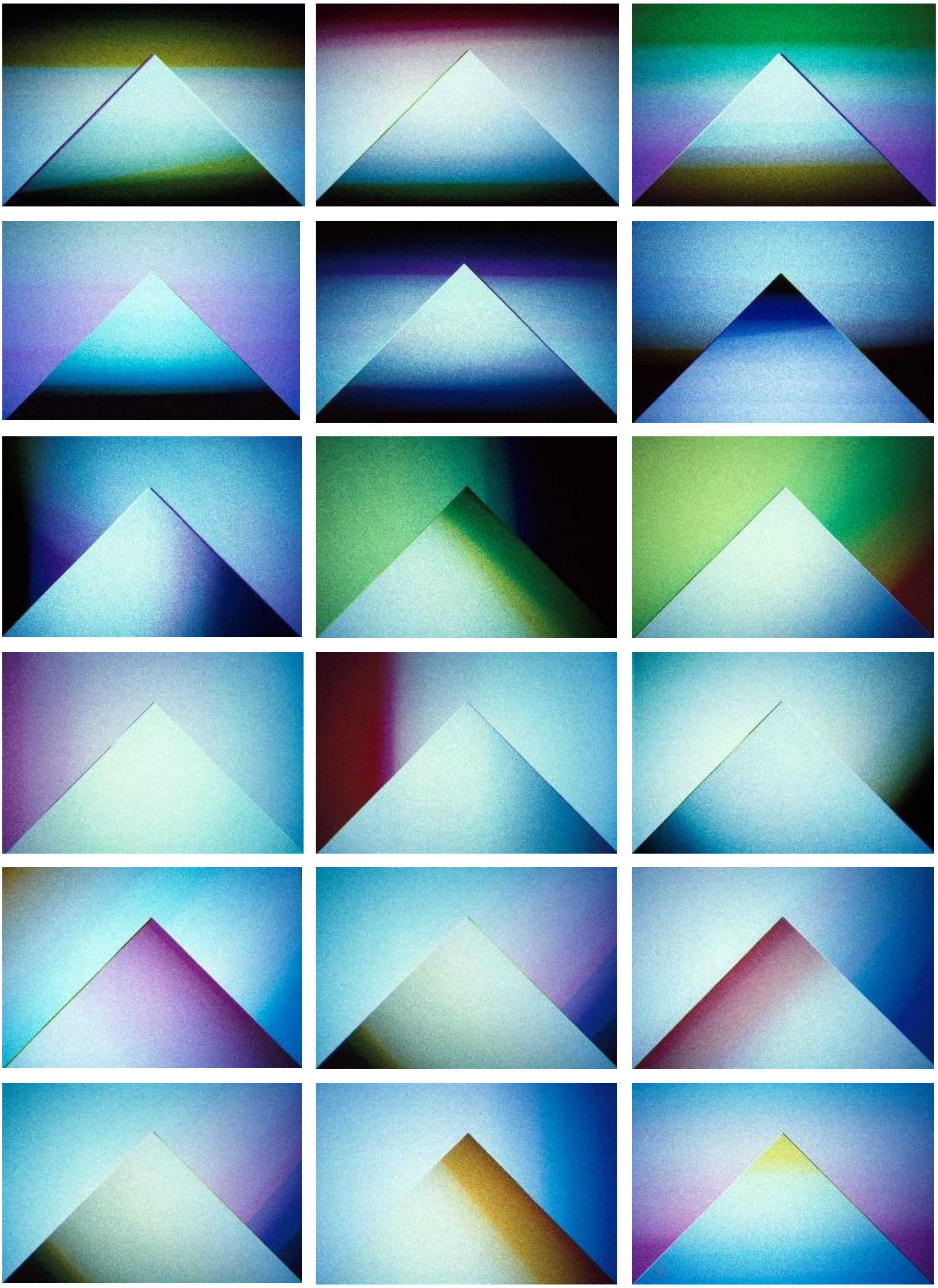
Appendix I

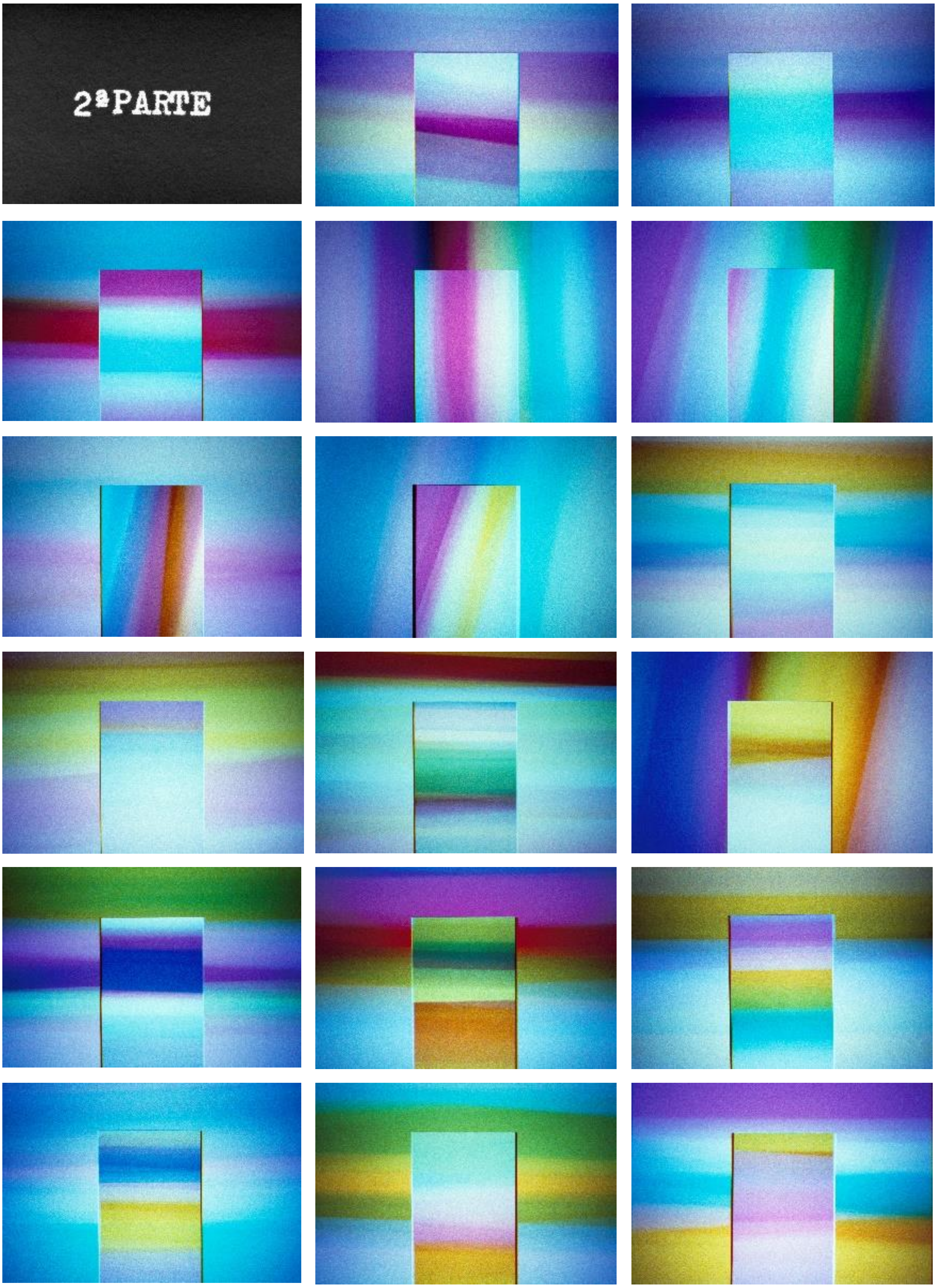
Ângelo de Sousa’s artworks and related documentation

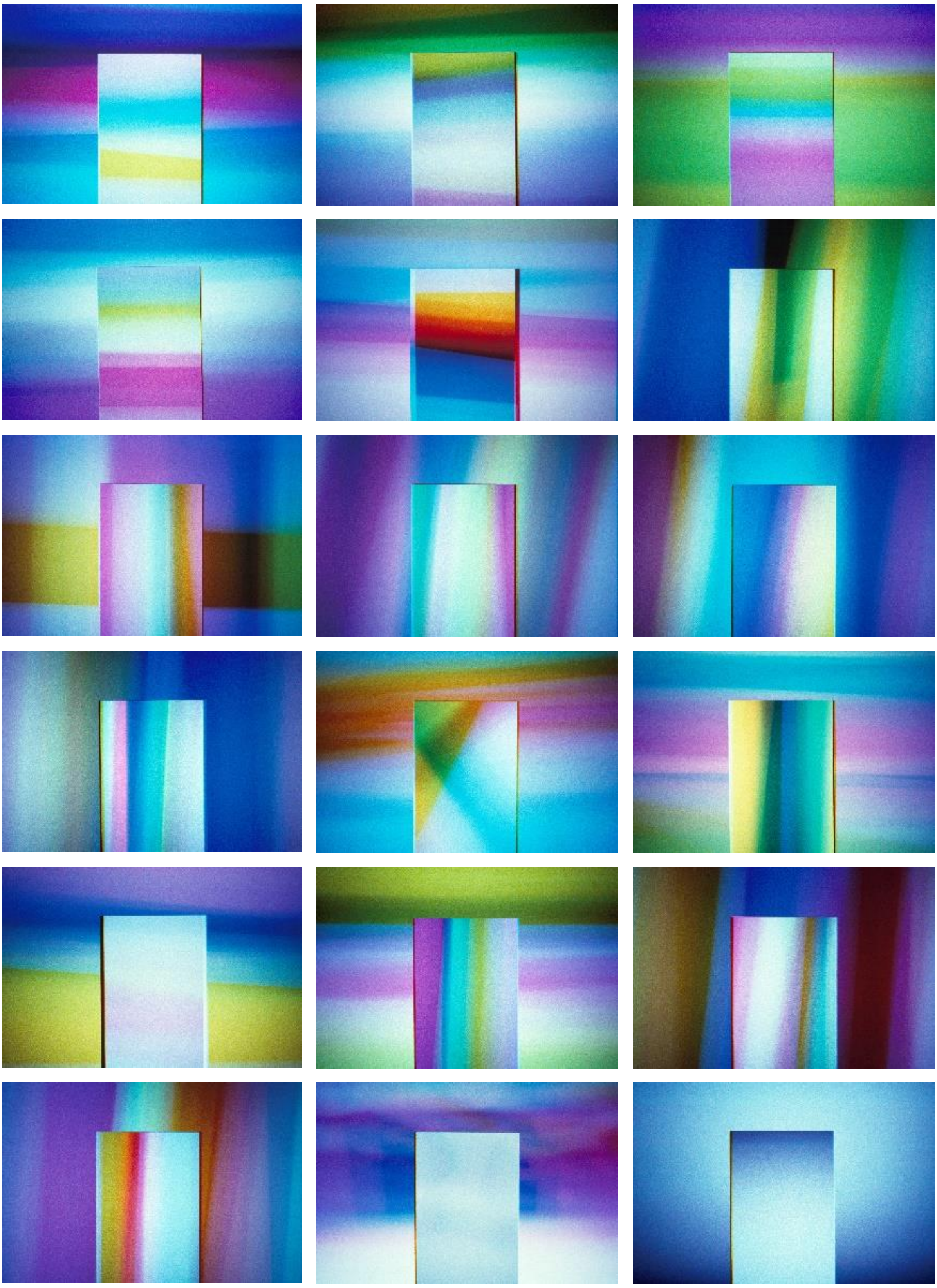
I.1 – *Slides de Cavalete* (1978-1979)








2ª PARTE



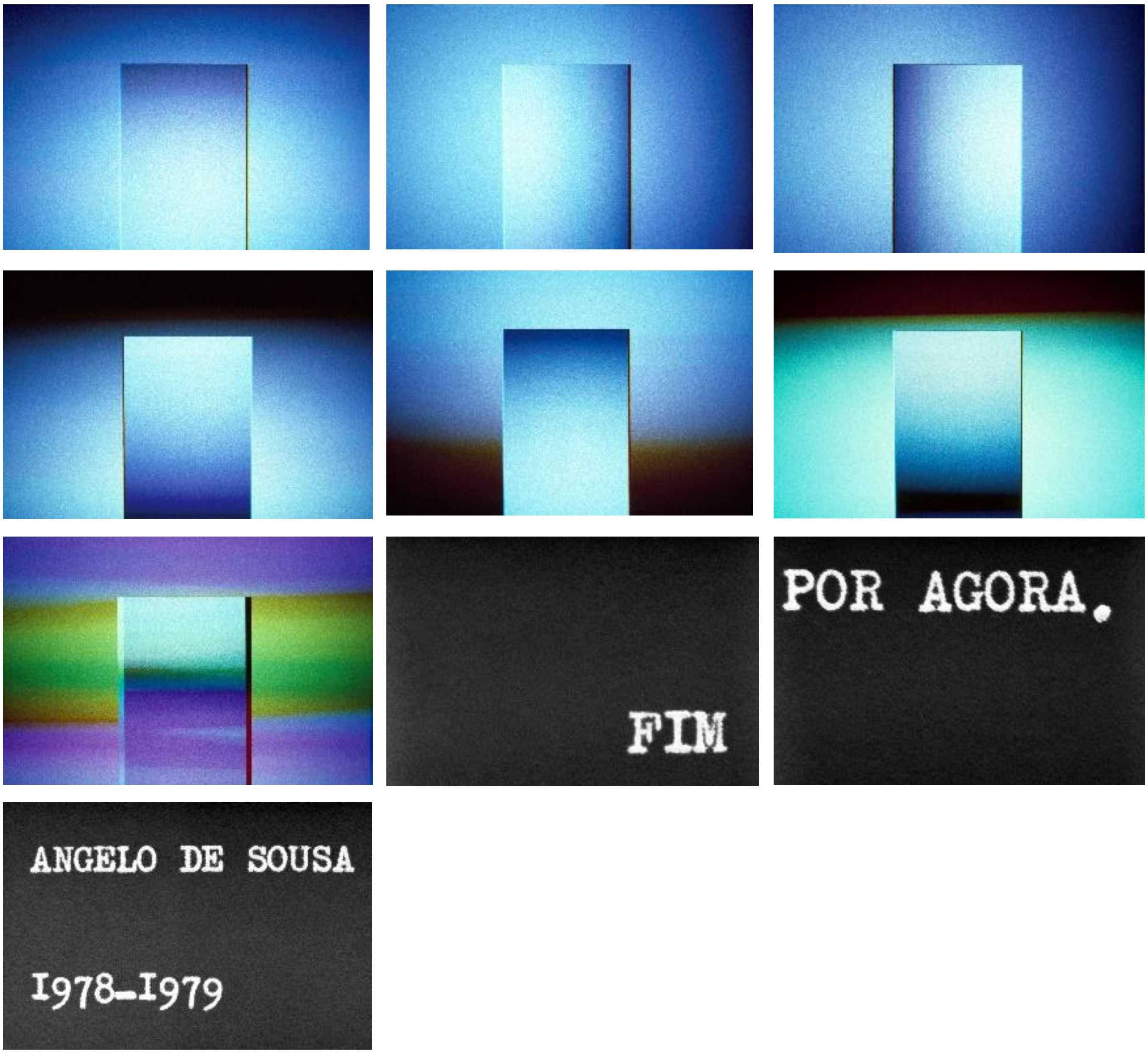


Figure I.1 - Ângelo de Sousa, *Slides de Cavalete* (1978-1979), chromogenic reversal films 35 mm. Artist collection. Diaporama composed of one hundred slides.

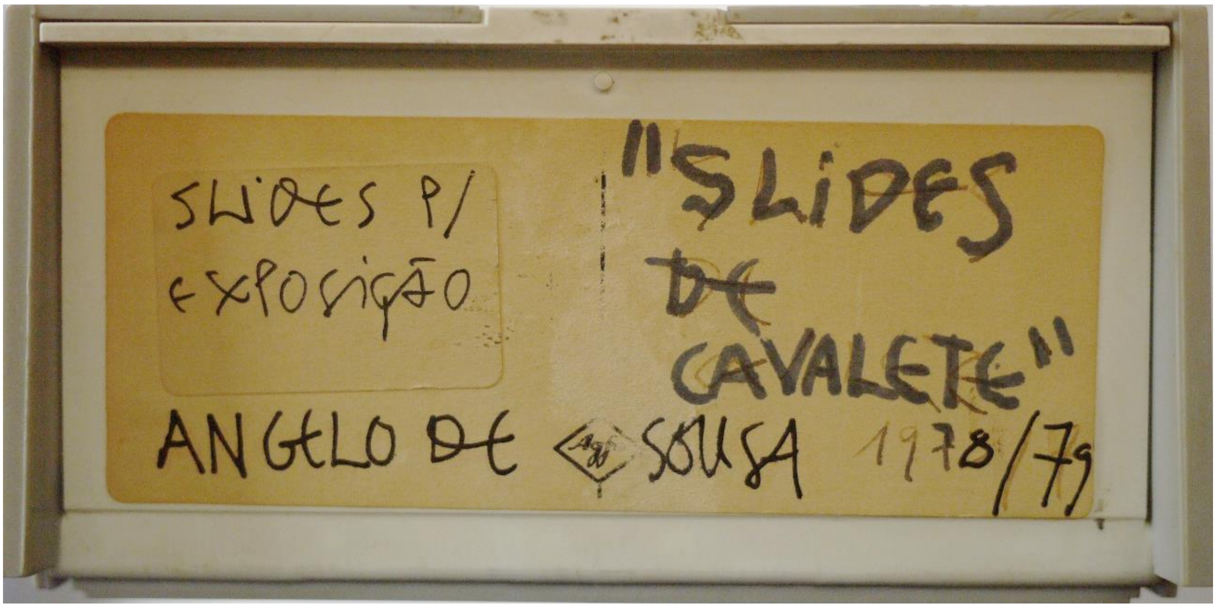


Figure I.2 - Original container from the work *Slides de Cavalete* (1978-1979).

I.2 – Documentation and materials related to the work *Slides de Cavalete* (1978-1979) and other works produced by using additive synthesis

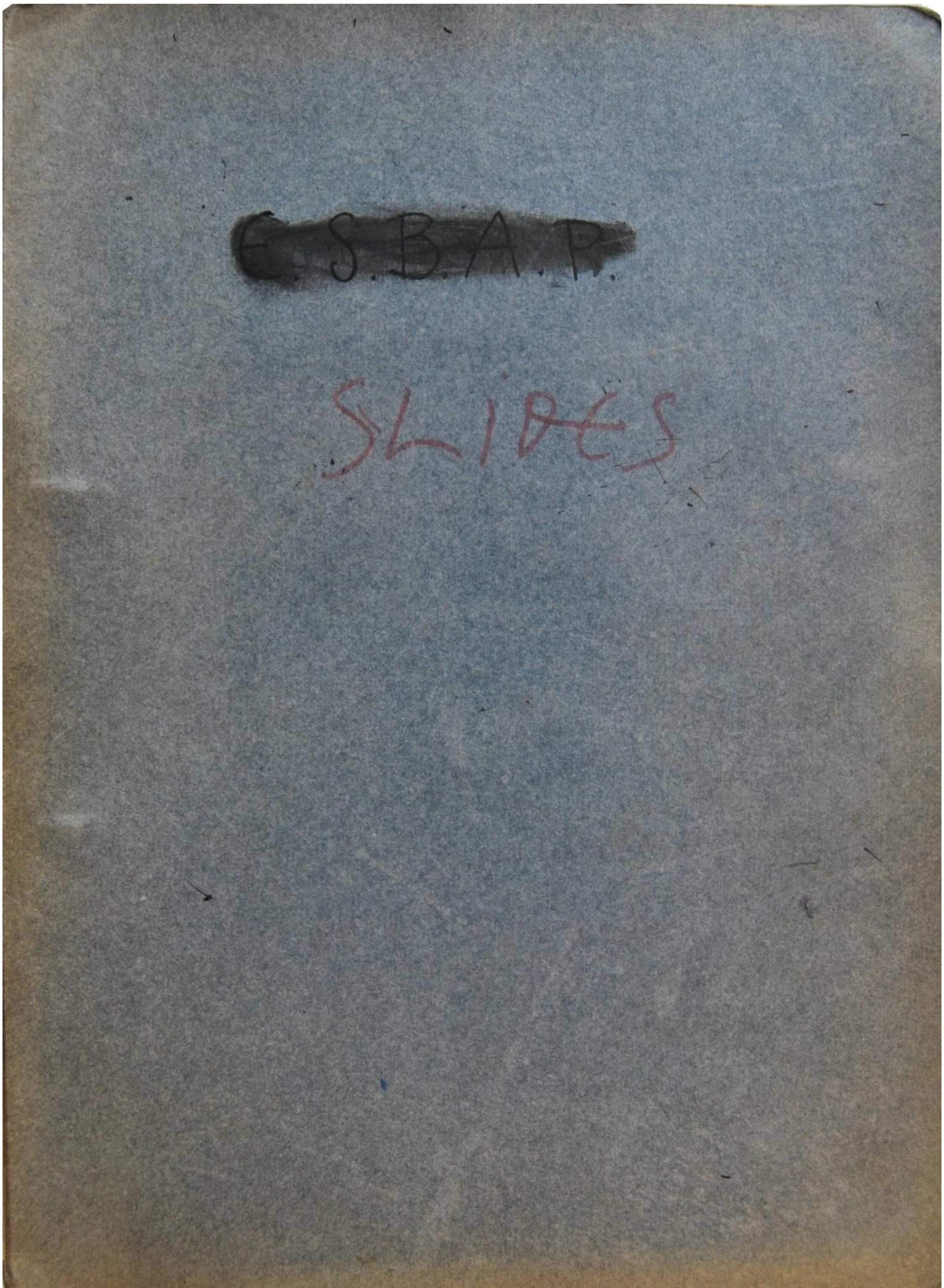
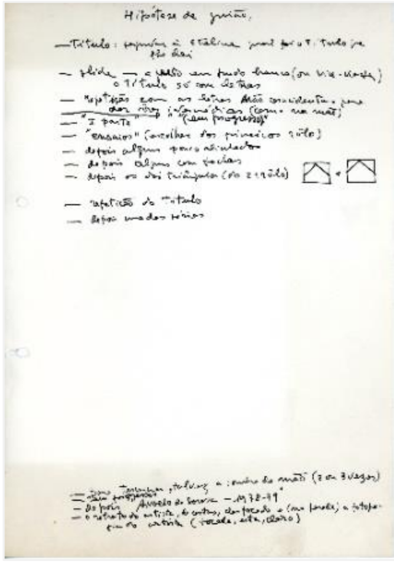
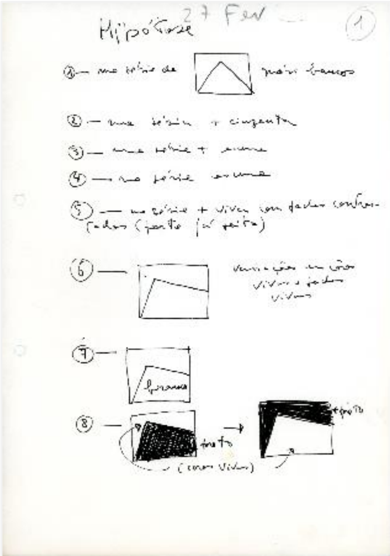
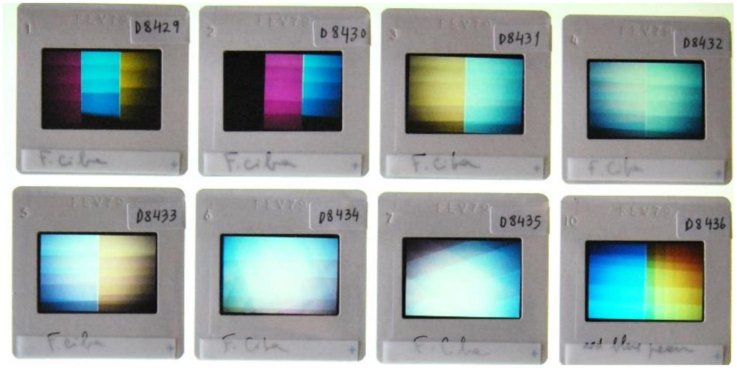
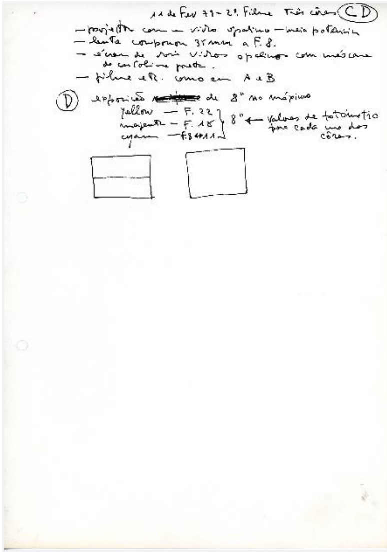
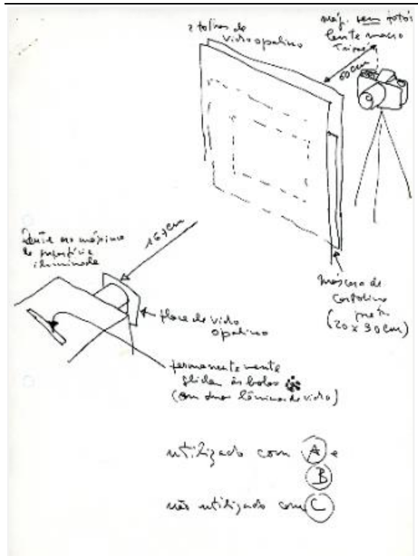
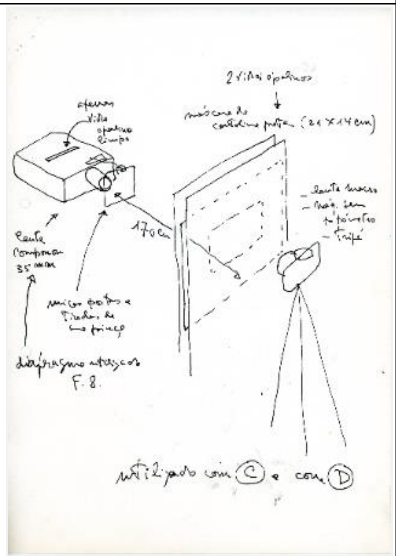
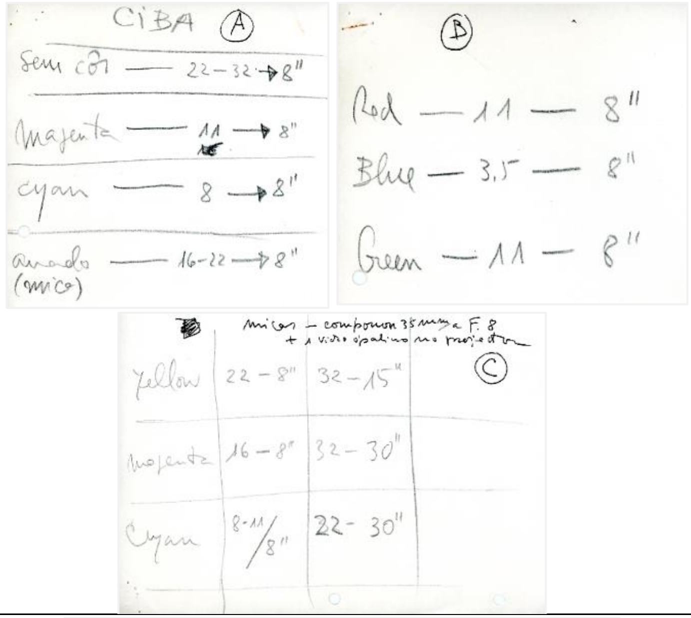
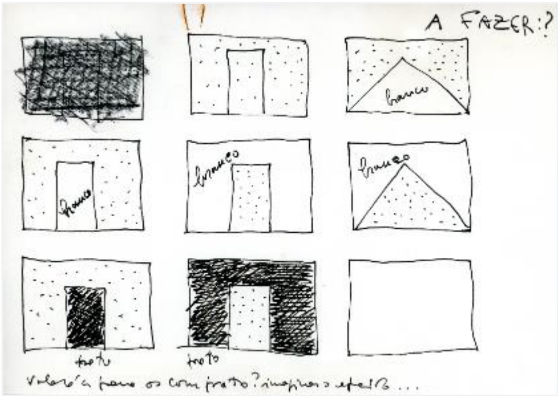
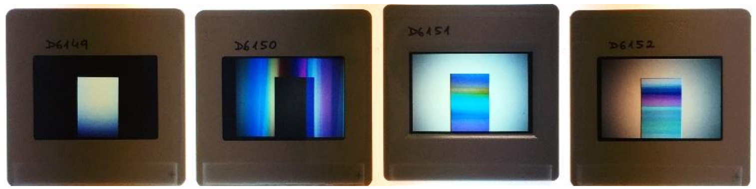


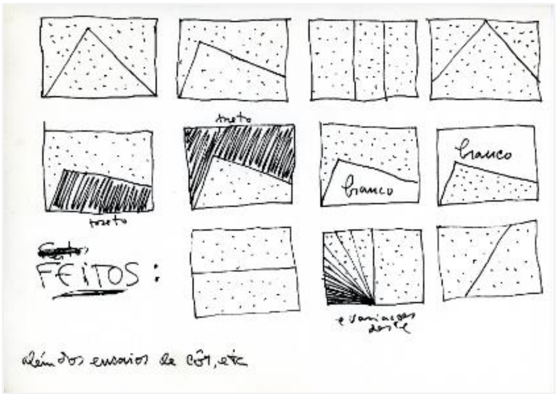
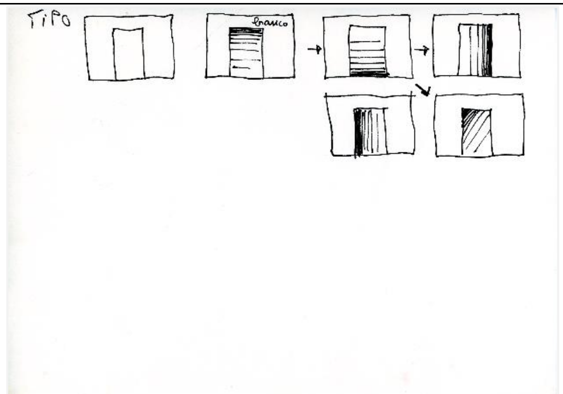
Figure I.3 - File *Slides*, describing the production process of the work *Slides de Cavalete*.

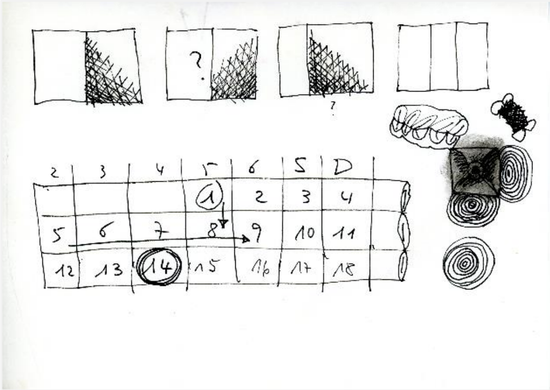
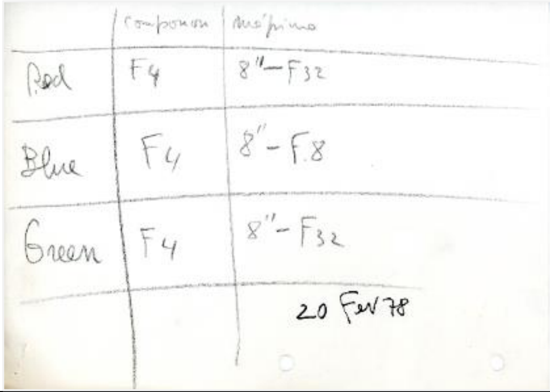
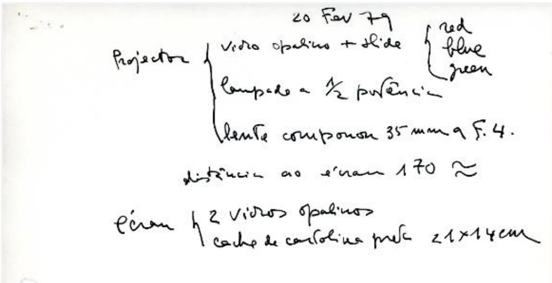
Table I.1 - Documents from the File *Slides*, describing the production process of the work *Slides de Cavalete*. Description of the documentation and association to the test slides found in the artists' archive

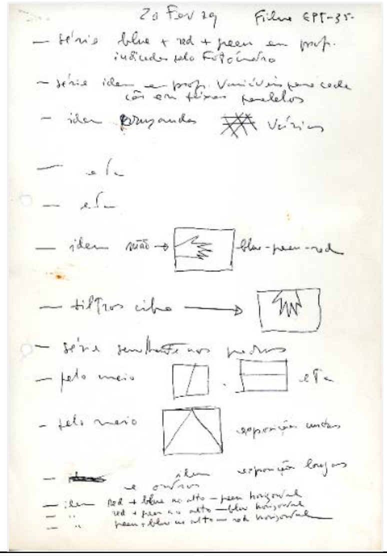
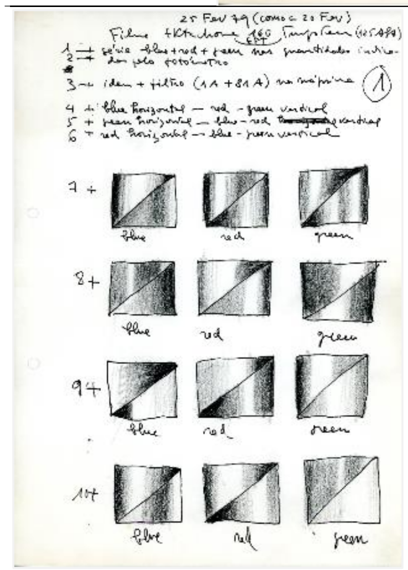
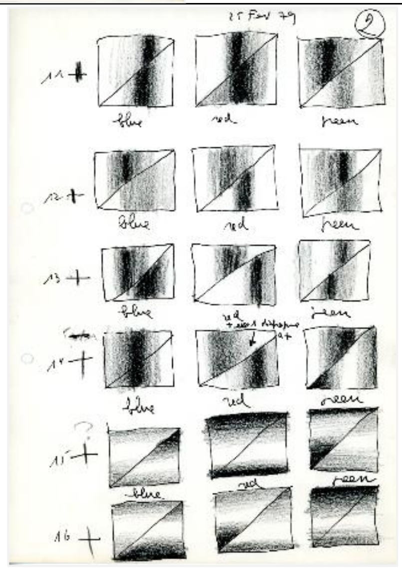
Documents from the file *Slides*	date	Description	Comments
 	undated	"Script hypothesis" Script hypothesis for the work *Slides de Cavalete.*	This was not the final script.
	11th February 1979	"Three colours" Tests performed by Ângelo de Sousa, in which three sets of experiments were conducted: A (with CMY CIBA filters), B (with RGB sheets) and C (with CMY sheets).	The setup used for *Slides de Cavalete* was apparently another. Those were probably Ângelo de Sousa's first experiences. Examples of slides matching the description: 

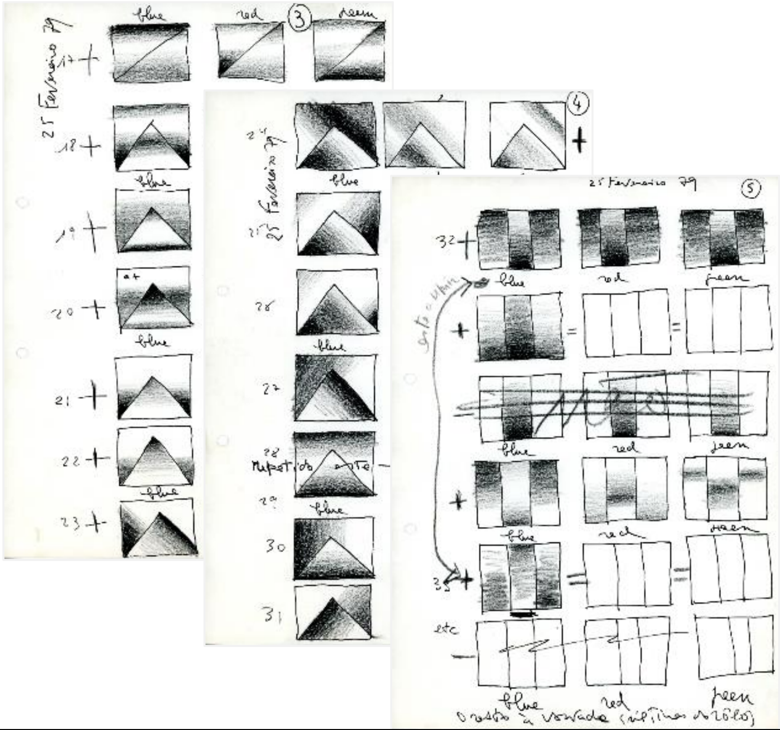
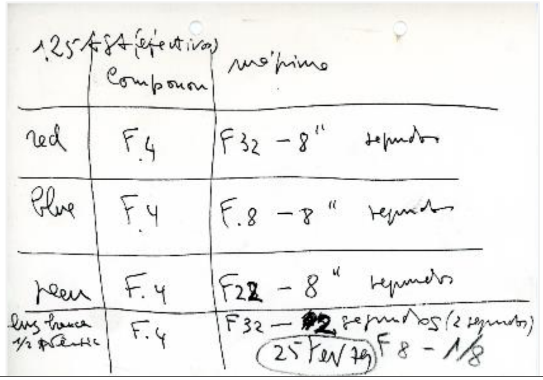
	11th February 1979	“Three colours” Description of a fourth experiment: D (with CMY filters).	The setup used for *Slides de Cavalete* was apparently another. Those were probably Ângelo de Sousa’s first experiences.
 	?	Schemes in which the artist has drawn two setups for the equipment and materials with specific indications. The first was used with A and B, and the second with C and D.	The setup used for *Slides de Cavalete* would have been similar to those. This setup was probably used for Ângelo de Sousa’s first experiences.

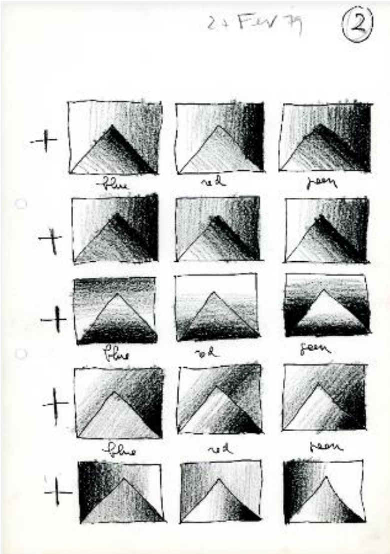
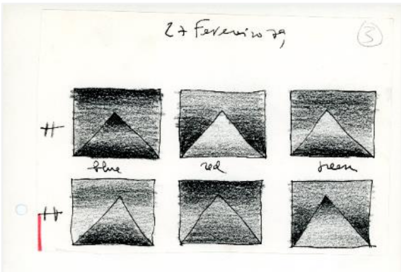
	?	Technical data (aperture and aperture) for the testing with A, B and C.	
	?	Schemes with rectangular and triangular shapes with different variations (white, or black shapes and/or backgrounds, or both areas with colour gradations). The artist wrote "to do?".	Some images from *Slides de Cavalete* could have been produced following these sketches. Examples of slides matching the schemes: 

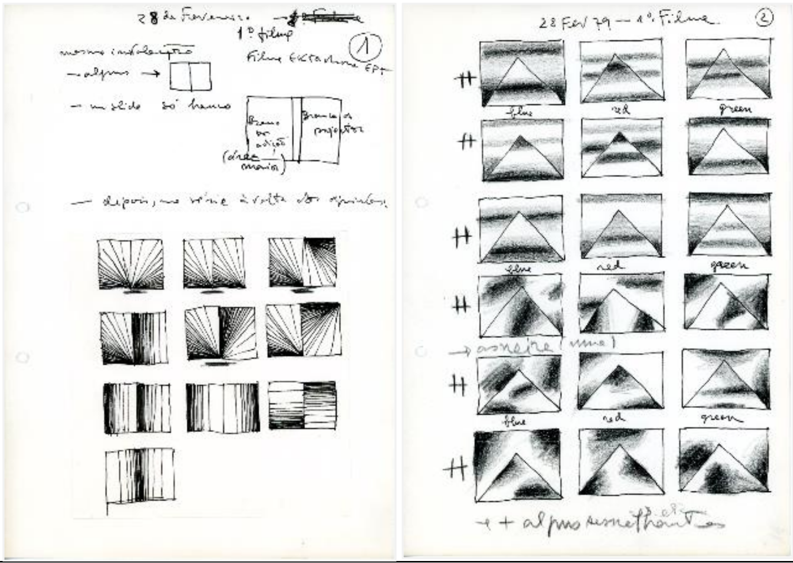
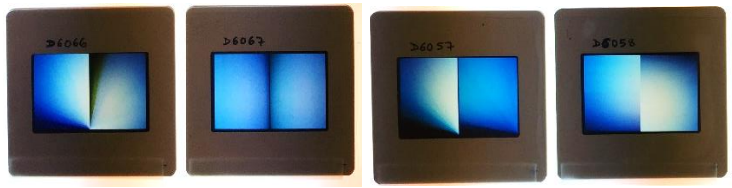
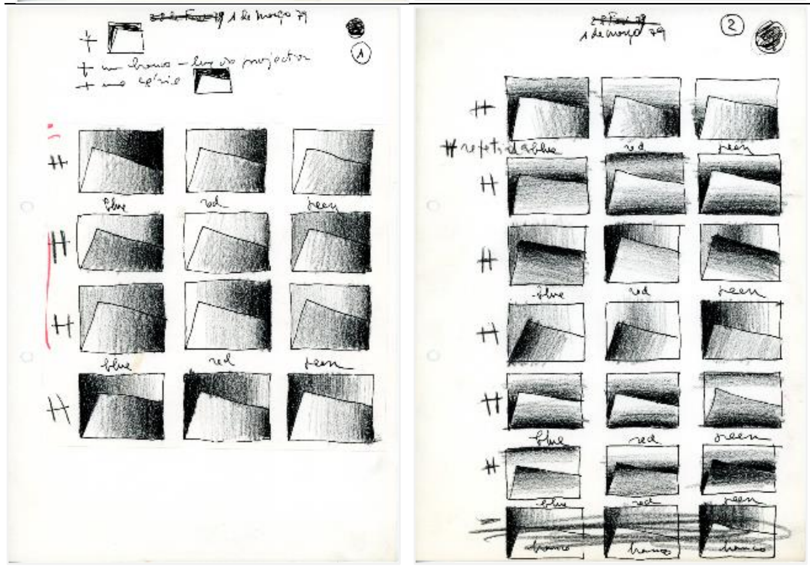
	?	Schemes with different shapes (symmetric and asymmetric triangles, stripes, among others) with different variations (black shapes and/or backgrounds, or both areas with colour). The artist wrote “beside the colour tests, done”.	Some images from *Slides de Cavalete* could have been produced following these sketches. Examples of slides matching the schemes: 
	?	Schemes with rectangular shape with different gradations.	Examples of slides matching the schemes: 

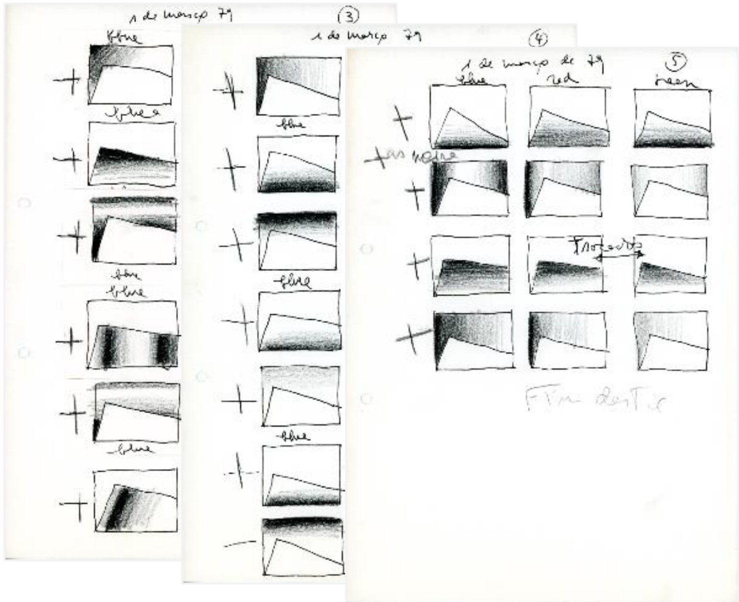
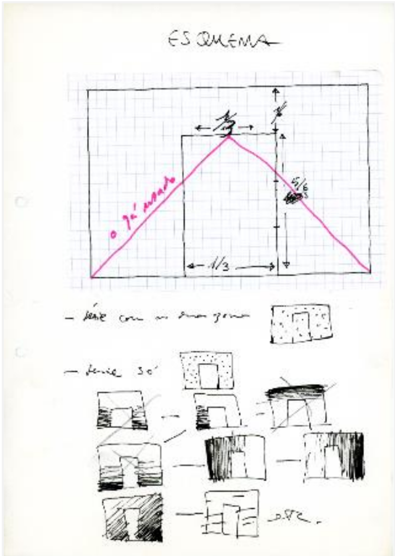
<table>
<tr><td></td><td>?</td><td>Schemes and calendar.</td><td></td></tr>
<tr><td>
</td><td>20th February 1979</td><td>Technical data (aperture and aperture) for R, G and B filters.</td><td></td></tr>
<tr><td>
</td><td>20th February 1979</td><td>Tests performed by Ângelo de Sousa, using:
Projector: i) frosted glass and RGB filters in the projector, ii) half power lamp, and iii) componon lens (35 mm with f4);
Screen: 2 froasted glasses and black cardboard cache (21x14 cm);
Distance between the screen and the projector: ±170cm;</td><td></td></tr>
</table>

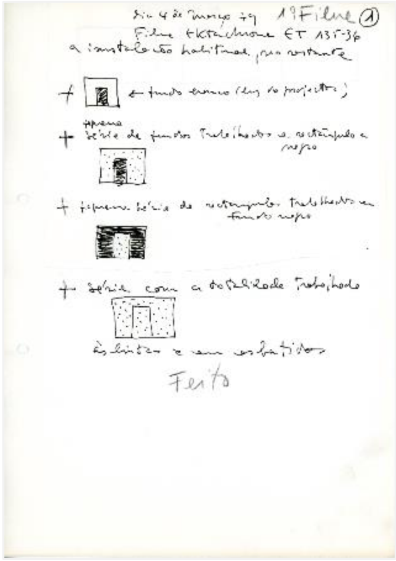
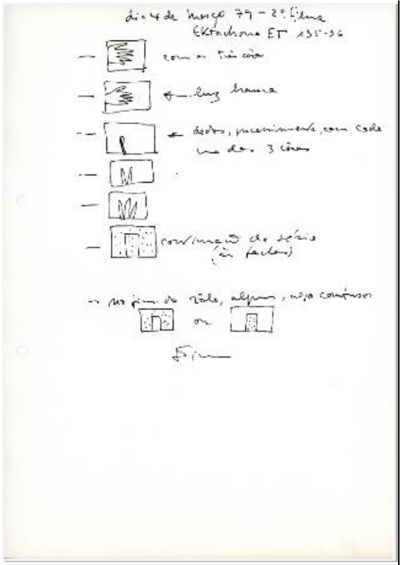
	20th February 1979	Tests performed by Ângelo de Sousa, using different shapes as well as hands.	This was the setup used to produce the images from *Slides de Cavalete*. Examples of slides matching the schemes: 
	25th February 1979	Schemes with the tests produced on that date by using the same setup described for the 20th February. Film: Ektachrome 160 EPT, Tungsten -125 ASA. Different shapes tested (triangle, stripes, diagonal line) with different gradations.	

	25th February 1979	(continuation)	Some images from *Slides de Cavalete* were apparently produced on that date. Examples of slides matching the schemes: 
 red F.4 F32 – 8" segundos blue F.4 F.8 – 8" segundos green F.4 F22 – 8" segundos F.4 F32 — 2 segundos 25 Fev 79 F 8 – 1/8	25th February 1979	Technical data (aperture and aperture) for R, G, B filters, and white light.	

	27th February 1979	Tests produced on that date by using the same setup described for the 20th February.	
 	27th February 1979	Schemes with the tests produced on that date by using the same setup described for the 20th February. Only triangular shapes with different gradations were sketched.	Some images from *Slides de Cavalete* were apparently produced on that date. Only two sheets produced on the 27th February 1979 were found, with the number 1 (previous line), 2 and 5. Thus, there is apparently documentation from that date that is lacking.

	28th February 1979	Schemes with the tests produced on that date by using the same setup described for the 20th February. Film: Ektachrome EPT. Different gradations tested within an image split in two halves (by a vertical line). Additionally, triangular shapes were tested with different gradations. The artist wrote: “and more atmospheric”.	Some images from *Slides de Cavalete* were apparently produced on that date. Examples of slides matching the schemes: 
	1st March 1979	Schemes with asymmetric rectangular shapes with different variations (white shapes and/or backgrounds, or both areas with colour gradations).	Examples of slides matching the schemes: 

		(continuation)	
	?	Scheme with the proportion of the triangle and rectangle in relation with the background. Schemes with rectangular shapes with different variations (white shapes and background with colour gradations).	Some images from *Slides de Cavalete* were apparently produced based on those sketches.

 	4th March 1979	Schemes with the tests produced on that date by using the same setup described for the 20th February. Film: Ektachrome ET 135-136. Schemes with rectangular shapes with different variations (white or black shapes and/or backgrounds, or both areas with colour gradations). The artist wrote “done”.	Some images from *Slides de Cavalete* were apparently produced on that date. Examples of slides matching the schemes: 

II de Fevereiro de 79---2ºfilme TRES CÔRES

filme Ektachrome I60 Tungsten--vel.real I25ASA--EPT I35-36
revelação E-6

iluminação com lâmpada de projecção 24volts-I50watts-I/2 potência

écran por transparência--dois vidros opalinos

com a lente do próprio projector A

1-filtros ciba-yel-mag-cyan(isoladamente),colocados no projector
vel.ind.pelo fotómetro a meio,diminuindo para um lado,aumentando para o outro a exposição(dividindo o écran em três zonas) *

2-filtros ciba--magenta-cyan,em variação gradual,cruzados

3-idem--çyan-yel,idem

4-idem--yel-mag,idem

5-idem---yel-mag-cyan,simultâneamente,em variação gradual,cruzadas

6-idem---idem,repetição

7-idem---idem,repetição,novamente

8-filtros ciba,interposição de uma sombra(copo?mão?)

lente F:8 compõem 3 linhas e um vidro opalino no projector C

1-micas soltas,directamente em frente da lente da máquina fotográfica,
vel.indicada pelo fotómetro,diminuindo para um lado,aumentando para o outro,
dividindo o écran em três zonas.

2-micas soltas--idem,magenta-cyan,em variação gradual,cruzados

3-idem--çyan-yel,idem

4-idem--yel-mag,idem

5-idem--as três côres--yel-mag-cy--simultâneamente,em variação gradual,cruzadas

6-idem--idem---repetição

7-idem--idem---repetição,novamente

8-micas soltas,interposição de uma sombra

com a lente do próprio projector B

1-micas red-blue-green,colocadas no projector,
vel.indicada pelo fotómetro,diminuindo para um lado,aumentando para o outro
a exposição(dividindo o écran em três zonas)

2-micas red-blue,em variação gradual,cruzadas

3-micas blue-green,idem

4-micasgreen-red,idem

5-micas green-red-blue,simultâneamente,em variação gradual,cruzadas

6-idem,idem,repetição

7-idem,idem,repetição,novamente

8-idem,idem,interposição de uma sombra

* yel substituído por mica

1

2

Figure I.4 – Sheet belonging to the file *Slides*, indicating the tests realized for the production of the work *Slides de Cavalete* (1978-1979), and related materials; three set of tests are described in the sheet: A (by placing CMY filters inside the projector), B (by placing transparent sheet protectors in front of the photographic camera) and C (by placing RGB filters inside the projector); 1) example of test obtained from A setup; 2) example of test obtained from B setup.

1

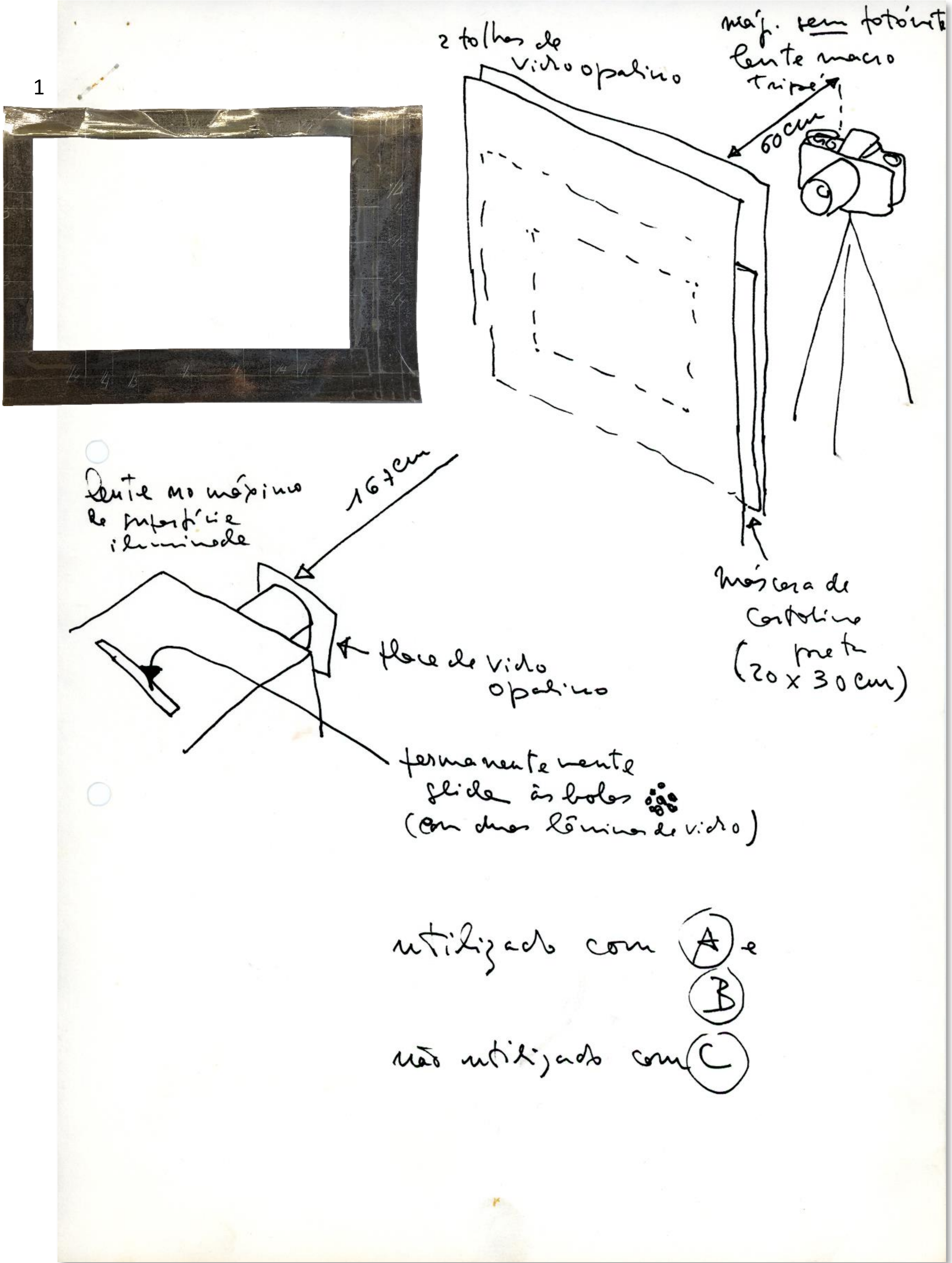


Figure I.5 – Sheet belonging to the file *Slides* indicating the equipment setup used to produce the tests and related materials; 1) black cardboard window with measures, to help the execution of the tests.

Figure I.6 – Box containing the filters used to produce the work *Slides de Cavalete* (1978-1979).

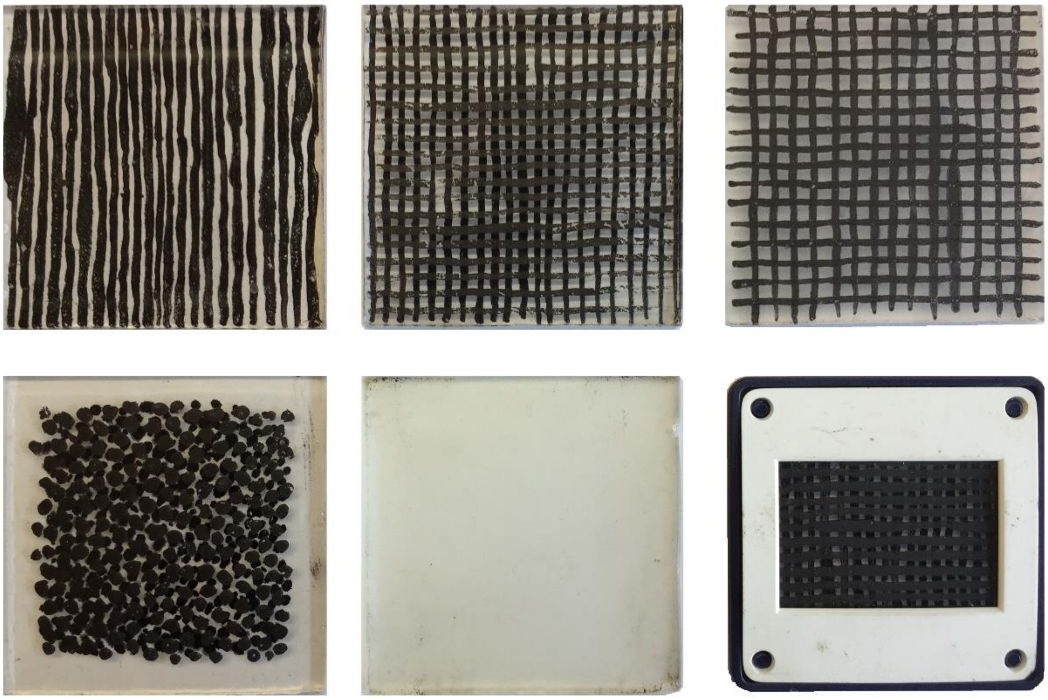
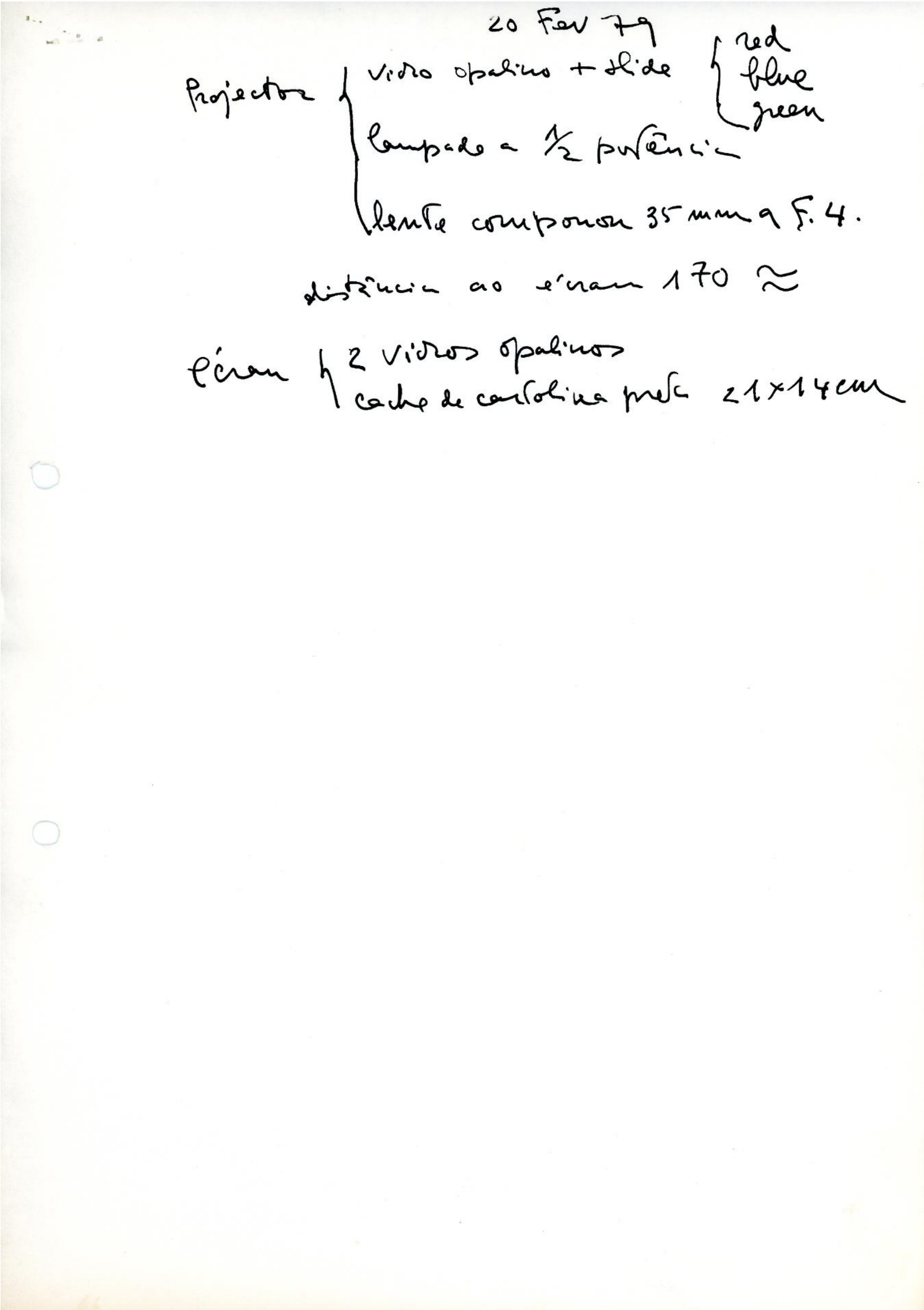


Figure I.7 – Glasses and transparent sheet in a plastic mounting, with painted surface (black), probably used to reduce the light intensity coming from the projector.

