BREADCRUMB

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DELIVERABLE 2.5

Case Study Estimates of Food Waste Generated due to Marketing Standards

BREADCRUMB

Project title	**BR**inging Evidence-b**A**se**D** food **C**hain solutions to prevent and **R**ed**U**ce food waste related to **M**arketing standards, and deliver climate and circularity co **B**enefits		
Project acronym	BREADCRUMB		
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D2.5 – CASE STUDY FOOD WASTE ESTIMATES

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LIST OF ABBREVIATIONS

Abbreviation	Description
AI	Artificial Intelligence
ARC	Approved Retail Consortium
B2B	Business to Business
BMC	Business Model Canvas
CS	Case Studies
CSRD	Corporate Sustainability Reporting Directive
D	Deliverable
EC	European Commission
EAB	External Advisory Board
EU	European Union
ERP	Enterprise Resource Planning
FAO	Food and Agriculture Organization
F&V	Fruits and Vegetables
FMS	Food Marketing Standards
FMSIG	Food Marketing Standards Interest Group
FSC	Food Supply Chain
FW	Food Waste
GA	Grant Agreement
GFSI	Global Food Safety Initiative
GRMS	Global Red Meat Standard
HACCP	Hazard Analysis Critical Control Points
HORECA	Hotel, Restaurant and Café / Catering
IFS	International Featured Standard
IDI	In-depth interview
JRC	Joint Research Centre
M	Month

PGI	Protected Geographical Indication
T	Task
UN	United Nations
WP	Work Package

EXECUTIVE SUMMARY

This report provides a comprehensive analysis of how Food Marketing Standards (FMS) influence food waste (FW) generation across key food commodities, as explored within the BREADCRUMB project. Focusing on fruits and vegetables, meat, eggs, cereals, and fish, the report draws from multiple case studies conducted in various European countries to examine the role of both public and private FMS in contributing to or preventing food waste.

The report begins with an overview of the BREADCRUMB project, its structure, and the links of this specific tasks to related work packages. It introduces key concepts and definitions relevant to the analysis, including distinctions between food, waste, food waste, and suboptimal products.

The methodology section outlines a structured, multi-step process for data collection, validation, standardization, and analysis. Challenges encountered by the case studies are discussed, along with the specific focus on commodities and products affected by FMS criteria.

Findings from each commodity sector highlight how FMS; particularly aesthetic or technical standards can result in the rejection of edible but non-conforming products, contributing to food waste at various points in the supply chain. For example:

- ✓ In fruits and vegetables, non-compliance with size, shape, or colour specifications leads to high volumes of suboptimal products.
- ✓ In the meat sector, private standards and market expectations impact waste through strict grading and processing criteria.
- ✓ In the egg sector, sorting requirements and fragility contribute to significant waste during handling and processing.
- ✓ In the cereal and fish sectors, specific quality or appearance standards similarly affect product utilization and waste levels.

The report concludes by summarizing the limitations of the study and providing research, policy, and general recommendations. These include calls for greater alignment and flexibility in FMS, improved data collection practices, and support for alternative valorisation pathways for suboptimal products. Collectively, the findings underscore the need to balance the objectives of food safety, quality, and trade with the growing urgency to reduce food waste and promote sustainability across the European food supply chain.

INTRODUCTION

1.1 BREADCRUMB Project Overview

The BREADCRUMB project aims to provide an empirical evidence-based understanding of the purpose and nature of FMS, their impact on FW generation, and based on this evidence, propose interventions that strike a balance between reducing FW and the other objectives pursued by these standards. Furthermore, the project strives to improve market access for suboptimal foods by guiding food businesses to select appropriate marketing channels, and by fostering change in consumers' acceptance of suboptimal foods. All of this information will be structured into operational and policy guidance on how to prevent / reduce FW related to marketing standards.

