Optimized food supply chains to reduce food losses

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Chapter Outline

8.1 Introduction

An important way to increase food supply and decrease the environmental consequences of current food production is to reduce food losses (Godfray et al., 2010). Reducing food losses can increase food availability without requiring additional production resources (Hodges et al., 2010). Foresight (2011) stated that food and drink loss is a significant issue for economic, environmental, and food security reasons. Although food loss arises at every stage of the food supply chain, the causes of food loss vary greatly depending on the stage of the supply chain. Almost the 50% of food produced is wasted along the supply chain and does not reach consumers. Food waste is waste of resources used in production (e.g., land, water, energy, crops). The production of food that is not being consumed not only pollutes the environment, but also it is a loss of economic value (FAO, 2011).

Food is lost or wasted throughout the supply chain, from the initial agricultural production down to final household consumption (Gustavsson et al., 2011). The authors suggest that food losses and waste in developing low-income countries are related to the upstream supply chain (producer to processor), whereas the losses in the affluent world are related to the downstream supply chain (retailer to final

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consumer). Food losses are not only a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments, and natural resources such as water. Food losses have an impact on food security for poor people, on food quality and safety, on economic development, and on the environment. The need for food losses reduction is not a recent issue. According to Foresight (2011) in 1974 at the World's Food Conference it was decided to reduce food losses to 50% by 1985 and a special action program for the prevention of food losses was established by the FAO with a technological focus in storage and farm on reduction in losses of durable grain. After that there is no recorded progress on food loss reduction until 2008 when Lundqvist et al. (2008) called for action to reduce food losses from producers to consumers by 50% to be achieved by 2025.

Reducing food loss is one of the prominent goals in the current research, which has also been set by the United Nations to achieve a more sustainable world by 2030. Given that previous studies mainly examined causes for food waste generation related to consumers, this chapter aims to provide an overview on losses in the food industry. In addition, ways to reduce food losses by optimizing supply chains are discussed in this chapter.

8.2 Definition of food loss

There are different definitions about food loss in terms of where in the food supply chain it is happening. Postharvest food loss (PHFL) and food waste are commonly used as synonyms to food loss in the literature (Kader, 2005; WRAP, 2009; Hodges et al., 2010; Atanda et al., 2011). The World Economic Forum (2011) defines PHFL as upstream loss in agriculture and transport prior to processing, and food waste as food fit for human consumption that is wasted in all further downstream parts of the supply chain. In some cases, food waste is termed as food loss occurring at the end of the food supply chain (FAO, 2012). Food loss refers to the decrease of edible food mass throughout the supply chain from farm to fork or from production to consumption (Sharma and Singh, 2011).

Food loss in this chapter is defined as the decrease of edible food mass that occurs from producers until reaching consumers and includes all the edible food that was lost either intentionally or unintentionally (FAO, 2011). Food waste is a type of food loss that is related to intentional spillage of edible food mass and could happen from the producers and after harvesting until postconsumption stages (Parfitt et al., 2010). Food waste is generated due to a conscious decision to discharge food. The highest rates of food waste are at the retailer and consumer stages of the supply chain as they intentionally throw food away. Whereas, in other stages of the supply chain (e.g., production, processing) food is usually unavoidably lost.

According to FAO (2010) food loss falls into three categories: (1) physical losses resulting from spoilage where the product is diminished by weight and/or quality, (2) opportunity or monetary losses where sales might be lost or only be made in a

lower value market, and (3) external losses that fall on both the value chain participants and the rest of the society (e.g., where the chemical pesticides used to protect grain impact on the environment or human health).

8.3 Overview of food losses in the food industry

In the food industry, food loss occurs across the supply chain, that is, from production to consumption. The exact causes of food losses vary throughout the world and are very much dependent on the specific conditions and local situation in a given country (Lupien, 2008). In broad terms, food losses may be influenced by crop production choices and patterns, internal infrastructure and capacity, distribution channels, and consumer purchasing, and food use practices (Hodges et al., 2010). Food losses in the food industry can be categorized in two elements: upstream supply chain (producer to processor), and downstream supply chain (retailer to final consumer). Parfitt et al. (2010) indicated that food losses and waste in developing low-income countries are related to the upstream supply chain, whereas the losses in the affluent world are related to the downstream supply chain. Table 8.1 shows the estimates of food losses in EU for both upstream and downstream supply chain (EU FUSIONS, 2016).

8.3.1 Food losses in the upstream supply chain

Losses in the upstream supply chain arise from the challenges experienced in harvesting techniques, storage and cooling facilities in difficult climatic conditions, logistics, warehousing infrastructure, packaging, and marketing systems (Lupien, 2008). Developing countries were found to have the highest percentage of upstream food losses (Parfitt et al., 2010), although variations in wastage rates exist for different types of food and it is difficult to estimate the actual loss (Premanandh, 2011).