Figure I.8 – Filters in a plastic mounting used for the testing, to place inside the projector.



20 Fev 79

Projector { vidro opalino + slide { red / blue / green
lampada a 1/2 potência
lente componon 35 mm a F. 4.

distância ao écran 170 ≈

écran { 2 vidros opalinos
cache de cartolina preta 21×14 cm

Figure I.9 – Sheet belonging to the file *Slides*, related to the work *Slides de Cavalete* (1978-1979). Notations describing the equipment setup and related materials adopted to produce the slides from the 20th February on, namely a frosted glass and RGC filters placed inside the slide projector. According the documentation, this was the setup used to produce the slides composing the work *Slides de Cavalete.*

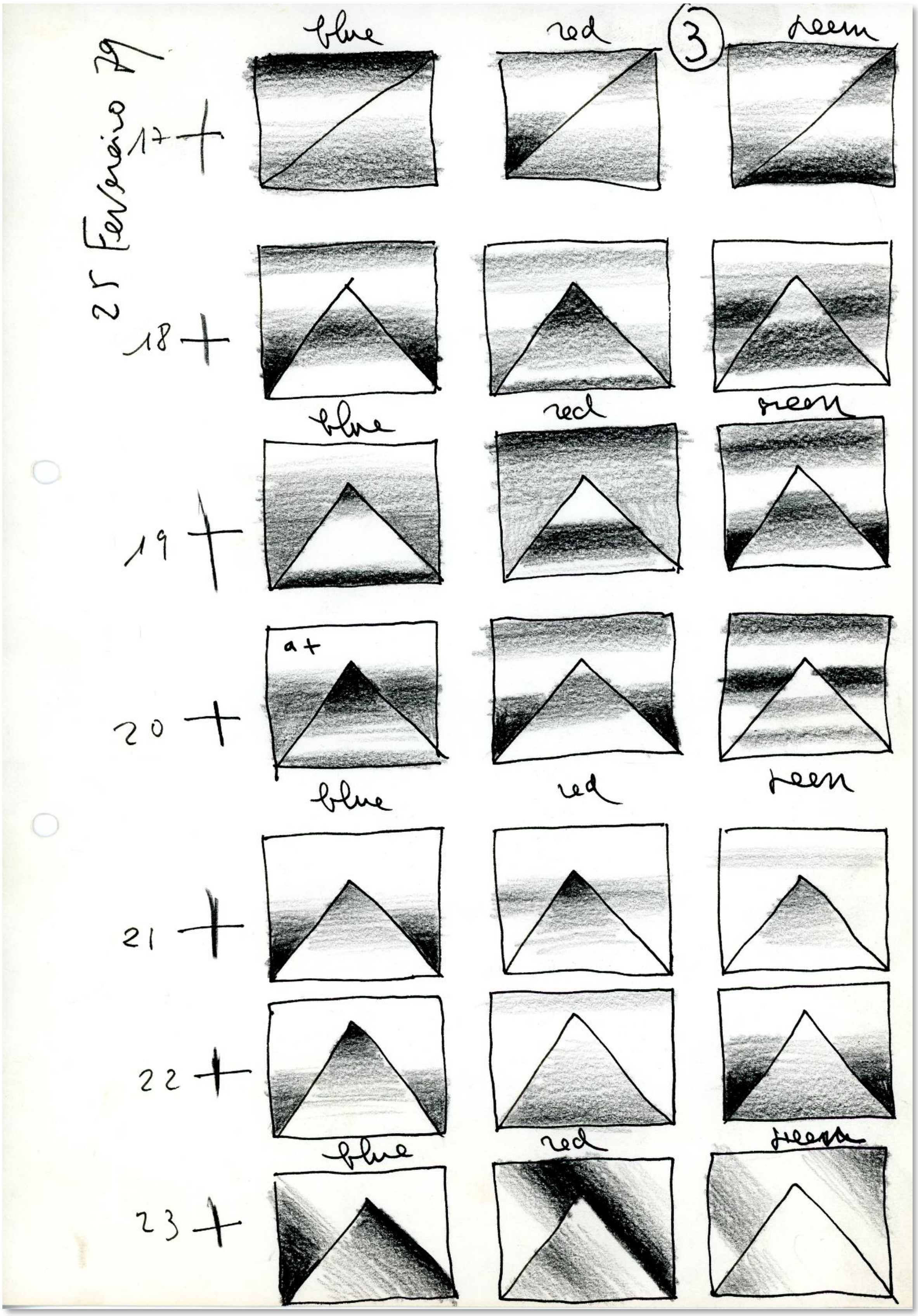
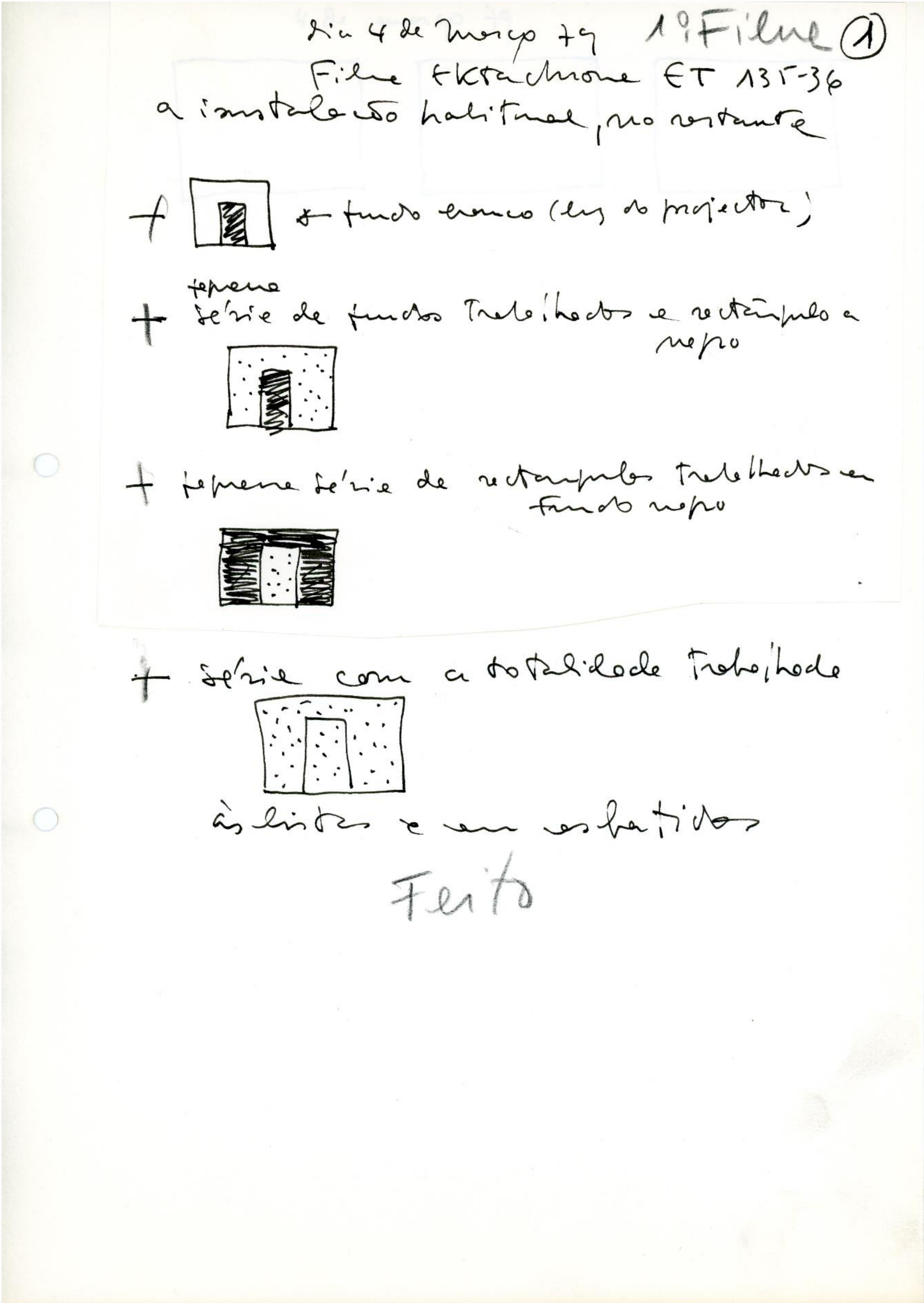


Figure I.10 – Sheet belonging to the file *Slides*, related to the work *Slides de Cavalete* (1978-1979). Sketches representing the secondary masks (opaque object) applied to reduce the exposure of the films in selected areas, and therefore produce the light gradations. Examples of masks applied to slides with triangular shape, and other tested composition. The black areas represent the areas where the light was blocked.



dia 4 de março 79 1º Filme (1)
Filme Ektachrome ET 135-36
a instalação habitual, no restante

+ o fundo branco (luz do projector)

+ pequena série de fundos trabalhados e rectângulo a negro

+ pequena série de rectângulos trabalhados em fundo negro

+ série com a totalidade trabalhada

às listas e em esbatidos

Feito

Figure I.11 – Sheet belonging to the file *Slides*, related to the work *Slides de Cavalete* (1978-1979). Sketches representing the secondary masks (opaque object) applied to reduce the exposure of the films in selected areas, and to therefore produce the light gradations. Examples of masks applied to slides with rectangular shape. The first references to the rectangular shapes are dated from 4th March.

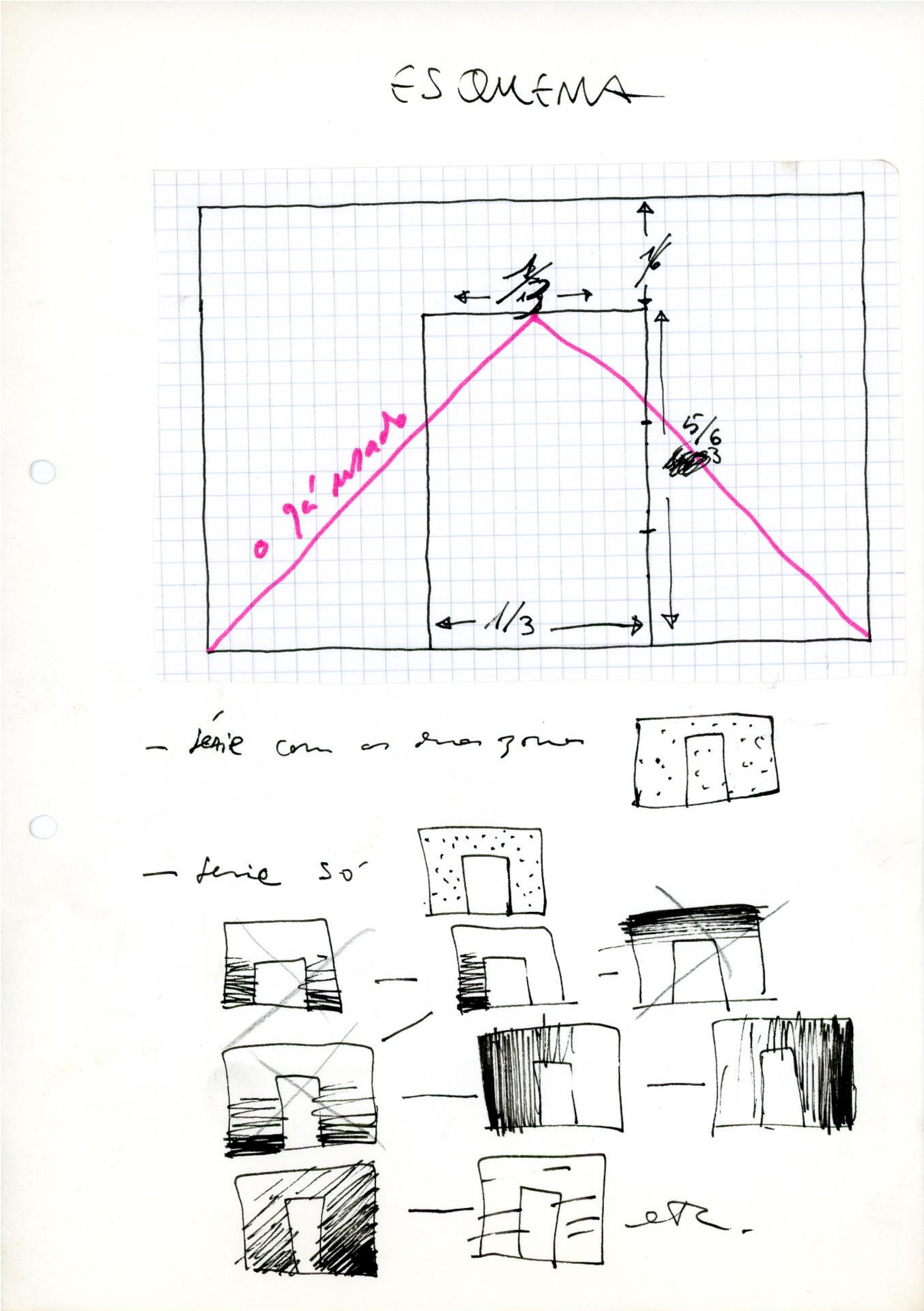


Figure I.12 – Sheet belonging to the file *Slides*, related to the work *Slides de Cavalete* (1978-1979). Scheme representing the proportions of the masks used to produce the triangular and rectangular shapes (on the top).

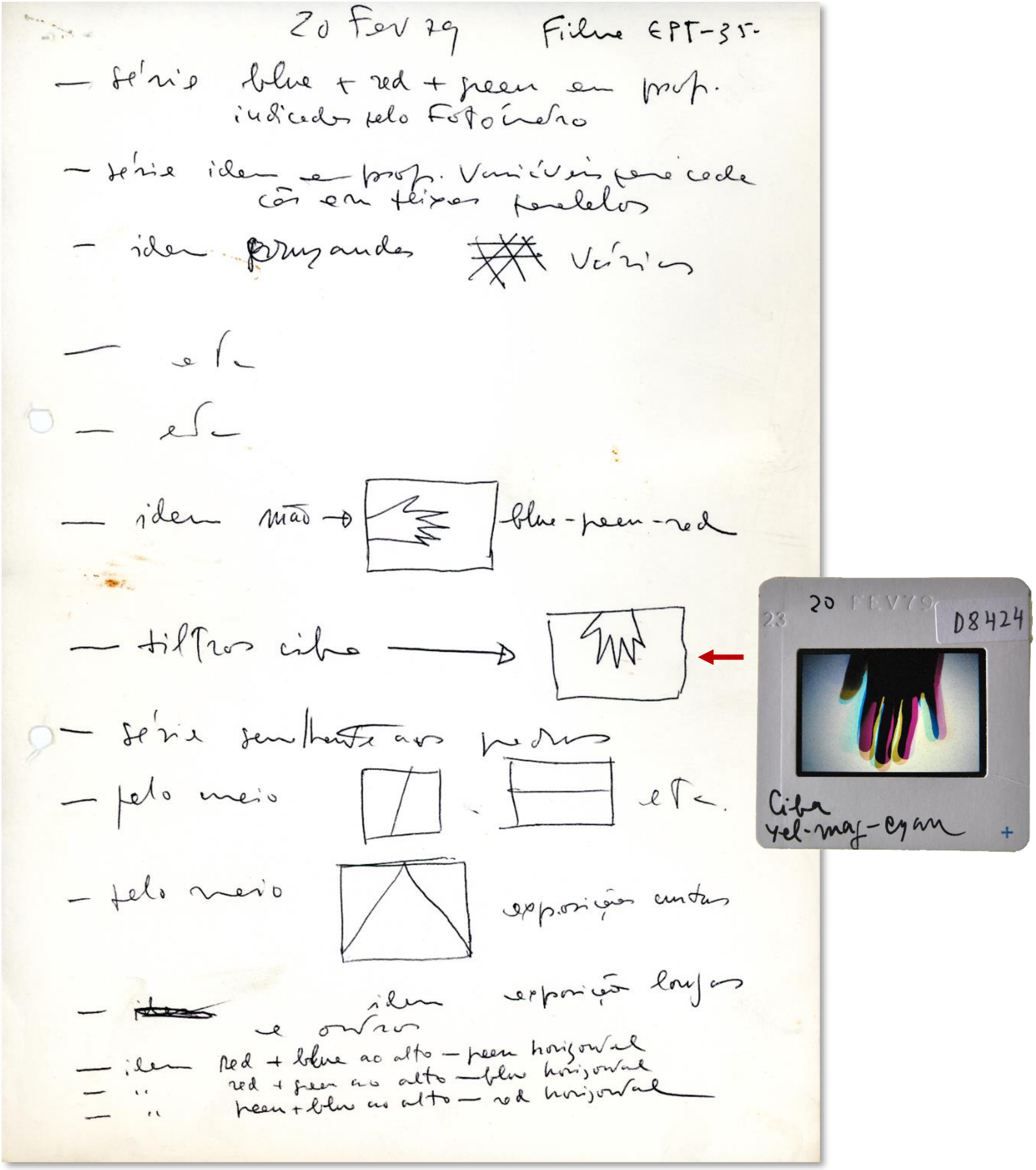


Figure I.13 – Sheet belonging to the file *Slides*, indicating the tests realized during the production of the works with additive synthesis, where the scheme to produce the untitled series (1979) is apparently outlined.

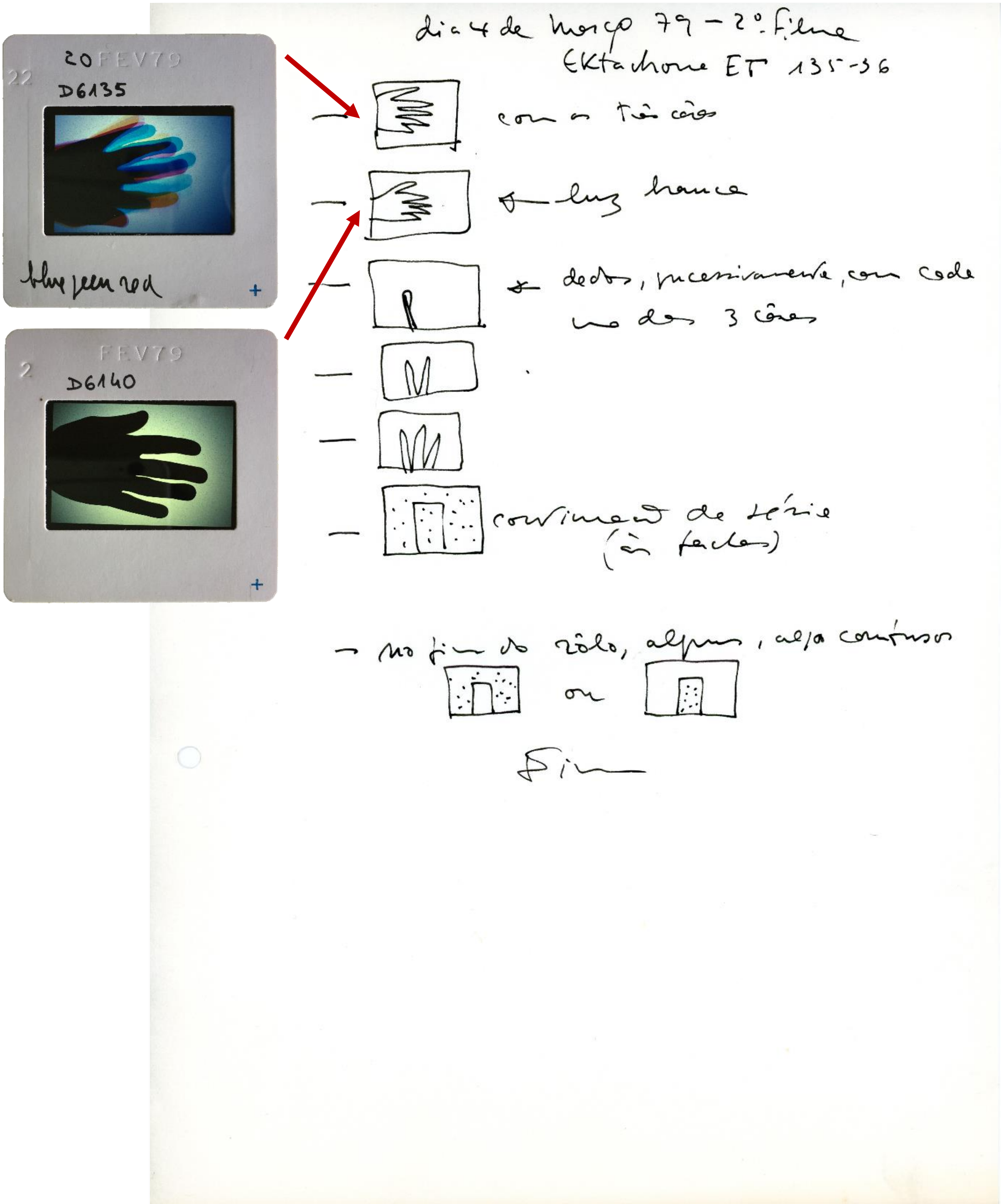


Figure I.14 – Sheet belonging to the file *Slides*, indicating the tests realized during the production of the works with additive synthesis, where the scheme to produce the untitled series [colourful hand shadows] (1979) is apparently outlined.

I.3 – Reproduction of the work *Slides de Cavalete* (1978-1979) and the colourful hand shadows (1979)

After analysing the documentation from the file *Slides*, the production process used to make the work *Slides de Cavalete* (1978-1979) and the untitled work [colourful hand shadows] (1979) was reproduced, following the indications left by the artist. The reproductions presented further on this section are the result of several tests realized between 2014 and 2017 at the Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia within different courses from the bachelor and master in conservation and restoration: *Introdução à Conservação e Restauro I* (bachelor), *Projecto I* and *História e Técnicas de Produção Artística II* (master). The reproduction of the works was very helpful to understand the complexity of the images composing the work, both in terms of its concept and execution process. It should be stressed out that, contrarily to Ângelo de Sousa who worked alone (as far as it is known), the reproduced images were obtained with the participation of several students managing the different tasks implied in the process (shooting, changing filters, changing masks, applying secondary masks to produce light gradations, etc.).

To reproduce the selected images, the equipment setup was arranged (Figure I.15 and I.16) according to the documentation left by the artist (Figure I.5 and I.9). Some adaptations had to be done, due to the specificities of the equipment and materials at use (distance between equipment's, exposure times, lens aperture, etc.), which were different from those of the artist. The first tests were carried out by using a digital camera (multiple-exposure mode), in order to immediately assess the obtained results. However, the multiple-exposure mode has some limitations, namely the short time between exposures, which forced a further planning and organization. Ironically, in the text in which Ângelo de Sousa described the production methodology of the work (Chapter 4, Fig. 4.12), he refers that: *"using other resources - electronic, computer – I could have obtained results, not only faster, but also with other ambitions with regards to the details' treatment"*[1].

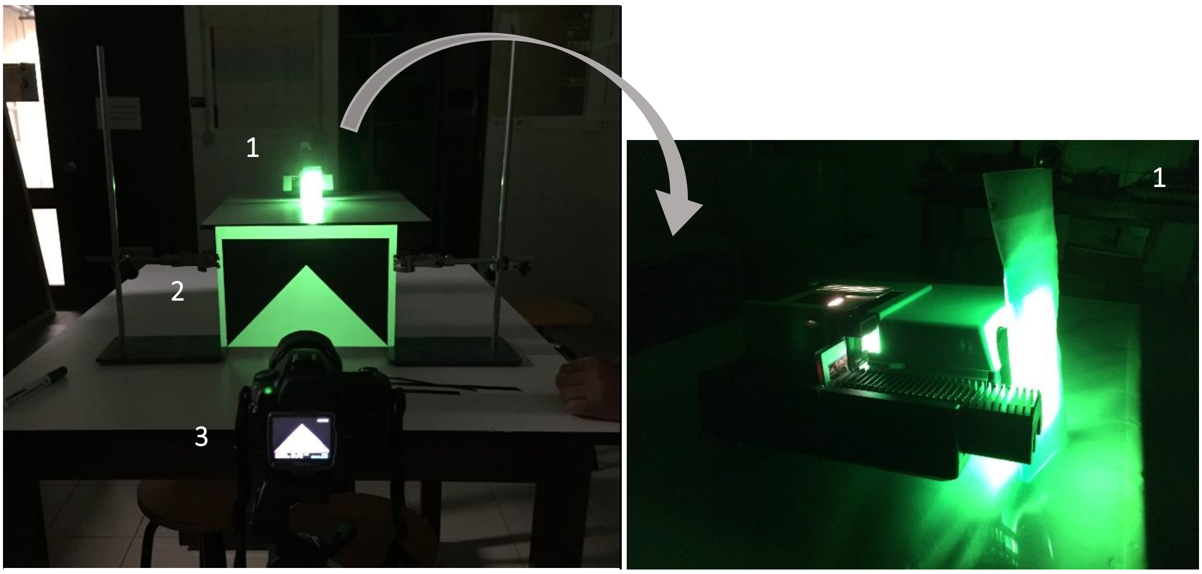


Figure I.15 – Display setup used for the reproduction of the work *Slides de Cavalete* (1978-1979): 1) Leica P150 slide projector where the RGB filters were placed (Rosco CalColor™ Kit mounted with slide mountings), with a frosted glass positioned in front of the lens in order to reduce the light intensity; 2) two frosted glasses sustained vertically by using laboratory tweezers, and in between a black cardboard masking the background in order to expose the triangular shape (following the dimensions described by the artist); 3) Nikon digital camera with a macro lens (60mm) over a tripod.

[1] Translation from the author of this dissertation.

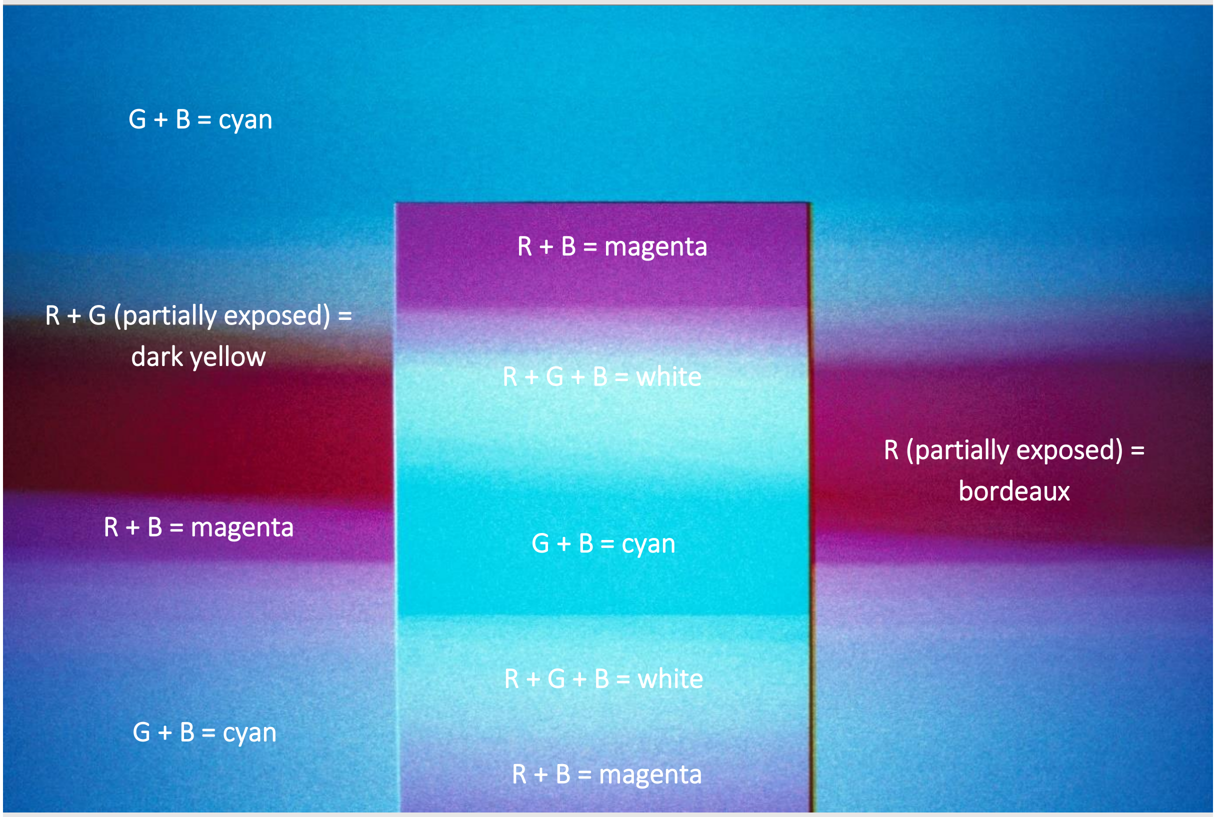
Figure I.16 – Students reproducing the work *Slides de Cavalete* (1978-1979).

After controlling the process, one slide from the diaporama (slide 58) was selected and captured by using an analogue camera. Despite the original work was captured in an Ektachrome 160T 125 ASA, since it is outdated, the film Fujichrome Provia 100F 100 ASA was used for the reproduction.

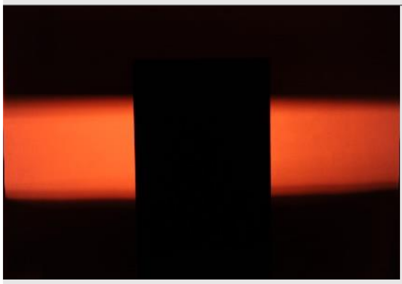
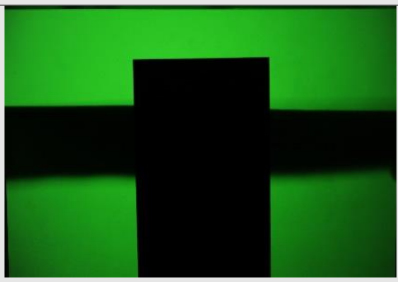
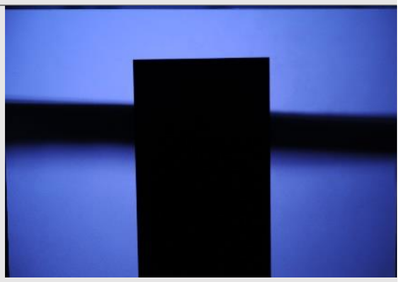
Before the reproduction of the selected slide, the process to obtain the slide in study was outlined, considering the additive synthesis of colours, as presented in Table I.2.

Table I.2 – Secondary masks used to block the R G B lights in necessary areas, to reproduce the slide 58 from the work *Slides de Cavalete* (1978-1979)

Slides de Cavalete (1978-1979) – slide 58

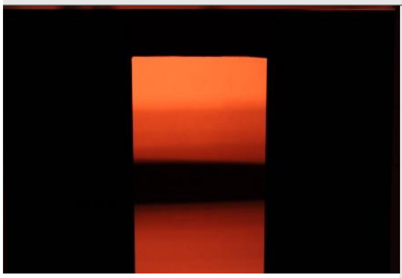
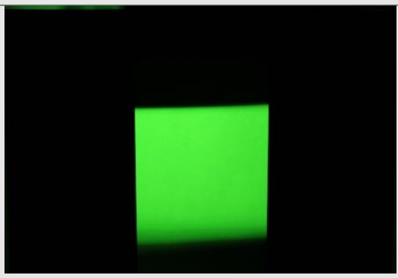
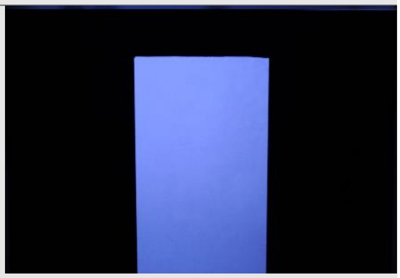


Background

Comments: Most of the background is blue/cyan, with a bordeaux and magenta stripe at the centre. Starting with red light (R), the film was exposed only in a stripe at the center (the light was obstructed in the remaing area by using a black cardboard secondary mask), wherein the upper area of the stripe was not totally exposed to the light in order to produce bordeaux. Next, the film was exposed to green light (G) in the opposite areas, with exception to the upper area of the stripe (right side) in order to produce a dark yellow (R+G=Y). At last, the film was exposed to blue light (B), with exception to the upper area of the stripe, in order to produce cyan (G+B=C) in the remaining background and magenta (R+B=M) in the bottom area of the stripe.

Shape

<u>Comments</u>: The shape is composed of a magenta (R+B=M) stripe, followed by a white (R+G+B=W) stripe, then a cyan (G+B=C) stripe, again a white stripe and at last a magenta stripe. Therefore, the film was exposed to R light in the extremities of the shape, to G light in the center of the shape and to B light in the overall area, in order to reproduce the colors of the shape.

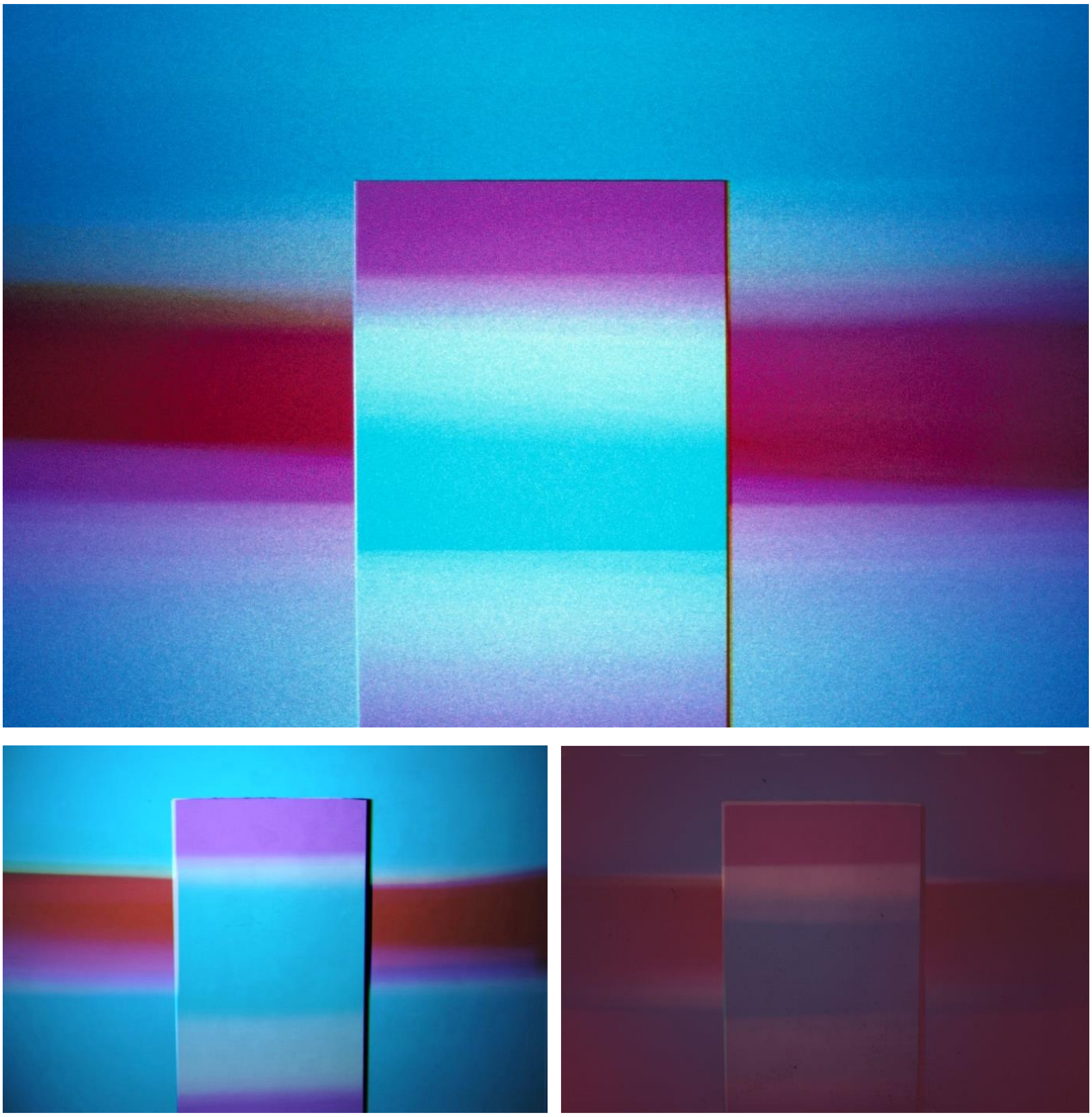


Figure I.17 – Slide 58 from the work *Slides de Cavalete* (1978-1979) – **Top:** original image; **Bottom (left):** reproduction obtained with the digital camera; **Bottom (right):** reproduction obtained with the analogue camera.

By observing Figure I.17 it might be said that the result obtained with the digital camera was quite satisfactory, by comparing it with the original. However, the results obtained with the analogue camera were not so satisfactory. This may be due to technical problems linked to the photographic camera (exposure) or to the chromogenic reversal film (film type, development, etc.). Anyway, the reproduction was carried out to understand the production process of the work *Slides de Cavalete* (1978-1979), which was achieved.

In order to reproduce the untitled work [colourful hand shadows] (1979), the same methodology used for the reproduction of the work *Slides de Cavalete* (1978-1979) was adopted (Fig. I.18).

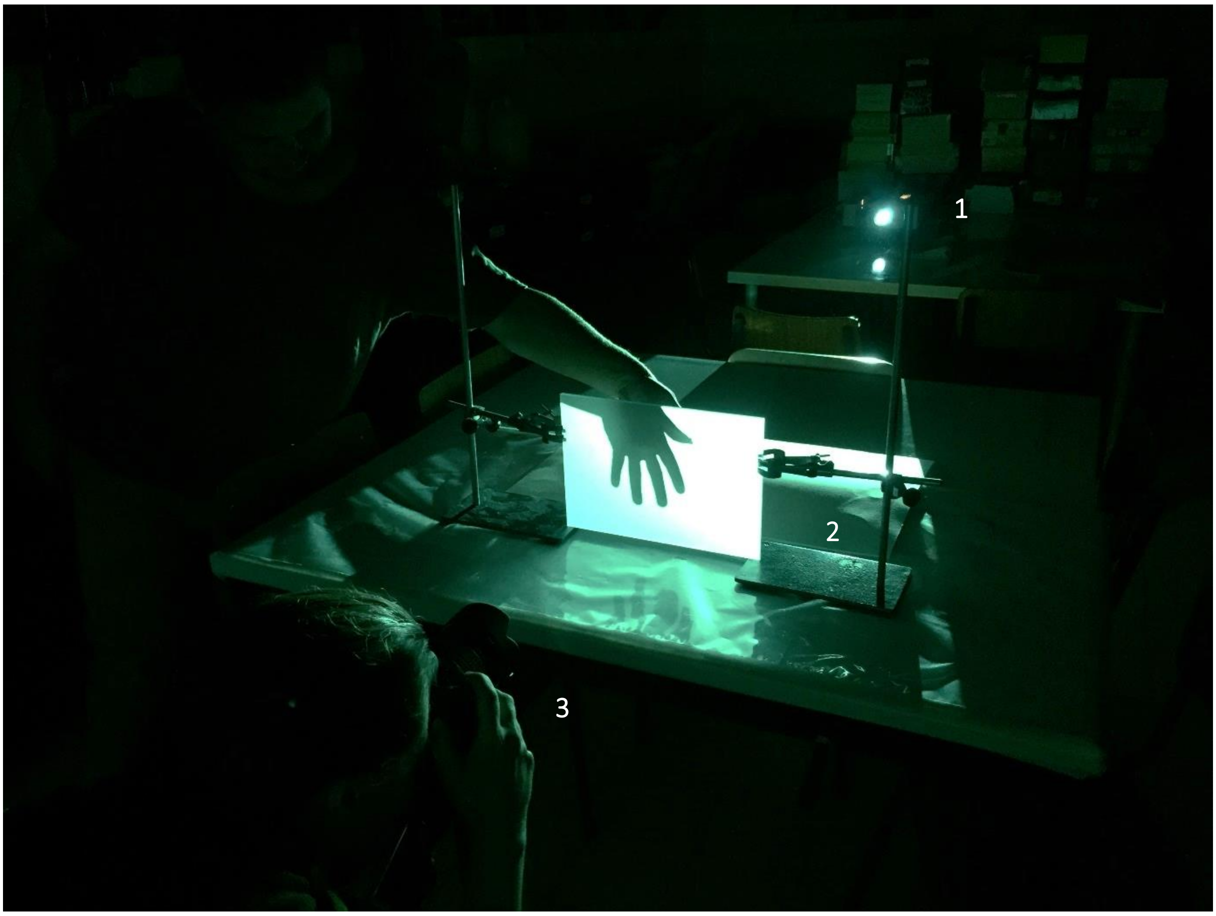


Figure I.18 – Display setup used for the reproduction of the untitled work [colourful hand shadows] (1979); 1) Leica P150 slide projector where the RGB filters were placed (Rosco CalColor™ Kit mounted with slide mountings), with a frosted glass positioned in front of the lens in order to reduce the light intensity; 2) two frosted glasses sustained vertically by using laboratory tweezers; 3) Nikon digital camera with a macro lens (60mm) over a tripod.

By observing Figure I.19, although some tonal deviations might be observed, both digital and analogue reproductions were quite satisfactory. These deviations might be due to the use of different equipment and materials, such as light source from the projector, colour of the filters and/or emulsion from the chromogenic reversal film.

Figure I.19 – Untitled [colourful hand shadows] (1979) – **Top:** original image; **Bottom (left):** reproduction obtained with the digital camera; **Bottom (right):** reproduction obtained with the analogue camera.

Appendix II

Additional results from the survey to the collection

II.1 – T and RH measurements (datalogger)

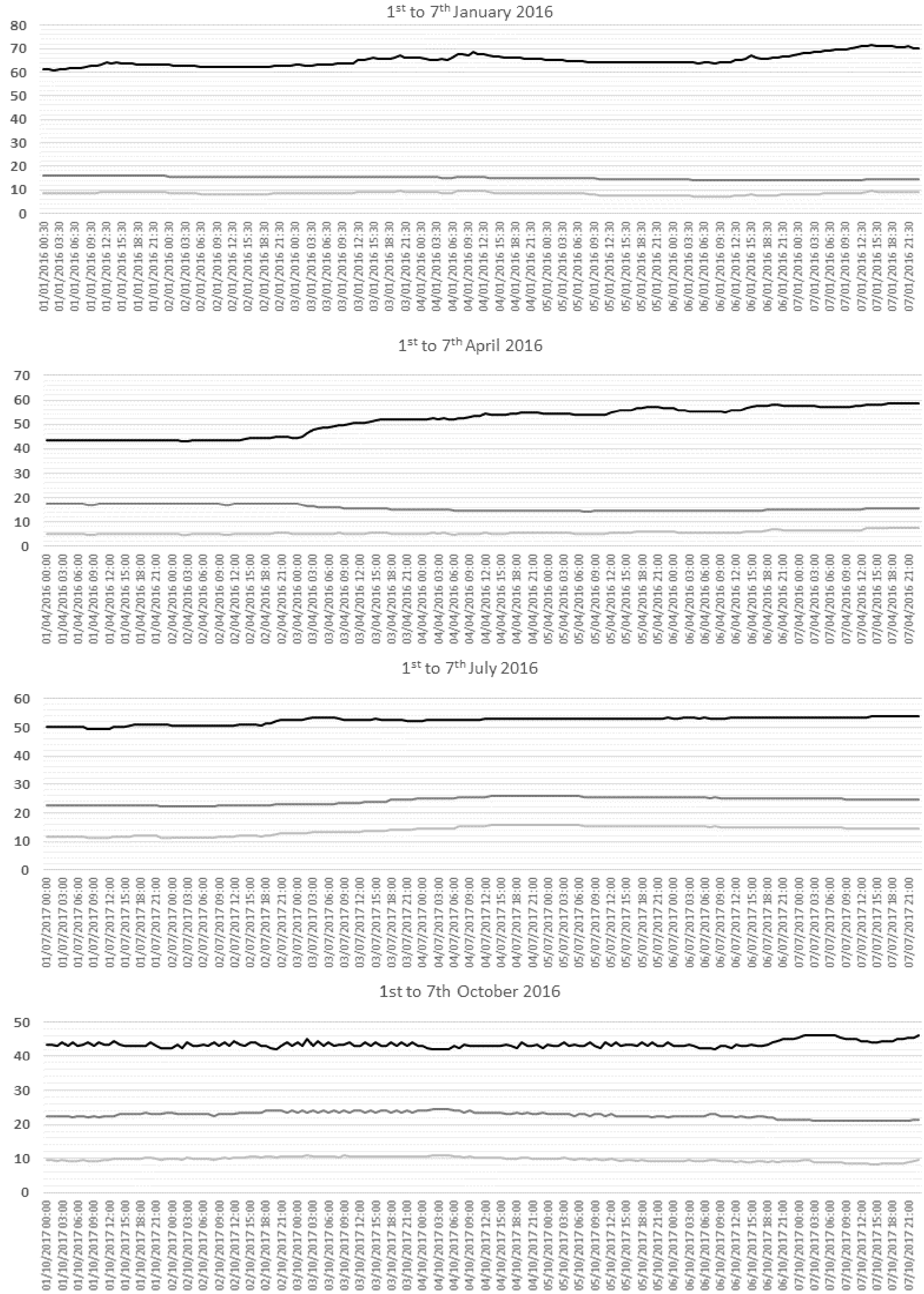


Figure II.1 - Relative humidity (black line), temperature (dark grey line) and dew point (light grey line) measured in the photographic and film archive. The measurements were collected during the first week of January (winter), April (spring), July (summer) and October (autumn) during the year 2016, every hour.

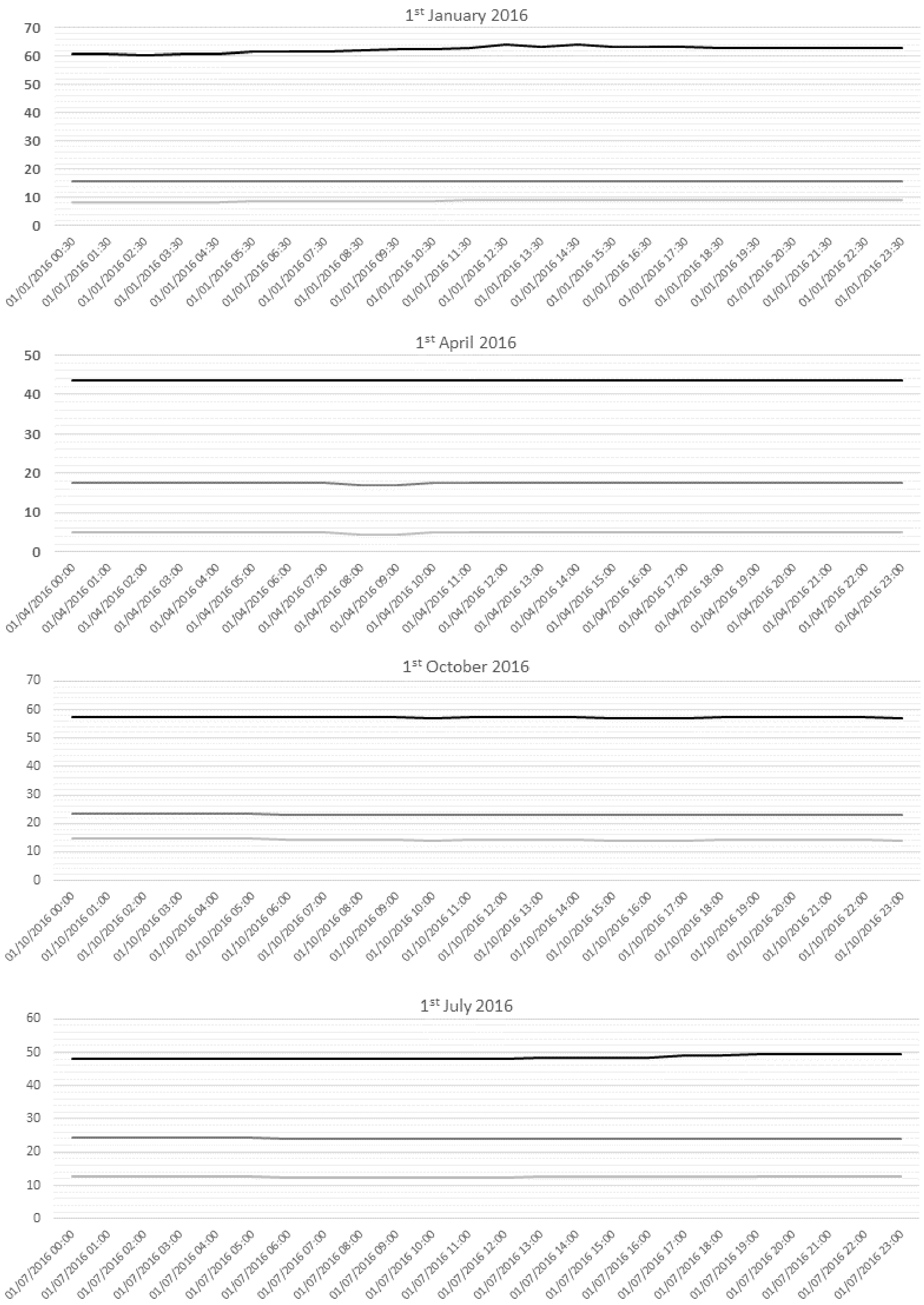


Figure II.2 – Relative humidity (black line), temperature (dark grey line) and dew point (light grey line) measured in the photographic and film archive. The measurements were collected during the first day of January (winter), April (spring), July (summer) and October (autumn) during the year 2016, every hour.

II.2 – Database

Table II.1 – Database fields described in the table 'container'

Field	Description
Object	Link to the table 'object';
Container	Numeration;
Supra Container	When the container is related with other containers which are all gathered in the same packaging, a supra container was created. As alphabetic numeration was attributed to supra containers;
Origin	Origin of the container. For instance: original (created by the artist), not original (created by someone other than the artist), temporary (temporary packaging created for preservation reasons);
Typology	Material and appearance of the container, to be easily identified;
Original Location	Location where the container was found before the survey;
Current Location	Location where the container was placed after the survey;
Inscriptions	Inscriptions found in the container;
Topics	Very brief description of the contents of the set of photographs/films inside the container;
Observations	Any information considered relevant to add to the description of the container, not included in the previous fields;

Table II.2 – Database fields described in the table 'object'

Field	Description
Container	Container were the object is placed;
Nº of objects	Total number of counted photographs or films;
Process	Photographic or filmic process identified by observation. The film base was identified using cross-polarized filters;
Format	Normalized format;
Generation	Generation of the object. For instance, 1st generation – negative, 2nd generation – print, 3rd generation – duplication, etc;
Condition Grade	Condition grade of the set of objects described in that entry (see Table II.3);
Conservation Condition	Description of the conservation condition and pathologies observed in the set of objects in that entry. The vocabulary used was chosen from a controlled list;
Brand	Brands and models based on the edge marking (reversal films and negatives) and inscriptions on the back of the objects (prints);
Observations	Any information considered relevant to add to the description of the object, not included in the previous fields;

Table II.3 – Condition grades for photographs and films

Very Good	The object is in perfect condition, without any signs of degradation;
Good	The object presents minor signs of degradation (mainly minor physical damage), which do not interfere with the legibility of the image. Examples: slight silver mirroring, little abrasion or dirt, etc.;
Fair	The object presents visible signs of degradation (chemical and or physical damage), which slightly interfere with the legibility of the image. Examples: slight curling, vinegar odour, fungi, yellowing, little fading, etc.;
Poor	The object presents significant signs of degradation (serious chemical and or physical damage), which interfere with the legibility of the image. Examples: curling, curving, pronounced silver mirroring, fading, change in colour balance, pronounced fungi, etc.;
Severe	The object is extremely degraded (severe chemical and or physical damage), and the legibility of the image is highly disturbed by those degradations. Examples: bubbles, channelling, pronounced fading, pronounced change in colour balance, etc.;

II.3 – Additional results

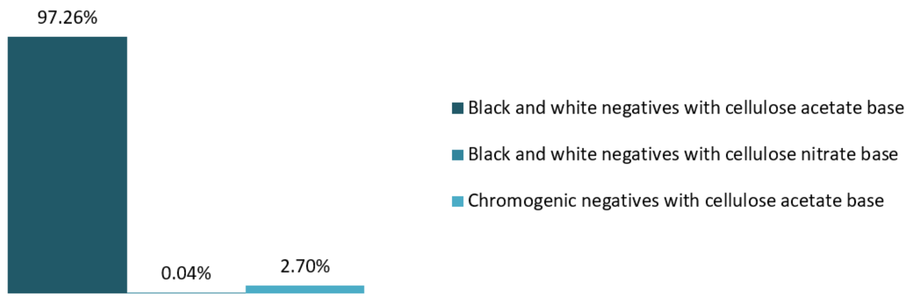


Figure II.3 – Different typologies of negatives found in Ângelo de Sousa's archive.

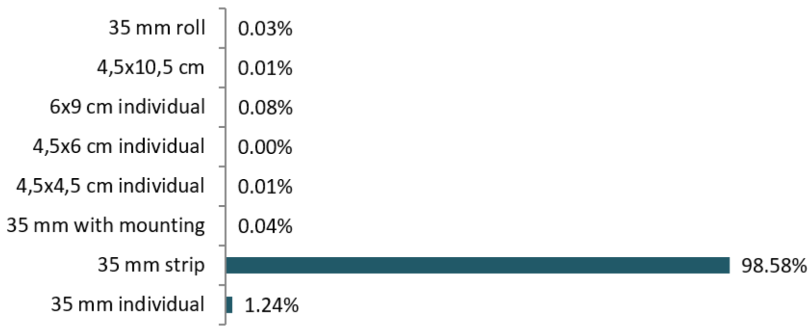


Figure II.4 – Different formats of black and white negatives with cellulose acetate base found in Ângelo de Sousa's archive.

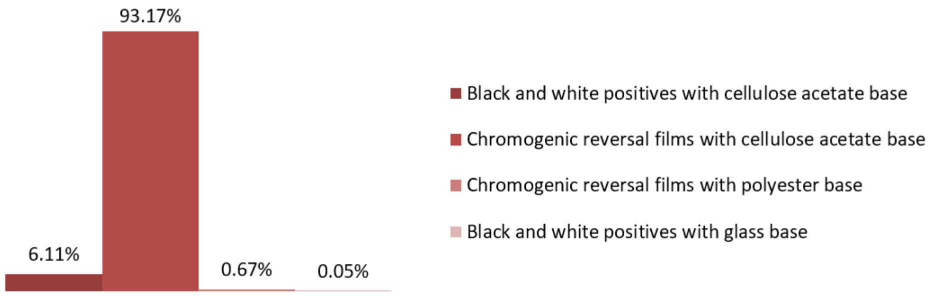


Figure II.5 – Different typologies of positives found in Ângelo de Sousa's archive.

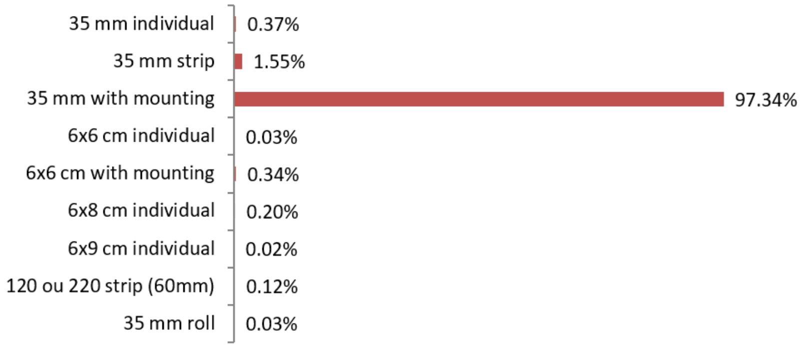


Figure II.6 – Different formats of chromogenic reversal films with cellulose acetate base found in Ângelo de Sousa's archive.

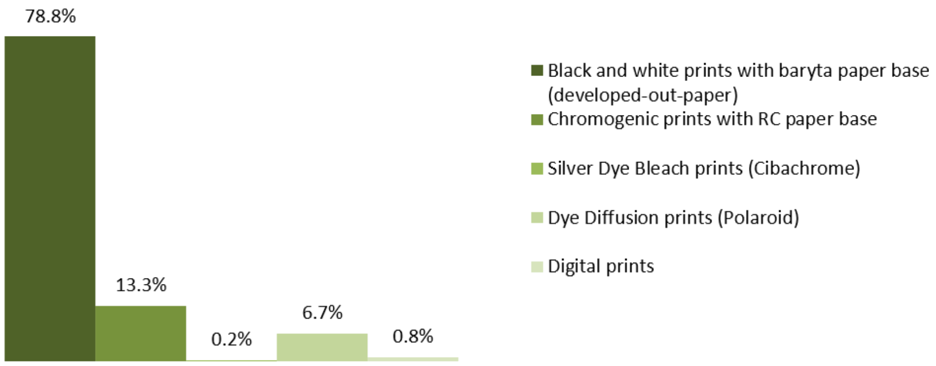


Figure II.7 – Different typologies of prints found in Ângelo de Sousa's archive.

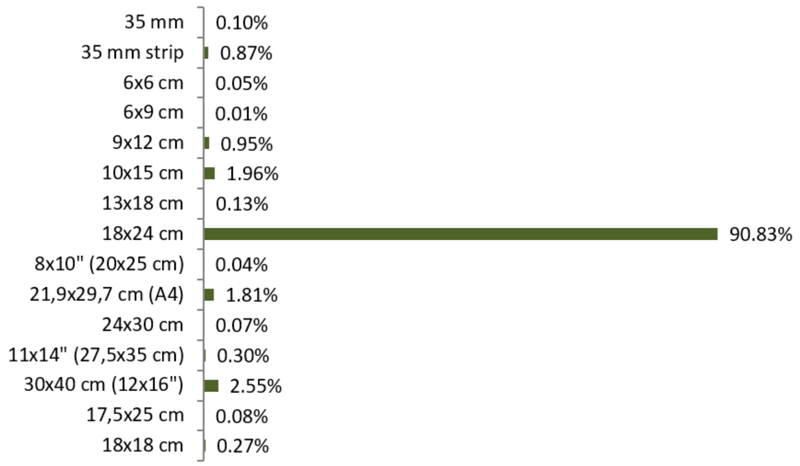


Figure II.8 – Different formats of black and white prints with baryta paper base found in Ângelo de Sousa's archive.

II.4 – AD-strips

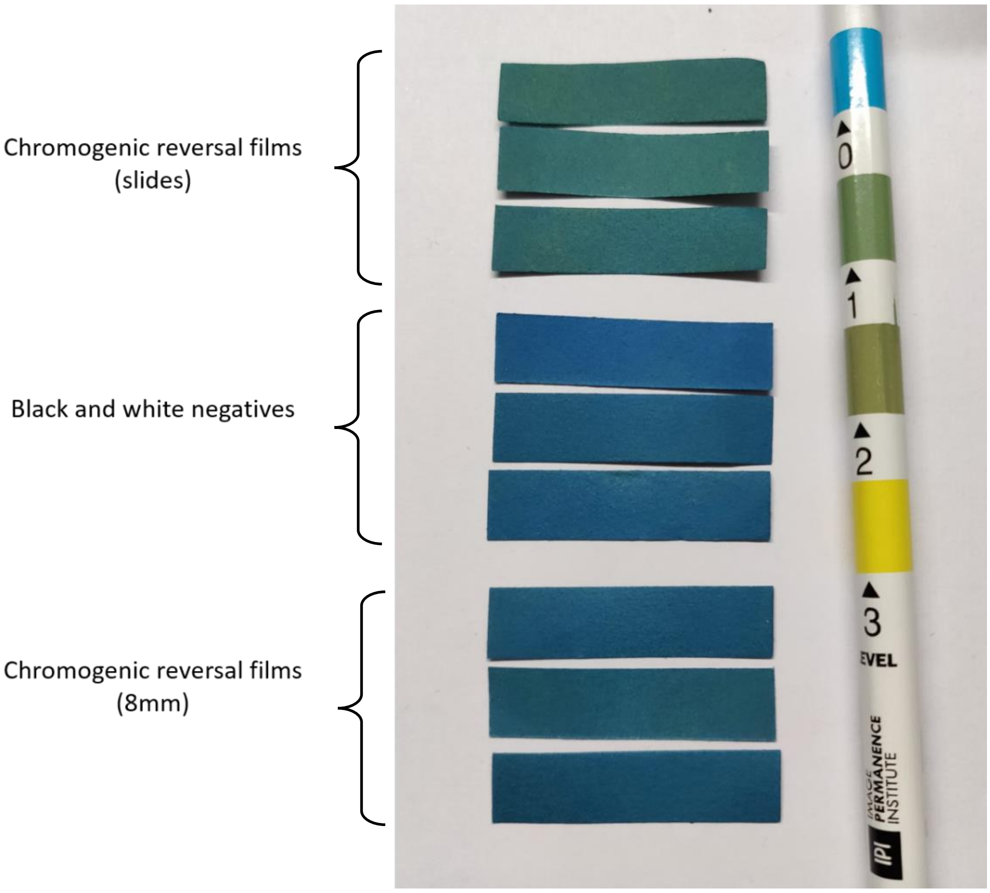


Figure II.9 – AD-strips after exposure to the three sets of materials: chromogenic reversal films (slides), black and white negatives and chromogenic reversal films (8mm analogue film).

A-D Strip Level	Film Condition	Recommended Actions
0	Good—no deterioration	Cool or cold storage
1	Fair to Good—deterioration starting	Cold storage Monitor closely
1.5	Rapid decay starting—point of autocatalytic decay	Cold or frozen storage
2	Poor—actively degrading	Freeze Copying advisable
3	Critical—shrinkage and warping imminent, possible handling hazard	Freeze immediately Copy

Figure II.10 – Data provided by IPI for the Interpretation of the A-D Strip Results.

