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FACTORS THAT INFLUENCE THE FOOD LOSSES AT THE PRIMARY PRODUCTION STAGE

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Abstract

Losses, at every point in the food system, impact how much the nutritional demands of an increasing world's population can be sustainably met. The food losses in the primary production (farm-level) play a significant role. The farmers believe that the food losses are not a problem and represent an intrinsic part of farming. Primary production losses are not trivial, and knowledge is needed about the factors that influence the food losses. Many factors can cause food losses that occur in the primary production, including but not limited to: insects, pests, diseases; unfavourable environmental conditions; improper harvesting techniques and distribution and storage infrastructure; price volatility, overproduction; high retail standards, limits on primary processing. This paper aims to provide an overview of the factors influencing food losses in the primary production phase.

Keywords: Food supply chain, agricultural primary production, food losses, diseases, unfavourable environmental conditions, improper harvesting and storage, overproduction, standards, limits on farm-level processing

1. Introduction

The food systems around the world are exposed to immense pressure due to reducing resource availability and growing population, the world's population being expected to increase to nearly 10 billion by 2050 (Alexander *et al*., 2017; Babbitt *et al*., 2021; FAO, 2017; The Economist, 2011; WWF, 2017). The activities related to primary agricultural production affect the efficacy of the food system in creating agricultural food biomass and its use for human nutritional demands. To achieve the objective of these activities, some aspects of the changes of the primary production systems and the role of diet, as well as the reduction of food losses and waste in both developed and developing countries can be taken into account (Alexander *et al*., 2017).

Food loss (FL) refers to a diminishing in the quantity or quality of edible food weight as a result of mismanagement, errors, and different inefficiencies in both primary agricultural

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production and industrial sector (unfavourable weather circumstances, unsuitable storage facilities, poor handling, improper infrastructure and logistics, etc.). At the same time, food waste (FW) also refers to a reduction in the quantity or quality of edible food weight but which is generated mainly at households-level and HoReCa services (Chauhan *et al*., 2021; Dumitru *et al*., 2021; Ishangulyyey *et al*., 2019; Jungowska *et al*., 2021; Lipinska *et al*., 2019; Ojha *et al*., 2020; Santeramo, 2021; Socas-Rodriguez *et al*., 2021).

FL and FW occur at each point of the food supply chain (FSC), from the farm (production) to fork (consumption). In other words, FL is the food wasted at the earlier phases of the FSC, and FW is the food lost at the end of the FSC (Dhir *et al*., 2020; FAO, 2011a, 2019; Nicastro and Carillo, 2021; Usmani *et al*., 2021; Wang *et al*., 2021). The primary production phase is the most important point for FL. In non-industrialized countries with improper infrastructure and logistics, FL occurs at the primary production phase of FSC. In contrast, in industrialized (more prosperous) countries with more modern infrastructure, FW occurs at the retail and consumption phase (Nicastro and Carillo, 2021). Taking into account their disadvantageous economic (especially at the consumption and retail phase), environmental (natural resource depletion and environmental pollution), and social (reducing food access and availability) consequences, FL and FW are seen to be one of the principal contributors to food insecurity issues and reduced sustainability of our food systems (Beullens and Ghiami, 2021; Dora *et al*., 2020; Ishangulyyey *et al*., 2019; Li *et al*., 2022; Ojha *et al*., 2020; Santeramo, 2021). The world is already exposed to food insecurity; many people still go hungry, food security being a severe discussion in essential areas of the developing countries (WWF, 2017; FAO, 2011).

This work/paper provides an overview of the significant factors influencing food losses in primary agricultural production (harvesting, farm-level post-harvesting, farm-level processing). If adequately monitored and managed, these factors will no longer pose a high risk of generating food losses.

2. Methodology

The method applied was exploratory research, which consisted of interrogating the existing literature. The data were collected from different databases such as Web of Science, Scopus, EBSCO, CABI, and specific platforms or webpages such as FAO, EIT, etc. The review of literature helped understand the difference between food losses and food wastes and causes/factors that influence the food losses at the primary production stage. The work is a start point of future research on food losses and it will be implemented into the research design of a doctoral thesis.

3. Results and discussion

3.1. Phases of the FSC

The food supply chain (FSC) defines the succession of food production (fruits, vegetables; dairy; eggs; meats; fish, seafood) and distribution from the farmer to the final consumer (Wunderlich, 2021). There are multiple phases in the FSC, each phase of the FSC being made up of various technological operations (agricultural/industrial), within which FL and FW occur (BCFN, 2012).

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In rural communities, FSC may be short (farmers - local market), while in urban areas, FSCs are longer and more complex, including six main phases (points): (1) primary production, harvest; (2) distribution; (3) farm-level processing and industrial processing (e.g., refrigeration, canning, freezing, drying, washing, chopping); (4) marketing; (5) retail; (6) consumption (households, HoReCa services) (Abideen *et al*., 2021; Chauhan *et al*., 2021; Dumitru *et al*., 2021; Ishangulyyey *et al*., 2019; Jungowska *et al*., 2021; Ojha *et al*., 2020; Perry, 2019; Santeramo, 2021; Socas-Rodriguez *et al*., 2021), as shown in Figure 1 (Perry, 2019).

Figure 1 displays the interconnected phases that bring food from farm (1) to the final consumer (6). The first phase (1) of the FSC consists of activities related to primary agricultural cultivation and production. The subsequent two phases (2 and 3) concern the storage, distribution, farm-level processing of agri-food products and industrial processing, including harvest procedures and their further change into edible foods. The next two phases (4 and 5) concern the market and wholesale and retail distribution processes. The end phase (6) coincides with the final consumption, which generally takes place in HoReCa services and households (BCFN, 2012).

Figure 1. The food supply chain in large urban areas (Adapted from Perry, 2019).

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3.2. The causes of FL and FW along with the FSC

This sub-section will only focus on factors (causes) influencing the FL at the primary production stage. In the early phases of the FSC, the FL can occur because of poor weather conditions, diseases, and infestations. Moreover, FL and FW can occur during and after harvesting at the subsequent two phases because of processing, storage, and distribution activities. A significant part of the FW can arise in wholesale and retail distribution, comprising unsold food due to compliance with food safety regulations and quality and aesthetic norms, marketing strategies, and logistics. The FW registered at the consumer phase is especially due to the unreasonable portions, the quantity of cooked food, the overabundance of acquired foods, incapacity to consume foods before the expiration date, and the difficulty in accurately reading instructions on labels (BCFN, 2012).

3.2.1. The causes of FL at the primary production stage

Primary products are intended for human consumption, but they never enter the FSC for different causes (Franke *et al*., 2022). In the primary production (cultivation and harvesting, farm-level post-harvesting, farm-level processing - Figure 2), numerous factors concur to FL, such as insects, pests, diseases; unfavourable climatic and environmental conditions; inadequate harvesting techniques and transportation and storage infrastructure; price volatility, overproduction; conformity with standards, limits on farm-level processing (FAO, 2011a; Jungowska *et al*., 2021; Nicastro and Carillo, 2021; Santeramo, 2021; Shee *et al*., 2019; Sugri *et al*., 2021).

Figure 2. Primary agricultural production

FL that occurs during cultivation and harvesting is mainly attributed to unfavourable weather, climatic and environmental conditions (e.g., drought, heat stress, cold stress, floods, soil salinity, and acidity stress), and biotic factors (e.g., diseases and pests). These factors (by far the most important) have a major impact depending on the different categories of cultivation, seasons, and production regions (BCFN, 2012; COMCEC, 2016; Elik *et al*., 2019; Wolfe *et al*., 2018). There are significant differences at this phase between industrialized (highest-income)

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and non-industrialized (low-income) countries; different techniques for preparing the soil (fertilizer technology, pesticides, adaptive microbial technology) and seeding and cultivation representing one of the first causes of FL (BCFN, 2012; COMCEC, 2016; Kumaraswamy and Shetty, 2016).

In the industrialized countries, the more extensive infrastructures, agronomic proficiency, ultramodern technologies, and more favourable environmental circumstances often evolve in a notably lower level of FL. In contrast, in developing countries, FL is primarily the result of inefficient and incorrect agriculture, immature harvests, inefficient harvesting methods, inadequate infrastructure, storage facilities and logistics (BCFN, 2012; Johnson *et al*., 2019). Inefficient and incorrect agriculture (e.g., plant protection, plant nutrition, irrigation, fertilization) causes crop losses. The farmers are on the front lines with direct impacts on crop losses (Elik *et al*., 2019; FAO, 2013; Wolfe *et al*., 2018). Harvesting at the wrong time may also impact crop loss rates; ripening at harvest time is the principal factor influencing the quality and shelf life of fruit and vegetables. Some farmers harvest unripe fruits and vegetables due to urgent food or economic reasons. On the one hand, unripe fruits are more vulnerable to damage and may have not only market value but also poor nutritional quality; on the other hand, over-ripe fruits have a low shelf life, being susceptible to physiological disorders and damage during transport (Elik *et al*., 2019; Johnson *et al*., 2019; Mesterházy *et al*., 2020).

Primitive harvest methods, poor quality equipment, and used materials can also cause losses (BCFN, 2012; Kasso and Bekele, 2018). Inadequate storage facilities (e.g., absence of pivotal key elements, such as cooling refrigerated-storage facilities; storage containers) lead to mechanical damage during harvesting of fruits and vegetables, resulting in certain losses (Minor *et al*., 2020). Another factor is handling that permits a safe and undisturbed distribution preventing bruising and crushing or damage (EIT, 2022). Inappropriate handling of agri-food products during harvest time, including the use of sizeable machinery, can generate deterioration, which enables the entry of microorganisms that lead to faster damage of crops, particularly roots and tubers. This is one of the significant causes of FL in farms that, particularly in industrialized countries, will produce more than the effective request to obstruct degradation caused by unpredictable weather (Tandzi Ngoune and Mutengwa, 2020). In the industrialized countries, and from time to time in the non-industrialized countries, the economic factors also contribute to FL. Thereby, FL happens when the farmers abandon crops in the field or choose to redirect the crops for animal feed (when supply exceeds demand) because the aesthetic and quality standards (shape, size, and colour of agricultural products) are not satisfied (BCFN, 2012; Minor *et al*., 2020; Nicastro and Carillo, 2021; Sugri *et al*., 2021).

The agri-food product that does not meet the aesthetic and quality standards or other demands, at any phase in the FSC (not only at the primary production phase), is susceptible to be rejected, either by the customer or by the final consumer (Minor *et al*., 2020; Sugri *et al*., 2021). Prices of fresh crops are volatile. When prices decrease under the cost, supplementary products go to market; growers cannot advance products through the FSC because doing so becomes unprofitable. As prices rise, growers harvest more intensely (either by employing more labour or lowering product thresholds). They may have incentives to market lower quality aesthetic products, which can then be subject to more significant losses. In particular, the harvesting workforce accounts for a relatively large share of the cost of growing and marketing fresh products. Wage growth and labour availability are often combined to enhance the price of harvesting, which causes farmers sometimes to abandon the crop before harvest and make many other production and marketing decisions that directly impact crop losses. Agreed product

quality (contracted quality) can decrease some of the variability in revenue for farmers that would otherwise be inevitable in product markets. Contracts can also generate FL, acting as an obstacle to access for omitted growers but may seek access to the excess product (Minor *et al*., 2020). Although the policy can play a positive role in supporting FL reduction, recovery, and recycling, however, some guidelines may unintentionally act as obstacles (e.g., restrictions on gleaning collection of the excess food for donation) or fail to address the underlying causes of FL (BCFN, 2012; Minor *et al*., 2020).

Losses at the primary agricultural phase are also related to farmers' traditional methods and practices. In addition, the elderly mainly undertake agricultural production, as young people in rural regions are willing to migrate to urban areas and opt for labour in other sectors than agriculture. The shortage of personnel in primary production can be viewed as another reason for FL at this phase (FAO, 2013). FL that occurs during farm-level post-harvesting is mainly attributed to storage infrastructure (cold-chain technique of storage, warehouses), handling, distribution, improper packaging (Lipinska *et al*., 2019; Nicastro and Carillo, 2021; Shee *et al*., 2019). A cold chain is the uninterrupted delivery of an agri-food product from the farmer to the consumer at a definite temperature, ensuring that the product arrives without damage (Elik *et al*., 2019; Sugri *et al*., 2021).

In industrialized countries, storage is constantly provided throughout FSC from the primary production phase. In addition, in these countries, cold storage is combined with postharvest techniques (e.g., controlled atmosphere), the shelf life of perishable agri-foods being substantially extended. In non-industrialized countries, about a quarter of the perishable agri-foods are damaged because the storage operation is carried out under unsuitable conditions, severe losses thus occurring in food products. The improper storage facilities in developing countries are considered the main factor of postharvest FL. However, it should be kept in mind that even if the products are stored in the best circumstances, their quality and capacity of consumption depend on the phases of the entire FSC (Elik *et al*., 2019). Transportation can be one of the leading causes of FL. In developed countries, delivering perishable foods with refrigerated vehicles is standard practice. In industrialized countries, distribution of perishable food by vehicles with a cooling system is a standard operation, FL in such situation appearing for the following reasons: the cooling system is broken down; an accident; there is a delay in the loading/unloading zones (Sugri *et al*., 2021).

In non-industrialised countries, which often have the inadequate infrastructure, the lack of adequate transport, poor roads, and inefficient logistics management prevent the proper preservation of perishable food (COMCEC, 2016; Elik *et al*., 2019; FAO, 2011b; Nicastro and Carillo, 2021). The poor roads in rural areas where most production occurs lead to an increase in FL during distribution. In addition, loading and unloading activities are carried out by unskilled workers, who do not carry products attentively, causing mechanical deterioration in agri-food products. One of the major reasons that crops are lost at farm-level postharvest is improper packaging and unsuitable (poor quality) food packaging material for a particular fruit and vegetable product, which cannot adequately protect the product from deterioration and decreases the shelf life of the harvest (Elik *et al*., 2019; Nicastro and Carillo, 2021). Poor-quality packaging containers are more common in developing countries (Elik *et al*., 2019).

In the farm-level processing (initial/preliminary processing) of agri-food products, the causes of the losses are mainly technical failures and inefficiencies in the production processes, leading to losses and deterioration of the products, these being rejected. In particular, errors during food processing cause defects in the product's weight, shape, or packaging. Even though

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these defects do not influence the safety or nutritional value of the food products, they are rejected. This happens the most frequently in non-industrialised countries, where technology is often unsatisfactory and may not always provide adequate food preservation, but also to some extent in developed countries (BCFN, 2012; Sugri *et al*., 2021).

4. Conclusions

Numerous factors generate food loss along the food supply chain. It is evident that avoiding and reducing food losses should be a priority to improve food security and minimize the related economic and environmental implications. Notwithstanding, understanding the contributing factors to food loss is essential for developing strategies to avoid and reduce food loss, large quantities of food being lost from primary production activities. This paper highlighted the contributing factors to food loss at the primary agricultural production (cultivation and harvest, farm-level post-harvesting, and farm-level processing). As pointed out in the paper, several factors (e.g., diseases, unfavourable climatic and environmental conditions, inadequate harvesting techniques, transportation and storage infrastructure, price volatility, policy implications, conformity with norms and standards, limits on farm-level processing) were identified. If adequately monitored and managed, these causes will no longer pose a high risk of generating food losses. However, effective strategies to reduce farm-level food loss must imply other factors (e.g., socio-economic, market) which shape the food system. In addition, strategies to reduce food losses should focus on the entire food supply chain, as there are opportunities for food loss to occur along the food supply chain, from the farm to final consumption.

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