More specifically, the Grant Agreement (GA) defines the following **procedure for the project** (Figure 1): "(i) establish a holistic view of marketing standards and identify those with key relevance to FW generation; (ii) create evidence-based estimates of FW generated as a consequence of marketing standards; (iii) provide solutions that alleviate the negative impacts of marketing standards on FW, based on a valid understanding of the underlying mechanisms of FW generation and trade-offs with other objectives (re-balancing marketing standards); (iv) enhance the business potential of "suboptimal" foods; (v) inform and guide food businesses, consumers, owners of standards and policy regulators on how to prevent/reduce FW related to marketing standards".[1]

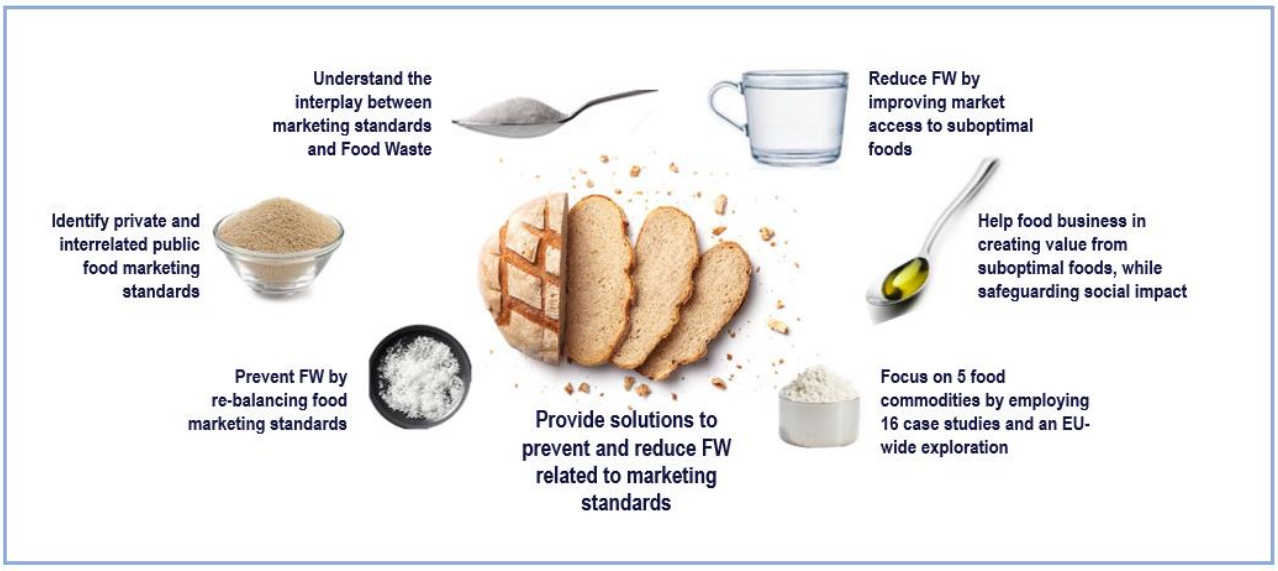


Figure 1: The BREADCRUMB project at a glance

Source: BREADCRUMB Grant Agreement, Part B, page 101 (electronic version).

[1] European Commission. (2023). "Grant Agreement Project BREADCRUMB." European Commission, European Research Executive Agency, (November), page 101 (electronic version).

Moreover, the project intends to incorporate a gender perspective and intersectional analysis across the project. Both are pertinent to better understand the design and response to marketing standards affecting food choices, usage, and waste.

To verify the results, the project will employ various **validation** methods involving participants external to the project. These include:

- ✓ The External Advisory Board (EAB, 6 individuals: researchers, practitioners with complementary expertise);
- ✓ Food Marketing Standards Interest Group (FMSIG, 25 individuals: food businesses, civil society organisations, FW entrepreneurs, policy actors, and Joint Research Centre (JRC) representatives);
- ✓ Specified consultation events, such as workshops, to widen the validation process with a larger group of diverse actors.

The research methodology and approach within the project has been approved by the COMESH **ethical committee** of the project's coordinating partner EV-ILVO.

1.2 Aim and structure of the report

This report D2.5 outlines the work conducted in T2.3, which actively engaged the project's 16 CSs across five food commodities (fruits and vegetables, cereals, meat, fish, and eggs) from M5 to M14 (April 2024 to February 2025). During this period data was collected, pre-processed and analysed. The report will highlight a comprehensive analysis of the objectives, methodologies, and findings related to the Breadcrumb project, with a particular focus on T2.3 and Deliverable 2.5.