II.5. Chromogenic reversal films found in Ângelo de Sousa's collection

Table II.4 – Brands and models of chromogenic reversal films used by Ângelo de Sousa

Emulsion code	Brand	Product name	Production date	Product code	Processing	Technical sheet	Reference
Fuji 183	FUJI						
Fuji 192	FUJI						
Fuji color	FUJI						
Fuji color 722	FUJI						
Fuji RA 654, 658, 661, 670, 679, 680, 684, 685, 686	FUJI	Fujichrome Sensia 100, ASA 100		RA	E-6 (Kodak) CR-56 (Fuji)	http://www.fujifilm.com/products/consumer_film/pdf/sensia_100_datasheet.pdf	
Fuji RAP 625	FUJI	Fujichrome Astia 100 Professional, ASA 100		RAP	E-6 (Kodak) CR-56 (Fuji)	http://photoweb.ru/exusr/pdf/fuji/AF3-943E.pdf	
Fuji RD 107, 108, 131, 136, 137	FUJI	Fujichrome Sensia 100, ASA 100	1994-	RD	E-6 (Kodak) CR-56 (Fuji)		[1]
Fuji RDP III 020, 025, 029, 030, 036, 041, 043, 044, 046	FUJI	Fujichrome Provia 100F Professional, ASA 100	1999-	RDP III	E-6 (Kodak) CR-56 (Fuji)	http://www.fujifilm.com/products/professional_films/pdf/provia_100f_datasheet.pdf	
Fuji RH 258, 263, 270	FUJI	Fujichrome Sensia 400, ASA 400	1993-1994	RH	E-6 (Kodak) CR-56 (Fuji)	https://www.fujifilmusa.com/shared/bin/sensia400.pdf	[1]
Fuji RHP III 201, 204, 208, 209, 210, 214, 215, 218, 220, 221, 223	FUJI	Fujichrome Provia 400F Professional, ASA 400		RHP III	E-6 (Kodak) CR-56 (Fuji)	https://www.fujifilmusa.com/shared/bin/PROVIA400FAF3-066E_1.pdf	
Fuji RTP 728	FUJI	Fujichrome 64 Professional Type T, ASA 64	1979-1983	RTP	E-6 (Kodak) CR-56 (Fuji)	https://www.fujifilmusa.com/shared/bin/T64_PIB.pdf	[1]
Fuji RVP 100 F 409	FUJI	Fujichrome Velvia 100F Professional, ASA 100		RVP 100 F	E-6 (Kodak) CR-56 (Fuji)	https://www.fujifilmusa.com/shared/bin/RVP100FAF3-148E_1.pdf	
Fuji RVP 545, 558, 579	FUJI	Fujichrome Velvia 50 Professional, ASA 50	1990-	RVP	E-6 (Kodak) CR-56 (Fuji)	https://www.digitaltruth.com/products/fuji_tech/Velvia50.pdf	[1]
Fuji RXP 104, 105, 106	FUJI	Fujichrome Provia 400X Professional, ASA 400		RXP	E-6 (Kodak) CR-56 (Fuji)	http://www.fujifilm.com/products/professional_films/pdf/provia_400x_datasheet.pdf	

Ektachrome (mountings dated from 1968-71)	KODAK	Ektachrome					
Ektachrome (mountings dated from 1977-81)	KODAK	Ektachrome					
Ektachrome B	KODAK	Ektachrome					
Ektachrome X	KODAK	Ektachrome-X, ASA 64	1963-1978	EX			[1][2]
HS Ektachrome B	KODAK	High Speed Ektachrome Type B, ASA 125	1959-1976				[1]
Kodak 5017	KODAK	Ektachrome 64 Professional, Daylight, ASA 64	1976-2007	EPR	E-6 (Kodak)	https://125px.com/docs/film/kodak/e8-Ektachrome_64_EPR.pdf	[1][2]
Kodak 5036	KODAK	Ektachrome 200 Professional, Daylight, ASA 200	1976-2002	EPD	E-6 (Kodak)	/	[1][2]
Kodak 5037	KODAK	Ektachrome 160T Professional, Tungsten, ASA 160	1976-2007	EPT	E-6 (Kodak)	https://125px.com/docs/film/kodak/e144-Ektachrome_160T_EPT.pdf	[1][2]
Kodak 5071	KODAK	Ektachrome Slide Duplicating Film, Tungsten	1977-1996	ESD	E-6 (Kodak)	/	[1][2]
Kodak 5077	KODAK	Ektachrome 160T film, Tungsten, ASA 160	1977-1996	ET	E-6 (Kodak)	http://www.photoweb.ru/exusr/pdf/kodak/e154.pdf	[1][2]
Kodachrome (mounting dated from 1965-79)	KODAK	Kodachrome					
Kodachrome II	KODAK	Kodachrome II film daylight, ASA 25	1961-1974	K	K-12 (Kodak)		[1][2]
Kodachrome X	KODAK	Kodachrome-X film Professional, Type A, ASA 40	1963-1974	KX	K-12 (Kodak)		[1][2]
Kodak 5032	KODAK	Kodachrome 64, Daylight, ASA 64	1974-2009	KR	K-14 (Kodak)	https://125px.com/docs/film/kodak/e55-1999_12.pdf	[1][2]
Kodak 5073	KODAK	Kodachrome 25 Daylight, ASA 25	1974-2001	KM	K-14 (Kodak)	https://125px.com/docs/film/kodak/e55-1999_12.pdf	[1][2]
Kodak 5074	KODAK	Kodak Elite Chrome 400, Daylight, ASA 400	1998-1999	EL 2	E-6 (Kodak)	http://www.photoweb.ru/exusr/pdf/kodak/e126.pdf	[1][2]
Eastman color	KODAK						
Agfa CT 18	AGFA	Agfachrome CT 18, ISO 50	1962-1974		AP-41 (Agfa)		[1]
Agfa CT 2711	AGFA						

Agfa CT 3340	AGFA							
Agfa 2166	AGFA							
Agfa 2461	AGFA							
Agfa 2751	AGFA							
Agfa 2856	AGFA							
Agfa 50 RS	AGFA	Agfachrome Plus Professional, ASA 50						
Boots color slide film	BOOTS							
3M 8	3M	3M Color Slide	1969-1974					[1]
ORWO 623 S	ORWO							

[1] http://www.bilderdienst.ch/
[2] Pénichon, S. 2013. Twentieth-Century Colour Photographs: The Complete Guide to Processes, Identification and Preservation. London: Thames and Hudson.

Appendix III

Interviews

III.1. Formal interviews

In order to produce new sources of information, the oral testimonies of Miguel de Sousa, Bernardo Pinto de Almeida and Miguel Wandschneider were collected following a series of questions previously defined. The three interviews were sound recorded.

Table III.1 – Formal interviews conducted within the framework of the present dissertation

Date	Details	Goal
12/03/2014	Sound recorded interview with Miguel de Sousa. Interview conducted by Joana Santos Lima da Silva at Ângelo de Sousa's archive. The interview has the approximate duration of 45 min.	This interview was conducted with the aim of gathering information mainly related to the history of the collection under study and its organization. Additionally, Miguel de Sousa was asked about his memories about his father's photographic and film production.
18/04/2018	Sound recorded interview with Bernardo Pinto de Almeida. Interview conducted by Joana Santos Lima da Silva at Faculdade de Belas Arte, Universidade do Porto. The interview has the approximate duration of 1 hour and 30 min.	Being Bernardo Pinto de Almeida one of the personalities knowing Ângelo de Sousa's work in-depth, in general, and his photographic and film production, in particular, his oral testimony was considered of major importance. During the interview, Almeida was asked about the artist production and the materials he chose to work with. Additionally, his opinion about display options undertaken by the artist during his lifetime was inquired, particularly concerning the artwork *Slides de Cavalete* (1978-1979).
20/10/2018	Sound recorded interview with Miguel Wandschneider. Interview conducted by Joana Santos Lima da Silva at a coffee shop in Lisbon. The interview has the approximate duration of 1 hour and 45 min.	Miguel Wandschneider worked closely with Ângelo de Sousa and his photographic and film production. Therefore, his oral testimony was considered of the utmost importance. Wandschneider was asked about his experience working with the artist, namely within the framework of project *Slowmotion* (1999) and the exhibition *Sem Prata* (2001). Like Almeida, his opinion about display options undertaken by the artist during his lifetime was inquired, particularly concerning the artwork *Slides de Cavalete* (1978-1979).

III.2. Informal interviews

Informal interviews were also conducted with different persons, to clarify specific doubts arising during the investigation. These interviews were carried out by telephone or in-person, and in some cases by email.

Table III.2 – Informal interviews conducted within the framework of the present dissertation

Date	Details	Goal
10/05/2016	Informal interview with the owner of FinePrint. In-person interview conducted by Joana Santos Lima da Silva at FinePrint.	FinePrint is the photographic laboratory where the RXP samples artificially aged within the framework of this dissertation were processed. The owner of the lab was asked about the details of the E-6 processing.
11/12/2016	Informal interview with Stephanie Hofner. E-mails exchanged with Joana Santos Lima da Silva.	Stephanie Hofner worked for the graphic atlas released by Image Permanence Institute, having carried out several cross-sections from photographic materials. Thus, Hofner was asked about the methodology adopted to prepare cross-sections of chromogenic reversal films.
06/02/2017	Informal interview with Fernanda Borges. Phone interview conducted by Joana Santos Lima da Silva.	Fernanda Borges, owner of the photographic store at Centro Comercial da Foz where Ângelo de Sousa developed his chromogenic reversal films during several years, was asked about the about the processing of these materials.
06/02/2017	Informal interview with Sr. Fraga. Phone interview conducted by Joana Santos Lima da Silva.	Sr. Fraga, technician at Sempre ID, laboratory making the E-6 processing for Centro Comercial da Foz, was asked about the details of this processing.
25/10/2017	Informal interview with Cristina Grande. Phone interview conducted by Joana Santos Lima da Silva.	The interview conducted with Cristina Grande, from Fundação de Serralves, aimed at gathering evidence on how the artwork *Slides de Cavalete* (1978-1979) was presented in the exhibition *Fotoporto: Mês da Fotografia* (1988).
05/01/0218	Informal interview with André Cepeda. Phone interview conducted by Joana Santos Lima da Silva.	André Cepeda made part of the digitisations of Ângelo de Sousa's photographs, namely of *Slides de Cavalete* (1978-1979). Therefore, this interview was performed to understand in which conditions *Slides de Cavalete* were digitized.

05/05/2018	Informal interview with Manuel Magalhães. In-person interview conducted by Joana Santos Lima da Silva at Magalhães' house.	Manuel Magalhães was one of the organizers of the exhibition *Fotoporto: Mês da Fotografia* (1988). Therefore, this interview was collected to gather evidence on how *Slides de Cavalete* (1978-1979) was presented in that exhibition.
17/10/2018	Informal interview with Julião Sarmento. Phone interview conducted by Joana Santos Lima da Silva.	Julião Sarmento was one of the artists represented in the exhibitions *A Fotografia como Arte / A Arte como Fotografia* (1979) and *Fotoporto: Mês da Fotografia* (1988), where *Slides de Cavalete* (1978-1979) was exhibited. Therefore, this interview was carried-out to gather evidence on how *Slides de Cavalete* (1978-1979) was presented in that exhibition.
18/10/2018	Informal interview with Isabel Alves. E-mails exchanged with Joana Santos Lima da Silva.	Isabel Alves, Ernesto de Sousa's widow, was asked if any photographic documentation related to the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979) or *Fotoporto: Mês da Fotografia* (1988) existed in her husbands' archive.

Appendix IV

Exhibition of slide-based artworks by Ângelo de Sousa

IV.1. Documentation related to photographs of the hand

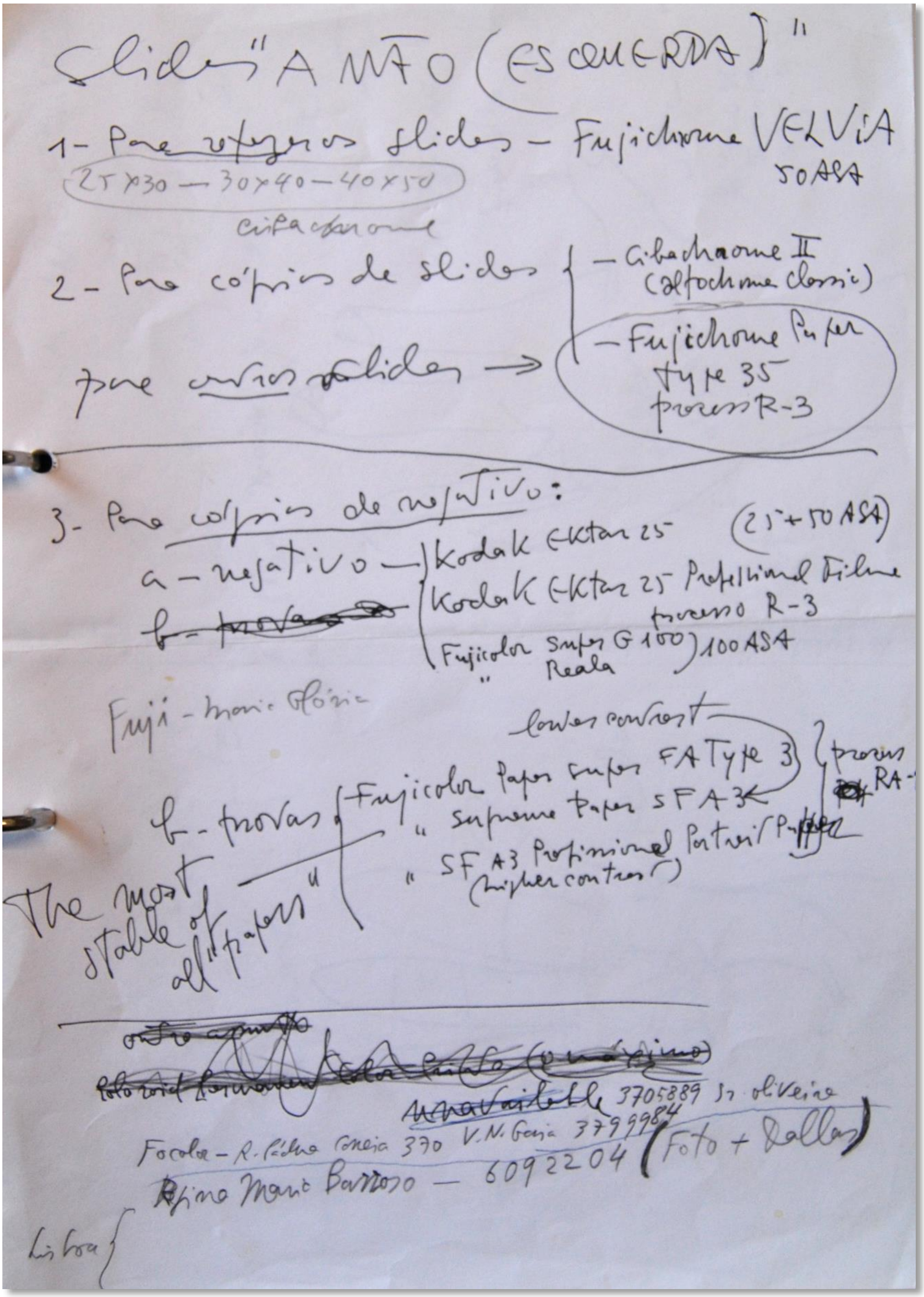


Figure IV.1 - Sheet belonging to the file *Mão* with indications by Ângelo de Sousa for the production of work *A mão esquerda (2ª série)* (1977), and for the duplication of the work *Mão esquerda* (1976).

... advantage; gain; superiority. *Hayward.* Competition; contest. *Shakspeare.* Transmission; conveyance. 1 *Kings*, xiv. Possession; power. *Hooker.* Pressure of the bridle. *Shakspeare* Method of government; discipline; restraint. *Bacon.* Influence; management. *Daniel.* That which performs the office of a hand in pointing. *Locke.* Agent; person employed. *Swift.* Giver, and receiver. *Tillotson.* An actor; a workman; a soldier. *Spenser. Locke.* Catch or reach without choice. *Judges.* Form or cast of writing. *Locke. Hand over head.* Negligently; rashly; without seeing what one does. *Bacon. Hand to hand.* Close fight. *Shaksp. Hand in hand.* In union; conjointly. *Swift.* Fit; pat. *Shaksp. Hand to mouth.* As want requires. *Bp. Reynolds. To bear in hand.* To keep in expectation; to elude. *Shakspeare. To be hand and glove.* To be intimate and familiar; to suit one another.

To HAND. *v. a.* To give or transmit with the hand. *Brown.* To guide or lead by the hand. *Donne.* To seize; to lay hands on. *Shakspeare.* To manage; to move with the hand. *Prior.* To transmit in succession; to deliver from one to another. *Woodward.*

To HAND. *v. n.* To go hand in hand; to cooperate with. *Massinger.*

HAND is much used in composition for that which is manageable by the hand, as, a *handsaw*; or borne in the hand, as a *handbarrow.*

HA'NDBALL. *n. s.* One of our ancient games with the ball. *Brand.*

HA'NDBARROW. *n. s.* A frame on which any thing is carried by the hands of two men, without wheeling on the ground. *Tusser.*

HA'NDBASKET. *n. s.* A portable basket. *Mortimer.*

HA'NDBELL. *n. s.* [hanðbell, Sax.] A bell rung by the hand. *Bacon.*

HA'NDBOW. *n. s.* A bow managed by the hand. *Old Ballad of Adam Bell.*

HA'NDBREADTH. *n. s.* A space equal to the breadth of the hand; a palm. *Exod.* xxv

HA'NDCLOTH. *n. s.* A handkerchief.

HA'NDCUFF. *n. s.* [hanðcopꞅe, Sax.] A manacle; a fetter for the wrist.

To HA'NDCUFF. *v. a.* To manacle; to fasten by a chain. *Hay.*

HA'NDCRAFT. *n. s.* Work performed by the hand.

HA'NDCRAFTSMAN. *n. s.* A workman. *Huloet.*

HA'NDED. *a.* Having the use of the hand, left or right. *Brown.* With hands joined. *Milton.*

HA'NDER. *n. s.* Transmitter; conveyor in succession. *Dryden.*

HA'NDFAST. *n. s.* [*hand* and *fast.*] Hold; cus-

du corps : *un maillot de bain.*

main n. f. Partie du corps humain, du poignet à l'extrémité des doigts. Objet qui saisit comme une main. *Fig.* Action, travail. *Forcer la main,* contraindre. *En venir aux mains,* en arriver au combat, se battre. *Faire main basse,* piller, voler. *N'y pas aller de main morte,* frapper rudement. *Avoir la haute main sur,* commander. *De main de maître,* avec habileté. *Coup de main,* entreprise hardie ; aide apportée à quelqu'un. *En un tour de main,* en un instant. *De longue main,* depuis longtemps.

main-d'œuvre n. f. Travail de l'ouvrier. Ensemble des ouvriers nécessaires pour l'exécution d'un travail donné.

Figure IV.2 – Photocopies from dictionaries with the meaning of the word hand and derivatives, present in the file *Mão.*

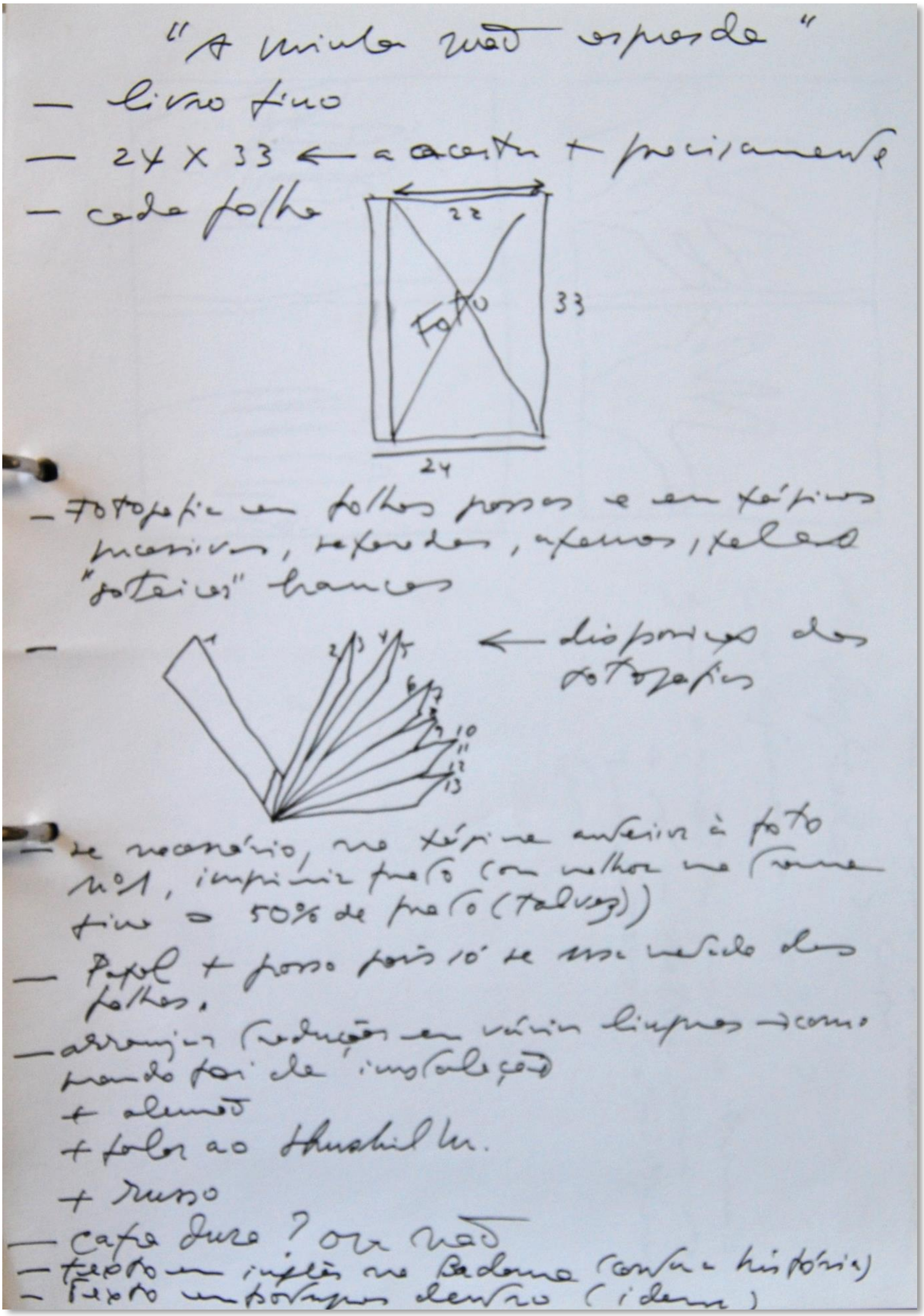


Figure IV.3 – Notes by Ângelo de Sousa for the book dedicated to his photographs of the hand found in the file *Mão.*

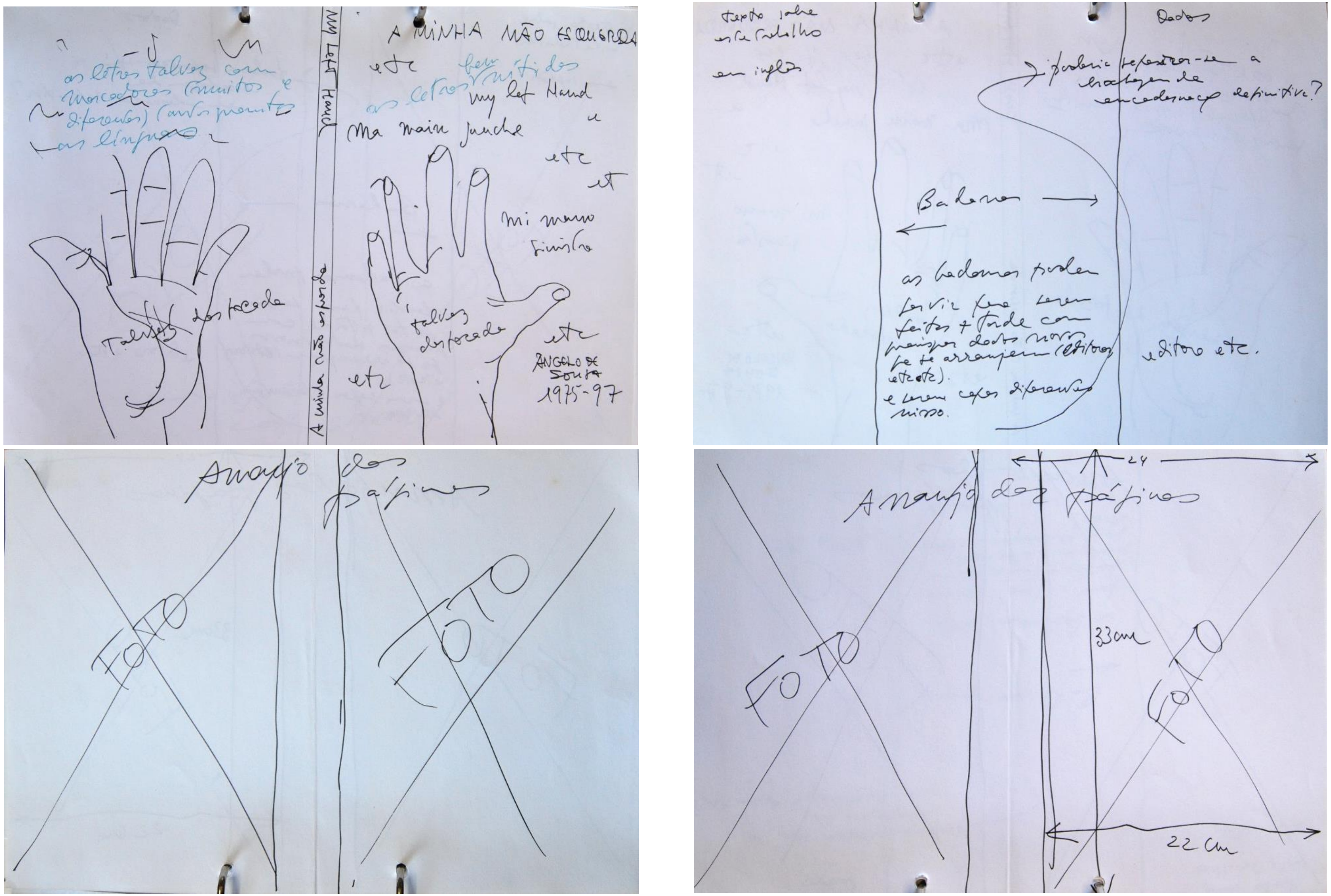


Figure IV.4 – Schemes by Ângelo de Sousa for the covers of the book dedicated to his photographs of the hand found in the file *Mão.*

IV.2. Exhibitions with photographs and films by Ângelo de Sousa

Table IV.1 – Survey of the individual and collective exhibitions in which photographs and films by Ângelo de Sousa were exhibited; the grey lines in the table represent the exhibition that took place during the artist's life, and the white lines table represent those that took place after the artist's death

Exhibition title	Place and Date	Work	Exhibition medium	Reference
AICA	Sociedade Nacional de Belas Artes, Lisbon (Portugal), 1974.	(?)	film projection (original)	[2] [3]
A Fotografia na Arte Moderna Portuguesa	Centro de Arte Contemporânea – Museu Soares dos Reis, Porto (Portugal), 1977.	*A mão esquerda (1º série)* (1975)[1]	slide projection (originals)	[1]
18x18: Nova Fotografia	Cooperativa Grafil, Lisbon (Portugal), 1978. Centro de Arte Contemporânea - Museu Nacional Soares dos Reis, Porto (Portugal), 1978.	*Mão esquerda* (1976)[2]	9 gelatin silver prints, 18x18 cm	[1]
Bologna Art Fair-Basel Art Fair	Basel Kunstmesse, Basel (Switzerland), 1978.	*A mão esquerda (2º série)* (1977)[1]	(?) cibachrome prints, 18x24 cm	[2]
La Biennale di Venezia 78	Magazzini del Sale alle Zattere, Venice (Italy), 1978.	*A mão esquerda (2º série)* (1977)[1]	(?) cibachrome prints, 18x24 cm	[2]
Arte Portoghese Contemporânea	Salone Brunelleschiano dell' Instituto degli Innocenti, Florence (Italy), 1978.	*A mão esquerda (2º série)* (1977)[1]	(?) cibachrome prints, 18x24 cm	[2]
A Fotografia como Arte / A Arte como Fotografia	Centro de Arte Contemporânea – Museu Soares dos Reis, Porto (Portugal), 1979; Edifício Chiado, Coimbra (Portugal), 1979 (the artwork was not presented in Coimbra) Fundação Calouste Gulbenkian, Lisbon (Portugal), 1979.	*Slides de Cavalete* (1978-1979)[1]	slide projection (originals)	[1]
Da Bienal de Veneza	Galeria Jornal de Notícias, Porto (Portugal), 1981.	*A mão esquerda (2º série)* (1977)[1]	(?) cibachrome prints, 18x24 cm	[1]

IV Encontros de Fotografia de Coimbra	Centro de Estudos de Fotografia, Coimbra (Portugal), 1983.	*Rolo 17/50* (1983)[2]	2 contact sheets and 12 gelatin silver prints, 30x40 cm	[1] [2]
Círculo de Artes Plásticas de Coimbra	Centro de Arte Contemporânea, Coimbra (Portugal), 1983.	*A mão esquerda (2ª série)* (1977)[1]	(?) cibachrome prints, 18x24 cm	[1]
Fotoporto: Mês da Fotografia	Casa de Serralves, Porto (Portugal), 1988.	*Slides de Cavalete* (1978-1979)[1]	slide projection (originals)	[1]
II Jornada de Arte Contemporânea	Casa das Artes, Porto (Portugal), 1993.	(?)[3]	video projection	[3]
Ângelo 1993: Uma antológica	Fundação de Serralves, Porto (Portugal), 1993; Centro Cultural de Belém, Lisbon (Portugal), 1994.	*A mão esquerda (2ª série)* (1977)[1]	(?) cibachrome prints, 18x24 cm	[2]
	Centro Cultural de Belém, Lisbon (Portugal), 1994.	*Chão (1º experiência)* (1972)[3]	(?)	
		Água no Chão (1) (1972)[3]		
		Água no Chão (2) (1972)[3]		
		Ribeiro (1973)[3]		
		Flores vermelhas (1) (1974)[3]		
		Sombra de Trepadeira (1974)[3]		
		Marmeleiro (1) (1974)[3]		
		Chão de pinhal (1977)[3]		
		Sem título (juncos) (1977)[3]		
O Rosto da Máscara: Auto-representação na Arte Portuguesa	Centro Cultural de Belém, Lisbon (Portugal), 1994.	*Auto-retrato* (1972)[2]	17 gelatin silver prints, 30x40 cm	[1]
III Jornada de Arte Contemporânea	Casa das Artes, Porto (Portugal), 1995.	*Chão (1º experiência)* (1972)[3]	video projection	[1]
		Água no Chão (1) (1972)[3]		
		Ribeiro (1973)[3]		
		Flores vermelhas (1) (1974)[3]		
		Muro (1973)[3]		
		Marmeleiro (1) (1974)[3]		

		A mão (1976)[3]		
IV Bienal de Fotografia	Edifício Patriarcal, Vila Franca de Xira (Portugal), 1995	(?)[2]	6 gelatin silver prints, (?) cm	[1]
3+3 Olhares sobre o Rivoli	Rivoli Teatro Municipal, Porto (Portugal), 1997.	*Sem título* (1997)[1]	6 inkjet prints	[1]
Circa 1968	Museu de Arte Contemporânea de Serralves, Porto (Portugal), 1999.	*A mão esquerda (2ª série)* (1977)[1]	slide projection (originals)	[1]
		Chão (1ª experiência) (1972)[3] *Água no Chão (1)* (1972)[3] *Ribeiro* (1973)[3] *Flores vermelhas (1)* (1974)[3] *Muro* (1973)[3] *Marmeleiro (1)* (1974)[3] *A mão* (1976)[3]	(?)	[2]
Slow Motion	Escola Superior de Tecnologia, Gestão, Arte e Design, Caldas da Rainha (Portugal), 2000.	*Sem título (mão)* (1968)[3] *A mão* (1976)[3] *Chão (1ª experiência)* (1972)[3] *Ribeiro* (1973)[3] *Flores vermelhas* (1973)[3] *Sem título (aterro)* (1977)[3] *Sem título (juncos)* (1977)[3] *Sombra de Trepadeira* (1974)[3] *Marmeleiro* (1974)[3] *Sem título (chão de cimento)* (1973)[3] *Água no chão* (1973)[3] *Scherzi* (1998)[4] *Ensaio para a mão esquerda* (1998)[4]	video projection	[4]

Movimentos	Galeria Tráfego, Porto (Portugal), 2000.	*Sem título (mão)* (1968)[3] *Chão (1º experiência)* (1972)[3] *Ribeiro* (1973)[3] *Flores vermelhas (1)* (1974)[3] *Sombra de Trepadeira* (1974)[3] *Marmeleiro (1)* (1974)[3] *A mão* (1976)[3] *Milho* (c. 1976)[3] *Sem título (aterro)* (1977)[3] *Sem título (juncos)* (1977)[3] *Scherzi* (1998)[4] *Ensaio para a mão esquerda* (1998)[4]	(?)	[1] [2]
A Indisciplina do Desenho	Fundação Cupertino de Miranda, Vila Nova de Famalicão (Portugal), 2000; Museu Malhoa, Caldas da Rainha (Portugal), 2000; Museu de Aveiro, Aveiro (Portugal), 2000.	*Uma Escultura* (1972)[3]	video projection	[1]
Fotografia	Galeria Quadrado Azul, Porto (Portugal), 2000.	*A mão esquerda (2º série)* (1977)[1]	20 cibachrome prints, 60x90 cm	[1]
Prémios EDP Arte: Desenho e Pintura	Palácio nacional da Ajuda, Lisbon (Portugal), 2000.	*A mão esquerda (2º série)* (1977)[1]	5 cibachrome prints, 60x90 cm	[1]
Sem Prata	Museu Arte Contemporânea de Serralves, Porto (Portugal), 2001	*Árvores desfocadas (sabugueiro) (1)* (1979)[1]	slide projection (11 original slides)	[1]
		Árvores desfocadas (sabugueiro) (2) (1979)[1]	slide projection (9 original slides)	
		Papiro (1980)[2]	8 inkjet prints, 24x35 cm	
		Sem título (1982)[2]	2 inkjet prints, 24x35 cm	
		Plantas (1976/1981)[1]	slide projection (60 original slides)	

		A mão esquerda (1º série) (1975)[1]	slide projection (51 original slides)	
		Mão esquerda (1976)[2]	21 inkjet prints, 24x35 cm	
		Sem título (1981)[2]	inkjet print, 24x35 cm	
		Sem título (1987)[2]	4 inkjet prints, 24x35 cm	
		Auto-retrato (1971)[2]	inkjet print, 24x35 cm	
		Auto-retratos (1972)[2]	13 inkjet prints, 24x35 cm	
		Sem título (sombras) (1972-83)[2]	6 inkjet prints, 24x35 cm	
		Sem título (1973)[2]	5 inkjet prints, 24x35 cm	
		Sem título (1974)[2]	inkjet print, 24x35 cm	
		Sem título (1982)[2]	inkjet print, 24x35 cm	
		Sem mosca (1976)[2]	inkjet print, 24x35 cm	
		Com mosca (1976)[2]	inkjet print, 24x35 cm	
		A corda (1976)[2]	6 inkjet prints, 24x35 cm	
		Sem título (1972)[2]	2 inkjet prints, 24x35 cm	
		Sem título (1980)[2]	inkjet print, 24x35 cm	
		Sem título (1974)[2]	inkjet print, 24x35 cm	
		Sem título (1978)[2]	7 inkjet prints, 24x35 cm	
		Sem título (1979)[2]	4 inkjet prints, 24x35 cm	
		Sem título (1978)[2]	5 inkjet prints, 24x35 cm	
		Sem título (1982)[2]	inkjet print, 24x35 cm	
		Sem título (1981)[2]	2 inkjet prints, 24x35 cm	
		Beaubourg (1978)[2]	5 inkjet prints, 24x35 cm	
		Sem título (1979/1983)[2]	3 inkjet prints, 24x35 cm	
		Sem título (1981)[2]	4 inkjet prints, 24x35 cm	
		Cabelo (2000)[1]	11 inkjet prints, 50x70 cm	
		Cotão (1997)[1]	9 inkjet prints, 50x70 cm	
		Epifanias (1967/1998)[1]	95 inkjet prints, 50x70 cm	
		Céu (1979/1997)[1]	9 inkjet prints, 50x70 cm	
		Auto-retratos (1995)[1]	12 inkjet prints, 24x52 cm	
		Chão (1º experiência) (1972)[3]	DVD projection	
		Muro (1973)[3]		

		Ribeiro (1973)[3]		
		Flores vermelhas (2) (1974)[3]		
		Chão de pinhal (1977)[3]		
		Juncos de Esmoriz (1977)[3]		
		Sem título (juncos) (1977)[3]		
		Chão com lixo (1977)[3]		
		Chão com vaca (1977)[3]		
		Sem título (aterro) (1977)[3]		
		Chão de cimento (1) (1973)[3]		
		Chão de cimento (2) (1973)[3]		
		Marmeleiro (1) (1974)[3]		
		Marmeleiro (2) (1974)[3]		
		Marmeleiro (3) (1974)[3]		
		Marmeleiro (4) (1974)[3]		
		Sombra de trepadeira (c. 1974)[3]		
		Papiro (1) (c. 1974)[3]		
		Papiro (2) (c. 1974)[3]		
		Sem título (mão) (1968)[3]		
		A mão (1976)[3]		
		Scherzi (1998)[4]		
		Ensaio para a mão esquerda (1998)[4]		
Sem Limites	Centro de Artes Visuais, Coimbra (Portugal), 2003.	*A mão esquerda (1º série)* (1975)[1]	slide projection (originals)	[1]
50 Anos de Arte Portuguesa	Fundação Calouste Gulbenkian, Lisbon (Portugal), 2007.	*Sem título (chão de cimento)* (1972)[3]	film projection (originals)	[1]
Articulações	Fábrica da Cerveja, Faro (Portugal), 2008.	*Ribeiro* (1973)[3]	DVD projection	[1]
		Flores Vermelhas (1974)[3]		
		Água no chão (1973)[3]		

		Marmeleiro (1974)[3]		
		Muro (1973)[3]		
Riso	Museu da Electricidade, Lisbon (Portugal), 2012/2013.	*Auto-retratos* (1995)[1]	13 inkjet prints, 24x52 cm and 52x24cm	[1]
Encontros com as Formas	Fundação EDP, Porto (Portugal), 2014	*Sem título* (1985)[2]	inkjet print, 28x42 cm	[1]
		Sem título (2006)[1]	6 inkjet prints, 28x42 cm	
		Sem título (1980)[2]	inkjet print, 28x42 cm	
		Sem título (1980)[2]	inkjet print, 28x40 cm	
		Sem título (1997)[1]	4 inkjet prints, 28x42 cm	
		A corda (1976)[2]	6 inkjet prints, 18x26 cm	
		Cabelo (2000)[1]	6 inkjet prints, 28x42 cm	
		Sem título (1983)[2]	inkjet print, 18x26 cm	
		A mão (1976)[3]	video projection	
		Sem título (1985)[2]	4 inkjet prints, 28x42 cm	
		Sem título (1987)[2]	inkjet print, 18x26 cm	
		Sombra de trepadeira (c. 1974)[3]	video projection	
		Sem título (1984)[2]	inkjet print, 18x26 cm	
		Sem título (1985)[2]	inkjet print, 28x42 cm	
		Sem título (2005)[1]	20 inkjet prints, 18x26 cm	
		Sem título (1978)[2]	3 inkjet prints, 28x42 cm	
		Sem título (1999)[1]	inkjet print, 56x86 cm	
		Sem título (1981)[2]	inkjet print, 56x86 cm	
		Sem título (1981)[2]	inkjet print, 56x86 cm	
		Água no Chão (1976)[3]	video projection	
		Chão de cimento (1973)[3]	video projection	
		Chão (1º experiência) (1972)[3]	video projection	
		Ribeiro (1973)[3]	video projection	
		Sem título (1968)[1]	inkjet print, 56x86 cm	
		Slides de Cavalete (1978-1979)[1]	slides projection (digitization + printing with film recorder into 35mm Fujifilm)	

		Marmeleiro (1974)[3]	video projection	
		Sem título (mão) (1968)[3]	video projection	
		Sem título (1979)[1]	4 inkjet prints, 18x26 cm	
		Sem título (undated)[1]	inkjet print, 56x86 cm	
		Sem título (undated)[1]	slide projection (8 slides, digitization + printing with film recorder into 35mm Fujifilm)	
La Couleur et le Grain Noir des Choses	Fundação Calouste Gulbenkian, Paris (France), 2017	*Céu* (1979)[1]	inkjet print, 50x70 cm	[1]
		Sem título [serie *umanistas*] (1985)[2]	inkjet print, 18x24 cm	
		Sem título [serie *umanistas*] (1969/1972)[2]	19 inkjet prints, 18x24 cm	
		Cabelo (2000)[1]	3 inkjet prints, 18x26 cm	
		Slides de Cavalete (1978-1979)[1]	DVD projection	
		Sem título [serie *epifanias*] (1969/2001)[1]	8 inkjet prints, 50x70 cm	
		A Corda (1976)[2]	4 inkjet prints, 18x26 cm	
		A mão esquerda (1º série) (1975)[1]	8 cibachrome prints, 60x90 cm	
		Sem título (1981)[2]	inkjet print, 56x86 cm	
		Sem título (1983)[2]	inkjet print, 18x26 cm	
		Sem título (1985)[2]	inkjet print, 28x42 cm	
		Sem título (1987)[2]	inkjet print, 18x26 cm	
		Sem título (undated)[1]	inkjet print, 56x86 cm	
		Sem título (2005)[2]	8 inkjet prints, 18x26 cm	
		Chão (1º experiência) (1972)[3]	DVD projection	
		Ribeiro (1973)[3]		
		Chão de cimento (1) (1973)[3]		
		Sem título (mão) (1968)[3]		
O Fotógrafo Acidental – Serialismo e Experimentação em Portugal, 1968-1980	Culturgest, Lisboa (Portugal), 2017	*Sem título* [serie London] (1968)[1]	slide projection (80 slides, digitization + screening + photographing with	[1]

			commercially available chromogenic reversal films)	
		Sem título [serie *umanistas*] (1968/1970)[2]	(?) gelatin silver prints, 21x30 cm	
		A mão esquerda (2º série) (1977)[1]	slide projection (reproductions: digitization + screening + photographing with commercially available chromogenic reversal films)	
Potência e Adversidade, Arte da America Latina nas Colecções em Portugal	Museu da Cidade, Pavilhão Preto, Lisboa (Portugal), 2017	*Slides de Cavalete* (1978-1979)[1]	DVD projection	[1]
		Sem título (mão) (1976)[3]	DVD projection	
		Sombra de trepadeira (c. 1974)[3]	DVD projection	
		Uma Escultura (1972)[3]	DVD projection	

[1] Catalogue of the exhibition.
[2] In *Ângelo de Sousa, sem prata,* ed. Maria Ramos, 271-276. Porto: Edições Asa.
[3] In *Movimentos,* Galeria Quadrado Azul.
[4] This project didn't have a catalogue. Data found in a flyer.

FONDATION
CALOUSTE GULBENKIAN
DÉLÉGATION EN FRANCE

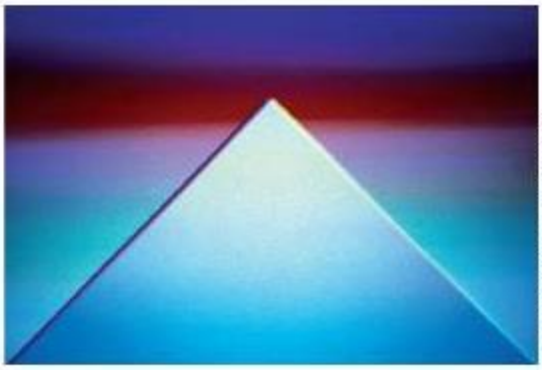
Communiqué de presse
Exposition

Ângelo de Sousa

25 janvier - 9 avril 2017

Commissaire : Jacinto Lageira

La Fondation Calouste Gulbenkian-Délégation en France présente, pour la première fois en France, une exposition de l'artiste portugais Ângelo de Sousa (Lourenço Marques, 1938 - Porto, 2011).



Bien qu'ayant commencé à exposer à partir de 1959, et ayant eu l'occasion de montrer ses œuvres à l'international (Madrid, Londres, Biennale de Venise, Biennale de São Paulo), c'est essentiellement au Portugal que la production d'Ângelo de Sousa a été vue et appréciée. Celle-ci étant aussi diversifiée que prolifique – peinture, sculpture, installation, photographie, vidéo, gravure, dessin –, le choix de la présente exposition s'est porté avant tout sur la peinture et la photographie. Choix difficile et drastique en raison de la quantité imposante d'œuvres, mais aussi parce que l'artiste aimait à travailler par séries, expérimentant les supports, les formats et les échelles, cela dans tous les domaines de sa pratique et sans exclusion de genre ou de style, si ces notions ont encore un sens par-delà leur inscription strictement historique et contextuelle.

De fait, Ângelo de Sousa pouvait aussi bien réaliser des œuvres figuratives et non figuratives, pratiquer une photographie de style documentaire mais aussi à tendance abstraite, mêler géométrique et organique, de petites œuvres sculpturales comme d'immenses installations, utiliser des matériaux bruts comme recherchés, capter le banal et concevoir des objets complexes, et il était donc impossible de montrer tout l'éventail de ses recherches et trouvailles. La période choisie (les quarante dernières années de la production de l'artiste) rend cependant compte de l'invention permanente de Ângelo de Sousa qui, tout en prêtant une grande attention au formel, n'est jamais formaliste, s'intéressant bien plutôt à la matérialité et à la corporéité des choses et des êtres, cela aussi bien sous leur aspect négatif, pauvre ou triste que sous leur aspect triomphant, vivant et joyeux. Si cette démarche par contrastes ou jeu d'opposés n'était pas nécessairement ce que l'artiste recherchait explicitement, il apparaît que son imagination débordante, toujours en quête de nouvelles formes, d'expériences inédites et d'expérimentations élaborées, mais aussi des plus simples, sollicite continuellement la plasticité de ses propres processus comme la plasticité de celle ou de celui qui est en présence des œuvres et ressent autant leur insistance que leur fugacité.

Le catalogue qui accompagnera l'exposition complétera les autres dimensions du travail d'Ângelo de Sousa et cherchera à en donner une vision élargie et ouverte.

Jacinto Lageira

Fondation Calouste Gulbenkian - Délégation en France. 39 bd de la Tour Maubourg. 75007 Paris
Contacts presse :
Miguel Magalhães : m.magalhaes@gulbenkian-paris.org ; 01 53 85 93 76
Clémence Bossard : c.bossard@gulbenkian-paris.org : 01 53 85 93 81
www.gulbenkian-paris.org
#GulbenkianParis

2 août 2016

Figure IV.5 – Press release from the exhibition *La Couleur et le Grain noir des Choses* (2017) in *Fundação Calouste Gulbenkian* (Paris).

POTÊNCIA E ADVERSIDADE

ARTE DA AMÉRICA LATINA NAS COLEÇÕES EM PORTUGAL

CURADORIA: MARTA MESTRE

O principal objetivo da exposição "Potência e adversidade – arte da América Latina nas coleções em Portugal" é a identificação de alguns nexos históricos que ainda passam à margem das narrativas institucionalizadas sobre a produção *artística da* América Latina. De forma a contornar a fragmentação intrínseca às diversas coleções aqui presentes, a exposição incide sobre um ângulo histórico demarcado – a produção artística da década de 1970 até hoje –, e percorre produções de artistas especialmente importantes para entender a vitalidade e originalidade de países tão diversos quanto a Argentina, Brasil, Cuba, México, Chile, Venezuela ou Colômbia. Tratando-se de uma seleção com inevitável contingência, a exposição estabelece dois núcleos distintos, distribuídos pelo Pavilhão Branco e Preto. Um primeiro núcleo de artistas seminais ou "históricos" - Cildo Meireles, Artur Barrio, Horacio Zabala, Anna Maria Maiolino, Antoni Muntadas, Ana Mendieta, Lydia Okumura, Raimundo Camilo, Lothar Baumgarthen, António Dias, Ângelo de Sousa, Eugenio Dittborn, Hélio Oiticica – que faz referência direta aos "conceptualismos" experimentais de vários países da América Latina (e Europa) na década de 70 e início dos anos 80. E um segundo núcleo, mais recente, agregando cerca de sessenta obras de trinta artistas que configura desdobramentos do denominado "legado conceptual". Os anos "quentes" de lutas sociais, contra as ditaduras e a repressão no mundo representados pela década de 1970 são marcados por uma produção cultural inédita, engajada em romper os lugares--comuns habitualmente associados à América Latina. Reivindica-se o fim das estruturas de opressão dos Estados estabelecem-se conexões entre a produção artística e a formação política e ideológica, num misto de radicalidade e marginalidade, de arte e vida. Um cenário

até 07 / 01 / 2018

terça a domingo

▼

10h–13h e 14h–18h

Pavilhão Branco e Pavilhão Preto

entrada pelo Palácio Pimenta
Museu de Lisboa, Campo Grande

Figure IV.6 – Handout available at the exhibition *Potência e Adversidade: Arte da America Latina nas Colecções em Portugal* (2017) in *Museu da Cidade* (Lisboa) (front).

de efetiva flexibilização intercultural, fruto da circulação intensa de artistas, alguns deles em exílio, faz despontar problemáticas "pós-modernas" e "pós-coloniais". Invertem-se as ideias de centro e periferias e propõem-se alternativas culturais ao mito civilizacional da modernidade ocidental.

Afastando-se da problemática do "multiculturalismo" e da "interculturalidade", a exposição "Potência e adversidade – arte da América Latina nas coleções em Portugal" aborda relações entre arte e política e procura colocar em evidência "pontos de vista críticos" (ou "paradigmas *daqui*"), que recusam ser meras apropriações da cultura internacional.

Um número significativo de trabalhos em exposição denuncia um particular tom de "fim de festa" que barra o otimismo da frase emblemática de Mário Pedrosa: "arte, exercício experimental de liberdade". Face ao contexto político autoritário em ascensão, nos últimos anos, em diversos países da América Latina, potência e adversidade contaminam as visões de futuro.

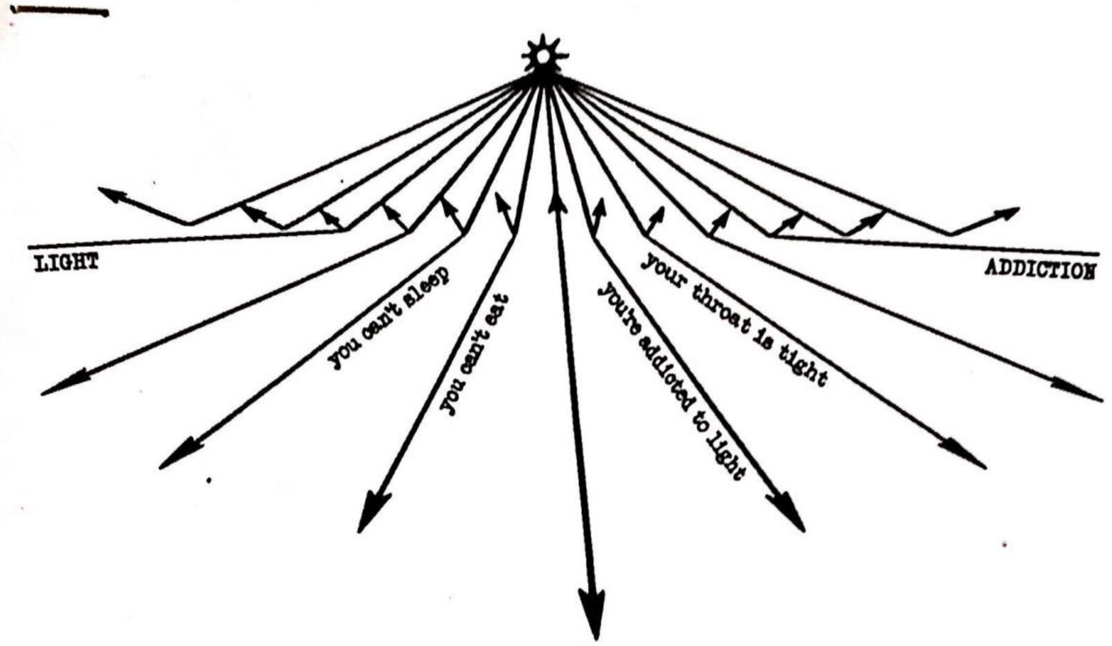
Artistas | Ana Mendieta, Ângelo de Sousa, Anna Maria Maiolino, Antoni Muntadas, Antonio Dias, Artur Barrio, Cildo Meireles, Hélio Oiticica, Horacio Zabala, Lydia Okumura.

Albino Braz, Ana Maria Tavares, Analia Saban, André Komatsu, Carmela Gross, Damián Ortega, Detanico & Lain, Emmanuel Nassar, Eugenio Dittborn, Gabriel Orozco, Gabriel Sierra, Ignasi Aballí, Iran do Espírito Santo, Jac Leirner, Jorge Macchi, Juan Araújo, Juan Munõz, Leonor Antunes, Letícia Ramos, Lothar Baumgarten, Magdalena Jitrik, Manuel Álvarez Bravo, Manuel Ocampo, Marepe, Mauro Restiffe, Nelson Félix, Nicolás Robbio, Paulo Nazareth, Raimundo Camilo, Rosângela Rennó, Tamar Guimarães, Tunga, Waltércio Caldas.

Coleções | Albuquerque Mendes, Arquipélago – Centro de Artes Contemporâneas, Caixa Geral de Depósitos, Fotografia contemporânea do Novo Banco, Fundação de Serralves – Museu de Arte Contemporânea, Fundação Leal Rios, Holma/ Ellipse, Jaime Prieto, Mário Teixeira da Silva, MMG, Museu Calouste Gulbenkian, Museu Coleção Berardo, P.O.P., Privada, Rita Freire, SILD, Teixeira de Freitas e Treger/Saint Silvestre em depósito no Núcleo de Arte da Oliva.

LISBOA Câmara Municipal | Lisboa 2017 | EGEAC | galerias municipais | Museu de Lisboa

Figure IV.7 – Handout available at the exhibition *Potência e Adversidade: Arte da America Latina nas Colecções em Portugal* (2017) in *Museu da Cidade* (Lisboa) (back).



JORNADAS LÚCIDAS *2* **ADDICTIVE LIGHT** Oporto 07 07 18

Slides de Cavalete, Ângelo de Sousa
One hundred 35 mm slides, color, 1978-79

Nobody Here, Daniel Lopatin
Track from the DVD-R Memory Vague
Color, sound, 2'05", 2009

Although television has dropped to unprecedented levels of quality, we can all agree that it is impossible to shut or even extinguish the channel. Humans are addicted to the continuous flow of RGB light, regardless of its content. A clear sign of this addiction is the recent shift from incandescent light to LED in public and private lighting around the world. Soon the planet will be fully led by Red Green Blue frequencies which, like television, will draw humanity into new levels of dependence and isolation.

In 1979, after winning the first prize at the Venice Biennale, Ângelo de Sousa was invited by the artist Floris M. Neusüss to participate in a traveling art exhibition. The participants were chosen for their conceptual use of photography. Ângelo decided to present an automated sequence of slides whose composition and color was created through the superimposition of Red, Green and Blue filters. According to the artist, the piece "Slides de Cavalete" [Easel Slides] was much like his other geometrical paintings, but instead of paint, it used the same additive light process television does. The contrast between the slideshow and the other pieces in the exhibition could not have been greater. Despite its degree of sophistication the curator was always reluctant to present the diaporama and left it isolated outside the main showroom, most likely for fear of cross-contaminating the black and white photographs with television frequencies.

In this Oporto special session, Jornadas Lúcidas 2, we will present the infamous piece "Slides de Cavalete", with a newly restored set of slides. This automatic light painting will be projected along the video "Nobody Here", an "earworm" created by Daniel Lopatin (Oneohtrix Point Never) mashing a youtube sequence from a jurassic videogame (Taito's Laser Grand Prix) and a looped sound clip from Lady in Red by Chris De Burgh. This ever moving rainbow road is here to remind us that TV will continue its image stream regardless of human presence.

Oporto would like to thank Miguel Sousa and the Estate of Ângelo de Sousa, Sérgio Mah, Joana Silva and the Conservation Department of Nova University, Lisbon; Daniel Lopatin, Eliza Ryan, Nelson Gomes, Software and Warp Records.

Figure IV.8 – Handout available at the session *Jornadas Lúcidas – Oporto* at *Casa dos Marinheiros Mercantes* (Lisbon), describing the session.

JORNADAS LÚCIDAS
2

Para esta apresentação da peça "Slides de Cavalete" no Oporto, utilizámos um projector de slides KODAK dos anos 70, modelo Carousel S-AV 2000, com uma lâmpada de 250 W. O carrossel do projector obrigou-nos a limitar a apresentação a oitenta dos cem slides que compõe a peça, uma hipótese expositiva que fora prevista por Ângelo de Sousa*. Para esta difícil tarefa de síntese recorremos a critérios formais e conceptuais que acreditamos respeitar a integridade, ritmo e fluidez do diaporama. Começámos por retirar da sequência introdutória dois slides separadores a negro (slides n.º 5 e 8), cuja cor não nos pareceu bem reproduzida. Do início, eliminámos os slides n.º 10, 11, 13 e 14 onde na composição o topo do triângulo aparece cortado. Retirámos por questões de repetição cromática os slides n.º 17, 19, 47, 56, 57, 80, 81, 82, 85, 86, 90, 93, 95 e 97. Por razões de composição, optámos por colocar entre os slides 27 e 28, o slide n.º 12. De resto, manteve-se a sequência original e a divisão do diaporama em duas partes: a primeira que começa a branco, no ponto máximo da síntese aditiva de luz, com composições triangulares cuja cor se vai intensificando até ao slide n.º 55; a segunda com composições de geometria vertical e rectangular, de cores saturadas, e que termina numa sequência em tons de azul.

Tal como na exposição "A Fotografia como Arte e a Arte como Fotografia" (1979), onde a peça foi pela primeira vez exibida, decidimos apresentar "Slides de Cavalete" em loop com a passagem dos slides automatizada. Cada slide é projectado durante 6 segundos, uma velocidade que nos permite não só captar com tempo estas pinturas de luz, como ainda acrescenta um forte efeito de persistência retiniana, um fenómeno perceptivo do domínio do filme.

A lente 70/120 mm do projector permite uma imagem de 4 m de largura, a 9 m e 54 cm de distância da tela do Oporto. Não havendo cavalete de pintura que sustente uma tela tão grande, optámos por utilizar como suporte do projector de slides um plinto de carvalho do princípio do século XX.

*Segundo Joana Silva, do Departamento de Conservação e Restauro da Universidade Nova de Lisboa

OPORTO
APRESENTA

07 07 18

Figure IV.9 – Handout available at the session *Jornadas Lúcidas – Oporto* at *Casa dos Marinheiros Mercantes* (Lisbon), describing the curatorial options.

IV.3. Experimental study at FCT NOVA

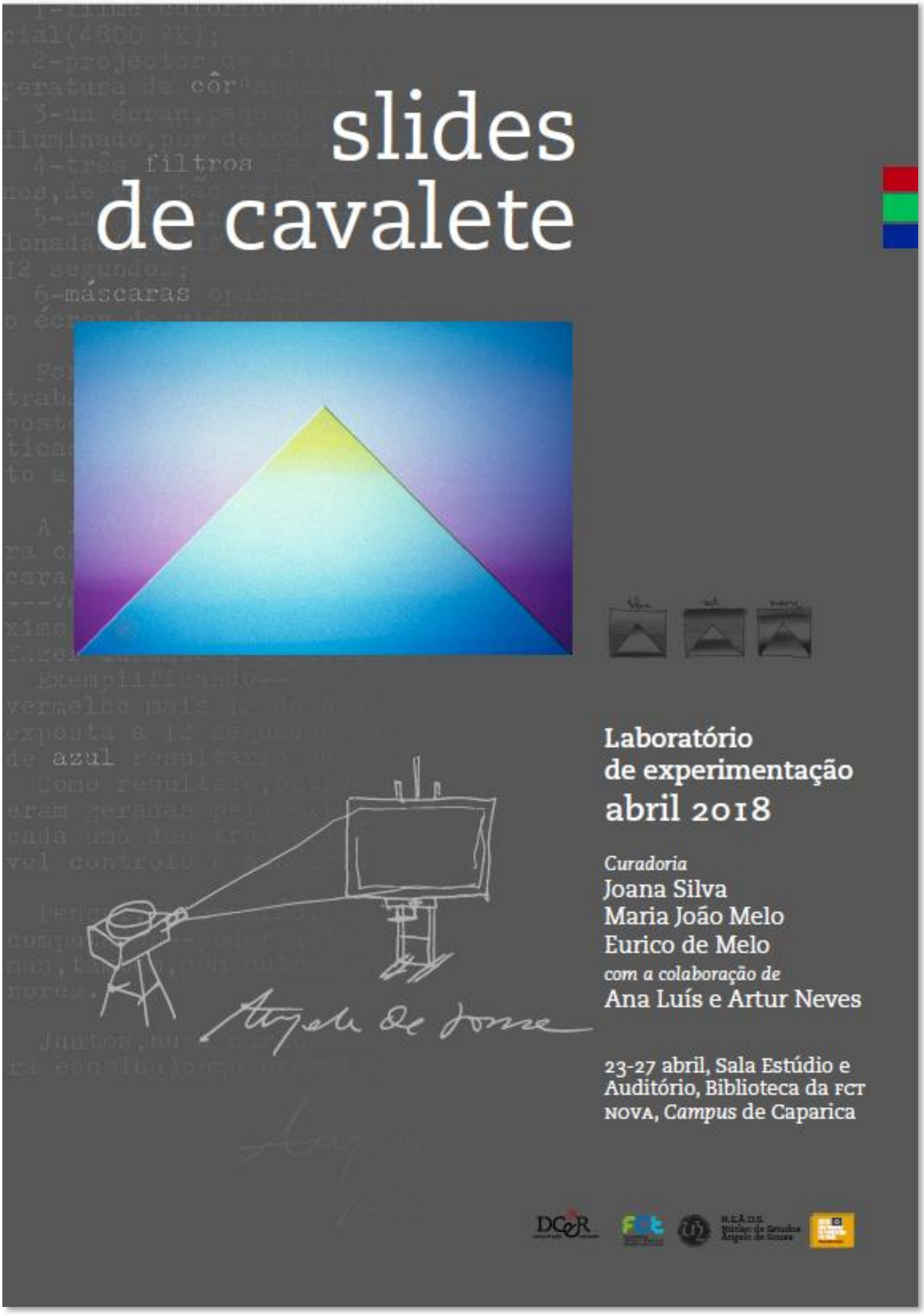


Figure IV.10 – Handout explaining the prouction process distributed during the experimental study conducted at FCT NOVA (front).

