A Work Project presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

Food Loss and Waste in the Food Supply Chain: Current situation and Potential Solutions.

OMAR RGUIBI

Student N°43316

Work project carried out under the supervision of:

Dr. Manuel Pedro Baganha

20 May 2021

Abstract

This research aims to identify the food waste and loss (FLW) at the different phases of the food supply chain (FSC) and provide some possible solutions that the various actors can implement to reduce the waste. This research starts by overviewing the FSC. It then focuses on describing how the waste occurs in the different phases of the supply chain and the main drivers of FLW in each stage. The impact of FLW is assessed and quantified in the study to sensitize the readers about the underestimated environmental and socio-economic effects of the issue. The findings emphasize the urgency to tackle the problem and involve all the actors, especially the consumers, to formulate some solutions and strategies that will alleviate the ecological and socio-economic effect of the issue. Additionally, as a support, based on an extensive literature review and successful examples, some solutions and recommendations are presented that can be adopted to reduce the waste by the different actors.

Keywords: Food waste and loss (FLW); Waste management; Food supply chain (FSC); Sustainable Consumption and Production.

Acknowledgments

I would like to express my gratitude to Dr Manuel Baganha and Hicham Affach for their guidance, commitment, and contribution to this study.

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209).

Table of Contents

I. Introduction

Human life depends on food as much as on water for livelihood, and nutrition was characterized by Maslow's pyramid of needs as a psychological need that must be satisfied before pursuing other needs. The second SDG goal is to achieve zero hunger, which shows how improving the nutrition of needy people is essential to achieve global development. However, even if the world leaders adopted this goal in 2015, the number of people who suffer from hunger is still increasing and this illustrates the complexity of the issue. People might think that the cause of this issue is a lack of production, but it is not the case. It is the reverse, according to the Food and Agriculture Organization of the United Nations (FAO), approximately one third of the total production of food products globally is lost or wasted (FAO 2019).

The term of food being wasted or lost can seem to be simple and easy to understand. Yet, there is not a universally agreed definition (FAO 2019), but what is generally meant by the notion is when the product is lost or wasted along the food supply chain, from the harvest/slaughter until the consumption level. Additionally, this issue is also a severe threat to the planet. Food waste is the cause of about 8% of the global greenhouse gas emissions(FAO 2011); which is greater than the amount of emission of a country like India or Brazil.

Besides its social and environmental impact, the waste of food also has an economic effect on both the producers and the consumers. From the producer's perspective, a surplus or waste of production is an avoidable cost that company could have prevented by a better forecasting or an efficient waste management strategy. The consumer is also impacted financially; in the United States, the cost of food waste for an average family of four members is between $1365 and $2275 per year (Gunders 2012).

Based on a qualitative approach, this research aims to describe the actual situation of food wastage in the different phases of the supply chain and discuss some possible solutions and their limitations.

II. Literature overview

The phenomenon of FLW has acquired a global dimension and is considered by numerous experts as a complex and topical challenge (Belyaev, Donskova, and Zueva 2020). The waste of food is also viewed as a critical subject since it has a high financial cost for companies and societies in addition to its relation to climate change issues and the waste management field (Chauhan et al. 2019). This problem also leads to significant losses in terms of precious resources, and at the same time it contributes to a critical ecological degradation (Beretta et al. 2013). When it comes to the greenhouse gas emissions, food loss and waste is responsible for approximately 8% of the worldwide greenhouse gas emissions (FAO 2019). Reducing and avoiding food waste is primordial to reduce world hunger, improve food security, and minimize its ecological impact (Jeswani, Figueroa-Torres, and Azapagic 2021).

However, one aspect that increases the complexity of this issue, is that the food loss in the supply chain is interdisciplinary and interdependent, which is why the subject is highly fragmented (Chauhan et al. 2019). The FSC is stretched and contains many stages, the waste of food occurs in each stage of the food supply chain, from the agriculture stage until the product arrives to the end-user consumer (Papargyropoulou et al. 2014). The FLW problem has recently become a subject to numerous studies and articles; additionally, governments have started tackling this issue due to its importance and high complexity (Luo, Olsen, and Liu 2021). In 1975, the FAO recognized in its first world food conference that reducing food loss and especially postharvest losses will be essential to reduce the world hunger problem, but the issue still persists (Parfitt, Barthel, and MacNaughton 2010).

Researchers developed frameworks to understand the issue and propose some solutions, in its publication Papargyropoulou with its co-authors, designed a framework to provide possibilities to manage the food surplus and distinguish between preventable and inevitable food wastes (Papargyropoulou et al. 2014).

III. Research Objective

This research thesis aims to answer the question of the current state of FLW in the food supply chain and some possible solutions to reduce the impact of the issue. To answer this question, the different phases of the FSC will be analyzed to detect how and where does the waste occur -We can identify five clear steps in the food supply chain production, postharvest & storage, processing & packaging, distribution & retail, and the end consumer phase (Gunders 2012) - the losses at each stage will be analyzed and quantified.

The environmental and the social impact of the food waste and loss will also be tackled in this paper since most people and researchers neglect this aspect and focus more on the economic effect. However, the global warming is a serious threat to our planet and the food loss phenomenon is one of the main reasons behind the annual greenhouse gas emissions.

This research objective can be divided into four different sub-subjects or questions, that will allow to dive deeper and have a more structured analysis; additionally, these sub-questions will help to guarantee the coverage of the different sides of this issue:

a. An overview of the food supply chain.
b. How does the food waste occur in the supply chain?
c. What is the impact of the food waste and loss?
d. How can this waste be reduced?

IV. Methodology

A qualitative methodology was followed in this research due to the complexity and the interdisciplinary aspect of the subject. A systematic literature was adopted in the first phase to gain deep insights about FLW in the food supply chain, in addition to what are some solutions that some experts suggested. To find the most appropriate articles and academic journals, only the sources that were published in the last 20 years were considered. Online researches were done in the databases B-on, SCOPUS, and Science direct. The search words were composed by

the interaction of “Food waste and loss”, “Food supply chain”, “World hunger”, and “Waste Management” which were used to ensure that the integrality of the subject will be covered. Additionally, reports from the Food Agriculture and Organization of the United Nations were studied to obtain the most updated data and statistics concerning the food waste in the world and how people are suffering in other parts of the world of hunger to illustrate the importance of the subject.

To complement the literature review, real-life examples will be used to illustrate the current situation and some solutions that can be used to decrease the quantity of wasted food products. Furthermore, virtual interviews were conducted with Mr. Hicham Affach, a supply and demand planner at a company that is the leader in the distribution of consumer and food products in Morocco. He is responsible for forecasting customer demand and ensuring its satisfaction. These interviews were conducted to provide guidance on my research process and show me some practices and procedures that are used in his department to reduce the waste and manage their inventory efficiently.

V. Food Supply Chain Overview

The Food industry is essential in any economy, in Europe, the number of actors in the food supply chain varies at each stage. According to the European commission, the food supply chain provides approximately 44 million jobs in the European countries (FAO 2019).

The food supply chain is described as the process that indicates how the food is produced and the steps that the product goes through before ending in the consumer's plates. This term can also be explained as a combination of interactions between producers and the final consumer interlaced with other food processing and distribution corporations (Jeswani, Figueroa-Torres, and Azapagic 2021). The food supply chain (FSC) diverges from other supply chains. It deals with the perishable characteristic of the products, the collaboration with many stakeholders, the intersectoral effect, and other complex problems (Mithun et al. 2019).

We can distinguish five main stages in the food supply chain: production, postharvest & storage, processing, distribution, and consumption; the three first stages are considered the upstream, while the two last stages are called the downstream supply chain. The FSC can be compared to a domino set, since all the stages are interrelated, which can be illustrated by the changes in prices that occur when there is a disturbance in a specific stage. As a result of industrialization and globalization like in many industries, the food supply chains have become extremely stretched, and each step can be located in a different location. There are two key reasons behind this stretching: the first one is that the firms are pursuing a cost-effective strategy and are outsourcing some of their activities to other parts of the world where the cost of production are less expensive, the second reason is the scarcity of the raw materials because in some reasons the primary resource can exclusively be found or cultivated in a specific region (Argan, for instance, can only be found in Morocco).