This report is organised into four main sections followed by a conclusion.

1. Introduction: which gives an overview of the objectives of the BREADCRUMB project and specific aims of T2.3 (D2.5), the links of T2.3/WP2 with other WPs in the project and some key definitions.
2. Overview of the CSs: gives an overview of the 16 CSs of the project
3. Methodology: which elaborates on data collection, pre-processing, and analysis approaches, including a detailed focus on the food commodities and product categories under study.
4. Findings from the different commodities: The core findings of the report are presented across five separate sections, each dedicated to a specific commodity: Fruits and Vegetables, Cereals, Meat, Fish, and Eggs. Each section evaluates the role of FMS and provides a FW estimate within the respective commodity category, ensuring a structured and detailed examination.

   Key conclusions: key insights are summarised, study limitations are addressed, and research and policy considerations are proposed to guide future work.

5. Finally, the document is supported by an extensive list of References and Appendices, ensuring readers' have access to supplementary information and sources for deeper exploration.

1.3 Links with other BREADCRUMB work packages and tasks

This report centres on task T2.3, **which presents the data collection, pre-processing and sensemaking of the 16 CSs. While this report focuses on the CS**, each WP leverages data and methods from this report. Below an overview is presented of the linkages of T2.3 with tasks of different WPs. This ensures comprehensive, cohesive, and impactful outcomes across the project.

- ✓ **WP1:** T2.3 benefited from the methodologies and data collection protocols established in WP1 (T1.1) and the conceptual model of the potential impact of FMS on FW generation (T1.2). A similar methodological approach of T1.3 was developed and applied to T2.3, ensuring consistency in dataset preparation, processing, and analysis across tasks.
- ✓ **WP2:** T2.3 benefited from the case study plans (D2.2, D2.3 and D2.4); a strategy to close plan, monitor and support the CSs in the realisation of their research objectives. Additional, this deliverable, together with D2.1will further contribute to D2.6.
- ✓ **WP3:** T2.3 synergizes with WP3 by providing essential inputs for developing agent-based (ABM) and macro-economic models methodologies. Developments in T2.3 inform T3.1, contributing to the modelling framework for trade-offs between reducing FW and achieving other objectives. Furthermore, T2.3 leverages information from WP2 to refine and enhance ABMs, which support holistic project analyses.
- ✓ **WP4**: The link between T2.3 and WP4 is strongly centred on the case studies (T2.2 and T2.3). These CS will collaborate in the selection of food products within each food category and will help to validate the Business Model Canvas (BMC) of suboptimal and tools developed in WP4, such as the ***freemium product model*** ("Food Value Navigator") in T4.3. In addition, data from T2.3 is critical for T4.2, where consumer acceptance and segmentation for suboptimal foods are analysed. The collaboration ensures that T2.3's outputs are integrated into testing and validation processes of marketing cues developed in T4.4.
- ✓ **WP5**: T2.3 contributes to WP5 by providing pre-processed datasets that facilitate the analysis of business models and policy impacts on FW reduction. Outputs of WP2 will generally contribute to the communication, dissemination, and exploitation activities of the project.
- ✓ **WP6:** The outputs of T2.3, such as its processed datasets and analytical methodologies are likely to be used in WP6 for overall project evaluation and project impact assessment. The alignment ensures that T2.3's results contribute to the broader objectives of the project.

1.4 BREADCRUMB PROJECT: KEY DEFINITIONS AND CONCEPTS

1.4.1 Food, Waste, and Food Waste

Food or foodstuff can be defined according to the European Commission's (EC) Regulation No 178/2002[2] as any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans. 'Food' includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment. Food shall not include feed, live animals (unless prepared for placing on the market for human consumption), plants prior to harvest, medicinal products, cosmetics, tobacco and tobacco products and narcotic substances.

Waste is generally defined in the EC's Directive 2008/98/EC[3] as any substance or object which the holder discards or intends or is required to discard.

The definition of FW varies from the entity defining it and the context on which it is regarded. In the BREADCRUMB project, the EC's definition of FW, which is considered broader and takes into all food supply chain (FSC) stages is adopted. Specifically, Directive 2008/98/EC[3] defines FW as all food that has become waste.