Na interacção luz-matéria há 3 peças essenciais: a fonte de luz, o objecto e o receptor.

A **fonte de luz** poderá ser o sol ou a lâmpada de um projector de slides; o receptor serão os nossos **olhos**. O sinal é processado pelo **cérebro**, e daí a cor ser dependente da nossa matriz cultural.

Apenas apresentam **cor visível** as partículas de luz (fotões) de energia entre 400-700 nm; nesse intervalo espectral, conseguimos distinguir as cores: violeta, azul, verde, amarelo, laranja e vermelho. Graças ao **arco-íris**, aprendemos desde cedo que aquilo que vemos como luz branca é de facto a adição de todas as cores da luz visível.

É comum classificar a cor como **aditiva** ou **subtractiva**; resultando da adição de fotões (efeito aditivo) ou da sua subtracção selectiva em relação à fonte luminosa (efeito subtractivo). **A cor** com origem no fenómeno subtractivo é ubíqua no mundo vegetal, e é-nos familiar pois desde crianças misturamos cores.

A adição de luz é utilizada em **ecrãs** de televisão, computadores e telemóveis para compor as cores que vemos, Fig 1. Ainda que presente no nosso dia a dia, é-nos muito mais difícil prever o que acontece quando misturamos fotões de luz.

fig. 1

slides de cavalete

Deixou-nos ainda muitos dos materiais que utilizou no fazer destes **slides**, incluindo os filtros de cor e de **interferência**, Fig. 4 (que atenuam a passagem da luz). Como resultado da sua experimentação intensiva, deixou-nos 100 slides que foram expostos por duas vezes no seu tempo de vida, e ainda várias dezenas que seleccionou, mas nunca expôs.

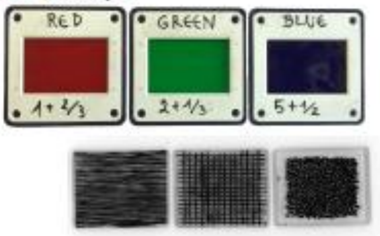


fig. 4

Foi ainda muito rigoroso nas instruções para a exibição da obra. A lista do material a utilizar inclui, nas palavras do artista: um **projector** de slides, automático, com carregador circular (para 100 ou 80 slides); um **cavalete**, dos do tipo de atelier, quanto mais século XIX melhor, e se tivesse manivela, então, seria o ideal; uma **tela branca**, como as usadas para pintar quadros; formato rectangular (120x90 cm); pode ser ainda maior mas dentro dessas proporções; uma colecção de **slides**, no formato 24 x 35 mm (o mais usual), todos projectados "à largura".

Para melhor sentir a beleza desta obra, participe no **workshop** "como se faz um slide de cavalete", junte-se a nós na descoberta do génio de Ângelo, pintando na **luz** com a luz!

Foi assim que Ângelo de Sousa criou estas pinturas imaginadas e inexistentes (excepto nos próprios slides, projectados), misturando **fotões**!

Deixou-nos **instruções** detalhadas sobre como produziu estas belas pinturas imaginadas, Figs. 2 e 5.

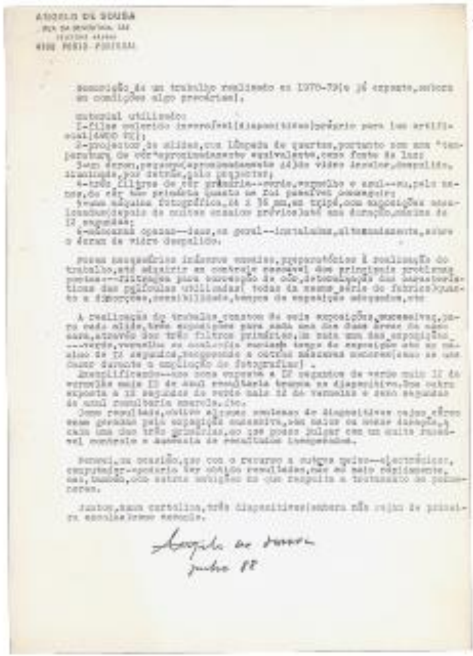


fig. 2

fig. 5

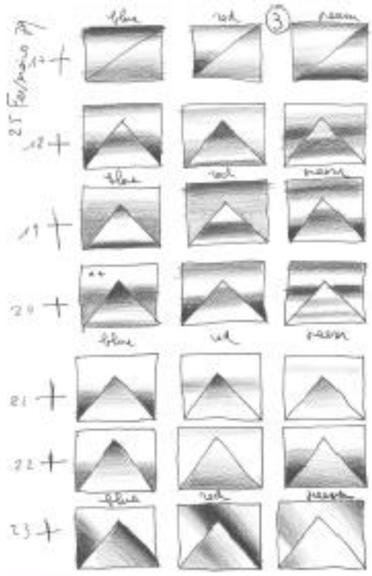


Figure IV.11 – Handout explaining the prouction process distributed during the experimental study conducted at FCT NOVA (back).

QUESTIONÁRIO

A EXPOSIÇÃO "SLIDES DE CAVALETE" DE ÂNGELO DE SOUSA

Nome (ou código de identificação caso queira permanecer anónimo)______________________

Este questionário insere-se na exposição "SLIDES DE CAVALETE" de Ângelo de Sousa que é, sobretudo, um laboratório de experimentação onde procuramos debater como preservar e exibir a obra singular de um grande artista.
A sua colaboração é extremamente importante, no sentido de garantir um número de respostas que confira fiabilidade aos resultados. A resposta é anónima e é garantida a estrita confidencialidade dos dados fornecidos.

1. **Caracterização**

(Esta secção só precisa de ser preenchida no primeiro questionário realizado)

1. Género:

□ Feminino
□ Masculino

2. Nacionalidade:

□ Portuguesa
□ Outra
2.1. Qual:___________________________________

3. Idade: ___________________________________

4. Qual o seu nível completo de habilitações literárias?

□ 1ª ciclo do ensino básico (4º ano)
□ 2ª ciclo do ensino básico (6º ano)
□ 3ª ciclo do ensino básico (9º ano)
□ Ensino Secundário (12º ano)
□ Bacharelato ou Licenciatura
□ Mestrado
□ Doutoramento
4.1. Área de formação: ______________________________________

Figure IV.12 – Questionnaire made available to the visitors during the experimental study conducted at FCT NOVA (1st page).

5. Profissão: ______________________________________

6. Costuma frequentar exposições? (Assinale com um X a sua opção)
□ 1 vez por semana
□ Várias vezes por mês
□ Várias vezes por ano
□ Uma vez por ano
□ Nunca

02. A exposição de Ângelo de Sousa

7. Frequentou o workshop referente a Ângelo de Sousa?
□ Sim □ Não

8. Na obra exposta de Ângelo de Sousa, como avalia os seguintes aspectos: (Para cada elemento, assinale com um X a sua opção)

	Excelente qualidade	Muita Boa qualidade	Média qualidade	Reduzida qualidade
Brilho das cores				
Beleza das cores				
Harmonia visual				
Qualidade cromática				

9. Na projeção/cenário da exposição (ambiente), como avalia os seguintes aspectos: (Para cada elemento, assinale com um X a sua opção)

	Excelente ambiente	Bom ambiente	Médio ambiente	Mau ambiente
Ritmo de projeção				
Som de Projeção				
Beleza de Projeção				
Harmonia entre a obra e a projeção				

Figure IV.13 – Questionnaire made available to the visitors during the experimental study conducted at FCT NOVA (2nd page).

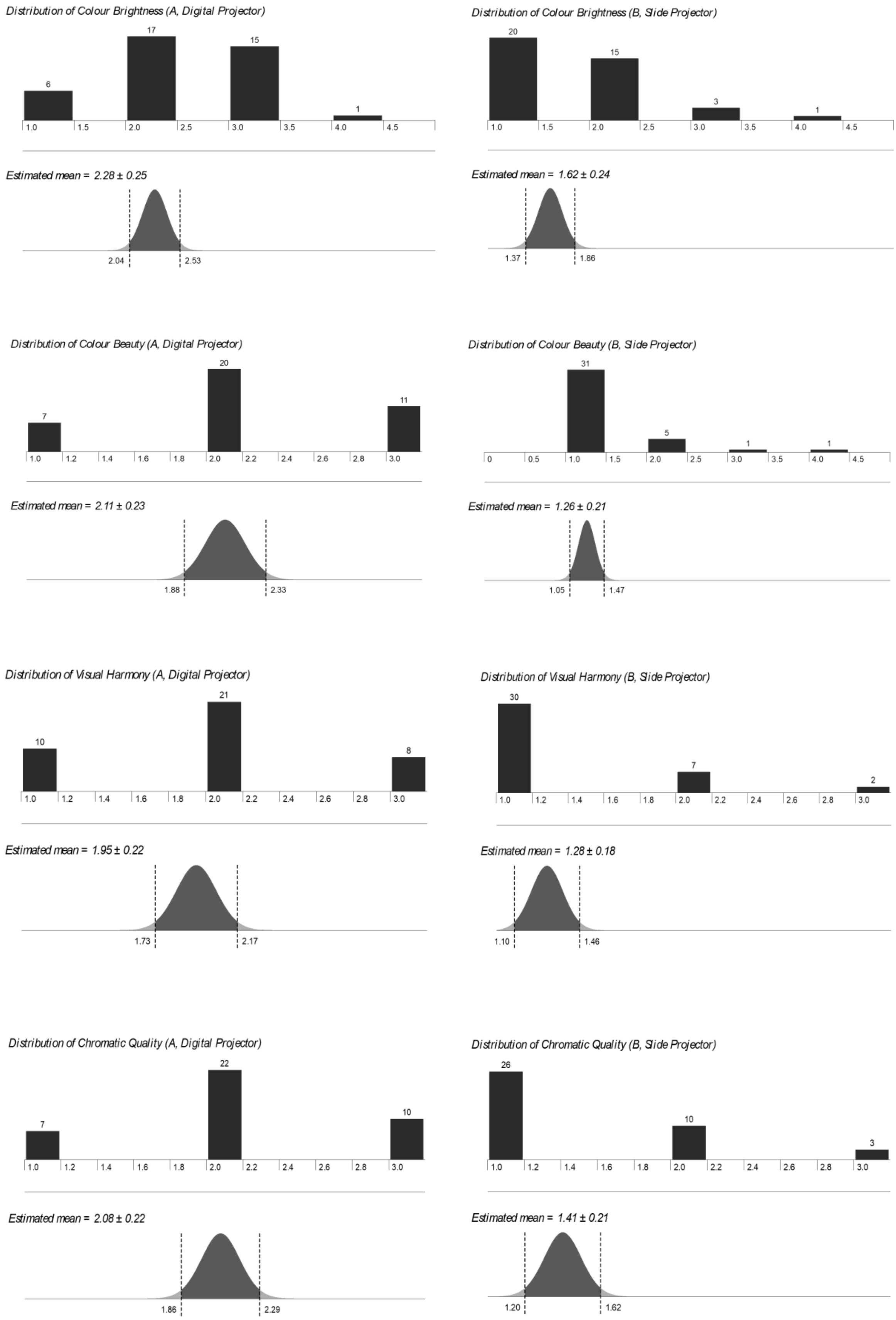


Figure IV.14 – Results from the statistical treatment made to the questionaire conducted during the experimental study conducted at FCT NOVA, regarding the image quality and beauty.

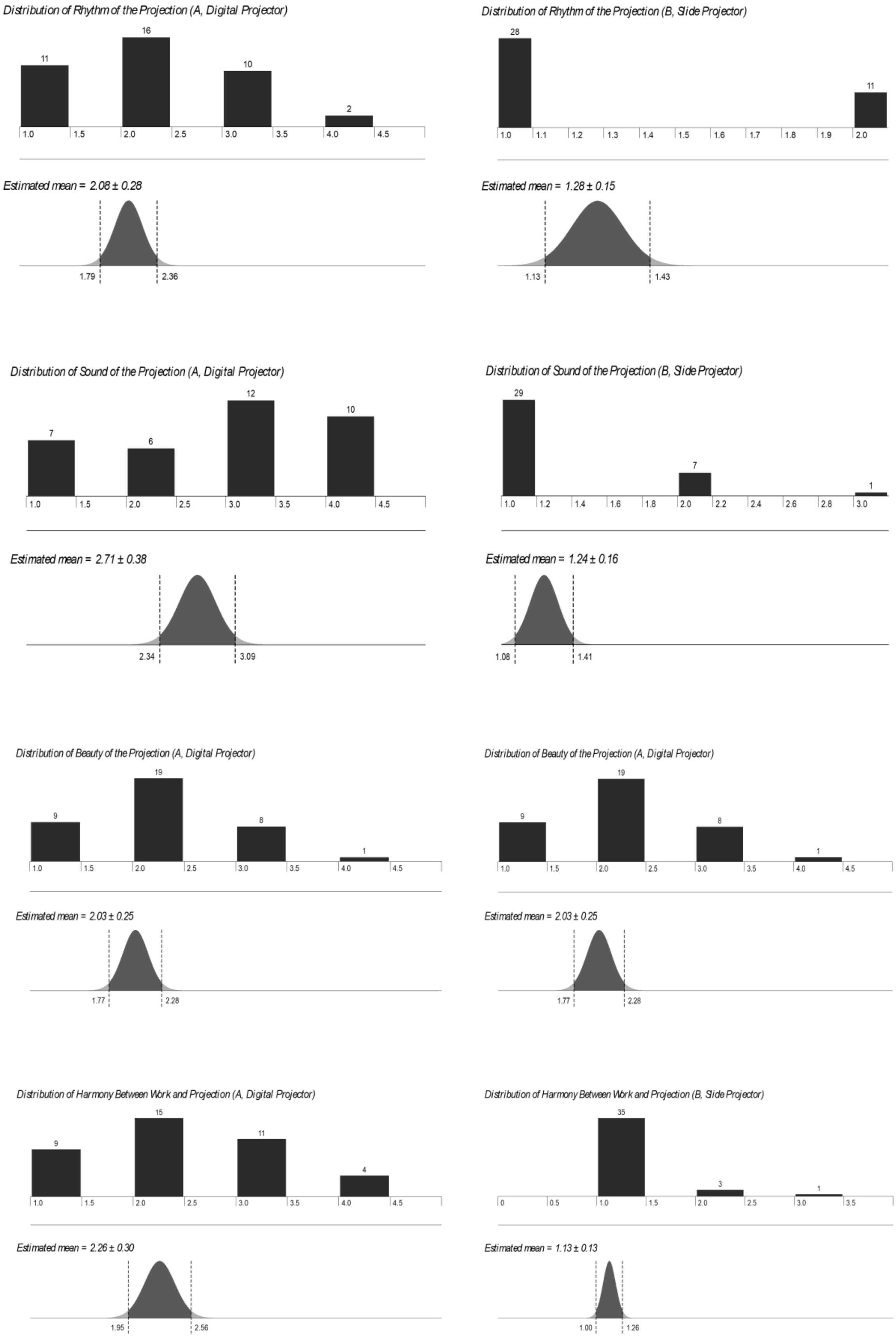


Figure IV.15 – Results from the statistical treatment made to the questionaire conducted during the experimental study conducted at FCT NOVA, regarding aspects of the global scenario/installation.

Colour Brightness (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 0.853$)

	Yes	No
1 Excellent Quality	3	3
2 Very Good Quality	13	4
3 Average Quality	12	3
4 Low Quality	1	0

Colour Beauty (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 0.751$)

	Yes	No
1 Excellent Quality	3	4
2 Very Good Quality	18	2
3 Average Quality	8	3
4 Low Quality	0	0

Visual Harmony (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 0.999$)

	Yes	No
1 Excellent Quality	6	4
2 Very Good Quality	18	3
3 Average Quality	5	3
4 Low Quality	0	0

Chromatic Quality (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 0.864$)

	Yes	No
1 Excellent Quality	3	4
2 Very Good Quality	19	3
3 Average Quality	7	3
4 Low Quality	0	0

Rhythm of the Projection (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 0.066$)

	Yes	No
1 Excellent Ambience	4	7
2 Good Ambience	13	3
3 Average Ambience	10	0
4 Bad Ambience	2	0

Sound of the Projection (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 1.000$)

	Yes	No
1 Excellent Ambience	6	1
2 Good Ambience	5	1
3 Average Ambience	7	5
4 Bad Ambience	9	1

Beauty of the Projection (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 0.962$)

	Yes	No
1 Excellent Ambience	5	4
2 Good Ambience	17	2
3 Average Ambience	6	2
4 Bad Ambience	0	1

Harmony Between Work and Projection (A, Digital Projector)

(Kolmogorov-Smirnov, $p = 1.000$)

	Yes	No
1 Excellent Ambience	6	3
2 Good Ambience	13	2
3 Average Ambience	7	4
4 Bad Ambience	3	1

Figure IV.16 – Results from the statistical treatment made to the questionaire conducted during the experimental study conducted at FCT NOVA, regarding the influence of the participation in the workshop in the perception of the artwork presented within scenario A (digital projection).

Colour Brightness (B, Slide Projector)

	Yes	No
1 Excellent Quality	15	5
2 Very Good Quality	11	4
3 Average Quality	2	1
4 Low Quality	1	0

(Kolmogorov-Smirnov, p = 1.000)

Colour Beauty (B, Slide Projector)

	Yes	No
1 Excellent Quality	25	6
2 Very Good Quality	3	2
3 Average Quality	1	0
4 Low Quality	0	1

(Kolmogorov-Smirnov, p = 0.891)

Visual Harmony (B, Slide Projector)

	Yes	No
1 Excellent Quality	22	8
2 Very Good Quality	5	2
3 Average Quality	2	0
4 Low Quality	0	0

(Kolmogorov-Smirnov, p = 0.999)

Chromatic Quality (B, Slide Projector)

	Yes	No
1 Excellent Quality	19	7
2 Very Good Quality	7	3
3 Average Quality	3	0
4 Low Quality	0	0

(Kolmogorov-Smirnov, p = 0.853)

Rhythm of the Projection (B, Slide Projector)

	Yes	No
1 Excellent Ambience	19	9
2 Good Ambience	10	1
3 Average Ambience	0	0
4 Bad Ambience	0	0

Sound of the Projection (B, Slide Projector)

	Yes	No
1 Excellent Ambience	21	8
2 Good Ambience	5	2
3 Average Ambience	1	0
4 Bad Ambience	0	0

(Kolmogorov-Smirnov, p = 0.999)

Beauty of the Projection (B, Slide Projector)

	Yes	No
1 Excellent Ambience	23	6
2 Good Ambience	5	3
3 Average Ambience	1	0
4 Bad Ambience	0	0

Harmony Between Work and Projection (B, Slide Projector)

	Yes	No
1 Excellent Ambience	27	8
2 Good Ambience	2	1
3 Average Ambience	0	1
4 Bad Ambience	0	0

(Kolmogorov-Smirnov, p = 1.000)

Figure IV.17 – Results from the statistical treatment made to the questionaire conducted during the experimental study conducted at FCT NOVA, regarding the influence of the participation in the workshop in the perception of the artwork presented within scenario B (slide projection).

Appendix V

Characterization of chromogenic dyes

V.1. Raman spectroscopy

Raman microscopy was carried out using a Horiba Jobin Yvon LabRAM 300 spectrometer, equipped with a He-Ne laser 17 mW operating at 632.8 nm and coupled to the Confocal Microscope with high stability Olympus BX41. Micro-samples were collected, from both the emulsion of EPT and RXP samples, using a micro-tool under a stereomicroscope. An attempt to remove only Y, M or C emulsion layers was pursued, for individual analysis of each dye. The collected micro-samples were placed over a microscope slide. Raman spectra were recorded as extended scans and the laser beam was focused either with a 50 x or a 100 x Olympus objective lenses or with a 50 x Olympus ultra-long working distance (ULWD) objective for depth probing. The Raman microscope allowed for the selection of precise areas of analysis, i.e, of each dye individually. The laser power at the surface of the samples was varied with the aid of a set of neutral density filters.

Raman spectra were collected between 200 and 2000 cm^{-1}. All spectra are presented without baseline correction.

V.2. Dissolution of the emulsion layer

The methodology developed for the extraction of dyes from chromogenic reversal films was adapted from both the works by Giovanna di Pietro (2007) and Ann Fenech (2011).

In order to characterize the different dyes present in RXP and EPT chromogenic reversal films, a sample of the emulsion layer was collected by scratching a portion of the black borders from the film (ca. de 0,002 g). The collected sample was then added to volumetric flask containing 3:1 ethanol:distilled water (v:v), and left for about 48 hours[1]. During the present study 2 ml volume was choose (1,5:0,5 ml) for the preparation of the solution, however, it can be prepared in the desired volume (since the solvent will be dried). The extraction process was aided by heating (circa 35˚C) and stirring. After extraction, the solution was filtered through a 0.45 µm teflon membrane filter, and then dried in a round-bottom flask under a stream of nitrogen until completely dry. The extract was then be re-dissolved in the desired solvent, according to the analysis to be performed (Fig. V.1).

Figure V.1 – Preparation of a chromogenic reversal film for further analysis of the different present in the emulsion layers.

[1] Ann Fenech (2011, 92) described a different method for dissolving dyes in chromogenic prints for further analysis in HPLC. She used 1:2 trifluoroacetic acid:ethanol mixture for 5 min. This method was tested but lead to a pinkish solution (acid solution possibly changed the structure of the chromophores), improper for analysis with TLC. The method described by Giovanna di Pietro (2007, 188) was adapted, adding water to ethanol, to enable a faster and more efficient dissolution of the dyes.

V.3. Thin-layer chromatography (TLC)

Pre-coated silica TLC sheets (ALUGRAM® Xtra SIL G/UV_{254},Machery-Nagel), cut in ca. 2x9cm, were used for the separation of the dyes present in both EPT and RXP chromogenic reversal films. The silica plate was selected, after making some tests with cellulose and aluminium plates, since it was possible to achieve good results and it would not compromise further analysis conducted to the TLC plate. Additionally, some tests were made in order to choose the best mobile phase for each film, as described in Table V.1:

Table V.1 – Results from the tests conducted for the selection of the most appropriate eluent for Ektachrome 160 T Professional (EPT) and Fujichrome Provia 400X Professional (RXP) chromogenic reversal films

mobile phase diethyl ether[2]: ethyl acetate[3] (v:v)	EPT	RXP
100:0	separation of the 3 dyes	did not separate cyan dye
90:10	good separation of the 3 dyes	did not separate cyan dye
50:50	separation of the 3 dyes	separation of the 3 dyes
0:100	did not separate the dyes	good separation of the 3 dyes

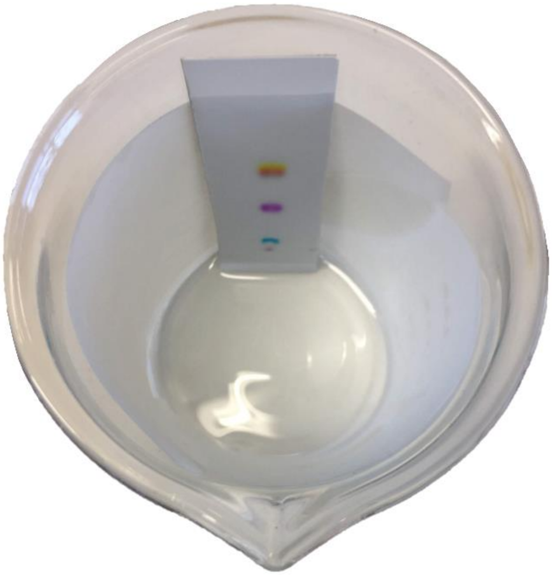


Figure V.2 – Development of the TLC sheet.

The extract described in the previous section was dissolved in ethyl acetate (just enough to acquire a concentrated solution) for the elution of the TLC. Both mixtures from the EPT and RXP were applied in a stationary phase (TLC plate), by putting several drops (ca. 5) in the same spot at the bottom of the TLC plate, by using a glass capillary. The TLC plate was then immersed in a beaker containing the mobile phase, covered with a watch glass, to be developed. Based on the tests obtained and presented in Table V.1, diethyl ether:ethyl acetate (90:10) mobile phase was selected to develop the EPT sample, and ethyl acetate to develop the RXP sample. A filter paper was used to cover the inside walls of the beaker and homogeneously spread the solvent onto the overall volume (Fig. V.2). The TLC plate was left the time necessary for the mobile phase to rise to the top of the plate (few minutes). This procedure led to a plate with separate spots of the different dyes. The retardation value (R_f) was calculated for the different dyes of both types of samples, for the two mobile phases used. All distances were measured from the origin/application baseline, that is the point where the sample is initially spotted on the plate.

[2] J.M. Gomes Santos
[3] J.M. Gomes Santos

Figure V.3 – Development of the preparative TLC plate.

The dyes present in both EPT and RXP chromogenic reversal films were also separated with a preparative TLC to enable the collection of the separated dyes and their further analysis with analytical techniques. For such a purpose, 20x20cm silica sheets, without fluorescent indicator, were selected (DC-Alufolien Kieselgel 60, Merck). Since higher quantities of the dyes were necessary to obtain enough sample for further analysis, instead of applying just a small spot of the EPT and RXP solutions, the solutions were applied in a line. To do so, a piece of cotton was placed inside a Pasteur pipette, to which the tip has been removed, allowing to control the application of the solution in the surface TLC sheet. The same mobile phases previously described were utilized for the development of the TLC sheets, according to the type of sample. Due to the larger size of the sheets, a glass tray was used for the development of the TLC sheets (Fig. V.3). The dyes seperated from both samples under study were then scraped with a scalpel (Figs. V.4 and 5). The different dyes adsorved in the silica were then kept in a volumteric flask with in ethyl acetate under stirring to allow the dissolution of the collected dyes (ca. 30 min). Only the C dye from the RXP sample could not be dissolved in ethyl acetate, which was substituted by ethanol. After complete dissolution, the mixture was filtred through a paper filter. Therefore, each dye from both EPT and RXP samples was gatehred separatly. The obtained solutions were then dried in a round-bottom flask under a stream of nitrogen. The extract can then be re-dissolved in the desired solvent, according to the analysis to be performed.

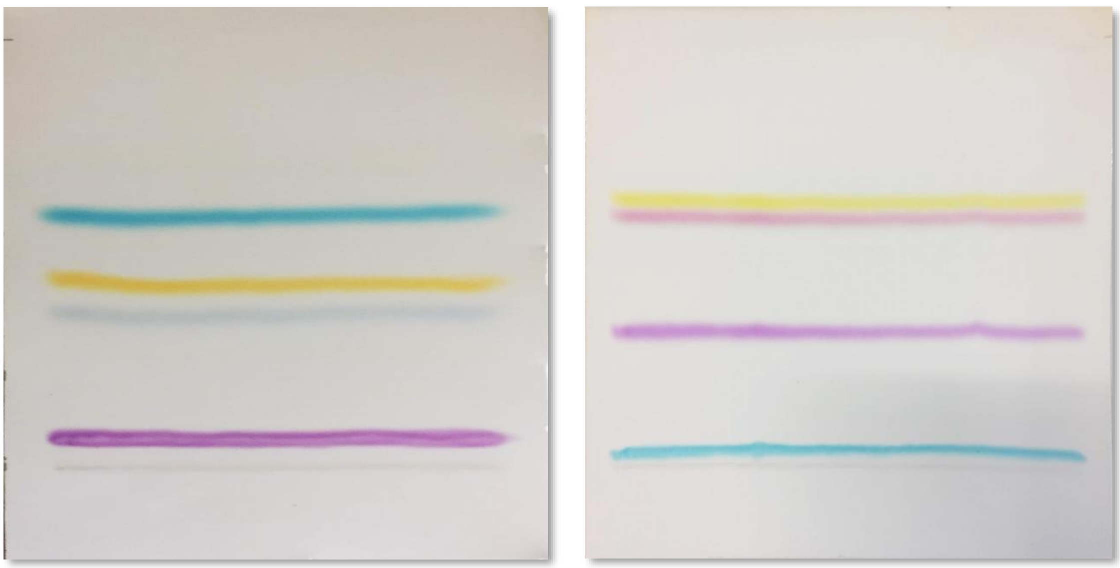


Figure V.4 – Dyes from the Ektachrome 160 T Professional (EPT) (left) and Fujichrome Provia 400X Professional (RXP) (right) chromogenic reversal films separated with a preparative TLC sheet.

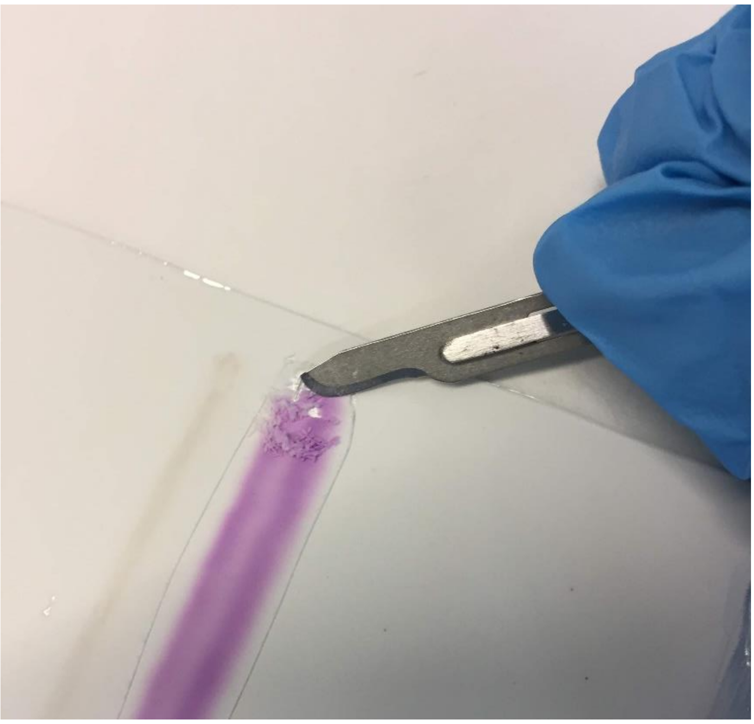


Figure V.5 – Example of dye adsorbed in the silica plate, being scraped with a scalpel for futher analysis.

V.4. Fourier-transform infrared spectroscopy (FTIR)

Infrared analyses were performed with a Nicolet Nexus spectrophotometer. The dyes were examined by placing small droplets of the dye in acetyl acetate solution over a KBr disc (Spectra-Tech Inc., 25 x 4 mm). Between each drop placed in the disc the solvent was left to evaporate.

Infrared spectra were acquired in transmission mode, from 4000 to 650 cm-1, with 64 scans and 4 cm^{-1} spectral resolution. Spectral analysis was performed using Omnic E.S.P. 5.2 and OriginPro 8 software. All spectra of the dyes presented in Chapter 6 were not baseline corrected.

V.5. High Performance Liquid Chromatography with Diode Array Detection and Mass Spectrometry (HPLC-DAD-MS)

HPLC-DAD experimental tests were carried out in an analytical Thermo Electron, FinniganTM Surveyor® HPLC-DAD system with a Thermo Electron, FinniganTM Surveyor® LC pump, autosampler and PDA detector, and using a reversed-phase RP18 analytic column (Chromolith, 100 x 4.6 mm). The wavelength range of the detector was 200-800 nm, with 0.8 second sampling interval and 4 nm resolution. Samples were injected into the column via a Rheodyne injector with a 25 µL loop. The elution gradient used at a flow rate of 1.0 mL/min consisted of A: HPLC-grade methanol and B: 0.3% (v/v) perchloric acid in Millipore ultrapure water.

Several elution gradients were tested to both EPT and RXP chromogenic reversal films:

1) A: methanol, and B: ammonium acetate (0,1M), method described by Ann Fenech (2011) for the separation of chromogenic dyes in prints[4];
2) A: methanol, and B: acidic water (0.1%, v/v percloric acid) (0,1M), method described by Micaela Sousa (2009) for the separation of anthocyanine dyes[5];
3) A: acetonitrile, and B: ammonium acetate (0,1M), method described by Micaela Sousa (2009) for the separation of mauveine dyes[6];
4) A: acidic methanol (0.1%, v/v formic acid) e B: acidic water (0.1%, v/v formic acid), method used for the separation of azo dyes[7].

The elution gradient 2) was the only one leading to good results. The elution gradient settings are provided in Table V.2.

Table V.2 – Elution gradient used for chromatographic determination of dyes in Ektachrome 160 T Professional (EPT) and Fujichrome Provia 400X Professional (RXP) chromogenic reversal films (HPLC-DAD equipment)

Time (min)	A MeOH (%)	B H_2O Acd (%)
0	7	93
2	7	93
8	15	85
25	75	25
27	80	20
29	100	0
35	100	0
40	100	0

[4] Fenech, A., 2011. Lifetime of Chromogenic Colour Photographs in Mixed Archival Collection. PhD thesis, UCL Bartlett School of Graduate Studies, Centre for Sustainable Heritage.

[5] Sousa, M. 2009. A study on historical dyes used in textiles: dragon's blood, indigo and mauve. PhD thesis, Universidade Nova de Lisboa.

[6] Idem

[7] LC-MS Determination of Sudan Dyes in Chili Oleoresin Using the CORTECS C18, 2.7 µm Column. In: http://www.waters.info/webassets/cms/library/docs/720005070en.pdf

The EPT sample was analyzing on an HPLC Dionex Ultimate 3000 composed of a binary pump HPG3200, an autosampler WPS300, a column oven TCC3000, and a Dionex DAD 3000 coupled in-line to a LCQ Fleet ion trap mass spectrometer equipped with an ESI ion source (Thermo ScientificTM). The separation was achieved on a Cortes C18 column (150 x 2.1 mm, 2.7 µm particle size, Waters). Mobile phase consisted in water containing 0.1% of acid formic (A) and methanol (B). The used elution gradient (A.B, v/v) was as follows: 70:30 from 0 to 2 min; 0:100 at 20min to 33 min; 70:30 at 35 min and 10 min of re-equilibration time.

The injected volume was 10 µL, the flow rate 300 µL min-1 and the temperature of the column was maintained at 35 °C. The wavelength was monitored between 250 and 700 nm.
The mass spectrometer was operated in the ESI positive and negative ion modes, with the following optimized parameters: ion spray voltage, ±4. 5 kV; capillary voltage, 16/-18 V; tube lens offset, -70/58 V, sheath gas (N2), 80 arbitrary units; auxiliary gas (N2), 5 arbitrary units; capillary temperature, 270 ºC. Spectra typically correspond to the average of 20–35 scans, and were recorded in the range between 100-1000 Da. Tandem mass spectra (MSn, n=2-3) were obtained with an isolation window of 2 u, 20-30 % relative collision energy and with an activation energy of 30 msec. Data acquisition and processing were performed using the software Xcalibur 2.2.

High resolution MS spectra were acquired on a quadrupole-time of flight (Q-ToF) mass spectrometer (Impact II, Bruker) equipped with an electrospray source operating in positive mode. Chromatographic separation was achieved with the same experimental conditions previously described. The spectrometric parameters were set as follows: end plate offset: 500 V; capillary voltage: 4.5 kV; nebulizer: 40 psi; dry gas: 8 L.min-1, dry temperature: 200 ºC, range: m/z 100-2000; and acquisition mode: data dependent analysis (autoMSMS) using a dynamic method with a fixed cycle time of 3 s and an isolation window of 0.03 Da. Calibration of the TOF analyzer was performed with a calibrant solution of sodium formate 10 mM. Data was processed using Data Analysis 4.2 software.

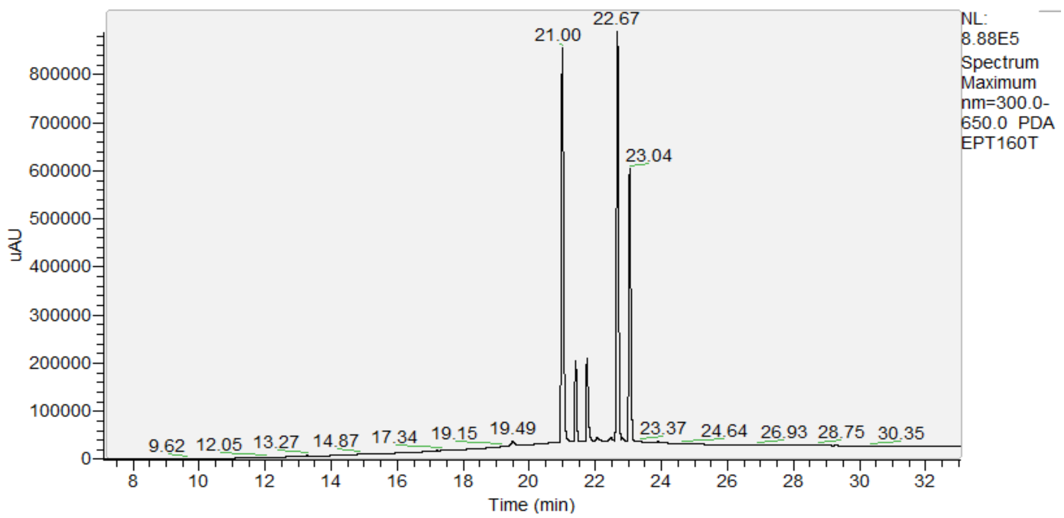


Figure V.6 – HPLC-DAD chromatogram (HPLC-DAD-MS equipment) of Ektachrome 160T Professional (EPT) chromogenic reversal film acquired (overall spectral region), where three different dyes can be identified.

Table V.3 - Absorbance maximum (λ_{max}) and retention times (R_t) of dyes from Ektachrome 160T Professional (EPT) in the HPLC-DAD-MS equipment.

cyan		magenta		yellow	
λ_{max} (nm)	R_t (min)	λ_{max} (nm)	R_t (min)	λ_{max} (nm)	R_t (min)
662	23.04	549	21.00	440	22.67

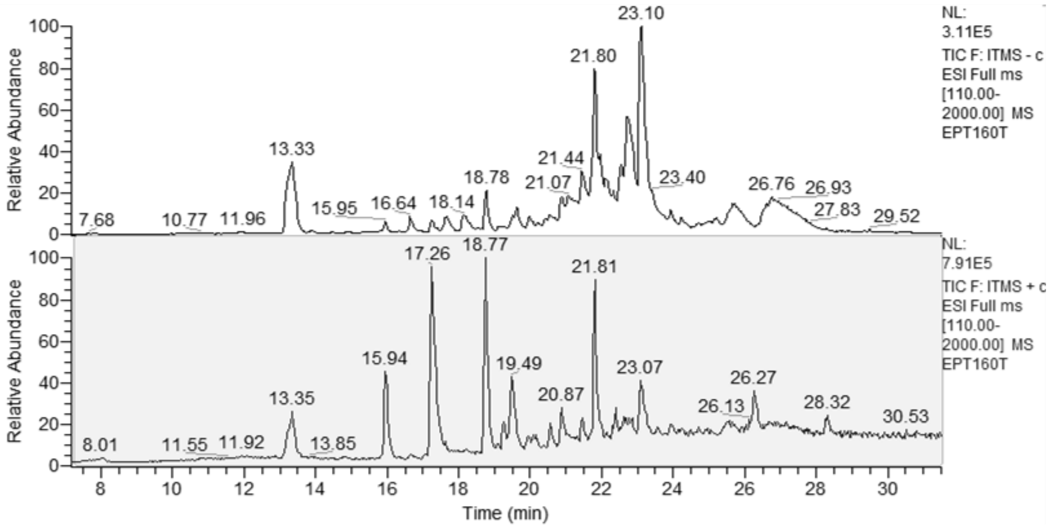


Figure V.7 – HPLC-MS chromatogram of Ektachrome 160T Professional (EPT) chromogenic reversal film. **Top:** ESI (-) chromatogram; **Bottom:** ESI (+) chromatogram.

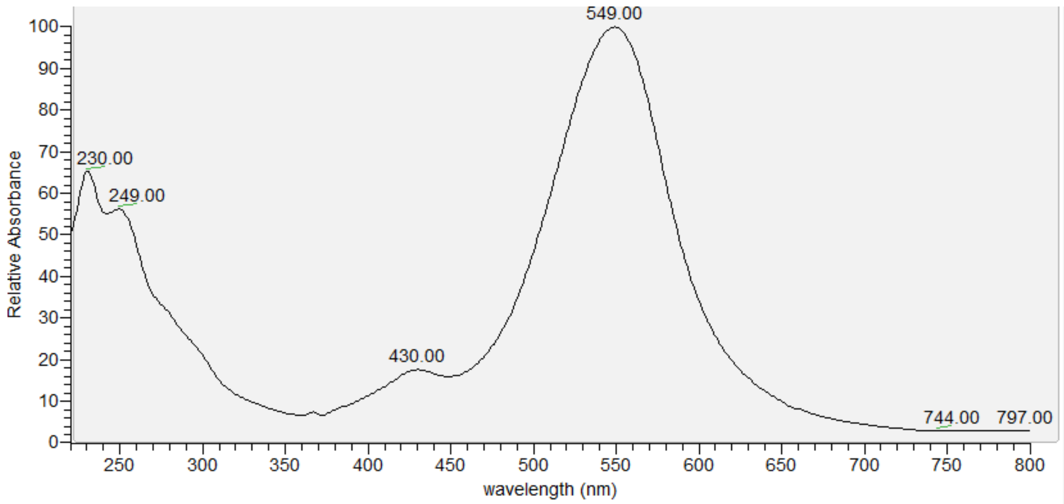


Figure V.8 – Spectral absorbance of the magenta dye (λ_{max}=549 nm) from Ektachrome 160T Professional (EPT) chromogenic reversal film separated with the HPLC-DAD analysis (HPLC-DAD-MS equipment).

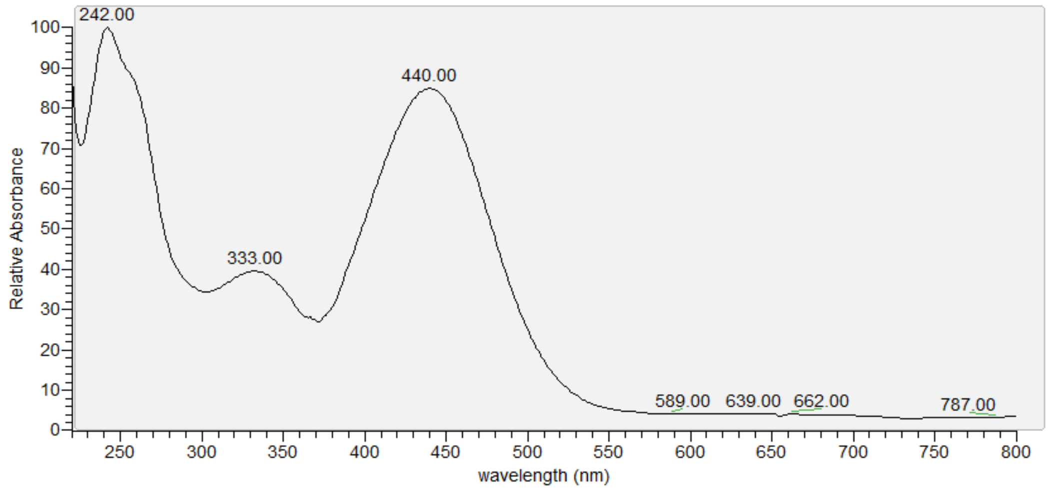


Figure V.9 – Spectral absorbance of the yellow dye (λ_{max}=440 nm) from Ektachrome 160T Professional (EPT) chromogenic reversal film separated with the HPLC-DAD analysis (HPLC-DAD-MS equipment).

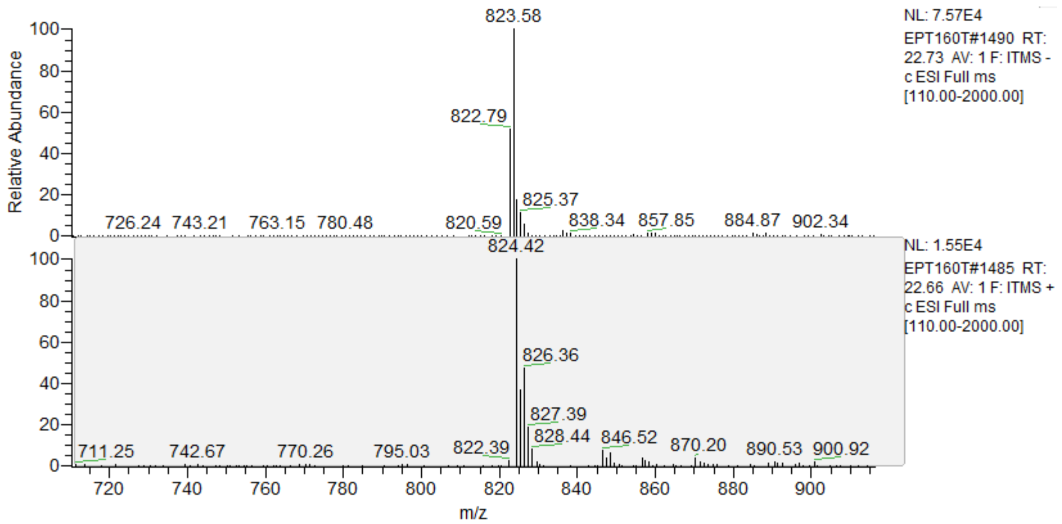


Figure V.10 – Ionic chromatogram of the peak m/z 822 (-) and 824 (+) (yellow dye) resulting from the HPLC-MS analysis. **Top:** ESI (-); **Bottom:** ESI (+).

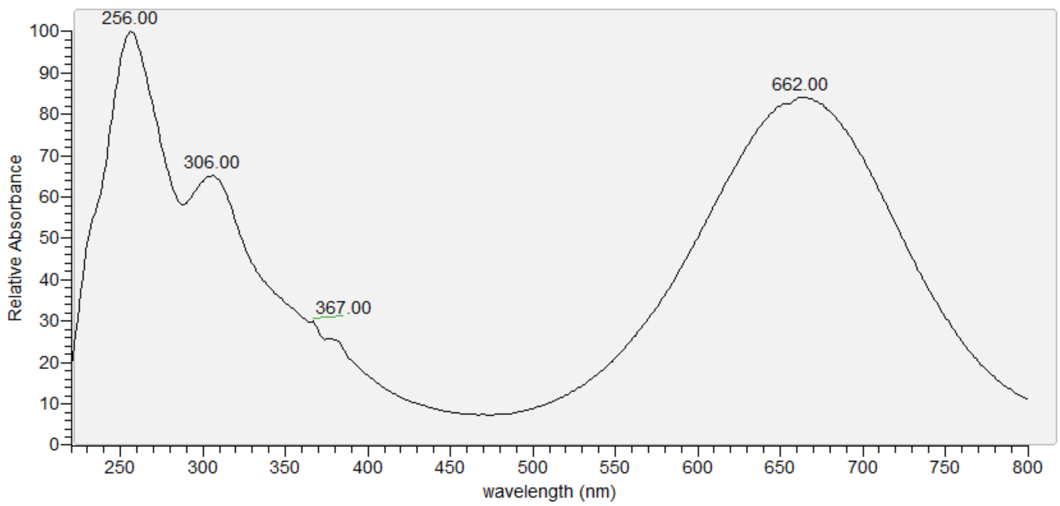


Figure V.11 – Spectral absorbance of the cyan dye (λ_{max}=662 nm) from Ektachrome 160T Professional (EPT) chromogenic reversal film separated with the HPLC-DAD analysis (HPLC-DAD-MS equipment).

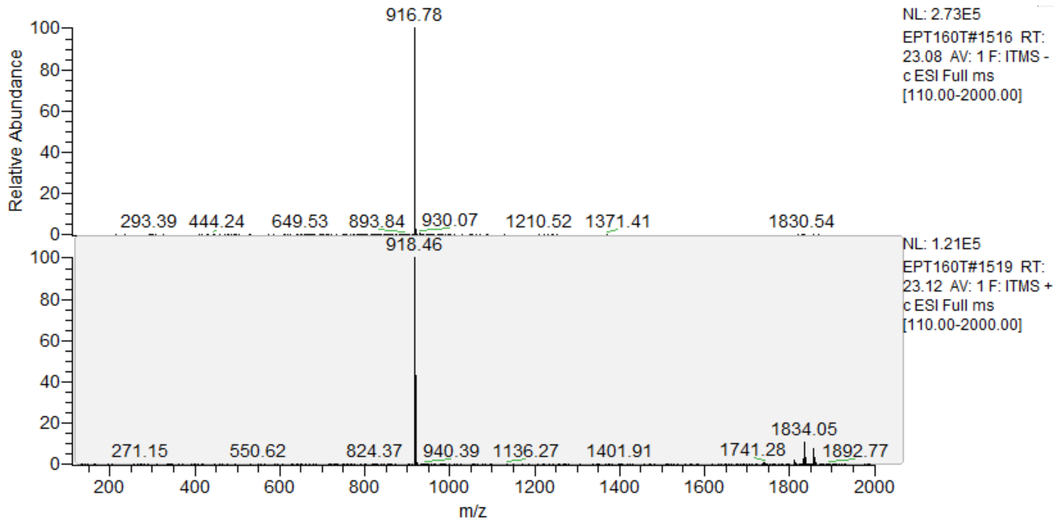


Figure V.12 – Ionic chromatogram of the peak m/z 916 (-) and 918 (+) (cyan dye) resulting from the HPLC-MS analysis. **Top:** ESI (-); **Bottom:** ESI (+).

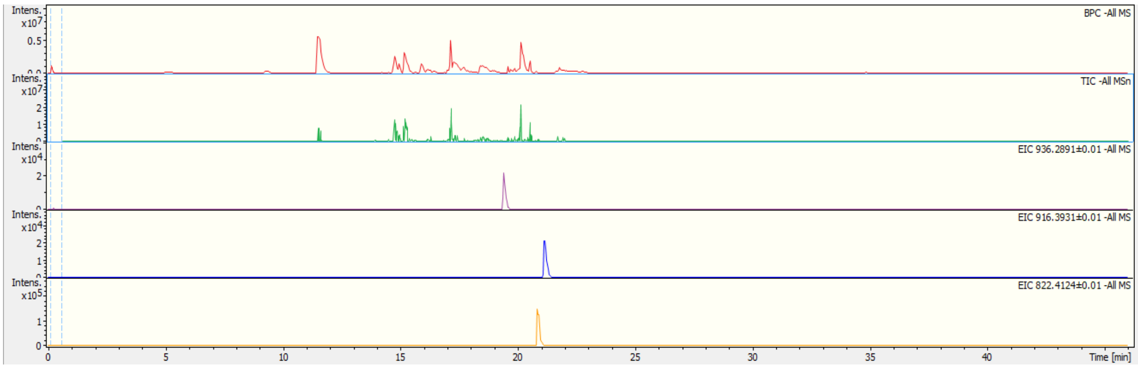


Figure V.13 – High resolution ionic chromatogram, ESI (-), of Ektachrome 160T Professional (EPT) chromogenic reversal film.

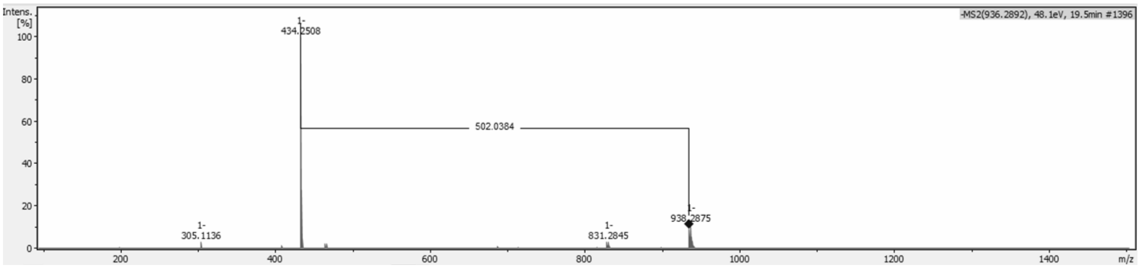


Figure V.14 – High resolution ionic chromatogram – ESI (-) - of the peak m/z 938 (magenta dye) resulting from the HPLC-MS analysis.

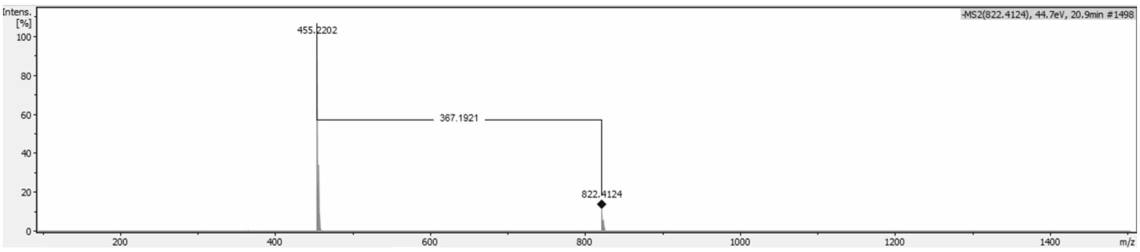


Figure V.15 – High resolution ionic chromatogram – ESI (-) - of the peak m/z 822 (yellow dye) resulting from the HPLC-MS analysis.

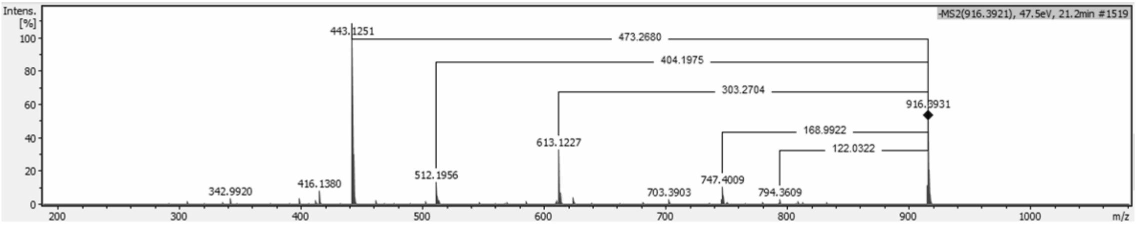


Figure V.16 – High resolution ionic chromatogram – ESI (-) - of the peak m/z 916 (cyan dye) resulting from the HPLC-MS analysis.

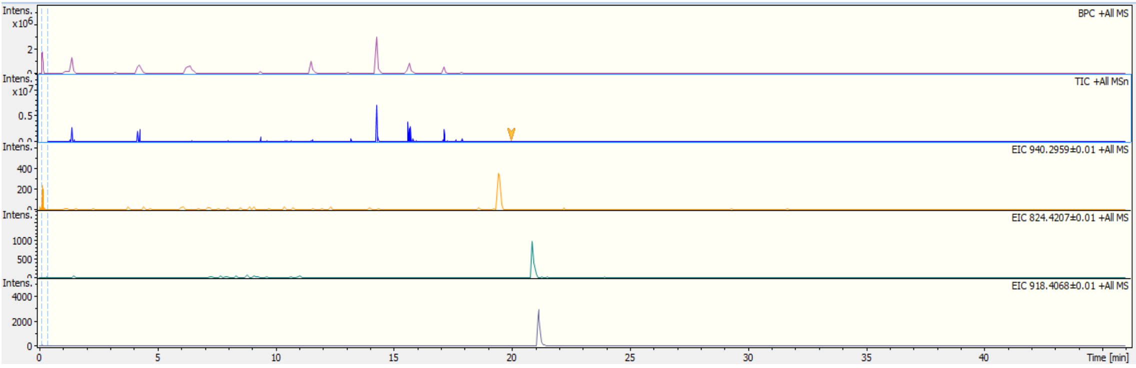


Figure V.17 – High resolution ionic chromatogram, ESI (+), of Ektachrome 160T Professional (EPT) chromogenic reversal film.

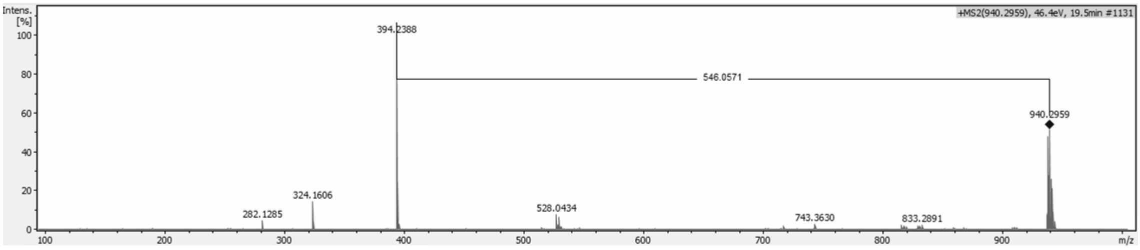


Figure V.18 – High resolution ionic chromatogram – ESI (+) - of the peak m/z 940 (magenta dye) resulting from the HPLC-MS analysis.

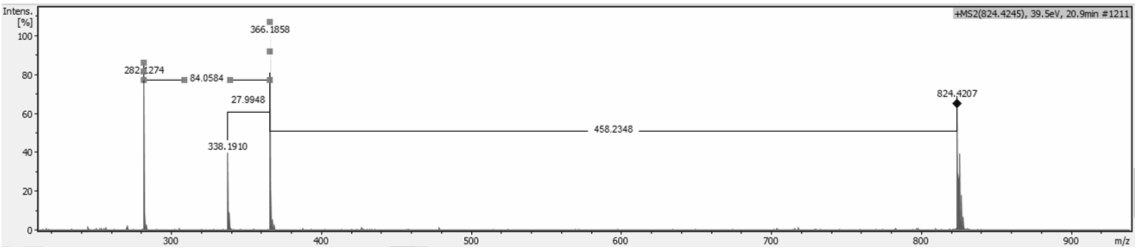


Figure V.19 – High resolution ionic chromatogram – ESI (+) - of the peak m/z 824 (yellow dye) resulting from the HPLC-MS analysis.

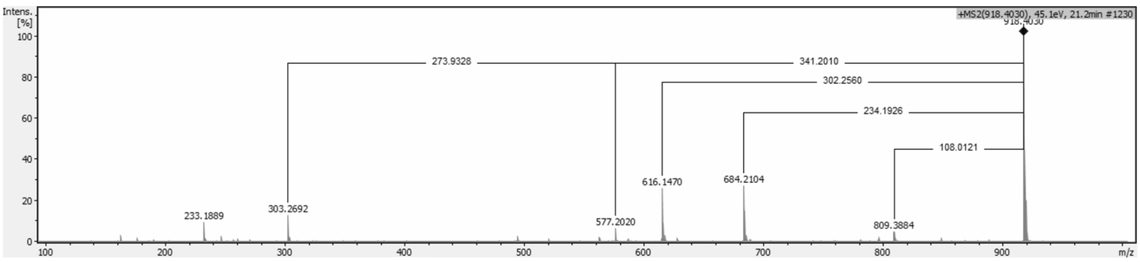


Figure V.20 – High resolution ionic chromatogram – ESI (+) - of the peak m/z 918 (cyan dye) resulting from the HPLC-MS analysis.

Appendix VI

Ageing studies

VI.1. Artificial ageing tests review (dark fading)

Table VI.1 – Artificial ageing tests: review for dark fading

Article	Authors	Aging conditions	Object	Analytical Techniques	Conclusions	Observations
"Methods for Testing Image Stability of Color Photographic Products", 1967	David Hubbell, Robert McKinney, Lloyd West Kodak	RH: 70%, T: 60°C RH: 90%, T: 71°C RH: dry, T: 77°C Forced air recirculated oven	Colour photographic products, special tablets were designed to make single-layer exposures of C, M, Y, N and D_{min} areas, in a nonintermittent sensitometer (time-scale exposure machine)	Colour densitometer with R, G, B filters (status A).	Comparison between different products. The amount of shift acceptable in a neutral area is less than an equivalent density change of the peak absorption region of C, M or Y patches.	
"Preservation of Motion-Picture Color Films Having Permanent Value", 1970	Peter Adelstein, Loren Graham, Lloyd West Kodak	RH: 40%, T: 27°C, 32°C, 43°C, 54°C, 60°C, 71°C, 77°C, 88°C ? dark cabinets, open air	Motion picture films: negative and print films of C, M, Y patches test strips with density 1.0	Colour densitometer	Prediction of the fading behaviour of a dye over time. Cyan dye was the least stable.	Time required for objectionable fading was recorded when the least stable dye faded 10%.
"Image Stability in Color Photography", 1979	Robert Tuite Kodak	RH: 40%, T: 52°C, 60°C, 68°C, 77°C, 85°C ?	Colour photographic products, in C, M, Y patches test with density 1.0	Colour densitometer		Specific information about each dye degradation, and association to products. Time required to fade 10%.
"Predicting Long-term Dark Storage Dye Stability	Charleton Bard, George Larson,	ANSI 1969 RH: 40%, T: 52°C, 60°C, 68°C, 77°C, 85°C, 93°C.	Colour photographic products, in single dye	Colour densitometer		All density measurements are corrected for D_{min}

Characteristics of Color Photographic Products from Short Term Tests", 1980	Howell Hammond, Clarence Packard Kodak	ovens, films hung on stainless-steel rods, open air	step-wedge exposures with density 1.0			changes (subtracted from changes in dyes densities). Time required to lose 0.1, 0.2, 0.3 and 0.4 densities.
“Étude experimentale de la stabilité dans l´obscurité de dix films cinématographiques couleus”, 1986	B. Lavédrine, C. Trannois, F. Flieder CRCC	RH: 40%, T: 50, 60, 66, 73, 80, 86, 92°C. Samples hang out in climatic cameras. For T < 72°C the samples were sealed inside aluminium bags.	Motion picture films, in single dye step-wedge exposures	Colour densitometer.	The difference between different densities levels was observed. Comparison between different products.	Number of days required for 10% loss of the least stable image dye.
“The Permanence and Care of Color Photographs”, 1993	Henry Wilhelm	Adaptation of ANSI PH 1-42-1969: RH: 40%, T: 62°C Samples inside desiccators inside ovens. Use of sodium dicRHomate saturated salts on the bottom, for RH control.	Colour photographic products, in single dye and neutral patches, with density 1.0	Colour densitometer, transmission densitometer for transparencies (with separate filters/channel that measure independently C, M and Y densities)	Comparison between products and their stabilities.	Number of days required for 20% loss of the least stable image dye. For all tested materials the limiting dye was the yellow. Densitometric correction.
“The Storage Guide for Color Photographic Materials”, 1998	James Reilly IPI	T: 50, 60, 70, 80, 90, 100; RH: 50%	Colour photographic products	Colour densitometer	After the 80s, C dye was the least stable. In all materials tested, the Y was the limiting dye.	1st study using both T and RH for studying dye fading. Time required for dye faded 30%.
ISO 18909:2006 (E), 2006	ISO	RH: 50% (real), T: at least 4 T, spaced by 10°C: 52, 60, 68, 77, 85°C.	Colour photographic products, in colour densities in D_{min} and at density of 1,0±0,05	Colour densitometer.		Step-by-step description.