VI. Food Waste in the Food Supply Chain

Many scholars have distinguished between food waste and loss (Chauhan et al. 2019), but as mentioned before, there is not a specific and unanimously agreed definition of the food waste and loss. Consequently, in this study, there will not be a distinction between food waste and loss and it will be considered as one notion.

Decreasing food waste is an essential factor in improving food security, reducing operational expenses, improving the efficiency of the FSC, and contributing to ecological sustainability. The food waste and loss has been subject to an increase in attention which is mirrored in the SDGs. SDG 12.3 calls for "for halving per capita global food waste at the retail and consumer levels and reducing food loss along production and supply chains by 2030" (FAO 2019).

In 2011, an estimate was prepared for the FAO that is still cited in many researches, assessed that nearly one third of the global food was either wasted or lost (FAO 2019). This issue is present in both developing and developed countries (Belyaev, Donskova, and Zueva 2020), this

means that the main reason for the waste or loss of food is not technology. For example, in the US, 40% of the food is wasted while reducing this waste by only 15% would be enough to nourish 25 million American citizens , at a time when nearly 17% of Americans need a secure supply of food (Gunders 2012).

FLW is not a recent issue, it was present for many years and is present in every part of the world. Based on the statistics that can be found on the food balance data and completing it with existing literature, the evolution of the FLW in the last years was quantified. From 1961 to 2011, the global FLW increased from 536 Mt per year to 1626 Mt, which is corresponding to a growth of 203% (Porter et al. 2016). Every region of the world contributed to this increase. Additionally, the rise of the quantity of wasted food was greater than the population growth. In order to diminish FLW, the initial step is to quantify and recognize the amount of waste that is wasted across the food supply chain (Chauhan et al. 2019).

1) *FLW in the production stage of the food supply chain*

The production phase of the food supply chain indicates the two initial stages of the FSC, which includes the agricultural production (pre-harvest) and the postharvest stage. During these two first stages, the main reason for food waste and loss is the damage caused by nature. It can take the form of severe weather conditions, pest infections, or natural disasters. The waste generated by the natural factors is considered as unavoidable. Furthermore, there are other factors that cause FLW at the production stage of the FSC, first operational mistakes and inadequate production techniques increase food loss during the production phase. This why the FLW in the pre-harvest and postharvest stages are higher in the developing countries (Jeswani, Figueroa-Torres, and Azapagic 2021), where more primitive farming methods are used in addition to the lack of proper storage facilities and poor transportation infrastructure. However, even in developed countries that have better transportation infrastructures and where more advanced farming techniques are used, the production wastage is still present. The FLW in the

developed countries is due to other factors that can surely be avoided. Overproduction, quality standards, and aesthetics are the main causes of food wastage within primary production in the developed countries.

The large retailers have a high bargaining power over the farmers and can influence the producers' farming practices. For instance, a retailer can include in the contract a clause that obliges producers to deliver products at a predefined date and in a specific quantity. This kind of clause incites producers to make some contingency strategies to ensure that the contracts will be honored, especially if the contract contains an exclusivity deal; the producers will be encouraged to overproduce to ensure that the yield agreement is met. Nowadays, customers are more demanding in the quality and the aesthetics of food products, which drives the retailers to specify some quality standards to define which products will be accepted. Conversely, these quality standards can result in rejecting up to 40% of the total yield (Bond, M., Meacham, T., Bhunnoo, R. and Benton 2013). These high-quality standards are unsustainable and lead to high amount of waste, where edible food is redirected as animal feed or thrown.

2) FLW in the processing stage of the food supply chain

The processing stage is the most automatized phase of the food supply chain, where the products enter the supply chain to undergo different types of procedures, from refining for example to more complex operations (e.g.: preparation of ready meals).

The FLW can take different forms in the processing & packaging stage of the food supply chain. Like in all the industrialized sectors, variability is present in all the processes, the variability cannot be eliminated from the operations but can only be accommodated. The errors and the defects are also present in the processing phase of the FSC, which results in FLW. The most popular type of waste at the processing facilities is the trimming phase, where both edible and inedible parts are removed from the products. All the processes across the FSC are subject to the risk of mechanical product damages, and these damages can take different forms and have

various effects. For instance, power blackout is a common problem in the processes and some products may be discarded if the goods were stored at a specific temperature or can be affected by microbial safety. Power blackouts are hard to prevent as they are due to external malfunctions and instabilities in public power.

The defect of equipment is another type of process failure that leads to FLW. Different types of equipment are used in the process phase of the food supply chain, the more critical ones are the equipment responsible for the storage temperatures. Due to the short shelf life of the food products, the defect of refrigeration and heating units results in an improper storage temperature which affects the safety and the quality of raw materials. Nevertheless, immediate decisions have to be taken in a short window of time; otherwise, the products will be lost and cannot be exposed on the shelves.

Human error can also cause processing failure that may lead to FLW. In the food supply chain, humans interventions are present in many phases. There are different types of human errors during the processing; for instance, employees may insert wrong process parameters that cause the equipment to be uncalibrated. They may also incorrectly handle the ingredients formula, resulting in food loss.

Packaging technologies have helped in reducing food waste by minimalizing microbial contamination and spoilage (Bond, M., Meacham, T., Bhunnoo, R. and Benton 2013). Packaging is essential in preserving the products for a longer time and assist in conserving food from deterioration. However, errors in the packaging are still present in the processes and cause food waste; errors in the packaging phase can cause package leaks and changes in conservation temperatures. Hence, the products will not be accepted by the retailers and discarded.

Most of the waste at the processing seems to be unavoidable due to the variability that exists in large scale industries; yet, there is always room for improving the operations and adopting new technologies to gain more efficiency in the food production (Gunders 2012).

3) *FLW in the retail and the distribution stage of the food supply chain*

In the US, the estimated food waste at the retail level reached 43 Billion pounds in 2010, and that has undoubtedly grown with the proportional increase of the demand for the agri-food products (Buzby, Wells, and Hyman 2014). However, the retail sector is responsible for more waste due to its influence both up and down the food supply chain, but unfortunately, retail managers consider food waste as part of doing business (Gunders 2012).

As discussed above, the aesthetic expectation is a large contributor to the FLW. Due to the high competitivity in the retail sector, retailers have to display and offer higher quality products to distinguish from the competitors, which leads to much of the discarding mentioned before. One other trend that emerged during last years is the overstocked shelves, retailers believe that shoppers prefer to purchase products from abundant, fully stocked displays, rather than from a meager basket. (Gunders 2012). This towering display will result in an overhandling by clients and employees that might cause damage to the products that will be later rejected.

Another cause of the FLW in the retail sector is that supermarkets offer prepared and ready-made food in their displays and buffets. Nevertheless, these prepared meals have to be fresh, so their shelf life is very short and if not bought, the products would need to be quickly replaced. Prepared food represents a significant portion of retail food waste, which accounts for about 25 percent of their food waste; additionally a grocery assessed that half of the rotisserie chickens that were prepared in the day were discarded (Gunders 2012).

The inexact science of forecasting demand is the highest challenge in the retail industry. The stores have the challenge of forecasting the optimal quantity to guarantee an appropriate level of stock rotation, increase sales, and reduce waste simultaneously (Bond, M., Meacham, T., Bhunnoo, R. and Benton 2013). Many factors and variables have to be considered for the demand forecasting, such as seasonality, new product launches, promotional campaigns, and holiday occasions like the new year and Christmas (Mena and Whitehead 2008). " On shelf

availability" is a key performance indicator that is used in the retail industries, this indicator measures the frequency that a product is not on display for sale, the retailers prefer to waste a product rather than lose a sale (Mena et al. 2014). With these preferences, the difficulty of accurate forecasting, and the satisfaction of indicators, managers tend to over-demand and overstock to avoid any shortage of sales. However, the food products are perishables; consequently, the products can only be stocked for a short period, and if not sold, they will be lost.

At the distribution stage, the FLW is lower than the previous phases discussed before, but an appropriate transport of the products is critical in the food industry. Especially that some of the products necessitate a specific temperature. With the technological advancement, refrigeration issues are less present in the transportation phase, yet due to some technical malfunctions or wrong settings the perishables may get wasted. Additionally, with the globalization trend, many food products are imported from different countries, consequently handling and organizational problems can occur in the ports. For instance, if the imported products need to be tested and the waiting period is long, the shelf life of the perishable will be reduced. Rejection of the shipment is the largest source of FLW at the distribution stage. If a shipment is rejected, another buyer has to be found; otherwise, the perishables may be dumped and even if the products make it to retailers, their shelf life would be shortened (Gunders 2012).

The management of the food products must be a primary concern on every retail strategic agenda since it was estimated that up to one in seven truckloads of food perishables delivered to the retailers is thrown away (Beswic et al. 2014) .

4) *FLW at the consumption stage of the food supply chain.*

Consumers should not be separated from the other actors in supply chain, as their decisions and practices influence all the other actors of the supply chain. In the developed countries, the consumption stage is where most food waste occurs. For instance in Europe, it

was estimated that 50% of the FLW is related to household consumption (Reynolds et al. 2019). Additionally, in South Africa as another illustration, the food waste at the consumer level was estimated to $2.7 billion, representing approximately 1% of the national GDP (Nahman and de Lange 2013). There are two main types of consumption FLW: household waste and the hospitality waste, which is the FLW that happens in restaurants, hotels, and other catering outlets.

In the United Kingdom, hotels, restaurants, Fast Food, and other catering services had produced a total of over 3 million tons of food waste in 2009 (Wrap, 2011), and it is expected to increase as eating out is becoming progressively more popular. The business concept of a company can be a reason for food waste, as it dictates the firm's activities and strategy in the market. The buffet style has become a popular concept in the hospitality industry, which is based on the concept of having the food ready and available to the clients. However, this concept makes it very challenging to control food waste, since the management has to predict the number of customers and prepare the food in advance by trying to avoid any shortage, which makes the service waste higher.

Another factor that affects the food waste in the hospitality industry is the product development and the procurement of ingredients. The quality of ingredients used during the preparation of the dishes has a direct influence on food waste. It was proven that when frozen bread is used instead of fresh bread, the amount of plate waste increases (Heikkilä et al. 2016). In addition to that, the constraint of batch size is an issue; some ingredients are not available in small and sufficient quantities; consequently, some ingredients will be left unused on the shelves. The professional skills can also be a cause of food waste in the hospitality sector. The ability of the employees to perform their tasks correctly and reduce the frequency of mistakes has an impact on the FLW. Errors in the cooking process or a misunderstanding of the customer's order will lead to avoidable food waste. Precaution, accuracy, and the ability to follow instructions are

very important to reduce the errors and the FLW in the kitchen, especially that the cooking process has become divided into different stages and the professionals have to anticipate and assess future situations (Heikkilä et al. 2016). The extensive menus that the restaurants propose to distinguish from the competition is also a contributor to the food waste in the food service sector. The companies are obliged to hold more inventory in hand to offer richer menus, but most of the ingredients are perishables. Consequently, some elements will be left unused and will be discarded.

Many factors contribute to the food waste in the household consumption, also these reasons vary significantly based on the food group. The disposal of food due to not using the products in their consumption time is the main contributor of avoidable FLW in the household utilization (Jeswani, Figueroa-Torres, and Azapagic 2021). Food products are considered as cheap commodities and are undervalued by citizens from developed countries, the products are widely available and are considered as relatively inexpensive goods. These characteristics have led to comportments that do not place high importance on utilizing the product, consequently the subject of FLW is not considered an important issue by many individuals, even those who believe that they are price-sensitive and environmental friendly (Gunders 2012). Additionally, retailers use many means to encourage customers to bulk purchasing, for instance, the promotional campaigns that supermarkets use. These store promotions incentivize the customer to spend more, even on the items that are not needed. Consequently, it results in customers buying an excessive quantity or ingredients outside their meal planning, to take advantage of the promotions.

Additionally, confusion over the label dates is another main contributor to food waste. In the UK, 20 % of the food waste in the households was estimated to be caused by date labeling confusion (Gunders 2012). “Best by” and “Use by” are the two most used terms by producers to indicate peak qualities and preferences when the perishables should be consumed. “Best by”

dates suggest the period for which food will still be at its peak quality. After this date, the quality, texture, or appearance may change but the product will still be safe and edible. “Sell by” dates are for the retailers and indicate the date by which the product should be removed from the shell, it is also more an indicator of quality than of safety. “Use by’’ is the most important date to remember since it is related to the safety of products, when the product passes the “Use By” date it is recommended not to consume it, as it can put you at the risk of poisoning after the indicated date. Many people are not aware of the differences between each of these dates; consequently, confusion over date labeling remains a prominent factor in food wastage (Bond, M., Meacham, T., Bhunnoo, R. and Benton 2013).

VII. Impact of the Food Waste and Loss

The significant amount of FLW is considered a primary international concern due to its several associated environmental, social, and economic impacts (Jeswani, Figueroa-Torres, and Azapagic 2021).

Food that is wasted, not consumed, or used helpfully, means that all the resources that were used to produce it, distribute it, and store it would have been used in vain (Ridoutt et al. 2010). Water is essential in the food production and the agriculture industry; moreover, it is vital for all living creatures. However, water is becoming an insufficient and overexploited resource in many regions of the world, and with the expected increase of the world population and their food demand, the situation will only intensify. Therefore, Food chains have to improve their operations and become more efficient in their water usage management. As an example, in Australia, the average virtual water content of 1 kg of domestic made mango consumed by a family is 5218L due to the wastage in the production and the distribution of the fruit, additionally at a national level, it was estimated that the FLW in the mango distribution and consumption represents an annual waste of 43.3gl of water (Ridoutt et al. 2010).

In all its stages, the food supply chain produces greenhouse gas (GHG) emissions from the farming process until waste disposal. The European commission estimated that the production of food accounts for 31% of the European total greenhouse gas emissions (excluding the hospitality sector) (Garnett 2011). The greenhouse gas emissions that result from food wastage are underestimated by public opinion, as most people relate the GHG to cars and industrials factories. However, if food wastage was a country, only China and the USA would be responsible for more GHG emissions, and the GHG from the food waste or loss is equivalent to 87% of the total road transportation emissions (FAO 2011). Additionally, what is more worrying is that FLW emissions show no signs of a decrease. The world population, food production, and food wastage are only expected to increase. FLW greenhouse gas emissions in 2050 are expected to be between 5.7-7.9 Gt CO2, which is equivalent to the emissions of the USA in 2011 (Porter et al. 2016). If we add to it, the electricity and fertilizers used to produce, store, and prepare the wasted food would have been used in vain. The prevention of food waste in the different phases of the supply chain have to be prioritized to reduce its environmental impact and prevent further climate change.

In 2013, 868 million people were estimated to be undernourished, which means that one over eight people in the world lacks access to nutritious and sufficient food to maintain a stable and healthy life (Bond, M., Meacham, T., Bhunnoo, R. and Benton 2013). A link exists between FLW and global food security, and it is widely recognized that reduction of food waste in the different stages of the supply chain will help in the reduction of the global hunger, improve the nutritional quality of food, and encourage sustainable agriculture (FAO 2019). Morally, it is unacceptable that edible food is wasted while a significant number of people are going to bed every day with empty stomachs. With the reduction of FLW, more food will be available, which will result in lower prices of food across the supply chain and increase the accessibility of food to lower income families. In countries with excessive levels of food insecurity, the main

progress in food security is likely to happen by diminishing food losses in the production stages of the supply chain (FAO 2019).

How a company is socially responsible affects its reputation and attractiveness. Many companies engage in corporate social responsibility and act in a way that is socially and environmentally friendly. However, as mentioned before, enormous food waste happens at the processing and distribution stage of the FSC, even if the main actors in the retail sector have integrated food waste reduction in their CSR strategy due to public pressure. Although this recognition and integration of the issue in the corporate strategy, the attitude of managers in the field does not reflect it and the problem seems only to be represented as a separate aspect of the CSR, rather than a problem that have social repercussion on the society (Filimonau and Gherbin 2017). Donation to food aid organization is a way to help the communities, demonstrates corporate social responsibility, and improve the company's reputation (Garrone et al. 2016), but in most cases, the wasted food is no longer edible and cannot be donated.

FLW has also an economic impact on the various actors in the food supply chain. Consumers who are the main contributors to food waste in the developed or high income countries are impacted financially by their acts, but the cost of FLW tends to be underestimated by the consumer and the governments (Nahman and de Lange 2013). However, even in the high income countries, food waste has a significant financial impact on consumers; for instance, in the United States, the food waste was estimated to cost an average household between 1350$ and 2275$ (Gunders 2012). Since this food waste happens on a daily basis, if it is taken separately, it is insignificant compared to a household budget. However, if it is aggregated, it represents a considerable amount of wasted money that could have been saved or invested.

Many studies emphasize that reducing food waste will have a positive economic impact on the consumers and the farmers (Luo, Olsen, and Liu 2021; FAO 2019). However, studies diverge for the retailers and the suppliers when it comes to determining if the profit of the reduction of

food waste will offset the cost of implementing the necessary procedures to avoid the waste. The data concerning the costs or investment needed to reduce food waste are difficult to find, as the required interventions vary depending on the type of products and the factor causing the discarding of the food (Rutten 2013). For instance, only a simple calibration of the machines or advanced training, which have a relatively low cost can be needed in some cases, but in others an improved transportation system or investments in storage facilities which represent an important investment is required. When the cost of implementing the solutions is higher than the residual value of the wasted products, companies consider these solutions as economically unfeasible (Luo, Olsen, and Liu 2021). In this case, the intervention of the public sector is justified. The public sector may encourage companies by some tax benefits or subventions to reduce their waste, and at the same time, the implementation of the measures will benefit the society as a whole by the creation of job opportunities, protection of the environment, and redistribution of the undesired products to the families that are in need (FAO 2019).

VIII. Potential Solutions for Reductions of FLW

1) *Increase Public Awareness*

In most countries, consumers are the main contributors to food waste and this is due mainly to the lack of public consciousness of the effect of food waste. Increasing public awareness may seem like a simple solution that is not enough to solve this complex issue, yet the consumers' attitude proves that public opinion is not aware of the impact of the FLW. “Love food hate waste” is the slogan of a successful awareness campaign that was launched in the United Kingdom, with this campaign the avoidable household food waste was reduced by 18 percent (Gunders 2012). An extensive public awareness campaign needs to be launched by the UN with the help of different public organizations and should feature celebrity spokespeople. This campaign has to draw attention to the economic, environmental, and social impact of food waste and show how with small gestures, the consumers could make a significant difference and help

in the reduction of food waste and its effects. The campaign needs to focus on three axes that are the main contributors of food waste at the household level.

First, explain the differences between the various labeling date; as explained before, some dates are only indicators of peak quality of the products and are not related to product safety.

Then to explain the necessity to revise their aesthetic and quality standards. The aesthetic criteria cause food waste across many phases in the supply chain. By relaxing their appearance standards, farmers and retailers will not be obliged to discard some edible products that are considered as imperfect products.

Additionally, the campaign has to encourage customers to donate to local charities and help in feeding people in need. However, past experiences have proved that marketing is not enough and has to be completed by tangible sustained activities that will involve households and trigger their awareness (Bond, M., Meacham, T., Bhunnoo, R. and Benton 2013). The smoking and sustainable transportation campaigns are examples of successful operations that raised people's awareness to quit smoking and opt for more sustainable transportation modes.

2) Closed Loop Supply Chain

Many researchers recognize the closed loop supply chain (CLSC) as a contributor to realize more sustainable operations (Sgarbossa and Russo 2020). A CLSC can also be referred to as product remanufacturing or recovery management. The remanufacturing process is when used or damaged products are reconditioned to useful life. Remanufacturing is generally preferred for its sustainable aspect as it has been proved to be more ecological compared to other disposal and end-of-life treatments, but this CLSC has some complex characteristics that make the supply chain more difficult to manage (Östlin, Sundin, and Björkman 2008). Normally, in the CLSC, the different types of wastes and residues are put back in the supply chain, and the companies have to select which processing operation will be chosen to remanufacture/ reprocess the waste.

The CLSC requires a significant up-front investment, and companies may be reluctant to implement this system if it is not economically profitable to the organization. Sgarbossa and Russo (2020) evaluated in their study the economic and the environmental impact of closing the loop in the meat industry. The meat industry is one of the most wasteful industries within the food sector, 60 to 70% of the slaughtered carcass is wasted (Bhaskar et al. 2007). Additionally, the water consumption in meat processing accounts for nearly 24% of the total consumed fresh water in the entire beverage and food industries (Sgarbossa and Russo 2020).

In the case study, the new node that was added to the classical meat processing supply chain was responsible for re-using the wasted meat from slaughter and converted it to an energy source (depurated water, electricity, and methane gas) in order to satisfy partially or entirely the energetic needs of all the processing activities of the chain. An investment of €16 million was needed to build the biogas and the cogeneration plant where the wasted meat would be re-used. To analyse the financial benefit of closing the loop, the authors used a profitability indicator that took into account the capital investment, the operating cost, the revenue gained from the sale of the energy, and the prevented cost of the energy supply and disposal. The economic analysis showed that both plants (biogas and cogeneration) were profitable, and their payback periods were reasonable and similar to the industry standards.

An energy self-sufficiency index assessed the environmental impact. The energy produced by these plants has a lower ecological impact than the energy produced from fossil resources, so if a system produces sufficient energy for its operations, it would not need to purchase any other source of energy. The results showed that the biogas plant was not able to achieve energetic self-sufficiency. It was only able to cover 15% of the electrical need. Whereas, the cogeneration unit was able to produce 135% of the electrical need of the production stage, which means that by aggregating the production of both plants, the investment allowed the company to produce the needed electrical energy for its production process and to send the surplus energy to the

national grid. The closed loop supply chain can be very efficient and can be adapted to many food sectors with the primary objective of avoiding the disposal of food products by re-using them in a more sustainable way that will benefit the company.

3) *Follow the example of efficient ideas from other companies.*

To reduce the food waste, it is not compulsory to innovate and find creative ideas. It is possible to follow the successful examples and implement proven ideas that helped other companies increase their efficiency and reduce waste.

Grocery Outlet is a group of discounted supermarkets that recorded an annual revenue of 960 million and owns more than 148 stores. The core strategy of their business is to sell the closeout and the overruns at a discounted price, 75 percent of their product offering are coming from the surplus inventory and closeout products and includes fresh produce offerings (Gunders 2012). Many retailers can replicate this model by dedicating a small space in their stores where discounted products will be sold, or open new stores that will serve a unique niche. This solution will contribute to increase the sales of the company and enhance its sustainability.

Marks & Spencer and Tesco, two of the world's largest retailers experimented new methods of packaging to reduce FLW. The retailers tested a new ethylene absorbing strip that would extend the life of the fruits and vegetables since ethylene is a hormone that causes products to turn moldy and infected (Tesco 2012). With this new technology, consumers are excepted to be able to keep their products fresher for a longer period; additionally, this packaging was estimated to have saved 1.6 million packs of tomatoes, more than 300,000 packs of avocados, and 40,000 packs of strawberries that were destined to be disposed (Gunders 2012). Continuous research and development to find new technologies that will improve the packaging, farming, or even the processing to reduce the quantity of waste has to be on every actor's agenda across the FSC.

The Campbell Soup company, a large processing food company located in the US, has reduced its waste by 36 percent in a short period of three years (Lipisinski 2020). The company aligned

its strategy with the SDG 12.3 objective. The group quantifies its FLW and shares the numbers in its sustainability report annually. The company avoids waste by adopting many actions; the main one is the diversion of the waste to feed animals. The discards and the defective products at the manufacturing level are redirected to be reused as animal feed and kept in the supply chain; in its potato chip factory, nearly one million pounds of wasted products were used to feed animals (Campbell's 2021).

Food donations and generating electricity are other methods that the company uses to reduce its waste. It sends the expired and undesired products to a third-party partner responsible for transforming the waste into electricity, additionally the leftover of frying oil is used to create biodiesel. The Campbell company also supports local communities by donating food that could have been wasted due to overproduction to food banks and local shelters.

4) Donations and new markets.

Donations to the homeless and other people in need are social solutions that restaurant and retailers can adopt to end two issues: hunger and food waste. In Europe, many organizations are pursuing this strategy which has proven to be effective. Re-Food is a Portuguese example, it is an independent organization that operates on a local level. It collects the surplus of food from its partners, recondition it and distribute it to the people from the local communities that are in need. "les Restaurants du Cœur" is another French organization, that operates in a larger scale, and give to homeless and disadvantaged citizens access to free meals. However, there is a lack of similar initiatives in North Africa and other developing countries, even if hunger is more present in these countries. That is why new strategies that bring financial incentives and induce the different actors to reduce the waste have to found.