1.4.1.1 Food Waste Estimates

A FW estimate would refer to a calculated or an approximated quantity of food that is discarded, lost, or wasted along the FSC. A major objective of this study that is to generate estimates for various products of the five food commodities is a step in understanding the magnitude of FW as a result of FMS and the development of mitigation strategies.

1.4.2 Food Marketing Standards

EU FMS are a set of regulations designed to ensure that the single market is supplied with standardized, high-quality agricultural products that align with consumer expectations. These rules aim to facilitate trade and create a level playing field for EU producers. They address both the external qualities of products (such as the appearance of fruits and vegetables) and the non-visible characteristics derived from specific production processes (e.g., the water content in poultry meat or the percentage of oleic acid in olive oil). EU FMS were originally based on existing national and

[2] REGULATION (EC) No 178/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety
[3] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

international guidelines, developed at different times and under varying conditions, tailored to specific products or entire sectors (European Commission, 2020).

The main purpose of FMS is to facilitate trade, ensure products meet consumer expectations, and maintain fairness in the supply chain. These standards aim to:

- ✓ Enhance economic conditions for production and trade.
- ✓ Improve product quality for producers, traders, and consumers.
- ✓ Provide transparent and adequate product information.
- ✓ Ensure standardized, satisfactory quality in the market.

Marketing standards are defined by legislation to guarantee product quality and accurate labelling, (Nes & Ciaian, 2021)

1.4.2.1 Public and Private Food Marketing Standards

Public Food Marketing Standards

Public FMS are regulations established and enforced by government bodies or international organizations to ensure baseline criteria for product quality, labelling, and safety. These standards aim to protect public health, promote fair trade, and safeguard the environment. For example, in the European Union, legislation such as Regulation (EU) 1308/2013 (CMO Regulation)[4] and the "breakfast directives" define mandatory rules on the composition, naming, and labelling of specific food products across member states. Public standards are legally binding and provide a uniform framework for fair trade practices and consumer protection.

Private Food Marketing Standards

Private FMS, on the other hand, are developed and managed by entities such as companies, manufacturers, non-governmental organizations, industry associations, and retailers. These standards are often more flexible and responsive to changing consumer preferences and global market demands. Private standards have emerged to address gaps in public regulations, manage risks, and build consumer trust in food safety and quality. They are also used strategically to enhance brand reputation, manage suppliers, and adapt to the evolving agri-food system.

[4] Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007

1.4.3 Suboptimal Food (Products)

Suboptimal food refers to food products that exhibit physical imperfections deviating from typical visual standards, despite having no issues with intrinsic quality or safety. These imperfections may include irregular shapes, inconsistent weights, or blemished appearances that fail to meet marketing standard and product specifications. Additionally, suboptimal food encompasses items with superficially damaged packaging or those nearing their expiration date, provided their nutritional quality remains intact (Aschemann-Witzel et al., 2019; Cao & Miao, 2021; de Hooge et al., 2017).

2. OVERVIEW OF BREADCRUMB CASE STUDIES

The BREADCRUMB project address five commodities (fruits and vegetables, meat (poultry, bovine, and pork), eggs, cereals, and fish) through 16 multi-actor case studies (Figure 2). The CSs were spread throughout several EU members states targeting different stages of the FSC to ensure the representativeness and enhance comparability of the results obtained. Households or consumers will only be targeted in tasks related to WP4 of the project where suboptimal products identified in the downstream FSC stages will be studied to determine alternative marketing channels. Figure 4 shows a geographical spread of the CSs in the BREADCRUMB project.