		Sealed-bag or free-hanging methods (for slides).	above D_{min}, for neutral, C, M and Y patches.			Time required to lose 0,30 in density from the inicial D_{min}.
"Lifetime of Colour Photographs in Mixed Archival Collections" (PhD), 2006	Ann Fenech	Validation of Colorimetric measurements: T: 80°C for 4 weeks and 90°C (dry air) for 4 weeks.	Chromogenic prints strips (prints with different ages, with image).	Colorimeter (X-Rite 530 Spectrodensitometer) and HPLC-DAD (spectra of the cRHomatographic peaks).	Colorimetry, non-destructive technique, easier than HPLC-DAD.	
"Lifetime of Colour Photographs in Mixed Archival Collections" (PhD), 2006	Ann Fenech	Design of Experiments (DOE) – Central Composite Designs (CCD): total of 17 experiments. C(AA): 0, 500, 1000 ppb, RH: 20, 40, 60 %, T: 50, 65, 80°C. Samples tRHeaded together using cotton tRHead twisted around a stainless-steel coil, inside a vessel. The cap with 2 ports allows the flushing of air with the desired composition.	Chromogenic prints samples with 6 mm diameter (prints with different ages, with image).	Colorimeter (X-Rite 530 Spectrodensitometer).	Comparison of the extend of the effect of different parameters of degradation (C(AA), T and RH), in colour prints. Study of different parameters simultaneously.	End of lifetime based on psychophysical studies to determine unacceptable change.

VI.2. Artificial ageing preparation

VI.2.1. Exposure

Two different images were prepared to be exposed on the RXP chromogenic reversal films selected for the artificial ageing test: i) a step-wedge with six coloured patches, 80% neutral grey (N80), 50% neutral grey (N50), 18% neutral grey (N18), Y, M and C, and ii) an image from the artwork *Slides de Cavalete* (slide 54) (Fig. VI.1).

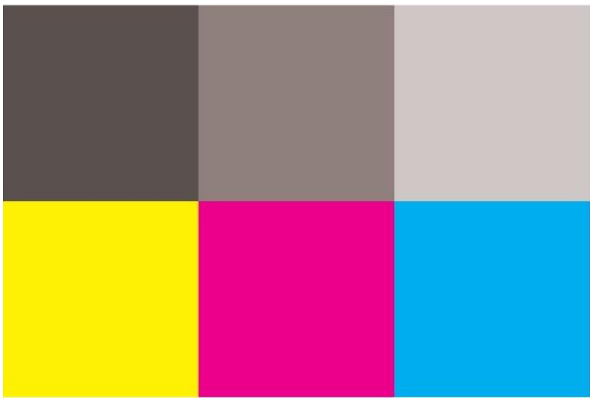
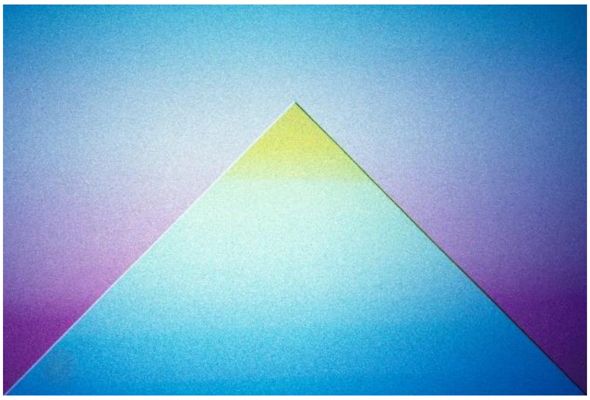



Figure VI.1 – Images selected for exposure of the Fujichrome Provia 400X Professional (RXP) films.
Left: step-wedge image; **Right:** image from the artwork *Slides de Cavalete* (slide 54).

The images were printed with a calibrated machine at Gamut (Lisbon). The step-wedge image was produced in Photoshop, considering the primary colours of the output printer, as described in Table VI.2. The high-resolution file produced for the exhibition *Encontros com as formas* (2014) was used to print slide 54 from the artwork *Slides de Cavalete*.

Table VI.2 – Colour characteristics of the patches from the step-wedge image

Patch	Output value (channel)			
	C	M	Y	K[1]
N80	80	80	80	0
N50	50	50	50	0
N18	18	18	18	0
Y	0	0	100	0
M	0	100	0	0
C	100	0	0	0

After a few exposure tests, the prints were photographed under controlled conditions to expose the RXP films to the selected images. To do so, the prints were mounted (fixed with tape) in a table and illuminated by four flash lights (5800 K) placed in pairs on both sides of the table (Fig. VI.2). An analogue photographic camera (Nikon Nikkomat) was fixed with a tripod, parallel to the print to be photographed. Two filters were used to optimize the colour balance: filter 81 and filter 10 (Kodak Wratten Filters). All the films were exposed with 1/8 s and f 5.6.

[1] black

Figure VI.2 – Setup for the exposure of Fujichrome Provia 400X Professional (RXP) films.

VI.2.2. Processing

Ângelo de Sousa used to process is chromogenic reversal films in a photography store at Centro Comercial da Foz (Porto). According to the information given by the owner of that store, Fernanda Borges, the films were sent to Sempre ID (Porto) for processing. At Sempre ID, E-6 processing is only performed since 2009. Prior to 2009, the films were sent to Fujifilm Portugal[2], so probably most of Ângelo de Sousa's chromogenic reversal films were processed in there.

Within the framework of this study, the films were developed at FinePrint (Lisbon) for practical reasons. The E-6 processing was conducted according to following steps[3]: 1) Developer (2 baths), 2) Water, 3) Fogging agent, 4) Colour developer (2 baths), 5) Pre-bleacher, 6) Bleacher (2 baths), 7) Fixer (2 baths), 8) Water (2 baths), 9) Stabilizer and 10) Dryer. The processing machine automatically renew the baths according to the number of films to be processed (Fig. VI.3). After processing, the samples were mounted with a plastic frame (polypropylene), similarly to the chromogenic reversal films from Ângelo de Sousa's collection.

[2] This information was kindly shared by Sr. Fraga from *Sempre ID* (see appendix III).
[3] This information was kindly shared by the staff from *Fine Print* (see appendix III).

Figure VI.3 – E-6 processing machine at *FinePrint*.

VI.2.3. Conditioning

The prepared samples were kept inside desiccators with saturated salts, before the artificial ageing test. Potassium carbonate (K_2CO_3) was chosen to produce circa 40% of RH, and sodium bromide (NaBr) circa 60% of RH[4]. The desiccators were maintained at T_{room} for 14 days, which is enough time for slides to reach the equilibrium with the environment[5]. According to the measurements made with a datalogger inside the desiccator, the RH values achieved were higher than the expected: K_2CO_3 produced circa 45% and NaBr 64% of RH.

Both salt solutions were prepared by adding the salt compound into a defined volume of distilled water, to produce a saturated solution. The obtained solutions were shed in the bottom reservoir of the desiccator. A support for the slides was created with polyethylene foam, where the slides were inset. The support with the slides was then placed over the ceramics support from the desiccator, on the top of the saturated salt solution (Fig. VI.4).

[4] TIP 0808-03: Equilibrium relative humidities over saturated salt solutions;
[5] Bigourdain, J. L., Adelstein, P. Z., Reilly, J. M. 1997. Moisture and temperature equilibration: Behavior and practical significance in photographic film preservation. Image Permanence Institute: https://www.imagepermanenceinstitute.org/webfm_send/298.

After 14 days, the samples were removed from the desiccators. Sets of three samples were immediately hot sealed inside combined bags made of one-side ESCAL (transparent film side) and one-side aluminium barrier films (opaque side), which offers an effective barrier against oxygen and RH[6] (Fig. VI.5). This process was conducted in the shortest timeframe possible in order to maintain the water content of the samples. At last, the samples were placed inside ovens at the desired T.

Figure VI.4 – Samples of Fujichrome Provia 400X Professional (RXP) arranged inside the desiccator with saturated salts.

Figure VI.5 - Set of three samples of Fujichrome Provia 400X Professional (RXP) sealed inside polyethylene and aluminium bag.

[6] ESCAL film - PP/ceramic deposited PVA/PE, 112 µm thickness, oxygen and vapour permeation (20°C) of 0.05 cm^3/m^2/day and 0.01 g/m^2/day, respectively; aluminium barrier film - PET/Al/LDPE, 120 µm thickness, oxygen permeation 0.01 cm^3/m^2 day and vapour permeation < 0.04 g/m^2/day (40°C/90%RH) (Mitsubishi Gas Chemical Co., Inc., n.d.).

VI.3. Optical microscopy

VI.3.1. Cross-section

Cross-sections were prepared from both EPT and RXP samples, processed and unprocessed films, and from samples induced to the artificial ageing test. To do so, a small sample was removed from the border of the chromogenic reversal films (about 2x2 mm). This fragment was taped over a small piece of CD to hold it steady. The CD coating was previously removed, mechanically, and the fragment was fixed to the piece of CD plastic with tape. Cross-sections were prepared by using a Leica RM 2155 rotary microtome equipped with low profile blades Leica DB 80 LX. The assembly previously set was fixed in the specimen clamping system (Fig. VI.6). 15 µm slices were cut by using a clean portion of blade for each cut and making a quick but relatively gentle motion (to get a clean cut and avoid ridges and fractures). The cuts were controlled by using a stereomicroscope. The samples slices were placed over a microscope slide and covered with a cover slip[7].

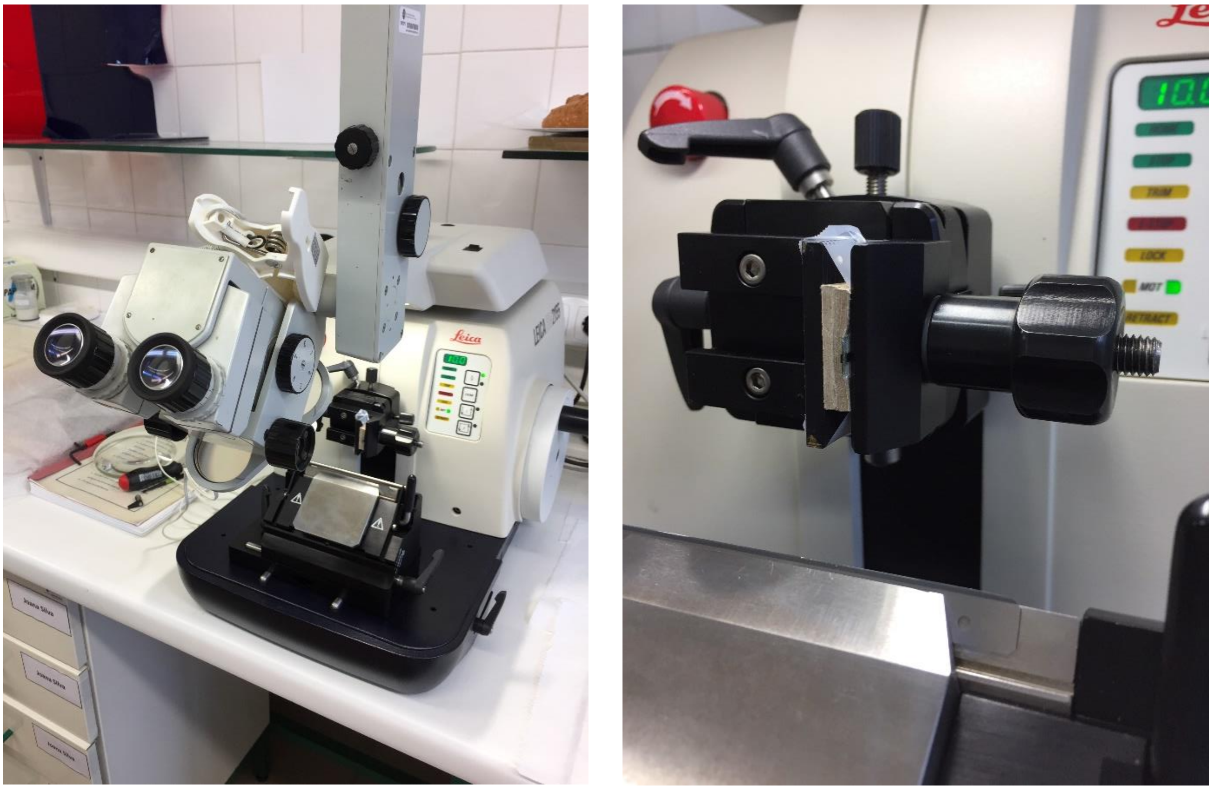


Figure VI.6 – Cross-section preparation in the Microtome Leica RM 2155. **Left:** general view of the apparatus necessary for cutting samples in the microtome; **Right**: detail of the sample fixed in the equipment.

[7] This methodology for preparing the samples was kindly explained by Stephanie Hofner. The method was used to prepare the images presented on the Graphic Atlas from the IPI. Before using this methodology, several tests were performed by mounting a piece of the film (ca. 1x1mm) in polyester or acrylic resin to observe the cross-section under the microscope. However, this method did not allow for a proper observation of the stratigraphic layers from chromogenic reversal films.

Conventional and fluorescence microscopy images were acquired using a Zeiss Axioplan 2 Imaging system (HAL 100) coupled to Nikon DXM1200F digital camera and ACT-1 software. A white card was placed on the condenser under the slides to obtain a uniform background in the image. Before photographing the samples, white spirit was carefully added between the cover glass and the slide (using capillary action) with a Pasteur pipette.

Different modes of reflected light illumination (polarised light and UV lights) were used to characterize the chromogenic reversal films under study. For the image acquisition under transmitted plane-polarised light, the rotatable compensator Lambda (±8° 6x20 mm) was used. The fluorescence behaviour of the films was assessed by exposing the samples to several filters:

- blue-violet light (Filter set 05, Zeiss): excitation BP 395–440 nm, beamsplitter FT 460 nm, emission LP 470 nm;
- green-blue light (Filter set 09, Zeiss): excitation BP 450-490 nm, beamsplitter FT 510 nm, emission LP 515 nm;
- yellow-orange light (Filter set 14, Zeiss): excitation BP 510–560 nm, beamsplitter FT 580 nm, emission LP 590 nm;
- ultraviolet light (Filter set 08, Zeiss): excitation BP 365 nm, beamsplitter FT 395, emission LP 420 nm[8].

All fluorescence images were acquired under the same conditions, i.e., the intensity power of the UV-light source was fixed with all light parameters kept constant. The obtained results are shown in Figure VI.7 and VI.8.

[8] BP: band pass filter; FT: colour splitter filter ('farb teiler'); LP: long pass filter, G: gaussian filter.

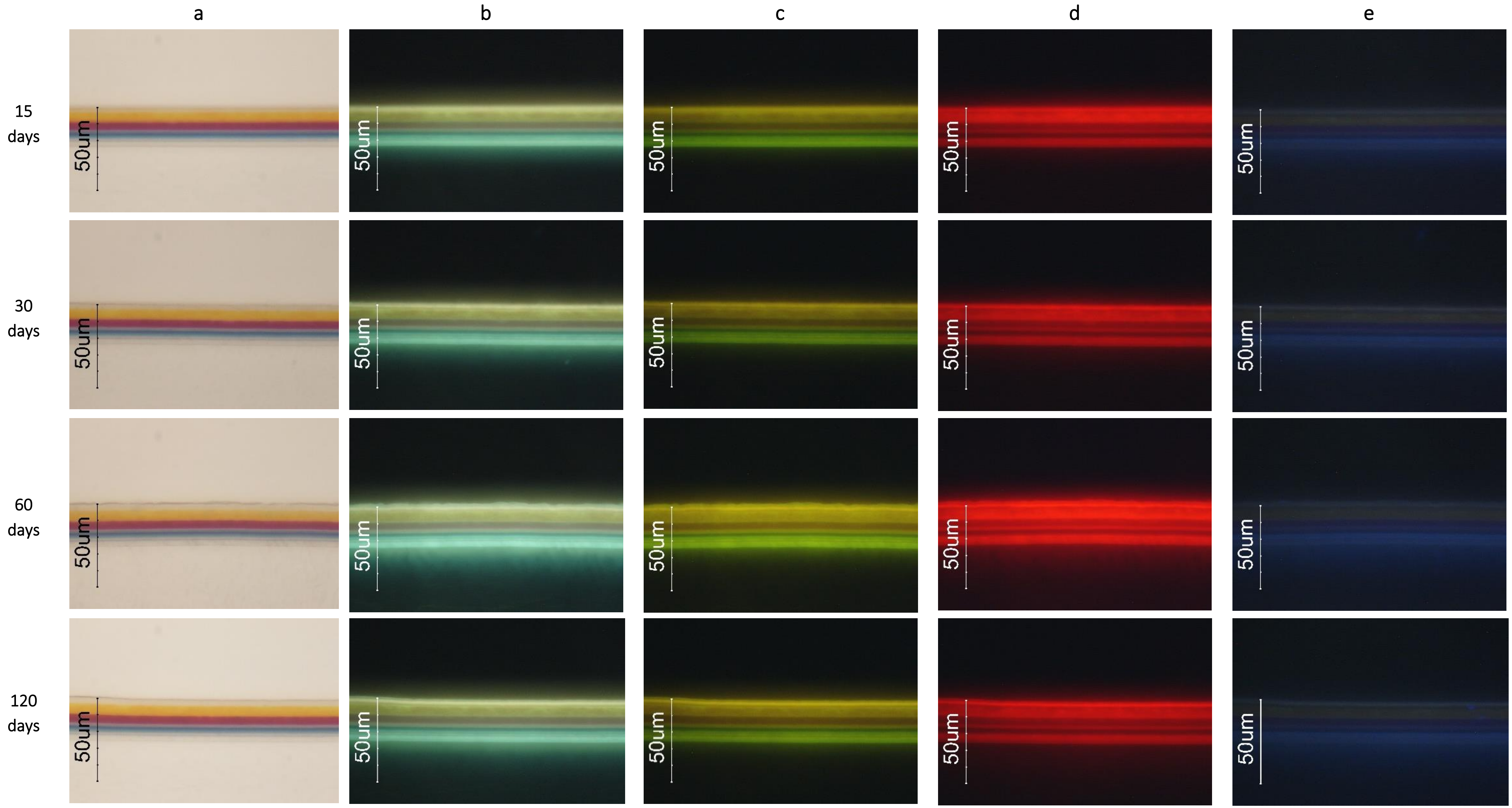


Figure VI.7 – Microscopy images of the cross-sections from samples after 15, 30, 60 and 120 days of artificial ageing at T=70˚C and water content (wt)≈12.5%: a) under reflected cross-polarised light, b) blue-violet light, c) green-blue light, d) yellow-orange light, and e) ultraviolet light.

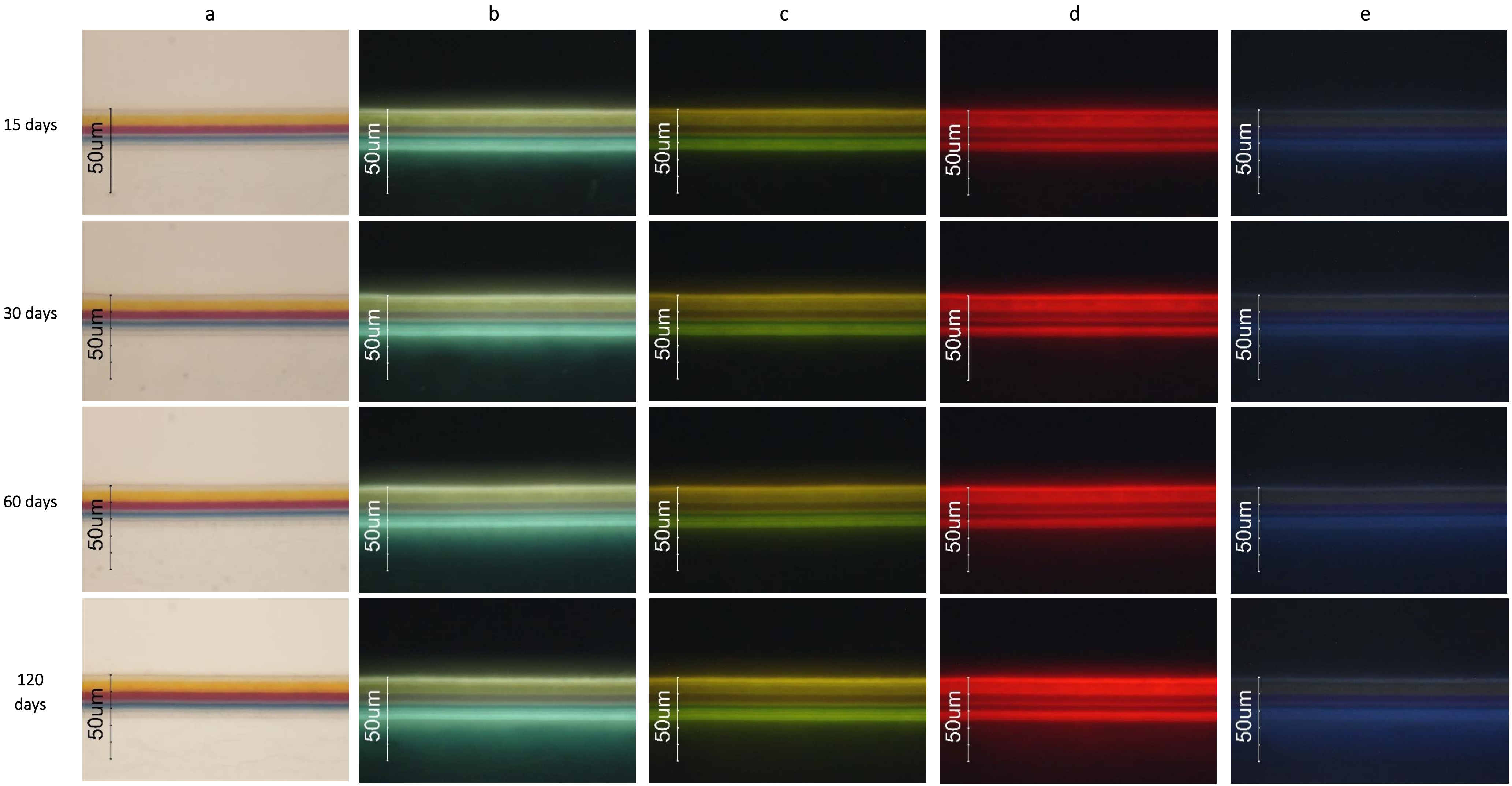


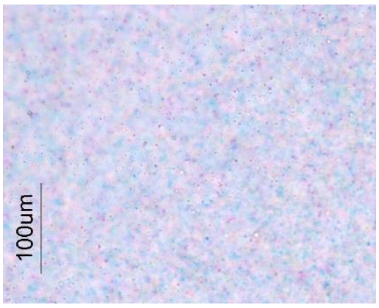
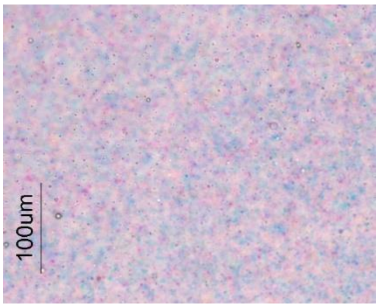
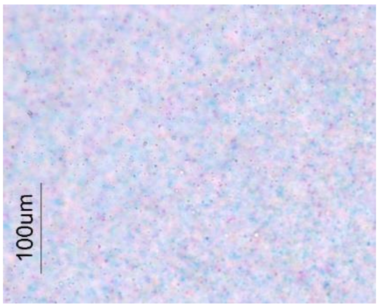
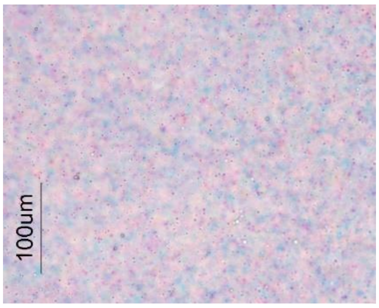
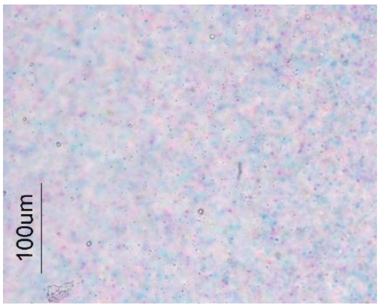
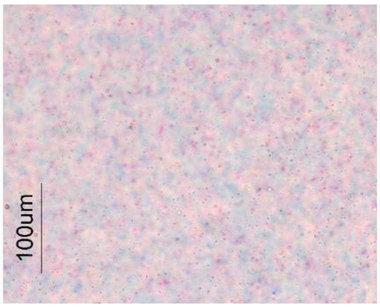
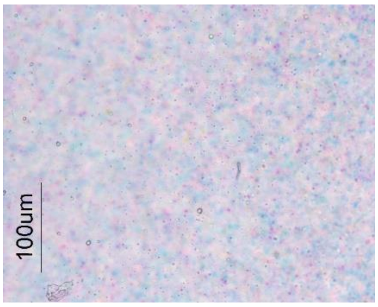
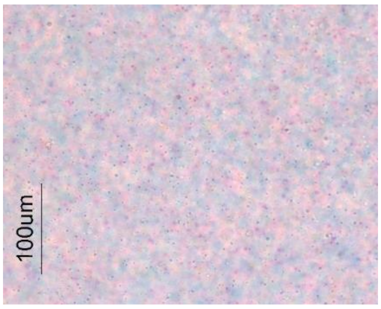
Figure VI.8 – Microscopy images of the cross-sections from samples after 15, 30, 60 and 120 days of artificial ageing at T=70˚C and water content (wt)≈15%: a) under reflected cross-polarised light, b) blue-violet light, c) green-blue light, d) yellow-orange light, and e) ultraviolet light.

VI.3.2. Superficial analysis

To characterise superficial changes occurring in RXP samples induced to the artificial ageing, conventional microscopy images were acquired with the same equipment described in the previous section. Transmitted light was used to monitor changes on the films' surface. All the images were acquired under the same conditions, i.e., the intensity power of the light source was fixed with all light parameters kept constant. The images were acquired by directly observing the samples placed under the microscope lens.

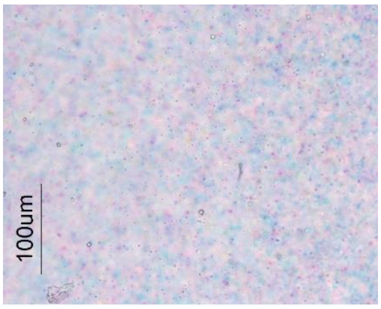
The obtained results are presented in the following tables:

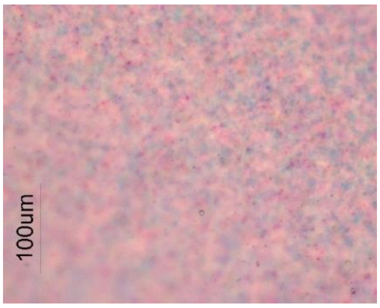
Table VI.3 – Microscopy images of the step-wedge samples (neutral 18% patch) before (t_i) and after (t_f) the end of each different artificial ageing test

	t_i	t_f
wt≈12.5% T=50°C 300 days		
wt≈15% T=50°C 300 days		
wt≈12.5% T=60°C 225 days		
wt≈15% T=60°C 225 days		

wt≈12.5%
T=70°C

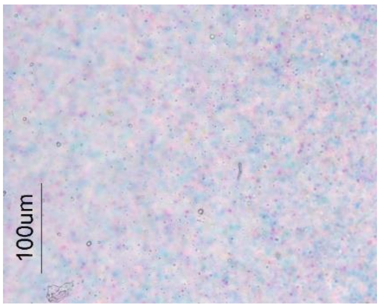
120 days

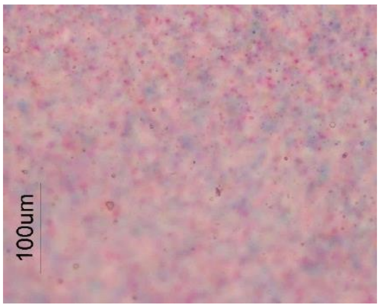




wt≈15%
T=70°C

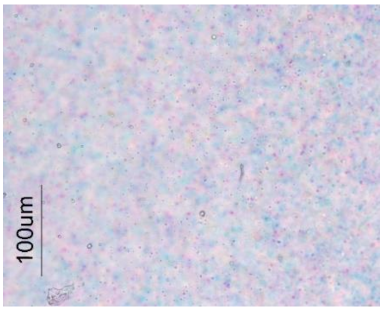
120 days

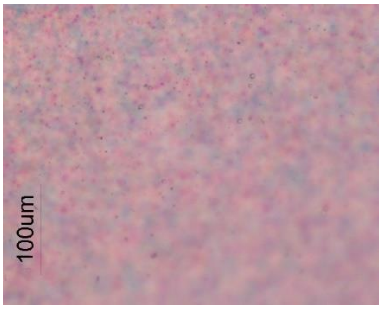




wt≈12.5%
T=80°C

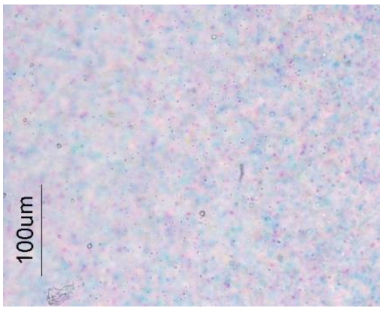
60 days





wt≈15%
T=80°C

60 days



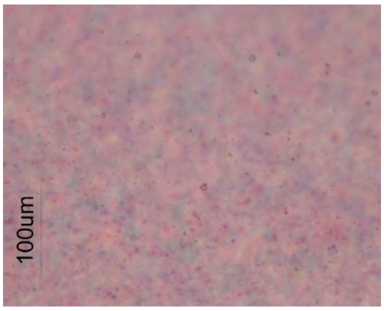
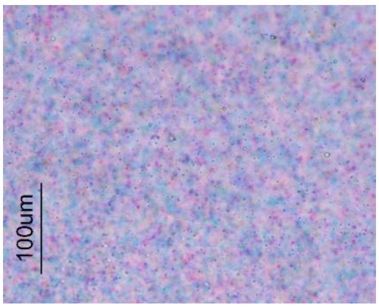


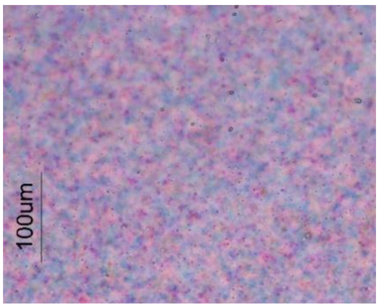
Table VI.4 – Microscopy images of the step-wedge samples (neutral 50% patch) before (t_i) and after (t_f) the end of each different artificial ageing test

t_i | **t_f**

wt≈12.5%
T=50°C

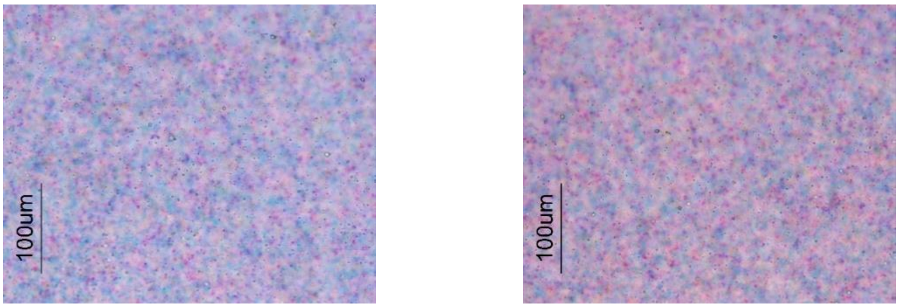
300 days





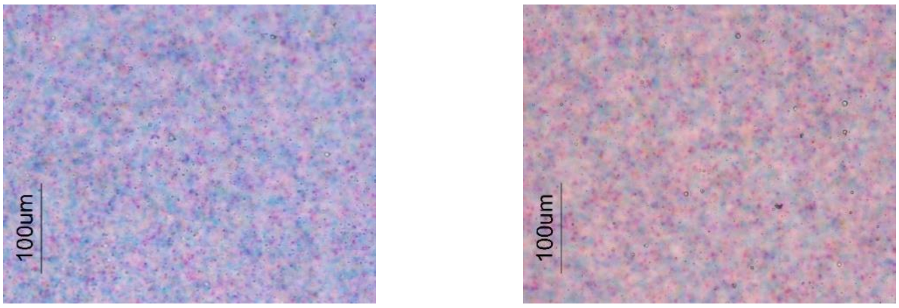
wt≈15%
T=50°C

300 days



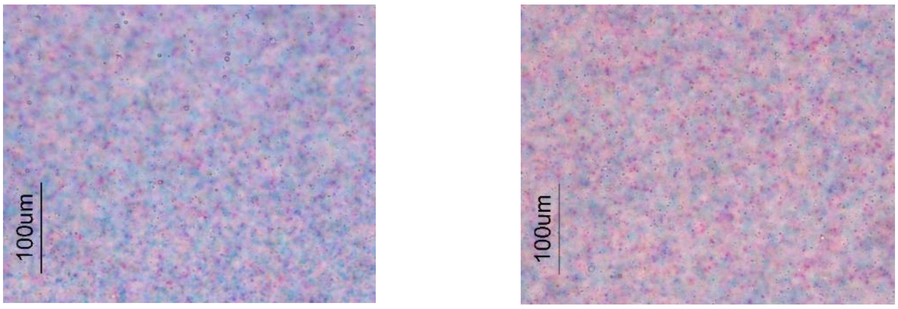
wt≈12.5%
T=60°C

225 days



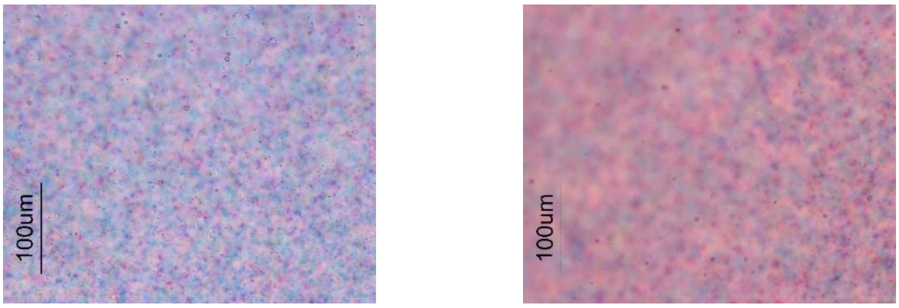
wt≈15%
T=60°C

225 days



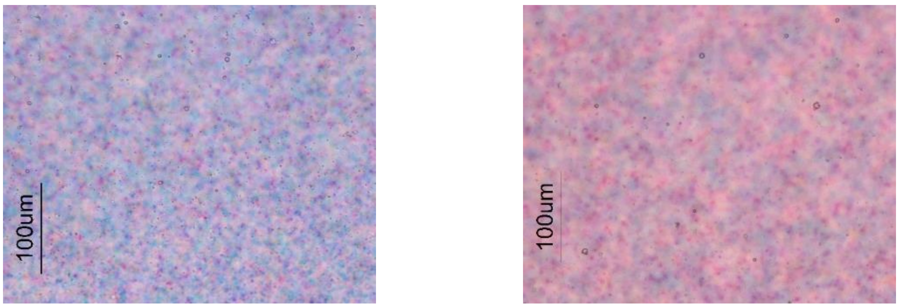
wt≈12.5%
T=70°C

120 days



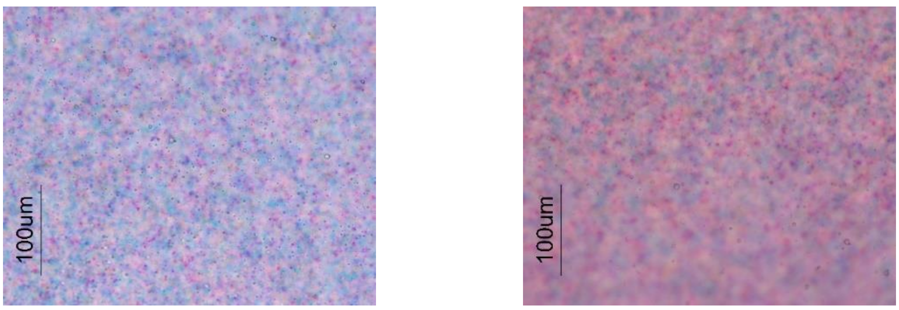
wt≈15%
T=70°C

120 days



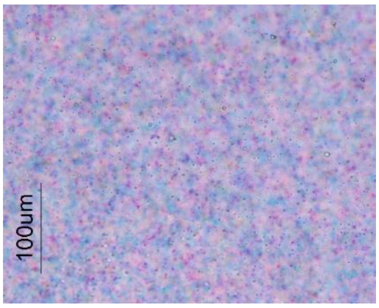
wt≈12.5%
T=80°C

60 days



wt≈15%
T=80°C

60 days



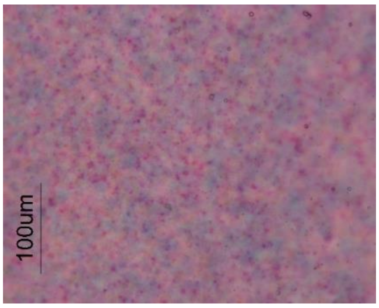
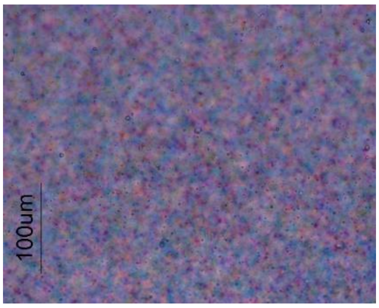


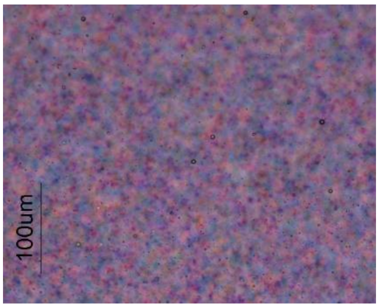
Table VI.5 – Microscopy images of the step-wedge samples (neutral 80% patch) before (t_i) and after (t_f) the end of each different artificial ageing test

t_i | **t_f**

wt≈12.5%
T=50°C

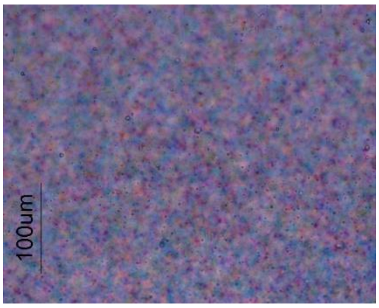
300 days

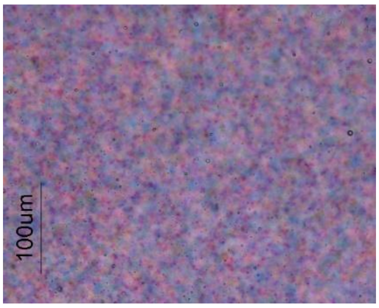




wt≈15%
T=50°C

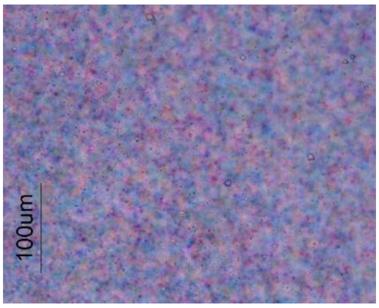
300 days

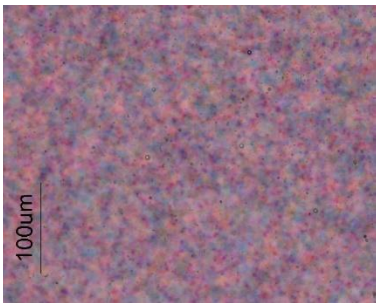




wt≈12.5%
T=60°C

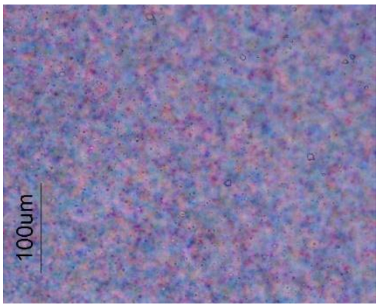
225 days

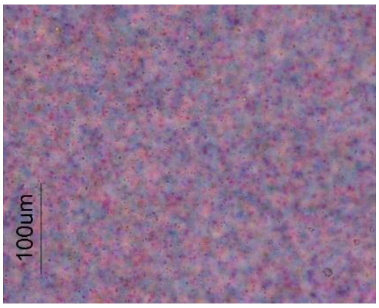




wt≈15%
T=60°C

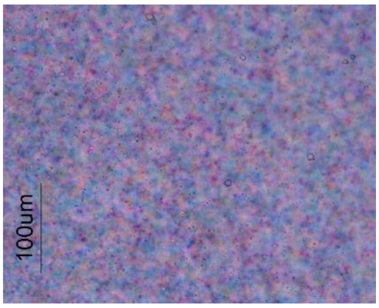
225 days

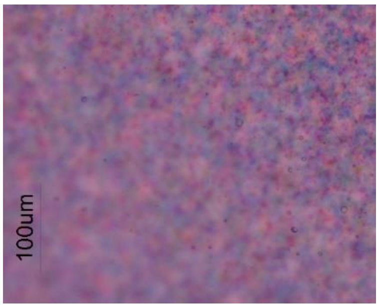




wt≈12.5%
T=70°C

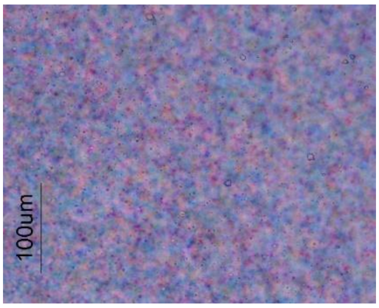
120 days

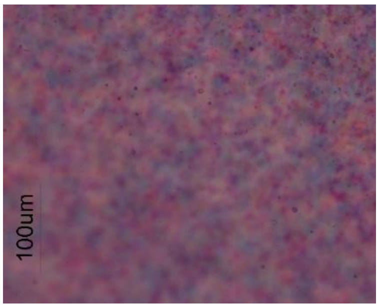




wt≈15%
T=70°C

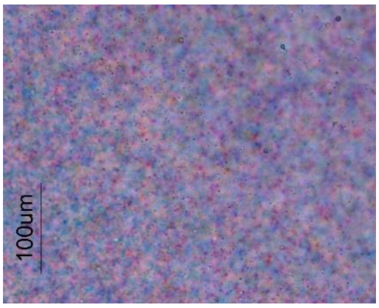
120 days

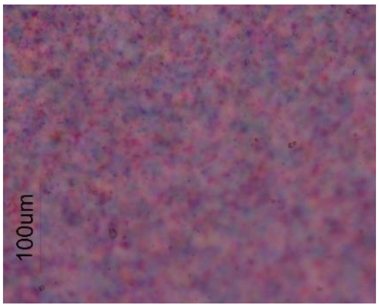




wt≈12.5%
T=80°C

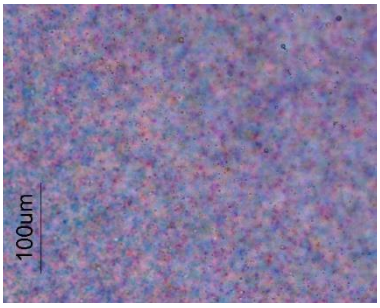
60 days





wt≈15%
T=80°C

60 days



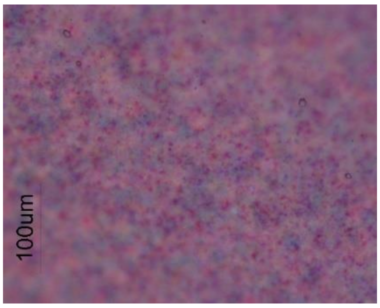
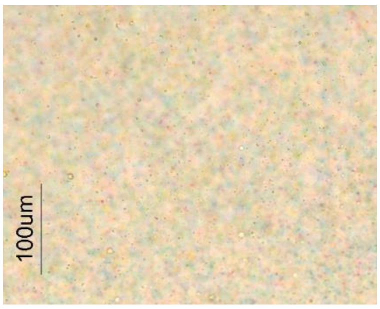


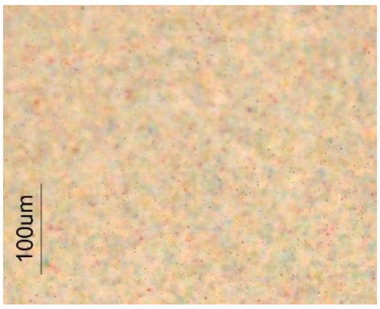
Table VI.6 – Microscopy images of the step-wedge samples (Y patch) before (t_i) and after (t_f) the end of each different artificial ageing test

t_i | t_f

wt≈12.5%
T=50°C

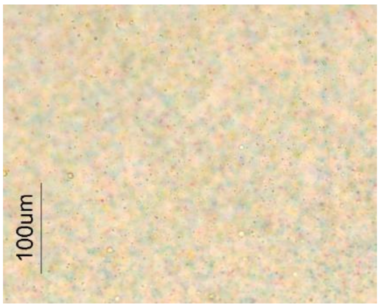
300 days

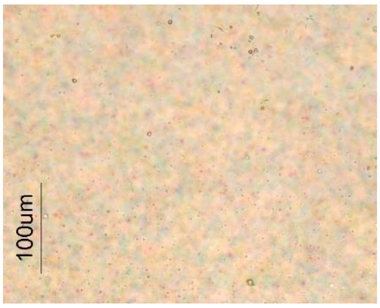




wt≈15%
T=50°C

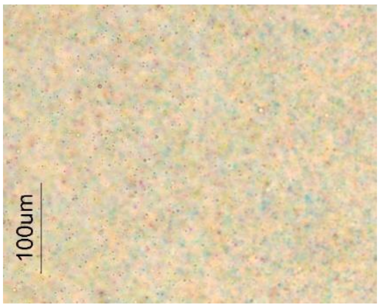
300 days





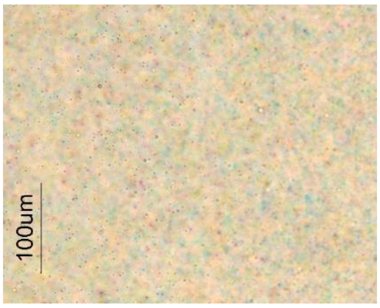
wt≈12.5%
T=60°C

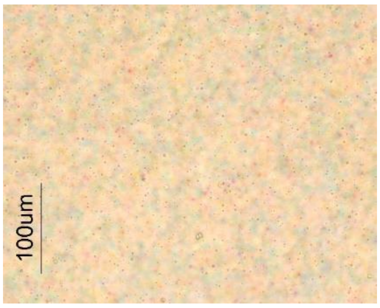
225 days



wt≈15%
T=60°C

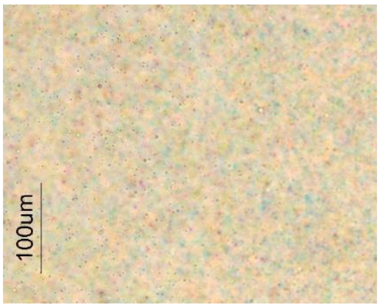
225 days

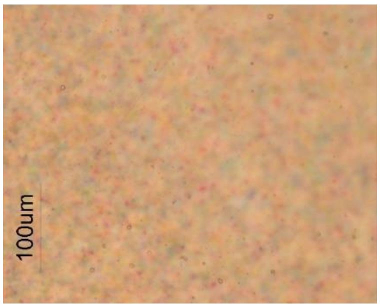




wt≈12.5%
T=70°C

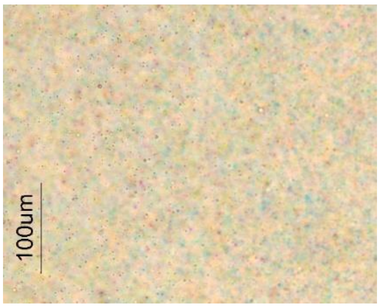
120 days

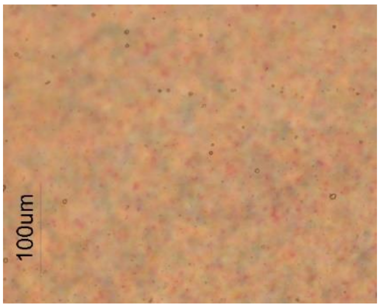




wt≈15%
T=70°C

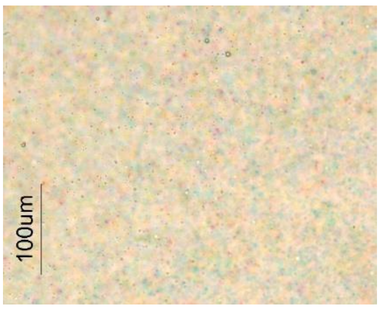
120 days

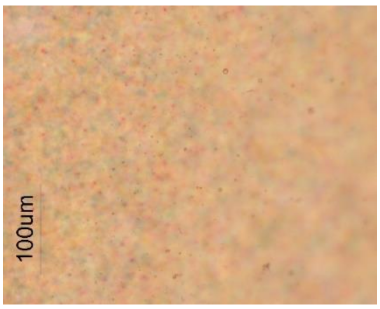




wt≈12.5%
T=80°C

60 days





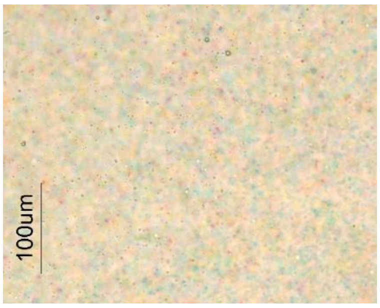
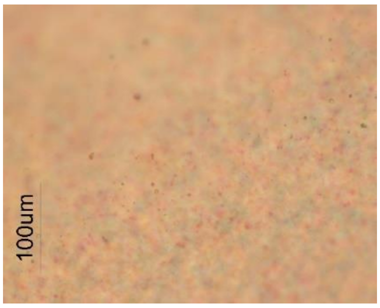
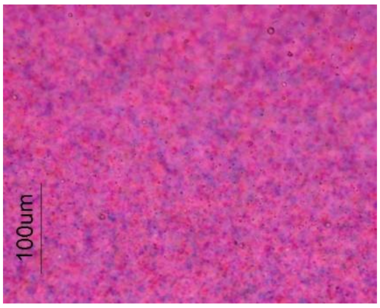
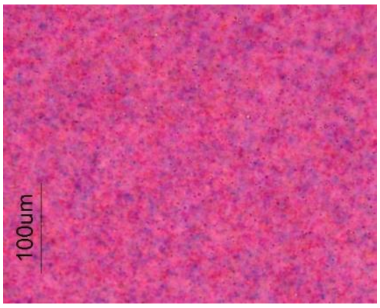
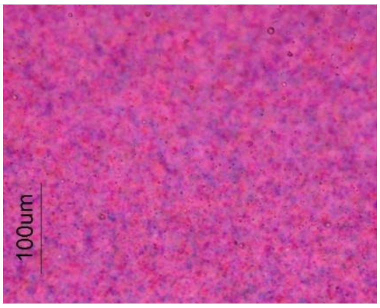
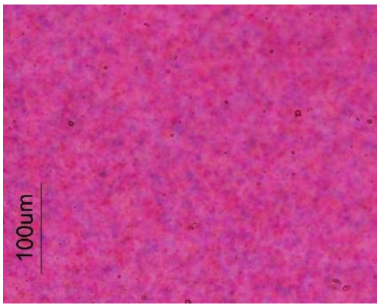
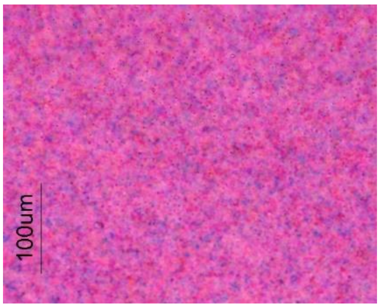
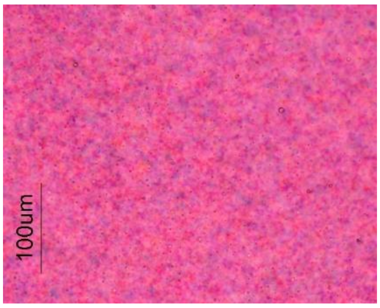
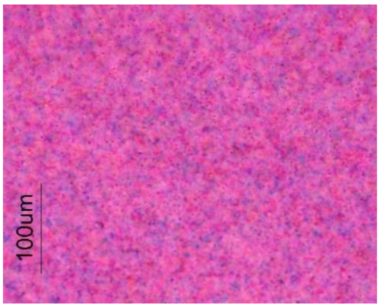
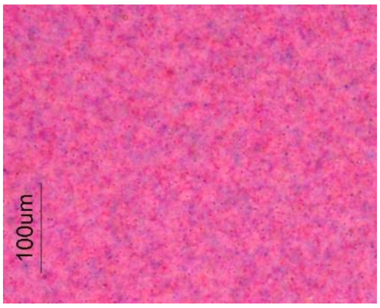
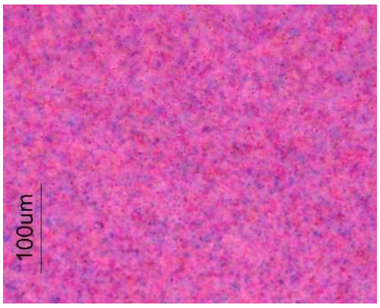
wt≈15% T=80°C 60 days		

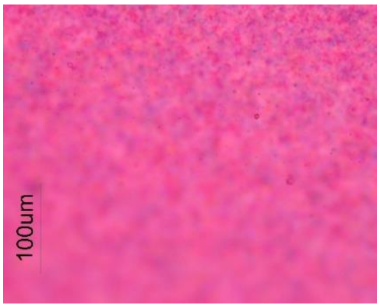
Table VI.7 – Microscopy images of the step-wedge samples (M patch) before (t_i) and after (t_f) the end of each different artificial ageing test

	t_i	t_f
wt≈12.5% T=50°C 300 days		
wt≈15% T=50°C 300 days		
wt≈12.5% T=60°C 225 days		
wt≈15% T=60°C 225 days		

wt≈12.5%
T=70°C

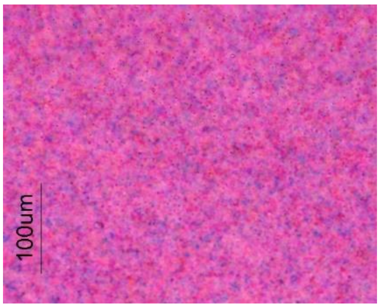
120 days

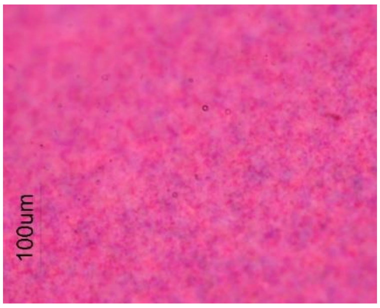




wt≈15%
T=70°C

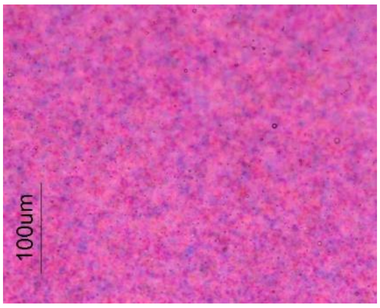
120 days

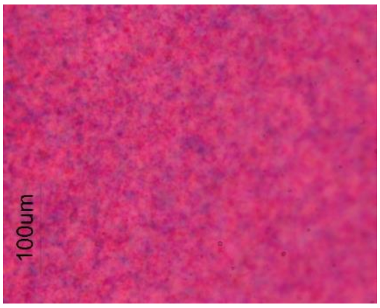




wt≈12.5%
T=80°C

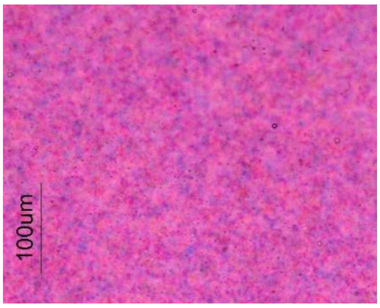
60 days





wt≈15%
T=80°C

60 days



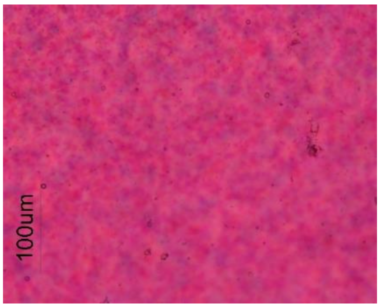
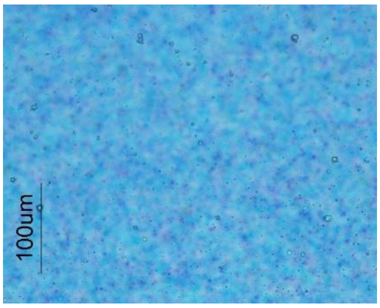


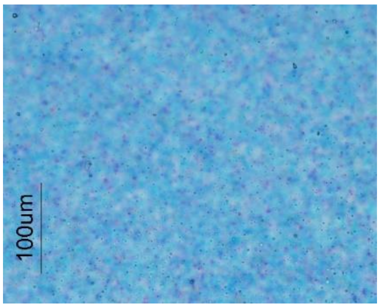
Table VI.8 – Microscopy images of the step-wedge samples (C patch) before (t_i) and after (t_f) the end of each different artificial ageing test

t_i **t_f**

wt≈12.5%
T=50°C

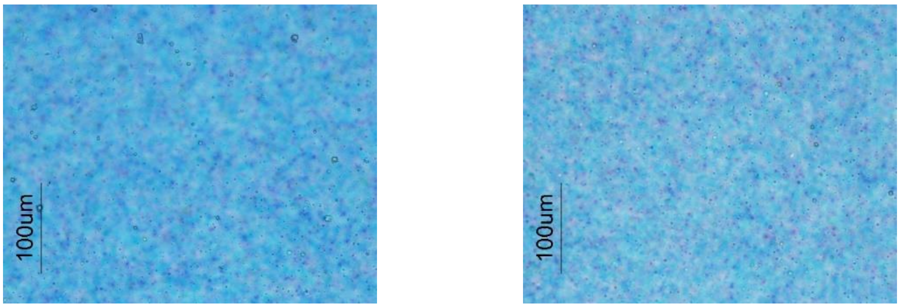
300 days





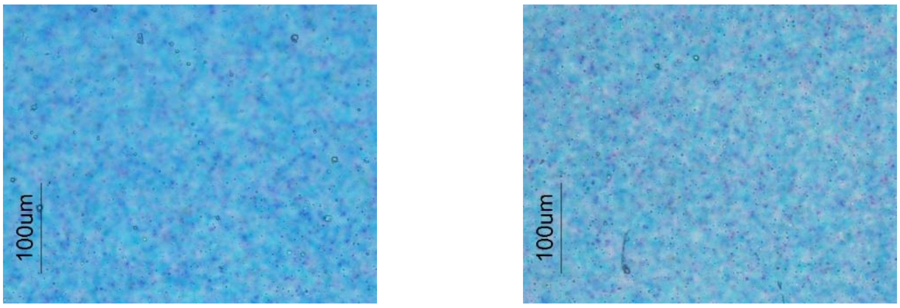
wt≈15%
T=50°C

300 days



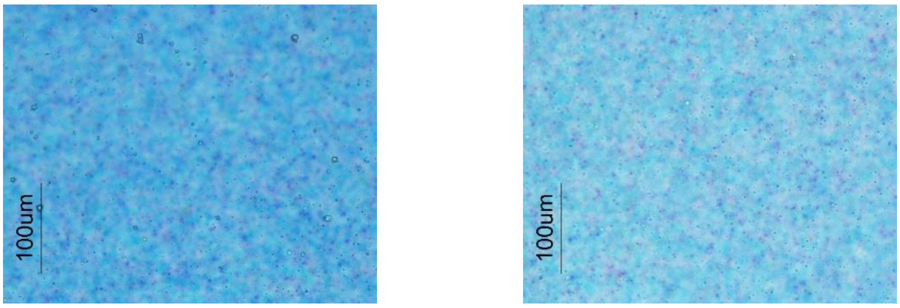
wt≈12.5%
T=60°C

225 days



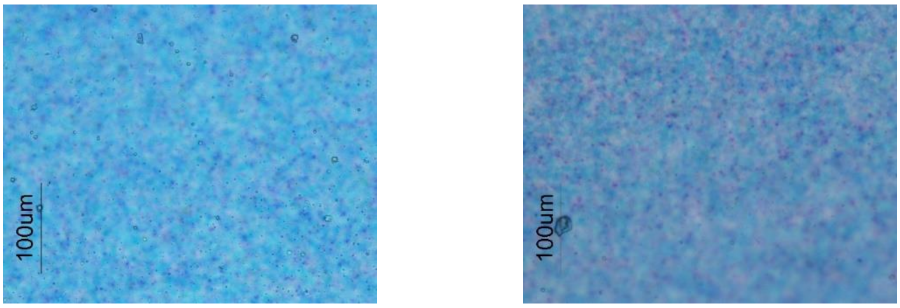
wt≈15%
T=60°C

225 days



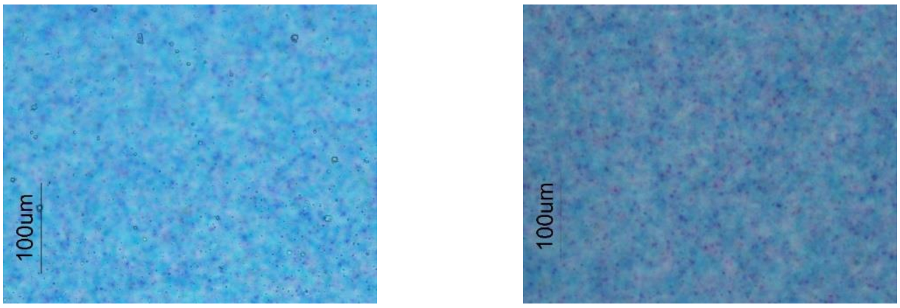
wt≈12.5%
T=70°C

120 days



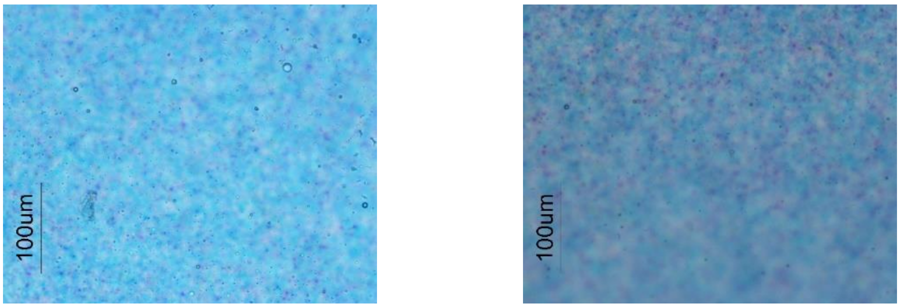
wt≈15%
T=70°C

120 days



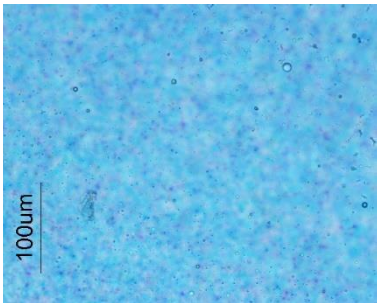
wt≈12.5%
T=80°C

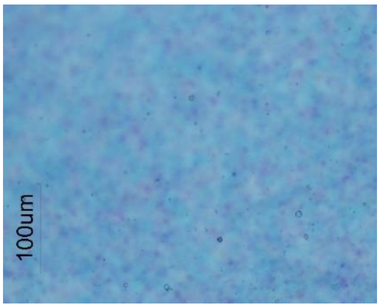
60 days



wt≈15%
T=80°C

60 days





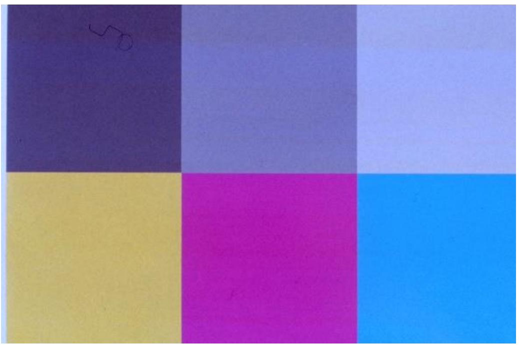
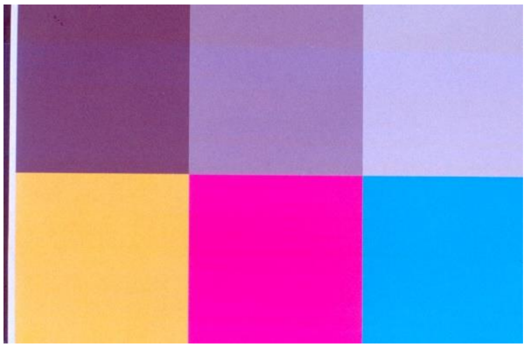
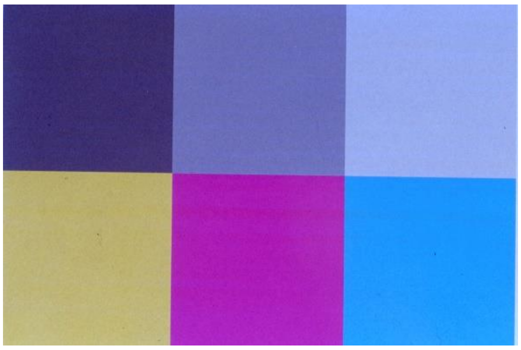
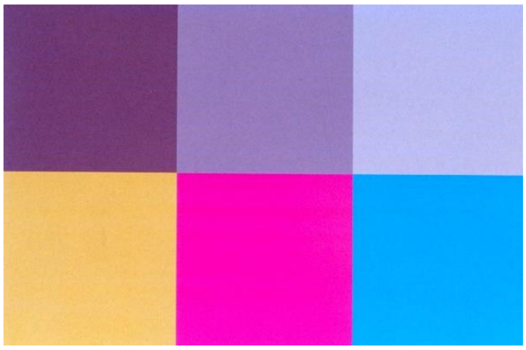
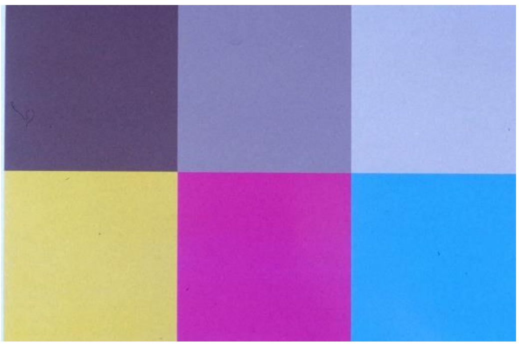
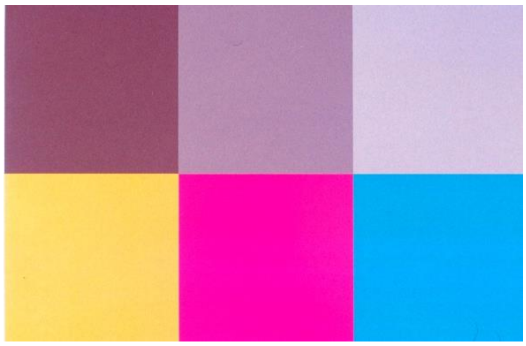
VI.4. Digitization

VI.4.1. Equipment and conditions

All RXP samples induced to artificial ageing were documented by digitizing the slides before and after ageing. The flatbed scanner Epson Perfection V600 was used for such purpose. All the images were scanned following the same parameters: i) the obtained TIFF images have 48 bits (colour) and 300 dpi of resolution, ii) the target size was adjusted based on the smaller side of the image, to fit 300 mm, iii) the colour profile attributed to the images was Adobe RGB (1998). The obtained image size was about 110 MB. These conditions were selected to obtain good quality images, without reaching too heavy and difficult to manage files.

