



Reducing food loss and valorizing fruits and residues to boost avocado industry sustainability and profitability

This brief was prepared by FAO's Responsible Fruits Project with input from the ReValueD project of the University of Passau.

Improve business success by reducing loss and valorizing by-products

Fruits and vegetables are essential for healthy and nutritious diets. However, they are susceptible to food loss and waste¹ due to their high moisture content and perishable nature. Tropical fruits can be particularly sensitive to food loss as they are grown in warm and humid climates, have a short shelf-life and need careful handling pre- and post-harvest. Changing weather conditions brought about by climate change also increases the likelihood of pre- and post-harvest losses. Elevated temperatures and increased humidity contribute to an increase in pests and diseases, can cause uneven flowering and ripening, and affect fruit size and shape, while strong winds, rain and hailstorms damage fruit and its skin. All these factors reduce the supply of fruit that meet the quality demanded by the market. Global value chains that lack the necessary infrastructure and technology to maintain fruit quality, contribute to an increased risk of food loss.

Avocado production, post-harvest handling and processing also generate by-products² from the peel and seed, wood from pruning and food loss that results from non-marketable or damaged fruits. These by-products can be used in the production of pharmaceuticals, fibres and other valuable non-food products, while the non-marketable and damaged fruits that are of edible quality can be upcycled³ to produce food products such as avocado pastes, oils, and others. Despite this, by-products and damaged fruits are often discarded in landfills or burned. These practices lead to the release of methane and CO₂, contributing to

¹ Food loss refers to decrease in quantity or quality of food during production or from harvest up to, but not including the retail stage of the value chain. Food waste refers to the decrease in the quantity or quality of food at the retail, food service provider and consumer stages of the value chain (FAO, 2019). For more information, see FAO's Food loss and waste database: <https://www.fao.org/platform-food-loss-waste/flw-data/en/>

² Organic residues may include materials left in the field/orchard after harvesting and materials left after processing. Non-organic waste such as plastics and hazardous waste from, for example, the use of agrochemicals, is also generated.

³ Upcycling food means converting items that would ordinarily have been wasted into new products or ingredients.

environmental degradation and climate change as well as health hazards for humans. They also negatively impact local biodiversity and contribute to pollution of water and soil.

The avocado industry is taking measures to meet these challenges. By doing so, avocado producers, companies and associations are strengthening their business performance, accessing new economic opportunities, and building the resilience and sustainability of their operations in the following ways:

- *Increased and diversified revenues.* Minimizing pre-harvest loss, while assuring quality maintenance at harvest and post-harvest, increases the quantity and value of produce available for sale and can contribute to the financial prosperity of growers, workers and communities. Creating usable by-products from residues generates additional incomes and fosters the development of other industries (e.g. textiles, food, pharmaceutical).
- *Operational efficiency.* Increasing efficiency in harvesting, handling, transport and storage processes helps to maintain quality, and reduce food losses and production costs.
- *Market access and trust.* Companies dedicated to managing quality and minimizing food loss in a sustainable manner can improve their access to markets with high sustainability requirements and build trust with consumers who value sustainable practices.
- *Resilience.* Efficiently managed value chains that maintain quality and bring losses to minimum levels gain greater resilience against market and weather disruptions, helping to ensure a continuous supply of fruits (FAO, 2023a).
- *Innovation and differentiation.* Commitment to reduction of food loss, the adoption of traceability in the value chain, sustainable packaging practices, and innovative storage and distribution methods, can help differentiate fruit products and facilitate access to markets with stringent sustainability standards and satisfy sophisticated consumers. The perishable nature of tropical fruits has made tropical fruit companies pioneers of post-harvest handling technologies, logistics and by-product processing.

Contributing to global sustainability objectives by reducing fruit losses and harnessing the potential of residues

By addressing social and environmental risks and strengthening resilience, the tropical fruit sector can contribute to achieving the Sustainable Development Goals (SDGs) (FAO, 2023b). In a context of increasing hunger, international conflicts and negative impacts of climate change, reducing food loss and waste has become an important sustainability objective (FAO, 2022; UNEP, 2021). Addressing food loss in the tropical fruit sector in a sustainable manner aligns with the SDGs, in particular **SDG 12** target 12.3 that explicitly calls for reduction of food loss and waste and contributes to the achievement of **SDG 2** (zero hunger), **SDG 13** (climate action), **SDG 14** (life below water), **SDG 15** (life on land) and **SDG 8** (decent work and economic growth).

By minimizing losses and making use of by-products, avocado businesses can contribute to sustainability in many ways including:

- *Increased food security.* Reducing food loss enhances the physical access to, and availability of nutritious fruits and can ensure a reliable supply. Reduction of food loss can stabilize prices without negatively affecting the total value of the sector and thereby making avocados affordable to more people. Decreased loss of valuable tropical fruits, such as avocados, increases the chances of people to access a variety of healthy food options, contributing to healthy diets.

- *Improved livelihoods.* The economic benefits of reducing food loss at source, upcycling non-marketable or damaged fruit through processing, and recycling of by-products can create new livelihoods and employment options for communities and populations in agriculture.
- *Climate change mitigation.* The disposal of non-marketable and damaged fruit and by-products in landfills is an unsustainable practice that contributes to greenhouse gas (GHG) emissions. GHG is generated through production, packaging and transport of fruits even if they do not reach the final consumer. Methane is also generated during decomposition of discarded food and by-products. Taking proactive measures to minimize food losses and to upcycle or recycle fruit that is not fit for sale on the fresh market can help companies to reduce their carbon footprint and contribute to climate change mitigation.
- *Resource efficiency and ecosystem preservation.* Reducing food loss and upcycling non-marketable and damaged fruit through processing as well as the valorization of by-products helps to preserve finite resources like water and soil, reducing strain on ecosystems. Minimizing food loss reduces the need for expanding agricultural frontiers, averting deforestation and biodiversity loss.
- *Health and hygiene.* Initiatives aimed at minimizing food loss and effectively upcycling non-marketable and damaged fruit and by-products play a crucial role in mitigating the risk of contamination from decomposing fruits and by-products. This safeguards local ecosystems and water sources, contributing to the attainment of clean water and sanitation goals, with associated health and hygiene benefits. Reduction of food losses and residues can also minimize the risk of outbreak and spread of airborne or foot-to-mouth pest and diseases.

How can businesses in the avocado sector reduce post-harvest loss?

Pre- and post-harvest losses can be reduced by identifying critical loss points and their underlying causes during production and post-harvest activities, and applying good practice that are under the direct control of producers and businesses to reduce these losses in a sustainable manner. Examples of these actions are provided in the table below.

Table 1. Actions to reduce pre- and post-harvest losses in avocado value chains

Action	Reason for action and observations	Challenges and possible solutions
Initiate cooling as soon as possible after harvest	Precooling is critical to remove the latent field heat in the fruit.	In areas where electricity is expensive or lacking or cooling storage units are unavailable, it can be difficult to ensure a quick cooling after harvest. Low-energy cooling systems and those powered by renewable energy can be considered for short-term storage.
Measure and control exposure to ethylene and other ripening gases	Measuring and controlling exposure to ethylene helps to extend the shelf-life of climacteric fruits, including avocados. Avocados are vulnerable to ethylene hormone and other gases that are released naturally by fruits; gases that influence the beginning and duration of ripening and decay processes. Overexposure to ethylene can cause over-ripening and speed up decay.	Ethylene sensors are increasingly used in tropical fruit chains. Small and precise sensors are expensive but research into the development of affordable ethylene and other gas monitoring sensors is being conducted.

Action	Reason for action and observations	Challenges and possible solutions
<p>Monitor temperature and moisture levels from harvesting to sales</p>	<p>The use of sensors and recording of temperature and moisture levels during precooling, cold-storage and transport help to identify points along the supply chain where improvements can be made to assure maintenance of produce quality.</p> <p>Too high or fluctuating temperature or humidity levels lead to uneven quality, growth of pathogens and decay in fruits. Temperature fluctuations can also lead to the accumulation of condensate on fruits or packaging materials which can support the growth of pathogens, affecting fruit quality and challenging compliance with phytosanitary standards of importing markets. At the same time, lower than optimal storage temperatures can cause chilling injury to fruits. Low humidity can lead to water loss and thereby loss of quality attributes and marketable weight.</p>	<p>Maintaining optimal temperature and humidity conditions across the entire value chain is difficult in poorly integrated value chains, in complex global value chains, and for smaller actors with limited economic capacity to invest in traceability technologies. High costs of sensors, particularly those that measure and record moisture levels, can limit the ability of businesses with low margins to monitor temperature and humidity conditions across the value chain. Hopefully the costs of such sensors will decline over time. Exploring options for cost-sharing of these devices between packers, exporters and importers/distributors may help in overcoming this issue, particularly when the economic benefits of improved quality and reduced losses generate increased margins for both parties.</p>
<p>Maintain and sanitize equipment and facilities</p>	<p>Regular maintenance and cleaning of machinery, packing houses, and storage and transport facilities helps prevent damage to fruits caused by diseases, including fungal infections.</p>	<p>Financial constraints may limit the capacity of small producers and businesses to access and maintain clean and fully functioning facilities and equipment. Exploring options for cost-sharing and pooling of resources can be considered.</p>
<p>Sanitize fruits</p>	<p>Fruits should be sanitized to increase shelf-life and avoid the spread of plant pests and diseases.</p>	<p>There is no single best practice for the sanitation of fruits and there is no consensus as to the most sustainable and effective methods of sanitation. Fruits may be washed in potable water with or without chemicals or treated with hot water as a phytosanitary measure. Washing can, however, remove the natural protective layer of fruits. Other methods to clean fruit surfaces to increase shelf-life include the use of UV irradiation, gaseous ozone or ozonated water, cold plasma treatment, or waxing with edible or inedible compounds to serve as a barrier to fungal and bacterial pathogens. Waxing also reduces moisture loss. Producers and businesses must enquire as to the methods that meet the requirements of their target market.</p>
<p>Automate grading, sorting and packaging</p>	<p>Automation increases the efficiency and reliability of quality grading, sorting and packaging. It also reduces the risk of human error and minimizes fruit damage caused by physical contact with humans.</p> <p>Most avocados are produced to be sold fresh. Higher grade avocados are often selected for export markets while lower grades are used for domestic markets, for the food service sector (where they are used, for example, in guacamole) or for direct processing to guacamole, avocado oil, and others. Inedible fruits are often discarded.</p>	<p>Automation of grading, sorting and packaging require large initial investments. Exploring options for cost-sharing and pooling of resources can be considered. Training people on the sorting line in good handling practices may also have a positive impact on efficiency and reliability.</p>

Action	Reason for action and observations	Challenges and possible solutions
Store different types of fruits separately	When avocados are stored and transported together with other fruits and vegetables, a standardized average temperature and level of humidity is often selected that is less than ideal for each individual produce type. This can increase the risk of post-harvest decay or lead to chill damage. Mixing avocados with fruits that produce large amounts of ethylene also risks leading to over-ripening and accelerate deterioration.	There are financial constraints for transporting in “avocado-only” containers. Exploring options for cost-sharing with other industries and pooling of resources can be considered.
Ensure proper ventilation	Ventilation adjusted specifically to avocados helps to avoid high moisture levels that accelerate the growth of fungi and bacteria or low moisture levels that lead to water loss. Ventilation also helps to avoid the excess of ripening gases in the storage space.	There are financial constraints to invest in adequate ventilation systems. Exploring options for cost-sharing and pooling of resources can be considered.
Use appropriate packaging and develop sustainable packaging materials	Packaging trays, bags and coatings can help to maintain optimal moisture levels. Recently the industry has begun to move away from plastic packaging to sustainable alternatives such as biodegradable bags and nets, and sometimes edible coatings. Moreover, materials designed to absorb ethylene are increasingly used in fruit storage spaces to extend the shelf-life of the fruit.	There are financial constraints to invest in new technologies and the development of new materials.
Market diversification	Producers and traders that rely on one or a few market outlets may risk ending up with oversupplies of fresh avocados, resulting in food losses, in instances of sudden reduction of demand.	Smaller producers and businesses may have limited access to markets. The benefits and constraints of public-private cooperation and public procurement to increase predictability of demand may be considered. Consideration may also be given to diversification through processing.
Research and innovation	Research and development into new varieties, for instance with greater resistant to pests, diseases and heat, and in sustainable technologies and logistics that contributes to durability of fruit can further help to reduce fruit losses.	Small-scale producers and small businesses may not access new technologies and innovations, exacerbating control over value chains among a few large actors. To avoid this, public investment and public-private cooperation, and increased collaboration with private and public research institutions, can encourage research and development that includes and considers the need of smaller industry stakeholders.
Quality standards and protocols	The development of standards and protocols for post-harvest handling can help to ensure the streamlining of post-harvest processes. This can support increasing efficiency of post-harvest operations, maintain produce quality and reduce food loss during packaging, processing and transport stages. It can also contribute to increasing the predictability of fresh fruit quality for retailers and consumers that desire fruits with specific characteristics.	Quality standards in some markets dictate that fruits are uniformly shaped and of a specific size. This can lead to high levels of fruit rejects if production is not carefully managed or if environmental conditions are unfavourable. “Imperfect” fruits may be discarded if alternative markets for these fruits are not available. To avoid waste of these fruits, they can be processed or used in the service sector.