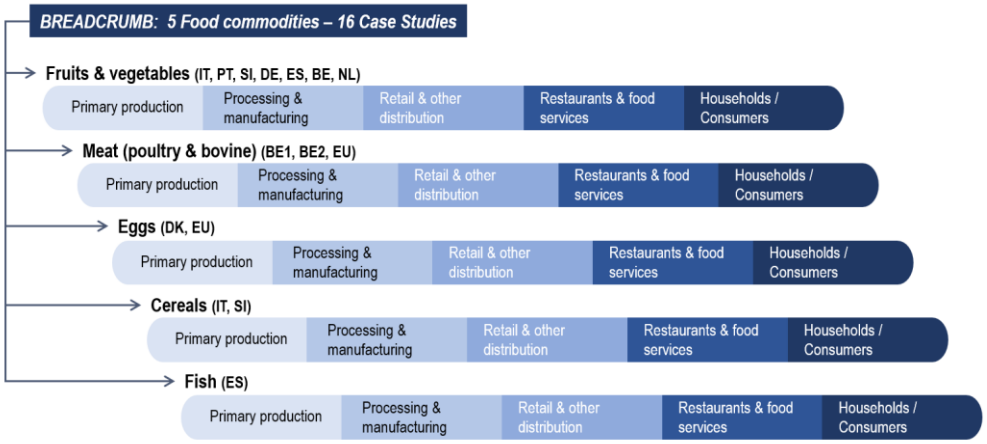


Figure 2: BREADCRUMB case studies, commodities targeted and EU member states involved

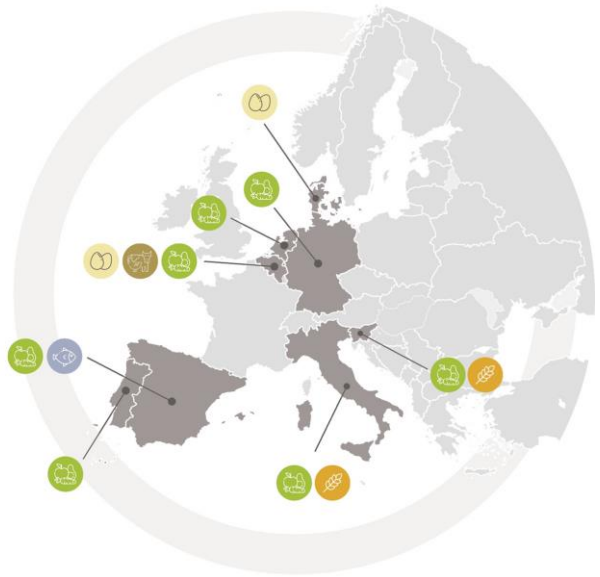


Figure 3: Geographical representation of the case studies

3. METHODOLOGY

The methodology used in T2.3 outlines different stages for the data collection, pre-processing, and sensemaking of CSs datasets. These six-step approach led to the creation of D2.5 (Figure 4):

- ✓ **Step 1 – Case Study data collection (M6 – M10):** CS data was collected using online surveys and in-depth interviews with external stakeholders. This step ensured that a wide range of perspectives and detailed information were gathered to provide a comprehensive understanding of FW caused by FMS.
- ✓ **Step 2 – data quality check (M10)**: Assigned 'data-processors', primarily non-CS project partners, conducted thorough quality checks on the collected data. This step was crucial to ensure the accuracy, reliability, and consistency of the data before further processing.
- ✓ **Step 3 – data standardisation (M10 – M11)**: Cleaned and anonymized data from various CS were filled into a standardized reporting template. This step facilitated uniformity across all datasets, making it easier to compare and analyse the information systematically.
- ✓ **Step 4 – data analysis (M11 – M12)** : Project-assigned CS data analysts, who in some cases were the same organisations/partners as the data processors, conducted detailed analyses of the standardized data. This step involved application of various analytical techniques to uncover patterns, trends, and insights related to FW generation due to FMS.
- ✓ **Step 5 – Reporting (M12)** The data analysts prepared comprehensive reports outlining the insights generated from the CS data analysis process. These reports highlighted key findings, identified significant factors influencing FW, and provided evidence-based conclusions.
- ✓ **Step 6 – review and compilation (M13):** The individual data analysis reports were reviewed to ensure accuracy and completeness. The major task output, D2.5, was then compiled, integrating the insights from all CS into a cohesive document. This final report serves as a critical deliverable for disseminating the findings of the BREADCRUMB project