VI.4.2. Digital images

Table VI.9 – Digital images from Fujichrome Provia 400 X Professional (RXP) samples with step-wedge, before (t_i) and after (t_f) artificial ageing test

	t_i	t_f
wt≈12.5% T=50°C 300 days		
wt≈15% T=50°C 300 days		
wt≈12.5% T=60°C 225 days		

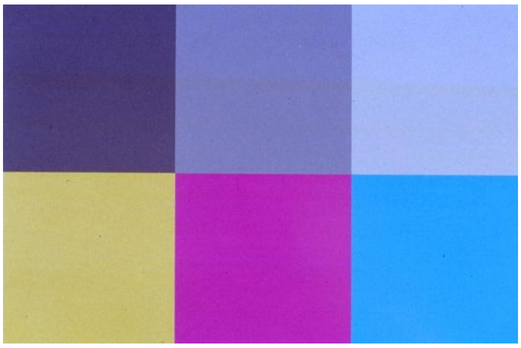
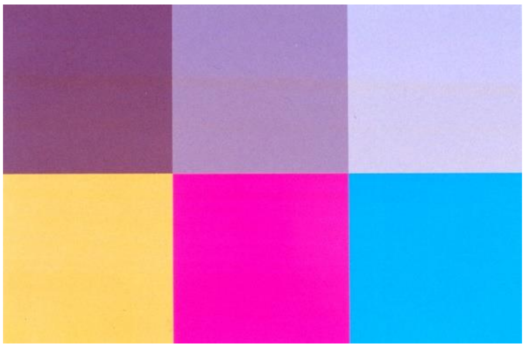
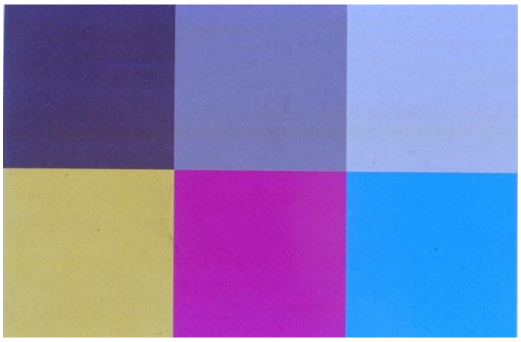
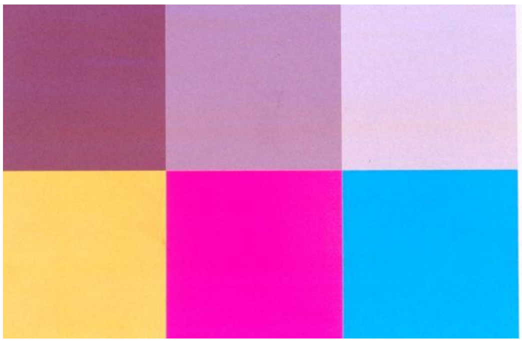
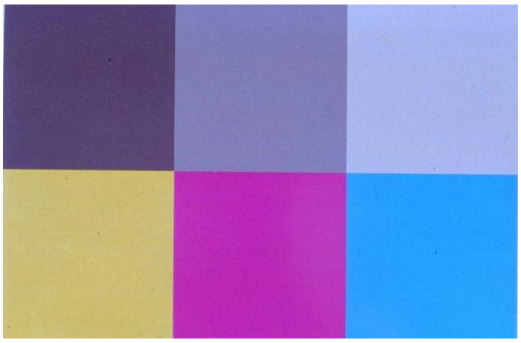
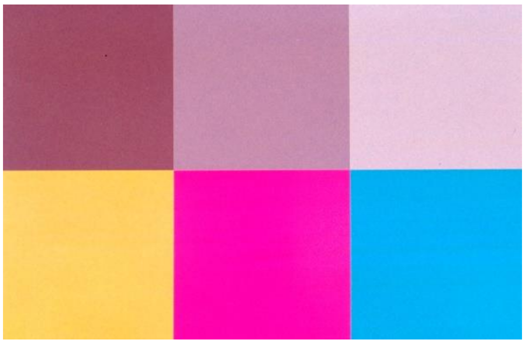
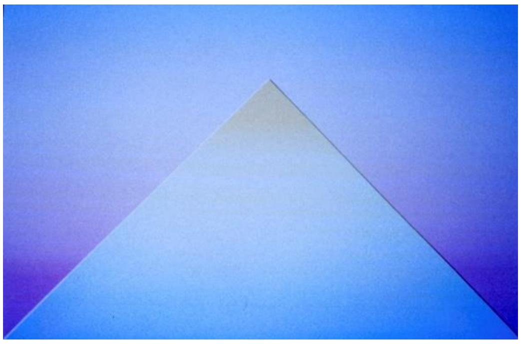
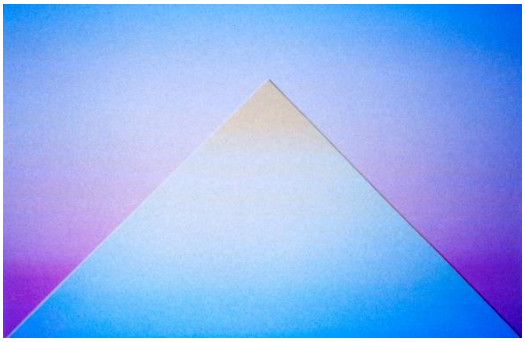
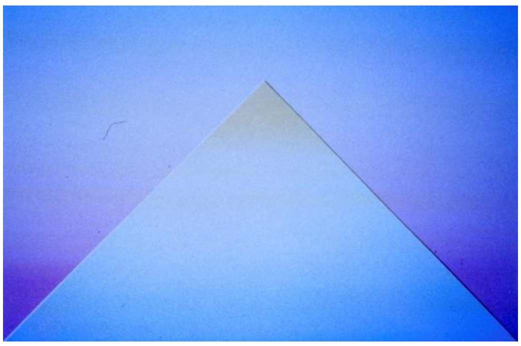
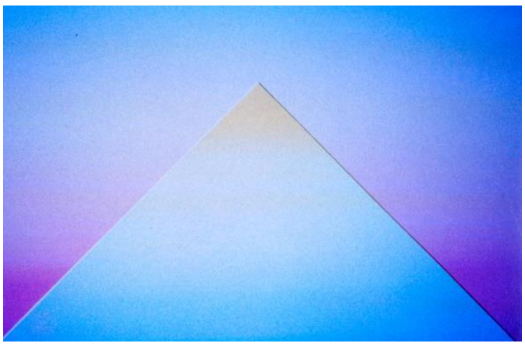
wt≈15% T=60°C 225 days		
wt≈12.5% T=70°C 120 days		
wt≈15% T=70°C 120 days		

Table VI.10 – Digital images from Fujichrome Provia 400X Professional (RXP) samples with image of the artwork, before (t_i) and after (t_f) artificial ageing test

	t_i	t_f
wt≈12.5% T=50°C 300 days		
wt≈15% T=50°C 300 days		

wt≈12.5%
T=60°C

225 days

wt≈15%
T=60°C

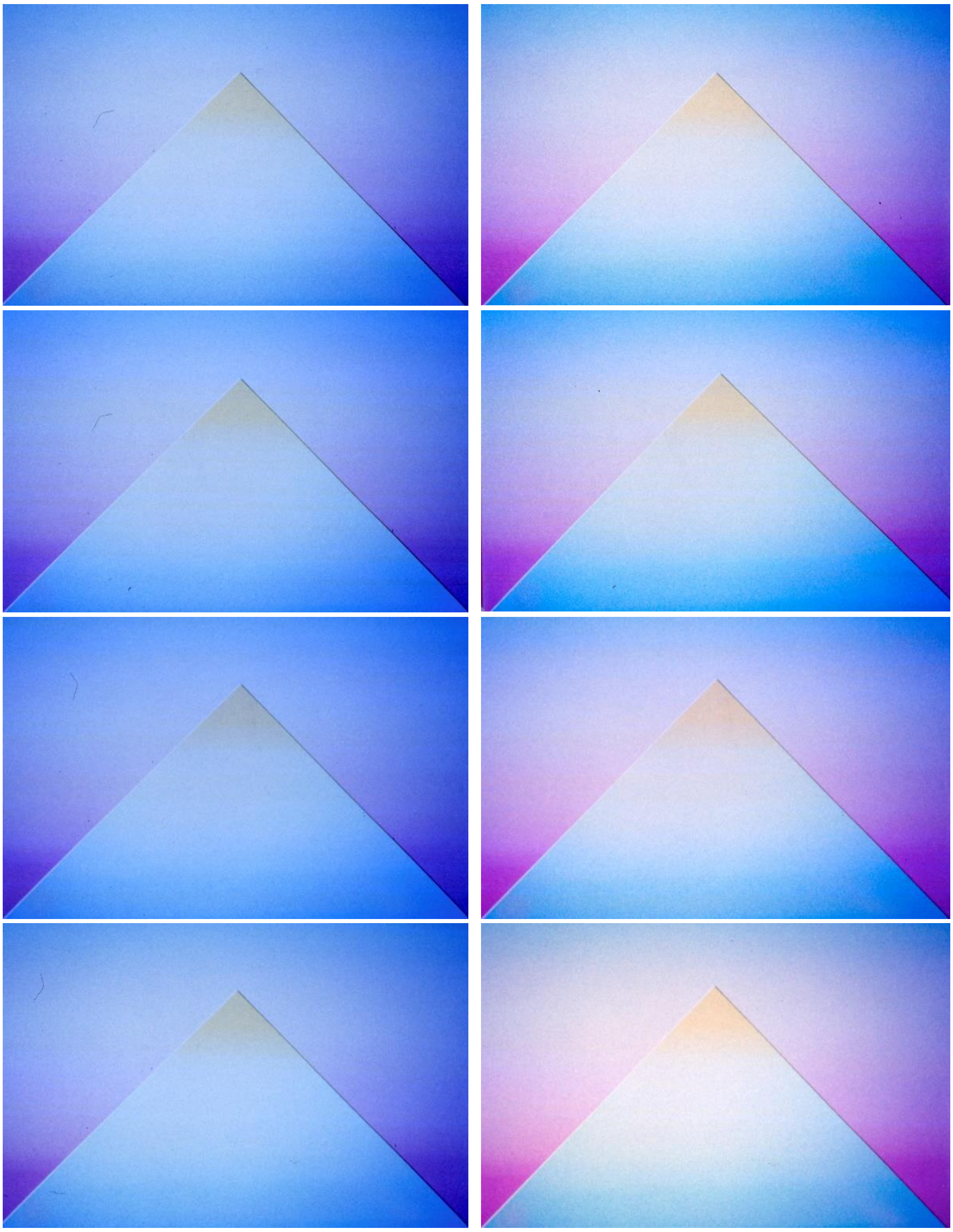
225 days

wt≈12.5%
T=70°C

120 days

wt≈15%
T=70°C

120 days



VI.4.3. Data analysis

RGB coordinates were calculated from digital images. The computations described next were made with a programme created in the open source software R. In order to assess the colour variation from the samples, before and after artificial ageing, the respective digital images were compared pixel by pixel according to the following code:

```
analyzeDiff<-function(imageFile1,imageFile2,coordinates) {
  options(warn=-1)

  library(tiff);
  image1<-readTIFF(imageFile1);
  image2<-readTIFF(imageFile2);
  ##cut images if necessay, in order to make them the same size
  minH<-min(dim(image1)[1],dim(image2)[1]);
  minW<-min(dim(image1)[2],dim(image2)[2]);
  image1<-image1[1:minH,1:minW,];
  image2<-image2[1:minH,1:minW,];

  if (coordinates=="RGB") {

  #######
  ##RGB##
  #######

  ##R
  difImage<-(image1[,,1])-(image2[,,1]);
  R_ABS<-sum(abs(difImage))/(dim(difImage)[1]*dim(difImage)[2]);
  R<-sum(difImage)/(dim(difImage)[1]*dim(difImage)[2]);

  ##G
  difImage<-(image1[,,2])-(image2[,,2]);
  G_ABS<-sum(abs(difImage))/(dim(difImage)[1]*dim(difImage)[2]);
  G<-sum(difImage)/(dim(difImage)[1]*dim(difImage)[2]);

  ##B
  difImage<-(image1[,,3])-(image2[,,3]);
  B_ABS<-sum(abs(difImage))/(dim(difImage)[1]*dim(difImage)[2]);
  B<-sum(difImage)/(dim(difImage)[1]*dim(difImage)[2]);

  result<-matrix(data<-
c(R_ABS,R,G_ABS,G,B_ABS,B),nrow=2,ncol=3,dimnames=list(c("Absolute
Value","Value"),c('Red (Cyan)','Green (Magenta)','Blue (Yellow)')));

  options(warn=-1);
  print(result);

  }

  else

    {

  #######
  ##LAB##
  #######
  image1Lab<-image1;
  image2Lab<-image2;
  deltaImage<-image2[,,1];

  ##Convert to LAB
   for (i in 1:dim(image1)[1]) {
     cat("\014");
     print(paste("Converting image1 to Lab coordinates:
",round(100*i/dim(image1)[1], 2), "%", sep=""));
     line<-do.call(cbind, list(image1[i,,1],image1[i,,2],image1[i,,3]));
     matrixLine<-matrix(line,ncol=3);
     labLine<-convertColor(matrixLine,from="sRGB",to="Lab");
     image1Lab[i,,1]<-labLine[,1];
     image1Lab[i,,2]<-labLine[,2];
     image1Lab[i,,3]<-labLine[,3];
   }

  for (i in 1:dim(image2)[1]) {
    cat("\014");
```

```
    print(paste("Converting image2 to Lab coordinates:
",round(100*i/dim(image2)[1], 2), "%", sep=""));
    line<-do.call(cbind, list(image2[i,,1],image2[i,,2],image2[i,,3]));
    matrixLine<-matrix(line,ncol=3);
    labLine<-convertColor(matrixLine,from="sRGB",to="Lab");
    image2Lab[i,,1]<-labLine[,1];
    image2Lab[i,,2]<-labLine[,2];
    image2Lab[i,,3]<-labLine[,3];
  }

  for (i in 1:dim(deltaImage)[1]) {
    cat("\014");
    print(paste("Calculating delta matrix: ",round(100*i/dim(deltaImage)[1], 2),
"%", sep=""));
    for (j in 1:dim(deltaImage)[2]) {
      deltaImage[i,j]<-sqrt((image2Lab[i,j,1]-
image1Lab[i,j,1])^2+(image2Lab[i,j,2]-image1Lab[i,j,2])^2+(image2Lab[i,j,3]-
image1Lab[i,j,3])^2);
    }
  }


  cat("\014");

  ##L
  difImage<-(image1Lab[,,1])-(image2Lab[,,1]);
  L_ABS<-sum(abs(difImage))/(dim(difImage)[1]*dim(difImage)[2]);
  L<-sum(difImage)/(dim(difImage)[1]*dim(difImage)[2]);

  ##A
  difImage<-(image1Lab[,,2])-(image2Lab[,,2]);
  A_ABS<-sum(abs(difImage))/(dim(difImage)[1]*dim(difImage)[2]);
  A<-sum(difImage)/(dim(difImage)[1]*dim(difImage)[2]);

  ##B
  difImage<-(image1Lab[,,3])-(image2Lab[,,3]);
  B_ABS<-sum(abs(difImage))/(dim(difImage)[1]*dim(difImage)[2]);
  B<-sum(difImage)/(dim(difImage)[1]*dim(difImage)[2]);

  ##Delta
  Delta<-sum(deltaImage)/(dim(deltaImage)[1]*dim(deltaImage)[2]);

  result<-matrix(data<-
c(L_ABS,L,A_ABS,A,B_ABS,B),nrow=2,ncol=3,dimnames=list(c("Absolute
Value","Value"),c('L','a','b')));

  options(warn=-1);
  print(result);
  print(paste("Delta:",Delta));

  };

  }
```

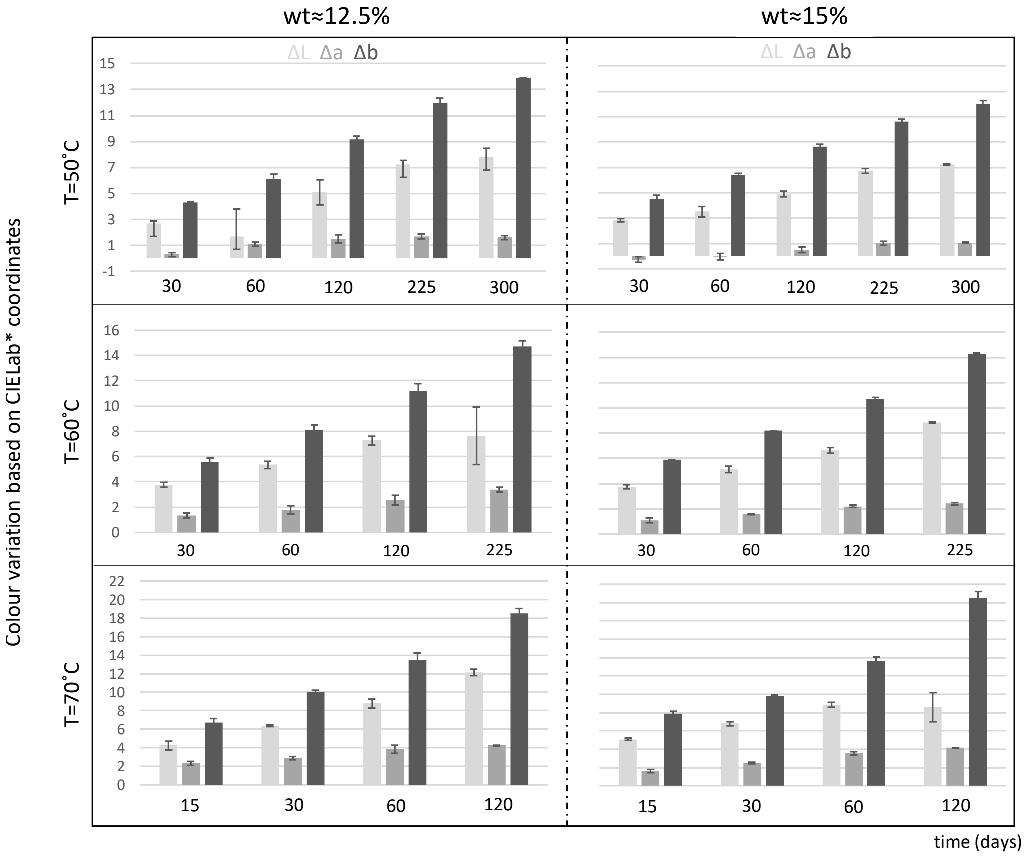


Figure VI.9 - Colour change variation based on CIE L*a*b* coordinates calculated from the RGB values of the overall digitised step-wedge samples, before and after artificial ageing at T=50, 60 and 70˚C.

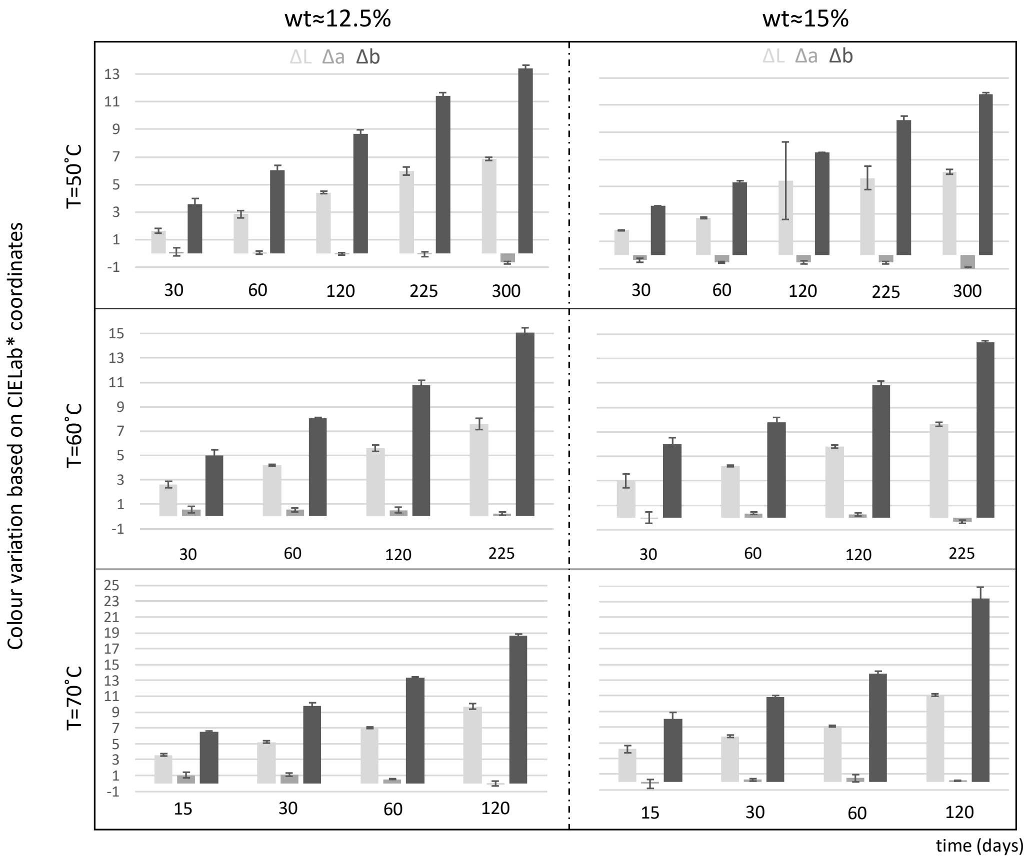


Figure VI.10 - Colour change variation based on CIE L*a*b* coordinates calculated from the RGB values of the overall digitised artwork samples, before and after artificial ageing at T=50, 60 and 70˚C.

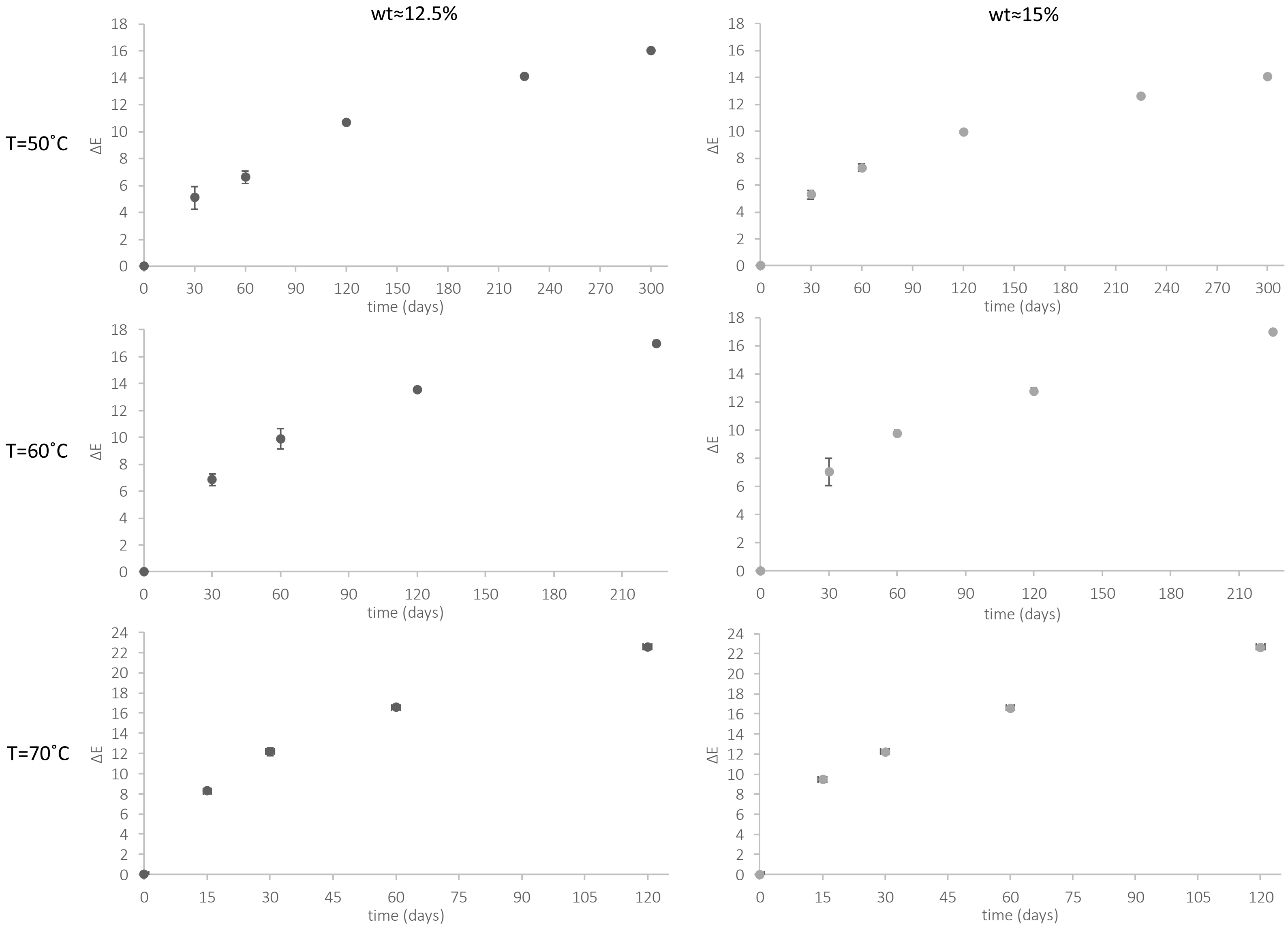


Figure VI.11 – Total colour change variation (ΔE*) calculated from the CIE L*a*b* coordinates variation calculated from the digitized step-wedge samples (overall image), upon ageing at water content (wt)≈12.5% (black scores) and wt≈15% (grey scores), and T=50, 60 and 70˚C.

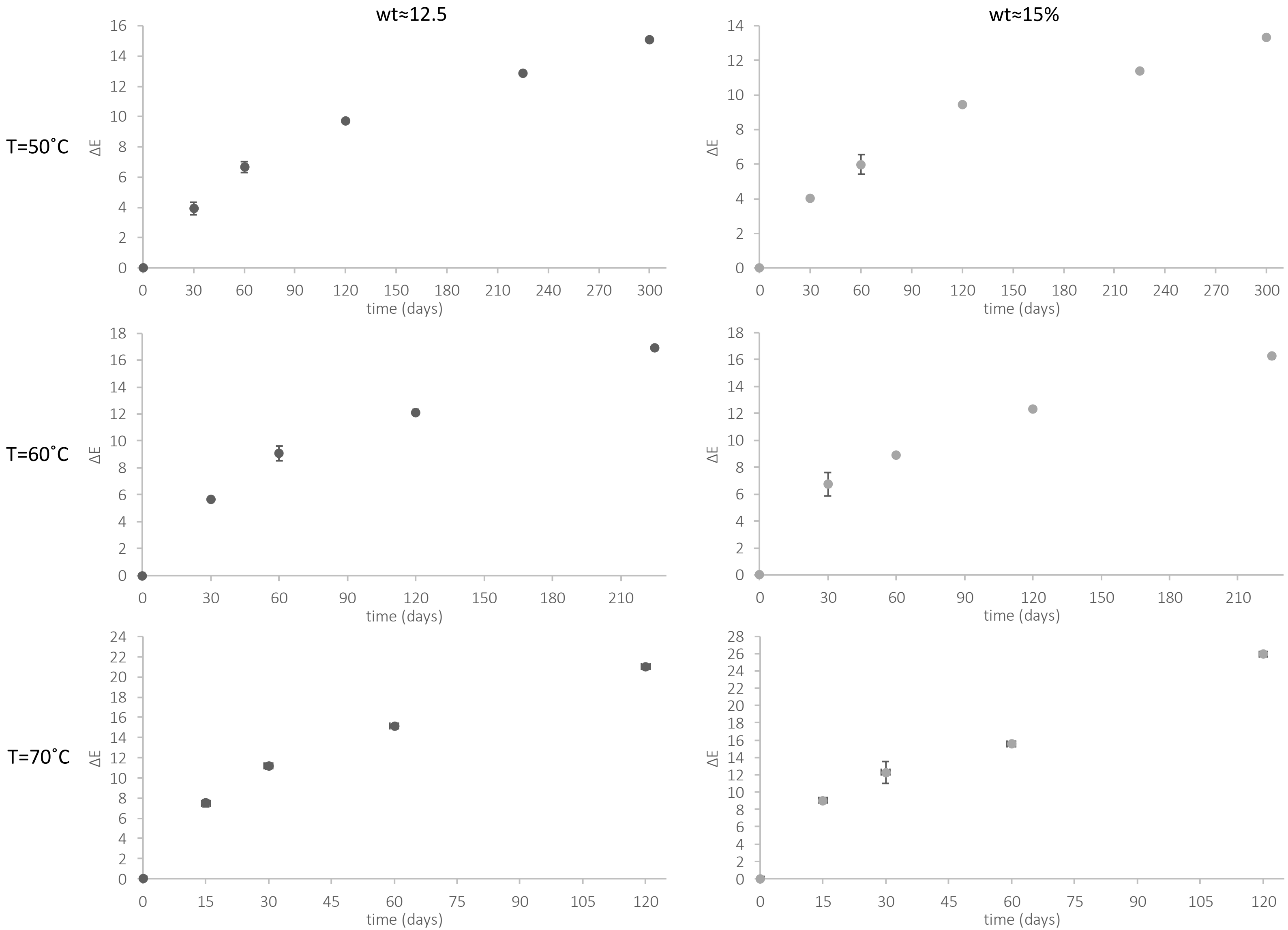


Figure VI.12 – Total colour change variation (ΔE*) calculated from the CIE L*a*b* coordinates variation calculated from the digitized artwork samples (overall image), upon ageing at water content (wt)≈12.5% (black scores) and wt≈15% (grey scores), and T=50, 60 and 70˚C.

VI.5. Attenuated total reflectance infrared spectroscopy (ATR-FTIR)

VI.5.1. Equipment and conditions

Infrared analyses were also performed with Agilent 4300 Handheld FTIR Spectrometer in ATR mode. Spectra were acquired in a spectral range between 4000 and 650 cm^{-1}, with spectral resolution of 4 cm^{-1} and 128 scans before Fourier transform. Background was updated every 6 min. Data was collected with MicroLab® software. RXP samples were analysed before and after artificial ageing. Each sample was analysed in 3 different spots (top, middle and bottom of the sample) on both gelatine and base sides. This technique was also used for the immediate identification of the base support of the films and plastic mountings studied within the framework of this dissertation.

Regarding the assessment of the degradation in RXP samples induced to artificial ageing, spectral analysis was performed using Omnic E.S.P. 5.2 and OriginPro 8 software. All spectra of the samples' base were baseline-corrected at circa 3745, 2535, 2160, 1990, 1540, 1340, 800 and 715 cm^{-1} absorption frequencies. The spectra were normalised to C–O–C absorption at 1030 cm^{-1} associated to the stretching of the anhydroglucose ring in the cellulose acetate base[9]. This peak was identified as the most intense and stable absorption during ageing. All spectra of the gelatine emulsion were baseline-corrected at circa 3755, 1960, 1835, 900 and 825 cm^{-1} absorption frequencies. The spectra were normalised to amide I absorption[10] at 1630 cm^{-1}. As all the peaks of the spectra slightly changed over time, this peak was considered of particular interest to compare the ratio amide I/amide II and to understand the degradation occurring upon ageing.

VI.5.2. Spectra

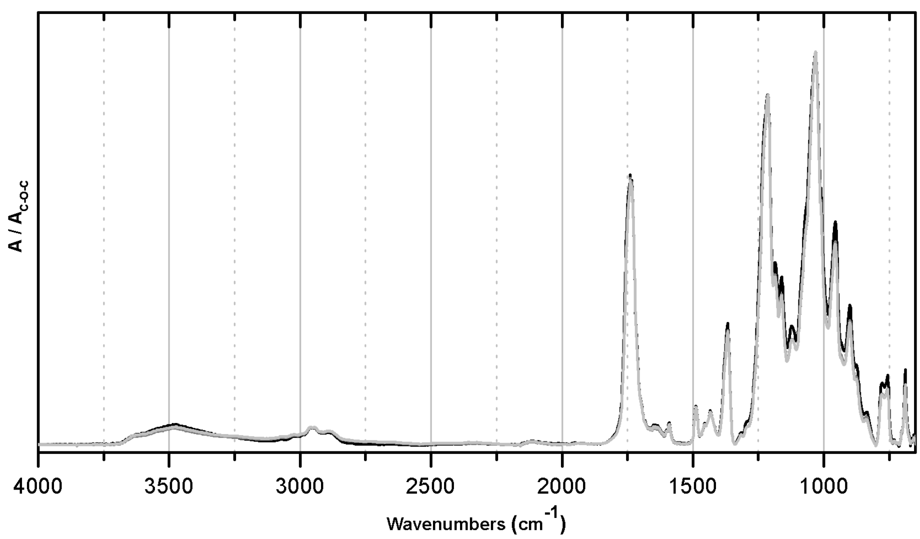


Figure VI.13 – Infrared spectra of the cellulose acetate base from samples before (black line), after 120 days (dark grey line) and 300 days (light grey line) of artificial ageing at T=50˚C and water content (wt)≈12.5%.

[9] Roldão, E. 2018. A contribution for the preservation of cellulose esters black and white negatives, PhD Thesis, Universidade Nova de Lisboa, 139.

[10] Daniel-da-Silva, A. L., Trindade, T., Salgueiro, A. 2013. Effects of Au nanoparticles on thermoresponsive genipin-crosslinked gelatin hydrogels. In in Gold bulletin, March, 4. DOI: 10.1007/s13404-012-0078-1

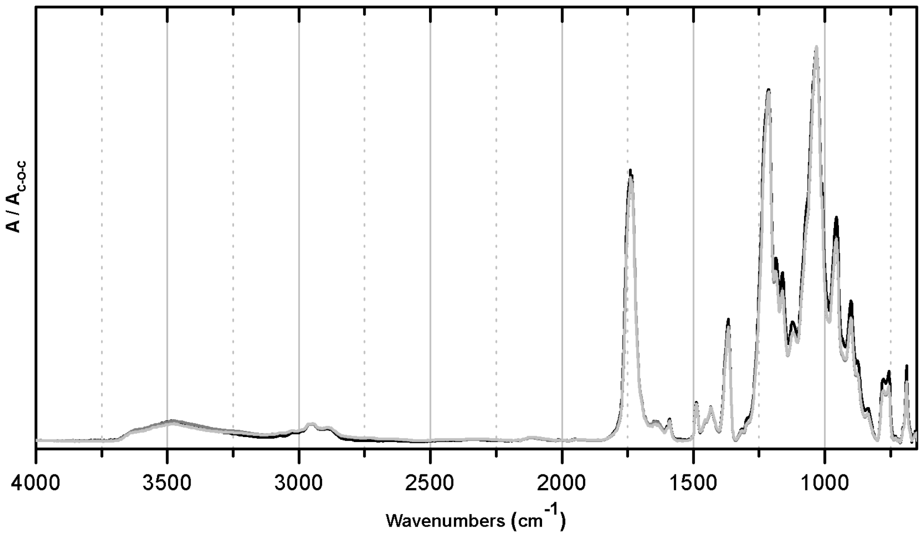


Figure VI.14 – Infrared spectra of the cellulose acetate base from samples before (black line), after 120 days (dark grey line) and 300 days (light grey line) of artificial ageing at T=50˚C and water content (wt)≈15%.

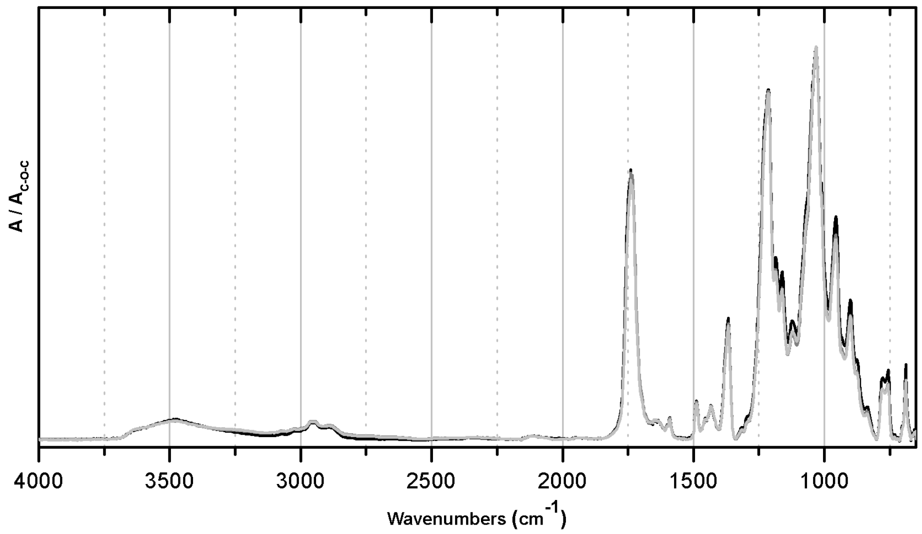


Figure VI.15 – Infrared spectra of the cellulose acetate base from samples before (black line), after 120 days (dark grey line) and 225 days (light grey line) of artificial ageing at T=60˚C and water content (wt)≈12.5%.

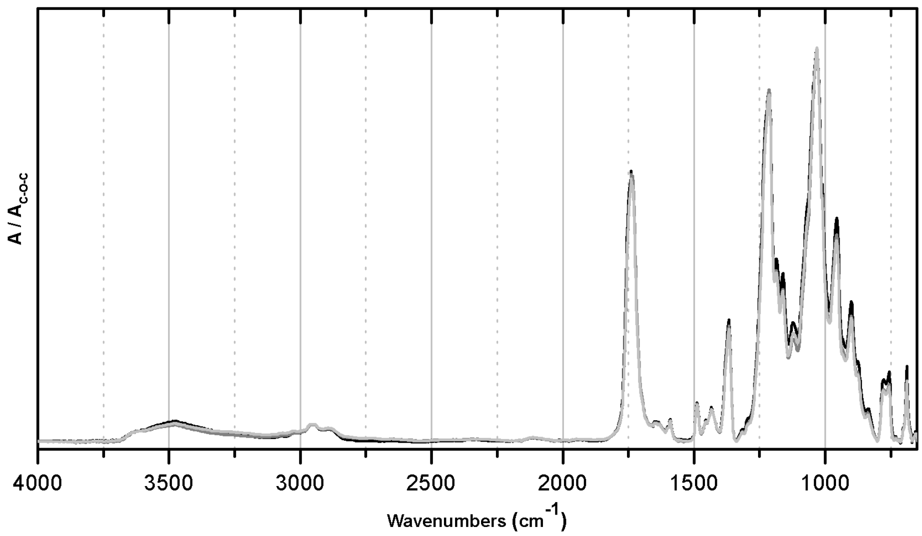


Figure VI.16 – Infrared spectra of the cellulose acetate base from samples before (black line), after 120 days (dark grey line) and 225 days (light grey line) of artificial ageing at T=60˚C and water content (wt)≈15%.

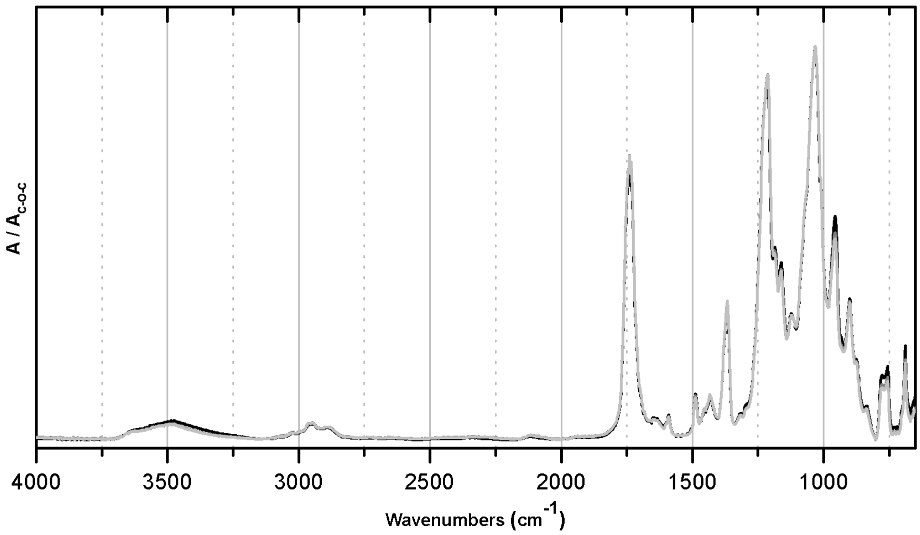


Figure VI.17 - Infrared spectra of the cellulose acetate base from samples before (black line), after 60 days (dark grey line) and 120 days (light grey line) of artificial ageing at T=70˚C and water content (wt)≈12.5%.

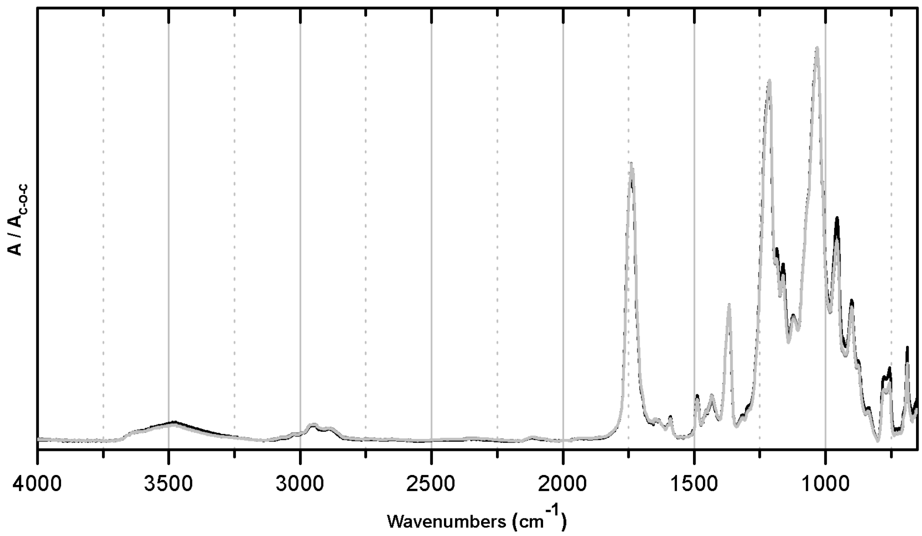


Figure VI.18 – Infrared spectra of the cellulose acetate base from samples before (black line), after 60 days (dark grey line) and 120 days (light grey line) of artificial ageing at T=70˚C and water content (wt)≈15%.

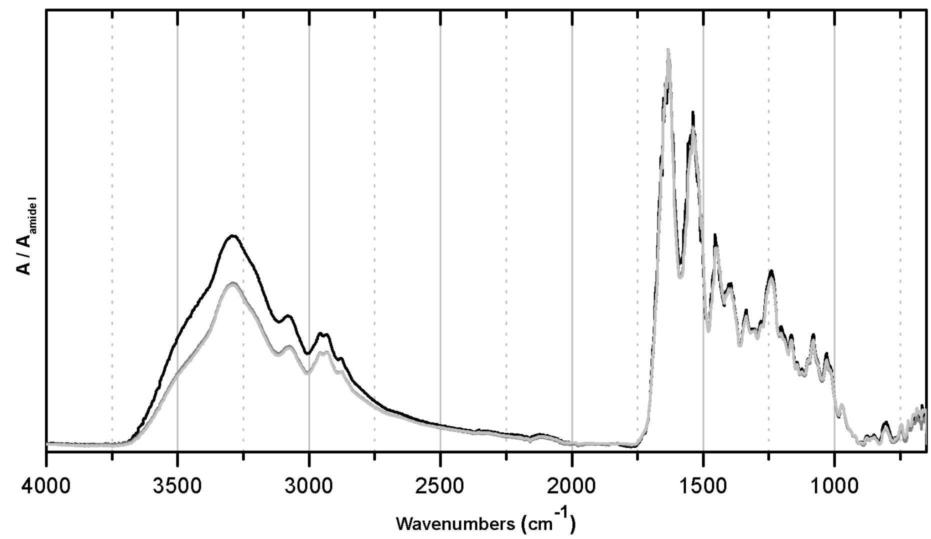


Figure VI.19 – Infrared spectra of the gelatine emulsion from samples before (black line), after 120 days (dark grey line) and 300 days (light grey line) of artificial ageing at T=50˚C and water content (wt)≈12.5%.

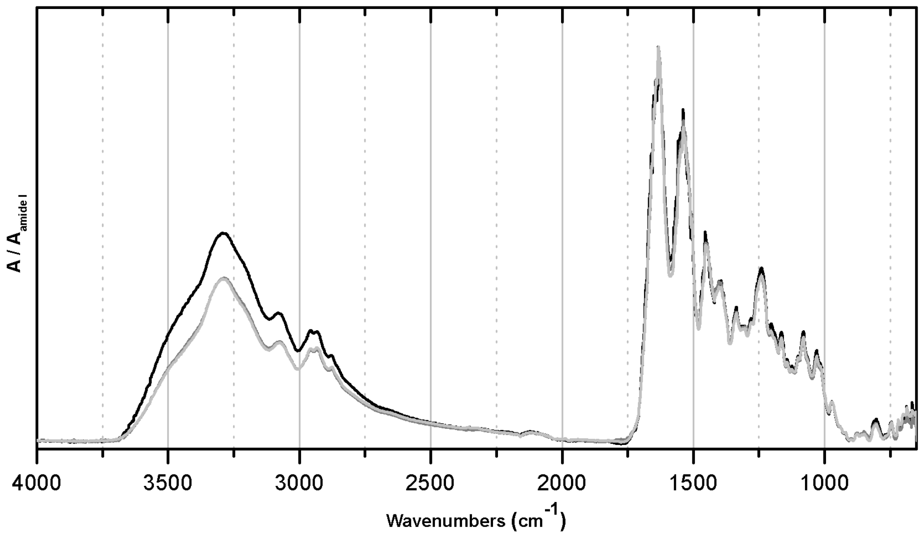


Figure VI.20 – Infrared spectra of the gelatine emulsion from samples before (black line), after 120 days (dark grey line) and 300 days (light grey line) of artificial ageing at T=50˚C and water content (wt)≈15%.

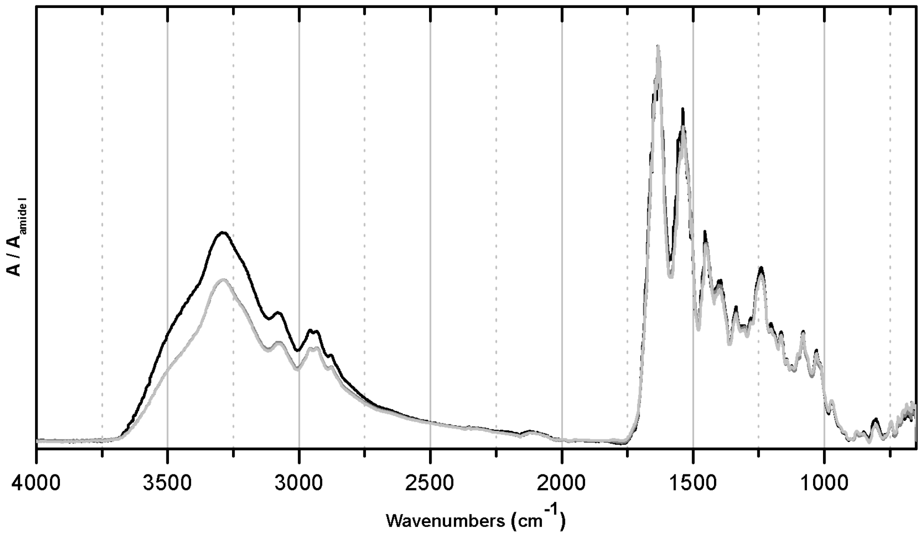


Figure VI.21 – Infrared spectra of the gelatine emulsion from samples before (black line), after 120 days (dark grey line) and 225 days (light grey line) of artificial ageing at T=60˚C and water content (wt)≈12.5%.

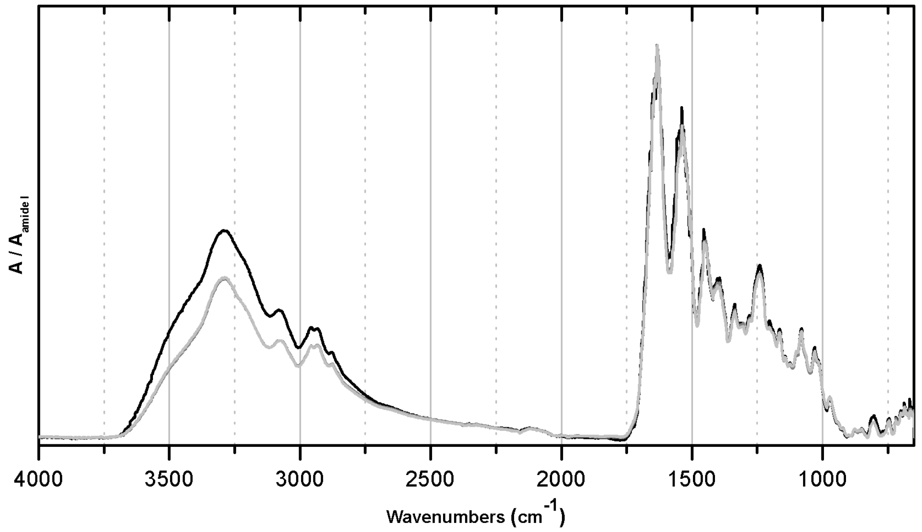


Figure VI.22 – Infrared spectra of the gelatine emulsion from samples before (black line), after 120 days (dark grey line) and 225 days (light grey line) of artificial ageing at T=60˚C and water content (wt)≈15%.

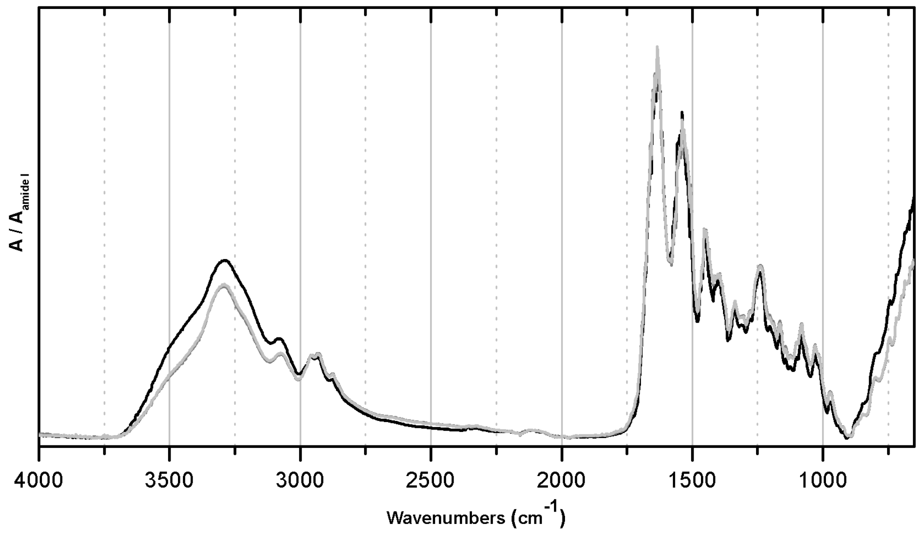


Figure VI.23 – Infrared spectra of the gelatine emulsion from samples before (black line), after 60 days (dark grey line) and 120 days (light grey line) of artificial ageing at T=70˚C and water content (wt)≈12.5%.

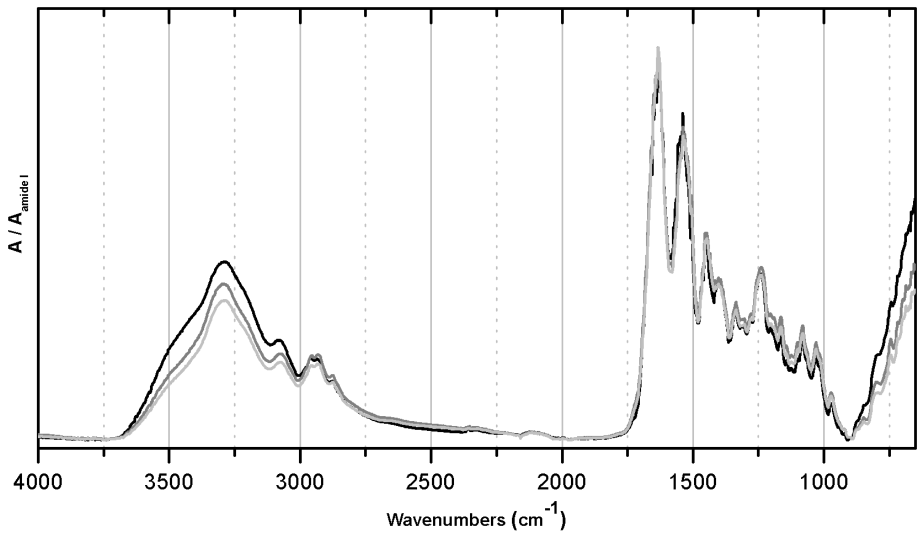


Figure VI.24 – Infrared spectra of the gelatine emulsion from samples before (black line), after 60 days (dark grey line) and 120 days (light grey line) of artificial ageing at T=70˚C and water content (wt)≈15%.

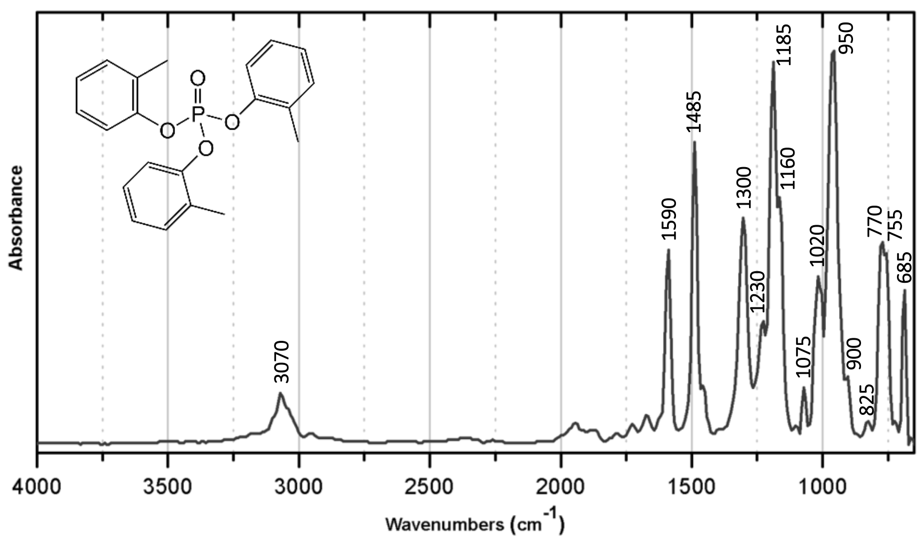


Figure VI.25 – Reference infrared spectra of triphenyl phosphate.

