Chapter 17

TOWARD SUSTAINABLE TRANSFORMATION THROUGH POSTHARVEST MANAGEMENT: LESSONS FROM KENYA'S MANGO VALUE CHAIN

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Management of postharvest food loss and waste (FLW) is an important strategy in efforts to sustainably meet the food and nutrition needs of the world's growing population. Sustainable food systems are critical to achieving food security and nutrition for all, now and in the future. Food systems cannot be sustainable when a large proportion of the food produced using limited resources is lost or wasted in the supply chain. At the global level, it is estimated that poor postharvest management means this is the case for 30 percent of the food produced for human consumption (FAO 2011, 2019).

The figure for Kenya is similar (Ministry of Agriculture, Livestock, Fisheries and Cooperatives 2018). The 2021 *Food Waste Index Report* (UNEP 2021) indicates that every Kenyan wastes about 100 kg of food every year, which adds up to 5.2 million metric tons[1] per year, excluding food loss that happens upstream, from production to retail. In monetary terms, wasteful consumption accounts for slightly over US$500 million annually (Mbatia 2021). FLW exacerbates food insecurity and has negative impacts on the environment through waste of precious land, water, farm inputs, and energy used in producing food that is not consumed. In addition, postharvest losses, caused by poor storage conditions, reduce income to farmers and contribute to higher food prices.

"Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). Food and nutrition security for all remains an elusive global goal, and especially in sub-Saharan Africa, where one in five people suffer from some form of food insecurity. According to the Food and Agriculture Organization of the United Nations (FAO) (2021), about 26 percent of Kenya's population

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[1] Tons refers to metric tons throughout this volume.

is food-insecure, a situation that has been aggravated by events such the COVID-19 pandemic, locust plagues, and insufficient rainfall.

With an estimated growth rate of 2.3 percent per year, Kenya's current population of 53 million is set to rise to more than 100 million by the year 2050 (World Bank 2021). This calls for a paradigm shift in food production and consumption. Significant efforts have been made to increase production through expansion of agricultural land; increased inputs such as seed, water, and fertilizers; and overall intensification of production. However, increasing production of food that is ultimately not eaten, whether it is lost during the production and transformation processes or wasted at the consumption stage, entails a waste of economic and natural resources (HLPE 2014). Achieving food and nutrition security for the current population should not compromise the economic, social, and environmental bases for generating food security and nutrition for future generations. To create resilient and sustainable food systems, we must look beyond increasing production. Efforts must be made to ensure the food produced is used efficiently to reduce pressure on limited and inelastic production resources.

FLW reduction has become a subject of interest at the global, regional, and national level. At global level, it is enshrined in the Sustainable Development Goals (SDGs). Specifically, under SDG 12 on responsible consumption and production, target 12.3 calls for halving per capita global food waste at retail and consumer levels and reducing food loss along production and supply chains, including postharvest loss, by 2030. At the regional level, the African Union Heads of State and Government included in the 2014 Malabo Declaration a call to reduce postharvest losses by 50 percent by 2025. In Kenya, acknowledging the critical role of FLW reduction in efforts to address food and nutrition security, the Big Four agenda, under the Food and Nutrition Security pillar, sets a target of reducing FLW to 15 percent by 2022.

The benefits of FLW reduction in the food supply chain are subject to discussion, with opinions varying. In efforts to reduce FLW, there are both gainers and losers (HLPE 2014; FAO 2019). There is a cost to FLW reduction, and those who bear it may not necessarily enjoy the benefits of their efforts. The impact of FLW reduction on various actors in the supply chain (farmers, distributors, traders, processors, or consumers) depends on how the effect on food prices is distributed along the supply chain (FAO 2019). Therefore, in analyzing the impact of FLW reduction, optimal levels of FLW must be considered from both a private and societal perspective. Moreover, some level of FLW is unavoidable and tolerable and therefore acceptable as part of doing business (HLPE 2014).

Nevertheless, FLW represents needless use of limited resources to produce food that is not consumed and that ends up in landfills, with an even greater negative impact on food systems. Production, transportation, and handling of such food also has a significant negative impact on the environment. The total carbon footprint of food wastage is around 4.4 $GtCO_2$ eq per year, which is about 8 percent of total greenhouse gas emissions (WRI 2020). As such, FLW exacerbates the climate change crisis, thereby negatively affecting food production now and for future generations. Acknowledging the definition of "sustainable food systems" as ensuring food security and nutrition for all without compromising the economic, social, and environmental bases for generating the food security and nutrition of future generations (HLPE 2014), the critical role of FLW reduction is undeniable.

FLW is a complex food systems problem, which varies significantly with the context. Therefore, efforts to address FLW must be contextualized. Relevant factors include differences in region or location, including agroecological, socioeconomic, sociocultural, and geopolitical variations. The causes and extent of FLW also vary significantly across food commodities, according to type, species, and even variety/breed within the same species. Food commodities have been categorized into five groups, namely cereals and pulses; fruits and vegetables; roots, tubers, and oil-bearing crops; animal products; and fish and fish products (FAO 2019).

In this chapter, we describe and discuss FLW in Kenya with a focus on the fruits and vegetables commodity group. We present a case study of mango because of its importance and contribution to Kenya's horticulture subsector. Over 80 percent of horticultural farmers in Kenya are smallholders who derive their livelihoods from 2–5 acres of land. Horticultural food crops produced in Kenya for the domestic and export market include fruits, vegetables, herbs, and spices. Among these, mango is the second most important fruit (by volume) produced in Kenya for the domestic and export markets (HCD 2018). Mango has great potential as a source of income and therefore economic empowerment for many smallholder farmers. The fruit is suited to different agroecological zones in Kenya (from sub-humid to semiarid) and therefore is grown in most of the 47 counties of Kenya as a cash crop. A steady increase in demand for mango, in both the domestic and the global markets, has led to expansion of the area under mango production from below 40,000 ha in 2015 to more than 50,000 ha in 2018 (HCD 2020).

However, as production volumes continue to increase in Kenya, high postharvest losses have been reported in the mango value chain. Such losses and other challenges in the mango value chain have hindered realization of the potential benefits of increased production volumes. Therefore, mango represents a good case study to highlight the importance of addressing FLW to complement efforts to increase production. The fruits and vegetables commodity group, to which mango belongs, sees high FLW (40–50 percent) (FAO 2011). The causes of and interventions to address FLW described in this chapter for mango are also relevant to other fruit and vegetable value chains.

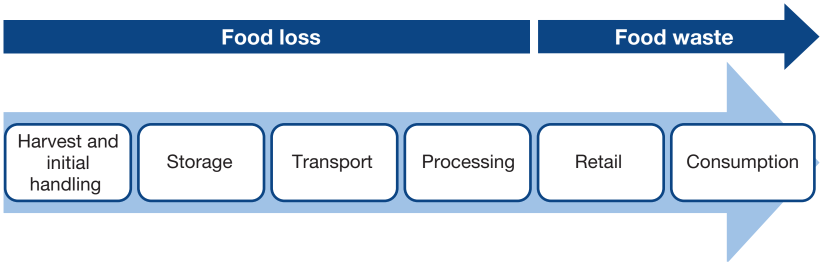
Defining the problem of food loss and waste

To tackle the problem of FLW, there is a need for a common understanding of what it means—the extent of FLW and the causes or drivers, including the critical loss points. In addition, to trigger the necessary action, the impact of FLW on food and nutrition security and its environmental footprint must be demonstrated. Further, there is a need to highlight regional and national initiatives in place to reduce FLW.

Definitions and distinctions of terms used in postharvest management

FLW refers to the decrease in the mass of food (quantitative FLW) and the nutritional and/or economic quality of food (qualitative FLW) that was originally intended for human consumption. Food loss refers to food that is spilled, spoilt, or otherwise lost, or incurs a reduction of quality and value prior to the retail stage of the supply chain. Food loss typically takes place at the production, postharvest, processing, and distribution stages in the chain. It is a result of decisions and actions by food suppliers in the chain, excluding retailers, food service providers, and consumers (Figure 17.1). Food waste refers to food of good quality and that is fit for consumption that is not consumed because it is deliberately discarded. Food waste typically (but not exclusively) takes place at the retail

FIGURE 17.1 The distinction between food loss and food waste



Source: Authors' illustration.

and consumption stages in the food supply chain (Figure 17.1). It results from decisions and actions by retailers, food service providers, and consumers.

A dimension of loss that is often ignored or sees little reporting is qualitative loss. Food quality loss or waste refers to the decrease of a quality attribute of food (nutritional, safety, or other aspect) that is linked to degradation at any stage of the food chain from harvest to consumption. Qualitative losses may occur without a decrease in the quantity of food and is therefore hardly reported. Decreases in nutritional value (for example, a decrease in vitamins) or economic value (for example, because of noncompliance with set standards) are examples of qualitative losses. Loss of quality can also lead to unsafe consumption that has a long-term effect on population health (HLPE 2014).