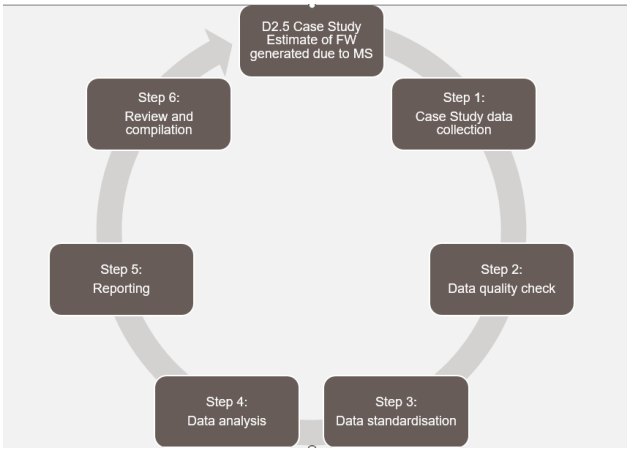


Figure 4: Six-step methodological approach of T2.3

3.1 Step 1: Data collection

3.1.1 Overview

BREADCRUMB CSs employed various data collection techniques (Table 2); and elaborated in D1.1 Data Protocol, to acquire estimates of FW related to FMS. Case studies also prepared and iterated three versions of case study plans (D2.2, D2.3 and D2.4) which further shaped their vision on data collection. The general protocol followed by all CSs involved the use of an information sheet and a consent form (Appendix I). This was used as a first step to inform and seek the approval of the external stakeholders who were contacted to participate in providing answers to the questions either through an online survey or an online/in-person in-depth interview (IDI). A general structure of questions was prepared and used (slightly modified to fit the context where necessary) by the CSs. The questions followed a logical structure to obtain FW estimates from the companies operating in the different food commodities (Figure 5). It also went further to understand the abilities or existing opportunities of companies to handle suboptimal products and their general future plans to reduce FW.

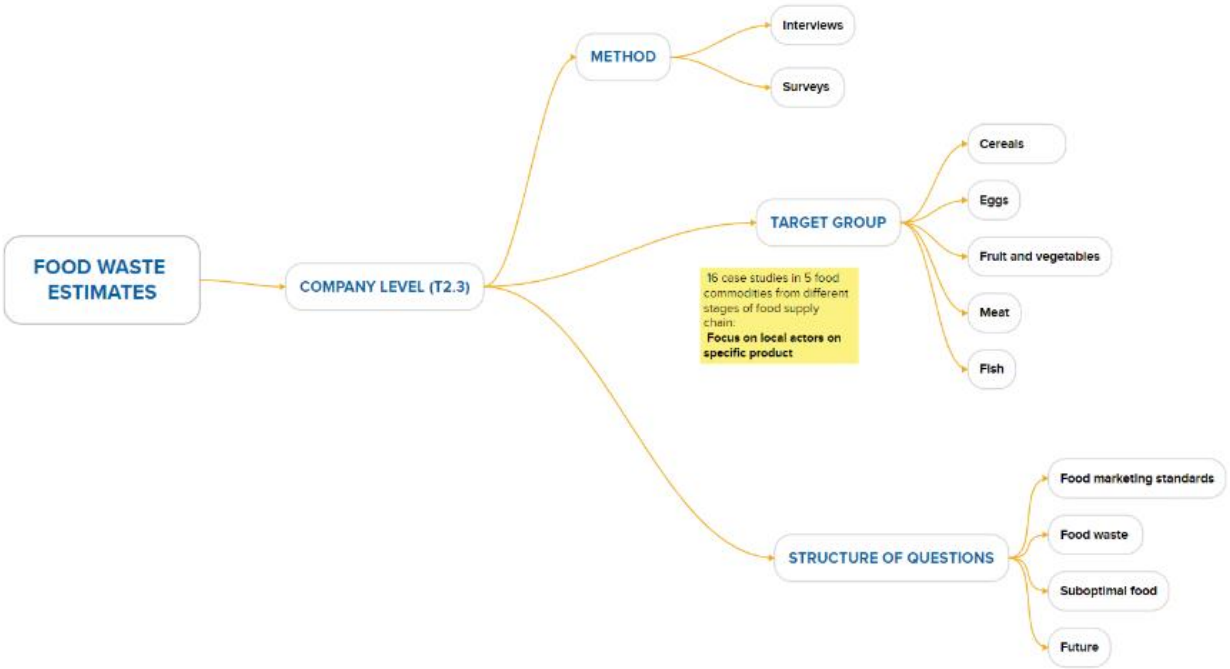


Figure 5: Structure and flow of questions in T2.3

Based on Figure 6, a guide template (Appendix II) with sample questions was prepared for the CSs to further translate and expatiate in their context. The development of survey and IDI questions was an iterative process involving several reviews of different draft versions to produce a final version supervised by CS data processors to ensure the final questions are applicable, understandable, and expected answers synchronized to enhance comparability. During the data collection period (mainly

from M7 – M10; July to October 2024), a total of 101 IDIs were conducted and 39 survey responses recorded (Table 1). Supplementary data was also collected by some companies such as Lehmann Natur through an “internal data collection” method.

Table 1: Case study data collection techniques, data processors and analysts

Food Commodity	**Case Study**	**Data collection techniques(s)**		**Data Processor**	**Data Analyst**
		IDI	Survey		
F&V	F&V.CS1.NN-IT	7		UNIBO	UNIBO
	F&V.CS2.MC-PT	8		VLTN	MC
	F&V.CS3.ZT-SI	16		ITC	ITC
	F&V.CS4.Men-SI	11			
	F&V.CS5.LN-DE	6	Internal data	CSCP	CSCP
	F&V.CS6.Ane-ES	8		AINIA	AINIA
	F&V.CS7.ILVO-BE	5		VLTN	EV-ILVO
	F&V.CS8.ILVO.BE_NL	5			
Meat	M.CS1.Fen-BE	3	9	EV-ILVO	
	M.CS2.AVE-BE_EU	3	11		
	M.CS3.Feb-BE	4	19		
Eggs	E.CS1.LF-DK	5		UCPH	UCPH
	E.CS2.AVE-BE_EU*	5		EV-ILVO	EV-ILVO
Cereals	C.CS1.NN-IT	5		UNIBO	UNIBO
	C.CS2.VN-SI	5		ITC	ITC
Fish	F.CS1.Opp-ES	5		CREDA	CREDA
* = egg case study analyzed in T2.4 for D2.6					

3.1.2 Challenges faced by the case studies

Several challenges were encountered during data collection by case study partners. The major difficulties include:

- ✓ **Stakeholder reluctance**: Many stakeholders, such as suppliers, were either unwilling or unavailable for interviews. Amongst other reasons for this unavailability, was the fact that the interviews were conducted during the summer holiday months. This reluctance often stemmed from concerns about confidentiality, time constraints, or a lack of perceived benefit from participating in the study.
- ✓ **Small sample size and incomplete data**: obtaining a sufficient sample size was challenging and the data, especially quantitative information, was often incomplete. This makes it difficult to draw comprehensive conclusions.
- ✓ **Claims of "No Food Waste"**: Some stakeholders claimed to have no FW, due to them not monitoring or measuring the potential FW which raised questions about the sensitivity of the topic.
- ✓ **Complex and ambiguous questionnaires**: The questionnaires were challenging for stakeholders, incorporating too many perspectives beyond the stakeholders comprehension. This is an aspect solely based on the complexity of the subject matter in question being studied; FMS. This complexity led to confusion and incomplete responses, as stakeholders struggled to understand and answer the questions accurately. These ambiguities resulted in varied interpretations and inconsistent data, complicating the analysis process.

3.1.3 Food commodity and product focus

During the draw-up of case studies plans (D2.2, D2.3 and D2.4), product mapping based on the five food commodities of interest in the BREADCRUMB project was carried out. This was to ensure CSs targeted the most relevant food products at various stages of the FSC to establish clear links between the hypothesized possibility of FMS contributing to the generation of FW. Table 2 below outlines the products and the stage of the FSC that was targeted by each CS.

Table 2: Food commodity, food products at various food supply chain stage targeted by case studies

Food Commodity	**Case Study**	**Products targeted**	**Stage of FSC**
F&V	F&V.CS1.NN-IT	Apples (fresh + processed), Pears, Apricots, Peaches, Plums, Fruit purees + smoothies, Canned + dried fruits	Primary production, Processing, Retail and Distribution,
	F&V.CS2.MC-PT	Lettuce, Round tomatoes, Carrot, Orange, Raspberry, