Food and Agriculture Organization of the United Nations

Reducing food loss and waste in the processing, distribution and retail operations of micro, small and medium-sized food-processing enterprises

A technical manual

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Foreword

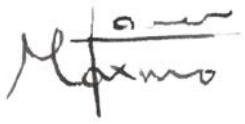
Micro, small and medium-sized enterprises (MSMEs) in the food-processing sector play a critical role in the socioeconomic development of developing countries through their contribution to food security, nutrition and poverty reduction in rural and urban areas, their income-generating activities and their contribution to exports.

How much food is lost in their processing and distribution operations? How can these MSMEs improve the quality and consistency of their outputs and, in the process, reduce food loss in their processing and distribution operations?

This training manual is designed to develop knowledge on how to apply a comprehensive and systematic science-based approach to minimizing food loss in the processing and distribution operations of MSMEs and how to reduce food waste of their processed outputs in retail in a sustainable manner.

The information presented in this manual is drawn from the processing practices of MSMEs in 5 subsectors across 66 of the 77 provinces in Thailand. Relevant case studies are presented and analysed to underpin the systematic approaches and actions that can be taken by MSMEs towards generating and realizing the economic, social and environmental benefits to be derived from reducing food loss and waste in their processing operations and in retail.

It is our hope that this manual will catalyse action in MSMEs to monitor, document and track food loss reduction in their operations; that academia will use this manual as a resource to mainstream food loss and waste reduction in their food science curricula; and that governments will support and incentivize the scale-up of food loss reduction in MSMEs in order to reduce their national food loss indices.



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This manual was elaborated from a very practical viewpoint, presenting learning that has been distilled from the direct experiences of MSMEs in Thailand.

FAO wishes to convey sincere thanks and appreciation to the Ministry of Agriculture, Fisheries and Forestry of Japan and to the Royal Thai Government for their high level of engagement in, and support to, the implementation of this project; and to Mahidol University for their outstanding technical collaboration in designing and implementing activities under the unprecedented conditions of the COVID-19 pandemic.

Sincere thanks and appreciation are extended to the many MSMEs in Thailand whose experiences are reflected in the learning distilled and documented in this manual.

It is hoped that the use of this manual will enhance the capacity of MSMEs to generate triple wins – economic, social and environmental benefits – by making simple strategic changes to reduce food loss in their operations towards impacting the communities in which they operate; that academia will use this manual as a resource for mainstreaming food loss and waste reduction in their food science curricula; and that governments will incentivize the scale-up of actions to reduce food loss in MSMEs.

Spillage of rice grains during the milling process can result in avoidable food loss

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Abbreviations

FAO	Food and Agriculture Organization of the United Nations
FLW	food loss and waste
MSME	micro, small and medium-sized enterprise
SDG	Sustainable Development Goal

THB	baht
USD	United States dollar
Conversion rate (December 2023):	THB 1 equivalent to USD 0.028

INTRODUCTION

Purpose of this manual

Food processing is critical to preserving food, enhancing its shelf-life and ensuring its year-round availability. Food processing contributes to improved nutrition and to enhanced dietary quality, while processing operations ensure that the nutritional quality of food is maintained. The food-processing sector also generates income and creates livelihoods, particularly for the large number of individuals working in micro, small and medium-sized food processing enterprises (MSMEs) in developing countries across the globe.

However, significant quantities of food are lost during processing and distribution, and smaller quantities are wasted in retail due to spoilage. The occurrence of food loss during processing and distribution operations of MSMEs and food waste in retail can negatively affect the profitability of businesses and, in extreme cases, adversely impact their public image and reputation.

Reducing food loss and waste (FLW) is an important concern for all stakeholders across the food value chain, from producers (those involved in harvesting, handling, distribution, processing and retail) to consumers. There is an urgent need to raise awareness and, more importantly, to build the technical capacities of MSMEs in the agrifood sector so that they can attend to the issues and take action to reduce food loss in their processing and distribution operations and reduce food waste of their outputs in retail.

This manual is designed as an easy-to-use, informational and instructional resource on how to measure and reduce food loss at the MSME level and to reduce food waste in retail. It presents salient information on:

- identifying food loss hot spots and their underlying causes during the processing and distribution operations of MSMEs;
- measuring the levels of loss at each hot spot;
- introducing simple innovations that are technically, economically and socially appropriate, as well as good practices to reduce food loss in processing operations and particularly at hot spots; and
- measuring food waste in retail and identifying actions that can measurably reduce the levels of food waste.

The content of this manual draws on the results of a government cooperation project, “Capacity Building to Reduce Avoidable Food Waste in Micro-, Small and Medium Food Processing Enterprises

and in Retail (GCP/GLO/809/JPN)", which built an evidence base by conducting field-level actions in five food-processing subsectors in Thailand: animal products, fishery, snack food, rice and dairy processing.

This manual is addressed to MSMEs operating in developing countries. It is designed to support actions to minimize food loss during processing and distribution at these enterprises and to reduce food waste of their processed products in retail by improving technical know-how.

What you will find in this manual

The manual was developed through a process that involved the conduct of qualitative surveys in 195 MSMEs in 66 out of 77 provinces across Thailand. This served to build an evidence base to inform the implementation of actions to reduce FLW in MSMEs across the country.

An analysis of the qualitative data obtained informed the selection of a group of 25 representative MSMEs (ones that exhibited common problems) to be further trained to measure and reduce food loss in processing and distribution operations and to reduce food waste in retail. These MSMEs operated in five key subsectors: animal products, fishery, snack food, rice and dairy processing.

Information is provided on how to measure food loss, identify critical loss points and their underlying causes, and the actions required during processing and distribution operations to reduce the levels of loss. The manual describes examples of the introduction of simple innovations and good practice to measurably reduce food loss in processing and distribution operations and food waste of their outputs in retail. Methodologies for calculating loss reduction are included in the Annex.

The retail sector is a hot spot for food waste. This manual identifies the underlying causes of food waste in retail as well as the actions required to reduce food waste in this sector.

The manual presents a broad overview of the context of MSMEs and the basics of FLW in five modules:.

- **Module 1** provides an overview of FLW in food-processing, food distribution and retail.
- **Module 2** focuses on how to conduct a qualitative survey to identify the causes of food loss in the processing and distribution operations of MSMEs, and how to analyse the results of the survey to design strategic actions to measurably reduce food loss during processing and distribution, and food waste in retail.
- **Module 3** focuses on how to pinpoint the critical loss points.
- **Module 4** focuses on measuring and reducing food loss during processing and distribution operations of MSMEs.
- **Module 5** presents examples of field-level case studies of good practice in pinpointing the critical loss points by measuring and reducing food loss during processing and distribution, and in assessing the economic benefit derived from the actions taken.

How to use this manual

This manual is intended for use as a training resource for MSMEs to customize their operations and establish specific guidelines and processes to reduce food loss in their processing and distribution operations and to minimize food waste in retail. The manual can be used to train employees and staff to identify, measure, monitor and reduce FLW. The manual also serves as a useful resource for academic institutions.

Micro, small and medium-sized food-processing enterprises

Micro, small and medium-sized enterprises (MSMEs) play an important role in food processing in countries at different stages of development. Across the developing world, these enterprises are engaged in the processing of low-cost, culturally accepted food products that contribute significantly to food security, income and employment and often account for most of the business in the local food-processing sector.

Strong, dynamic and efficient MSMEs are therefore critical to ensuring sustainable, inclusive and broad-based economic and social development in developing countries.

Characterization of the enterprises

Traditionally, MSMEs have been characterized according to their scale of operation, location (rural versus urban), level of organization (formal versus informal), level of technology (appropriate, intermediate or high) and the level of value added. Current trends in many developing regions highlight an emerging scenario in which MSMEs may be better categorized as either modern or traditional according to their target markets (see Table 1).

This manual focuses on reducing food loss in the operations of traditional MSMEs, with a few examples of modern MSMEs. The processing operations of most MSMEs embrace the principles of sustainability by making use of renewable energy sources and applying circularity in their operations.

The packaging and weighing station for rice, prior to vacuum sealing

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Table 1. Characteristics of modern and traditional micro, small and medium-sized food-processing enterprises

Modern	Traditional
Market-oriented (supply supermarkets, institutions, etc.)	Produce mainly to meet the food security needs of mass markets
Invest in product, processing and packaging innovation	Limited capacity to invest in upgrading processing operations
Conform to food safety and quality standards	Often do not conform to safety and quality standards, particularly for high-risk (high-moisture and low-acid) food

Sources: **FAO**. 2015. *Policy measures for micro, small and medium food processing enterprises in the Asian region.* Rome. https://openknowledge.fao.org/handle/20.500.14283/i4299e; **Rolle, R.S.** 2024. Chapter 22: Reducing food loss and waste in food systems. In: *Food Security Issues in Asia.* World Scientific Publishing, Singapore. https://doi.org/10.1142/9789811278297_0022

Sorting to remove defective or discoloured rice grains that constitute a qualitative and quantitative food loss

Understanding food loss and waste

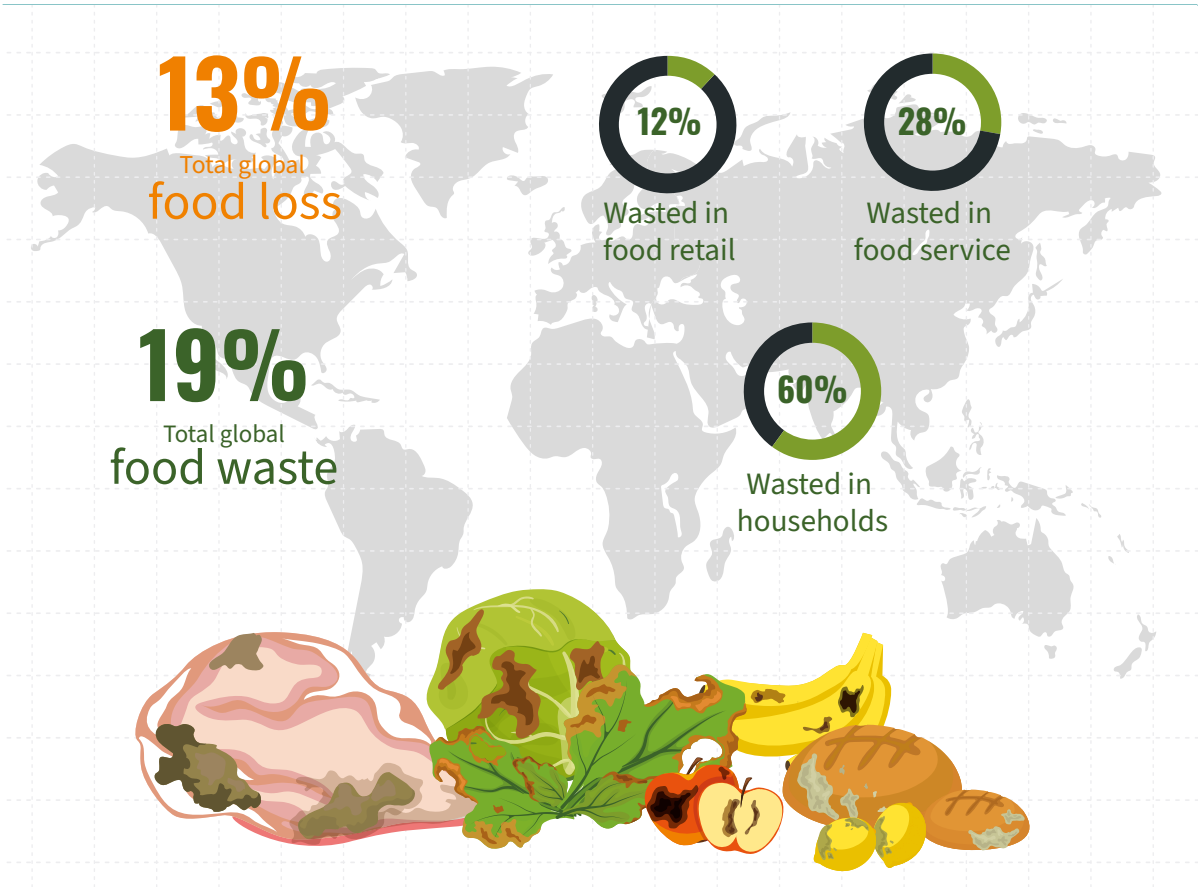
An estimated 13 percent of food produced globally is lost in the supply chain from post-harvest up to, but not including, the retail stage of the food supply chain (FAO, 2022). Food loss takes place in the processing and distribution operations of MSMEs, that is, when food inputs are transformed during processing (cooking, drying, frying and fermentation) to improve taste, texture, shelf-life and maintain quality, and are packaged (to protect and contain the product, assuring its quality and shelf-life) and transported to markets and supermarkets (see Figure 1).

A further 19 percent of food is wasted (UNEP, 2024) when food is sold in stores and supermarkets, where it may undergo spoilage; when consumers eat away from home and leave large quantities of uneaten food on their plates; and when consumers discard leftovers of prepared meals at home or allow food to spoil in the refrigerator or in the storage cupboard as a result of poor planning, overbuying or negligence. Food loss and waste are a global issue. Food loss, however, predominates in developing regions (see Figure 2).

The production, processing and distribution of food require natural, financial and human resources. The economic costs associated with food loss during processing and distribution can, accordingly, impact producers, businesses and society.

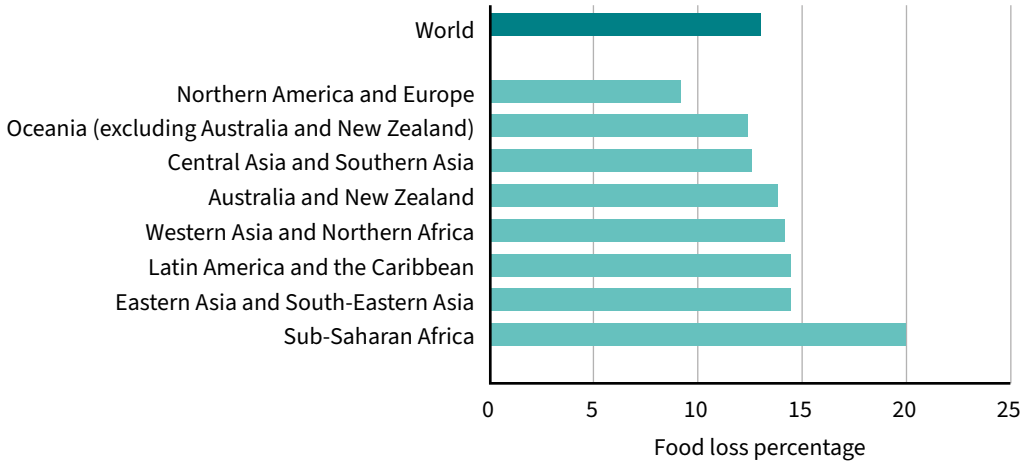
Air drying of scaled and degutted fish

Figure 1. **Global food loss and waste**



Sources: **FAO** (Food and Agriculture Organization of the United Nations). 2023. *SDG Indicators Data Portal.* Rome. [Accessed on 8 June 2023]. https://www.fao.org/sustainable-development-goals-data-portal/en; **UNEP (United Nations Environment Programme)**. 2024. *Food Waste Index Report 2024. Think Eat Save –Tracking Progress to Halve Global Food Waste.* https://wedocs.unep.org/20.500.11822/45230

Figure 2. Global and regional estimates of food loss percentages



Source: **FAO**. 2023. *SDG Indicators Data Portal.* Rome. [Accessed on 8 June 2023]. https://www.fao.org/sustainable-development-goals-data-portal/en

Box 1. Food-processing operations

When engaged in processing operations, MSMEs pay little attention to reducing food loss because they are unaware of its occurrence and the associated loss of income. For the few who may be aware of this problem, their limited technical knowledge about how to identify where the loss occurs and its underlying causes significantly constrains their ability to properly address the issues.

In developing countries, where MSMEs supply most of the food consumed in local markets, there is a general impression that business solutions and innovations require costly investment and technology, so these enterprises are reluctant to adopt new practices. It is important to understand what comprises FLW and the underlying causes of where and why it occurs during food processing and distribution.

It is also essential to understand the factors that contribute to the occurrence of food waste in retail.

This understanding will lead to the identification of concrete actions and solutions to reduce food loss during processing and food waste in retail.

Source: Authors' own elaboration.

MODULE 1.

FOOD LOSS AND WASTE: A BUSINESS CONCERN

Food loss and waste take place along the food supply chain. Food loss takes place during the processing and distribution operations of MSMEs, while food waste is prevalent in retail.

Tackling food loss requires an understanding of where it occurs in the processing and distribution operations, how much is lost, the factors in processing and distribution operations that cause this loss, and the solutions that can be adopted by MSMEs to reduce the levels of loss.

Retail, on the other hand, is a hot spot for food waste. As with food loss, it is useful to identify how much food is wasted in retail, the underlying cause of the food waste, and the actions and context-appropriate solutions that may be applied to minimize food waste.

This module aims to introduce the problem of FLW in agrifood MSMEs and to highlight why these are critical business concerns that must be addressed.

Learning objective

By the end of this module, the trainee should be able to:

- define FLW; and
- explain the benefits of reducing FLW during the operations of MSMEs and in retail.

1.1 What is food loss?

Food loss is defined as the decrease in the quantity or quality of food because of decisions and actions made by food suppliers, excluding retailers, food service providers and consumers (FAO, 2019). Food loss takes place in the supply chain from post-harvest up to, but not including, retail (see Figure 3). In short, food loss across the food supply chain represents food that is discarded because it was damaged at or after harvest, during transport to the MSME, and during the processing, packaging and distribution of the food prior to its arrival in retail. Within the context of food-processing MSMEs, the focus is on food that is lost in processing, packaging and distribution operations.

The leader of a rice processor group showcasing packaged rice produced by the group

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Figure 3. **Food loss and waste in the supply chain**

Source: Authors' own elaboration.

Unavoidable food loss from bananas

Characterizing food loss

Food loss that occurs in food-processing operations may be either avoidable or unavoidable, depending on whether it is edible for a particular group or local context. For example, modern cultures consider fruit peelings to be inedible and discard them during food preparation. In some contexts, however, they are processed into food products such as local candies or pickles.

Unavoidable food loss refers to the inedible parts of food that are discarded during processing. These include parts of the raw material such as eggshells, bones, seeds, fruit stems and peelings, fish offal and rice hulls. These are unavoidable because they are "expected" and are inevitable as part of the process of preparing the product.

Avoidable food loss results from a range of controllable factors that, if addressed, can be minimized or avoided. Examples include:

- Broken rice grains that occur during milling operations. Properly adjusting the milling equipment and drying the paddy to an appropriate final moisture content can minimize or avoid this loss.
- Rice that is spilled during processing or when it is transported from the processor to retail stores. This is an avoidable food loss and occurs because of poor-quality packaging or handling of the packaged product. This loss can be avoided by properly sealing the packaged product and the use of good secondary packaging (reusable plastic crates) for distribution.
- The use of oversized processing equipment to process small batches of product. This can result in large quantities of the product being left behind in the processing equipment, which can constitute a significant level of avoidable food loss, depending on the batch size processed.
- Excessive peeling or trimming of edible portions of food during processing. This can be the result of human error, negligence or carelessness such as when workers do not pay attention to the processes of preparing the raw material. During the processing of banana chips, for example, substantial food loss can occur if the bananas are not uniformly cut.

Avoidable food loss may be characterized as being either qualitative or quantitative.

Qualitative food loss refers to a decrease in the attributes or physical characteristics of food such as appearance, taste and texture, which in turn reduces its value in terms of its intended use (FAO, 2019):

- Changes in the appearance or colour of a food product: For example, burnt banana chips make them less appealing to many consumers, causing them to be either unsellable or sellable at a reduced price.
- Mouldy rice that results from inadequate drying of the rice paddy, which causes the product to be unsafe and unfit for sale or for human consumption. The rice must therefore be discarded owing to food safety risks that could result from mould contamination. The images below show qualitative loss in processed food products.

Deformed meatballs are sold at a reduced price

Dark, oily banana chips are sold at a reduced price

Banana chips of optimal quality

Quantitative food loss results from a decrease in the mass of the food product meant for consumption.

- This loss typically results from poor quality of the inputs, inadequate process control and the use of inefficient or oversized equipment that can lead to large quantities of residual product remaining inside.
- Inadequate or improper packaging and handling of the packaged product during distribution can also result in quantitative food loss from product spillage.
- Milk spillage during packaging is a good example of the occurrence of quantitative loss, as it leads to a decrease in the overall product quantity (volume).

Qualitative and quantitative food loss can be avoided if the controllable factors that cause them are addressed or given careful attention, good practices are implemented, and simple tools are used to manage and mitigate their occurrence. Taking systematic action to reduce this food loss typically results in product outputs of improved quality that can generate increased savings or profits and wider market opportunities for the products.

Weighing raw fish for processing

The challenge of monitoring and measuring food loss

- **Lack of awareness of the occurrence of food loss in processing and distribution operations.** Many MSMEs are unaware that they are losing substantial quantities of food during processing. Their main focus is either on delivering the processed product on time or hurriedly processing the highly perishable raw materials. Little attention is given to the careful examination of process control or product loss during processing and distribution.
- **Limited availability of labour in MSMEs.** In MSMEs, and especially in household enterprises, labour is often limited, and as few as two or three people are engaged in processing and distribution operations. Micro, small and medium-sized enterprises of this type perceive tracking and monitoring of food loss as an additional task that entails the need for scarce labour and additional resources.

- **Absence of clear procedures for monitoring food loss.** Micro, small and medium-sized enterprises (MSMEs) may not regularly measure, record or track food losses during processing and distribution. Even when MSMEs are aware of the occurrence of quantitative loss and that product quality has declined during processing, the limited technical know-how for measuring or tracking this loss and, more importantly, addressing it can result in minimal attention and priority being given to these issues.

1.2 What is food waste?

A shopping cart containing both packaging and food waste in a supermarket

Food waste refers to the decrease in the quantity or quality of food because of the decisions and actions of retailers, food service providers and consumers (FAO, 2019).

Food retail follows distribution and is the stage when food products are on store shelves for sale or have been delivered to customers for consumption. Food retail is a hot spot or a critical point for avoidable food waste:

- Packs of banana chips containing large quantities of broken pieces are unappealing to consumers. They are often left unsold on retail shelves and must be discarded.
- Improperly sealed packaged products such as biscuits, chips and other snack foods lose their freshness, crispiness and consumer appeal and are often sold at a reduced price or subsequently disposed of in landfills.
- Mouldy bread must be discarded.

Quantitative food waste results from the spoilage of products in retail owing to improper/inadequate environmental conditions such as storage temperature and relative humidity during storage.

Lack of, or inadequate, cool storage of perishable food products such as fish and yoghurt shortens their shelf-life and results in retail food waste that ends up in landfills. Retail food waste can be the result of overproduction because of poor forecasting of market requirements, which results in product spoilage. Products that show signs of spoilage must be removed from the store shelves and discarded, constituting a quantitative and economic loss.

1.3 What factors contribute to food loss during processing and distribution?

Much of the avoidable qualitative and quantitative food loss that takes place during processing and distribution operations of MSMEs results from poor managerial factors that pertain to decisions and actions of the food processors and staff who are responsible for quality control of the raw material procured for processing and scheduling, in addition to technical issues that include process control, product spillage, improper packaging practice and the scale of equipment versus the scale of operations.

Factors that contribute to food loss

Managerial

- **Inadequate planning and forecasting of processing operations.** Errors in forecasting the demand for products processed by MSMEs can result in the overproduction of items that cannot be sold in the markets available to MSMEs, resulting in spoilage. Lack of quality criteria for the procurement of raw material inputs for processing also poses a problem.

Technical

- **Poor quality of the raw material input** is a major concern for the processing operations of MSMEs. Quality inputs are critical to producing quality outputs that are affordable and appealing to consumers.
- **Inadequate process control.** This includes poor management of temperature and time during processing; inadequate management of the moisture content during drying operations or the level of acidity (pH) during fermentation, which results in products of variable quality (qualitative loss). Poor management of these processing parameters can compromise product safety and make it necessary to discard the product (quantitative loss).
- **Product spillage during processing** can result in quantitative loss and is a common occurrence during processing in MSMEs. Spillage is frequent when grain is processed. The spillage of liquid products such as milk and juices during packaging can also result in significant quantitative loss.
- **Processing equipment that is of an inappropriate scale** can result in significant levels of quantitative loss because of the entrapment of significant quantities of residual product within the processing equipment when small batches are processed using large equipment. When operated below full capacity, processing equipment is less efficient in terms of functionality and energy cost, which can contribute to economic loss owing to these increased costs.
- **Improper packaging practices such as inadequate sealing** of packaged products can result in product spillage or degradation owing to moisture absorption (qualitative loss). The product

may become mouldy or lose its crisp texture or flavour attributes by developing a rancid taste due to oxidation, resulting in qualitative loss that eventually leads to quantitative loss when the product is discarded.

- **Poor distribution practice.** Poor handling during distribution can result in damage of the packaged product, spillage and premature spoilage of the product in retail. Products such as banana chips and rice crackers may break into pieces (qualitative loss) if they are not properly packaged or transported in sturdy secondary packaging such as reusable plastic crates or boxes with proper cushioning to minimize damage from physical impact.
- **Poor maintenance of processing tools and equipment** can lead to faulty processing equipment and tools such as mixers and weighing scales, which can cause food spillage during processing and result in quantitative food loss. Faulty machines are also less likely to record accurate measurements of product quantity or weight, which can impact steps during processing and result in errors in product formulation.

See Figure 4 for points where food loss can take place and the possible causes.

Improper sealing of packaged rice (left), can result in spillage during distribution

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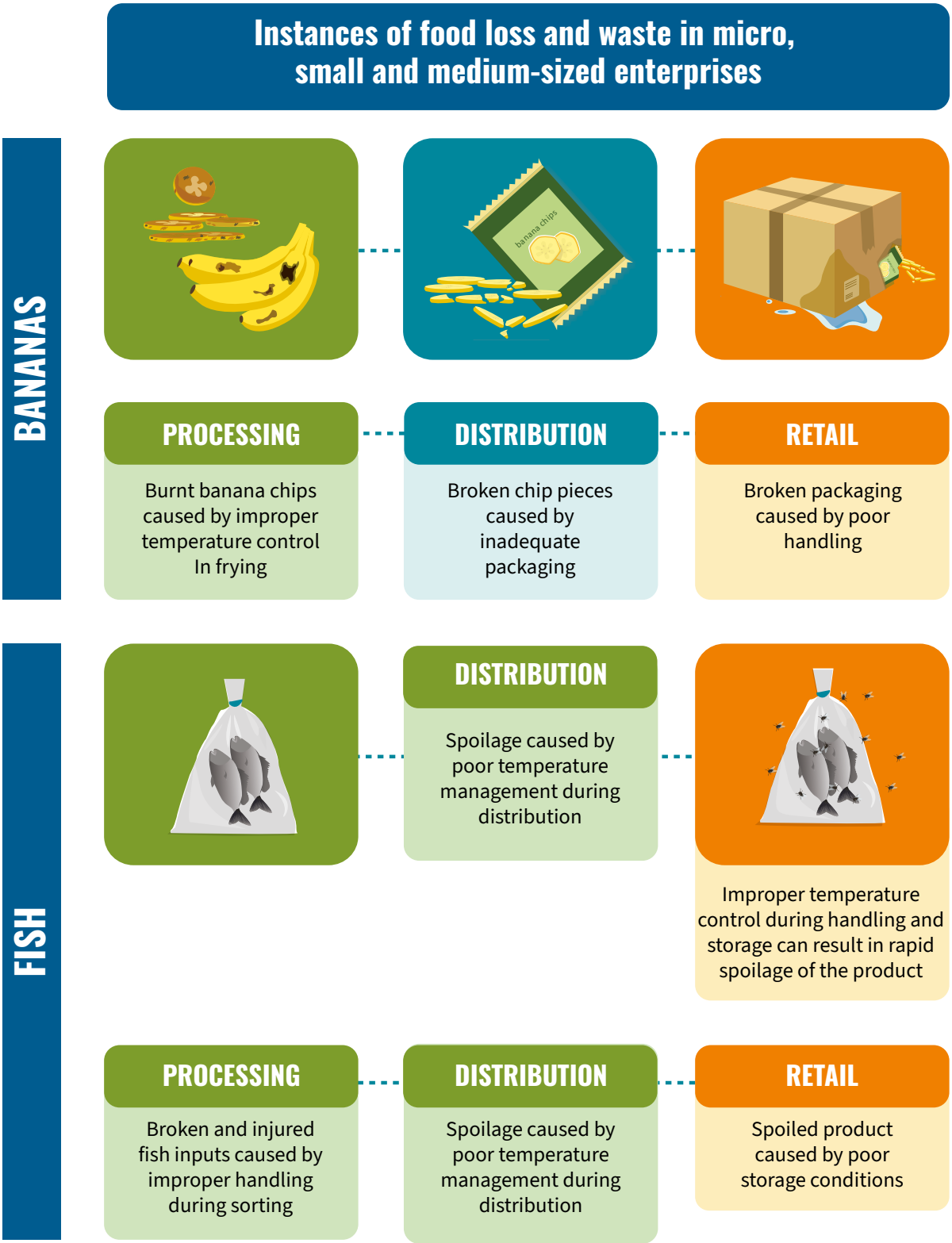
Figure 4. **Causes of food loss and waste in the processing and distribution of bananas and fish in MSMEs**



Source: Authors' own elaboration.

1.4 What factors contribute to food waste in retail?

Factors that lead to food waste

Managerial

- **Inefficient stock management.** Micro, small and medium-sized enterprises (MSMEs) may not have the proper systems in place to manage their product inventory. This can lead to errors in forecasting customer demand. Overstocking of product in retail can result in waste because of spoilage. Typically, products that are close to their best before dates with the packaging intact are prominently situated within reach of the consumer (e.g. in the front display of the business or on the first row of shelves) to accelerate the pace of sales of these products. They are generally safe to consume, but their texture may not be the best (e.g. chips may have lost their crisp texture).
- Failure to apply first in, first out principles, and ensure that products reach store shelves in advance of their use-by dates and are stored under appropriate temperature conditions, results in food waste. Foods should not be eaten after the use-by date and must not be sold after this date because they may pose a health or safety risk to consumers.

Figure 5. **Use-by date printed on the product**

Source: Authors' own elaboration.

Technical

- **Packaging damage**. Product spoilage in retail is often the result of damaged packaging, which results in exposure of the product to oxygen, moisture and contamination, compromising product quality and safety. Crackers and chips may be excessively broken, lose their crisp texture or assume a rancid flavour because of oxidative deterioration and humid conditions when on store shelves, rendering them unappealing to consumers.

- **Conditions of storage**. Perishable products such as fermented fish and yoghurt that are kept under inappropriate temperature conditions in retail can undergo rapid microbiological deterioration well ahead of their use-by date, rendering them unsafe and unsuitable for consumption. They must be discarded, resulting in food waste.
- **Improper or inadequate packaging of food products** can compound the effects of inadequate storage conditions for all categories of processed foods.
- **The absence of labelling** and storage instructions and information on packaged foods is a critical issue that must be addressed by MSMEs.

1.5 The economic, social and environmental impacts of food loss and waste

- **Economic impacts.** The occurrence of food loss during the processing and distribution operations of MSMEs represents considerable economic costs in terms of the labour, energy and inputs, which include the cost of raw materials, ingredients, water, electricity and packaging. Spoilage of food products in retail represents an economic loss for retailers and, depending on the retailing arrangements with the MSME, can involve a loss for them.
- **Social impacts**. Food loss and waste reduce the availability of food for consumption and increase the market price of food commodities, in turn negatively impacting the affordability of food for consumers and thus affecting the quality of their diets and their food security. In turn, reduced economic access of consumers to food means reduced consumer demand for the product outputs of MSMEs and reduced business opportunities in their local markets.
- **Environmental impacts**. Food-processing operations in MSMEs generate by-products or unavoidable food loss such as offal, bones, peels and husks. When these by-products are discarded in landfills, they rot and produce greenhouse gas emissions that contribute to climate change. Climate change contributes to global warming, drought and flooding, which can negatively impact food production and storage and minimize access to and availability of food supplies. Therefore, MSMEs must seek to maximize the use of food in their processing operations and divert the by-products of food processing from landfills by applying circular practices in their operations (see Section 1.7).

1.6 The triple wins derived from reducing food loss and waste

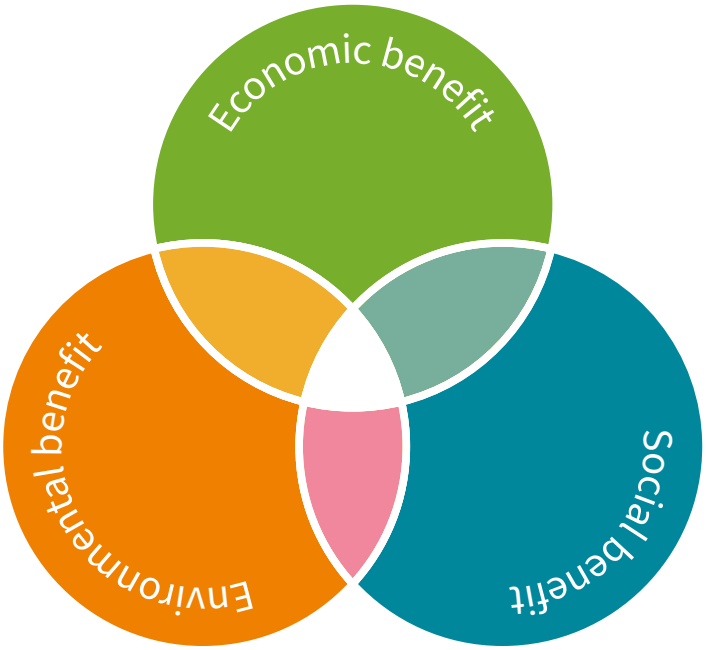
- **Economic benefit.** A direct benefit of reducing FLW for MSMEs is increased profitability. This benefit can be maximized through improved planning of their processing operations to avoid overproduction, in addition to improved process control and packaging to enhance processing efficiency and improve the quality and shelf-life of their processed outputs.

- **Social benefit.** By improving the efficiency of their processing operations, reducing FLW and improving the quality of their processed outputs, MSMEs can increase access to and availability of locally produced and culturally accepted food products in local markets, contributing to the food security and nutrition of many.
- **Environmental benefit.** Micro, small and medium-sized enterprises (MSMEs) can reduce the impact of their operations on the natural resource base by optimizing the use of water and energy through cost-efficient practices and by properly managing the by-product streams of their processing and distribution operations, keeping them out of landfills to reduce greenhouse gas emissions. These practices support the promotion of a circular economy (Section 1.7), which can generate positive environmental impacts.

By generating economic, social and environmental impacts, MSMEs enhance the sustainability of their operations (see Figure 6).

Solar drying of rice is a low-energy, environmentally friendly process

Figure 6. **Benefits to be derived from reducing food loss and waste**



Source: Authors' own elaboration.

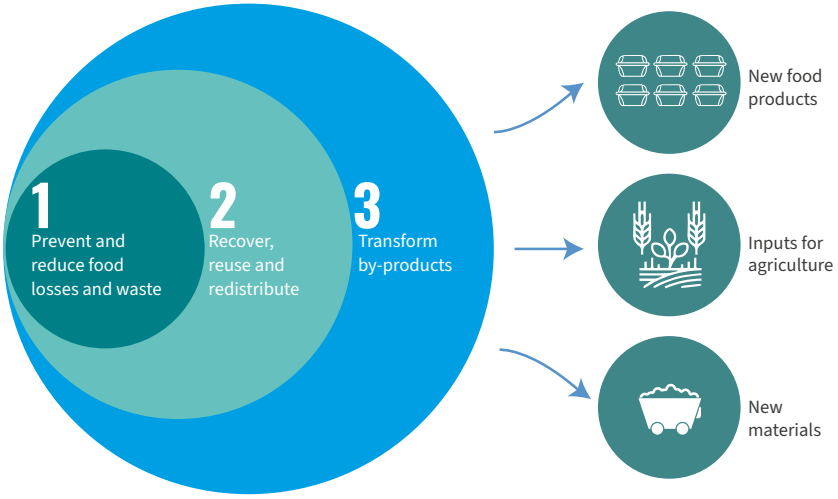
1.7 Towards a circular system that benefits people and the planet

The circular economy is a model of production and consumption that prevents FLW through proper handling, processing, packaging and storage. This is followed by the rescue, recovery and redistribution of surplus or unsold or unmarketable food that is safe and suitable for consumption, and then the upcycling or recycling of food through circular strategies.

Upcycling means finding new, higher-value uses for items that would otherwise not have been used for human consumption, resulting in positive environmental impacts.

Recycling of food allows for the composting of food waste and scraps for use as fertilizer. Proper disposal is the last option (see Figure 7 and Table 2).

Figure 7. Applying circular practices to keep food loss and waste out of landfills



Source: Adapted from **Ellen McArthur Foundation**. n.d. Circular Economy. In: *Ellen Macarthur Foundation*. Isle of Wight, UK. [Cited 8 June 2023]. https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Table 2. Upcycling and recycling options

	Upcycling	Recycling and composting
When to use	To produce a new food product from by-product streams.	To turn by-products and unavoidable FLW into organic fertilizer.
What to use	Parts of a raw material such as unavoidable food loss, including offal to produce new edible products such as fish pastes.	Food scraps, by-products and unavoidable FLW consisting of eggshells, spent coffee grounds, fruit and vegetable peelings and product spills.
Benefits	Unavoidable FLW does not go to landfills. New products are produced and increased income streams are generated by MSMEs.	By-products and unavoidable FLW are diverted away from landfill; nutrients are introduced into the soil.
Applicability for MSMEs in developing countries	In many developing countries MSMEs are already engaged in the application of these processes, particularly for high-value products such as meat and fish.	Small and large food enterprises and manufacturers with access to land or an area for composting.

Source: Authors' own elaboration.

1.8 The contribution of food loss and waste reduction to the Sustainable Development Goals

Reducing FLW is enshrined in Sustainable Development Goal (SDG) 12, Target 3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (see Figure 8). Reducing FLW is not a goal in and of itself, but it provides a means to achieving other objectives.

Reducing FLW in MSMEs increases the availability of and access to nutritious food and improves smallholder incomes and livelihoods, contributing to their food security (SDG 2). Improvements in efficiency within the processing operations of MSMEs and improved product quality create considerable prospects for MSMEs to generate economic benefits (SDG 8). By applying the circular economy to maximize the use of food in a sustainable manner, keeping by-products of food processing out of landfills, greenhouse gas emissions associated with food-processing operations are reduced, generating climate benefits (SDG 13) and minimizing impacts on biodiversity.

By optimizing the use of resources such as water and energy, and enriching soils through the composting of by-products, reducing FLW in processing and distribution can also generate beneficial impacts on natural resources (SDG 14 and SDG 15).

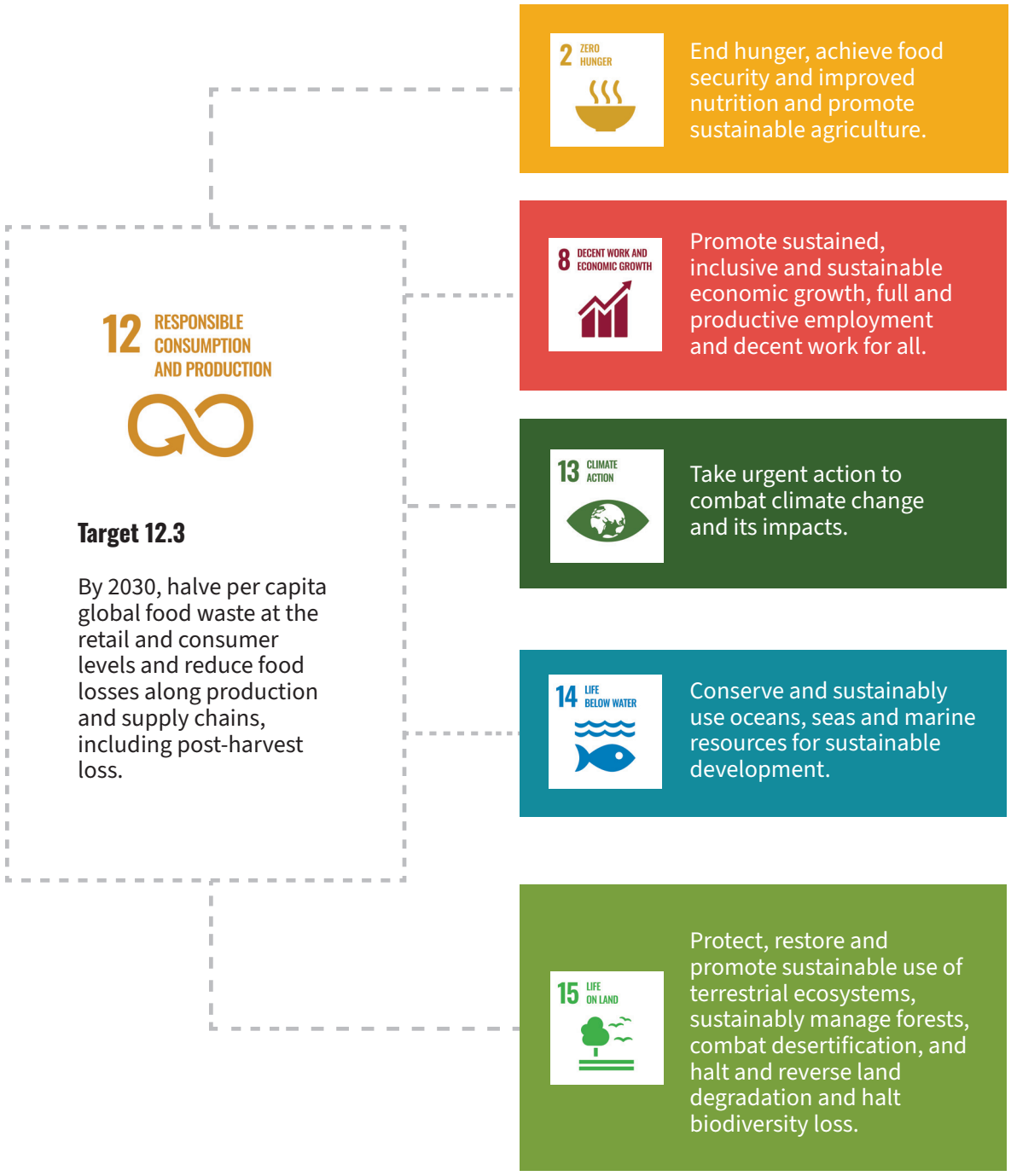
All these beneficial impacts contribute to transforming agrifood systems towards enhancing their sustainability.

Summary of module 1

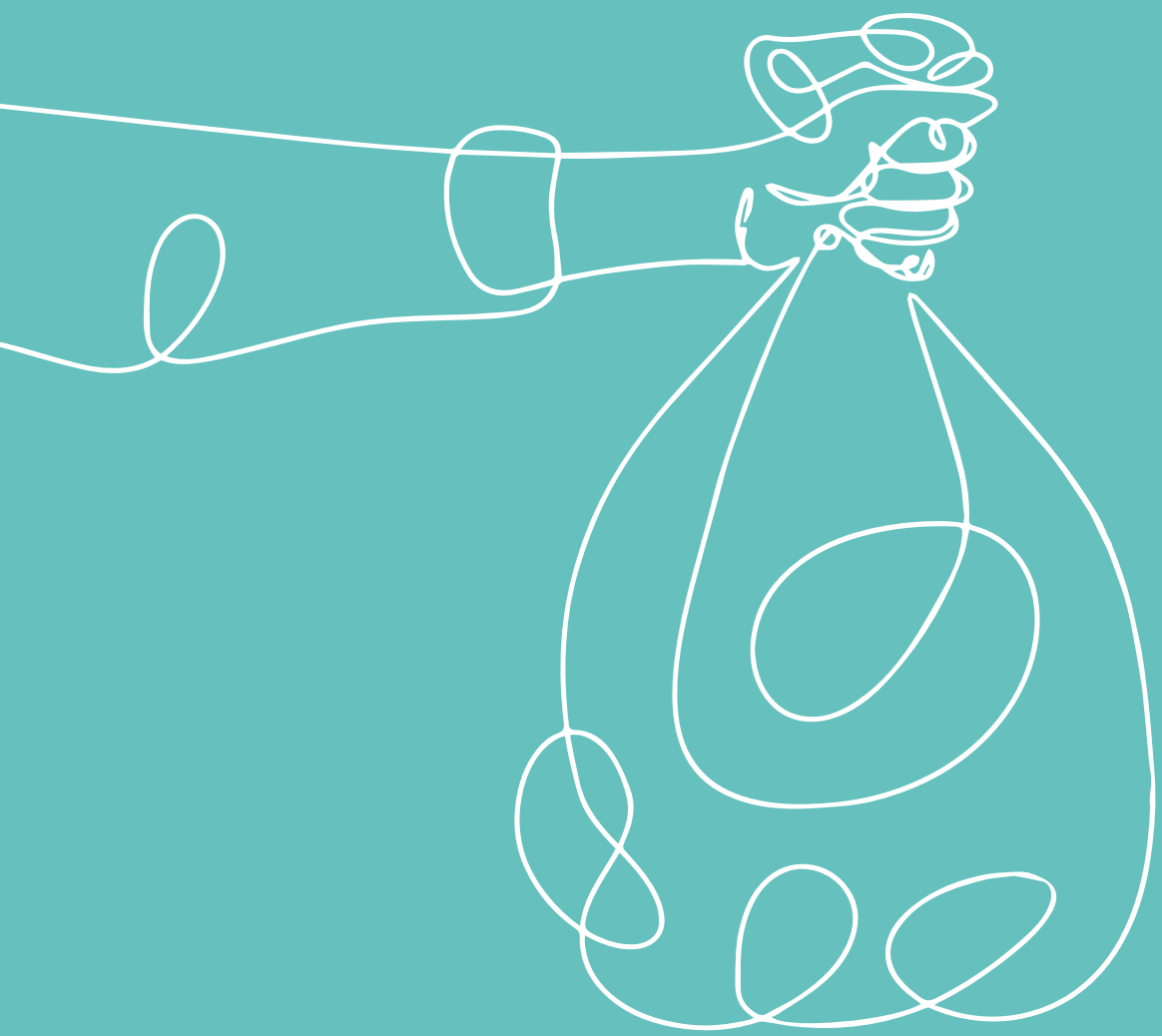
- Food loss in MSMEs predominates during processing and distribution operations while food waste predominates in retail.
- Avoidable FLW may be qualitative or quantitative in nature.
- Food loss and waste can result in significant income loss for food MSMEs.
- Food loss and waste in MSMEs can also indirectly reduce access to locally produced and affordable food products for low-income consumers.
- Food loss and waste contribute significantly to climate change when it ends up in landfills.

By reducing FLW in processing, distribution and retail operations and applying circular strategies, all of these negative impacts can be mitigated, leading to greater economic, social and environmental benefits for stakeholders and countries as a whole.

Figure 8. **Sustainable Development Goal 12**



Source: Adapted from **FAO**. 2019. *The State of Food and Agriculture 2019 – Moving forward on food loss and waste reduction.* Rome. https://doi.org/10.4060/CA6030EN



MODULE 2.

TOWARDS REDUCING FOOD LOSS AND WASTE IN PROCESSING

Identifying the causes of food loss and waste

Reducing food loss during food processing and distribution operations requires targeted interventions and solutions to address both the managerial and technical issues that contribute to it.

Module 2 introduces the use of qualitative surveys to identify the perspectives of stakeholders concerning food loss, their interest in estimating and reducing food loss, and the critical loss points (see Figure 9).

An analysis of the findings of these qualitative surveys is helpful in designing strategies and guiding actions that can be taken by food-processing MSMEs to reduce food loss during processing and distribution.

A moisture meter used for measuring the moisture content of rice grains

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Discoloured rice grains constitute a qualitative loss. When separated and discarded, they constitute a quantitative food loss

Figure 9. Strategies to prevent and reduce food loss

Source: Authors' own elaboration.

Learning objective

By the end of this module, the trainee should be able to:

- explain the importance of conducting a qualitative survey; and
- analyse the results of a qualitative survey to identify strategic actions to be taken along with simple context-appropriate equipment inputs to improve efficiency and product quality and reduce food loss in a sustainable manner.

2.1 What is a qualitative survey?

Reducing food loss begins with the awareness that it is being generated during food processing and distribution operations of MSMEs. It is therefore important to conduct qualitative surveys to obtain a generalized overview of each subsector as to where this food loss may be occurring, as well as to estimate the amount and the likely causes. Qualitative surveys provide a straightforward and inexpensive way of making such assessments.

Qualitative surveys make use of simple questionnaires to obtain information on the perspectives of stakeholders regarding food loss during processing, their interest in reducing food loss, estimates of food loss and the tentative identification of critical loss points.

By responding to the simple questionnaire, MSMEs are able to examine their practices, which in turn provide insights into their processing and distribution operations:

- estimates of how much avoidable food loss takes place;
- potential underlying causes of this food loss;
- current practices for managing and handling unavoidable food loss, by-products and other avoidable food loss;
- key considerations concerning the management of unavoidable food loss, by-products and avoidable food loss; and
- estimates of how much food is wasted in retail operations and the underlying causes.

2.2 Identifying causes of food loss and recommended actions through qualitative surveys

Point 1. A qualitative survey allows MSMEs to obtain information on the symptoms of food loss or how food loss is manifested qualitatively (in terms of changes in product attributes or appearance) or quantitatively (in terms of reduction in product quantity or weight).

For example:

- Qualitative symptoms of food loss are manifested in products that do not conform to certain colour, shape or size specifications or that show signs of the onset of decay or degradation. These may be burnt spots on the product, unusual texture, irregular shapes, broken or cracked pieces of the product or off flavours such as rancidity.
- Quantitative symptoms of food loss result from spillage during processing and distribution that cannot be recovered, which results in reduced product weight or quantity.

- Qualitative loss can also result in quantitative loss if the products must be discarded for reasons of food safety. Mouldy rice, for example, must be discarded as there is a food safety risk.

Box 2. Questions for a qualitative survey

A qualitative survey may ask:

- What are the reasons for discarding or throwing away food in your enterprise? Choose the three most common.
  - Poor-quality raw material.
  - Cosmetic defects (e.g. pieces that are burnt, of irregular size or cracked).
  - Spillage of products during preparation, cooking or packaging.
  - Leftover product in the processing equipment.
  - Raw materials or products that undergo spoilage prior to distribution.
  - Products that were not properly cooked (undercooked/overcooked owing to incorrect temperature) or product batches that encountered problems (e.g. poor consistency) during preparation or processing.

Source: Authors' own elaboration.

Point 2. Once these symptoms are determined, a qualitative survey can help assess the likely underlying causes of this loss by asking MSMEs to identify the possible critical points and stages in their operations where the loss may have occurred, from handling of the raw materials to packing for distribution.

For example:

- **Failure to conform to shape or size specifications** is the likely result of the use of inadequate equipment to peel or slice raw material for the processing of products such as banana chips.
- **Failure of products to conform to colour specifications** may be the result of poor process control (temperature and time) during cooking.
- **At the distribution stage, loss of product integrity** (e.g. fragmentation of banana chips) may result from inappropriate handling (product packages are transported in boxes without proper or adequate cushioning) or poorly sealed packaging (due to an inadequate vacuum seal).
- **Product spoilage** may result from inadequate temperature management during processing, resulting in products being undercooked or improper control of the fermentation process.

Inadequate drying and storage of products under conditions of high relative humidity can also cause rapid product spoilage due to mould growth, as in the case of germinated rice and other dried products.

The following questions may be included in a qualitative survey (see Figure 11).

- **What are the main causes of food loss in your business? Choose the three most important factors.**
  - Trimming, sorting and grading of raw material.
  - Loss due to spillage.
  - Loss due to retention of product in the processing equipment.
  - Product spoilage prior to distribution.
  - Cosmetic defects such as texture, colour, flavour and product freshness.
  - Packaging damage.

Micro, small and medium-sized enterprises can use the information obtained from qualitative surveys to determine potential impacts or effects of this loss on the product and on the overall business (see Figure 10).

Consider the following:

- **Cosmetic defects related to colour, size and shape** that render the finished products unfit for retail because they do not conform to the standards or specifications required by sellers, resulting in qualitative loss. Cosmetic defects can negatively affect the sale of these products or lead to them being sold at a low price, resulting in reduced income for the MSME.
- **Spillage during processing** (quantitative food loss) can result in reduced quantities of the finished product, also resulting in loss of income.
- **Spoilage prior to distribution** results in quantitative food loss and loss of income.

Three varieties of rice

Box 3. Food loss in processing

A qualitative survey may ask:

- In your opinion, how much avoidable food loss is generated during your processing operations?
  - Little (less than 25 percent).
  - Some (about 25 percent to 50 percent).
  - Much (more than 50 percent).
  - Don't know.
  - How much do you think is the retail value of this avoidable food loss if it was translated into a sellable product? See Figure 10.

Source: Authors' own elaboration.

Banana chips of uniform size that are slightly burnt must be sold at a lower price, resulting in economic loss

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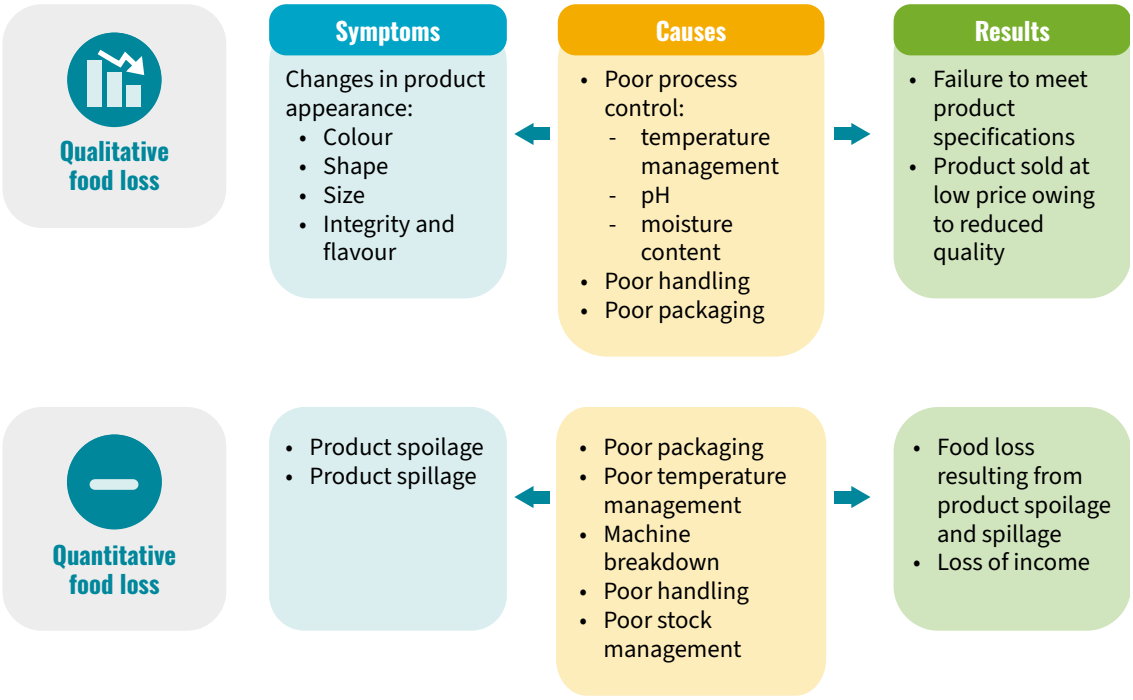
Figure 10. **Symptoms, causes and impacts of food loss**



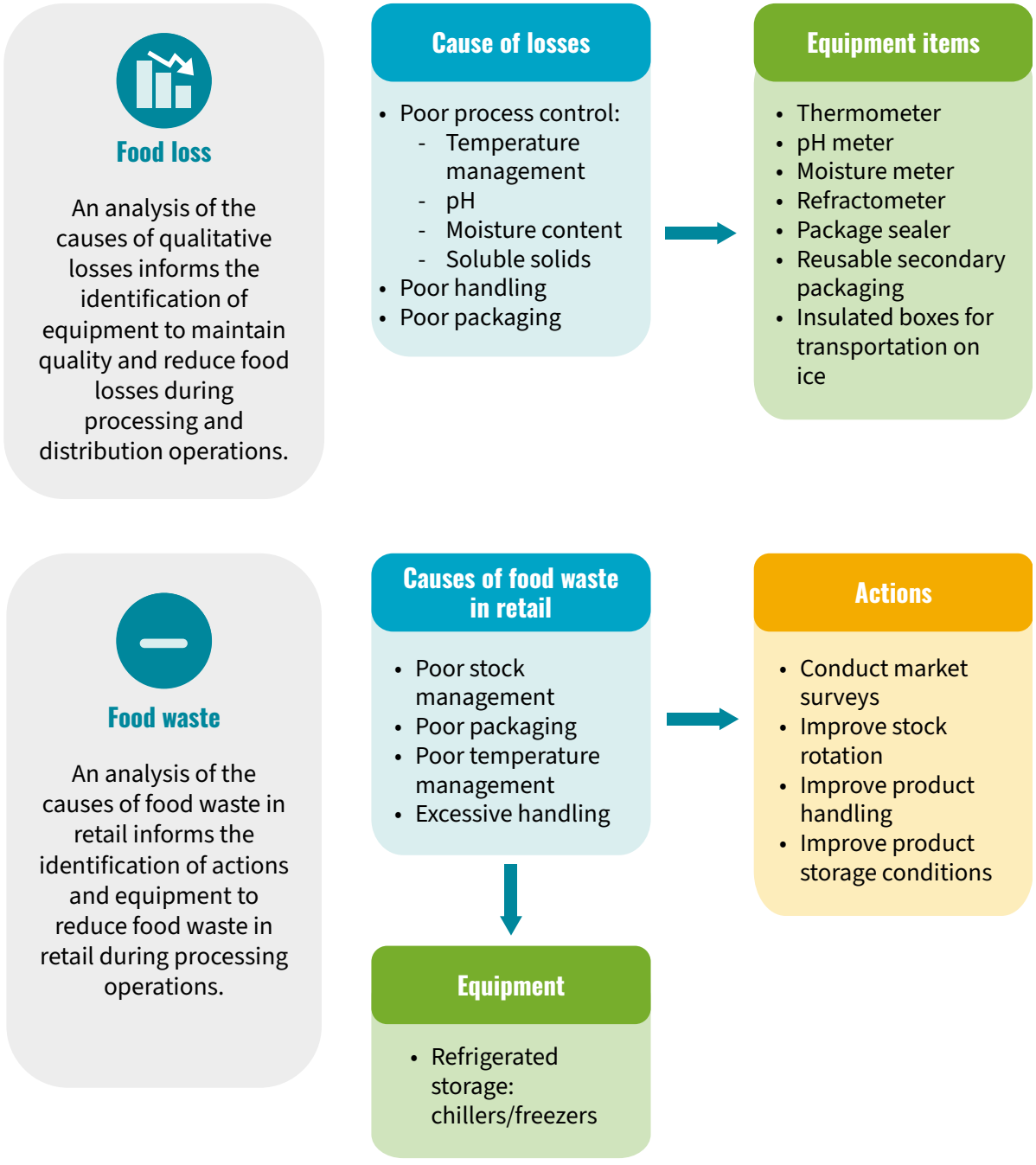
Source: Authors' own elaboration.

Finally, an analysis of the causes of food loss based on qualitative surveys can inform MSMEs of the actions and equipment requirements needed to improve operations and reduce this loss (see Figure 10).

Consider the following:

- Qualitative food loss caused by poor process control can be addressed by introducing simple instruments such as a thermometer to manage the temperature of a product during frying and a stopwatch to monitor frying time to ensure that the product is cooked evenly and consistently (not undercooked or burnt).
- Quantitative food loss can result from spoilage as a result of poor temperature management and storage of the raw material during preparation, distribution and retail. This loss can be minimized by investing in freezers and chillers for the storage of perishable raw materials in processing and retail, transportation of the products on ice, and storage and display of the products in chillers or freezers in retail.
- Quantitative food loss can also result from spillage of the product during processing, packaging and distribution and from improper storage conditions. Mould growth on rice and dried food because of improper drying and storage of products under conditions of high humidity can also contribute to rapid spoilage and deterioration.

Figure 11. **Identifying equipment requirements and action to reduce loss, based on survey results**



Source: Authors' own elaboration.

Box 4. Preventing and reducing food loss in processing and distribution

A qualitative survey may ask:

- In your opinion, which factors can prevent or reduce avoidable food loss in your processing and distribution operations? Choose the three most important.
  - Quality control of raw material.
  - Proper raw material handling.
  - Maintenance of the processing equipment.
  - Process control (use of equipment or tools to ensure better process control during cooking/preparation, drying operations, etc.).
  - Adequate and proper packaging – properly sealed packaging.

Source: Authors' own elaboration.

The importance of process control

Process control involves the application of procedures and the use of equipment to:

- ensure product quality and consistency;
- ensure process and product safety;
- enhance efficiency and reduce food loss in processing operations; and
- optimize energy efficiency.

Good process control hinges on:

- managing process parameters such as temperature, pH, moisture content and time of cooking/drying/mixing during processing operations;
- making use of processing equipment at an appropriate scale for the batch size to be processed in a manner that is cost-effective and efficient; and
- being aware that the entrapment of product in oversized processing equipment results in food loss.

Why is process control needed in food-processing operations?

- The optimization of processing conditions allows MSMEs to ensure the quality, safety and consistency of their products, thus reducing loss.
- Improved quality means that products conform to national food standards or those of the buyer, thereby improving access to wider market opportunities for the MSMEs.

Poor process control is one of the most common causes of food loss in processing and distribution.

Consider the following:

- **Inadequate or insufficient conditions for drying, fermentation, cooking, etc.** The sun drying of fish is a traditional preservation method practised in many countries. Unfavourable or unpredictable weather during the drying process may result in inadequate drying of the product, resulting in rapid spoilage. Improving process control through the adoption of improved drying technologies such as solar drying increases the efficiency of drying. Product quality and shelf-life can be considerably improved by monitoring the final moisture content of the dried product and packaging and storing it under dry conditions.
- **Inconsistent cooking or frying temperature.** The processing of crispy banana chips requires proper temperature control of the frying oil. If the oil gets too hot, the chips are burnt on the surface and become undesirable, resulting in qualitative and economic loss. To reduce the risk of burning of the product, a thermometer can be used to ensure the oil temperature is maintained within a range of 150 °C to 180 °C. Adjustment of the ratio of oil to banana chips is equally important to allow for uniform frying. Alternatively, a thermostatically controlled fryer can be used.

2.3 Use of qualitative surveys to identify the causes of food waste in retail

Point 1. Conducting qualitative surveys in retail can help to identify the symptoms and underlying causes of food waste (see Figure 12).

For example:

- The visual appeal of a product may change over time because it darkens during storage and on retail shelves. Many bottled jams and dried fruits lose their consumer appeal because they darken over time and end up in landfills as food waste.
- Product integrity or texture (crispiness) can also be lost owing to moisture absorption by the product because the packaging has been poorly sealed, or because of product fragmentation in the case of banana chips owing to excessive or improper handling of the packaged product during transportation and on retail shelves.

- Products can also develop off flavours if not properly packaged: germinated brown rice and banana chips may taste rancid when exposed to the air in cases where the package was not properly sealed or was damaged during handling.
- Some products such as sauces, can undergo a phase separation during storage when the fat layer may separate from the liquid or non-fat layer, making them unattractive to consumers.
- Other products such as fermented fish, meat and dairy products, if not stored under chilled or frozen conditions, can undergo rapid microbial spoilage, which can shorten the shelf-life, compromise their safety and increase food waste.

A qualitative survey may ask:

Which of the following is discarded or thrown away in retail in your enterprise? Check all that apply.

- Products with cosmetic defects (e.g. pieces that are burnt, of irregular size, cracked or discoloured).
- Products that have deteriorated in quality (e.g. loss of crispness, change in colour, flavour or texture).
- Products that are visibly spoiled (showing mould growth).
- Products with damaged packaging.

In your opinion, what are the main underlying causes of avoidable food waste in retail? Check the three most common.

- Poor packaging.
- Poor storage conditions.
- Poor handling in the warehouse.
- Excess stock.
- Overproduction because of poor forecasting of consumer demand for the product.

Point 2. Qualitative surveys for food waste in retail operations can also guide agrifood retailers and MSMEs in identifying actions and equipment requirements to reduce food waste.

Consider the following:

- Cosmetic defects such as the breakage of banana chips can be minimized through careful and proper handling of the packaged product from the store warehouse to the display shelves.
- Spoilage in retail operations can be reduced by ensuring the first in, first out system when stocking shelves, refrigerators and freezers and the regular and consistent checking of the temperatures of chilling cabinets and freezers used in the storage of perishable products.

- Procedures for maintaining and monitoring stock inventory and consumer demand for specific products, in particular those that are highly perishable, can also minimize errors in forecasting and prevent overstocking of these products.

Box 5. Avoiding food waste in retail

A qualitative survey may ask:

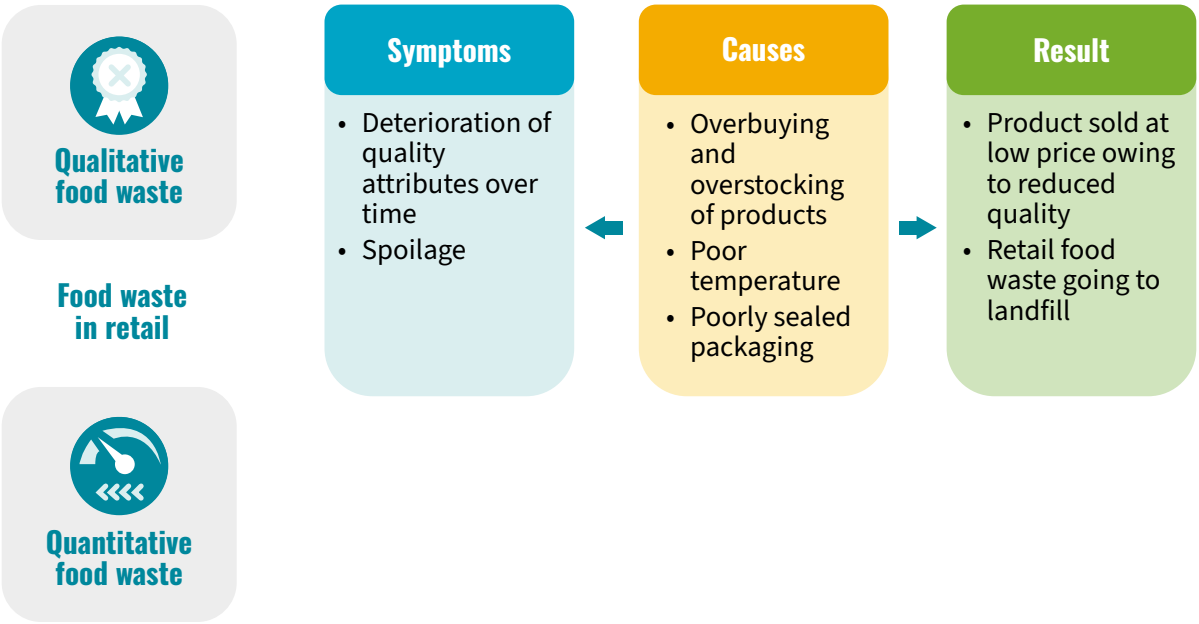
- In your opinion, how can this avoidable food waste in retail be prevented?

  Choose the three most common.

  - Proper handling of products from warehouse to display.
  - Improving stock inventory and rotation practices.
  - Monitoring customer demand.
  - Monitoring storage conditions of freezers and chillers.

Source: Authors' own elaboration.

Figure 12. **Symptoms, causes and impacts of food waste**



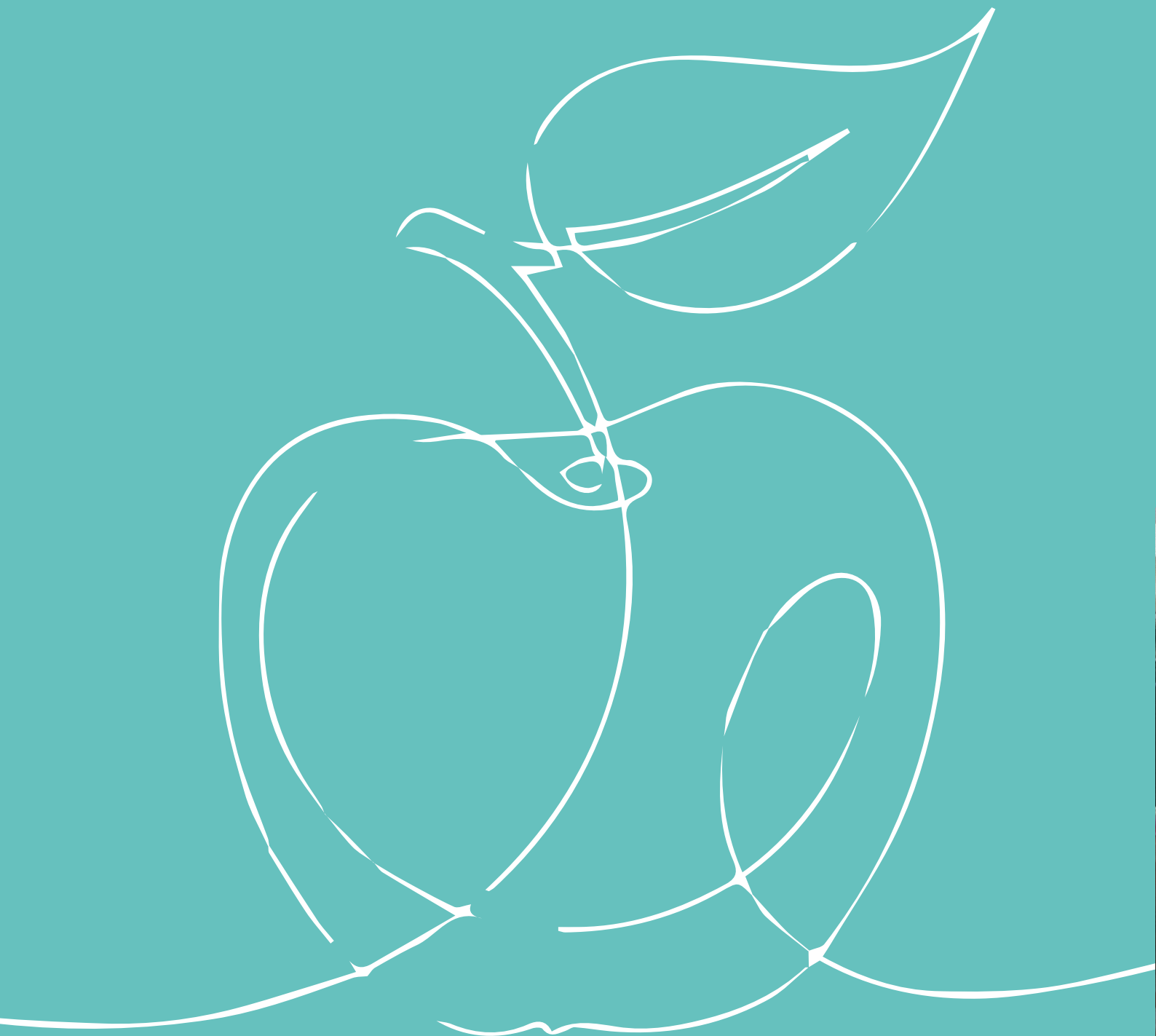
Source: Authors' own elaboration.

Summary of module 2

A qualitative survey comprises a simple set of questions that can be used by MSMEs to identify the ways in which food loss is evident or manifested (symptoms), where in their processing and distribution operations these symptoms occur, and where they are likely at their highest levels (critical loss points or hot spots).

An analysis of this information allows MSMEs to identify possible actions to take to minimize food loss and to identify the requirements of the equipment and tools that can be introduced to control and minimize the underlying causes. A qualitative survey of products on store shelves also provides an understanding of the factors that contribute to food waste.

Packaging pork balls of good quality and consistency in terms of size and shape



MODULE 3.

IDENTIFICATION OF CRITICAL LOSS POINTS

Reducing food loss during processing and distribution operations of MSMEs requires the identification of evidence of loss and the design of targeted interventions and solutions to address the underlying causes of this loss.

To this end, it is important to identify where in the processing and distribution operations food loss occurs, how much food is lost at each of these points, and why food loss occurs there, that is, the underlying cause of this loss.

Critical loss points or food loss hot spots are the steps in the processing and distribution operations where the highest levels of food loss are recorded.

Handing over a digital thermometer packaging sealer and a plastic crate to a microentrepreneur engaged in the processing of banana chips

© N.Tangsuphoom

A thorough analysis of the evidence and the underlying causes of food loss informs the design of strategic interventions to reduce the levels of food loss at the critical loss points in processing operations in a sustainable manner.

These interventions range from the introduction of good practice such as improved handling of raw materials to the introduction of simple items of equipment such as thermometers, moisture meters, pH meters, refractometers and tools to improve process control and reduce the underlying causes of food loss at these critical loss points and at all steps of the food-processing operations.

Food retail is a critical waste point or food waste hot spot. A thorough analysis of the storage and handling conditions of food products in retail, as well as an examination of inventory records, can be used to inform the design of solutions and strategies to reduce food waste in retail and keep it out of landfills.

Figure 13. Critical loss points and their underlying causes in the processing and distribution chains of MSMEs with similar problems across five subsectors

Critical loss point	Evidence	Underlying cause
Raw material input	Excessive trimming	Poor quality raw material/equipment
Processing	Spillage/damage/ poor quality	Equipment design/ poor quality control
Packing/filling	Spillage or damage	Poor packing equipment/improper packaging
Distribution	Damage/spoilage	Improper/inadequate packaging

Source: Survey data collected under project GCP/GLO/809/JPN.

MODULE 4.

MEASURING AND REDUCING FOOD LOSS AND WASTE

Module 2 presented a qualitative survey to obtain a generalized overview of where food loss takes place in the processing and distribution operations of a large number of MSMEs working in a variety of sectors.

The identification and measurement of the extent of food loss at all stages of food processing and distribution operations of a particular product allow enterprises to pinpoint critical loss points or hot spots. This information, together with that consolidated through the qualitative surveys and through observance of the operations and practices during processing operations, is then used to further evaluate the underlying causes of loss at these points and to map out an action plan to reduce it by introducing good practice, appropriate technology and innovations.

This module introduces the concept of quantifying food loss during processing and distribution operations of MSMEs and introduces good practices supported by the introduction of simple tools for reducing food loss. An analysis of the results of the quantitative survey can provide insights into the extent of FLW that can be reduced and the financial savings and economic benefits that can be gained.

Weighing fish prior to processing as a baseline for measuring quantitative loss during processing

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Learning objectives

By the end of this module, the trainee should be able to:

- identify and measure food loss in food processing and distribution operations;
- identify critical loss points in the processing and distribution operations of MSMEs;
- design a strategic approach to introduce good practice and technological innovations to reduce food loss, based on information obtained through qualitative surveys and food loss measurements;
- implement the strategic approach; and
- measure food loss at each step of the processing and distribution operations before and after applying improved practice and calculate the result (see Annex).

4.1 What is a quantitative survey?

A quantitative survey allows MSMEs to measure and obtain data on food loss at all steps of processing and distribution in order to pinpoint the critical loss points in the food-processing operation.

Quantitative surveys also allow for the measurement of food waste in retail.

4.2 Methods used to measure food loss

Quantitative data are obtained through either a direct weighing method or a counting method. Quantitative data provide insights that help to inform decision-making.

- **A direct weighing method** is used to measure food loss in food-processing operations. It makes use of a weighing scale. Weights of product are measured and recorded.
- **A counting method** is used to measure food loss in distribution operations and to measure food waste in retail. This entails multiplying the number of items by their unit weights, excluding the weight of packaging.

4.3 Collection of quantitative data on the processing of fermented fish

The case study of fermented fish operations illustrates how the analysis of findings of a quantitative survey can reveal a substantial reduction in FLW thanks to improved process control and good practice. A detailed presentation of the processing, distribution and retail operations of a fermented fish processing MSME is also presented in Module 5.

Point 1. Measuring FLW in the conventional processing and distribution operations of fermented fish.

The processing of fermented fish involves descaling of the raw fish, followed by washing and sorting to remove defective or rotten items. The good-quality cleaned fish thus obtained is mixed with cooked rice and other ingredients in a tumbler and is then weighed and packaged in plastic bags. The packaged fish is incubated to allow the initiation of spontaneous fermentation and then transferred to a chiller or stored on ice prior to shipping or sale to customers.

Collecting quantitative data during the processing of fermented fish

Measuring and reducing food loss

Avoidable food loss, as measured using the direct weighing method at the washing and sorting stages of the processing operations and in the mixing, packaging and fermentation operations, is documented in Table 3.

Table 3. **Estimates of food loss and waste at critical points in conventional processing, distribution and retail of fermented fish**

Operation	Food loss	Loss/waste at critical points in processing, distribution and retail*†	Underlying cause of food loss or waste	Destination
Processing (food loss)		16.06 ± 2.84		
Descaling + removal of entrails	Scale, viscera and roe	(21.95 ± 3.56)	Unwanted parts	Upcycled (used as ingredients in other products)
Washing + sorting	Rotten/ cosmetic defects	9.64 ± 2.56	Poor raw material quality	Upcycled
Mixing + packaging + fermentation	Defects	6.43 ± 0.43	Poor process control	Upcycled
Distribution (food loss)		–	–	–
Retail (food waste)	Spoilage	6.00 ± 8.94	Improper product handling/storage	Landfill

Notes: ± Standard deviation for five production batches. * Mean. † Percentage input weight and moisture corrected.

Source: Authors' own elaboration.

Critical loss points identified during conventional processing of fermented fish:

- Washing and sorting were identified as critical loss points, with a 9.6 percent quantitative food loss (fresh weight equivalent) recorded because of the input of poor-quality fish.
- Mixing, packaging and fermentation were also critical loss points in which a 6.4 percent loss (fresh weight equivalent) was recorded.
- In total, an estimated 16 percent quantitative food loss (fresh weight equivalent) occurred during the processing of fermented fish.

Measuring food waste of conventionally processed fermented fish in retail. Food waste of fermented fish in retail was identified by observing the product for qualitative signs and symptoms of spoilage such as appearance and odour. The level of food waste was estimated using the counting method, in which the number of packages of the product that showed symptoms of waste was counted. The weight of the packages was multiplied by the unit weight of the packaged product, without packaging, and reported as retail waste.

- An estimated 6 percent of the fermented product was wasted in retail.

Point 2. Designing strategic approaches to reduce food loss during conventional processing and distribution of fermented fish and to reduce food waste in retail.

To better understand the underlying causes of food loss in food-processing operations, the symptoms of food loss manifested at the critical loss points must be examined.

- **Mechanically damaged fish** that had been identified during washing and sorting were removed and set apart for later use in upcycling.
- **Defective product** that had resulted from inadequate control of mixing, fermentation or packaging was observed.

Strategic approaches to reducing food loss during processing and reducing food waste in retail:

- improve the quality of the raw material input for processing;
- minimize defects and breakage of the washed and sorted fish; and
- slow or delay the onset of the fermentation process to avoid food waste in retail.

Strategic actions taken to reduce quantitative food loss in processing and food waste in retail

Managerial policy

To ensure good quality raw material for processing, a decision was made by the management of the processing facility to return the fish to the supplier when rotten fish exceeded 10 percent of the batch purchased.

Technical

- Use of raw fish of improved quality.
- An increase in the size of the containers used for mixing to minimize defects from mechanical injury and breakage of the fish during mixing.
- Transportation of the packaged product on ice or in a refrigerated truck; use of a thermometer to monitor the temperature of the product during transportation; use of a pH meter to monitor the final pH of the product over time.
- Chilling of the product in retail to prevent the onset of fermentation prior to purchase by customers.

Point 3. Measurement of FLW following the implementation of improved practices (see Table 4).

Food loss was measured at critical loss points in processing operations using the direct weighing method, as previously carried out.

Measurement of quantitative food loss at critical loss points

- Loss during washing and sorting was reduced from 9.6 percent (fresh weight equivalent) to 6.9 percent, representing a 29 percent reduction in loss.
- Loss during mixing, packaging and fermentation was reduced from 6.4 percent (fresh weight equivalent) to 2.9 percent, representing a 54 percent reduction in loss.
- Overall, a 38.7 percent reduction of quantitative food loss was recorded in processing with the introduction of improved practices.

Measurement of food waste in retail

Food waste was measured in retail using the counting method.

- No food waste was recorded in retail following the implementation of improved practices in processing operations.
- A 100 percent reduction in food waste was achieved in retail after the introduction of good practice.
- An estimated 55 percent reduction in FLW was achieved in processing and in retail.

Point 4. Estimating the economic gains obtained from introducing improved practices in fish processing.

The economic benefit derived from reducing FLW during processing and in retail can be calculated on the basis of the quantity of product that is lost and wasted and the retail price of the finished product.

By reducing FLW by more than half (55.4 percent) across the value chain, improving the quality of the raw material and controlling the fermentation process, an estimated 488 kg of fish valued at approximately THB 87 000 (approximately USD 2 500) would be saved by the enterprise monthly.

Table 4. Comparison of quantitative food loss or waste levels for conventional and improved practices in the processing, distribution and retail operations of fish

Operation	Food loss or waste at each processing step*†		Reduction in food loss (percentage)
	Conventional practice	Improved practice	
Processing (food loss)	16.06 ± 2.84	9.85 ± 1.12	38.67
Washing + sorting	9.64 ± 2.56	6.89 ± 0.53	28.52
Mixing + packing + fermentation distribution	6.43 ± 0.43	2.96 ± 0.97	53.88
Food waste			Reduction in food waste
Retail (food waste)	6.00 ± 8.94	–	100
Food loss and waste			
	22.06	9.85	55.35

Notes: ± Standard deviation for five production batches. * Mean. † Percentage input weight and moisture corrected.
Source: Authors' own elaboration.

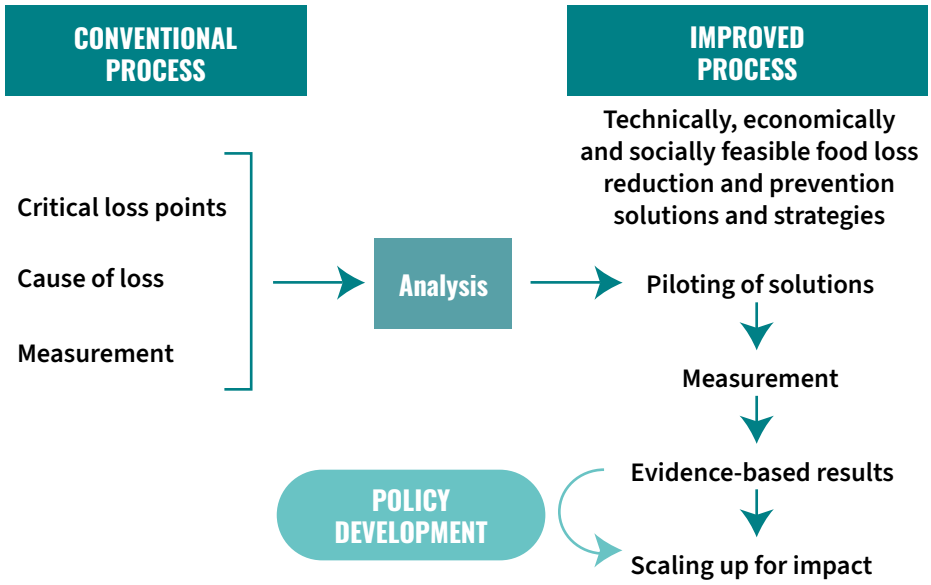
Point 5. Summary of key steps and actions required to generate an evidence base to measurably reduce food loss.

Once the evidence base has been generated, and the good practice (process control using the appropriate tools) has been consistently applied, periodic measurements of food loss should be recorded to ensure continued efficiency of the processing operation (see Figure 14).

Maximizing the use of fish offal through upcycling

Offal produced as a by-product during processing was upcycled by including it as an ingredient in the processing of other fish-based products such as fish pastes. Upcycling keeps these products out of landfills and maximizes the use of all parts of the fish as food.

Figure 14. Key steps in generating an evidence base to inform and validate actions to measurably reduce food loss in MSMEs



Source: Authors' own elaboration.

Summary of module 4

Quantitative surveys provide a means to measure and monitor food loss generated in the processing and distribution operations of MSMEs and food waste of their products in retail. Quantitative data collected at critical loss points and an understanding of the underlying causes help to pinpoint strategic actions supported by key equipment requirements and specific adjustments to reduce FLW.

Weighing raw fish before processing

MODULE 5.
CASE STUDIES OF GOOD PRACTICE TO REDUCE FOOD LOSS AND WASTE IN PROCESSING, DISTRIBUTION AND RETAIL

This module focuses on field-level case studies on reducing food loss in the processing and distribution operations of MSMEs in five subsectors: meat, fish, snack food, rice processing and dairy. The case studies concretize the information provided in the first two modules of this manual. They are designed to provide examples of how the application of good practice, coupled with the introduction of simple innovations and adjustments to conventional food-processing operations of MSMEs, can reduce food loss, improve the quality of processed outputs and reduce food waste in the retail operations of MSMEs. In the process, economic benefits can be generated. In addition, the environmental and social benefits that can be achieved when FLW are reduced in a sustainable manner are highlighted.

Insights can be derived from the following case studies of the meat, fish, snack food, rice processing and dairy subsectors. These insights can be applied to other sectors. Working examples of actions to reduce food loss in the processing and distribution operations of MSMEs show that economic returns can be maximized.

Measuring the moisture content of dried fish using a moisture analyser

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Learning objective

By the end of this module, the trainee should be able to:

- identify good practice from the case studies; and
- apply solutions to reduce food loss in processing and distribution operations and food waste in retail.

Box 6. Key messages on good practices to minimize food loss and waste

Raw material of good quality must be the starting point for all food-processing operations to ensure the products produced are of good quality.

- Process control involves measuring the temperature, pH and moisture content, which are critical for assuring product quality, consistency and safety and reducing FLW.
- Training staff to prevent product spillage can substantially reduce avoidable food loss in all categories of food-processing operations. Preventing spillage is particularly critical for food-processing operations with low production capacity, few workers and limited access to equipment.
- Good packaging practice is critical for ensuring the shelf-life and quality of products and reducing FLW across the supply chain and in retail.
- To maximize the efficiency of food-processing equipment in terms of functionality and cost of energy, attention must be paid to the scale of the equipment. The use of large-scale equipment to process small batches increases energy costs and often results in significant food loss in the form of residual product in the processing equipment, with a negative economic impact.
- The upcycling of by-products such as fish offal to produce other value-added food products is one of the most effective ways to maximize the use of raw materials for food use and minimize food loss while offering additional sources of income for MSMEs.
- A spectrum of approaches can be explored to apply the circular economy. This might include repackaging poorly sealed packaged products or sale of products with cosmetic defects at a discounted price. Products spilled during processing can be used as animal feed or as compost, thus diverting them away from landfills.

Source: Authors' own elaboration.

Preparing a sample of fish for measurement of pH

Measuring the pH of an extract of fermented fish

Preparing to stuff sausage meat into the casing

Case study 1. Processing pork sausage

The enterprise: The MSME is a three-person operation with a production capacity of 40 kg of pork on a weekly basis and an output of 40 kg of product.

The product: Cooked pork sausage.

Processing

Raw material: Pork purchased from a slaughterhouse and butcher.

Steps in the conventional processing of pork sausage: The pork was either minced or chopped and then transferred to a mixer, where it was mixed with herbs, spices and seasonings. The seasoned meat was manually stuffed into a natural casing and cooked by steaming. The cooked sausage links were air-dried prior to grilling on an electric grill. The grilled sausages were cooled under ambient conditions, packaged in vacuum-sealed plastic bags and frozen (see Figure 15).

Product distribution

The finished product was delivered chilled or frozen to retailers, where it was stored frozen. The producer also delivered or sold the frozen product directly to consumers.

Critical loss and waste points and their underlying causes in the conventional processing of pork sausages.

Food loss in processing operations. An estimated 6 percent (equivalent fresh weight) was lost in processing operations, with sorting and packaging as the critical loss point.

- Qualitative loss: A loss of approximately 5 percent of pork (fresh weight equivalent) was recorded during sorting and packaging. This loss resulted mainly from defects caused by poor temperature control during case stuffing, steaming and grilling of the product, which resulted in cracked sausages with burnt spots and non-uniform length and weight.

Food loss in distribution. No loss occurred during distribution up to direct sale to the customer.

Food waste in retail. No food waste was recorded.

Packaged products on sale in retail

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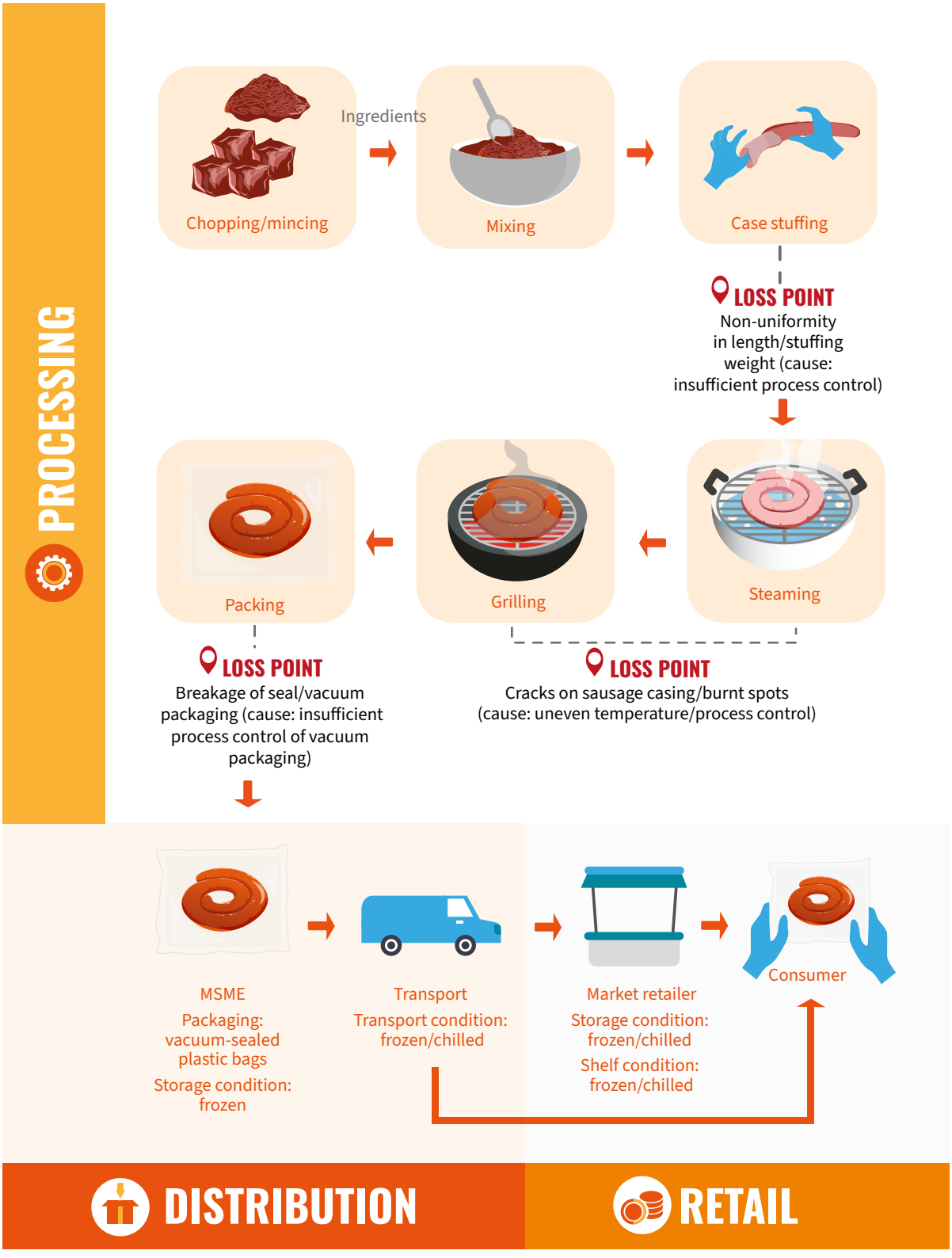
Figure 15. **Traditional method of pork sausage processing, distribution and retail, highlighting critical loss points**



Source: Authors' own elaboration.

Introduction of improvements for pork sausage

Improvements in process control were introduced to address the main underlying causes of food loss in the sorting and packaging steps of the conventional process:

- **Improving product uniformity.** To ensure uniformity of the product, a sausage-packing machine was introduced to stuff the sausage casings.
- **Temperature control in steaming and grilling.** Monitoring the core temperature of the product during cooking minimized changes in the colour and appearance of the sausage (cracks and burnt spots). This was achieved by introducing a thermometer to control the core temperature of the sausages during steaming and grilling and ensure even and thorough cooking. Cooking time was carefully monitored to prevent overcooking. Standardizing the sausage weight and length by improving process control and product specifications improved product quality and consistency. Thus, the product appeal improved, potentially opening up wider market opportunities for the business.

Impacts of improved practice

- An estimated 6 percent of pork (fresh weight equivalent) was lost during the conventional processing of pork sausage.
- With the introduction of improved practice, the estimated percentage of loss was reduced to 3.8 percent (fresh weight equivalent).
- A 39 percent reduction of food loss was achieved with the introduction of improvements in the processing operations (see Table 5).

Mechanized stuffing of the sausage links

Weighing of the sausage links

Measuring the core temperature and process time

Table 5. **Comparison of quantitative food loss levels for conventional and improved practices in the processing operations of pork sausage**

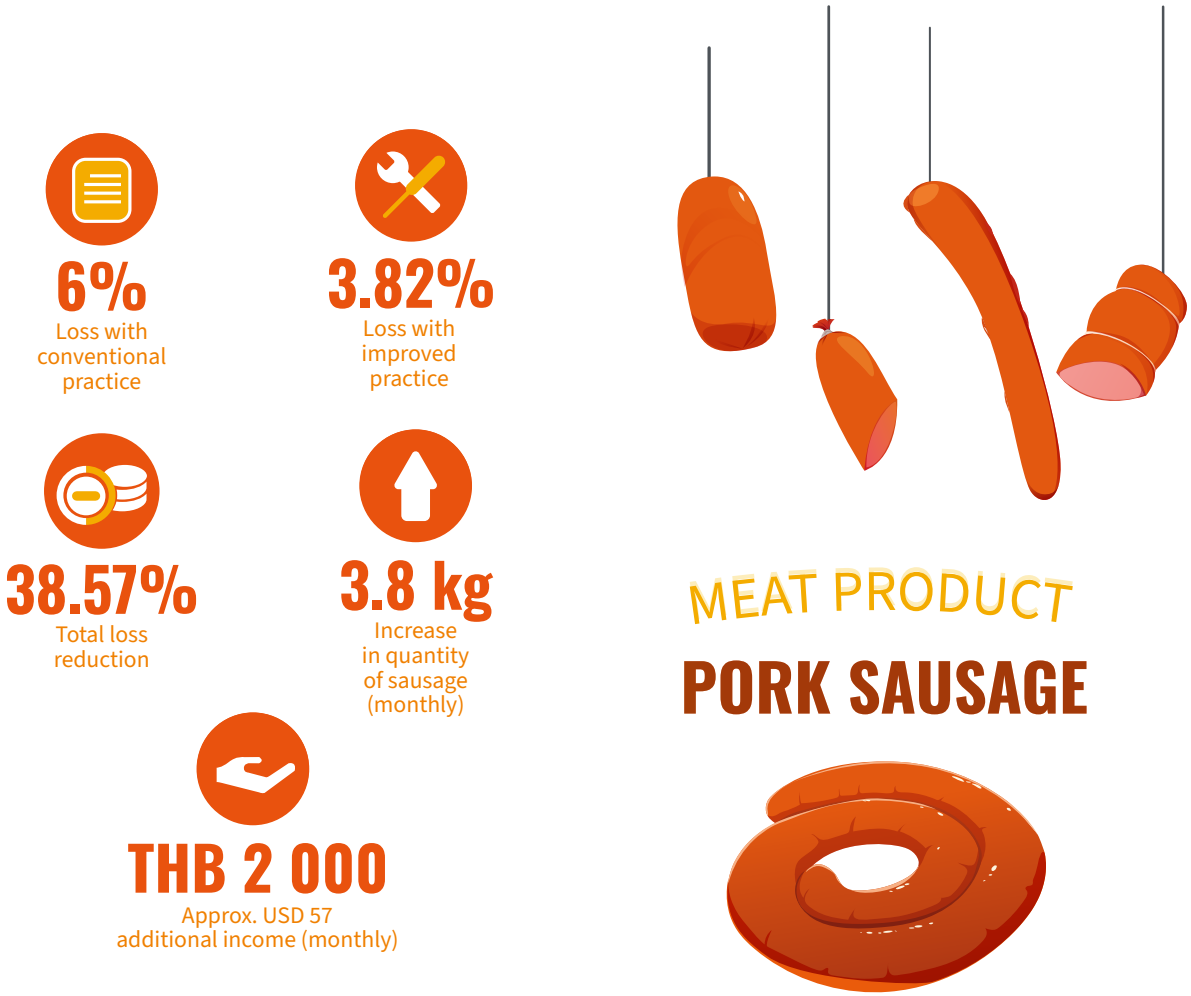
Operation	Amount of food loss at each step* (percentage fresh equivalent weight)		Reduction in loss (percentage)
	Conventional	Improved	
Processing	6.22 ± 3.84	3.82 ± 1.31	38.57
Sorting + packing	5.06 ± 3.36	3.79 ± 1.20	25.23

Notes: ± Standard deviation for five production batches. * Mean.
Source: Survey data collected under project GCP/GLO/809/JPN.

Economic benefit

A 39 percent reduction in quantitative food loss could lead to an estimated 3.8 kg increase in the quantity of good-quality pork sausages produced monthly and an estimated additional income of THB 2 000 per month (approximately USD 57.00) for the MSME (see Figure 16).

Figure 16. **Gains from improved practices in pork sausage processing**



Source: Authors' own elaboration.

Application of the circular economy to defective product and processing of by-products

Defective products that were burnt or cracked, but still edible, were sold at a reduced price or used as tasting samples, thereby keeping the product out of the landfill.

Descaled and degutted fish prior to marinating with the rice and seasonings

Marinating fish

Case study 2. Processing fermented fish

The enterprise: The MSME employs 15 people and processes 1000 kg of fish weekly.

The product: Fermented fish.

Processing operations

Raw material: Silver barb fish supplied by local producers.

Conventional processing:

- **Washing and sorting.** The processing of fermented fish involved descaling and degutting of the raw fish, followed by washing and sorting to remove defective or rotten fish.
- **Mixing, packaging and fermentation.** The cleaned fish was mixed with cooked rice and other ingredients in a tumbler. The rice-fish mixture was then weighed and packed in plastic bags. The bagged fish mixture was then transferred to a cooler and stored prior to shipping under refrigerated conditions.

Preparing fish for processing

Product distribution

The packaged fish product was transported to retailers under chilled conditions to delay the onset of the fermentation process.

Product retail

The packaged fish product was stored refrigerated in retail. Once purchased it was transported by consumers under ambient conditions to allow spontaneous lactic fermentation to take place.

Consumers were instructed to keep the mixture at room temperature for a few days to allow completion of the fermentation process prior to consumption or further storage.

Alternatively, the packaged mixture was allowed to sit in closed plastic boxes at room temperature in retail for 1–2 days to allow fermentation to take place prior to shipping to consumers (see Figure 17).

Loss and waste points and underlying causes of food loss during conventional processing of fermented fish

Quantitative food losses during conventional processing:

- **Food loss in processing operations.** An estimated 16 percent loss (fresh weight equivalent) was recorded during conventional processing. The main underlying cause was poor quality of the raw material and inadequate process control.
- **Food loss in distribution.** No food loss was recorded during product distribution.
- **Food waste in retail.** Food waste in retail was estimated at 6 percent (fresh weight equivalent) and was largely due to inadequate temperature control.

Introduction of improvements for fermented fish

Improved quality control of fish inputs for processing resulted from the creation of a policy to improve the quality of raw fish, which reduced the quantity of rotten fish, improved control of the fermentation process and reduced levels of food loss in the product.

Managerial policy to ensure input quality control. To ensure good quality raw material inputs for processing, a decision was made to return the fish to the supplier when rotten fish exceeded 10 percent of the batch purchased.

Technical improvements introduced:

- **The quality of the raw fish for processing was improved.**
- **Adjustments in mixing.** The size of the containers for mixing was increased to minimize defects from mechanical damage and breakage of the fish during mixing.
- **Improved process control.** This was achieved by monitoring the temperature and pH. The product was transported on ice or in a refrigerated truck. A thermometer was used to monitor the temperature of the product during transportation. A pH meter was used to monitor and control the final pH of the fermented product.
- **The product was chilled at the retailer.** This prevented the onset of fermentation prior to purchase by customers.

Impacts of improved practice

With the introduction of improved practice:

- The estimated loss during processing was reduced from 16 percent (fresh weight equivalent) in the conventional process to 9.9 percent.
- A 100 percent reduction of food waste in retail was recorded.
- Overall, a 39 percent reduction of food loss was achieved after the introduction of improvements in processing.
- A 55 percent reduction of FLW was achieved in processing, distribution and retail operations.

Table 6. Comparison of quantitative food loss and waste levels for conventional and improved practices in processing and retail operations of fermented fish

Operation	Quantity of food loss or waste at each step* (percentage fresh equivalent weight)	
	Conventional	Improved
Processing (food loss)	16.06 ± 2.84	9.85 ± 1.12
Washing + sorting	9.64 ± 2.56	6.89 ± 0.53
Mixing + packing	6.43 ± 0.43	2.96 ± 0.97
Retail (food waste)	6.00 ± 8.94	-
TOTAL	22.06 ± 7.79	9.85 ± 1.12

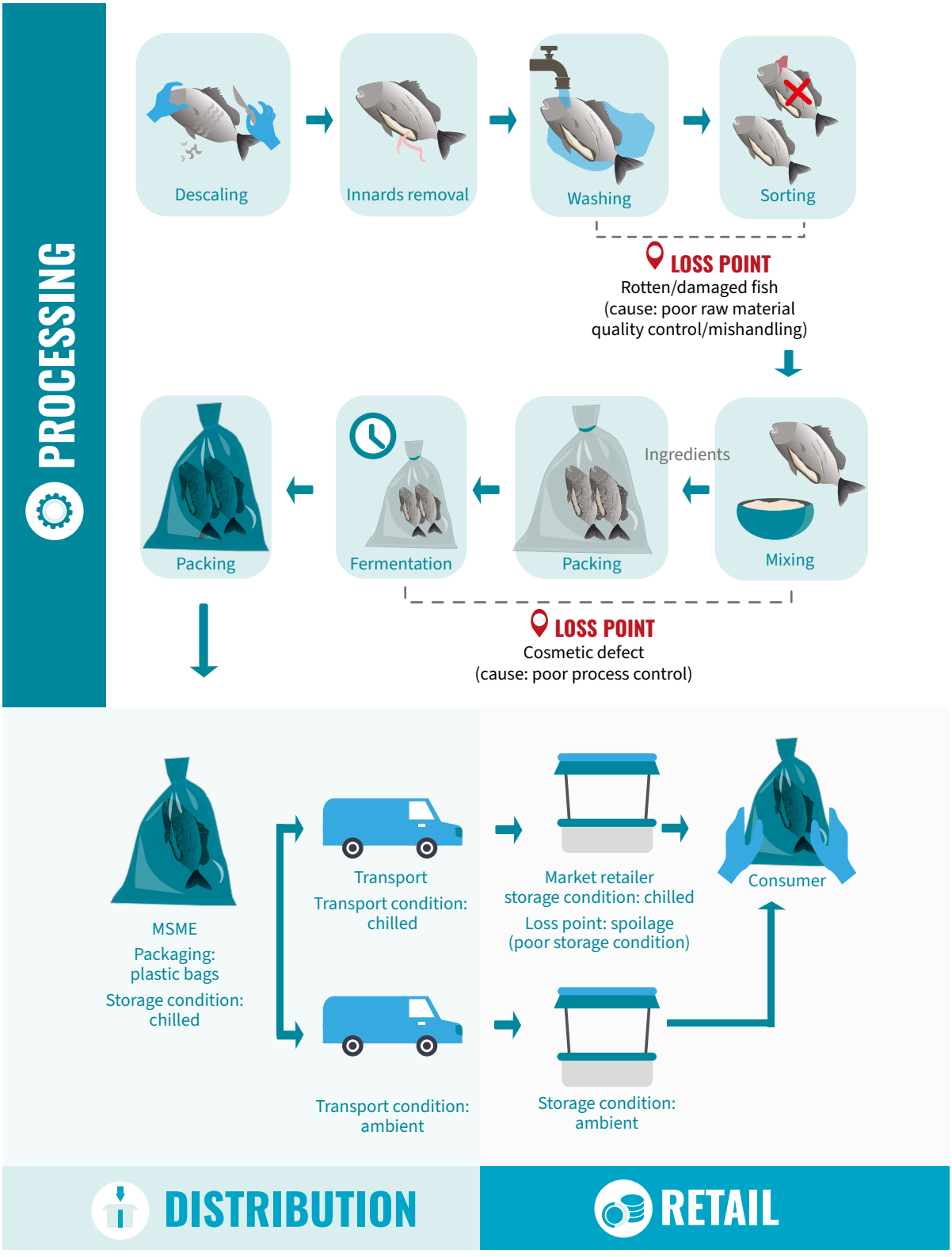
Notes: ± Standard deviation of five production batches. * Mean.
Source: Survey data collected under project GCP/GLO/809/JPN.

Economic benefit

A 55 percent reduction in quantitative loss of fermented fish saved the enterprise an estimated 488 kg of fish monthly, valued at THB 87 000 (approximately USD 2 500).

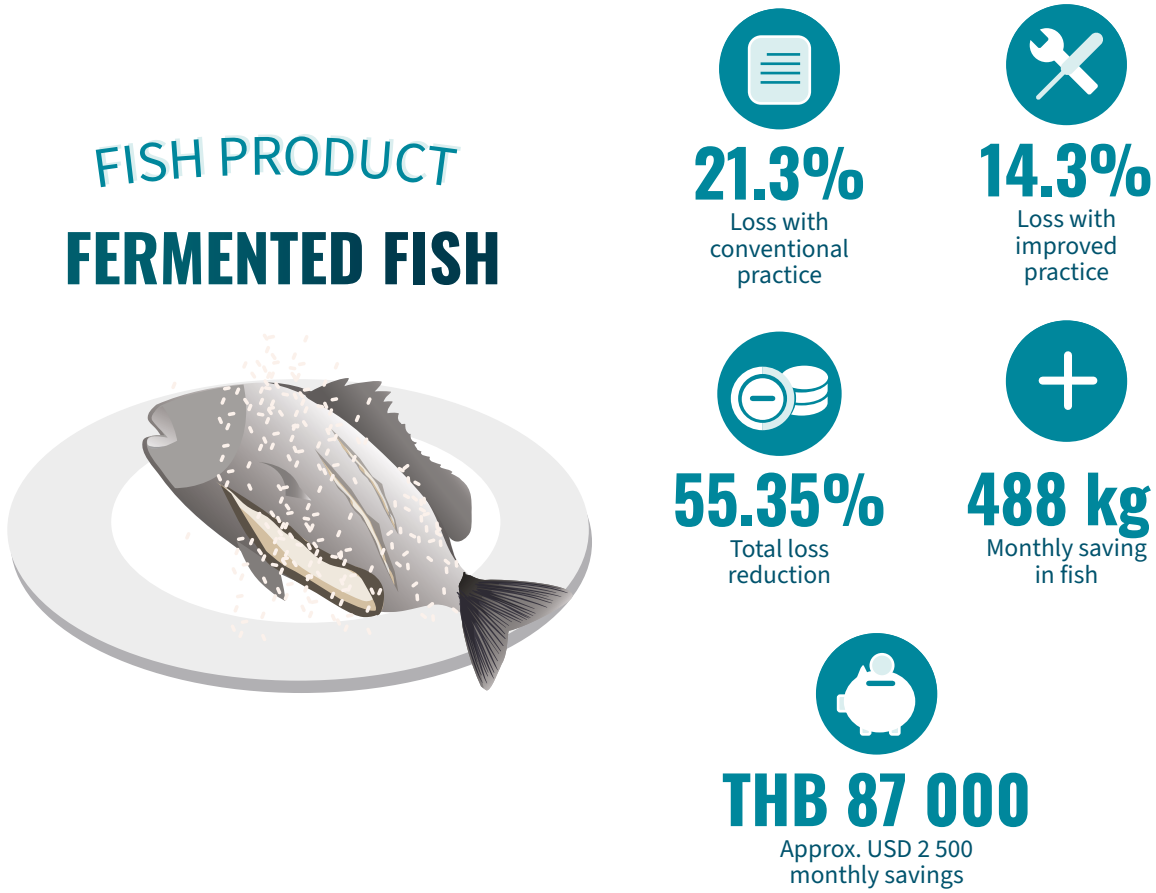
Improvements in product quality resulted from improved process control. Better quality increased the potential of increasing economic returns for the processors and increasing market opportunities for the product (see Figure 18).

Figure 17. **Processing, distribution and retail of fermented fish**



Source: Authors' own elaboration.

Figure 18. **Gains from improved practices in fermented fish processing**



Source: Authors' own elaboration.

Application of the circular economy to keep fish by-products out of landfills

Fish by-products such as defective fish, viscera and roe were upcycled and used as ingredients in the processing of other products such as fermented fish paste and fish chili paste.

Case study 3. Processing banana chips

The enterprise: The business is a farmer-spouse community, a traditional MSME that employs 13 people.

The product: Banana chips.

Frying banana chips in a "modern" enterprise

Frying banana chips in a "traditional" enterprise

Measuring the temperature of the oil

Reusable plastic crates for transporting banana chips

Use of dried banana leaves as cushioning in cartons used to transport banana chips

Processing

Raw material: 300 kg to 350 kg of bananas are processed weekly to produce 100 kg of product.

Conventional processing: Green bananas were purchased in bunches from group members or suppliers in the vicinity of the enterprise. After removal of the stems, the bananas were washed, dried, peeled and trimmed to remove the tips and any torn and bruised parts. They were then thinly sliced using a blade slicer or shredded into small sticks. The banana chips or sticks were immediately deep-fried in palm oil and mixed either with powdered seasoning or a sugar coating prior to a second round of frying to enhance crispiness. The banana chips were then sorted and packed in sealed plastic bags (see Figure 19).

Product distribution

The banana chips were transported in paper cartons or large plastic bags under ambient conditions.

Critical loss points and their underlying causes during conventional processing of banana chips

Quantitative food loss

A quantitative food loss of approximately 12 percent (fresh weight equivalent) occurred during processing, owing to cosmetic defects and fragmentation of the fragile banana chips during processing.

While most of this food loss (10 percent) was quantified during sorting and packaging, the main underlying cause of loss was improper temperature during frying, which resulted in darkening of the chips.

Loss in distribution. A quantitative food loss of approximately 7 percent (fresh weight equivalent) was recorded in distribution because of poor handling and inadequate packaging.

Waste in retail. No food waste was recorded in retail.

Improvements introduced

Improved processing

- Temperature control during frying: A thermometer was introduced to monitor the temperature (150 °C to 180 °C) and the frying time to prevent overcooking and discoloration or excessive darkening of the chips.
- Adjustment of the ratio of frying oil to banana sticks or chips optimized the cooking process to ensure uniform cooking.
- Proper sealing of the packaged product helped to extend the shelf-life of the chips by reducing exposure to air and development of rancidity.

Improved distribution

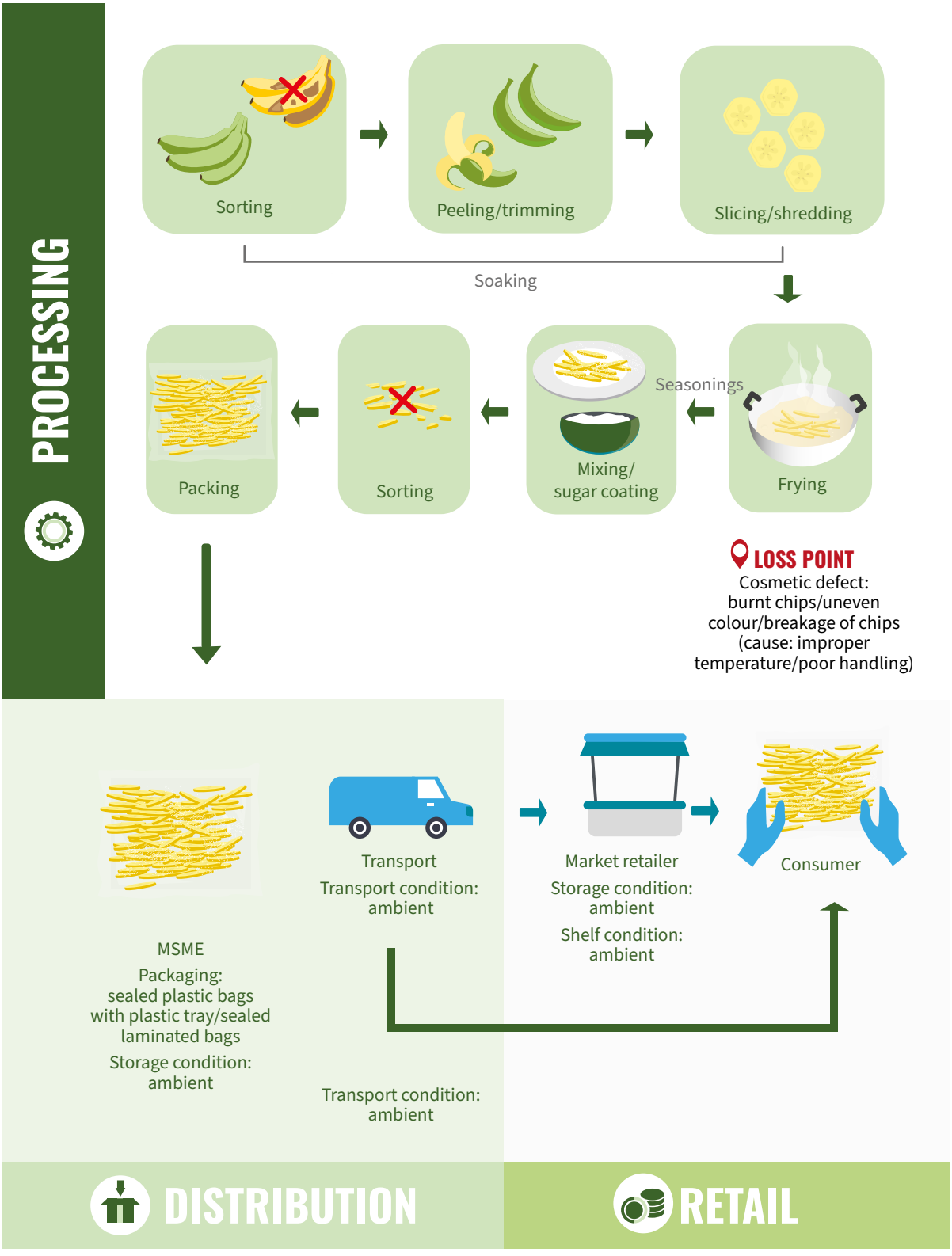
- Cushioning of the packaged product in cartons for transportation: The packaged banana chips were transported in plastic crates or packed for shipping in cartons lined with dried banana leaves or bubble wrap (a less sustainable practice) to minimize the effect of physical damage to the chips.

Impact of improved practice

- An estimated 21 percent of bananas (fresh weight equivalent) was lost during the conventional processing and distribution of banana chips.
- With the introduction of improved practice, the estimated loss during processing and distribution was reduced to 14 percent (fresh weight equivalent).
- With improved practices, a 28 percent reduction in food loss in processing and distribution operations was achieved.

A comparison of the levels of quantitative food loss for the conventional and improved practices in the processing and distribution of banana chips is presented in Table 7.

Figure 19. **Processing, distribution and retail of banana chips**



Source: Authors' own elaboration.

Table 7. **Comparison of quantitative food loss levels for conventional and improved practices in the processing operations of banana chips**

Operation	Quantity of food loss at each step* (percentage fresh equivalent weight)	
	Conventional	Improved
Processing	12.43 ± 7.60	9.08 ± 4.08
Slicing + frying	1.90 ± 1.01	-
Sorting + packing	10.51 ± 7.30	9.08 ± 4.08
Distribution	7.40 ± 2.51	5.22 ± 5.29
TOTAL	21.35 ± 5.08	14.30 ± 6.21

Notes: ± Standard deviation of five production batches. * Mean.

Source: Survey data collected under project GCP/GLO/809/JPN.

Impacts of improved practice

Reduced qualitative loss and improved product quality

- Improvements in temperature control and management of the frying process (oil to chip ratio) resulted in evenly coloured banana chips that maintained their crisp texture.

Economic benefit: On a monthly basis, the enterprise could save approximately 68 kg of bananas, valued at THB 5 100 (USD 146.00) (see Figure 20).

Application of the circular economy to maximize the use of banana chips

Application of the circular economy to maximize the use of banana chips as food and to keep by-products out of landfill.

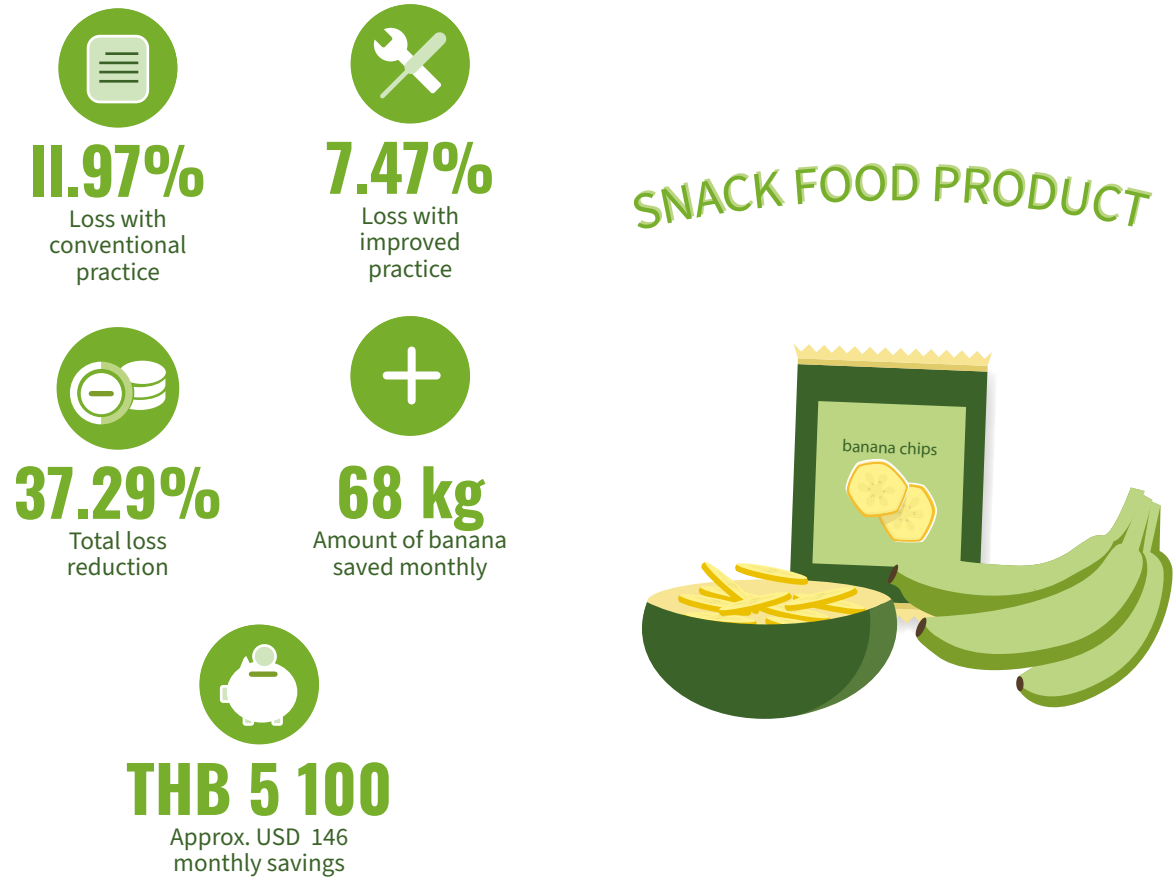
Recovery and redistribution.

- Finished products that did not conform to aesthetic standards but were edible were donated to the needy.
- When the product packaging was damaged in the distribution chain, it was repackaged and sold at a discounted price.

Composting or production of animal feed.

- Banana trims and peels that constituted unavoidable FLW were composted or used as animal feed.

Figure 20. Gains from improved practices in banana chip processing



Source: Authors' own elaboration.

Case study 4. Processing germinated brown rice

The enterprise: The product is produced by a rice community enterprise that engages 15 individuals in its processing, distribution and retail operations.

The product: Germinated brown rice.

Product processing

Raw material: Approximately 1 500 kg of rice paddy was processed monthly into 100 kg of germinated brown rice (see Figure 21).

Conventional processing: The rice paddy was purchased from member farmers, soaked in water and left to germinate overnight in stainless steel basins. The germinated paddy was then cooked by steaming in woven bamboo baskets on a wood stove and dried in a solar dome dryer. It was then milled to remove the husks and polish the grain. The milled rice was conditioned by drying in a solar dome dryer as required.

The grains were sorted either manually or mechanically using a sorting machine, packaged in vacuum-sealed plastic bags and stored at room temperature.

Product distribution

Packaged germinated brown rice was transported in plastic bags to retail shops and stored at ambient temperature.

Inspecting the quality of brown rice during the drying process in a solar dome dryer

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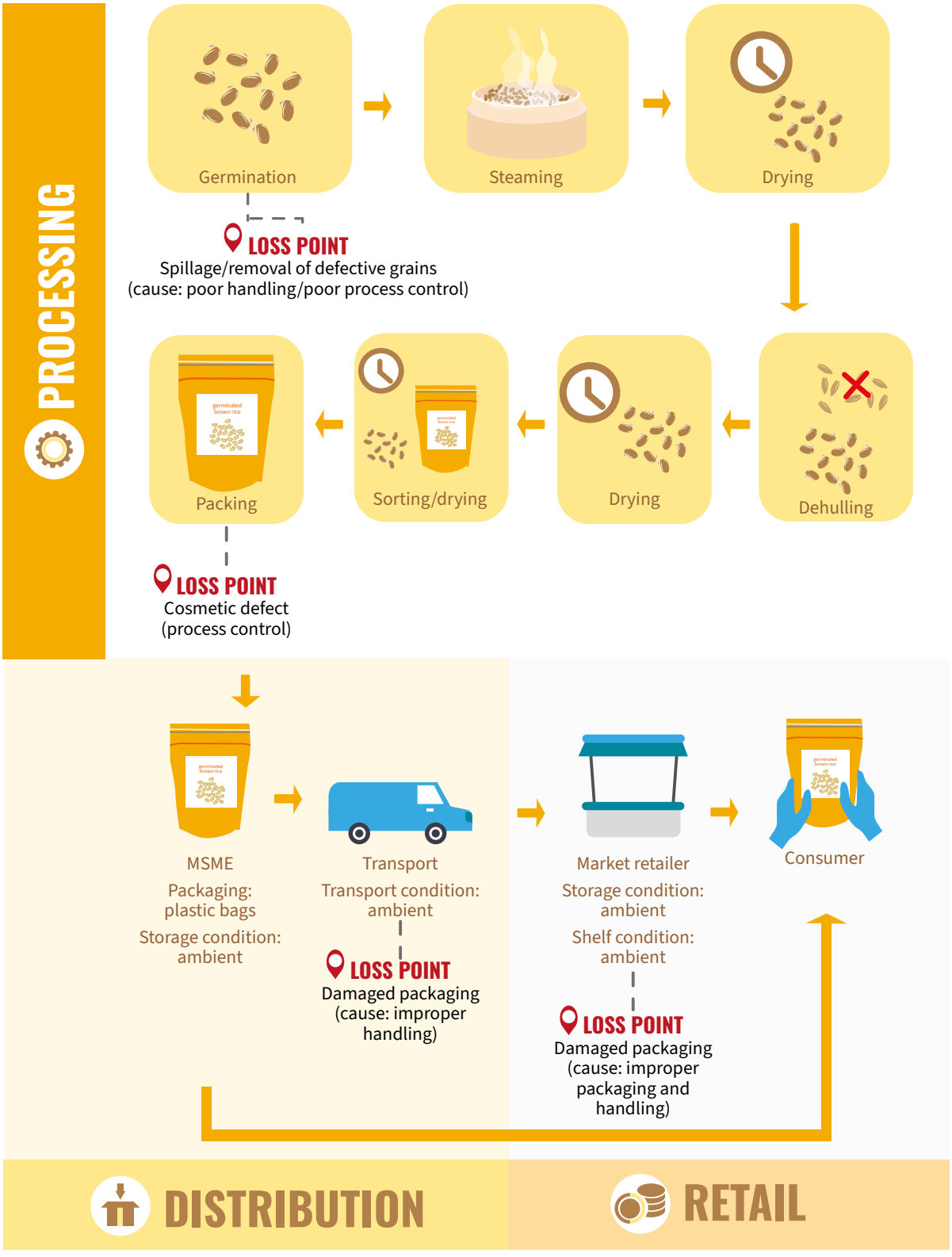
Figure 21. **Processing, distribution and retail of germinated brown rice**



Source: Authors' own elaboration.

Transferring cooked rice grains to a solar dome dryer

Critical loss points and their underlying causes during conventional processing of germinated brown rice

Food loss during processing and distribution

An estimated 28 percent loss (fresh weight equivalent) occurred during processing:

- Soaking and germination accounted for an estimated 14 percent loss (fresh weight equivalent) owing to poor quality of the rice paddy.
- Poor process control during steaming, drying and packaging contributed to a further 14 percent loss (fresh weight equivalent).

Losses in distribution

An estimated 10 percent of loss occurred during the distribution of rice because of poor handling and transportation in poorly sealed plastic bags, which resulted in leakage, breakage and spillage of their contents.

Food waste in retail

An estimated 3.7 percent of germinated brown rice was wasted in retail. The main underlying cause of food waste in retail was damaged packaging that exposed the product to the environment, resulting in oxidation and rancidity of the product that led to spoilage over time.

Improvements introduced for germinated brown rice

Simple items of equipment and good practice were introduced to improve process control during processing and to reduce loss during distribution and waste in retail:

- Improved temperature control during steaming: A thermometer was introduced to monitor the temperature and time of steaming of the paddy to ensure even cooking and a standardized uniform product.
- Improved handling during processing to avoid grain spillage helped to minimize and prevent quantitative loss in processing operations.
- A thermometer was used to monitor the temperature of the solar dome dryer, and a moisture meter was introduced to measure the moisture content of the dried paddy. With proper drying of the paddy (from 12 percent to14 percent moisture), the milling efficiency and quality of the milled rice was improved, with minimal shattering and breakage of the rice grains, thereby significantly reducing loss and improving grain quality.
- Improved sealing of the packaged rice prevented spillage during distribution and reduced the level of food waste caused by oxidative degradation in retail.

Measuring the temperature of the solar dryer

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Measuring the temperature of the rice grains during steaming

Measuring the moisture content of rice grains

Impacts of improved practice

- An estimated 38 percent loss of rice (fresh weight equivalent) occurred during the conventional processing and distribution of germinated brown rice.
- A further 3.7 percent of rice was wasted in retail, largely due to poorly sealed packaging.
- With the introduction of improved packaging and distribution practice, loss in processing and distribution was reduced by 31 percent, and food waste in retail was reduced by 40 percent.

Overall, a 40 percent reduction in FLW was achieved in processing, distribution and retail.

Weighing and packaging rice

Vacuum-packaged rice

Table 8. **Comparison of quantitative food loss or waste levels for conventional and improved practices in the processing and distribution operations of germinated brown rice**

Operation	Quantity of food loss or waste at each step* (percentage fresh equivalent weight)	
	Conventional	Improved
Processing (food loss)	28.11 ±10.39	19.35 ± 3.72
Steaming	3.37 ± 6.18	2.89 ± 1.39
Drying	4.85 ± 6.05	4.14 ± 1.33
Sorting	1.54 ± 0.19	1.07 ± 0.09
Packing	2.87 ± 0.52	2.08 ± 6.21
Distribution (food loss)	10.02 ± 0.79	7.40 ± 1.43
Retail (food waste)	3.69 ± 1.15	2.28 ± 1.07
TOTAL	41.99 ± 10.34	25.16 ± 10.43

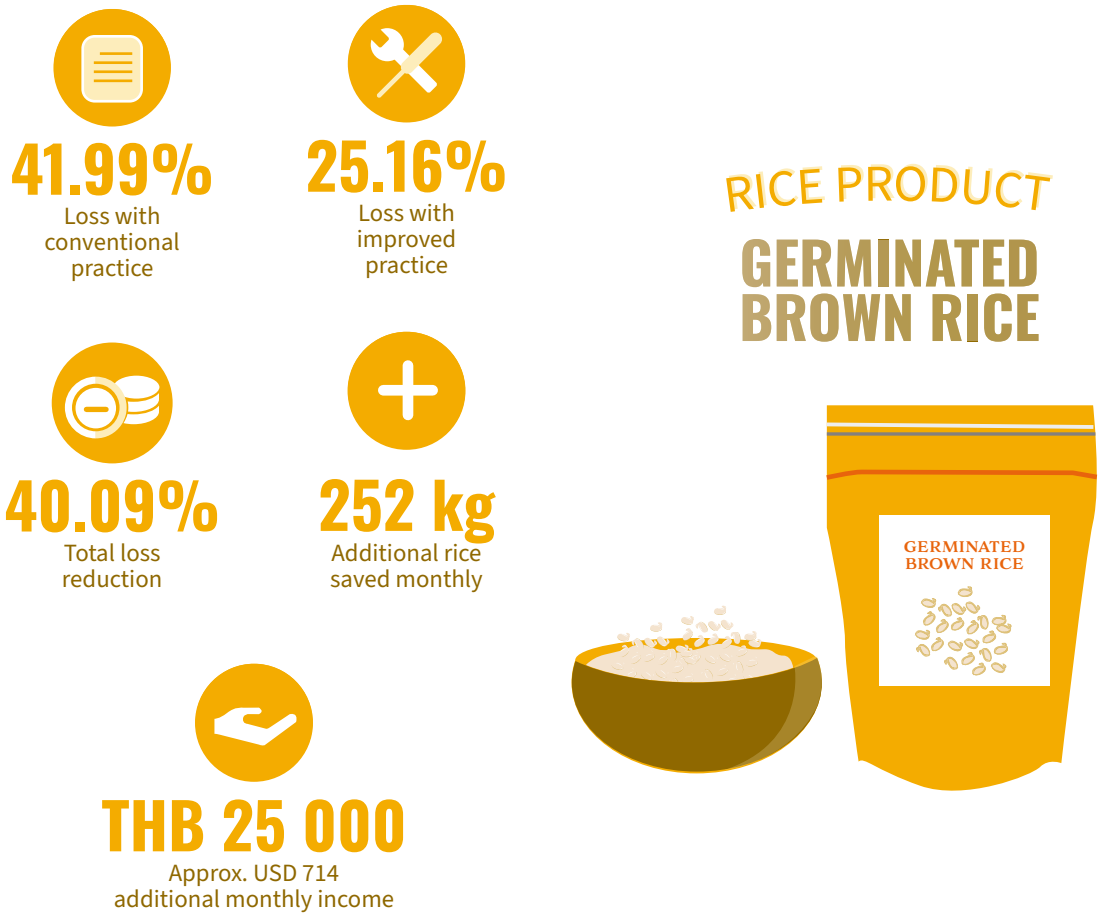
Notes: ± Standard deviation of five production batches. * Mean.

Source: Survey data collected under project GCP/GLO/809/JPN.

Economic benefit

With improvements in process control and packaging and the introduction of improved handling practice to minimize spillage, approximately 252 kg of rice was saved each month, the equivalent of THB 25 000 (USD 714) monthly, based on a retail price of THB 80/kg (see Figure 22).

Figure 22. Gains from improved practices in germinated brown rice processing



Source: Authors' own elaboration.

Applying the circular economy to keep germinated rice and processing by-product out of landfills

Recovery and repackaging of spilled product: product that was spilled during distribution was dried and repackaged for sale.

Composting of processing by-products and avoidable food waste: product spills during processing steps and avoidable food loss such as the husk and bran were used in composting or production of animal feed.

Case study 5. Processing stirred yoghurt

The enterprise: The business is a two-person microenterprise with a production output of 100 kg yoghurt on a weekly basis.

The product: Commercial stirred yoghurt.

Measuring the temperature of milk during pasteurization in a double-jacketed stainless steel pot

Processing operations

Raw materials: Commercial pasteurized milk; commercial stirred yoghurt as a microbial inoculant.

Conventional processing: Store-bought pasteurized milk was stored on ice in a cooler. The milk was pasteurized at 80 °C to 85 °C for 15 seconds in a double-jacketed stainless steel pot on a gas stove and immediately cooled to 45 °C in an ice bath. The cooled milk was inoculated with stirred yoghurt and thoroughly mixed, following which it was incubated in a controlled environment (a warm plastic storage box) for 10 hours. It was then transferred to a cooler, where it was retained overnight at 5 °C to allow curd formation.

The fermented milk (curd) thus formed was filtered through cheesecloth to remove the excess whey and was blended using an electric blender to a homogeneous consistency.

Sugar, fruit puree or both were added at this point for sweetened and flavoured yoghurt. The yoghurt was packed either in plastic bags/tubs or in glass jars with lids and stored in a cooler for sale at an MSME-owned outlet (see Figure 23).

Product distribution

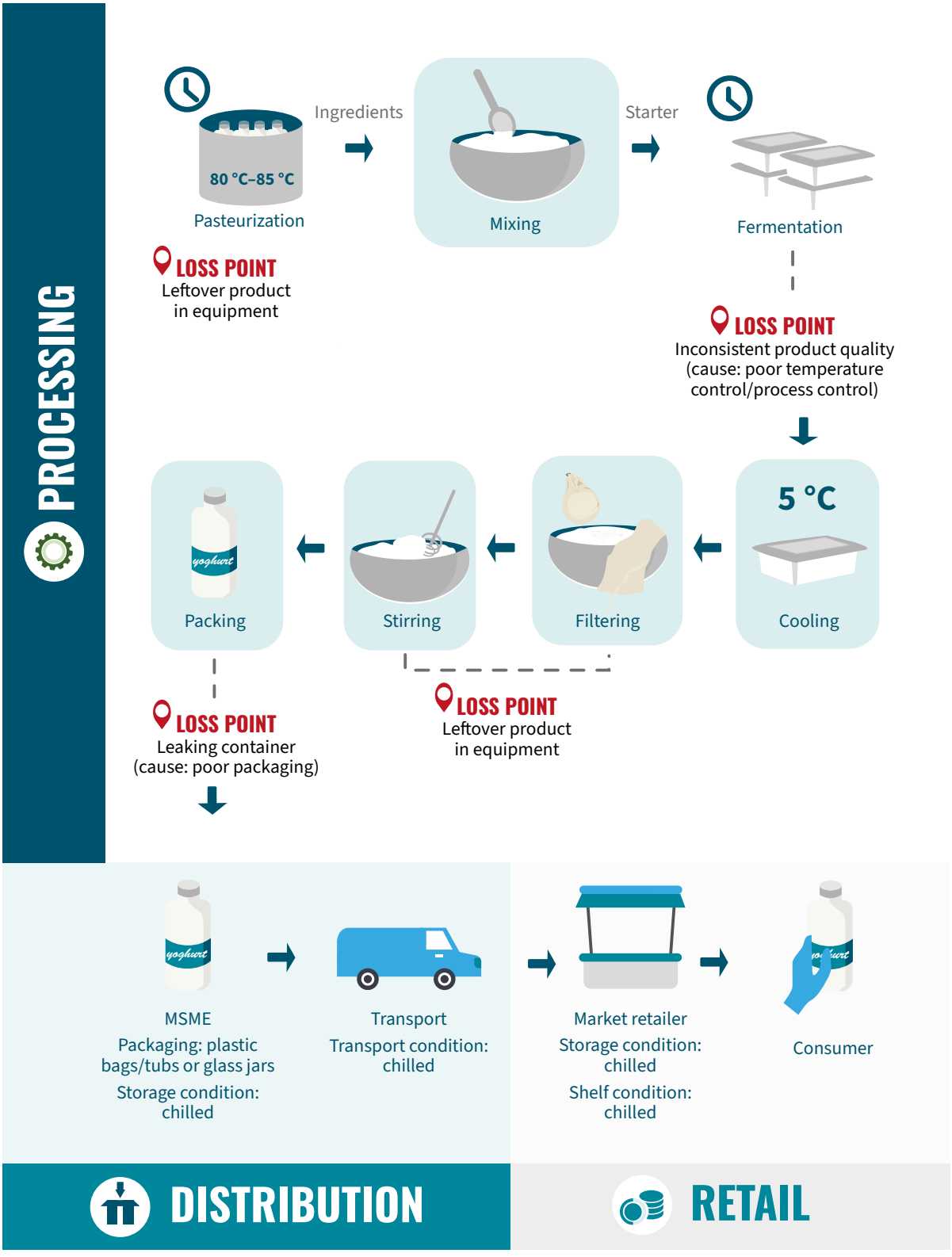
The tubs of yoghurt were shipped under chilled conditions to consumers or to nearby shops.

Product retail

Good stock rotation practice was implemented in retail, with the use of the first in, first out method for displaying product inventory. Older inventory or stock was shipped out and sold prior to putting new stock on display. This ensured that waste from unsold products exceeding their use-by dates was minimized.

Yoghurt on display in retail

Figure 23. **Processing, distribution and retail of stirred yoghurt**



Source: Authors' own elaboration.

Critical loss points and their underlying causes in the conventional processing of stirred yoghurt

Food loss during processing

An estimated 16 percent loss (fresh weight equivalent) occurred during conventional processing of stirred yoghurt. The underlying causes were the following:

- Quantitative loss: leftover product in the equipment during the filtration step of processing and during the stirring process.
- Qualitative loss: loss appearing in the form of inconsistent product quality, mainly non-uniformity in the texture and appearance of the fermented curd that resulted from poor temperature and pH control during the fermentation process.

Loss in distribution: No food loss was detected in distribution.

Waste in retail: No food waste was detected in retail.

Improvements introduced

Measures introduced to reduce food loss at the processing stage and to maintain product quality and consistency were as follows:

- Temperature control of the fermentation process: A thermometer was introduced to monitor the temperature of the fermentation chamber and to facilitate adjustments as required.
- Monitoring of the pH of the fermented milk: The fermentation process was carefully monitored using a pH meter to monitor the lactic acid production and ensure product consistency in terms of flavour (sourness), aroma and texture.
- Monitoring of the total soluble solids content of the milk to ensure product consistency: For this purpose, a refractometer, an instrument for measuring total soluble solids, was used.

Impacts of improved practice

- An estimated 16 percent (fresh weight equivalent) was lost in the processing operations of yoghurt.
- With the introduction of improvements, a 48 percent reduction in loss during processing was achieved (see Table 9).

Table 9. Comparison of quantitative food loss levels for conventional and improved practices in the processing operations of yoghurt

Operation	Quantity of food loss at each step* (percentage fresh equivalent weight)	
	Conventional	Improved
Processing	16.04 ± 1.74	8.31 ± 0.97
Filtering	6.79 ± 0.97	5.07 ± 0.32
Stirring	5.87 ± 1.03	2.05 ± 0.81
Packing	1.13 ± 0.20	0.70+ 0.49

Notes: ± Standard deviation of five production batches. * Mean.
Source: Survey data collected under project GCP/GLO/809/JPN.

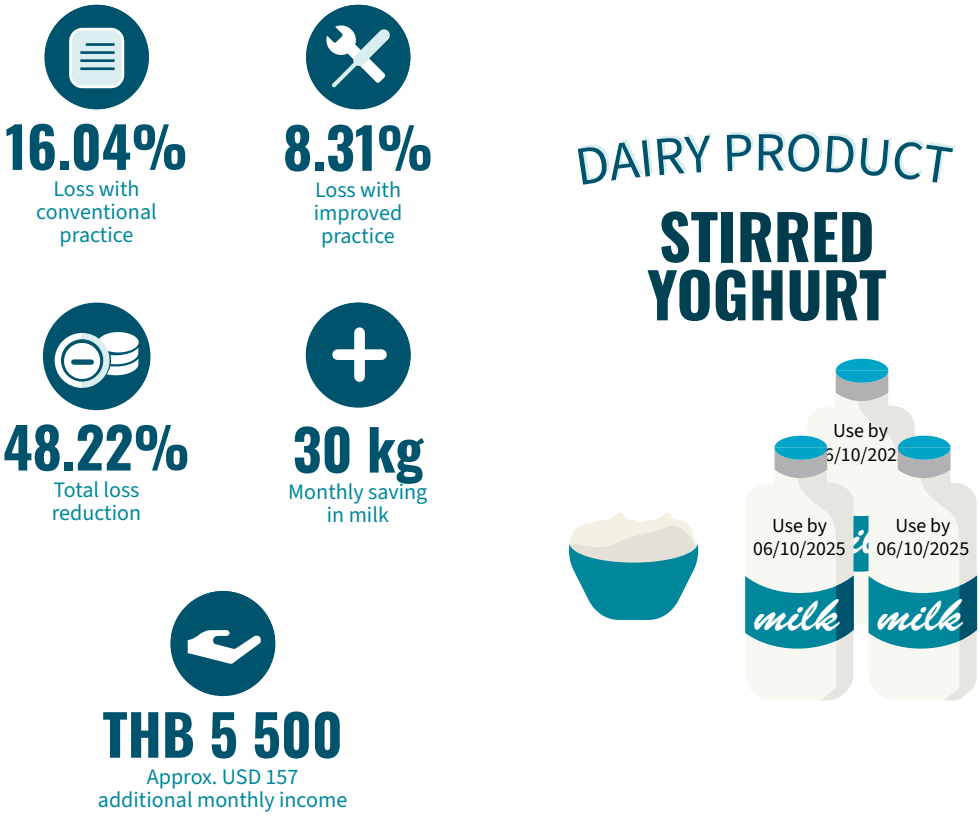
Economic benefit

The enterprise was able to save 30 kg of milk every month, valued at THB 5 500 (USD 157) (see Figure 24).

Measuring the pH of a yoghurt sample

Using a refractometer to measure total soluble solids in the finished product

Figure 24. **Gains from improved practices in stirred yoghurt processing**



Source: Authors' own elaboration.

Applying the circular economy

Recovery and resale of product. Yoghurt in leaking containers, as well as that approaching the use-by date, was collected and served as a "yoghurt bowl" or processed into frozen yoghurt.

Upcycling. Whey, as a by-product of the filtration process, can be used as a baking ingredient substitute or to produce fermented drinks. Upcycling could in the future provide the enterprise with an opportunity to maximize the use of this by-product.

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GLOSSARY

Avoidable food loss	Edible food that is discarded as a result of negligence or as a conscious decision during processing and distribution.
Best before date	The date before which food is of the highest quality. Foods that have passed their best before date can still be consumed.
Circular economy	A model of production and consumption that focuses on waste reduction and creating new value through sharing, recycling and repurposing of products and goods.
Critical loss and waste points	Steps during the processing, distribution and retail stages in which the highest levels of loss or waste are recorded (also called hot spots).
First in, first out	A method of managing the inventory of a product whereby the items that enter the storage area, cupboard or refrigerator first are the first to leave.
Food loss	A decrease in the quantity or quality of food resulting from actions by food suppliers, excluding retailers, food service providers and consumers.
Food waste	A decrease in the quantity or quality of food resulting from decisions and actions of retailers, food service providers and consumers.
Process control	A set of techniques, procedures, practices and machinery, including tools and equipment, that are monitored and adjusted as needed to achieve desired outputs.
Qualitative food loss	A decrease in the attributes or physical characteristics of the food that reduces its value in terms of its intended use.
Quantitative food loss	A decrease in the mass of the food product meant for consumption.
Unavoidable food loss	Inedible food that is thrown away during processing and food preparation.
Use-by date	The date after which food should not be consumed because it could make the consumer ill.

ANNEX

Calculating the levels of food loss and waste

Food loss in processing operations

with

$$\text{Food loss in processing}_{(\%)} = FL_{P1} + FL_{P2} + FL_{P3} + \ldots + FL_{Pi}$$

$$FL_{P\,(\%)} = \frac{W_{In} - W_{Out}}{W_{In}} \times 100 = \frac{W_{Discard}}{W_{In}} \times 100$$

$$W_{In} = W_{In} \times \frac{m_0}{m_{In}} \times \frac{f_0}{f_{In}}$$

$$W_{Out} = W_{Out} \times \frac{m_0}{m_{Out}} \times \frac{f_0}{f_{Out}}$$

$$W_{Out} = W_{Discard} \times \frac{m_0}{m_{Discard}} \times \frac{f_0}{f_{Discard}}$$

where FL_P = food loss during each processing operation step; W_{In} = weight (or volume) of food input to the processing step; w_{In}, w_{Out} and $w_{Discard}$ = weight (or volume) of food output or food discarded from the processing step, respectively; m_0, m_{In}, m_{Out} and $m_{Discard}$ = moisture content of food first entering processing operations, food input, food output or food discarded from the processing step, respectively; and f_0, f_{In}, f_{Out} and $f_{Discard}$ = fat content of food first entering processing operations, food input, food output or food discarded from the processing step, respectively.

Food loss in distribution operations

$$\text{Food loss in distribution}_{(\%)} = \frac{N_{L1}U_1 + N_{L2}U_2 + N_{L3}U_3 + \ldots + N_{Li}U_i}{N_{D1}U_1 + N_{D2}U_2 + N_{D3}U_3 + \ldots + N_{Di}U_i} \times 100$$

where N_{L1} to N_{li} = number of packages of each packaging size that was lost during distribution operations; U_1 to U_i = unit weight (excluding packaging weight) or volume for each packaging size; and N_{D1} to N_{di} = number of packages of each packaging size that enter distribution operations.

Food waste in retail

$$\text{Food loss in retail}_{(\%)} = \frac{N_{W1}U_1 + N_{W2}U_2 + N_{W3}U_3 + \ldots + N_{Wi}U_i}{N_{R1}U_1 + N_{R2}U_2 + N_{R3}U_3 + \ldots + N_{Ri}U_i} \times 100$$

where N_{W1} to N_{Wi} = number of packages of each packaging size that was wasted in retail; U_1 to U_i = unit weight (excluding packaging weight) or volume for each packaging size: and N_{R1} to N_{Ri} = number of packages of each packaging size that entered retail operation.

Estimation of impact of FLW

$$\text{Quantity loss} = \frac{\text{food loss or food waste (\%)} \times \text{production capacity}}{100}$$

$$\text{Monetary loss} = \text{quantity loss} \times \text{retail price per unit}$$

Reduction in food loss and waste

$$\text{Reduction in food loss}_{(\%)} = \frac{FL_{Conventional} - FL_{Improved}}{FL_{Conventional}}$$

$$\text{Reduction in food waste}_{(\%)} = \frac{FW_{Conventional} - FW_{Improved}}{FW_{Conventional}}$$

where $FL_{Conventional}$ and $FL_{Improved}$ = Food loss during operations of conventional and improved practice, respectively

Reducing food loss and waste is an important concern for all stakeholders across the food value chain. There is an urgent need to raise awareness and, more importantly, to build the technical capacities of micro, small and medium-sized enterprises (MSMEs) in the agrifood sector so that they can take action to reduce food loss during processing and distribution.

This manual is designed as an easy-to-use, informational, and instructional resource on how to measure and reduce food loss in MSMEs and to reduce food waste in retail.

Information is presented on:

- identifying food loss hot spots and their underlying causes during processing and distribution;
- measuring the levels of loss at each hot spot;
- introducing simple innovations that are technically, economically and socially appropriate, as well as good practices to reduce food loss at each hot spot; and
- measuring food waste in retail and identifying actions that can measurably reduce the levels of food waste.

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