Table 8.1 Estimates of food waste in EU-28 in 2012 from this quantification study; includes food and inedible parts associated with food

Sector	Food waste (million tonnes) with 95% CI[a]	Food waste (kg per person) with 95% CI[a]
Primary production	9.1 ± 1.5	18 ± 3
Processing	16.9 ± 12.7	33 ± 25
Wholesale and retail	4.6 ± 1.2	9 ± 2
Food service	10.5 ± 1.5	21 ± 3
Households	46.5 ± 4.4	92 ± 9
Total food waste	87.6 ± 13.7	173 ± 27

[a]Confidence interval. https://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf.

8.3.1.1 Food losses in primary production

Food losses during production are usually due to spillage during growing of the produce, harvest operation (e.g., threshing, crop picking), or mechanical damage (treatment of the produce). Uncontrollable factors such as temperature and weather variations are the main causes of food losses at the production stage (Lupien, 2008). Insect infestation and improper handling could also cause food losses at this stage. The heterogeneity of the primary production sector in terms of the different products that are produced makes it difficult to quantity the food losses.

Further assessing the crop quality based on the climate behavior and the weather events, Ahmed and Stepp (2016) indicated that the quality of the agricultural produce is affected by the atmospheric changes in precipitation, the carbon dioxide levels that are on the rise because of the emission of greenhouse gases, and temperature changes through the ongoing climate change. The climatic variables affected both the quantity and the quality of crops that are produced based on the antioxidant activities that result from the changes in the climate. In addition, the changes in the quality and quantity of crops that are produced can be noted in the variations of grades of the crops. This alteration of the crops has in turn affected the agricultural strategies that are used to produce the crops.

With the climatic changes affecting on agriculture, it can be deduced that there are implications on the operations with regards to the farming processes. Gornall et al. (2010) indicated that the changes in the temperatures caused losses of up to $5 billion on maize, wheat, and barley in the United States. Lobell et al. (2014) stated that changes in the weather patterns occurred in a way that has balanced the losses in some countries due to other countries increasing their production. The researchers cite the case of soybean and rice where the countries with gains balanced those with losses. Coumou and Rahmstorf (2012) further indicated that in 2010, the Pakistani flooding and the Moscow heat wave not only led to the loss of lives, but the losses of up to 30% of the grain harvest, which led the government to ban exports.

With reference to the change in climate and the extreme weather events, it can be noted that there is a notable difference in the crop quality. According to Lobell et al. (2011), climatic change affected the food availability due to the changes in the weather in the farming land. The growing seasons in most countries are affected by the changes in temperature that impact the quality of the crops produced. Further, Schlenker and Roberts (2008) state that the emission of greenhouse gases has affected the production of crops, especially in the United States. According to the research, the change in the climatic conditions is noted to have implications on the quality of crops being produced, which is reflected on the types of crops produced. Hence, deterioration of crop quality leads to further food losses. Mirza (2003) stated that the vulnerability of the agricultural land also plays a role in the losses incurred with the extremities in climatic and weather events.

8.3.1.2 Food losses in postharvest handling, storage, processing, and distribution

Food losses in handling and storage occur due to spillage and degradation during handling, lack of storage facilities, and transportation between farm and distribution (Akkerman and Van Donk, 2008). In storage, considerable quantitative losses can be attributed to pests and microorganisms. While, losses in processing of food products include losses due to spillage and degradation during industrial or domestic processing, for example, juice production, canning, and bread baking. Food losses may occur when crops are sorted out if not suitable to process or during washing, peeling, slicing, and boiling or during process interruptions and accidental spillage. Food losses in distribution occur due to lack of appropriate transportation methods, time constraints, and power relationships.

The food losses incurred in the logistics can be seen in terms of the changes in quantity and quality of exports (Coumou and Rahmstorf, 2012). Rosenzweig et al. (2001) pointed out that the deterioration in food production in the United States led to taxpayers giving approximately $3 billion in relief to corn farmers. The changes in the climate affect the production as there are constraints in the production of food.

8.3.2 Food losses in the downstream supply chain

Food losses in the downstream supply chain refer to food losses at the retailer and consumer stages. In the developed countries the majority of the food losses occur due to intentional spillage of the food, which is called food waste. Fig. 8.1 shows the top US food groups in terms of annual food loss at both retailer and consumers level measured by amount value and calories (USDA, 2010). In terms of the food