Action	Reason for action and observations	Challenges and possible solutions
Encourage increased consumption of lower grade fruits	Many fruits are discarded based on aesthetic reasons since customers have become accustomed to uniformly shaped fruits without any blemishes. Businesses along the value chain, including retailers, can invest in education and awareness raising of consumers about the benefits of purchasing and consuming “imperfect” fruits and incentivize this behaviour by selling blemished fruits at a lower price.	Inadequate collaboration and communication between producers and retailers hampers the design of communication and educational strategies to sensitize and educate consumers about the consumption of “imperfect” fruits.
Donate surplus food to charity	The donation of surplus fruits to charity organizations can contribute to reducing food losses at source, providing nutritious and healthy options for food insecure people such as the homeless.	Depending on the context, donations can be financially unsustainable for small businesses if by-products are commercialized. Alternative business models may be sought to cover transportation and other costs associated with the donation.

Source: Authors' own elaboration.

How can the avocado sector use by-products and non-marketable and damaged fruit to add value and contribute to sustainability?

Avocados are rich sources of nutrients and phytochemicals. Second grade or discarded fruits can be upcycled for use as food or can be used along with the peel and seed in the pharmaceutical and cosmetic industries (Salazar-López *et al.*, 2021). The waste generated by pruning old avocado trees can be processed to create biofertilizers or used in the construction industry. The table below gives a few non-exhaustive examples of how by-products and non-marketable and damaged organic avocado residues can be used productively. These practices must be considered on a case-by-case basis as commercial viability is context dependent and may not be confirmed in all cases.

Table 2. Products derived from avocado residues (non-exhaustive)

By-product	Observations
Avocado oil	Avocado oil is extracted from ripe and mature avocados. Oil is obtained from the pulp paste by grinding it and malaxing at 45–50 °C for 40–60 minutes. To minimize waste, low-grade fruits considered as such due to their size or other organoleptic properties can be used. However, overripe fruits or fruits with major disorders should be avoided. By using the flesh only, by-products like skin, rotten/overmatured fruit, pulp and seeds are generated.
Starch for the textile industry	Discarded avocado seeds contain starch that can be used as natural and inexpensive textile dye, warp and for other textile applications. Warp is traditionally made from corn starch. The use of avocado seeds can reduce pressure on land that would otherwise produce industrial corn.
Starch in the food industry	The starch from the avocado seed also be used in food products to provide texture and consistency in processed food products.
Biopolymer in bioplastic	Starch extracted from the avocado seed can be used to produce bioplastics. This can be used as a sustainable alternative in packaging, food processing and paper production.
Avocado powder	Peels and seeds can be dehydrated through spray drying technology and transformed into storable commodities. Aside from reducing waste, the practice can extend the shelf-life of high nutritious foods, with high antioxidant properties, such as avocado powders, with different food uses (e.g. food supplements, plant-based milk alternatives, and seasoning).

By-product	Observations
Avocado tree wood chips or shavings	The wood chips and shavings from avocado trees can be used to produce compost, biofertilizers, compacted wood panels, among others. The use of wood derived from avocado tree pruning aims to avoid burning the wood in the open air and reduce greenhouse gas emissions.

Source: See the Reference list on page 9.

Conclusion

Embracing strategies to reduce post-harvest losses and maximize the food use of non-marketable and damaged avocado fruit and residues is a win-win for businesses and global sustainability objectives including food security and climate action. Reduction of food loss increases the volume of marketable produce and reduce strain on natural resources. Valorizing non-marketable and damaged avocados through upcycling to produce food and maximizing the use of residues can help to create higher-value products and support a circular economy. While challenges exist, particularly for small-scale producers, public-private cooperation and pooling of resources through associations and other means can help overcome obstacles. Ultimately, adopting food loss reduction, upcycling of non-marketable and damaged fruit and residue valorization strategies is a smart business move that aligns with global sustainability objectives and enhances a company's or producer's reputation and competitiveness.

Further reading

FAO. Undated. Food Loss and Waste Database <https://www.fao.org/platform-food-loss-waste/flw-data/en/>

ReValueD project of the University of Passau focusing on residue valorization for bio-based products in developing countries <https://www.uni-passau.de/en/bioecon/research>

For more information about the link between climate change and loss and waste see: **FAO.** 2024. *Adapting to climate change in the tropical fruit industry: a technical guide for avocado producers and exporters.* Rome. <https://doi.org/10.4060/cc9309en>

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