Selling the leftovers at a discount is a method that will simultaneously enable the restaurants and supermarkets to increase revenues and reduce waste. " RESQ CLUB," "Too Good To Go," and "Food for All" are examples of applications that connect businesses and consumers, this

type of application can be described as a marketplace for leftovers. It offers the opportunity to businesses to reach new customers and recover their sunk costs. At the same time, the users will have the opportunity to get takeaway meals that they cannot usually afford, at a discounted price, and avoid the ecological impact of disposal of these leftovers.

5) *Increase the forecasting accuracy*

To accurately forecast customer demand is the core part of the supply and demand management. The forecasting practices differ among the producers and retailers, additionally the seasonality and the perishability that characterizes the food products increase the complexity of the forecasting (Mena et al. 2014). Retailers face the uncertainty of both demand and supply since the season may not be as productive as expected, resulting in a shortage of products. Members of the supply networks are usually focusing on internal waste reduction, and this focus on internal optimization can result in inefficient results for the actors of the supply chain (Mena et al. 2014).

Interorganizational communication is indispensable for a high forecasting accuracy, and this was confirmed during my interview with Hicham. He emphasized that transparent information sharing within the company and communication with the other actors of the supply network can significantly increase forecasting accuracy. That's why organizations within the supply chain have to engage in a collaborative approach with each other and agree to share information transparently. For instance, a retailer can agree with the producers of a specific product to have an implant or chip in the shelves. The suppliers can monitor the sales and replenish when the available quantity reaches the re-order level. This will help to avoid overproducing and over-ordering. Instead the retailer will order a minimum quantity and agree on a continuous replenishment strategy with the supplier. Consult the concerned departments and get their feedback will be useful to make better decisions across the business departments and enhance the supply chain resiliency. In particular, it has been proven that a close collaboration between

the retailers and other actors in the supply chain is the initial step to improve information sharing and increase the accuracy of the forecasting (Mena, Adenso-Diaz, and Yurt 2011). According to Hicham, the Collaborative planning, forecasting, and replenishment (CPFR) approach is used by many international companies. This strategy aims to enhance the efficiency of the supply chain by integrating stakeholders in the supply chain strategies and enhance the information sharing within the different departments and with the suppliers. It is a continuous collaborative approach that, if it is adopted correctly, will be beneficial for the company to improve the forecasting accuracy and improve the flow of the products and information across the supply chain.

Furthermore, most of the companies rely heavily on quantitative forecasting and automated software to estimate the expected demand; however in many cases, historical data has to be completed by qualitative opinions from experts and other stakeholders. This has been confirmed during my conversation with Hicham, in which he assured me that the software and historical data are very useful for forecasting. Still, the organization cannot rely exclusively on it. Nevertheless, it has to be acknowledged that uncertainty will always be present and that forecasting errors can only be reduced.

IX. Limitations and future directions

Some limitations were encountered during this study; specifically, the major limitations were: the lack of standardization of the methods that are used to quantify FLW. As it was mentioned before, there is not an agreed definition of the issue. Some researchers are separating the waste and the loss, whereas other authors do not make the distinctions. Also, a lack of distinction was observed between avoidable and unavoidable waste. The Data inconsistency was another limitation that I faced; most of the quantitative data that I found concerned the UK and the USA. For the other countries, mainly secondary sources and outdated data were used. In addition to that, I was confronted with a lack of analysis of the waste of food for the different

stages of the supply chain. The majority of the studies focus on the waste at the consumption stage, and researchers neglected the FLW at the preharvest and postharvest stages. Consequently, future researchers could focus first on quantifying the waste in regions outside of the current focus area (the US and Europe) and analyze the waste in all the stages of the FSC, since the reasons of the waste at the different phases of the chain are in many times interrelated and should not be looked independently. Secondly, fieldwork has to be encouraged to update the current data and reduce the discrepancies that are found in the different sources. Also, a clear definition of FLW has to be agreed on to enable a comparison between countries and a precise classification of avoidable and unavoidable waste.

X. Conclusion

There is an evident need to reduce FLW around the world, and it is essential to not underestimate the relevance of the issue as a serious part of the ecosystem. It is true that a certain level of FLW is required to guarantee a constant availability of food (FAO 2019), but the current level of food waste is extraordinary and cannot be tolerated. Improving the efficiency of the food supply chain is a triple-bottom-line solution that necessitates the involvement and cooperative efforts of companies, public authorities, and consumers. Only ten years are left to meet the objective of SDG 12.3, which is to reduce the worldwide food waste by 50 percent. Progress has been made in many countries and by different businesses, but it is still insufficient. For the future, the advances of technology have to be adopted by companies to improve the efficiency of their operations. There is not a miracle solution that will eliminate the waste. The reduction of the issue can only happen by the involvement of all the actors of the food ecosystem and by the aggregation of their acts. Every actor in the FSC has to feel the urgency of the subject to meet the objective of the SDG 12.3 and achieve a triple win by reducing its environmental impact, feed more people, and achieve financial savings for organizations and individuals.

References:

Belyaev, Nikolay, Lyudmila Donskova, and Olga Zueva. 2020. "Efficient Value Chain as a Factor for Reducing Losses and Ensuring Food Security." *E3S Web of Conferences* 222: 1–5. https://doi.org/10.1051/e3sconf/202022206030.

Beswic, Paul, JAMES BACOS, NICK HARRISON, SIRKO SIEMSSEN, RICCARDO TRENTINI, and BERNARD DEMEURE. 2014. "A RETAILER ' S RECIPE FRESHER FOOD AND FAR LESS SHRINK A RETAILER ' S RECIPE." *Oliver Wyman, Boston*, 2014.

Bhaskar, N., V. K. Modi, K. Govindaraju, C. Radha, and R. G. Lalitha. 2007. "Utilization of Meat Industry by Products: Protein Hydrolysate from Sheep Visceral Mass." *Bioresource Technology* 98 (2): 388–94. https://doi.org/10.1016/j.biortech.2005.12.017.

Bond, M., Meacham, T., Bhunnoo, R. and Benton, T.G. 2013. "Food Waste within Global Food Systems." *Global Food Security Programme*, 1–43.

Buzby, Jean C, Hodan Wells, and Jeffrey Hyman. 2014. "The Estimated Amount , Value , and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States." https://doi.org/10.2139/ssrn.2501659.

Chauhan, Chetna, Amandeep Dhir, Manzoor Ul Akram, and Jari Salo. 2019. "Food Loss and Waste in Food Supply Chains. A Systematic Literature Review Andframework Development Approach." *Science of the Total Environment*, 135907. https://doi.org/10.1016/j.scitotenv.2019.135907.

FAO. 2011. "Food Wastage Footprint & Climate Change Global Food Loss and Waste." http://www.fao.org/3/bb144e/bb144e.pdf.

———. 2019. "The State of Food and Agriculture." *Routledge Handbook of Religion and Ecology*. https://doi.org/10.4324/9781315764788.

Filimonau, Viachaslau, and Adriano Gherbin. 2017. "An Exploratory Study of Food Waste

Management Practices in the UK Grocery Retail Sector." *Journal of Cleaner Production* 167: 1184–94. https://doi.org/10.1016/j.jclepro.2017.07.229.

Garnett, Tara. 2011. "Where Are the Best Opportunities for Reducing Greenhouse Gas Emissions in the Food System (Including the Food Chain)? Q." *Food Policy* 36: S23–32. https://doi.org/10.1016/j.foodpol.2010.10.010.

Garrone, Paola, Marco Melacini, Alessandro Perego, and Sedef Sert. 2016. "Reducing Food Waste in Food Manufacturing Companies." *Journal of Cleaner Production* 137: 1076–85. https://doi.org/10.1016/j.jclepro.2016.07.145.

Gunders, Dana. 2012. "Wasted: How America Is Losing up to 40 Percent of Its Food from Farm to Fork to Landfill." *NRDC Issue Paper*, no. August: 1–26. http://www.nrdc.org/food/files/wasted-food-IP.pdf?mkt_tok=3RkMMJWWfF9wsRonuqjPZKXonjHpfsX56+woXaS1lMI/0ER3fOvrPUfGjI4ATMphI/qLAzICFpZo2FFUH+GbbIFU8g==.

Heikkilä, Lotta, Anu Reinikainen, Juha Matti Katajajuuri, Kirsi Silvennoinen, and Hanna Hartikainen. 2016. "Elements Affecting Food Waste in the Food Service Sector." *Waste Management* 56: 446–53. https://doi.org/10.1016/j.wasman.2016.06.019.

Jeswani, Harish K., Gonzalo Figueroa-Torres, and Adisa Azapagic. 2021. "The Extent of Food Waste Generation in the UK and Its Environmental Impacts." *Sustainable Production and Consumption* 26: 532–47. https://doi.org/10.1016/j.spc.2020.12.021.

Lipisinski, Brian. 2020. "SDG Target 12 .3 on Food Loss and Waste : 2020 Progress Report." Washington DC, Banbury. https://champions123.org/2018-progress-report/.

Luo, Na, Tava Lennon Olsen, and Yanping Liu. 2021. "A Conceptual Framework to Analyze Food Loss and Waste within Food Supply Chains: An Operations Management Perspective." *Sustainability (Switzerland)* 13 (2): 1–21. https://doi.org/10.3390/su13020927.

Mena, Carlos, B. Adenso-Diaz, and Oznur Yurt. 2011. "The Causes of Food Waste in the Supplier-Retailer Interface: Evidences from the UK and Spain." *Resources, Conservation and Recycling* 55 (6): 648–58. https://doi.org/10.1016/j.resconrec.2010.09.006.

Mena, Carlos, Leon A. Terry, Adrian Williams, and Lisa Ellram. 2014. "Causes of Waste across Multi-Tier Supply Networks: Cases in the UK Food Sector." *International Journal of Production Economics* 152: 144–58. https://doi.org/10.1016/j.ijpe.2014.03.012.

Mena, Carlos, and Peter Whitehead. 2008. "Evidence on the Role of Supplier-Retailer Trading Relationships and Practices in Waste Generation in the Food Chain." *Cranfield University*, 28. http://sciencesearch.defra.gov.uk/Document.aspx?Document=FO0210_8437_FRP.doc.

Mithun, Syed, Abdul Moktadir, Golam Kabir, Jewel Chakma, Jalal Uddin, and Tawhidul Islam. 2019. "Framework for Evaluating Risks in Food Supply Chain : Implications in Food Wastage Reduction." *Journal of Cleaner Production* 228: 786–800.

Nahman, Anton, and Willem de Lange. 2013. "Costs of Food Waste along the Value Chain: Evidence from South Africa." *Waste Management* 33 (11): 2493–2500. https://doi.org/10.1016/j.wasman.2013.07.012.

Östlin, Johan, Erik Sundin, and Mats Björkman. 2008. "Importance of Closed-Loop Supply Chain Relationships for Product Remanufacturing." *International Journal of Production Economics* 115 (2): 336–48. https://doi.org/10.1016/j.ijpe.2008.02.020.

Papargyropoulou, Effie, Rodrigo Lozano, Julia K. Steinberger, Nigel Wright, and Zaini Bin Ujang. 2014. "The Food Waste Hierarchy as a Framework for the Management of Food Surplus and Food Waste." *Journal of Cleaner Production* 76: 106–15. https://doi.org/10.1016/j.jclepro.2014.04.020.

Parfitt, Julian, Mark Barthel, and Sarah MacNaughton. 2010. "Food Waste within Food Supply Chains: Quantification and Potential for Change to 2050." *Philosophical Transactions of the Royal Society B: Biological Sciences* 365 (1554): 3065–81. https://doi.org/10.1098/rstb.2010.0126.

Porter, Stephen .D, David .S Reay, Peter Higgins, and Elizabeth Bomberg. 2016. "A Half-Century of Production-Phase Greenhouse Gas Emissions from Food Loss & Waste in the Global Food Supply Chain." *Science of the Total Environment* 571: 721–29.

Reynolds, Christian, Liam Goucher, Tom Quested, Sarah Bromley, Sam Gillick, Victoria K. Wells, David Evans, et al. 2019. "Review: Consumption-Stage Food Waste Reduction Interventions – What Works and How to Design Better Interventions." *Food Policy* 83 (December 2018): 7–27. https://doi.org/10.1016/j.foodpol.2019.01.009.

Ridoutt, B G, P Juliano, P Sanguansri, and J Sellahewa. 2010. "The Water Footprint of Food Waste : Case Study of Fresh Mango in Australia." *Journal of Cleaner Production* 18 (16–17): 1714–21. https://doi.org/10.1016/j.jclepro.2010.07.011.

Rutten, Martine M. 2013. "What Economic Theory Tells Us about the Impacts of Reducing Food Losses and/or Waste: Implications for Research, Policy and Practice." *Agriculture and Food Security* 2 (1): 1. https://doi.org/10.1186/2048-7010-2-13.

Sgarbossa, Fabio, and Ivan Russo. 2020. "A Proactive Model in Sustainable Food Supply Chain : Insight from a Case Study." *Intern. Journal of Production Economics* 183 (2017): 596–606. https://doi.org/10.1016/j.ijpe.2016.07.022.

Appendix

Figure 1: The Stages of the food supply chain

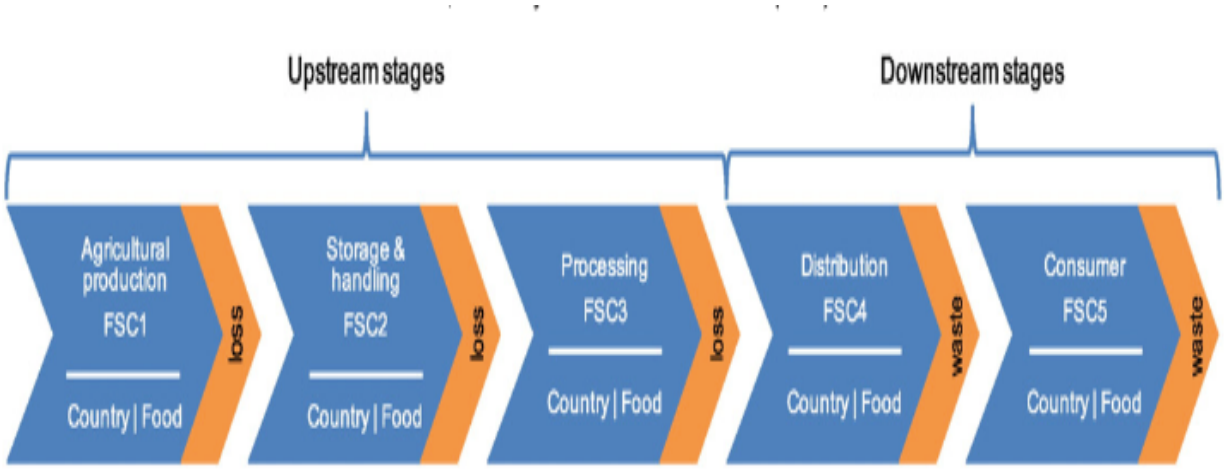

Figure 2: Food chain impacts and the distribution of the different gases

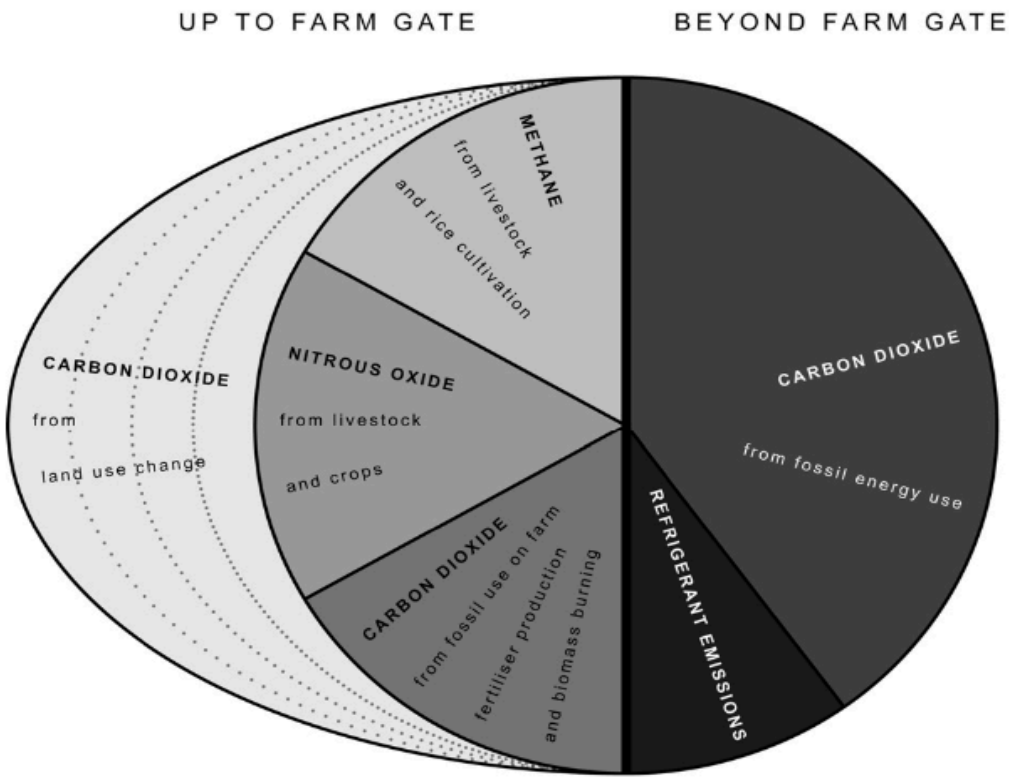

Figure 3: Distribution of FLW by region

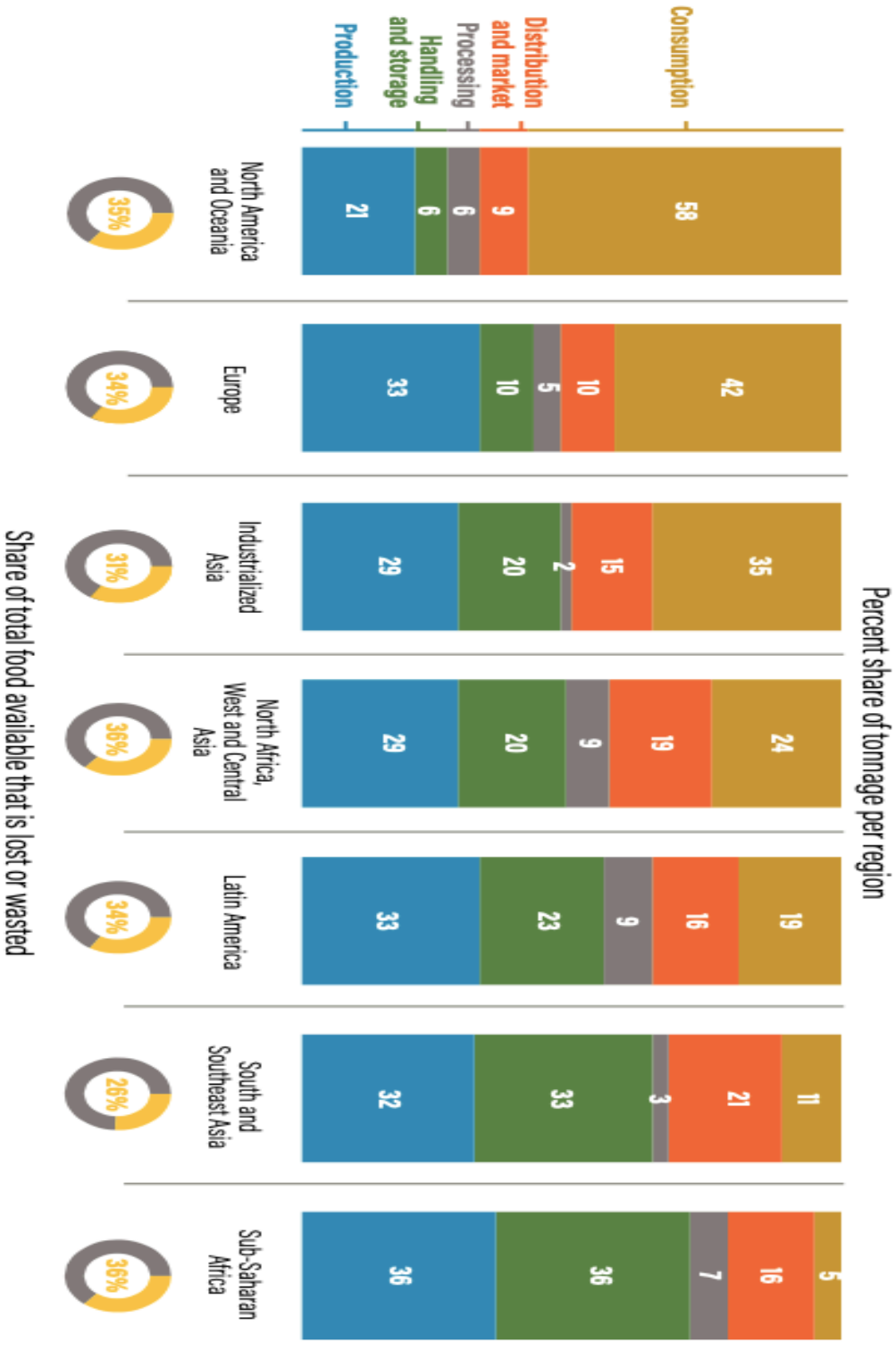

Figure 4: Contribution of each stage of the supply chain to FLW and GHG

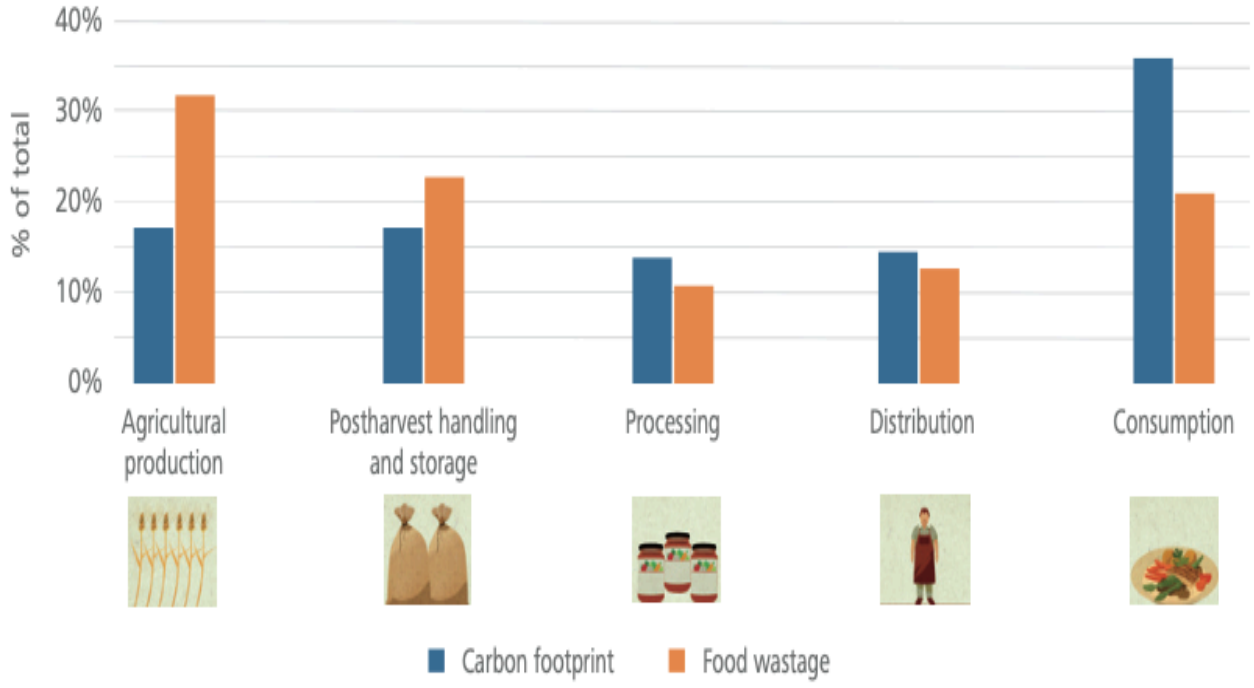

Figure5: Breakdown of the FLW at the retail and consumption level

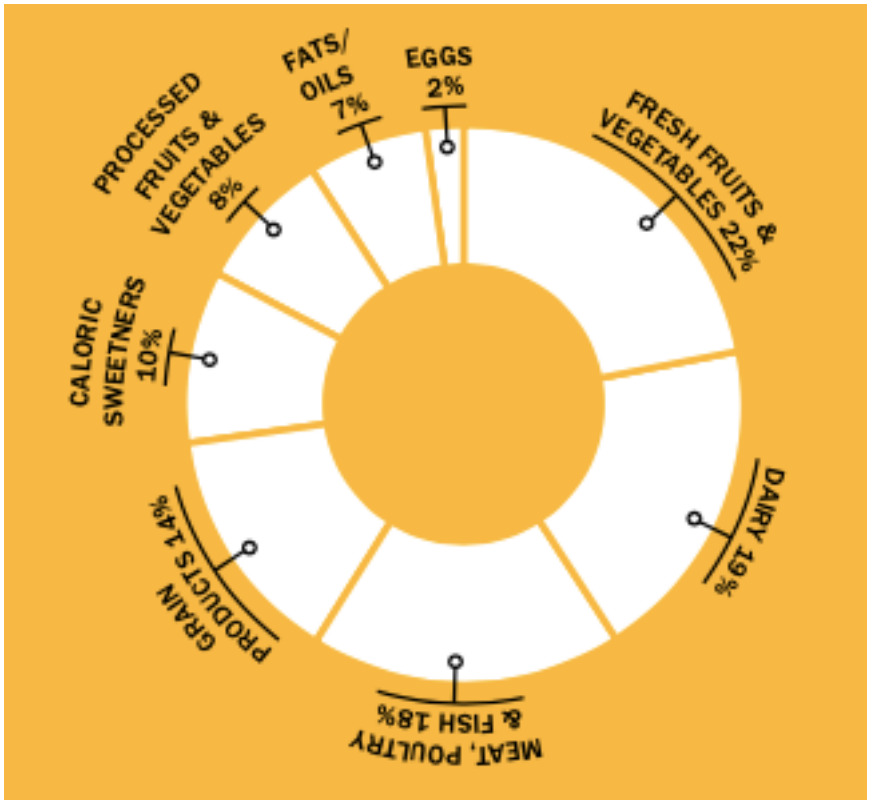

Figure 6: Potential causes of FLW at the different phases of the food supply chain

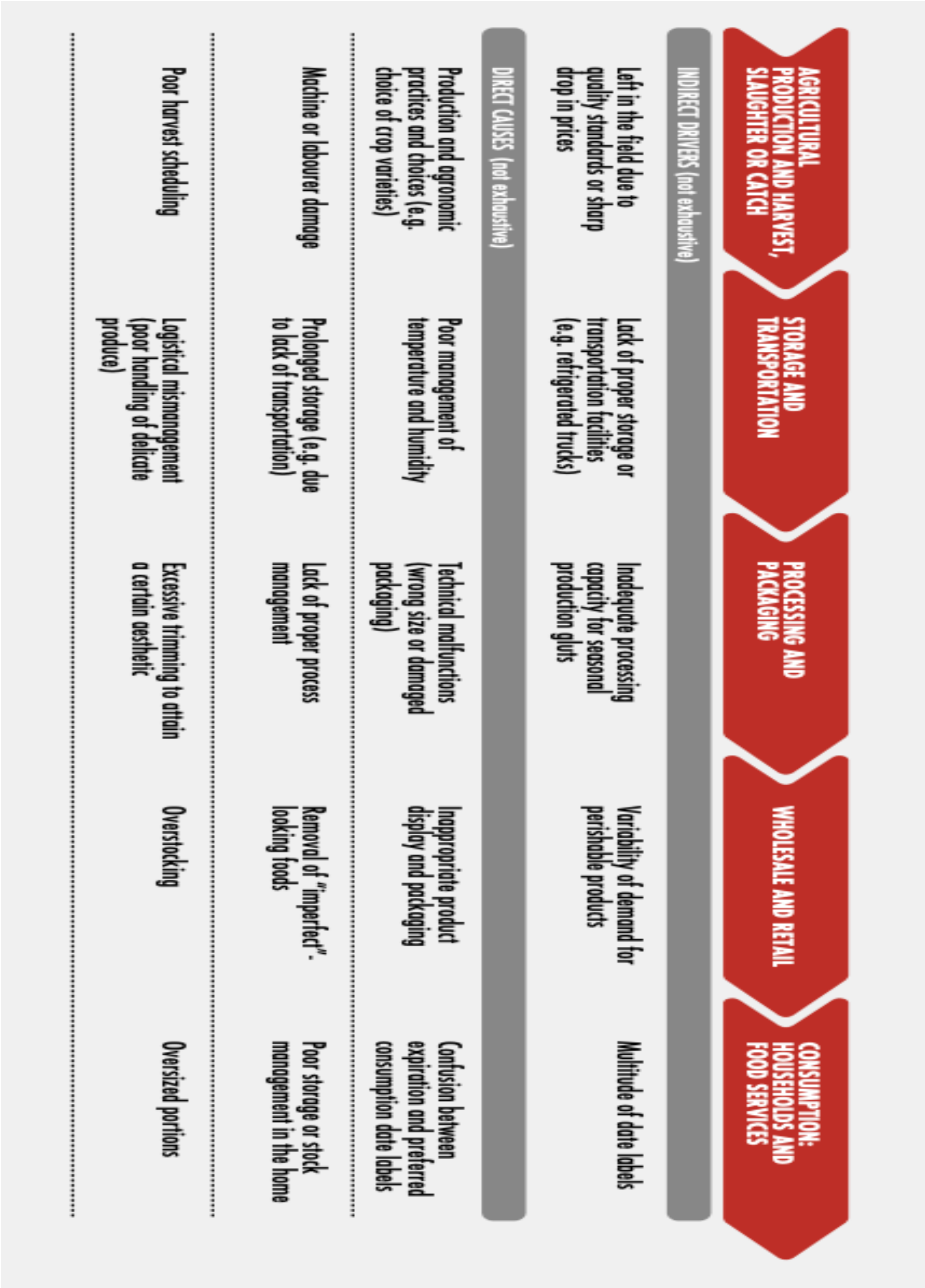

Figure 7: Traditional Closed Loop Supply Chain model

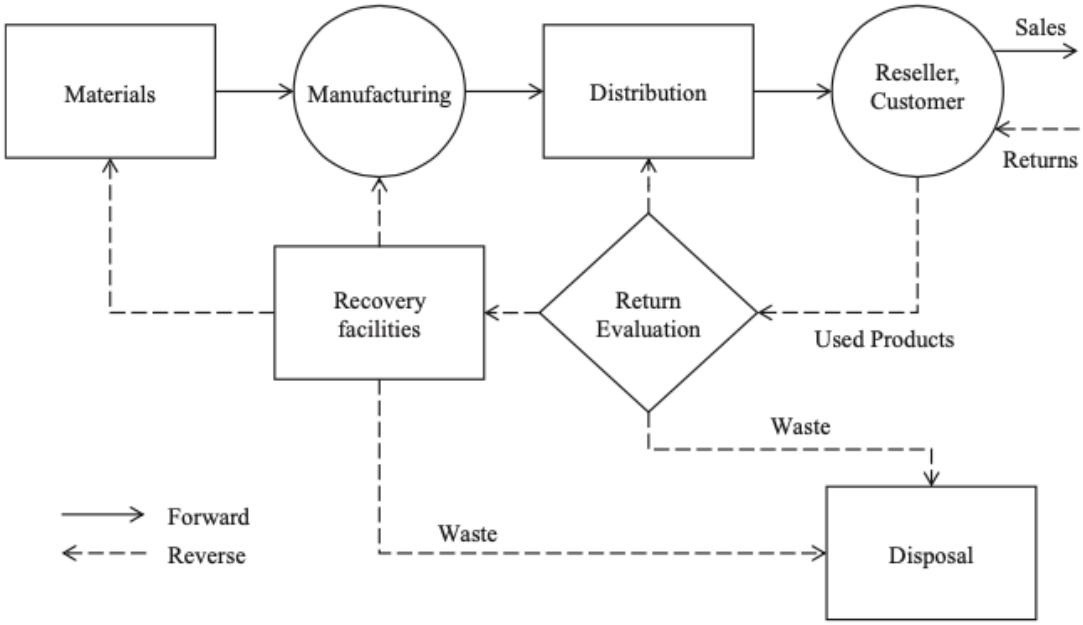

Figure 8: Weekly food purchase of a German Family

Figure 9: Weekly food purchase of a Malian Family