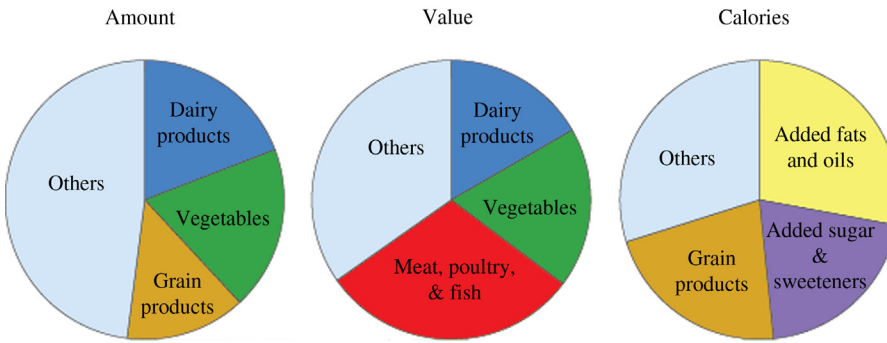

Figure 8.1 The top three US food groups in terms of annual food loss at the retail and consumer levels vary depending on if measured by amount, value, or calories.
Source: USDA, 2010. Economic research service loss-adjusted food availability data. <https://www.ers.usda.gov/amber-waves/2014/june/food-loss-questions-about-the-amount-and-causes-still-remain/>.

amount wasted all three categories, that is, dairy, vegetables, and grain were found to have similar amount of losses. The "other" category represented almost half of the wasted food products. The value "other" and the meat, poultry, fish category were found to have the higher losses in terms of value. The caloric losses were the same for all categories. Thus, some food product categories seem to have a higher amount of losses than others.

8.3.2.1 Food losses of retailers

From the retailers' perspective food loss is created mainly due to poor demand forecasting and inventory management, which results in overproduction. Some other reasons for food loss are temperature sensitivities, weather conditions during transportation, disposal of unsold food, and inappropriate packaging (Defra, 2009). Retailers also contribute to waste as a result of their contractual arrangements with suppliers. Failure to supply agreed quantities renders producers or processors liable to have their contracts canceled. Therefore, producers need to plan to produce more than actually required to meet the contract requirements.

Retailers throw away significant quantities of food that have reached best before, sell-by, or use-by dates. Even at the consumer level the food industry plays a crucial role in influencing consumers' behavior towards food losses (Defra, 2006). Consumers throw away food that was not expired due to misinterpreting the product labeling. Retailers have been also accused of creating food waste through their in-store promotions. This is because consumers perceive it as a bargain and they buy more food products that they need.

8.3.2.2 Consumer and postconsumer food losses

Food losses at the consumer level arise due to many reasons such as the individual shopper's psychology, lack of awareness regarding the negative implications of food losses, lack of knowledge regarding efficient food use, cultural perceptions regarding food consumption, lack of shopping planning, packaging confusion (best before versus use-by dates; Defra, 2009). Household food losses can be classified according to their avoidability into avoidable, possibly avoidable, and unavoidable waste (WRAP, 2009):

- Avoidable waste is food and drink thrown away because it is no longer wanted or has been allowed to go past its best. The vast majority of avoidable food is composed of material that was, at some point prior to disposal, edible, even though a proportion is not edible at the time of disposal due to deterioration.
- Possibly avoidable is food and drink that some people eat, and others do not (e.g., bread crusts), or that can be eaten when prepared in one way but not in another (e.g., potato skins). As with "avoidable" waste, "possibly avoidable" waste is composed of material that was, at some point prior to disposal, edible.
- Unavoidable waste is the waste from food preparation that was not edible under any circumstance.

8.4 Ways to reduce food losses

Effective food loss management will benefit all the food supply chain entities. By reducing raw material usage and increasing recycling and reusage activities, cost reduction, increased performance, and increased sustainability could be achieved. The US EPA (2011) proposed the food waste recovery hierarchy model (Fig. 8.2). Instead of three R's (Reduce, Reuse, and Recover), the EPA suggested that reducing the amount of food waste being generated is the most important aspect in food loss reduction. After that feeding people, feeding animals, industrial use of food waste, and composting follow.

All the food supply chain entities should consider the EPA's model in their food loss reduction efforts to achieve zero waste. First the more proactive approaches to food loss reduction should be actioned by the food supply chain entities and then the food loss treatment methods should be considered. In the sections that follow different approaches to food loss reduction are suggested, which are categorized as follows: primary production solutions, solutions at handling, storage, processing and distribution stage, solutions at retailer stage, and supply chain solutions.

8.4.1 Primary production solutions

Primary production involves the producers and their respective relationships with business partners to whom they sell their produce. The role of producers in reducing food losses is highlighted by Food Agricultural Organization (FAO, 2012). The majority of the food losses are happening at the producers' stage (FAO, 2011). Different ways are suggested below to reduce food losses at this stage of the food supply chain.

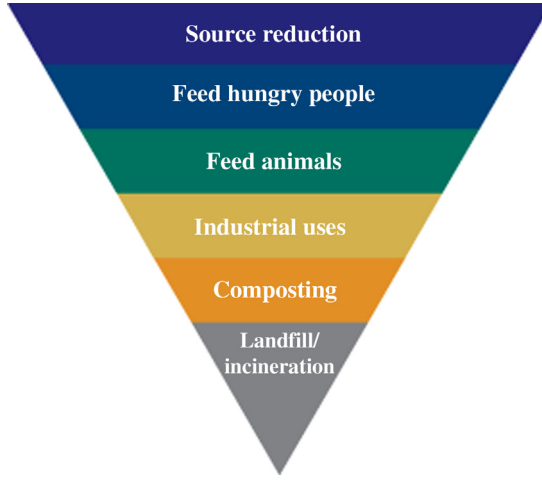

Figure 8.2 Food waste recovery hierarchy (EPA, 2011).

8.4.1.1 Focus on collaboration and collective action at producers' stage

Recent research found that higher levels of collaboration between producers and agricultural cooperatives could reduce food losses (Despoudi, 2016; Despoudi et al., 2018). Forms of collective action at the producers' stage can significantly support producers in sharing best practices, resources, and information to enable food loss reduction. Agricultural cooperatives in the form of producer organizations (POs) can be further developed as tools for producers to improve their competitiveness and strengthen their bargaining position towards retailers (Kaditi and Nitsi, 2010). Following the guidelines of the reformed CAP will enable producers to build strong POs that could compete internationally (Paisiadis, 2013). Through the POs improvements in the quality of the fresh produce is expected to be seen by adopting international quality certifications, improved packaging and labeling, adoption of new management techniques, and by highlighting the quality and the recognition of the food products. Market institution development and collective marketing generally improve the marketing system (Lupien, 2008; Kader, 2010). Formation of collective marketing groups to process unsold food is proposed as a way to reduce food losses.

The structure of the supply chain also influences the price of the product, as the more intermediaries are involved, the more the payments and the greater the spoilage of the product (Kamenidis, 2004). Elimination of the intermediaries involved is essential for small-scale producers to not only provide better quality of products, but also to get better prices and increase bargaining power. Through the development of cooperatives and the POs intermediaries could be eliminated and better prices with the retailers could be achieved. Collaboration between producers and wholesalers or retailers could also be considerably improved by having specific contractual agreements.

8.4.1.2 Training of the producers

The changes in the food industry environment require partners to develop and acquire new skills and capabilities. Food producers need to adopt new farming methods through seminars and by sharing best practices among them. Producers not only need to improve their technical skills, but they also need to be better organized, act collectively, an acquire stronger group business and marketing skills. The more recent emphasis on market-oriented approaches and on "linking producers to markets" has been fundamental for understanding the constraints and lack of incentives for food loss improvements (The World Bank, 2011). Producers need to be educated and informed about new production methods, the different food regulations, and the changing consumers' needs and wants. In this way producers will become more resilient and they will be able to respond appropriately to the changing market needs with new high-value products that consumers require.

8.4.1.3 Focus on value-added and high-quality products

Consumers look for branded and high-quality food products. Producers should focus on exceptional quality and high value-added products (e.g., Protected Destination of

Origin, Geographical Indication, organic farming). In this way the confidence of the consumers will be increased and the demand for the products and the income of the producers will increase too. There is a need for an efficient marketing strategy in the EU fresh produce sector (Fotopoulos and Krystallis, 2003). The EU producers need to focus on product differentiation and take advantage of the land and climate characteristics that enable this differentiation. Producers need to put more effort in the development of branded and certified products.

Also, producers need to develop their knowledge in terms of using unmarketable crops. Value-added products such as puree, juice, and marmalades could be created by using any crops that are not in perfect shape or are damaged and cannot be sold in the market (FAO, 2011). Creation of value-added activities means waste elimination either by preventing waste or by converting waste into another product. These value-added products could increase producers' income and at the same time reduce food losses.

8.4.1.4 Agroecology

Agroecology is an approach that takes into account natural ecosystems and uses local knowledge to plant a diversity of crops that boost the sustainability of the farming system as a whole (Moore, 2016). It helps to deliver contextualized solutions to global issues. There is a need for contextual solutions to address food losses. Instead of trying to provide generic solutions to unsustainable agricultural systems, the system's adaptive capacity and autonomy needs to be enhanced. According to FAO (2018) there are 10 guiding principles of agroecology: diversity, synergies, efficiency, resilience, recycling, cocreation and sharing of knowledge, human and social values, culture and food traditions, responsible governance, circular and solidarity economy. The focus is on social and economic aspects of the food systems related to local producers, youth, and women. An example is the improvement of soil and plant quality through available biomass and biodiversity instead of using chemical inputs.

8.4.2 Solutions at handling, storage, processing, and distribution stage

8.4.2.1 Postharvest storage and handling solutions

Appropriate storage technologies should be implemented such as evaporative coolers, and storage bags. Investment in cold chain facilities is essential due to the perishability of the products. Governmental support or close collaboration with the supplier is recommended for supply chain entities who the lack cold chain facilities due to financial issues.

8.4.2.2 Postharvest processing and transport solutions

In the processing stage, food losses could be reduced through improved packaging solutions that increase the shelf-life of the product and optimize the portion size.

Packaging protects food from damaging and preserves its freshness. However, sometimes inappropriate packaging can lead to considerable food waste (Williams and Wikström, 2011). Close collaboration with the suppliers is fundamental to understand the product and customer requirements and identify the right packaging solutions. In an effort to reduce food waste Tesco and M&S are using new packaging to extend fruits' and vegetables' shelf-life (Smithers, 2010). Intelligent container technologies could be used to reduce food losses. Some examples of intelligent container technologies are (GoSupplyChain, 2018):

- The time temperature indicator (TTI): This is useful for determining if foods have been temperature abused. An irreversible change (such as color change) will occur if the TTI experiences abusive conditions.
- Gas indicators: Food can respire and may therefore change its own atmosphere when inside a package. Gas indicators monitor the composition of gases inside a package and typically signal presence or absence of oxygen or carbon dioxide.
- Biosensors: Foodborne pathogens are of great concern to the food industry. A biosensor can detect a substance (a pathogen in this case) and then transmit the information in a quantifiable manner.

In terms of the transportation methods and lack of proper road infrastructure especially in developed countries alternative routes to markets should be identified in collaboration with the supply chain partners. Appropriate use of the different distribution hubs can reduce food losses. A First Expiry First Out strategy could be employed to first transport products with short expiry date. Also, supply chain demand decisions need to be considered in relation to seasonality, and changes in weather patterns. In addition, any food product losses due to spillage or degradation at this stage should be recycled or redeveloped to a byproduct.

8.4.3 Solutions at retailers stage

At this point of the supply chain the food loss is rather called food waste as it is food that is wasted intentionally. The perishability of the food products, the short expiration dates, the not perfectly looking food products, the unsold products, and the overordering of food products are some of the causes of food loss at this stage of the food supply chain. To reduce food losses at the retailers' stage different solutions are suggested that include modification of the product labeling, change of consumers' food waste behavior, donations and recycling, and technological investments.

8.4.3.1 Modification of product labeling

Product labeling contributes significantly to food losses. The "best by" dates are usually misinterpreted by consumers resulting in unsold food. Modifications in the product labeling to enable consumers to understand when the products should be discharged could reduce food losses. For example, a "sell by" label and a "best by if used" label could be used for the retailers and consumers understanding of the expiration dates respectively (Kor et al., 2017). Providing more information about

the ingredients of the products and its freshness could help consumers make more informed decisions about when the products are not safe for consumption.

8.4.3.2 Change of consumers' food waste behavior

Retailers' food product promotions have been blamed for food losses at the consumer's point of the supply chain. This is because consumers overbuy products and then they discharge them. Educating consumers about the issue of food loss and its economic, social, and environmental implications could reduce food losses. Many supermarkets started to have food waste reduction campaigns to educate consumers and to change their mindset. Retailers could also promote food loss reduction through food waste reduction tips and recipes for utilizing leftover food. This could be done using online platforms and forums for sharing waste reduction ideas to engage the younger generation too. Organizing special campaigns about food loss reduction through the engagement of consumers could also be used as a way to make consumers aware of the food loss issue. Creation of online shopping lists and matching them to recipes could be another way to help consumers towards buying only what they need.

The high cosmetic standards in the food sector are one of the major causes of food losses at the retailers' stage. Consumers need to be educated regarding the appearance of the food products. The perception of having perfectly looking fruit and vegetables should be changed. Some retailers already promote this product category of products as "wonky" vegetables and they explain to consumers that they are perfect for consumption. This is an effort to educate consumers that fruit and vegetables cannot all have the same appearance.

8.4.3.3 Donations, recycling, and compost

Any surplus or unsold food with short expiration date should be donated to food banks or other similar charitable organizations. Some retailers cooperate with charitable organizations or food banks to distribute food and advise consumers how to use food that will be wasted otherwise (Kaye, 2011). While others are prevented from doing this in case of any food contamination issues. Special agreements with charities should be put in place to have a systematic process for distribution the food products. This would not only contribute to food loss reduction, but it could also increase the retailers' corporate social responsibility efforts. Store-to-distribution strategies could be used to move unsafe for consumption food products for recycling or recovery. Any leftovers of food could be used for composting. Small-scale anaerobic digestion could be used at retail stores to recover materials for energy production.

8.4.3.4 Technological investments

Investing in new technologies to increase transparency in the supply chain and improve the time to market of the food products is essential to food loss reduction (Kor et al., 2017). This requires also better collaboration with suppliers to

eliminate any intermediaries. The benefits of this technology would be increased visibility in the supply chain and thus better management of the inventory of the food products.

Also, special smart sensors to check the quality and freshness of food products could also be placed on the retailers' trucks or on the packaging of the products. Any change in the food product quality during its transport to the retailers' store or within the store could be noticed before the product's quality deteriorates. Besides, consumers will be able check the product freshness in real time. According to Capgemini (2017) retailers can invest in applications that can match the supermarket supply with the demands of food banks. Using this app the food banks can adjust their food needs in real time and donors can check the availability of the required products.

8.4.4 Supply chain solutions

Although solutions for food loss reduction at the different stages of the supply chain are essential, there are supply chain wide solutions that should be implemented too. In this section different supply chain solutions for food loss reduction and thus supply chain optimization are suggested. These are namely awareness of the changing food standards and regulations, collaboration, across the supply chain, formation of communities of practice, technological and infrastructural solutions, lean and total quality management (TQM), sustainability across the supply chain, and developing a resilient supply chain.

8.4.4.1 Awareness of the changing food standards and regulations

The surrounding policy and regulatory framework might affect the ability of the supply chain entities to reduce food loss levels (HLPE, 2014). When food safety rules are well designed, they will enable food loss reduction (HLPE, 2014). The main regulations that food supply chain members need to comply and adopt are food safety regulations, food quality regulations, food labeling and packaging regulations, food traceability regulations, food transport and handling regulations, and organic food regulations. According to Waarts et al. (2011), in Europe private food safety regulations are the main reason of food loss occurrence. This is because food products are getting rejected due to noncompliance to the private food safety standards that are required from buyers in other EU countries. According to Despoudi et al. (2015) producers perceived that there are no specific guidelines on what food regulations they need to adopt and comply with.

Adoption and compliance with food safety and quality standards can help to reduce food losses (Lupien, 2008). For example, for a producer who wants to export his products in another country and his products do not comply with the food safety standards in this country (e.g., banned pesticides), the products will be rejected, and all the crops will get wasted. Upstream chain members, that is, producers, processors, and retailers need to be aware of the different international food regulations to

prevent any noncompliance. Establishing a common communication channel among supply chain members to communicate order requirements in terms of food regulations could significantly reduce food losses.

8.4.4.2 Collaboration across the supply chain

Chapman (2010) referred to food loss as a shrinkage problem and characterized it as a "complex" problem that needs to be addressed in a collaborative way involving a wide range of stakeholders to get different perspectives and deliver holistic solutions. Recent research showed that better producer–buyer and supplier–retailer relations and collaborative action could possibly reduce food losses (WRAP, 2011; Despoudi, 2016; Despoudi et al., 2018). Other research suggested that better and closer collaboration between suppliers and retailers can be the starting point to deal with the majority of root causes of food losses (Mena et al., 2011). There are many benefits for supply chain partners achieving collaboration, some of which are the following: information exchange, improved planning and support, joint problem solving, sharing resources gain of competitive advantage, reduced costs, and reduction of negative bullwhip effect (Daugherty, 2011).

Supply chain collaboration (SCC) can be achieved in different forms such as vertical and/or horizontal and external and/or internal collaboration (Barratt, 2004). Vertical collaboration involves internal and external collaboration with customers and suppliers, respectively. Horizontal collaboration involves internal collaboration, but also external collaboration with competitors and other organizations. Internal collaboration refers to an organization's collaborative culture (e.g., existence of elements of trust and commitment). A common case with internal collaboration is the dilemma arising between decisions to be made for the interest of all chain partners and/or the individual firm (Simatupang and Sridharan, 2002). External downstream collaboration involves customer relationship management, while external upstream collaboration involves supplier management. Each entity in the supply chain might collaborate in different levels; not all partner relationships need to be involved in high levels of SCC (Holweg et al., 2005). There are different types/levels of SCC such as transaction collaboration, cooperative collaboration, and cognitive collaboration (Whipple and Russell, 2007). Transaction collaboration involves simple communication and partners exchanging data, while cooperative collaboration involves partners sharing data, processes, and setting common supply chain objectives. Cognitive collaboration requires higher levels of involvement as partners work together in joint planning and decision making.

Collaboration requires resources and effort from all partners (Whipple and Russell, 2007). Food supply chain entities do not need to collaborate closely with everyone in their supply chain; they rather focus on a small number of strategic partners (De Leeuw and Fransoo, 2009). However, there is a dilemma with whom and in what level to collaborate with partners; collaborating internally, with customers, with suppliers, with competitors, with governments and/or other institutions. To determine what level of SCC is needed for a specific chain or a specific problem first the current levels of SCC need to be assessed and after that seek for ways

to improve collaborative efforts/practices (Simatupang and Sridharan, 2002). However, achieving collaboration with partners does not always have the expected benefits (Kampstra et al., 2006). There are a number of challenges mentioned in the literature as impediments in achieving collaboration. The main barriers associated with SCC are the following: difficulties in implementation, overreliance on technological solutions of collaboration, failure to differentiate with whom to collaborate with, and lack of trust between trading partners (Barratt, 2004).

8.4.4.3 Formation of communities of practice and learning alliances

Creation of learning alliances has been proposed as a way to reduce food losses (World Bank, 2006). Learning alliances are about identifying, sharing, and adapting good practices in research and development in specific contexts between research organizations, development agencies, policymakers, and private business. FAO's (2010) workshop on reducing food losses in Africa proposed a strategy for developing communities of practice about food losses to facilitate information exchange and share knowledge about new technologies and strategies to manage crops. It is essential to develop strategies that promote coordination, collaboration and information flow among all actors in the chain.

8.4.4.4 Technological and infrastructural solutions

Investments in technology and technology transfer are considered to be essential for better processing of food and better management of processed food and avoid food losses (Hodges et al., 2010). For example, collaborative planning forecasting could be implemented across the supply chain to better forecast the product demand. Technological advancements in the processing and transportation of the products could diminish food losses (Caixeta-Filho, 1999). This could involve new packaging solutions and/or innovations in cold chain logistics. Development of better infrastructure is a crucial step for reducing food losses including creation of better warehouses and logistics development such as cold chain facilities and handling equipment (Kader, 2010).

The nature of the agricultural products requires them to be distributed on time and to be stored under the right conditions (Zanoni and Zavanella, 2012). The lack of cold chain facilities or any delay in cooling of the products can result in quality deterioration or quality losses (Nunes et al., 2009). Temperature control during processing of the crops is a challenging task and fluctuating temperatures have an effect on product's quality (Brecht et al., 2003). Inadequate and improper management of cold chains leads to food loss (Atanda et al., 2011). Perishability, shelf-life, and quality variations are significantly influencing food loss levels (Mena et al., 2011). Both technological and infrastructural improvements are needed to enable food loss reduction and their absence seems to be a major obstacle to achieve it.

8.4.4.5 Total quality management and lean

TQM is a management philosophy and a set of accompanying quality continuous improvement techniques (Slack et al., 2013). By applying TQM philosophy and techniques, businesses undertake continuous improvement across all operations by seeking to discover the reasons for poor quality performance and customer service and implementing methods to reduce and/or eliminate the causes of poor quality. TQM is an effective system for integrating the quality development, quality maintenance, and quality improvement efforts of the various groups in an organization to enable production and service at the most economical levels that allow for full customer satisfaction. Food loss reduction could be achieved by implementing TQM across the supply chain.

There are different aspects in TQM implementation. The first aspect of TQM is about meeting the needs and expectations of customers. Customer centricity is essential to meet the customer's perception of quality and the changing needs and wants of customers (Slack et al., 2013). The customer's voice should be translated into quality objectives to increase customer satisfaction. TQM is about covering all parts of an organization and involving everyone, that is, each department, each activity, each person, and each level need to work together. Everyone is a customer and supplier within an organization. Service level agreements or contracts are usually used within an organization, for example, for response times and range of services. Another aspect of TQM is that all the costs of quality need to be considered. The different costs of quality are prevention costs, appraisal costs, internal failure costs, and external failure costs. Systems and procedures to support quality improvement should be implemented. For example, ISO 9001 could be implemented to provide guidance and tools for organizations who want to ensure that their products and services consistently meet customer requirements, and that quality is consistently improved.

Developing a continuous process of improvement is a core principle of TQM. Lean philosophy can be used to determine value-adding and nonvalue-adding activities at every stage of the food supply chain. Lean refers to approaches that focus on the elimination of waste in all forms, and smooth and efficient flow of materials and information throughout the supply chain to obtain faster customer response, higher quality, and lower costs. The different types of waste need to be identified first and then ways of eliminating them should be implemented. Food loss and its different waste implications need to be identified first. Then, different lean tools such as value stream mapping and 5S could be implemented in the food supply chain to eliminate food losses across the supply chain.

8.4.4.6 Implement sustainability across the supply chain

Climatic changes are impacting yields, altering weather patterns, increasing the uncertainty and likelihood of disruption (Bereuter et al., 2014). Food supply chains are not always able to respond appropriately and on time resulting in lost production, resources, and sales. SustainAbility (2011) defined a sustainable food supply

chain as a reliable, resilient, and transparent, one that produces food within ecological limits, empowers food producers, and ensures accessible and nutritious food for all. A sustainable food supply chain:

1. produces safe and healthy products,
2. supports the viability and diversity of the communities,
3. enables sustainable livelihoods by respecting human rights and fair trade terms, and
4. sustains the available resources and minimizes inputs (Defra, 2006).

A sustainable food supply chain must meet the world's need for food and avoid adverse environmental impacts (Defra, 2006). Hence, by increasing the sustainability efforts across the supply chain food losses could be reduced. However, to achieve supply chain sustainability efforts from all supply chain entities are needed.

In the supply chain from the product's perspective, sustainability can be illustrated through the product stewardship concept. Product stewardship can be defined as the shared responsibilities that all the participants in a product's lifecycle have for minimizing its environmental and health impacts (Product Stewardship Institute, 2011). The producers' responsibilities lie from the downstream (customer end of the supply chain) in the supply chain to the upstream (supplier end of the supply chain supply chain). The responsibilities in a supply chain do not end when the product is delivered to its customers. Companies that produce goods are responsible for the whole lifecycle of their products, from raw material extraction to use and disposal. Thus, there is a need for increasing the awareness regarding the shared responsibility of all the food supply chain entities to increase sustainability.

8.4.4.7 Developing a resilience supply chain

Lal et al. (2014) referred to resilience as the state of having the natural ecosystem to withstand environmental changes based on the ability to have resistance to certain forms of disturbances. Shenggen et al. (2014) defined resilience in the food and agricultural sector as the ability to prevent crises and disasters by being able to anticipate, engross, and accommodate the effects of the disaster and creating an efficient and timely solution that will manage any potential issues in a timely manner. The authors further indicate that the protection, restoration, and improving on the systems of agriculture will assist in improving food security.

Almas and Campbell (2012) indicated that the effectiveness of the agricultural strategies in the management of sustainability will be able to determine the effectiveness of the resilience strategy that has been set. In addition, the authors indicate that the policies that are set aside by the governing body will assist in the management of resilience in the organization. The measurement of resilience and its supply chain processes can be assessed through the assessment of the differences in operation during and after the crisis (Barthel and Isendahl, 2012). Having no decrease in operations in food production, resilience can be noted as being effective in the management of the food supply chain.

According to Christopher and Peck (2004) resilience in the supply chain process is a method that creates effective operations in terms of the distribution of the food

products. A resilient supply chain is able to manage the consumer needs without risking the delivery of the products to the end use. The resilience of the supply chain is based on the development of a process that is able to withstand the volatility and turbulence in the operating environment. In addition, the supply chain processes in place should be able to ensure that any changes in the operating environment factors of the organization such as politics, the economy will have limited impact on the supply chain. A resilient supply chain may be also managed through redundancy management and having flexibility in the supply chain process (Sheffi and Rice, 2005).

The selection of the different strategies in the management of the food chain supply chain is effective in controlling the losses that may be incurred in the supply process (Ceryno et al., 2013). Whipple and Russell (2007) suggested that the use of the collaborative approaches such as having a collaborative management of transactions, and collaborating management of events and processes assists in the effective creation of a resilient supply chain process. Hudson (2009) stated that the management of the environmental footprint will assist in ensuring that the supply chain process is effectively managed. Sonnino and Marsden (2006) stated that the supply chain process should be built derived from the implications that the actions will have on the rural and agricultural development.

In the assessment of the resilient food supply chain, Sonnino and Marsden (2006) indicated that the relationships in the operating environment should be managed effectively. Having sustainable relationships between the key players in the supply chain will assist in building a strategy that will have minimum negative implications. The food production systems should be mirrored on the management of the processes, which should be driven by the goals of the retailer, those of the consumer, and the producers (LeBlanc et al., 2014). Having a resilient food supply chain further incorporates the participation of different actors in the agricultural industry, who will assist in the attainment of the set goals in the supply chain. The current food supply chain processes have been affected by the complexity of the operations in the market. According to the findings, the social and environmental implications on the processes and logistics have affected the resilience of the operations in the market. The systems created in the different strategies of maintaining resilience have affected the operations in the market and in turn food supply.

The management of a resilient food chain is dependent on the availability of resources in the market. Manning and Soon (2016) stated that the availability of resources will assist in ensuring that the supply chain in food production is conducted effectively. The use of the resources available will assist in the assessment of the different tools that will be used to measure the best and most effective strategy to be applied. According to Maslaaric et al. (2013), the management of the resources that are invested in the supply chain processes will be effective in ensuring that there is availability of food in the market. The management of the costs of operations will assist in ensuring that there is no compromise in the quality of the food being produced, which may have adverse effects if costs are decreased.

Min et al. (2005) asserted that collaboration efforts in the supply chain processes are one of the most effective means in the management of resources. Having

collaborative efforts in the food industry is important in ensuring that the people have access to the adequate food supply. Brabeck-Letmathe (2016) stated that the efficiency of resources can be managed through the mitigation of the climate changes by the different food production organizations. In the assessment, the maintenance of stability is a critical aspect that will have an implication on the operations in the food market. Foley et al. (2011) mentioned that the environmental changes affected the yields of the crops, hence the need to manage the current resources to ensure that there is sufficient food supply in the global growing population.

8.5 Conclusion

This chapter provided an overview of the food losses in the food supply chain. Also, solutions to reduce food losses by optimizing supply chains are discussed. The occurrence of food losses in the supply chain is described in terms of the upstream and downstream supply chain. Food losses occur across the supply chain and there are different causes at each stage. The different ways to reduce food losses are discussed based on the different supply chain entities and on the whole supply chain. Different solutions for each supply chain entity need to be considered. However, to enable food loss reduction both actor specific and supply chain solutions are needed. Overall supply chain optimization suggestions can provide holistic solutions to the food loss issue.

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