Extent of food loss and waste

Globally, an estimated 30 percent of food produced for human consumption is lost or wasted (FAO 2011, 2019. According to FAO (2011), FLW ranges between 26 and 36 percent globally but the distribution of food loss versus food waste along the supply chain differs across regions. For example, in sub-Saharan Africa, where FLW is estimated to be 36 percent, the highest losses (*food loss*) occur upstream at the production, postharvest handling, and storage stages. These stages alone account for 72 percent of total FLW, while the consumption stage accounts for only 5 percent. Developed economies in Europe and North America grapple more with downstream losses (*food waste*), with the retail and consumption stages accounting for most of the FLW (FAO 2011; HLPE 2014).

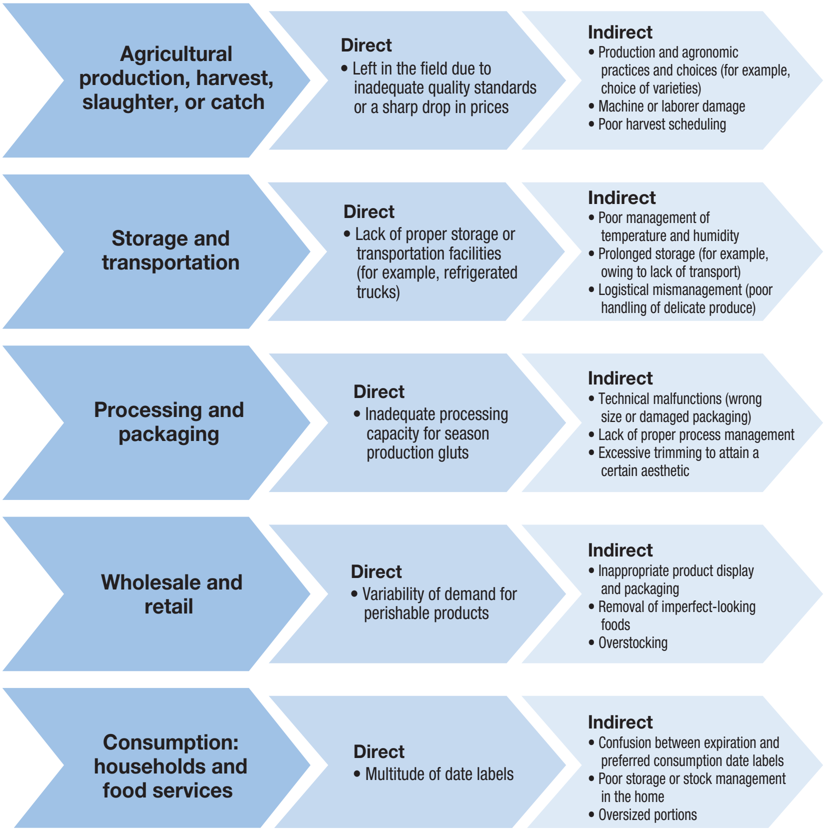
Certain value chains are more prone than others to FLW. For example, FLW in cereals and pulses is estimated to be about 8 percent, whereas 22 percent of fruits and vegetables are lost between production and the retail stage (FAO 2019). In Kenya, FLW in fruits and vegetables is even higher (40–50 percent or more) depending on the commodity. For mango in particular, FLW ranges between 35 and 45 percent (Gor et al. 2012; Snel et al. 2021). A major reason for high losses in fruits and vegetables is their perishability, which predisposes them to deterioration right from the point of harvesting up to consumption. The high losses in these nutritious food commodities have a negative effect on nutrition security, as Kenyan diets are generally deficient in fruits and vegetables.

Causes and drivers of food loss and waste

Identification of causes of FLW is critical in efforts to find context-appropriate solutions. Causes of FLW along the food supply chain are interrelated such that actions at one stage can affect all the rest. Immediate or direct causes of losses are linked to individuals' actions in dealing with the primary effects of a biological, microbial, chemical, biochemical, mechanical, physical, physiological, or psychological nature that lead to FLW. However, these immediate causes could be a result of other secondary reasons beyond the control of the individual actors.

Broadly, the causes of FLW can be organized into three levels, as micro-, meso-, and macro-level causes, based on the actors involved and the level of economic activity at which FLW is produced (HLPE 2014). Micro-level causes are primary causes of FLW that are attributed to actions or lack of action by individual actors at each stage of the supply chain from production to consumption. Meso-level causes are secondary or structural causes of FLW attributed to organizations or relationships of actors, the state of infrastructure, and other

FIGURE 17.2 Direct versus indirect causes of food loss and waste at different stages of the supply chain



Agricultural production, harvest, slaughter, or catch	**Direct** • Left in the field due to inadequate quality standards or a sharp drop in prices	**Indirect** • Production and agronomic practices and choices (for example, choice of varieties) • Machine or laborer damage • Poor harvest scheduling
Storage and transportation	**Direct** • Lack of proper storage or transportation facilities (for example, refrigerated trucks)	**Indirect** • Poor management of temperature and humidity • Prolonged storage (for example, owing to lack of transport) • Logistical mismanagement (poor handling of delicate produce)
Processing and packaging	**Direct** • Inadequate processing capacity for season production gluts	**Indirect** • Technical malfunctions (wrong size or damaged packaging) • Lack of proper process management • Excessive trimming to attain a certain aesthetic
Wholesale and retail	**Direct** • Variability of demand for perishable products	**Indirect** • Inappropriate product display and packaging • Removal of imperfect-looking foods • Overstocking
Consumption: households and food services	**Direct** • Multitude of date labels	**Indirect** • Confusion between expiration and preferred consumption date labels • Poor storage or stock management in the home • Oversized portions

Source: Adapted by authors from FAO (2019).

factors beyond individual actions. They contribute to the occurrence and extent of micro-level losses. Macro-level causes are attributed to systemic issues such as an inadequate institutional or policy environment to enable proper functioning and coordination of food system actors. Macro-level causes point toward a food system malfunction.

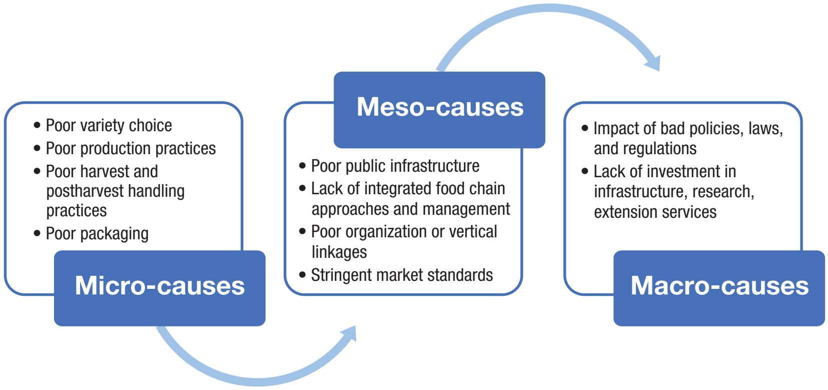
Causes of FLW can also be categorized as direct and indirect (FAO 2019). The FAO describes direct causes as those attributed to actions (or lack of action) of individual actors that lead to FLW along the chain. Indirect causes are more systemic and concern the economic, cultural, and political environment of the food system in which the actors operate, and which may influence their decisions that lead to FLW. From a policy perspective, the indirect causes affect the decisions of individual actors that must be addressed so as to establish targeted interventions. It is noteworthy that, often, the losses observed at one stage of the supply chain could be a result of actions (or lack of action) at a different stage. Therefore, the supply chain should be viewed as a conveyor belt whereby the action of one actor at one stage could compromise the whole chain. Therefore, interventions to address FLW should be holistic and not isolated to the apparent causes at a single stage.

Causes of food loss and waste in the smallholder mango value chain

Mango is a climacteric fruit (like many other tropical fruits and vegetables), making it highly perishable, with a short shelf life after harvest. In postharvest handling, fruits such as mango are considered "living." This is because they still perform physiological functions such as respiration and transpiration, which are critical for living. As a climacteric fruit, mango can be harvested at physiological maturity and left to continue ripening after harvest. During ripening, the fruit undergoes compositional changes that transform the inedible form into the edible form with desirable eating characteristics. Biological/physiological processes that continue after harvest and that contribute to deterioration of mango fruits after harvest include respiration (which leads to depletion of stored food reserves), transpiration (which results in water loss), softening (which makes the produce prone to mechanical damage and subsequent rotting), and ethylene evolution (which triggers ripening and/or deteriorative changes). The rate of these biological processes depends on environmental factors including the temperature, humidity, and gas composition of the environment in which the fruit is stored or handled. Therefore, measures to preserve postharvest quality and slow deterioration and consequent FLW in mangoes are premised on the need to manage the biological and environmental factors that contribute to deterioration.

Poor harvest practices; poor handling of the harvested fruits; inappropriate storage practices, including poor cold chain management; and lack of capacity to transform the perishable fruit into shelf-stable products are some of the upstream micro-level causes of losses in mangoes and other fruits. At the meso level, poor public infrastructure, including roads, not only contributes to mechanical injuries during transport but also affects accessibility to markets. In addition, poor organization of actors in the value chain and stringent market standards are some of the meso-level drivers of FLW in mango value chains. At the macro level, FLW in mango is attributed to the impact of poor policies, laws, and regulations. For example, taxation regulations that deter the import of postharvest technologies have a negative impact on access to affordable technologies. Moreover, lack of investment in research and extension services by the government has negative impacts on efforts to develop and disseminate homegrown solutions to FLW. Figure 17.3 depicts the organization of common causes of FLW in the mango value chain (and those of other fruits and vegetables) at micro, meso, and macro levels.

FIGURE 17.3 Organization of common causes of losses in mango and other fruit and vegetable value chains



Source: Authors' illustration.

Addressing the causes of food loss and waste in the mango value chain

The solutions to FLW, like the causes, can also be organized at three levels (micro, meso, and macro) depending on the value chain. In the sections below, the interventions described focus on the mango value chain but are also applicable to most fruit and vegetable value chains in the Kenyan context.

Micro-level interventions to reduce food loss and waste

Interventions to address FLW must be designed to be context-appropriate, with attention to the characteristics of the geographic region, commodity, scale of operation, and stage of the supply chain, among other key considerations. There is no single intervention that can be recommended to holistically address the drivers/causes of postharvest losses. However, a set of technologies, practices, and other interventions may be combined to reduce FLW. Simple technologies and practices that individual actors (or actors organized in groups) can apply at different stages of the supply chain to preserve quality and reduce losses are described.

HARVEST AND IMMEDIATE HANDLING AFTER HARVEST

Poor harvest and immediate postharvest handing practices contribute significantly to postharvest losses in mango and other fruits and vegetables. Poor harvest practices result in mechanical injuries leading to immediate and/or later spoilage of commodities because they are predisposed to biological agents of deterioration. Although the injuries may not be evident at the time of harvest, they ultimately manifest at later stages of the supply chain, leading to disposal of the fruits (Snel et al. 2021). Therefore, harvesting practices should be aimed at minimizing mechanical injuries to the fruits. For example, in mango, simple harvesting tools such as fruit pickers can be used instead of the common practice of shaking tall trees to fell the fruits. After harvest, presorting the fruits to remove those that are infected or infested by pests and diseases is important to avoid contamination of the whole batch (Kader 2005). Further, sorting the fruits based on the size and stage of ripening can reduce on-farm losses because it reduces handling further down the supply chain.

PACKAGING AND TRANSPORT

Rough handling of produce during packaging for transport also results in mechanical injuries that affect the quality of the produce. Other handling practices such as using inappropriate containers may either cause injuries or predispose the fruits to faster deterioration as a result of the unfavorable environment in the packaging containers. Common materials used for packaging

FIGURE 17.4 Packing options for mango fruits

A. Standard bread crate

B. Bread crates packed with mangoes

C. Mangoes packed in a sack

Source: Authors.

fruits and vegetables by smallholders in developing countries like Kenya include wooden or plastic crates, nylon sacks, polythene bags, woven palm baskets, and jute sacks (Teutsch 2018). The aim of the packaging process is to protect the fruits from mechanical damage; to prevent physical, chemical, and biological contamination; and to avoid tampering with the fruits (Prasad and Kochhar 2014). Some of the packaging materials used by farmers and traders to package mango fruits, such as nylon sacks and polythene bags (Figure 17.4, plate C), accelerate produce deterioration leading to qualitative and quantitative losses.

Crates have been promoted as the preferred containers for handling fruits and vegetables. Traders prefer wooden crates because of the cost but their rough surfaces inflict injury on fruits. Packaging and handling of fruits and vegetables is shifting to plastic crates, which are clean, light, and durable. They deliver satisfactory protection against compression damage. Notably, unlike wooden types, they have a smooth inside finish, are easy to clean, and are reusable and stackable (Accorsi et al. 2014). A standard bread crate with a capacity of 20–30 kg (plates A and B) costs approximately $6. Special crates that are stackable, nestable, or collapsible cost a little more ($15–25) but have the advantage of saving space when empty. Nestable crates are especially recommended because they can be nested/stacked when packed with produce without causing any injuries to the produce.

COLD CHAIN MANAGEMENT IN MANGO VALUE CHAINS

Maintenance of low but safe temperatures during handling from harvest to end-user (the cold chain) is critical to preserve the quality of perishable produce such as mango (Ambuko et al. 2016). The cold chain for perishable produce ensures that cool temperatures are maintained as the fruit is handled during harvest, collection/aggregation, transport, storage, processing, and marketing until it reaches the final consumers (Kitinoja 2014). This includes minimizing delays between harvesting and cooling of the produce that could result in significant quantitative and qualitative losses (Kader 2002). Handling of perishable produce at suboptimal temperatures aggravates deterioration from biological agents. Research shows that an increase in temperature by 10°C above optimum increases the deterioration rate in perishable commodities two to threefold (Kader 2005).

A cold chain is often perceived as a complex and sophisticated system with high-tech facilities such as conventional cold rooms and refrigerated transport. However, a 2021 study of mango by Amwoka and colleagues revealed that an appreciable cold chain could be achieved through appropriate harvest and postharvest handling practices coupled with simple low-cost storage technologies. During harvest, the time of day at which harvesting is carried out has a significant effect on the postharvest longevity of the fruits (ibid.). For the majority of mango farmers, harvesting is a continuous process that can take place at any time of day as long as there is a buyer. However, harvesting produce at cooler times of day reduces the heat load on the produce that results from high temperatures and exposure to direct sunlight when fruits are harvested at hotter times of the day (Kiaya 2014; Amwoka et al. 2021). Harvested produce should be transported from the field to storage immediately. Delays in the field can expose the produce to more heat, leading again to a high heat load in harvested crops, which negatively affects shelf life and quality (Kiaya 2014). After harvest, mango fruits destined for long-term storage benefit greatly from precooling to remove the field heat. Precooling not only saves energy during cold storage but also ensures uniform produce temperature during storage (Amwoka et al. 2021).

Proper cold chain management practices complement storage technologies to preserve the quality of harvested produce. Conventional cold rooms provide the best temperature-controlled storage environment for fruits and vegetables. However, the cost of installation and maintenance of conventional cold rooms is beyond reach for most small-scale farmers in developing countries like Kenya. Unreliable access to electricity also presents a major constraint in adopting such technologies.

To overcome the challenge of access to conventional cooling for smallholders, there have been research efforts to find low-cost alternatives that are suited for rural areas in Kenya. These include off-grid evaporative cooling technologies, solar-powered cold storage, and affordable on-grid technologies. Off-grid evaporative cooling operates on the principle of evaporative heat exchange. When hot air from outside passes over a wetted pad/medium, the water in the wetted pad evaporates as it draws heat from the surrounding air, creating a cooling effect

(Lal Basediya, Samuel, and Beera 2013). The cooler and more humid conditions inside the evaporative cooling chamber preserve the quality and extend the shelf life of perishable horticultural produce. Research has shown that a temperature difference of 2–15°C between ambient air and inside an evaporative cooling chamber can be achieved depending on the time of day and season (Appendix 17.1). In addition, high relative humidity (≥99 percent) has been achieved in evaporative cooling chambers (Ambuko et al. 2017; Amwoka et al. 2021).

Various evaporative cooling technologies have been tested and proven effective at preserving quality in perishable produce. Examples of these include the evaporative charcoal cooler, the zero energy brick cooler, the pot-in-pot cooler, and the hessian sack cooling chamber. Appendix 17.1 describes the zero energy brick cooler and the evaporative charcoal cooler.

Other, off-grid solar-powered, cold storage technologies that have been promoted for application in mango and other perishable produce include Freshbox[2], Solar Freeze[3], and JuaBaridi, among others. Although these off-grid technologies have proven effective in preserving postharvest quality of mango and other fruits and vegetables, their adoption rate is still very low.

Low-tech on-grid solutions have also been proposed to overcome the cost constraints of conventional cold rooms. An example of this is the Coolbot™ cold room, which is a walk-in on-grid cold room that offers a low-cost alternative to conventional cold rooms. The Coolbot controller is an electronic gadget that uses multiple sensors and a programmed microcontroller that directs the air conditioner to operate at the desired temperature without freezing up (Dubey and Raman 2014). A 4 m by 4 m unit can cool up to 200 standard bread crates of stored fresh produce to temperatures as low as 4°C. The Coolbot technology is environmentally friendly, uses little energy, and has very low carbon emissions. The technology was introduced in Kenya on a pilot scale in 2015 and is available on order. On-station and on-farm studies have demonstrated its effectiveness in preserving quality and extending the shelf life of mango fruits (Karithi 2016; Ambuko et al. 2018a; Amwoka et al. 2021). Even though the Coolbot has significant cost advantages over conventional storage facilities, the costs are still out of reach for many smallholder farmers. A standard 4 m by 4 m unit can cost between $3,000 and $6,500 (compared with $10,000 for a conventional facility with similar capacity) depending on the level of sophistication and the availability of materials used in its fabrication (Kitinoja 2014; Karithi 2016; Ambuko

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[2] www.freshbox.co.ke

[3] www.solarfreeze.co.ke

et al. 2018a). However, the Coolbot has the advantage of low installation and maintenance costs compared with conventional cold rooms.

COMPLEMENTARY TECHNOLOGIES FOR QUALITY PRESERVATION IN MANGO (AND OTHER FRUITS AND VEGETABLES)

In addition to improved practices and cold chains, there are complementary technologies that can be applied to enhance quality preservation in mango and other fruits. Examples of these are modified atmospheric packaging (MAP), the application of edible coatings and waxes, and natural plant hormones that can reduce losses. These technologies extend shelf life and preserve quality by reducing the rate of deteriorative processes such as respiration, transpiration, ethylene evolution, and pathological breakdown. For example, MAP using the right film has been shown to preserve the postharvest quality of mango fruits (Githiga et al. 2014). However, these beneficial effects of MAP can be realized only when the right film, whose permeability characteristics have been optimized to suit the physiological characteristics of the fruit, is used. In addition, the right storage temperature is important. A combination of the Coolbot cold room and MAP has been shown to extend the shelf of mango further compared with cold storage alone (Ambuko et al. 2018b).

The shelf life of mango fruits can also be extended through application of edible coatings or waxes. The thin film lowers the loss of water and slows gas diffusion resulting in reduced shriveling and respiration rates in the stored fruits. In addition, the thin film prevents fruit bruises during handling. Waxing effectiveness in mango has been demonstrated in the Apple mango variety, where waxing extended the fruits' shelf life by at least five days relative to unwaxed fruits (Maina et al. 2019).

The use of natural hormones can also improve the shelf life of fruits such as mango. An example of natural hormone-line compounds that have application in fruit quality preservation is 1-Methylcyclopropene (1-MCP). It is a competitive inhibitor of the ripening hormone, ethylene, which is known to trigger ripening and the related physiological processes that lead to spoilage of fruits and vegetables. The effectiveness of 1-MCP in extending the shelf life of mango fruit has been demonstrated in various mango varieties of commercial importance in Kenya, including Tommy Atkins and Apple (Ambuko et al. 2016). Although 1-MCP is widely used globally in fruit and vegetables, its adoption is limited in Kenya, and mainly in avocado fruits. Efforts are being made by the parent company, AgroFresh[4], to promote the use of 1-MCP in Kenya for other fruits and vegetables.

Meso-level interventions to reduce food loss and waste

Although the technologies described above have been shown to be effective and have the potential to reduce FLW in mango and other perishable commodities, their adoption is limited. Factors that limit adoption include high initial costs of installation (particularly for individual farmers), lack of scale to generate a positive return on investments, and absence of financial incentives to improve the quality of produce. This last issue arises because, especially in the local market, pricing is not guided by any quality standards. The organization of actors into groups can overcome these barriers and facilitate better vertical integration and market access. Operationalization of this can be achieved using different approaches. The sections below describe two approaches to the organization of horticultural farmers and linking them to markets (horizontal and vertical integration). The approaches represent meso-level interventions that have been tested and proven to work in Kenya's context.

SMALLHOLDER HORTICULTURE AGGREGATION CENTERS

Produce aggregation can help farmers achieve the scale traders demand. In groups, farmers can collectively demand premiums for quality and share the costs of expensive technologies. In Kenya, the concept of produce aggregation has been pursued among smallholder mango farmers under the Rockefeller Foundation's YieldWise initiative. In this, smallholder mango farmers who are organized in groups gain access to cold storage facilities, allowing them to aggregate their individual small volumes over time to achieve the quantities traders demand. In addition, such centers set standards for the produce to be delivered by smallholder farmers, and thus accept only high-quality produce. This approach assures not only the quality but also the quantity and consistency of the produce aggregated. Box 17.1 describes the Karurumo smallholder horticultural self-help group (in Embu county in Kenya), which is one of the beneficiaries of the initiative's pilot. The farmers affiliated with the group have been able to aggregate their produce for targeted traders including exporters and local anchor buyers and traders.

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[4] www.agrofresh.com

BOX 17.1 Smallholder horticulture aggregation and processing centers: Mango case study

It is estimated that 40–50 percent of mango fruits produced in Kenya goes to waste, especially during the peak season between November and March. Because farmers lack storage facilities for the highly perishable fruit, they are at the mercy of brokers. A price survey conducted in 2017 and 2020 revealed that, while most traders buy mangoes at a paltry KSh 3–5 at the farmgate, the same fruits retail for as much as KSh 100 in Nairobi's retail outlets. In 2017, the University of Nairobi Postharvest Project team set out to change this with support from the Rockefeller Foundation's YieldWise initiative. The project sought to demonstrate the potential of smallholder aggregation and processing to reduce postharvest losses in fruits such as mango.

A smallholder horticultural aggregation and processing center was established for the Karurumo horticultural self-help group in Embu county. The center is a full-scale aggregation and processing center with cold storage facilities for aggregation complemented by simple equipment for small-scale wet and dry processing. The installed cold facilities include an evaporative charcoal cooler and two zero energy brick coolers as well as a Coolbot cold room. Based on best practices for horticultural produce handling and cold chain management, produce is sorted and graded based on the market destination. Thereafter, it is precooled in the evaporative coolers to remove the field heat prior to storage in the Coolbot cold room.

Installed small-scale processing facilities include a juice processing line and two solar tunnel dryers. These have enabled farmers to transform the unsold fruit into shelf-stable products. During the peak season, the fruits that are too ripe for the market or that have some defects that make then unsellable are pulped and pasteurized. The pulp is later used to make other products, such ready-to-drink juices, juice concentrates, and jam. With these facilities, farmers are no longer forced to sell the fruits to brokers at low prices. Meanwhile, with cold storage, they can aggregate produce that meets the requirements of traders, in quantity, quality, and consistency terms. This means they can collectively negotiate for better prices from traders. At this point, farmers have been able to negotiate KSh 10 per piece—more than twice the standard farmgate price paid by traders. And if traders are unwilling to pay better prices, farmers can transform the perishable fruits into shelf-stable products. With market access, these processed products have been shown to fetch even better returns than the fresh fruits. When mango fruits are out of season, farmers can use the storage and processing facilities for other fruits and vegetables.

Source: Ambuko (2020).

SHORT AND EFFICIENT SUPPLY CHAINS FOR FRUITS AND VEGETABLES

Production of fruits and vegetables must be linked to markets and consumers through stable value chains to ensure sustainability (FAO and CIRAD 2021). Long and inefficient supply chains contribute to high postharvest losses that affect supply. They also affect access to and affordability of fruits and vegetables, especially for low-income consumers (as seen in Chapter 4). Most urban consumers in Kenya depend on informal markets for their supply of fresh fruits and vegetables. The informal supply chain is highly inefficient, with very high postharvest losses reported at each stage. The cost of the losses is borne by smallholders and consumers, who end up paying for the inefficiencies in the supply chain.

Recognizing that 90 percent of the retail market in sub-Saharan Africa is informal and highly inefficient, Twiga Foods Ltd. (TFL)[5] saw a business opportunity that would address inefficiency by removing the many layers of intermediaries. This would in turn reduce postharvest losses and lower the cost of food, especially for urban consumers. Since the company entered the Kenya market space in 2014, it has revolutionized the retail trade that connects small-scale fruit and vegetable farmers in rural areas to traders in cities. TFL has addressed the market access challenge of smallholder farmers by replacing the unscrupulous brokers who take advantage of farmers by offering below-market prices for the produce or fail to buy produce during peak seasons. With the entry of TFL, farmers are assured of markets for their produce and fair pricing as TFL collects produce directly from them. TFL has registered traders who place orders through a sales representative or directly on TFL's app. The company then dispatches the order within 24 hours using its vehicles—free of charge. Payment to farmers is made within 24 hours of collection through the mobile money platform M-Pesa. This short and highly efficient chain has contributed to a reduction of postharvest losses from 30 percent to 4 percent for produce sold through the TFL platform. If this model could be replicated countrywide for various fruits and vegetables, it would not only reduce postharvest losses but also make fruits and vegetables accessible at affordable prices for many, while improving incomes for farmers.

Small-scale processing to reduce food loss and waste

Food processing minimizes undesirable biochemical changes that alter the nutritional and sensory composition or wholesomeness of food and thereby prolongs

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[5] https://twiga.com/

food shelf life. Food processing can be a game changer in sustainably reducing food loss and waste, boosting food security, contributing to livelihoods through gainful employment, and increasing national GDP. Processing perishable produce into shelf-stable products is especially important for perishable commodities such as fruits and vegetables where high postharvest losses are reported.

MANGO FRUIT PROCESSING—THE OPTIONS

Mango is a highly perishable seasonal fruit with significant postharvest losses reported during the peak season, which occurs between November and March in Kenya. To minimize such losses, the perishable fruit can be transformed to shelf-stable products through small-scale processing. Mangoes can be processed in a variety of ways, and each type of processing adds value to the final product, as shown in Appendix 17.2 (Owino and Ambuko 2021). For small-scale processors, some of these options are more viable than others. For example, preparing fresh cut mango is relatively low cost, and fresh cut mango is in demand in urban areas and can help improve the nutritional quality of street food. However, food safety remains an issue, and to assure fresh-like quality, minimize microbial contamination, and extend the shelf life of fresh cut mango, there is a need to use hygienic water with a combination of disinfectants, antimicrobials, anti-browning, and texture-maintaining preservatives (ibid.).

Mangoes can also be processed into pulp, to serve as a base for juice, wine, probiotic dairy drinks, or jellies (wet processing). The promotion of fruit-based beverages over soda can improve dietary quality. If mangoes are processed as dried fruits (for example, dehydrated), they can be added as supplements in formula or baked goods to increase micronutrient intake. In the case of drying, the type of mechanism used changes nutrient retention. For example, refractance window drying leads to better-quality and more nutritious mango leather than does solar drying (Owino and Ambuko 2021). The waste products of mango processing—peels and kernels—can be incorporated into other food products, cosmetics, and animal feed.

Kenya is well placed to take advantage of food processing as a way to reduce FLW, boost food security, generate value for small farmers and enterprises, and build food systems resilience. Both the demand and supply conditions are in place for transformative effects through processing. Data from the Kenya Association of Manufacturers (KAM) reveal that Kenya spends $2.4 million on imports of food and beverages, pointing to local market demand for processed food products (KAM 2018). This demand is expected only to increase in coming years as a result of a growing middle class and urbanization.

The food processing subsector is already one of the largest in Kenya's manufacturing sector, contributing about 2.5 percent to national employment and 5.1 percent to Kenya's GDP (Chapter 2), while accounting for 15.3 percent of exports in 2021 (KIPPRA et al. 2023). The sector contains large-scale processors but is dominated by small and medium food processing enterprises (food processing SMEs) as well as informal businesses. In 2020, the Kenya National Bureau of Statistics economic survey (KNBS 2020) showed that the middle-class made up 44 percent of the population and was expected to continue expanding by an average annual rate of 5 percent. These rising numbers mean that more and more Kenyans have more disposable income and hence are demanding healthier diets (Chapter 4). Further, by 2030, 63 percent of the population is expected to reside in urban areas, where consumers are increasingly buying from supermarkets and county/municipal markets and turning to a more diversified diet, but also to easy-to-cook and highly palatable meals. These population trends point toward increased demand for processed, nutritious, and healthy food products, and consequently an opportunity for the expansion of food processing SMEs.

On the supply side, Kenya is the third-largest mango producer in Africa, with a production area of 50,550 ha, a production volume of 772,700 tons, and a value of KSh 11.72 billion in 2017 (TechnoServe 2021). Makueni, Machakos, Kilifi, and Kwale are the leading counties in terms of mango production, accounting for 28.2, 21.5, 15.0, and 7.7 percent shares, respectively. Only 3 percent of mangoes are exported, pointing toward a strong local market (SNV Netherlands and ProFound 2019; Mujuka et al. 2020). However, processed mango makes up a small portion of domestic sales: the domestic fresh market accounts for about 90 percent of mango produced while only about 5 percent is processed. With a short harvest season, more than 40 percent of production goes to waste as a result of processing and demand constraints. To take advantage of the potential of mango processing, several initiatives have been launched (Box 17.2).

INCREASED VALUE FROM MANGO PROCESSING

Although marketing of mangoes as fresh whole fruits is the most common practice among small-scale farmers in developing counties, processing the fruit into nutritious and safe products has the potential to accrue bigger profits for farmers and other actors (Owino and Ambuko 2021). As Figure 17.5 shows, any value addition to mango yields better returns compared with fresh mango sales. The most lucrative processed product from mango fruit is wine, with a net profit of $5,500 per ton of mango fruit. However, a sophisticated system is required to

BOX 17.2 Mango processing initiatives

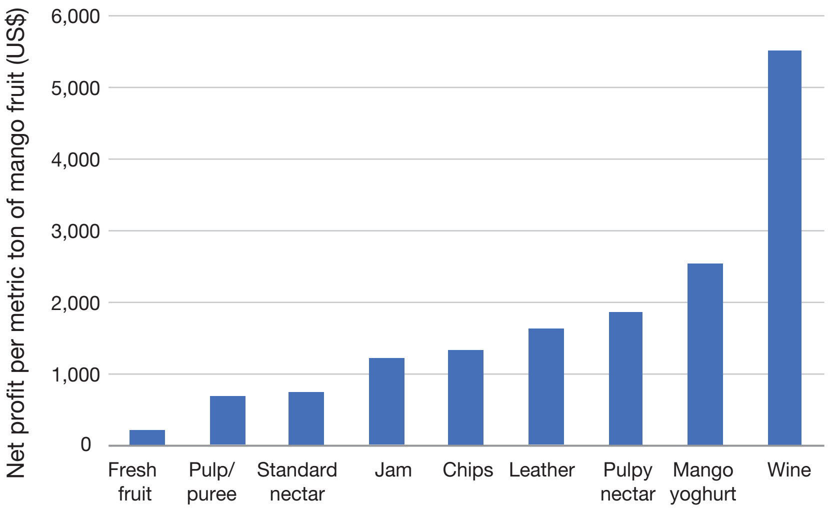
A number of private and public sector initiatives for mango processing have been undertaken recently in Kenya. For instance, Makueni county government established the county-owned Makueni Fruit Processing Plant in 2017. Its objectives are to process mango pulp into purees and juices so as to stabilize fruit prices, reduce mango postharvest losses, provide local farmers with sustainable channels to generate an income, train farmers on new technology and processes, and create employment opportunities for community members.

Revival of the Tana River-based mango pulp manufacturer, Galole Fruit Processing Factory, in 2020 by the Coast Development Authority was intended to reduce mango postharvest losses, improve the living standards of over 30,000 coastal smallholder mango farmers, and create employment for youth in Tana River, Lamu, and Kilifi counties. The mango processing plant has the capacity to crush over 1,200 tons of mangoes per year.

Kitui Enterprise Promotion Company is a private business based in Kitui county that has taken advantage of the processing potential of mango and is involved in the production and distribution of mango juice, mango flakes, mango powder, and fortified flour, targeting mainly the local market.

Source: Makueni County Food Development and Marketing Authority, accessed June 2022. https://mcfdma.co.ke

FIGURE 17.5 Net profits for different processed products from mango fruit



Source: Owino and Ambuko (2021).

produce the quality and quantity needed to compete favorably with imported wines in the Kenyan market. Mango puree requires only pulping and pasteurizing capacity, and is a common product for many small-scale processors but also the product with the lowest returns. The net profit on pulp from 1 ton of fruit is $700 (Owino and Ambuko 2021).

One of the simplest processing options for smallholder farmers/processors is drying (dehydration) because it does not require sophisticated equipment or facilities. The dried products include mango chips and mango leather (rolls). Mango chips and leather from 1 ton of mango fruits can fetch a net profit of $1,300 and $1,600, respectively. If mango drying is conducted using recommended good manufacturing practices and high hygiene standards, which ensure preservation of quality (nutritional and aesthetic) and safety, the dried products are highly recommended for small-scale farmers/processors in developing countries.

CHALLENGES TO SMALL-SCALE PROCESSING OF MANGO (AND OTHER FRUITS AND VEGETABLES)

Processing of mango (and other fruits and vegetables) in Kenya faces a number of challenges, particularly for small-scale processors. These challenges have hindered the contribution of small-scale processing to FLW reduction among smallholder farmers in mango (and other fruit and vegetable value chains).

First, lack of an all-season access road network, especially in rural areas, limits the ability to access high-quality raw materials for processing. Long transit times, high fuel consumption, and increased vehicle wear and tear increase the cost of transportation. It also hampers the distribution of processed products in rural markets, particularly during periods of heavy rain. In addition, the high cost and unreliable supply of electricity increases the production costs of small processors. Kenyan electricity tariffs are the fourth-highest in Africa, but the government has announced a 15 percent reduction across the country as a way of reducing production costs for locally manufactured products (KPLC 2021). However, voltage fluctuations and blackouts remain an issue, and substitution of alternative sources, such as diesel, is insufficient to reduce production costs, especially with the recent dramatic rise in global fuel prices.

Other than infrastructural issues, the high initial investment costs of setting up a processing plant, and difficulties in obtaining the proper machinery and equipment are major roadblocks to expanding the processing sector. Availability of and easy access to suitable machinery and equipment; a good and reliable supply of spares; equipment maintenance and other after-sale services; technical skills to operate the machinery; and efficient technology upgrading and advisory services are essential in the production of competitive food products. Currently, most food processing machinery and spare parts are imported from European countries, China, India, or Brazil, among others. This entails high import declaration fees, among other levies. Inability to accurately determine if foreign-manufactured machinery will suit local conditions can lead to the importation of inappropriate items. Availability of spares or service repairs may also be costly for imported machinery and equipment (Diao, Silver, and Takeshima 2016). Meanwhile, local manufacturers of processing machinery face a myriad of challenges, including high import duty on raw materials, poor aesthetics of locally fabricated equipment, high electricity costs, and proliferation of comparatively cheaper and aesthetically better food processing equipment (Ampah et al. 2021). The result is that many producers use obsolete equipment, which drives up their costs and makes their products less competitive on the market.

Access to finance has been one of the key challenges in expanding the activities of food processing SMEs, especially in their early growth and start-up phase, when they need to procure the prerequisite equipment and have sufficient operational capital. The perception of formal finance providers that there is a higher risk in lending to food processing SMEs leads to higher interest rates and an excessive collateral requirement, which, in turn, raises the cost of borrowing and limits access to finance (Were 2016).

The unpredictable supply of mango also constrains processers. Climate change impacts include adverse and erratic weather conditions, making supply fluctuations more common. High costs of production inputs (seed, fertilizer, etc.) can also result in a decline in levels of production, thus increasing the cost of raw materials for food processing SMEs. Maintaining the quality of the food raw material after harvest is another major constraint. This is partly the result of inadequate infrastructure for transporting or storing raw food materials, especially during periods of glut (Mujuka et al. 2020; George et al. 2021; Musyoka, Isaboke, and Ndirangu 2021; Snel et al. 2021).

In terms of marketing, food processing SMEs tend to produce and sell similar products to those of their competitors, with very few innovations to vary the composition, aesthetics/packaging, or even price. This lack of diversity weakens their positioning in the market since customers end up with limited variety (Chikez, Maier, and Sonka 2021). Further, counterfeit food products are displacing legitimate products in the market through informal channels. These are generally (although not always) retailed at lower prices than their legitimate equivalents, and with time they can squeeze the latter out of the market, reducing revenues for law-abiding companies. Despite the existence of quality inspection of imported food products by government agencies, counterfeit products still find their way into and distort local markets, affecting the profitability of food processing SMEs. Occasionally, counterfeit food products are seized and destroyed. However, it appears that government agencies lack capacity or willingness to deal with violations of regulations on the importation of counterfeit processed food.

Lack of expertise in processing constrains the sector too. Effective food processing depends on the availability of technical specialists. In general, most food processing SMEs are owned by local entrepreneurs, who generally have access to some capital to start the business but few to no technical skills in processing. Those food processing SMEs that engage experts with high levels of processing knowledge and management skills are more predisposed to adopt technologies and expertise that enable their products to penetrate markets and survive competition. Lack of adequate knowledge and management skills is one of the major causes of smallholder processing enterprise failure.

Academia is a source of knowledge creation, innovation, and technological advance, and ideally should generate the knowledge and technologies demanded by food processing SMEs. However, R&D in the food processing sector is largely governed by universities and research institutions, with very little involvement of the food industry. Universities are still regarded as ivory towers, generating knowledge without solving the challenges that would result in economic advancement for food processing SMEs.

Finally, the current regulatory framework poses a challenge to the sector. Kenya's national food safety system comprises 22 pieces of food safety and quality legislation that have been passed through various acts of parliament, and is managed by various agencies under different ministries and laws. The food processing SME business registration process and regulatory requirements are quite stringent and can be time-consuming. For instance, a business needs a Kenya Bureau of Standards (KEBS) certificate to operate. To obtain this, it needs processing facility approval by the public health authority, a hazard analysis and critical control point plan, compliance with labeling requirements, a National Environment Management Authority certificate, a public health certificate, and a medical certificate for each staff member. KEBS has 20 regional offices at which application for certification can be carried out. However, food products have to be sampled and taken for analysis at food laboratories in Nairobi, so the certification process can drag on for quite some time. Then there are taxes and levies, including municipal and county taxes and distribution levies, which can be prohibitive and drive food processing SMEs to informal operations.

Unless these challenges are addressed, the contribution of small-scale processing to FLW reduction efforts may not be realized in full.

Macro-level interventions to address food loss and waste

Although micro- and meso-level interventions have a direct effect on FLW reduction, an enabling policy environment is key to their success. Macro-level interventions are linked to the policy and regulatory environments that will affect actions (or lack thereof) by actors at the micro and meso levels.

POSTHARVEST MANAGEMENT POLICIES AND STRATEGIES

The African Union Commission's Continental Postharvest Loss Reduction Strategy developed in 2018 recognizes lack of relevant policies and coordination as one of the macro-level causes of FLW in most African countries. For example, in Kenya, although several national programs and strategies contain components of postharvest management, there is no specific policy to guide FLW reduction initiatives. A draft national strategy for postharvest management 2018–2025, cascaded from the continental strategy, is anchored on four pillars identified as drivers of postharvest loss reduction in Kenya: policies, institutions, reduction practices, and reduction services. Under the policy pillar, the strategy acknowledges that there is no policy focus on FLW reduction, along with no specific legislation and regulations on postharvest losses in Kenya. The overall framework on food losses is provided for in various laws. These include the Constitution of Kenya (2010), the Food, Drugs and Chemical Substances Act (Cap 254), the Crops Act (No. 16 of 2013), the Agriculture and Food Authority Act (No. 13 of 2013 revised 2015), the Meat Control Act (Cap 356), the Fisheries Act (Cap 378), the Dairy Industry Act (Cap 336), and the Standards Act (Cap 496), among others.

In addition, over the years, the Kenyan government has put in place several programs and strategies that have components aimed at addressing the drivers of FLW. Although these are not designed specifically to address postharvest loss reduction, there are initiatives therein aimed at FLW reduction. Examples include the National Agribusiness Strategy 2012, Kenya Youth Agribusiness Strategy 2018–2022, the Ministry of Agriculture, Livestock, and Fisheries Strategic Plan 2013–2017, the National Food and Nutrition Policy 2017–2022, the Agricultural Sector Transformation and Growth Strategy 2019–2029, and the food and nutrition pillar of the Big Four Agenda 2018–2022. All these strategies/programs allude to the importance of postharvest loss reduction through technology adoption, value addition, capacity building, and market access/linkages. The food and nutrition pillar of the Big Four Agenda has a set target to reduce overall postharvest losses from 30 percent in 2018 to 15 percent in 2022 and to increase agro-processing from 16 percent in 2018 to 50 percent in 2022.

These documents reflect the government's acknowledgement that FLW reduction is critical to the goal of attaining food and nutrition security. However, action on and support to FLW reduction initiatives remain limited. It is for this reason that Kenya falls short in the African Union's biennial review on progress toward realization of the 2014 Malabo targets for FLW reduction. For example, in the 2019 review, on the commitment to end hunger by 2025, Kenya scored 4.04 out of 10 against a target of 5.04 . On the commitment to postharvest loss reduction, Kenya scored a paltry 0.02 against a target of 3.00 out of 10. This indicates that Kenya is not on track to halve postharvest losses by 2025. Although this dismal performance is attributed in part to lack of data, it may also reflect a lack of commitment to assigning the resources to address the challenges identified. The national (draft) and continental strategies reveal that existing subsector policies focus more on boosting production and promoting markets, with less emphasis on FLW reduction along food supply chains. The strategies recommend a review of and update to existing FLW reduction policies and the development of policies that directly address FLW reduction.

STRENGTHENING INSTITUTIONAL CAPACITIES FOR FOOD LOSS AND WASTE REDUCTION

National institutions engaged directly or indirectly in FLW reduction activities require adequate capacity to collaborate with county governments, other public institutions, and the private sector in FLW reduction efforts. There is a need to strengthen existing institutional capacities toward effective implementation of FLW reduction interventions at national and county levels. This will require assessment of the existing institutional setting for FLW reduction and then strengthening technical capabilities, interaction and partnerships, reduction information management, and human capital and skills development.

INVESTMENT IN FOOD LOSS AND WASTE REDUCTION RESEARCH, CAPACITY BUILDING, AND EXTENSION

Globally, disproportionately small amounts of agricultural resources have been invested in the preservation of food (5 percent, compared with 95 percent invested in food production). Likewise, little research funding is allocated to postharvest management (Kitinoja et al. 2010). Education also puts more emphasis on production-inclined disciplines. It is noteworthy that most of the research in Kenya on postharvest management, including FLW reduction solutions, is supported by development partners. Therefore, research to find homegrown and context-appropriate solutions to FLW reduction is urgent. To address the knowledge and skills gap in postharvest management, capacity building at all levels is recommended. Very few tertiary institutions in Kenya offer diploma or degree programs in postharvest management (or anything closely related). This means that graduates lack hands-on skills in this domain. Curricula and short courses that target practitioners in food systems would help bridge the knowledge and skills gap among practitioners and extension agents.

In Kenya, access to extension services by farmers has continued on a downward trend over the years as the extension workforce ages and leaves the service. The devolution of agriculture and consequently extension services has aggravated the situation. Strengthening extension capacity is therefore critical to ensure extension agents are well equipped to reach out to farmers (and other practitioners) with the most current knowledge and skills on best practices and technologies for postharvest management.

Examples of food loss and waste reduction efforts that incorporate micro-, meso-, and macro-level solutions

FLW reduction requires multifaceted, multistakeholder, and complementary approaches that are context-appropriate. Such an approach is envisaged to include the application of appropriate technologies and practices, research to find sustainable solutions, education and training of food supply chain actors, and enabling policies. This section highlights two examples of multifaceted strategies that have been tested and proven effective to address FLW among smallholder fruit and vegetable farmers.

The YieldWise initiative

As described above, one approach to FLW reduction entails the smallholder aggregation and processing centers piloted under the YieldWise initiative supported by the Rockefeller Foundation. This has proven effective in addressing FLW among smallholder mango farmers.

The YieldWise initiative recognizes five barriers to addressing FLW reduction:

1. Limited knowledge of food loss and solutions
2. Broken distribution channels for loss-reducing technology
3. Limited capacity of farmers
4. Limited credit/financing
5. Difficulties in efficiently linking supply and demand

FIGURE 17.6 The four intervention areas of the YieldWise initiative

Market demand and linkages

- Linking large anchor buyers' demand for fresh and processed crops to smallholder supply, and local alternative markets to excess crops

Smallholder farmers' training and aggregation

- Aggregation of smallholder farmers into farmer groups to meet the quantity, quality, and consistency requirements of buyers
- Capacity building and other adoption measures to ensure smallholder farmers take up technology and other interventions, including adoption of best practices in the field (preharvest) to ensure high-quality produce

Technology

- Distribution and use of loss-reducing technologies to improve handling, storage, and processing of crops
- Supporting targeted breakthrough innovative technologies in specific value chains (for example, cold storage)

Financing

- Required to facilitate manufacturing, distribution, acquisition, and adoption of technologies, for example, loans and leasing models
- Investment capital to fund the scale-up of promising technologies and innovative distribution models

Source: TechnoServe (2021).

FIGURE 17.7 The Target-Measure-Act approach

Target

Countries/companies should set targets for FLW reduction that are aligned with the SDG 12.3 target of halving FLW by 2030 or the Malabo 2014 target of halving FLW by 2025. The hypothesis is that such targets will create ambition that will motivate action toward FLW reduction.

Measure

Each entity (government/company) should measure its own FLW. This is premised on the assumption that quantifying FLW within borders, operations, or supply chains can help decision-makers better understand how much food is lost/wasted, and where and why food is being lost or wasted. This evidence base provides a solid foundation for targeted and prioritized FLW reduction interventions. It is also key to monitoring progress toward achieving the set targets.

Action

Urgent action toward FLW reduction is needed to deliver results and progress on the set targets. There is no one solution to FLW that fits all, no silver bullet. All actions/interventions should be context-specific, taking into consideration the socioeconomic dynamics for each situation. There is a call to action by all actors in the food supply chain.

Source: Adapted from Flanagan (2019).

To address these barriers, the YieldWise strategy, which has been piloted in mango (Kenya), maize (Tanzania), and tomato and cassava (Nigeria), has focused on four intervention areas (Figure 17.6).

Although the pilot among smallholder mango farmers in Kenya faced some challenges that may have hindered full realization of the intended benefits, this is a promising approach that has been scaled to other commodities.

The Target-Measure-Act approach

The World Resources Institute proposes a multisectoral and multidisciplinary strategy for FLW reduction (Flanagan 2019). The strategy is anchored on three interventions—Target-Measure-Act, as Figure 17.7 shows. The generic model can be customized in the Kenyan context to target prioritized commodity value chains at the national or subnational levels or by individual companies.

Conclusion

The need to address FLW in our food supply chain is urgent, not only to realize food and nutrition security in sustainable food systems but also to ensure that the carbon footprint and negative impacts on the environment are reduced. The food system is complex, with diverse commodities and contexts, and requires solutions that are tailormade to each scenario. There is no single solution to FLW that fits all.

This chapter has used mango as a case study to represent the fruits and vegetables commodity group, which in Kenya and globally reports the highest losses. The causes of FLW in mango at the micro, meso, and macro levels and the corresponding solutions, as highlighted in this chapter, can be contextualized to other fruits and vegetables. Simple solutions, including low-tech postharvest handling practices and technologies for FLW reduction, have been described. These must be considered in context to achieve the intended impact.

Key to FLW reduction efforts is continued research to find homegrown and context-appropriate solutions, as well as capacity building of food supply chain practitioners on proper postharvest management. Similarly, there is a need to strengthen outreach and extension programs to ensure target users adopt research outputs. In addition, better coordination in supply chains in an enabling policy environment is a key ingredient to complement best practices and technologies adopted by individual actors in the supply chain.

Appendix 17.1 Off-grid evaporative cooling solutions

Evaporative cooling is a natural and physical phenomenon that operates on the principle of evaporative heat exchange. When hot air from outside passes over a wetted pad/medium, the water in the wetted pad evaporates as it draws heat from the surrounding air, creating a cooling effect (Lal Basediya, Samuel, and Beera 2013). The evaporative cooling decreases temperatures while increasing humidity inside the storage chambers. The cooler and high humidity conditions preserve the quality and extend the shelf life of perishable horticultural produce. Research has shown that evaporative coolers can achieve a temperature difference of as much as 15°C below ambient temperatures and increased humidity of ≥99 percent (Ambuko et al. 2017; Amwoka et al. 2021). Various evaporative cooling technologies have been tested and proven effective. Examples of these are the evaporative charcoal cooler, the zero energy brick cooler (zero energy cooling chamber), the pot-in-pot cooler, and the hessian sack cooling chamber. The zero energy brick cooler and evaporative charcoal cooler are described below.

Zero energy brick cooler (ZEBC): This is a double-walled structure made of bricks and covered with a moisture absorbing material. In between the double-walled bricks is sand that retains added water and keeps the inside of the ZEBC cool under the principle of evaporative cooling (Ambuko et al. 2016, 2017). As water evaporates from the wetted sand, it takes heat away from the produce and surrounding environment, leading to cooler and humid conditions inside the chamber. According to Roy (2011), the standard size of a ZEBC is 165 cm long, 115 cm wide, and 67.5 cm high, with the space between the doubled brick walls estimated to be 7.7 cm. The original design has some limitations with

FIGURE A17.1 Zero energy brick cooler designs


A. Original design ZEBC with a double brick wall and no reinforcement

B. Improved ZEBC using an improved single wall and cavitied bricks with reinforced steel rods

Source: Authors.

respect to capacity, stability, and longevity. There have been efforts to improve this through adaptive research. The improved ZEBC is larger and reinforced with steel rods to ensure stability of the structure, since the bricks are simply interlocked and not cemented. Figure A17.1 shows two versions of a ZEBC designed and fabricated by biosystems engineers from the University of Nairobi.

The ZEBC can achieve a temperature difference of between 2° and 15°C when compared with the ambient temperature and a relative humidity difference of up to 50 percent relative to the ambient room humidity. The relatively cool temperature and high humidity have been shown to extend the shelf life of mango fruits by 5–10 days in comparison with ambient room conditions (Amwoka et al. 2021).

Evaporative charcoal cooler (ECC): The evaporative charcoal cooler is a larger, walk-in, structure wherein the medium that holds water is charcoal. The charcoal is sandwiched between a double wall, usually made from chicken wire. The cooling efficacy of the ECC is similar to that of the ZEBC (Ambuko et al. 2017). There are various designs, with the choice depending on available resources and the prevailing conditions. Figure A17.2 shows the traditional charcoal cooler and an improved version, designed by biosystems engineers from the University of Nairobi. The improved version has been reinforced with an external fiberglass wall, which makes it stronger and able to withstand hard environmental conditions. The charcoal cooler can extend the shelf life of mango fruit by four days to two weeks depending on the harvest maturity of the fruits and the prevailing weather conditions.

Figure A17.3 presents a comparison of the cooling efficiency of the ZEBC and the EEC relative to ambient air conditions. Figure A17.4 shows differences in relative humidity for the evaporative cooling technologies and ambient air.

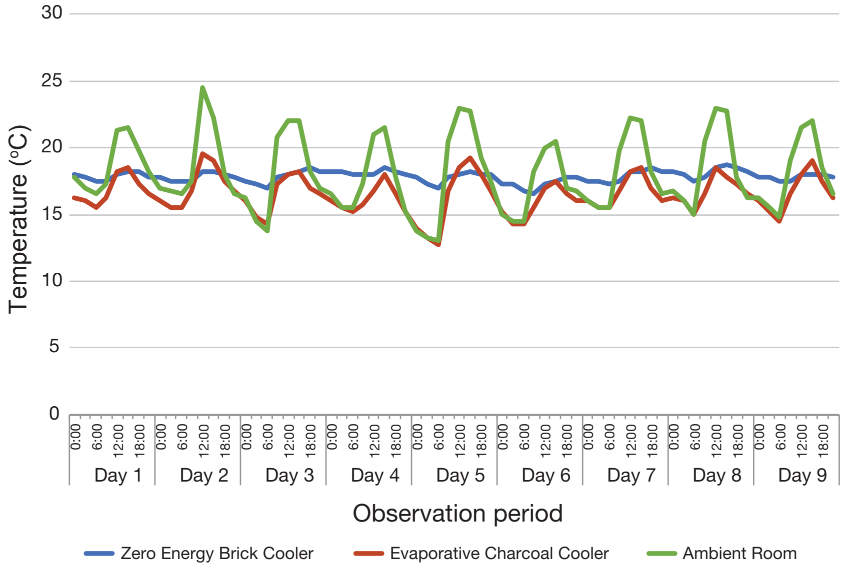
FIGURE A17.2 Evaporative charcoal cooler designs

A. Traditional charcoal cooler with improved and galvanized aluminum frames.

B. Improved evaporative charcoal cooler (right) reinforced with fiberglass walls.

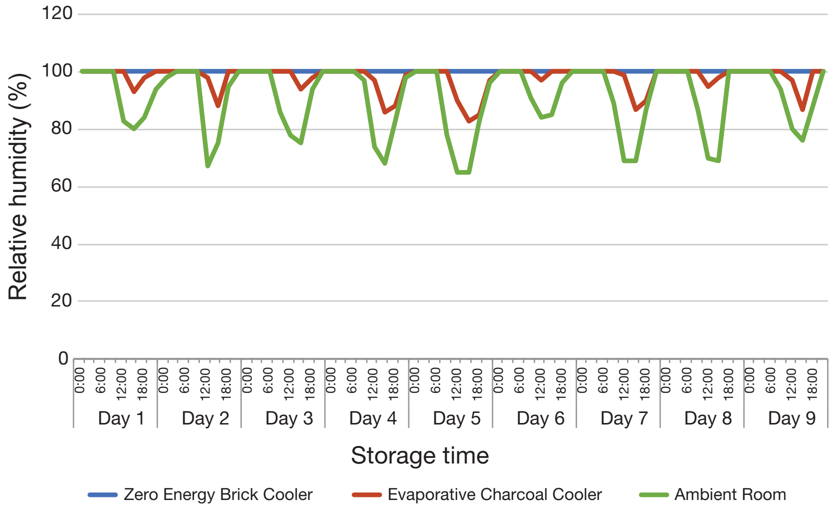
Source: Authors.

FIGURE A17.3 Realtime changes in temperature in a ZEBC, EEC, and ambient room during a nine-day observation period



Source: Ambuko et al. (2018b).

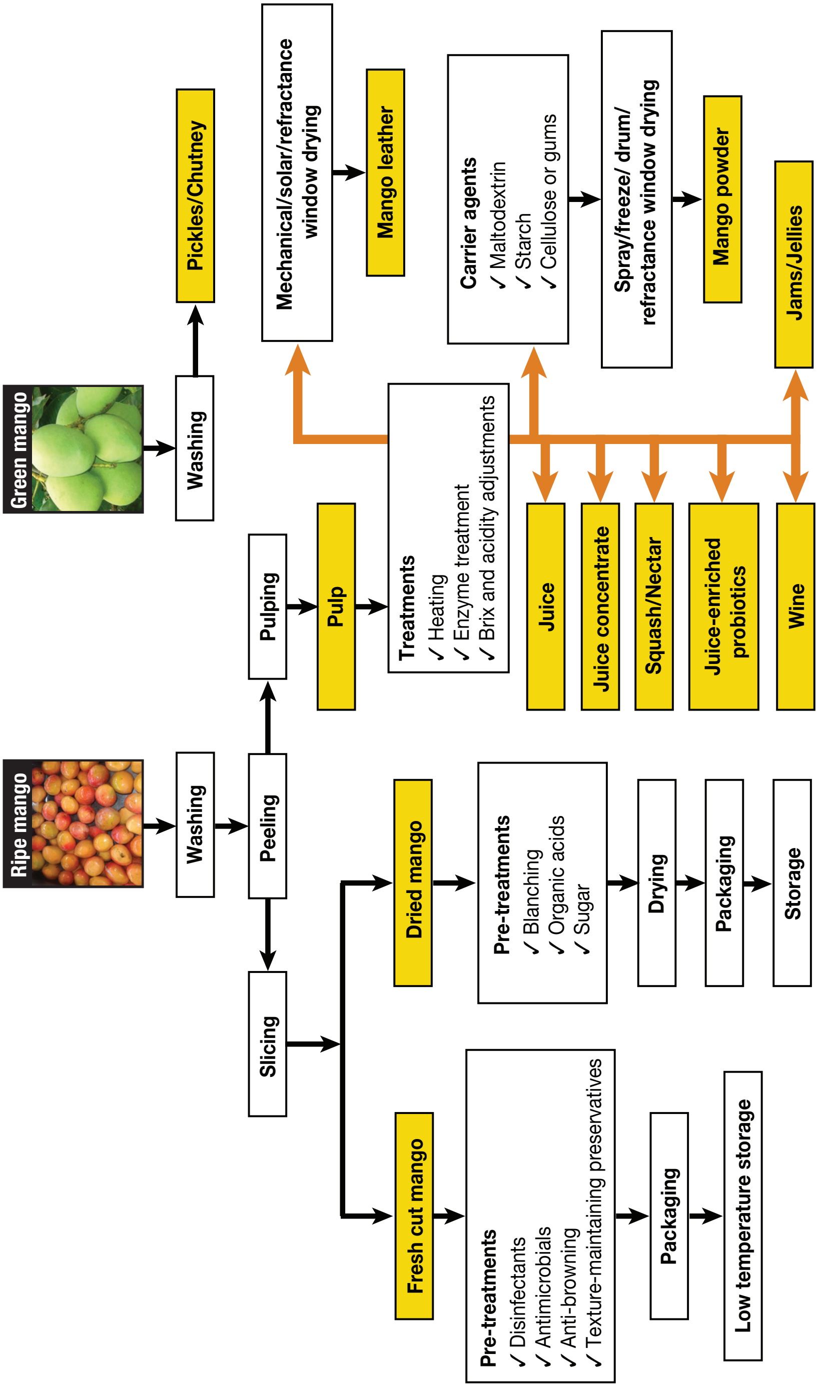
FIGURE A17.4 Realtime changes in relative humidity in a ZEBC, EEC, and ambient room during a nine-day observation period



Source: Ambuko et al. (2018b).

Appendix 17.2 Processing of mango products

FIGURE A17.5 Processing of different products derived from mango



Source: Owino and Ambuko (2021).

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