Table VI.11 – Characteristic absorptions in the infrared for polystyrene[11]

Wavenumber (cm^{-1})	Type of vibration	Assignment
3150-3000	stretching	$=CH_2$
3000-2840	asymmetric and symmetric stretching	CH_2 and CH_3
1600-1372	stretching	benzene ring
1181	in-plane deformation	=CH
1154	in-plane deformation	=CH
1069	in-plane deformation	=CH
1028	in-plane deformation	=CH
906	out-of-plane deformation	=CH
841	out-of-plane deformation	=CH
749	out-of-plane deformation	=CH

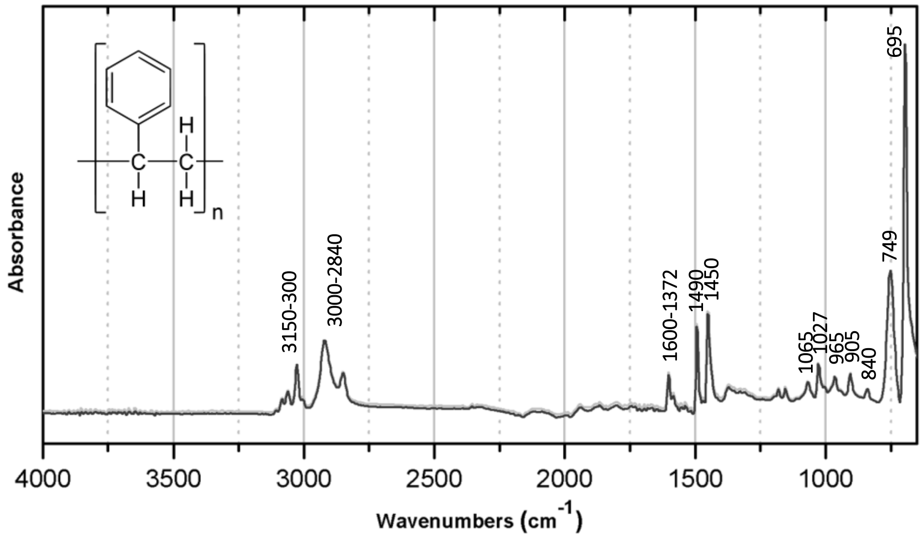


Figure VI.26 – Infrared spectra from the polystyrene mounting of the samples induced to artificial ageing, before (dark grey line) and after (light grey line) ageing. The presence of the characteristic butadiene peak can be seen at 965 cm^{-1}.

[11] Shashoua, Y. 2008. *Conservation of Plastics - Materials Science, Degradation and Preservation*. Oxford: Butterworth-Heinemann.

VI.6. UV-vis spectrophotometry

VI.6.1. Equipment and conditions

Absorbance spectra were acquired using a Varian Cary 5000 spectrophotometer and Software Scan. The measurements were done on a specific small area of the image (Ø = ± 1 mm) by using UV-Vis optical fibre probes. The spectra were acquired in transmittance mode, in a spectral range from 300 to 800 nm. The acquisition average time was 0.066 s and the scan rate 909 nm/min. The samples were placed in a variable collimating lens holder for optical fibre probes, being the samples analysed in 0˚ angle (perpendicularly to the light beam) in transmittance mode. The analyses were performed in the dark to reduce light interaction with the sample (Fig. VI.27).

For colorimetric calculations, the standards observer CIE 1931 and Illuminant D65 were considered.

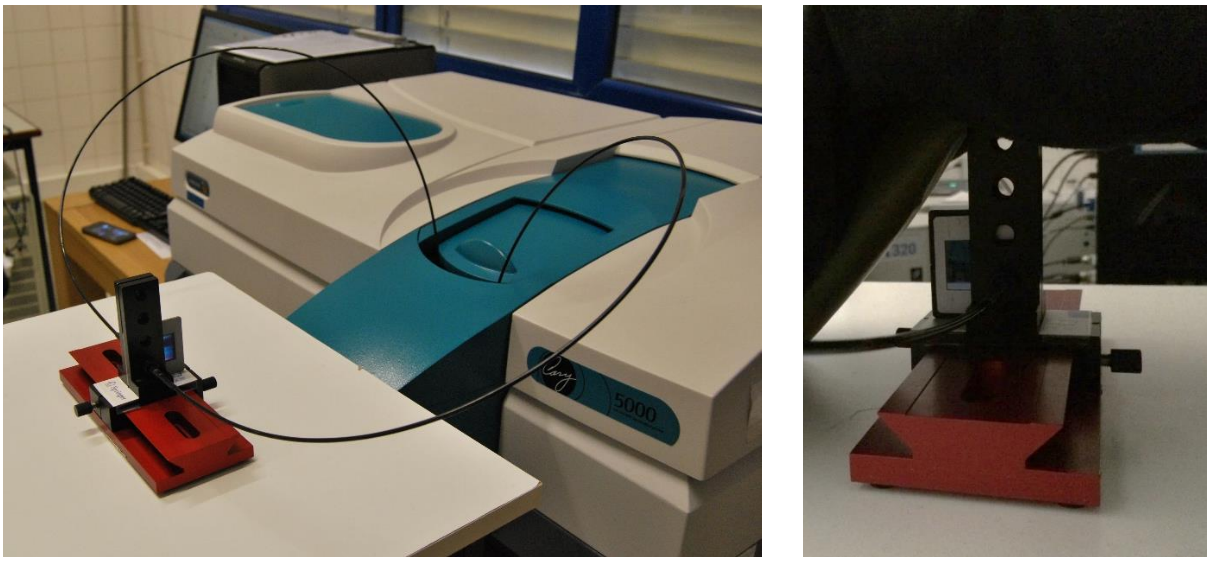


Figure VI.27 – UV-vis spectrophotometer Cary Varian 5000 with optical fibre probes; **Left:** general view of the equipment, **Right**: sample placed in a variable collimating lens holder for optical fibre probes.

VI.6.2. Ageing studies

Regarding the artificially aged samples, every step-wedge sample was analysed in six spots (N80, N50, N18, Y, M and C) and every artwork sample in four different spots (magenta, cyan, yellowish and whitish areas), before and after ageing (Fig. VI.28). Since every artificial ageing condition had tripled samples and no significant variations were detected when analysing the same area at first, only one spectrum was collected per spot.

The collected UV-Vis spectra were treated by recording the intensity maximums at 441 nm (absorbance maximum of the yellow dye), 558 nm (absorbance maximum of the magenta dye) and 657 nm (absorbance maximum of the cyan dye) before and after artificial ageing. The intensity variation was calculated in order to understand the behaviour of each dye independently. Moreover, the spectra were used to calculate CIE L*a*b* coordinates and the total colour variation (ΔE*) for all aged samples.

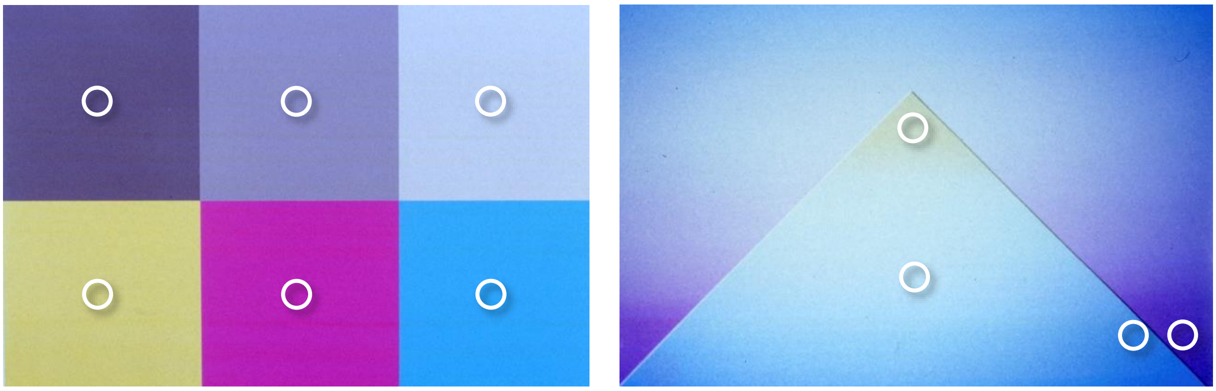


Figure VI.28 – Areas of analysis with the UV-Vis spectrophotometer (marked with white circles) in the step-wedge and artwork samples induced to artificial ageing tests.

A selection of slide-based artworks by Ângelo de Sousa are being monitored for colour change by using UV-vis spectrophotometry. 6 slides from the artwork *Slides de Cavalete* (1978-1979) (3 triangles: slide 15, 20 and 54; and 3 rectangles: slide 58, 61 and 90) (Fig. VI.29) and 15 test slides produced within the outline of *Slides de Cavalete* (Fig. VI.30), were selected. Only slides presenting relatively homogenous coloured areas for analysis were chosen. Each slide was analysed in the four corners, and each analysis was repeated 3 times.

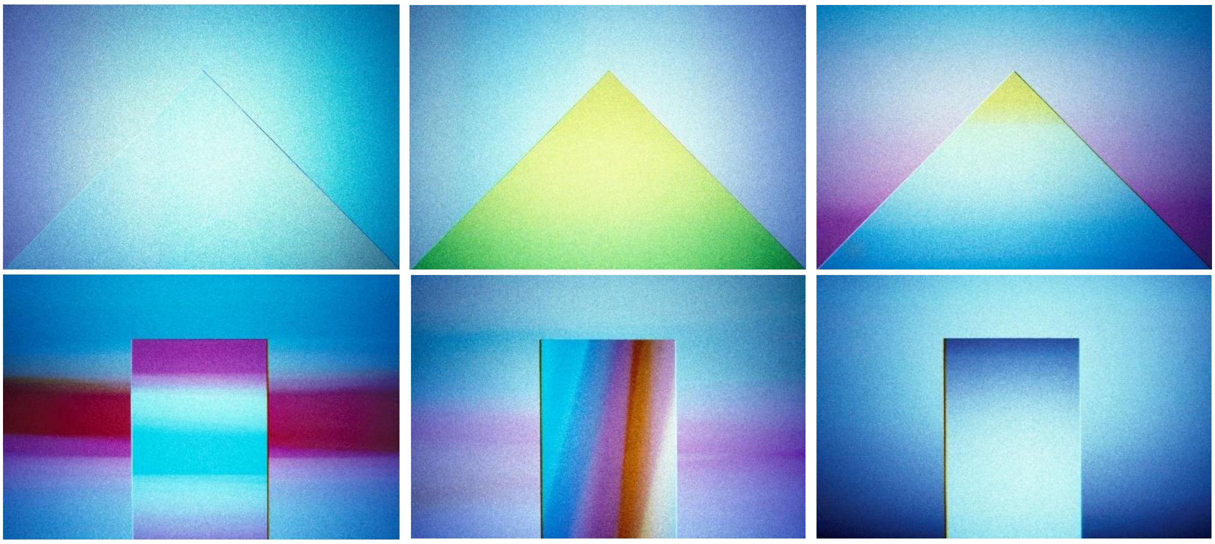


Figure VI.29 – Selection of slides (15, 20, 54, 58, 61 and 90, respectively) from the work *Slides de Cavalete* (1978-1979), analysed with UV-Vis spectrophotometry.

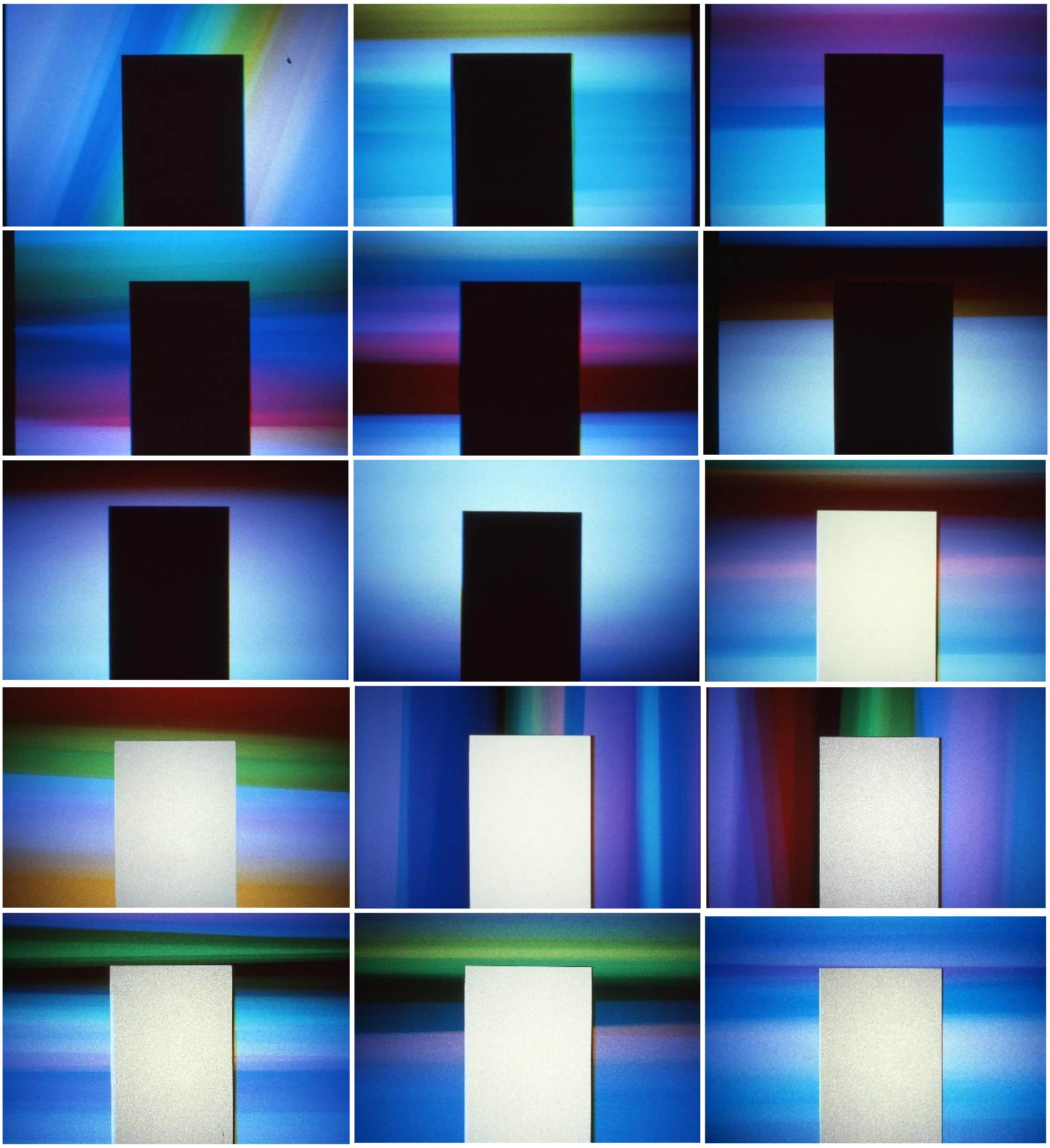


Figure VI.30 – Selection of slides produced within the outline of the work *Slides de Cavalete* (1978-1979), analysed with UV-Vis spectrophotometry.

VI.6.2.1. Intensity maximum variation in artificially aged samples

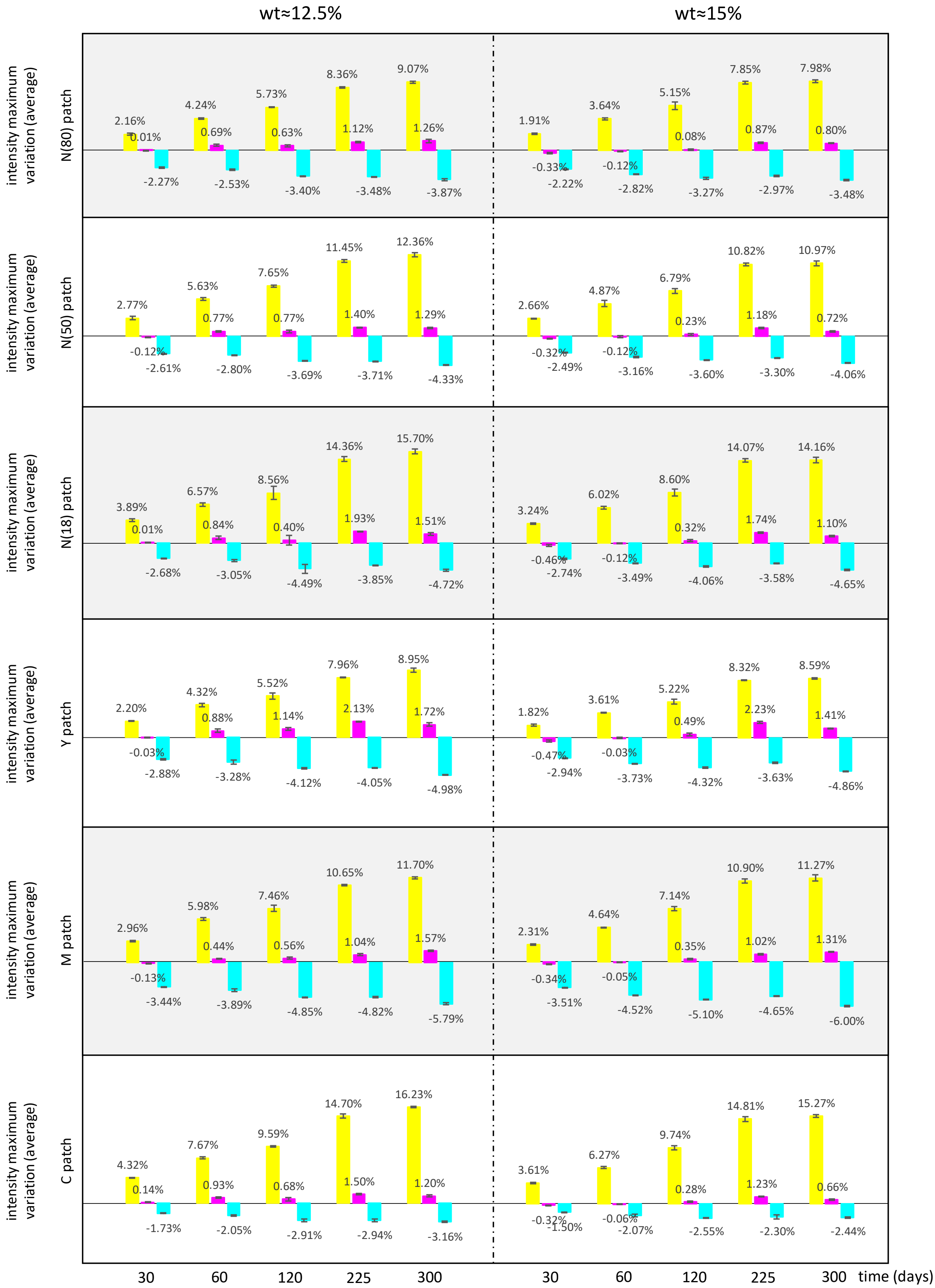


Figure VI.31 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the step-wedge samples before and after artificial ageing at T=50˚C.

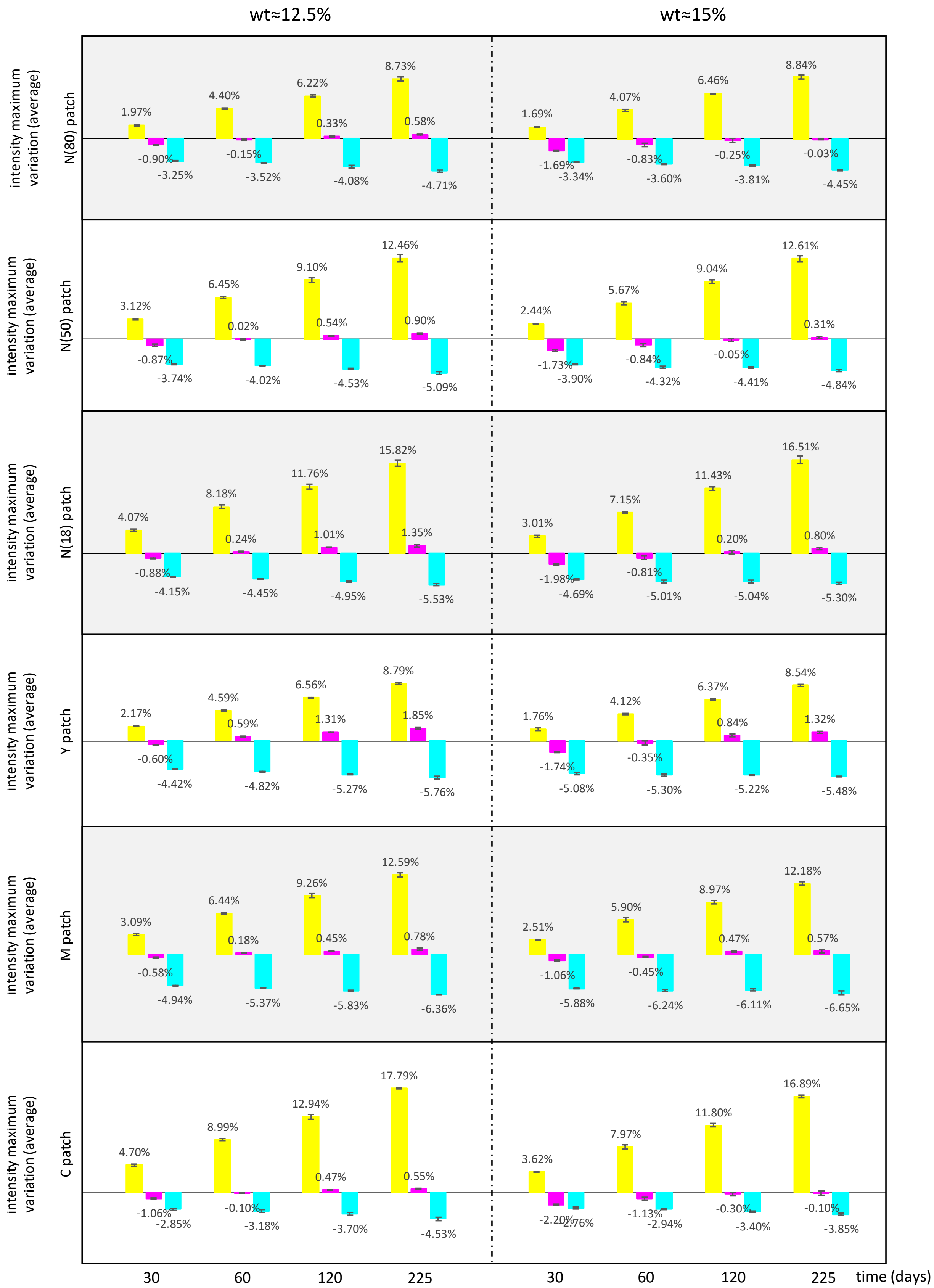


Figure VI.32 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance of the step-wedge samples before and after artificial ageing at T=60˚C.

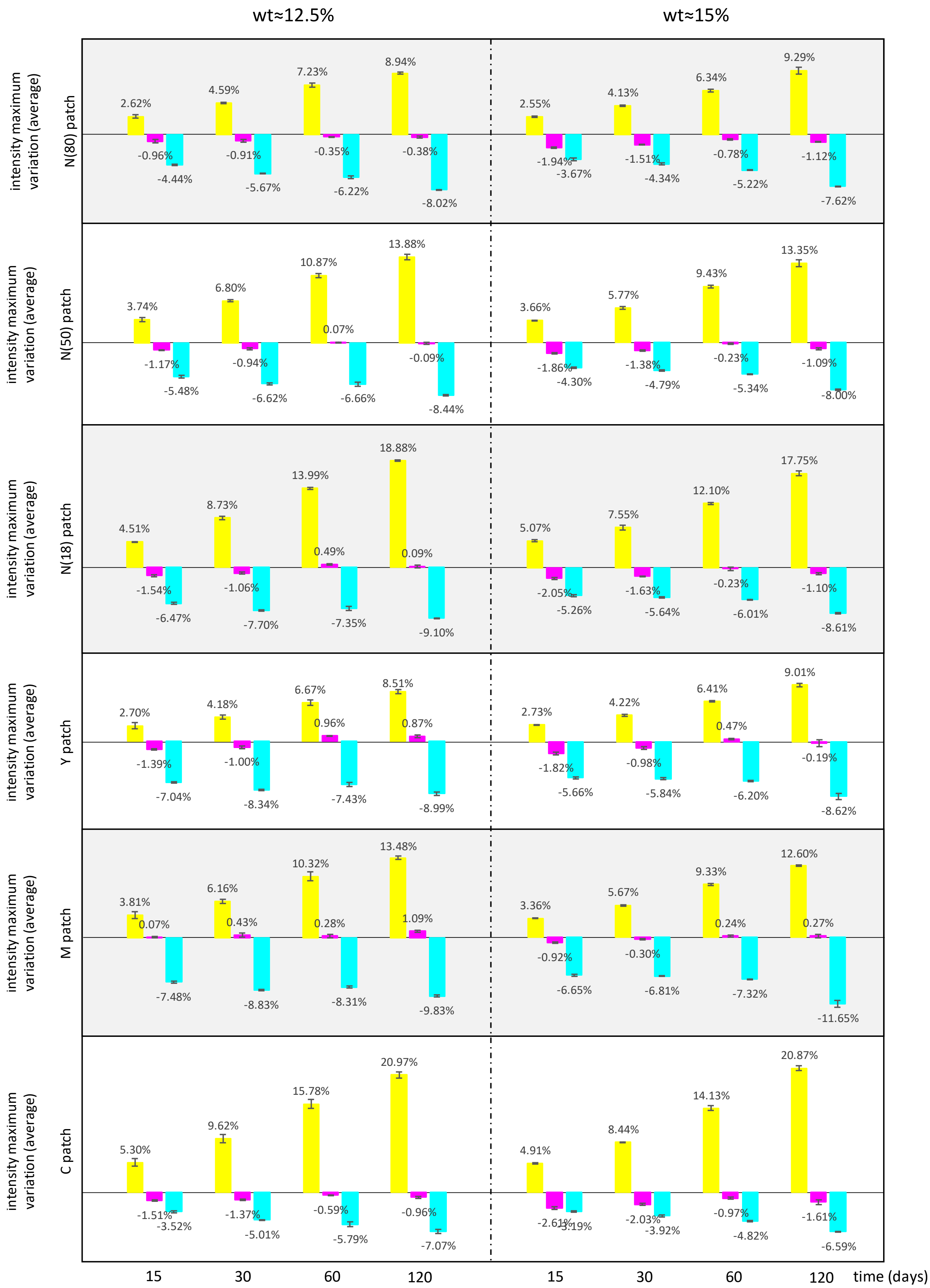


Figure VI.33 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the step-wedge samples before and after artificial ageing at T=70˚C.

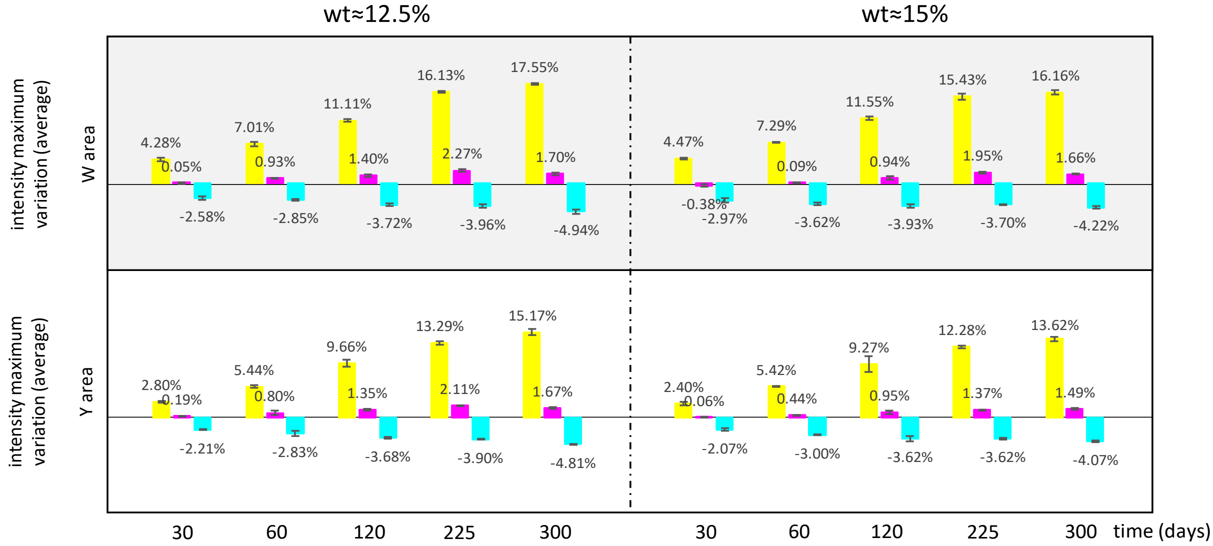


Figure VI.34 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the artwork samples before and after artificial ageing at T=50˚C.

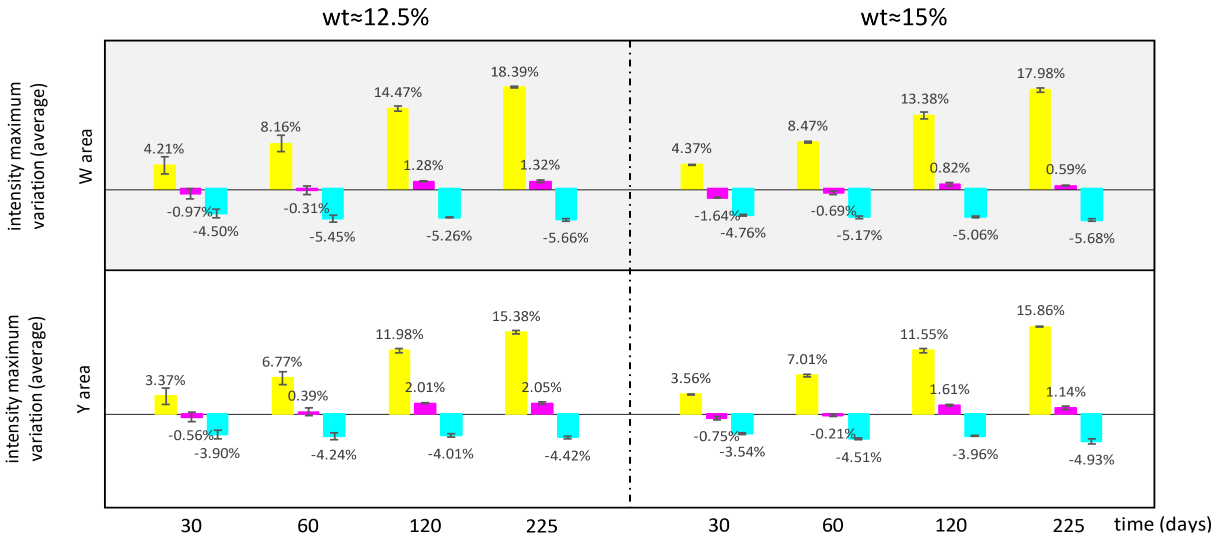


Figure VI.35 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the artwork samples before and after artificial ageing at T=60˚C.

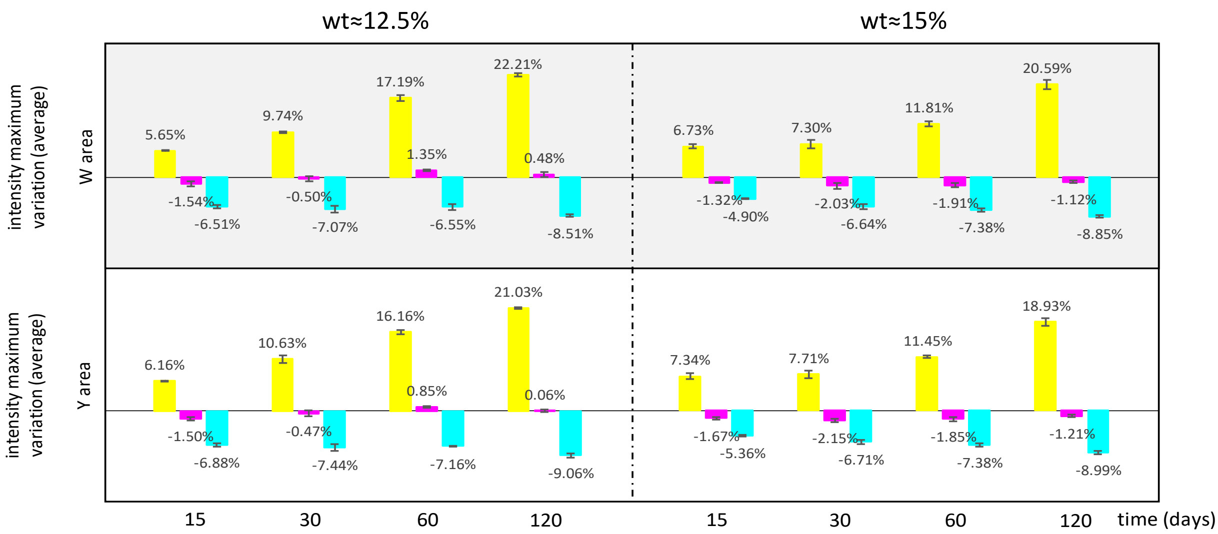


Figure VI.36 - Intensity maximum variation (average %) at 441 nm (yellow dye), 558 nm (magenta dye) and 657 nm (cyan dye), obtained from the absorbance spectra of the artwork samples before and after artificial ageing at T=70˚C.

*VI.6.2.2. CIE L*a*b* coordinates and ΔE* variation in artificially aged samples*

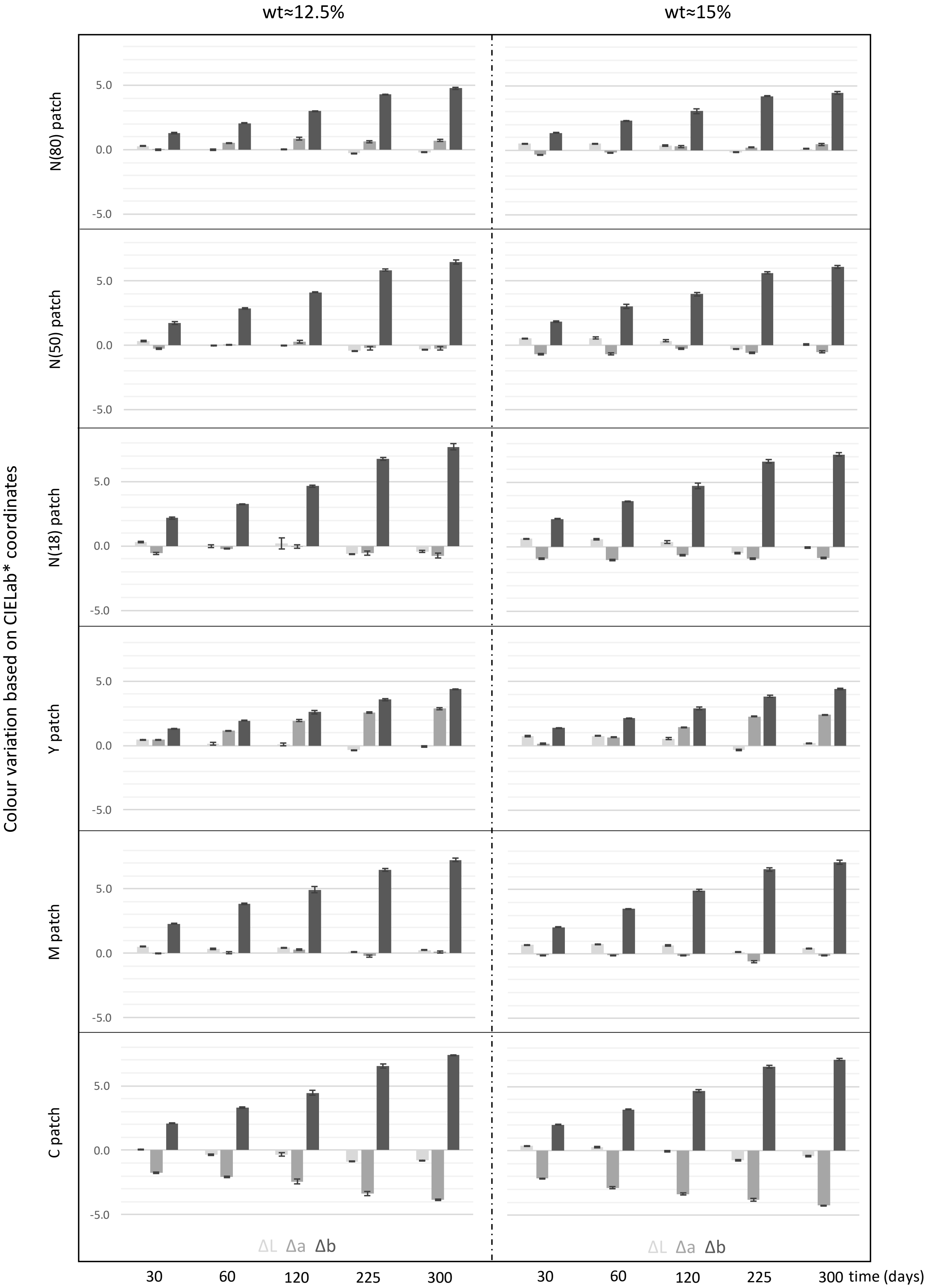


Figure VI.37 – Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the step-wedge samples, before and after artificial ageing at T=50˚C.

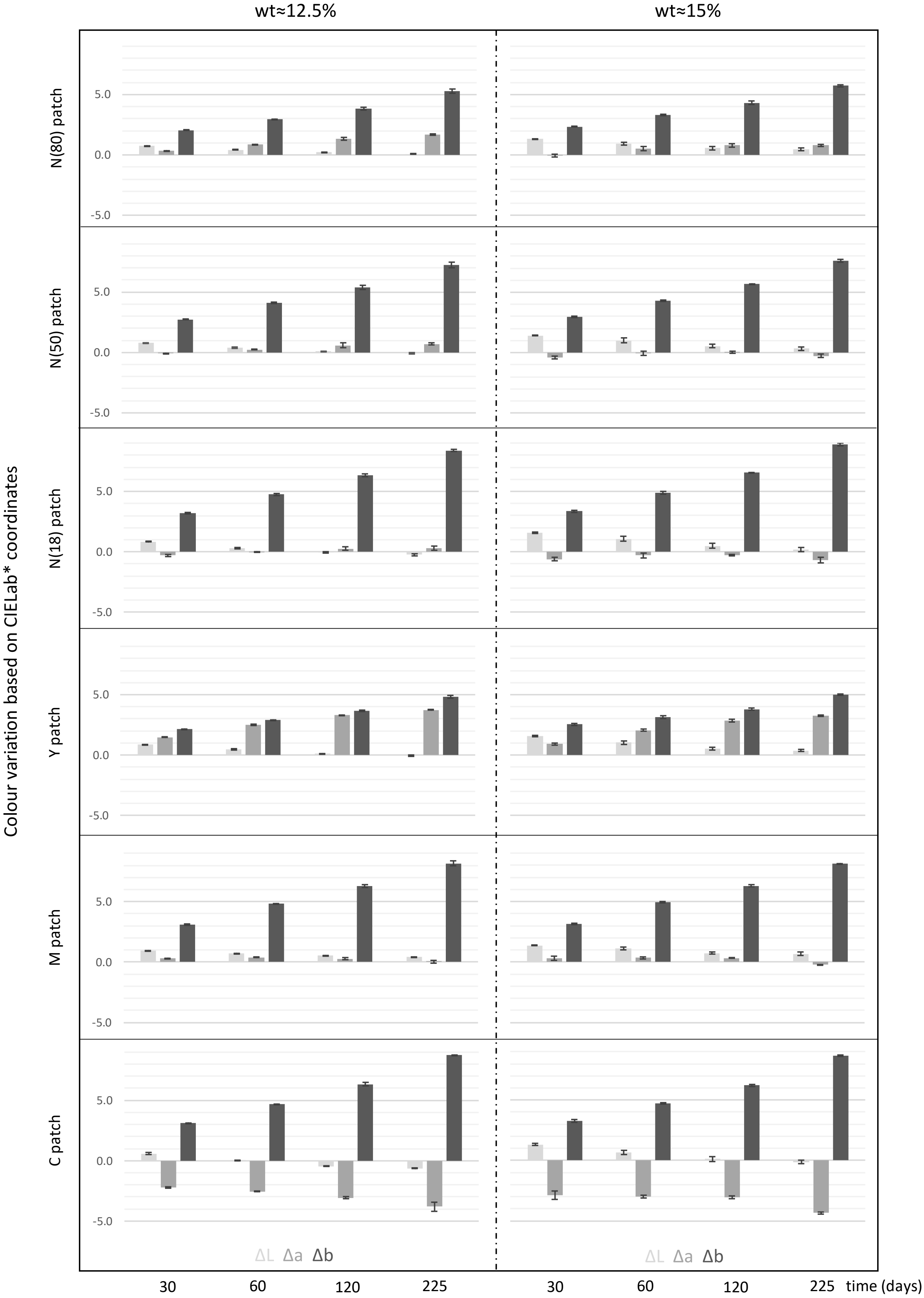


Figure VI.38 – Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the step-wedge samples, before and after artificial ageing at T=60˚C.

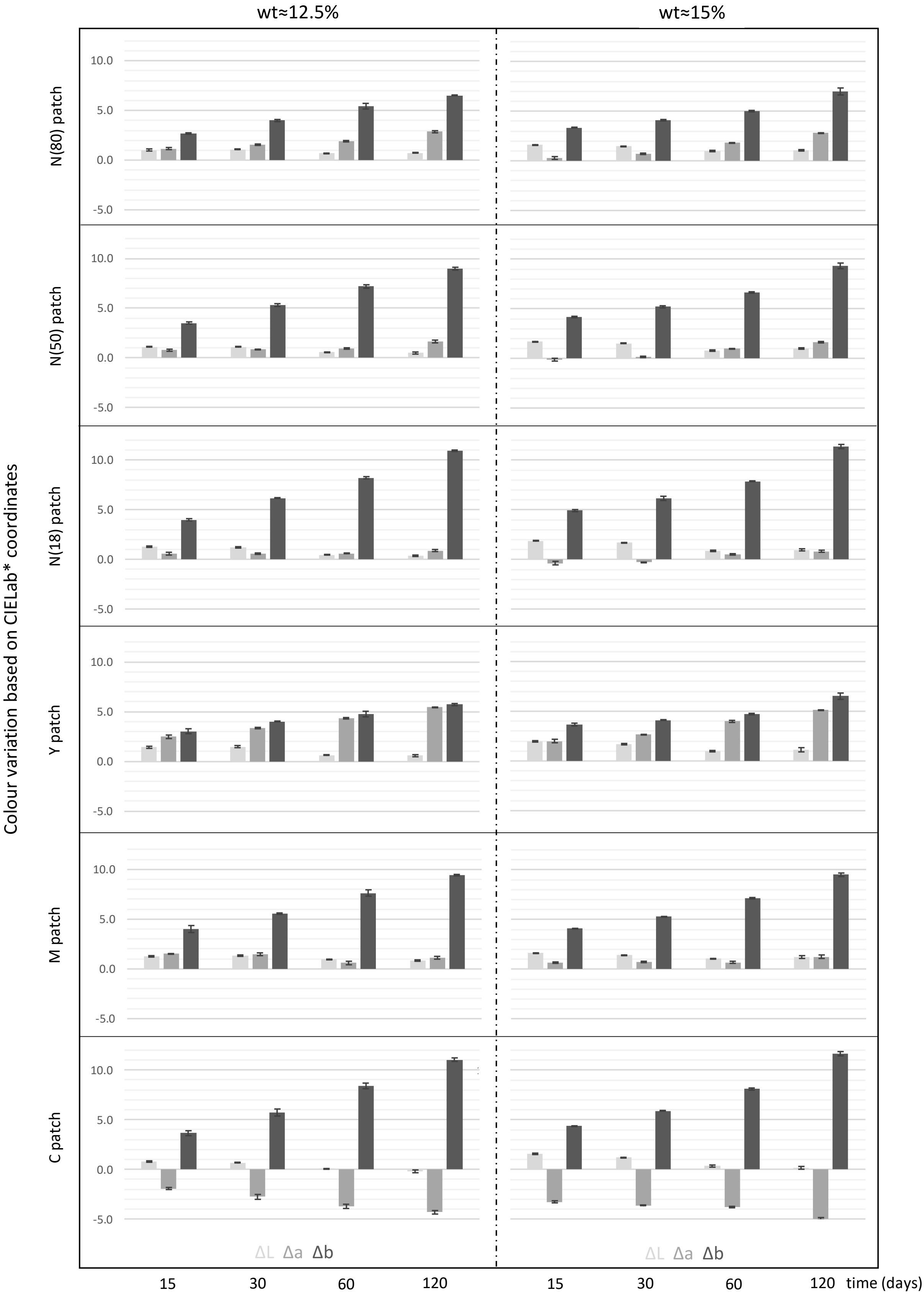


Figure VI.39 – Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the step-wedge samples, before and after artificial ageing at T=70˚C.

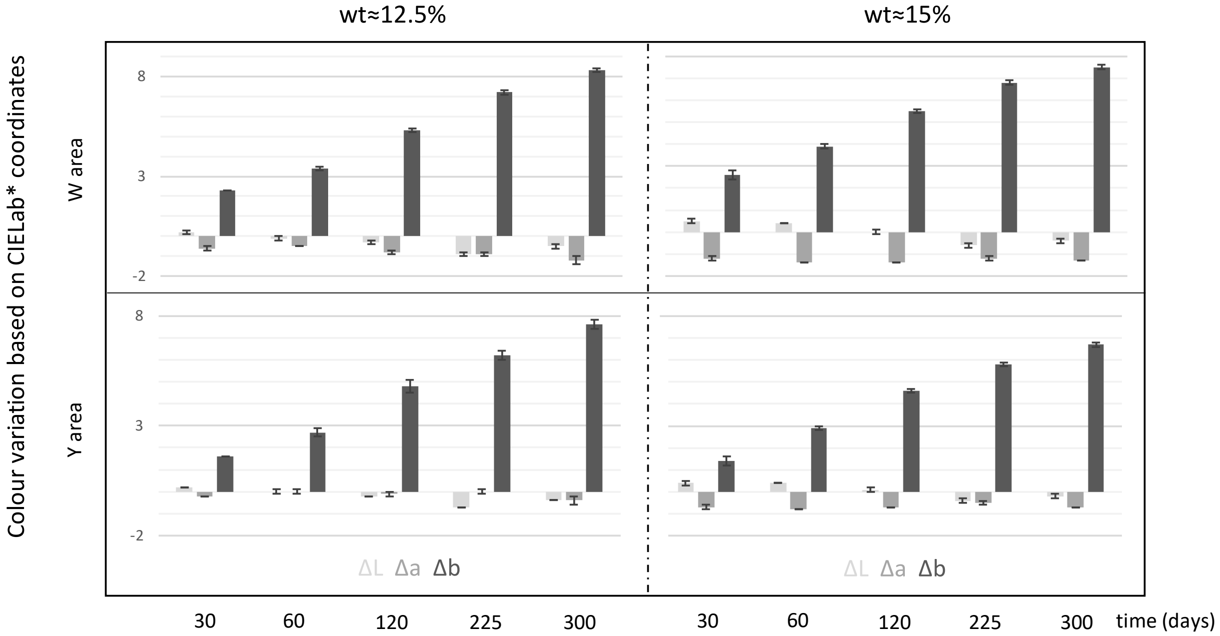


Figure VI.40 – Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the artwork samples, before and after artificial ageing at T=50˚C.

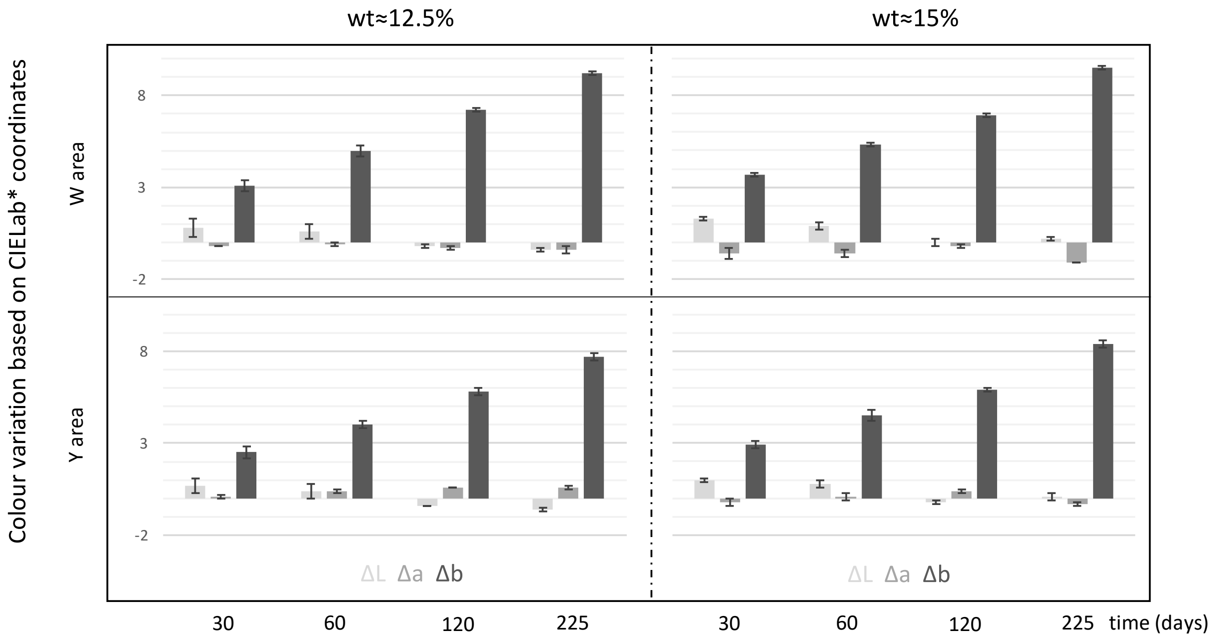


Figure VI.41 – Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the artwork samples, before and after artificial ageing at T=60˚C.

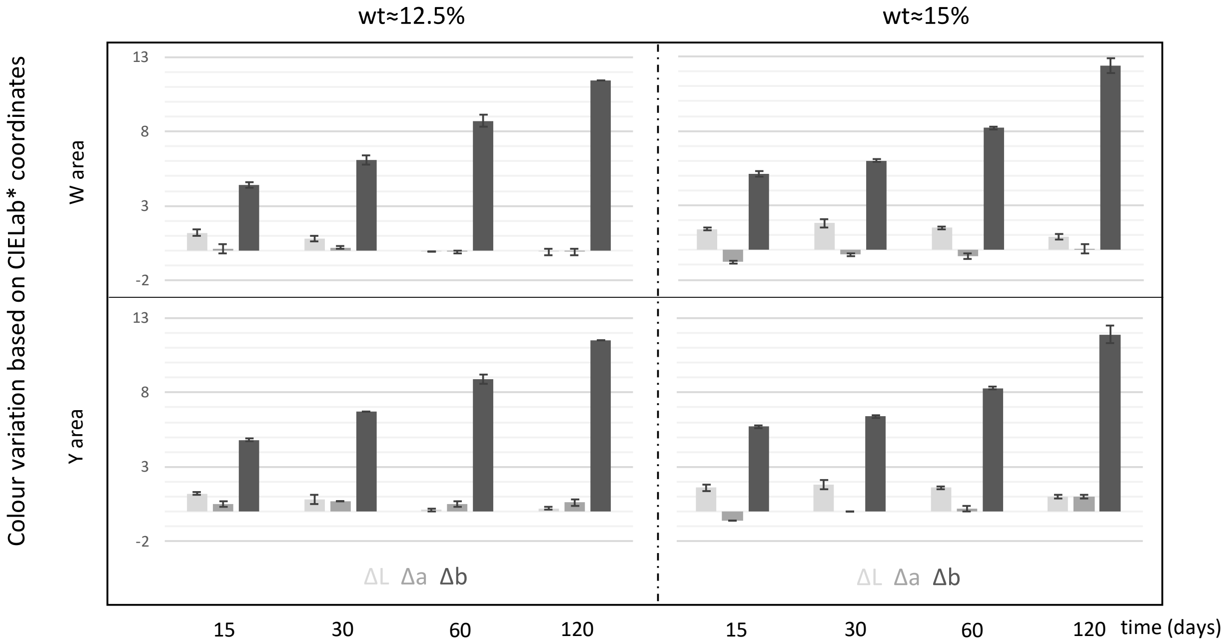


Figure VI.42 – Colour change variation based on CIE L*a*b* coordinates calculated from the absorbance spectra of the artwork samples, before and after artificial ageing at T=70˚C.

Table VI.12 – ΔE^* values calculated in the step-wedge and artwork samples after 938 days of ageing at T_{room}

	T_{room} and wt≈12.5%	T_{room} and wt≈15%
sw N(80) patch	1.2	1.5
sw N(50) patch	1.4	2.3
sw N(18) patch	1.5	2.6
sw Y patch	0.9	1.4
sw M area	1.5	2.3
sw C patch	1.8	3.3
i W patch	1.7	2.6
i Y patch	1.4	2.3

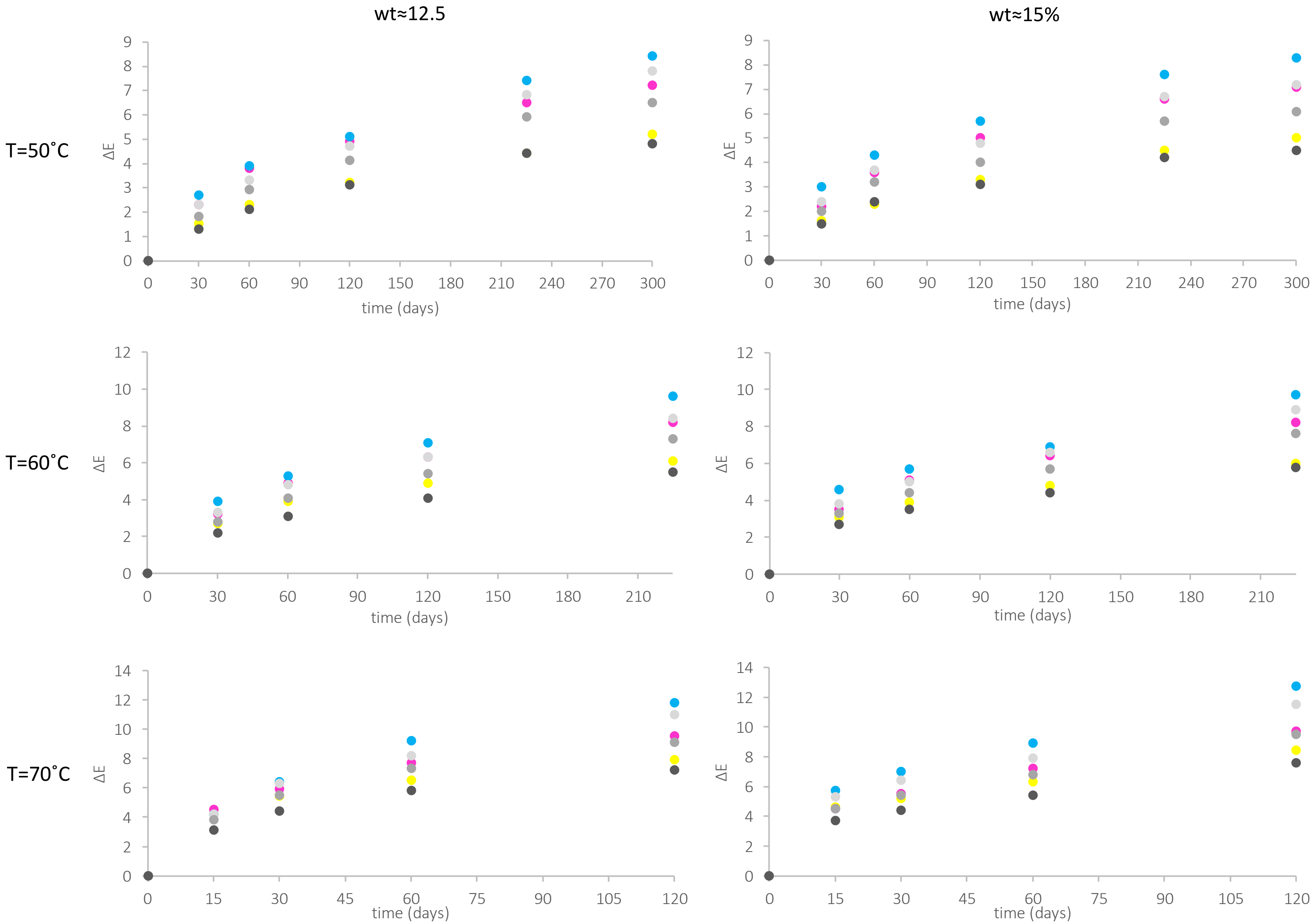


Figure VI.43 – Total colour change variation (ΔE*) calculated from the CIE L*a*b* coordinates of the six patches from the step-wedge samples, upon ageing at T=50, 60 and 70˚C. The standard deviation did not exceed ±0.2 for all the obtained values.

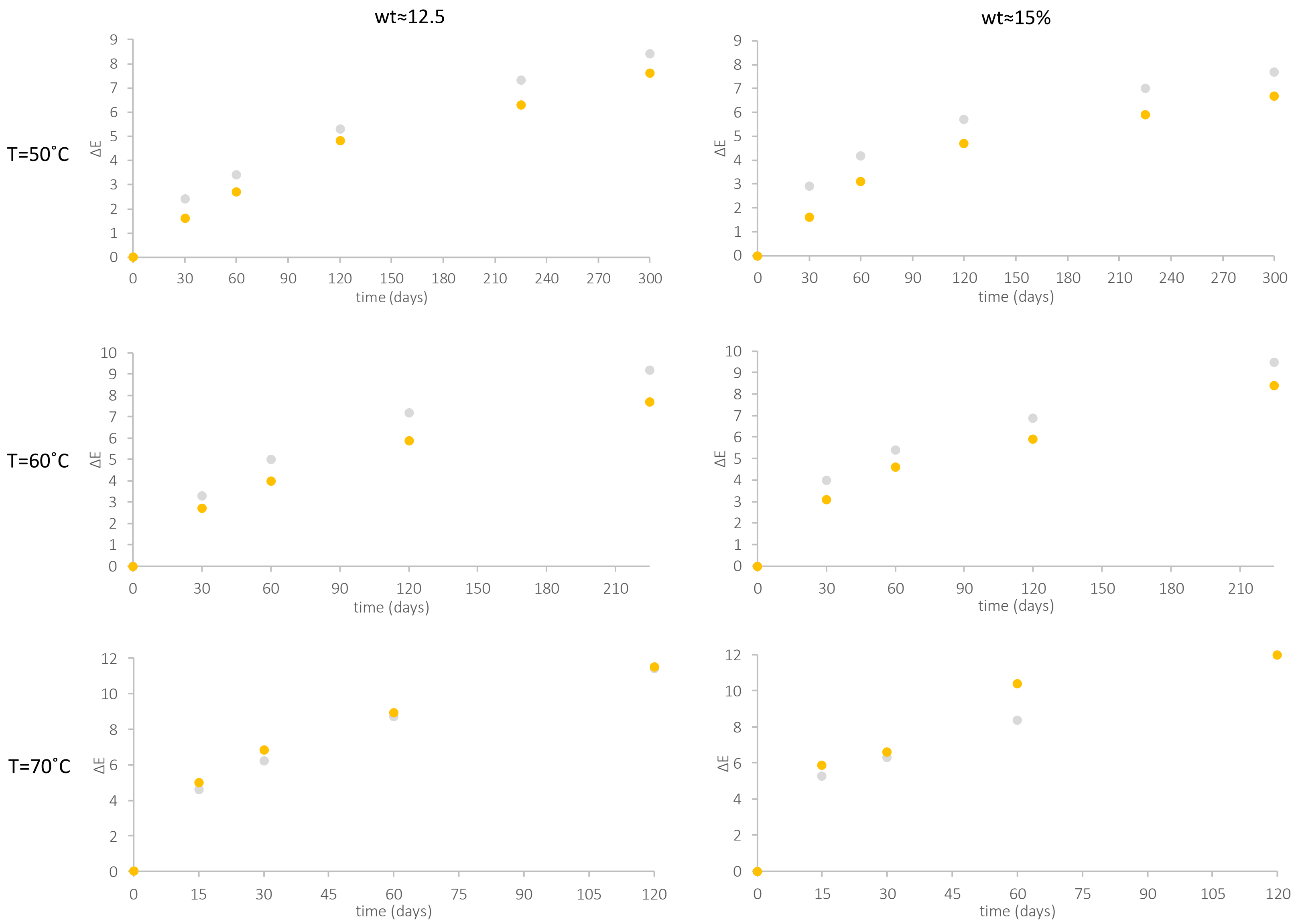


Figure VI.44 – Total colour change variation (ΔE*) calculated from the CIE L*a*b* coordinates of the two areas of analysis from the artwork samples, upon ageing at T=50, 60 and 70˚C. The standard deviation did not exceed ±0.3 for all the obtained values.

VI.6.2.3. Following colour change in naturally aged samples from Ângelo de Sousa's collection

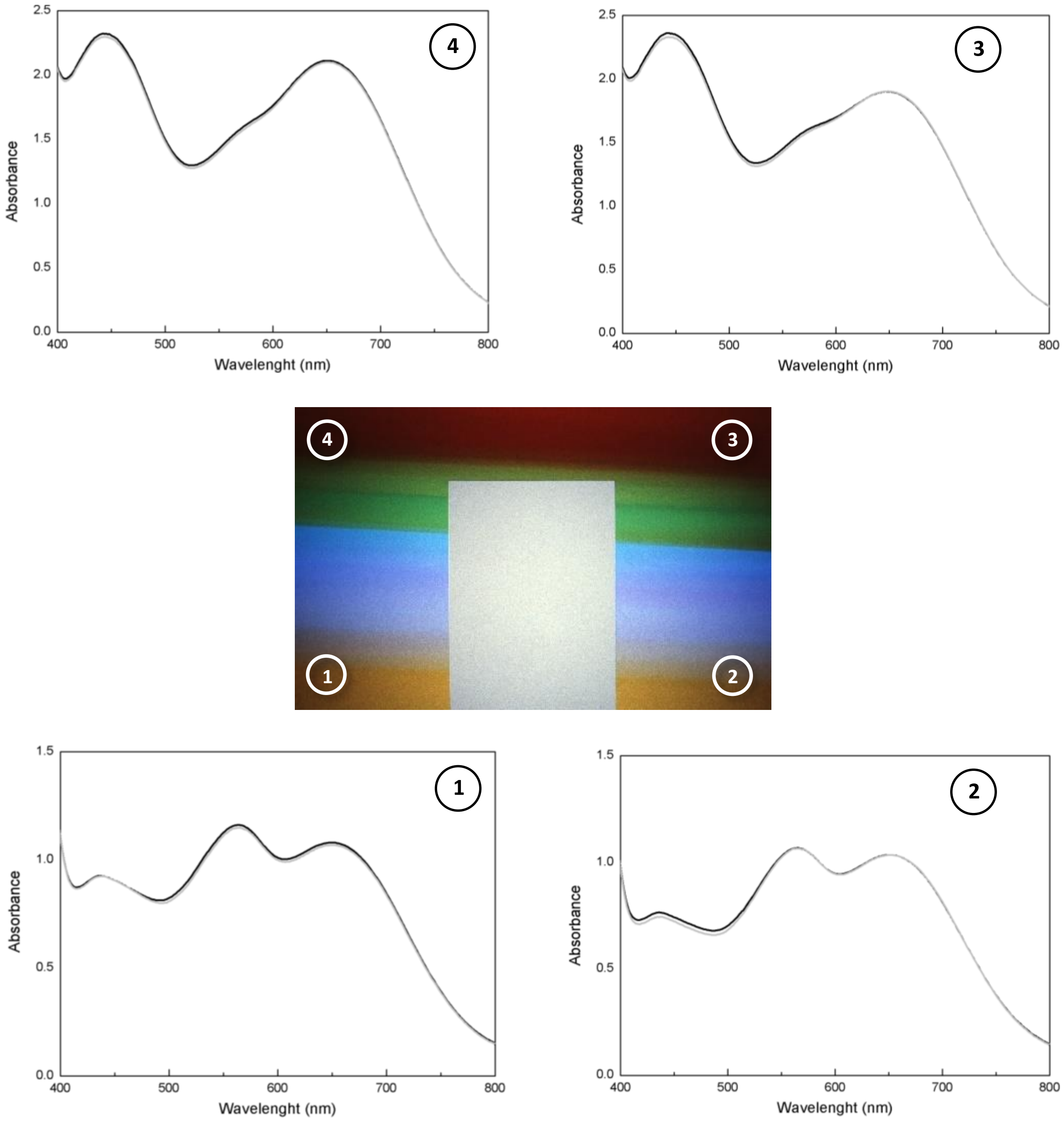


Figure VI.45 - Spectral absorbance of a test slide produced within the framework of *Slides de Cavalete* (1978-1979) by Ângelo de Sousa, in February 2017 (black line) and in February 2018 (grey line). No significant changes were noted after one year of natural ageing at T_{room} and RH≈50%.

VI.7. Densitometry

VI.7.1. Equipment and conditions

The optical densities of RXP samples were measured with a X-Rite 310 Color Transmission densitometer, with a measuring range of 0.00D to 4.0D. The equipment was calibrated using the calibration check plaque (P/N 302-33). The measurements were made using Status A, and capturing the response of the analysis on R, G and B channels. Only step-wedge samples aged at T=80°C were studied. Each coloured patch was analysed 3 times, in the centre of the square. The measured area was 3 mm to achieve the better resolution possible. The values read by the equipment and indicated in the display panel were manually transcribed into an excel sheet.

VI.8. Differential scanning calorimetry (DSC) and Thermogravimetric analysis (TGA)

Two thermal analytical techniques, differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA), were performed in the gelatine emulsion from the RXP samples in order to understand the behaviour of the material according to the T induced in the different artificial ageing tests. Specifically, DSC was used to determine the glass transition temperature (T_g) of the gelatine, and TGA to detect physical phenomena such as water desorption. To the analysis with both techniques, about 2-5 mg were prepared by scraping the surface of the emulsion layers with a scalpel. Three sets of samples were pre-conditioned at RH=40, 60 and 100%.

VI.8.1. DSC

The DSC analysis was carried out using a Differential Scanning Calorimeter from Setaram, model DSC 131, with a cryogenic system. The temperature range was from -50 to 100˚C. The samples were analysed in 100 µl sealed aluminium crucible at a constant heating rate of 10˚C/min and with a resolution of ±0.2 µW. The samples were continuously purged with 50 ml/min nitrogen. The instrument was calibrated with an indium standard. The T_g was obtained in the second heating cycle.

Figure VI.46 presents one of the thermograms obtained, showing the two heating cycles and the T_g determined at wt≈15%.

Table VI.13 – Glass transition temperature (T_g) of the gelatine from RXP samples based on the obtained DSC thermograms

Stabilization of the RXP sample (% RH)	T_g (˚C)
40	non-defined
60	70.2
100	non-defined

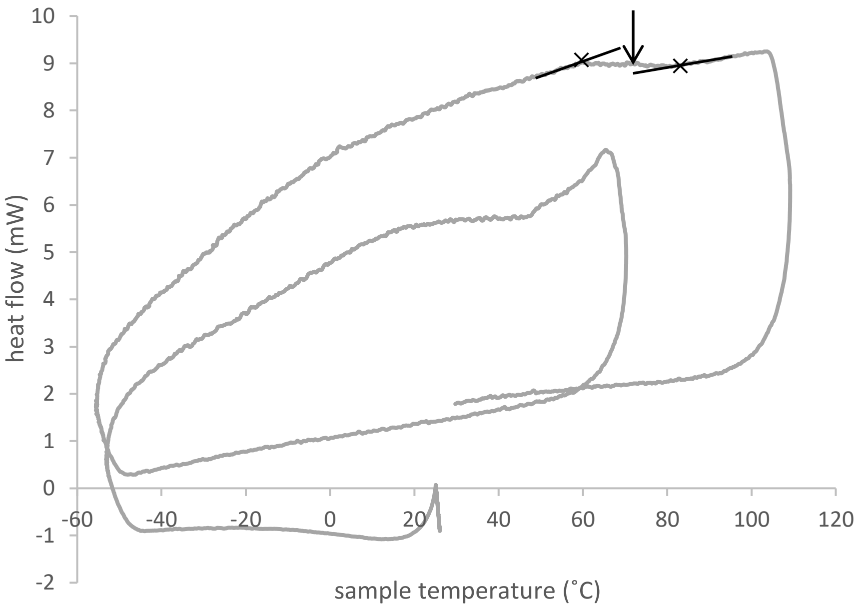


Figure VI.46 – DSC thermogram of the gelatine from RXP sample conditioned at RH=60%.

VI.8.2. TGA

The TGA analysis was performed with a Thermogravimetric Analizer from Setaram, model Labsys EVO. The initial mass of the sample was about 5 mg. The thermograms were obtained under argon atmosphere 50 ml/min, from room temperature to 350˚C. The heating rate was 10˚C / min^{-1}.

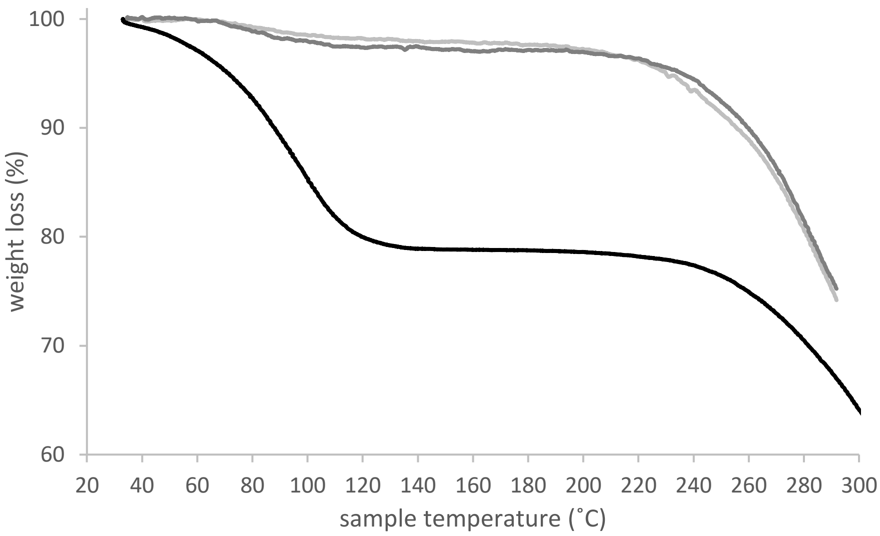


Figure VI.47 – TGA thermograms of the gelatine from RXP sample conditioned at RH=40% (light grey line), at RH=60% (dark grey line) and at RH=100% (black line).

VI.9. Technical data sheets

VI.9.1. Kodak Ektachrome 160T Professional

TECHNICAL DATA / **COLOR REVERSAL FILM** **May 2007 • E-144**

KODAK EKTACHROME 160T Professional Film / EPT

THIS FILM HAS BEEN DISCONTINUED.

KODAK EKTACHROME 160T Professional Film is a medium-speed color-transparency film featuring very fine grain and high sharpness. It is designed for exposure with tungsten illumination (3200 K). You can also expose it with photolamps (3400 K), daylight, or electronic flash using filters.

The film is well-suited for photojournalism, theater, fashion, editorial portraiture, architectural interiors, and motion-picture still photography where there is tungsten illumination. It has an intended exposure range of 1/10,000 to 1/10 second with no filter or exposure adjustment.

Use this film to produce color transparencies for projection or viewing with 5000 K illumination. You can also make duplicate transparencies by direct printing. To make color prints, you can print transparencies directly onto color-reversal paper. Or make internegatives for printing onto color-negative paper. You can also scan transparencies for digital printing, and for graphic-arts and Photo CD applications.

FEATURES	BENEFITS
• Bright, bold colors	• Good color reproduction even in dimly lighted conditions
• Very fine grain at 160 speed • Balanced for tungsten illumination	• Ideal for theater performances, fashion, and motion-picture still photography

SIZES AVAILABLE

Sizes and catalog numbers may differ from country to country. See your dealer who supplies KODAK PROFESSIONAL Products.

Rolls	Code	Acetate Base
135-36	EPT	5-mil (0.13 mm)
35 mm x 100 ft	EPT / SP 404*	
120	EPT	3.9-mil (0.10 mm)

*Perforated on both edges.

STORAGE AND HANDLING

Load and unload film in subdued light.

Store unexposed film in a refrigerator at 13°C (55°F), or lower in the original sealed package. To avoid moisture condensation on film that has been refrigerated, allow the film to warm up to room temperature before opening the package.

Process the film as soon as possible after exposure.

Protect processed film from strong light, and store them in a cool, dry place. For more information on storing transparencies, see KODAK Publication No. E-30, *Storage and Care of KODAK Films and Papers—Before and After Processing*.

DARKROOM RECOMMENDATIONS

Do not use a safelight. Handle unprocessed film in total darkness.

EXPOSURE

Exposure Index Numbers

Use the exposure index (EI) numbers below with cameras or light meters marked for ISO or ASA speeds or exposure indexes. Do not change the film-speed setting when metering through a filter. Metering through filters may affect meter accuracy; see your meter or camera manual for specific information. For critical work, make a series of test exposures.

Light Source	KODAK WRATTEN Gelatin Filter	Exposure Index
Tungsten (3200 K)	None	160
Photolamp (3400 K)	81A	125
Daylight or Electronic Flash	85B	100

Tungsten Light

For best color rendition, use tungsten photolamps (3200 K) at their rated voltage. If voltage varies significantly, the color of the lamp will change. Other light sources may not give equally good results, even with filters. Unless you want a special effect, do not mix light sources of different color qualities, particularly tungsten light and daylight.

These exposure recommendations are based on two tungsten (3200 K) reflector-type photolamps at 45 degrees from the camera-subject axis. Use one lamp as a fill-in light close to the camera at lens level, the other lamp as the main light 2 to 4 feet higher.

Use these exposure settings as guides. They give a lighting ratio of about 3 to 1. For a 2 to 1 ratio, move the fill-in light to the same distance as the main light and use a 1/2-stop smaller lens opening.

Lamp-to-Subject Distance in Feet

	Lens Opening at 1/60 Second				
	f/8	*f*/5.6	*f*/4	*f*/2.8	*f*/2
EAL R-40 Lamps (General Electric)					
Main Light	4	5.5	8	11	16
Fill Light	5.5	8	11	16	22
DXH R-32 Lamps (Sylvania)					
Main Light	5	7	10	14	20
Fill Light	7	10	14	20	28

Fluorescent and High-Intensity Discharge Lamps

Use the color-compensating filters and exposure adjustments below as starting points to expose this film under fluorescent or high-intensity discharge lamps. For critical applications, make a series of test exposures under your actual conditions. Vary the recommended filtration by at least ±CC10, and increase or decrease exposure accordingly.

To avoid the brightness and color variations that occur during a single alternating-current cycle, use exposure times of 1/60 second or longer with fluorescent lamps; with high-intensity discharge lamps, use exposure times of 1/125 second or longer.

Fluorescent Lamps	KODAK Color Compensating Filters	Exposure Adjustment
Daylight	No. 85B + 40M + 30Y	+1 2/3 stops
White	50R + 10M	+1 1/3 stops
Warm White	50M + 40Y	+1 stop
Warm White Deluxe	10R	+1/3 stop
Cool White	60R	+1 1/3 stops
Cool White Deluxe	20M + 40Y	+2/3 stop
Unknown Fluorescent*	50R	+1 stop

*When the type of fluorescent lamp is unknown, try this filter and exposure adjustment; color rendition may be less than optimum.

High-Intensity Discharge Lamps	KODAK Color Compensating Filters	Exposure Adjustment
General Electric Lucalox*	50M + 20C	+1 stop
General Electric Multi-Vapor	60R + 20Y	+1 2/3 stops
Deluxe White Mercury	70R + 10Y	+1 2/3 stops
Clear Mercury	90R + 40Y	+2 stops

*This is a high-pressure sodium-vapor lamp. The information in the table may not apply to other manufacturers' high-pressure sodium-vapor lamps due to differences in spectral characteristics.

Note: Consult the manufacturer of high-intensity lamps for ozone ventilation requirements and safety information on ultraviolet radiation.

Some primary color filters were used in the previous tables to reduce the number of filters and keep the exposure adjustment to a minimum. Red filters were substituted for equivalent filtration in magenta and yellow. Blue filters were substituted for equivalent filtration in cyan and magenta.

Daylight

Use the exposures in the table below for average front-lit subjects from 2 hours after sunrise to 2 hours before sunset.

Lens opening with a KODAK WRATTEN Gelatin Filter No. 85B.

Lighting Conditions	Shutter Speed (second)	Lens Opening
Bright hazy sun on light sand or snow	1/125	f/22
Bright or hazy sun, distinct shadows	1/125	f/16*
Weak, hazy sun, soft shadows	1/125	f/11
Cloudy bright, no shadows	1/125	f/8
Heavy overcast, open shade†	1/125	f/5.6

*Use f/8 for backlit close-up subjects.
†Subject shaded from the sun but lit by a large area of clear sky

Electronic Flash

Use a KODAK WRATTEN Gelatin Filter No. 85B, or equivalent. Calculate the guide number based on the film speed for daylight, ISO 100.

Adjustments for Long and Short Exposures

No filter correction or exposure adjustment is normally required for EKTACHROME 160T Professional Film at exposure times from 1/10,000 second to 1/10 second. For a 1 second exposure, increase exposure by 1/3 stop and add a CC10R filter. Longer exposures are not recommended.

Note: This information applies only when the film is exposed to tungsten illumination. The data are based on average emulsions and assume normal, recommended processing. Use the data only as a guide. For critical applications, make tests under your conditions.

PROCESSING

Process EKTACHROME 160T Professional Film in KODAK Chemicals, Process E-6. For best quality, use the normal speed rating of EI 160 and normal processing.

For consistent processing of this and all other EKTACHROME Films, use a lab that is a member of the KODAK Q-LAB Process Monitoring Service.

RETOUCHING

Use KODAK E-6 Transparency Retouching Dyes. You can chemically retouch the 120 format on both the base side and the emulsion side. Retouch only the emulsion side of 35 mm formats.

For information on retouching equipment, supplies, and techniques, see KODAK Publication E-68, *Retouching Color Transparencies on KODAK EKTACHROME Film.*

SCANNING TRANSPARENCIES

For Graphic Arts Applications

The KODAK EKTACHROME Film family is characterized by sets of image dyes that perform similarly when scanned. The scanner operator can set up one basic tone scale and color-correction channel for all EKTACHROME Films, and then optimize the tone scale and gray balance for the requirements of individual images.

Use the KODAK Color Input Target / Q-60E1 (4 x 5–inch transparency) or Q-60E3 (35 mm slide) to establish the setup for KODAK EKTACHROME Films on all scanners. These targets meet ANSI standards and represent the dye sets of all EKTACHROME Films.

For Photo CD Applications

Use the Universal E-6 Film Term to scan all KODAK EKTACHROME films for Photo CD Imaging Workstation applications.

For Output to a Photo CD Player: Using the Universal E-6 Film Term should result in an image that closely matches your original transparency in density, tone scale, and overall color balance when viewed on a player.

For Output to Devices Other than Photo CD Players: The YCC data that results when using the Universal E-6 Film Term is capable of producing a high-quality duplicate of your original transparency in terms of density, tone scale, and color reproduction. Final quality of your reproduced image depends on the capabilities of your output device, the viewing environment, and the rendering path that is used.

PRINTING TRANSPARENCIES

You can reproduce images made on EKTACHROME 160T Professional Film by using a variety of Kodak materials.

Duplicate Color Transparencies

For direct printing, use—

KODAK PROFESSIONAL EKTACHROME Duplicating Film EDUPE

Color Prints

You can scan your image to a file and print digitally to—

KODAK PROFESSIONAL PORTRA, SUPRA, and ULTRA ENDURA Papers

KODAK PROFESSIONAL ENDURA Clear Digital Display Material

KODAK PROFESSIONAL ENDURA Transparency Display Material

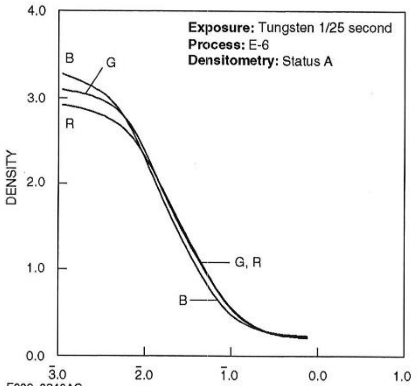
KODAK PROFESSIONAL ENDURA Metallic Paper

CURVES

Diffuse rms Granularity* **13 (very fine)**

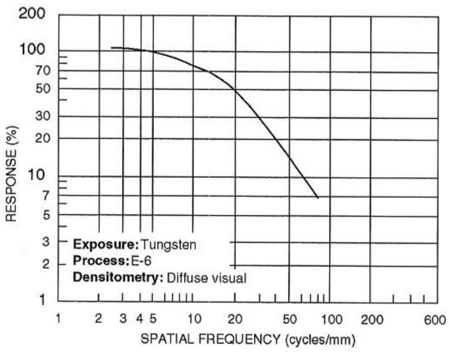
*Read on a gross diffuse visual density of 1.0, using a 48-micrometre aperture, 12X magnification.

Characteristic Curves



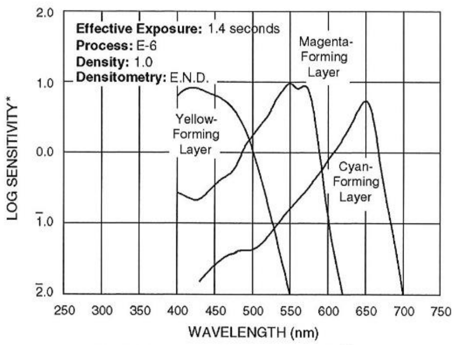
F009_0346AC

Modulation-Transfer Curve



F009_0345AC

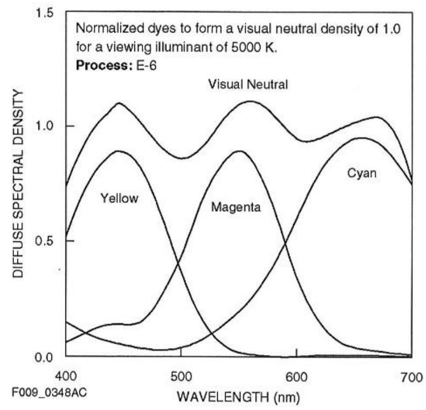
Spectral-Sensitivity Curves



*Sensitivity = reciprocal of exposure (erg/cm^2) required to produce specified density

F009_0347AC

Spectral-Dye-Density Curves



F009_0348AC

NOTICE: The sensitometric curves and data in this publication represent product tested under the conditions of exposure and processing specified. They are representative of production coatings, and therefore do not apply directly to a particular box or roll of photographic material. They do not represent standards or specifications that must be met by Eastman Kodak Company. The company reserves the right to change and improve product characteristics at any time.

MORE INFORMATION

Kodak has many publications to assist you with information on Kodak products, equipment, and materials.

The following publications are available from Kodak Customer service, from dealers who sell Kodak products, or you can contact Kodak in you country for more information.

E-8	*KODAK EKTACHROME 64 Professional Film*
E-27	*KODAK EKTACHROME 100 Professional Film*
E-28	*KODAK PROFESSIONAL EKTACHROME Film E200*
E-30	*Storage and Care of KODAK Photographic Materials—Before and After Processing*
E103RF	*KODAK PROFESSIONAL Color Reversal Films*
E-113	*KODAK EKTACHROME 100 Plus Professional Film*
E-130	*KODAK EKTACHROME 64T Professional Film*
E-145	*KODAK EKTACHROME 320T Professional Film*
E-147	*KODAK EKTACHROME 1600 Professional Film*
E-161	*KODAK EKTACHROME 400X Professional Film*
E-163	*KODAK PROFESSIONAL EKTACHROME Film E100VS*
E-4024	*KODAK PROFESSIONAL EKTACHROME Films E100G and E100GX*
Z-119	*Using KODAK Chemicals, Process E-6*

For the latest version of technical support publications for KODAK PROFESSIONAL Products, visit Kodak on-line at:
http://www.kodak.com/go/professional

If you have questions about KODAK PROFESSIONAL Products, call Kodak.
In the U.S.A.:
1-800-242-2424, Ext. 19, Monday–Friday
9 a.m.–7 p.m. (Eastern time)
In Canada:
1-800-465-6325, Monday–Friday
8 a.m.–5 p.m. (Eastern time)

Note: The Kodak materials described in this publication for use with KODAK EKTACHROME 160T Professional Film are available from dealers who supply KODAK PROFESSIONAL Products. You can use other materials, but you may not obtain similar results.

KODAK EKTACHROME 160T Professional Film / EPT

EASTMAN KODAK COMPANY

Kodak Professional
Imaging Solutions

KODAK EKTACHROME 160T
Professional Film / EPT
KODAK Publication No. **E-144**
CAT 817 6885

Minor Revision 5-07
Printed in U.S.A.

VI.9.2. Fuji Fujichrome 400X Professional

FUJIFILM AF3-0213E

PRODUCT INFORMATION BULLETIN

COLOR REVERSAL FILMS

FUJICHROME PROVIA 400X Professional [RXP]

1. FEATURES AND USES

FUJICHROME PROVIA 400X Professional [RXP] is a daylight-type high-image-quality color reversal film with an ISO speed rating of 400. This film boasts one of the world's highest levels of grain quality and sharpness, while delivering the same vivid color reproduction and regulated gray balance as that of ISO 100 film. Furthermore, it produces fine results in push-/pull-processing for exposures ranging from −1/2 stop (EI 280) to +2 stops (EI 1600). These qualities make this a highly versatile film for general applications, including landscape, nature, snapshot and portrait photography.

Features

- **Brilliant Color Reproduction** ········ Brilliant ISO 100-level color reproduction through the incorporation of new-generation couplers and Multi-Color-Correcting Layer Technology
- **Fine Grain** ········ RMS granularity of 11, one of the world's highest levels among ISO 400 color reversal films
- **Rich Tone Reproduction** ········ Smooth tone reproduction from the highlights to the shadows and subtly differentiated gray gradation
- **Excellent Long-exposure Suitability** ········ Minimal reciprocity-related speed reduction and color balance variation in long exposures
- **Superb Push/Pull Processing Suitability** ···· Minimal color and gradation variation during push/pull processing from −1/2 stop (EI280) to +2 stop (EI1600), and up to +3 stops (EI3200), depending on the subject, making this film ideal for low-light and other situations requiring high film sensitivity
- **Enhanced Color Image Storage Permanence and Fade-resistance** ······ Dramatic improvement over RHPIII in color image storage permanence and color fading resistance as a result of new-generation couplers

* RMS stands for "Root Mean Square", a widely used standard method for measuring the degree of grain in photographic film. The lower the RMS number, the smaller the apparent grain.

2. SPEED

Light Source	Speed	Filter
Daylight	ISO 400/27°*	None
Tungsten Lamps (3200K)	ISO 125/22°*	No. 80A**

* Indicates the effective speed resulting from designated filter use.
** Wratten filter

3. FILM SIZES, EMULSION NUMBER, BASE MATERIAL AND THICKNESS

Sizes	Emulsion Number	Base Material	Base Thickness
• Rolls*			
135 ··· 36-exp.	#101–	Cellulose Triacetate	127μm
120 ··· 12-exp. ··· 12-exp. (5-roll packs)	#101–	Cellulose Triacetate	98μm

*Some sizes are not available in certain markets.

4. EXPOSURE GUIDE FOR VARIOUS LIGHT CONDITIONS

Use a meter for exposure determination. If a meter is not available, refer to the following table.

Light Conditions	Seashore or Snow Scenes under Bright Sun	Bright Sunlight	Hazy Sunlight	Cloudy Bright	Cloudy Day or Open Shade
Lens Aperture	f/16	f/11	f/11	f/11	f/8
Exposure Time (sec.)	1/1000	1/1000	1/500	1/250	1/250

NOTES

- The foregoing settings are for 2 hours after sunrise and 2 hours before sunset.
- Provide a lens opening 1/2-stop smaller during the summer and 1/2-stop larger during the winter (except for snow scenes).
- Excessively bright (or dark) or backlighted subjects may require plus (or minus) 1-stop lens opening adjustments.

Daylight

Under normal daylight conditions, color balancing filters are not necessary, but the following exposure conditions may require the indicated filters.

– 1 –

- A UV filter No. 2C* or other appropriate ultraviolet absorbing filter is recommended for scenes that are shone upon by strong ultraviolet light, such as seaside locations, snow scenes, and bright distant views.
- Excessively high or low color temperatures may require the following filters and exposure corrections.

Subject Conditions	Filter	Exposure Correction
High Color Temperature: Cloudy weather landscapes or portraits in open shade in clear weather.	No.81A*	+1/3 stop**
Low Color Tempreature: Morning and evening twilight scenes and portraits.	No.82A* or No.82C*	+1/3 to +2/3 stop**

* Wratten Filter
** A "+" followed by a number indicates the required increase in lens opening.

Electronic Flash

- Electronic flash produces light similar to daylight, so filters are not needed. However, the possibility of undesirable effects on color balance, due to various factors (differences in equipment, use duration, etc.) should be taken into consideration. Test exposures are recommended.
- The use of a flash meter is advisable, but the following formula can also be used to obtain satisfactory lens opening.

$$\text{Lens Aperture (F-number)} = \frac{\text{Electronic Flash Guide Number (at ISO 400)}}{\text{Electronic Flash-to-Subject Distance (meters)}}$$

- Set the film speed at ISO 400. Since the amount of light reflected onto the subject from surrounding surfaces will differ with the conditions, refer to the flash unit instructions.

Daylight Photoflood / Photo-Reflector Lamps

- Daylight-type photoflood or photo-reflector lamp output may be lower than that indicated by the exposure meter. So it is advisable to compensate for this by increasing exposure time or lens opening. Whenever possible, test exposures are recommended.
- Other factors requiring consideration when determining the exposure time are lamp configuration, use duration and line voltage, as they may affect lamp output and color balance.

Fluorescent Lamps

- The use of the following combinations of color compensating filters is advisable when photographing under fluorescent lighting.
- For exacting work, however, test exposures are recommended because lamp brand and age may affect light output and color balance.

Fluorescent Lamp Type	White (W)	Daylight (D)	Cool White (CW)	Warm White (WW)
Color Compensating Filters*	20M	40R	25M+5R	40B+5M
Exposure Corrections**	+2/3 stop	+1 stop	+1 stop	+1 2/3 stops

(Exposure time: 1/2 sec.)

* Wratten Color Compensating Filters are recommended.
** Exposure correction values when using a filter relative to unfiltered exposure results. A "+" followed by a number indicates the required increase in lens opening.

NOTES

- Use a shutter speed slower than 1/30 second.
- For shutter speeds of 2 minutes or more, exposure adjustments will be necessary to compensate for reciprocity law failure.

Tungsten Lamps

- A Wratten Filter No.80A is required when using 3200K tungsten lighting. A 1 2/3-stop larger lens opening is also required.
- If household tungsten lighting (room lamps, etc.) constitutes the main source of illumination, in addition to the above filter a Wratten Filter No.82A is required, plus an aperture increase of 1/3 stop (total 2 stops).

Mixed Light Sources

Under mixed light conditions, the basic filter configuration should suit the main light source. In the case of cameras with TTL metering, there is no need for additional exposure compensation for any CC filter(s) used.

5. LONG AND MULTIPLE EXPOSURE COMPENSATION

No exposure correction or color balance compensation is required for exposures within a shutter speed range of 1/4000 second to 1 minute. However, for exposures of 2 minutes or longer, 'reciprocity law failure'-related color balance and exposure compensations are required.

Exposure Time	1/4000 sec. – 1 min.	2 min.	4–8 min.
Color Compensating Filter	None	2.5R	5R
Exposure Corrections*		+ 1/2 stop	+ 1 stop

* Exposure correction values when using a filter relative to unfiltered exposure results. A "+" followed by a number indicates the required increase in the lens opening.

Note : The above figures are based on the use of standard processing for films with average emulsions. These figures should therefore be used as a rough guide only. For more accurate results, it is recommended that test exposures be made under the actual shooting conditions.

7. EXPOSURE PRECAUTIONS

With artificial light, such as electronic flash, photoflood, fluorescent, tungsten, high intensity discharge lamp (metal halide, sodium, mercury vapor), etc., the lamp output and color temperature may be affected by such factors as brand, age of equipment and line voltage. Reflectors and diffusers can also influence light intensity and color temperature.

8. UNPROCESSED FILM HANDLING / STORAGE

HANDLING

- Expose film before the expiration date indicated on the film package and process as soon as possible after exposure.
- Roll film should be loaded and unloaded quickly and away from direct sunlight.
- Film loaded in cameras should be exposed and processed promptly.
- X-ray inspection machines used to inspect checked-in baggage at airports can cause fogging of film. Put both exposed and unexposed film into carry-on baggage (preferably in a transparent plastic bag or a net bag that allows the film to be seen). Because of the increasing number of airports using strong X-ray machines for carry-on baggage, it is recommended that you remove film from your carry-on baggage and request a visual (manual) inspection of your film.
- Film fogging may occur near X-ray equipment used in hospitals, factories, laboratories and other places where radiation is used. Always keep film away from sources of radiation.

STORAGE

Storing exposed or unexposed film under hot and humid conditions may adversely affect the speed, color balance and physical properties of the film. Although it is best to store film at a low temperature, for practical purposes, film should be stored as follows:

Short-term Storage	Store at 15°C or below
Long-term Storage	Store at 0°C or below

- New building materials, newly manufactured furniture, paints and bonding agents may produce gases which could affect photographic film. Do not store film, lightproof boxes containing film or cameras or film holders loaded with film near these materials.
- Film should be sealed in plastic bags* prior to cold storage When taken out of cold storage, film should be allowed to reach room temperature before opening by letting it stand over 3 hours (for refrigerated film) or over 6 hours (for frozen film). Opening film while it is still cold may cause condensation to form on the film surface, causing color changes or the emulsion to become more susceptible to scratches.

* Polyester, polystyrene, polyethylene, polypropylene, etc.

9. PROCESSING

This film is designed for processing by Process E-6 or its equivalent, as well as Fujifilm Process CR-56.

10. PROCESSED FILM HANDLING AND STORAGE

Since the purpose of film is often to provide a long-term record of memorable events, as much effort as possible has been made to use materials that exhibit the least amount of change over time, but the effects of light, heat, atmospheric oxygen, contaminant gases, humidity and mold cannot be completely avoided. It is possible, however, to minimize change in the photographic image or base material by maintaining appropriate storage conditions, such as those used by museums and art galleries. Temperature and humidity control is the most important key to minimizing the change that occurs in film. Films stored in the dark under the following conditions may be expected to show almost no change over time.

Storage Period with Almost No Change	Temperature	Relative Humidity
More than 20 years	Below 10°C	30%–50%
10–20 years	Below 25°C	30%–50%

(1) Color reversal film should be mounted or inserted into sleeves* for storage.

* Made of polyester, polystyrene, polyethylene, polypropylene, etc.

(2) Processed film should be stored at a place as far away as possible from high temperatures, direct sunlight and other strong light and direct illumination. The following conditions are not desirable for the storage of film and should be avoided in the case of long-term storage:

- Storage in a closet lying against a wall that is exposed to cold, outside air (where condensation may form).
- Storage in an attic or on top of a closet or cabinet near the ceiling (where high temperatures may form).

11. VIEWING LIGHT SOURCES

Use a standard viewer. Visual responses will differ with light source quality and brightness. Therefore, employ a viewer which meets the ISO/ANSI standard.*

* The ISO standard (ISO/DP3664-2000) specifies an illuminated viewer surface with a color temperature derived from a CIE illuminant D50 (D: Daylight) with a reciprocal color temperature of 5000K, an average brightness of 1270cd/m² ± 320cd/m², a brightness uniformity of more than 75 and an average color rendition assessment value of more than Ra90. Transparency viewers should meet these standards.

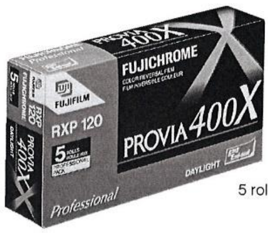
12. PRINTS AND DUPLICATES

Prints can be directly made from this film to FUJICHROME papers or color papers for digital output. High-quality duplicates can be made on FUJICHROME DUPLICATING FILM CDU TYPE II.

13. RETOUCHING

Changes in density and color balance can be made by using readily available retouching dyes and bleaching chemicals. However, due to this film's improved image permanence (color fading resistance), the color dyes of this film are harder to remove than those of the current RHPIII.

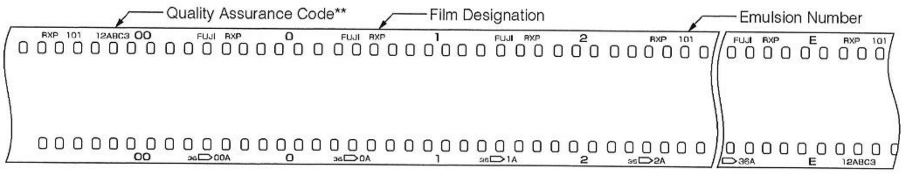
14. PACKAGING SPECIFICATIONS

Size	Item	Contents
135	Film Box	New Design Identification Color : Black 
	Plastic Case	Same as the current product.
	Cartridge	New Design Identification Color : Black 
120	Film Box	New Design Identification Color : Black   5 roll pack

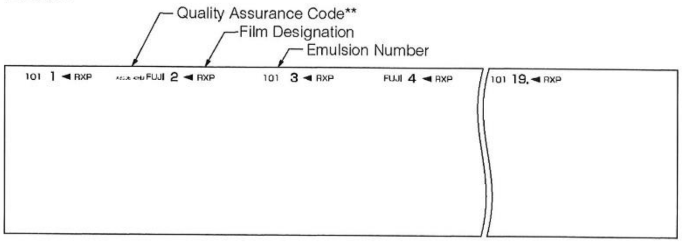
Size	Item	Contents
120	Envelope	PROVIA 400X and RXP printed 
	Backing Paper	New Design (Before Exposure)  (After Exposure) 

15. PROCESSED FILM EDGE MARKINGS*

• 135 Size



• 120 Size



NOTES

* The emulsion is on the opposite side. (Base side facing you)

** This code represents an identification marking enabling Fujifilm's manufacturing quality control system to assure individual quality.

16. TECHNOLOGIES INCORPORATED IN PROVIA 400X

1. ESC (Epitaxial Sigma Crystal) Technology

The newly developed Epitaxial Sigma Crystal technology fuses fine grain of a different composition to the apex of aspect-ratio-enhanced Sigma grain to enhance the fineness of the emulsion grain. The result is the attainment of an ISO-400 film with an extremely high granularity (RMS11) approaching that of ISO-100 reversal film.

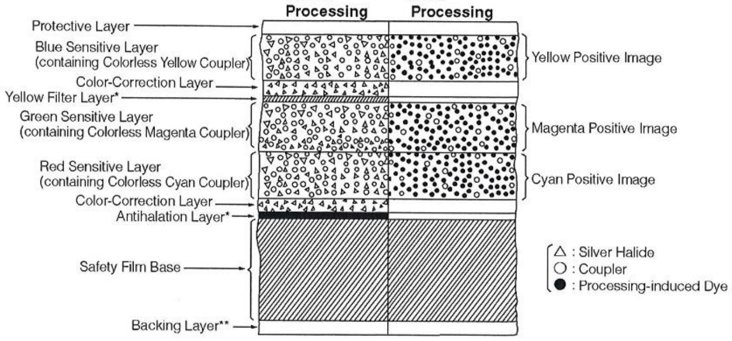
2. PSHC (Pure, Stable & High-performance dye-forming Coupler) Technology

Through the adoption of the high-color-saturation yellow, magenta and cyan couplers used in Velvia 100/100F and ASTIA 100F and other films, PROVIA 400X is able to produce colors of extremely high purity. Furthermore, the couplers' superb color material durability has enabled a dramatic improvement in image permanence over the previous RHP III.

3. MCCL (Multi-Color-Correction Layer) Technology

Through the incorporation of Fujifilm's proprietary Multi-Color-Correction Layer technology used in Velvia 100/100F and ASTIA 100F to control the inter-image effect, PROVIA 400X is able to provide a color saturation level suitable for landscape photography, as well as skin tones suited to portrait photography.

17. FILM STRUCTURE



* These layers become colorless and transparent after processing.
** 135-size film does not have a backing layer.

18. DIFFUSE RMS GRANULARITY VALUE ···· 11

Micro-Densitometer Measurement Aperture : 48 μm in diameter

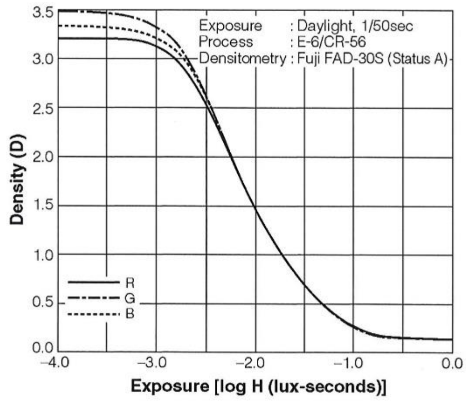
Sample Density: +1.0

* Based on Fujifilm measurements. Due to difference in measurement conditions, comparison with color negative film is not possible.

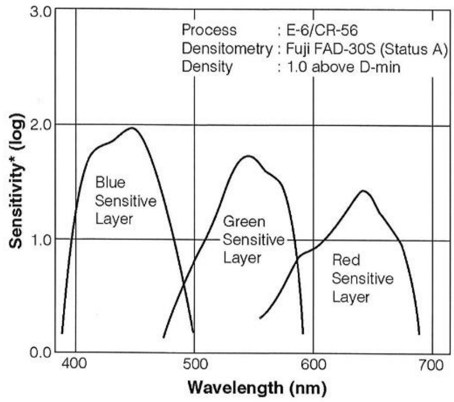
19. RESOLVING POWER

Test-Object Contrast: 1.6:1 .... **55** lines/mm
Test-Object Contrast: 1000:1 .... **135** lines/mm

20. CHARACTERISTIC CURVES

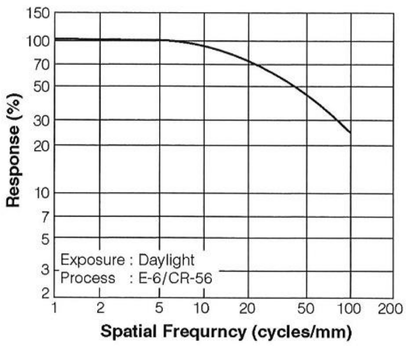


21. SPECTRAL SENSITIVITY CURVES

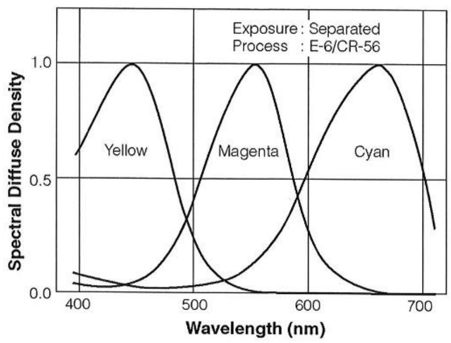


* Sensitivity equals the reciprocal of the exposure (J/cm^2) required to produce a specified density.

22. MTF CURVE



23. SPECTRAL DYE DENSITY CURVES



NOTICE The data published herein were derived from materials taken from general production runs. However, as Fujifilm is constantly upgrading the quality of its products, changes in specifications may occur without prior notice.

FUJIFILM FUJI PHOTO FILM CO., LTD.
26-30, Nishiazabu 2-chome, Minato-ku, Tokyo 106-8620, Japan

Ref. No. **AF3-0213E** (ESD-06.1-FP) Printed in Japan

VI.8.3. E-6 Processing

1 PROCESSING SOLUTIONS AND THEIR EFFECTS

OVERVIEW OF PROCESSING *KODAK EKTACHROME* FILMS

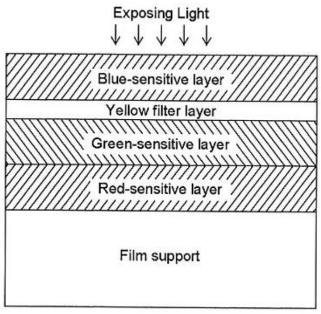
KODAK EKTACHROME films are reversal, subtractive color materials. When properly exposed and processed, they yield positive color images, i.e., transparencies.

The general structure of EKTACHROME Films is shown in Figure 1-1, enlarged to show detail. The transparent film support is at the bottom of the illustration. Reversal films contain three emulsion layers that are light-sensitive. The red-sensitive emulsion layer is located at the bottom of the film closest to the support material. The green-sensitive layer is located in the middle, and the blue-sensitive layer is at the top. Although the red-sensitive layer is primarily sensitive to red light and the green-sensitive layer is primarily sensitive to green light, both of these layers are somewhat sensitive to blue light. The yellow filter layer absorbs blue light and prevents blue light from exposing the red- and green-sensitive layers.

When reversal film is exposed, latent images are formed in each of the three emulsion layers. The blue-sensitive layer contains a record of the images formed by the blue component of the exposing light; the green-sensitive layer contains the image formed by the green component; and the red-sensitive layer contains the image formed by the red component. The images are formed simultaneously and are superimposed.

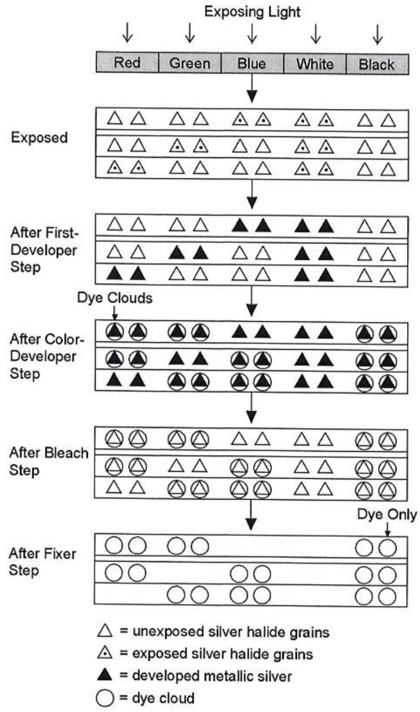
Figure 1-2 shows the formation of the color image during processing. For more information about each processing step in Process E-6, see the descriptions on page 1-2.

Figure 1-1



F009_9000AC

Figure 1-2



F009_9001CC

PROCESS E-6

Understanding Solution Functions

Use the following descriptions to become familiar with the function of each processing solution. This understanding, along with the information in section 14, "Diagnostic Charts," and section 15, "Control-Chart Examples," will help you analyze process problems.

First Developer

The chemical reducing action of the first developer converts exposed silver halide grains (the latent image) into metallic silver (the silver image). This is a negative image. The first developer step is the most critical step of Process E-6. The amount of silver formed depends on developer activity.

Time, temperature, agitation, developer concentration, and utilization affect first-developer activity. In Process E-6, increased first-developer activity causes too little dye to form; decreased activity causes more dye than normal to form.

First Wash

The first wash stops the action of the first developer and removes first developer solution from the film. Insufficient water flow, incorrect temperature, or too little wash time will affect density (speed) and color balance.

Reversal Bath

The reversal bath prepares the film for the color-developer step. A chemical reversal agent is absorbed into the emulsion and prepares the remaining silver halide for the chemical reversal that occurs in the color developer. Do not use a wash between the reversal bath and the color developer; the reversal agent must be in the emulsion when the film enters the color developer.

Incorrect replenishment, excessive oxidation, incorrect mixing, and utilization can affect overall density and color balance.

Color Developer

When film enters the color developer, the reversal agent absorbed by the emulsion in the reversal bath chemically "exposes" the remaining silver halide. The color developing agent then reacts with the silver halide to form metallic silver. As this metallic silver image is formed, the oxidized color developer agent reacts with the color couplers in each of the three dye layers (yellow, magenta, and cyan) of the film to form colored dyes. The dye forms only at the sites where the image was converted to metallic silver.

Changes in the color developer pH, agitation, time, temperature, developer concentration, utilization, and replenishment rate affect color balance, contrast, maximum density, minimum density, and uniformity.

Pre-Bleach

The pre-bleach prepares the metallic silver developed in the first and color developers for oxidation to silver halide in the bleach step. It helps preserve the acidity of the bleach solution by reducing carryover of color developer into the bleach. The pre-bleach also enhances dye stability. Pre-bleach that is too concentrated can cause leuco-cyan dye to form, resulting in low red D-max. If the pre-bleach is too dilute, the dye stability could be substandard. Do not use a wash between the pre-bleach and the bleach; pre-bleach carry-in is necessary for proper bleaching.

Bleach

The bleach converts the metallic silver image back to silver halide; the silver halide is later removed in the fixer.

During bleaching, iron III is reduced to iron II. Iron II must be converted back to iron III by aeration so that satisfactory bleaching can continue. Aerate the bleach by bubbling air through it.

Inadequate aeration, underreplenishment, too little time, low temperature, and over-dilution by pre-bleach can cause silver retention, low red D-max, high blue D-max (and to a lesser degree, high green D-max), and yellow D-min.

Fixer

The fixer converts all of the silver halide into soluble silver compounds. Most of the silver compounds are removed in the fixer and can be recovered.

You must aerate any bleach carried into the fixer (by bubbling air into the fixer or with manual agitation) to prevent exhausted bleaching agent from causing leuco-cyan dye to form. However, too much air will oxidize the fixer; aerate the fixer only when film is in the fixer.

Too little time, underreplenishment, or fixer dilution will cause silver-halide retention, increased blue density, or yellow D-min.

Final Wash

The final wash removes chemicals remaining in the film emulsion. Complete washing at this stage is important for image stability; any chemicals remaining in the film may deteriorate the image dyes. For best results, use a 2-stage countercurrent-flow wash.

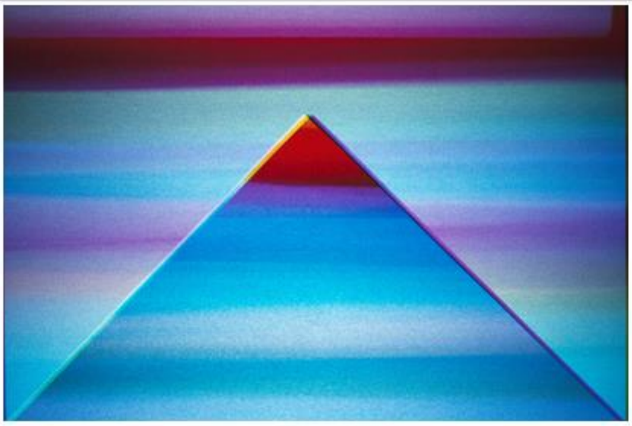
Final Rinse

The final rinse contains a wetting agent to reduce water spotting and provide uniform drying. To help prevent water spots and streaks, maintain solution cleanliness by replacing the final rinse once a week or more frequently.

Appendix VII

Slides de Cavalete (1978-1979): Catalogue

Artwork



Artist
Ângelo de Sousa (1938-2011)

Title
Slides de Cavalete:
Fotografias (slides) de algumas pinturas imaginadas e inexistentes (excepto nos próprios slides projectados)

Date
1978-1979

Medium
Slide-based artwork

Description
One hundred 35 mm chromogenic reversal films with mounting (colour slides) to be projected, following a specific order, on a canvas placed over an easel.
The work begins with a few introductory slides with text. The introduction is followed by the images constructed with the additive mixture of colours. This set is composed of two parts: a triangle (Part I) and a rectangle (Part II), both shapes having the same proportion. The work ends with slides containing typed text.

Image size
90 x 120 cm, or larger if within the same proportion.

Duration
8 to 12 second each slide; total duration between 15 min and 22 min (considering time between images).

Room size
Undefined

Component information

List of components
- 100 colour slides (exhibition copies);
- slide projector (non-specific);
- white canvas (non-specific);
- easel with 19th century appearance and a hand crank (non-specific);
- Plinth (non-specific);

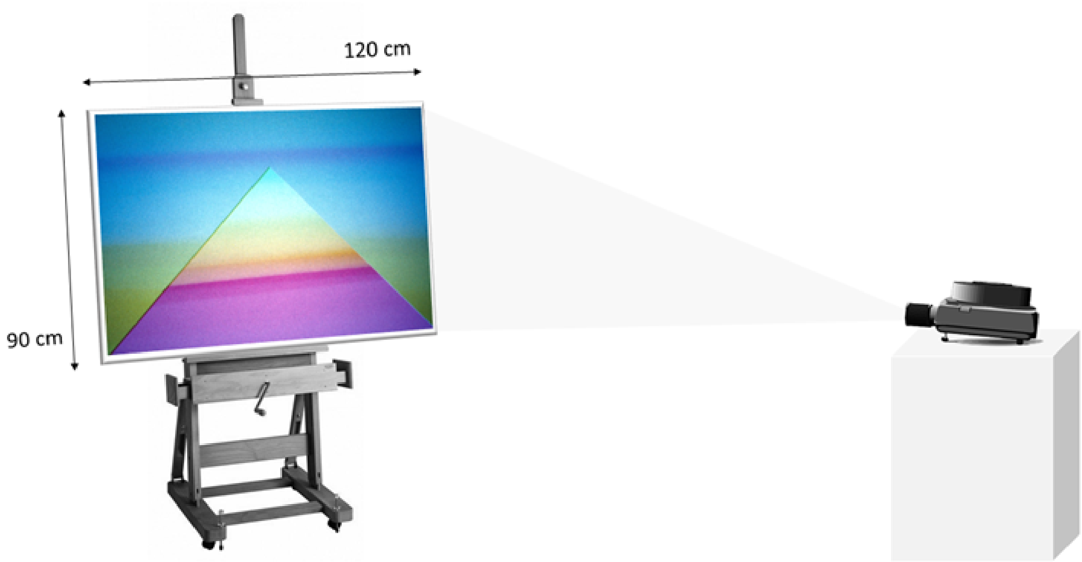
Image carrier
Set of exhibition copies (chromogenic reversal films) necessary to cover the time-frame of the each exhibition.

Display equipment
Automatic carousel slide projector with capacity for 100 slides, equipped with a quartz lamp or equivalent.

Display specifications

Subtitle (example)
Slides de Cavalete: Fotografias (slides) de algumas pinturas imaginadas e inexistentes (excepto nos próprios slides projectados) (1978-1979)
Duplication slides (restored version) made from the original one hundred 35 mm chromogenic reversal films
15 min
Artist collection

Setup



Room conditions
The levels of luminosity have to ensure that the easel and canvas are slightly visible. Though, they should not be too high to allow the proper observation of the colours of the slides. The installation does not require an individual room.

Display history

- *A Fotografia como Arte / A Arte como Fotografia* (1979), Centro de Arte Contemporânea – Museu Soares dos Reis, Porto (Portugal), and Fundação Calouste Gulbenkian, Lisbon (Portugal);
- *Fotoporto: Mês da Fotografia* (1988), Casa de Serralves, Porto (Portugal);
- *Encontros com as Formas* (2014), Fundação EDP, Porto (Portugal);
- *La Couleur et le Grain Noir des Choses* (2017), Fundação Calouste Gulbenkian, Paris (France),
- *Potência e Adversidade, Arte da America Latina nas Colecções em Portugal* (2017), Museu da Cidade, Pavilhão Preto, Lisboa (Portugal);
- *Jornadas Lúcidas 2 - Oporto*, the work *Nobody Here* (2009), Casa dos Marinheiros Mercantes, Lisbon (Portugal).

Documentation and materials

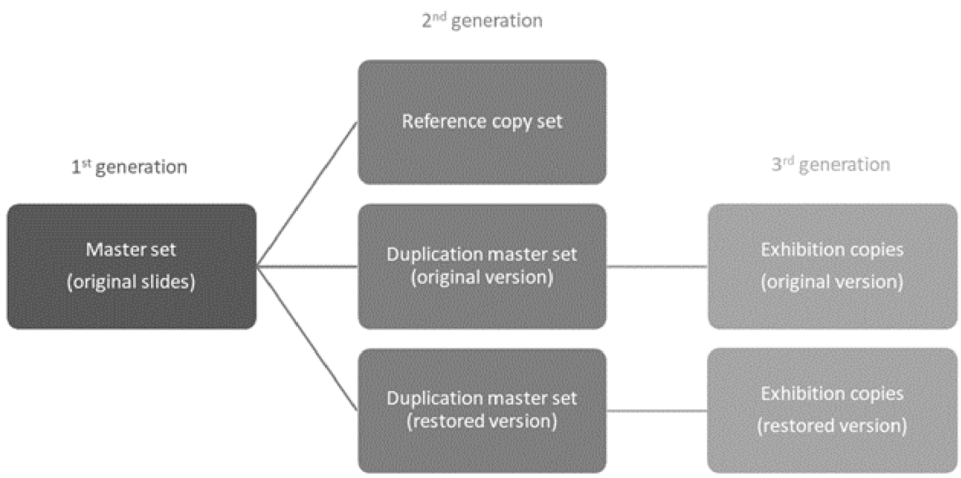
Production Process
- Dossier *Slides* held by the owner of Ângelo de Sousa's collection, containing documentation related to the production process;
- Filters used to produce the artwork;
- Masks used to produce the artwork;
- Test slides produced within the framework of the artwork.

Exhibition
Documentation held by Fundação Calouste Gulbenkian, related to the display of the artwork in the exhibition *A Fotografia como Arte / A Arte como Fotografia* (1979).

Preservation

Condition
The chromogenic reversal films composing the slide based artwork present colour shift and dye fading.

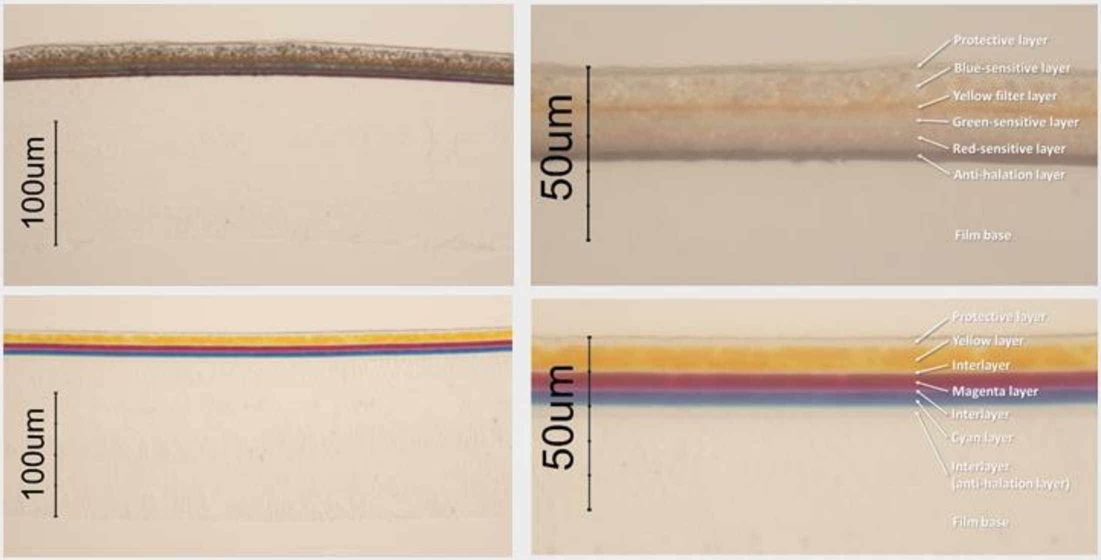
Recommended media migration



Storage guidelines
The original colour slides (Kodak Ektachrome 160T Professional), reference copy set and duplication masters should be kept a low T and RH values, while exhibition copies are made for display. ISO recommendation: RH=50%, T=-10˚C / RH=40%, T=-3˚C / RH=30%, T=2˚C. The materials should be stored in paper (acid free) or plastic (polyester, polyethylene, polypropylene) packaging.

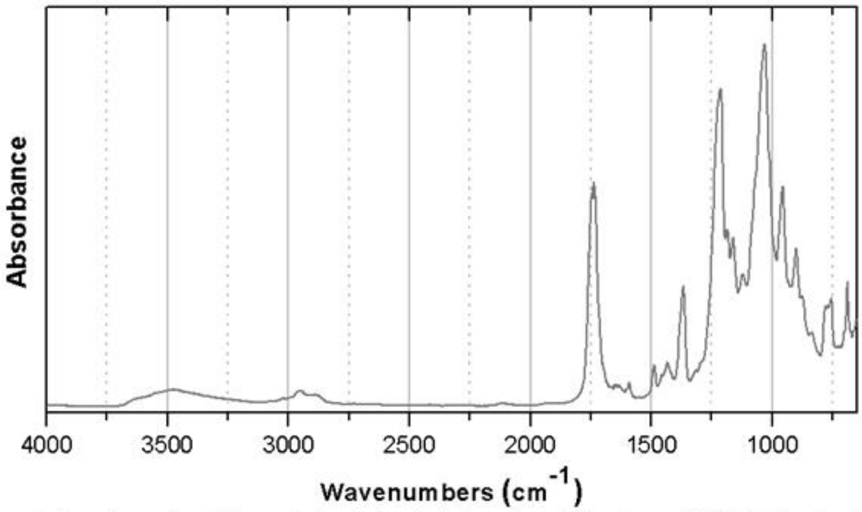
Scientific analyis

Optical microscopy

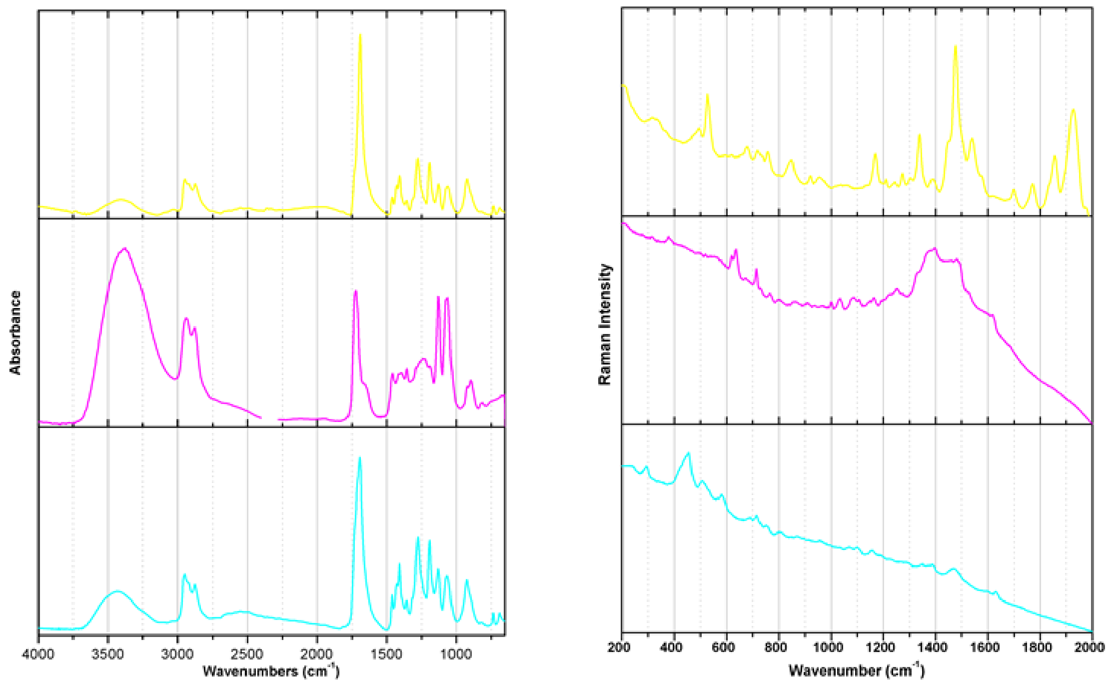


Cross-sections of Ektachrome 160T Professional film, before (top images) and after (bottom images) processing.

Infrared and Raman spectroscopy

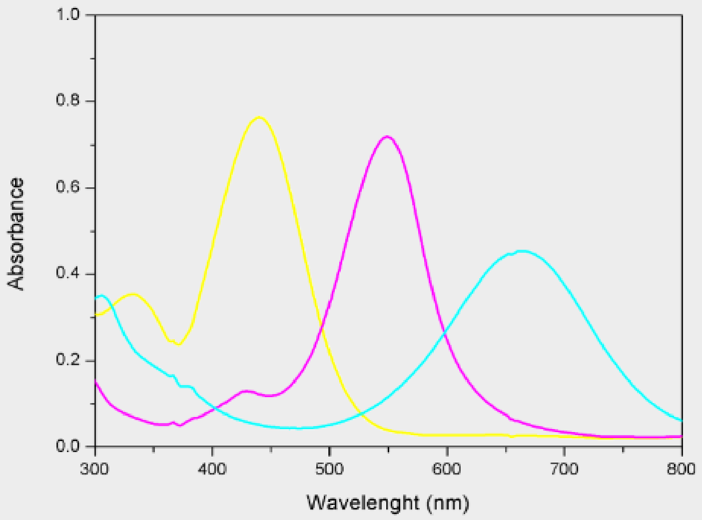


Infrared spectra of the cellulose triacetate base from Ektachrome 160T Professional.



Infrared spectra (left) and Raman spectra (right) of the chromogenic dyes from Ektachrome 160T Professional.

UV-vis spectrophotometry



Absorbance spectra of chromogenic dyes from Ektachrome 160T Professional.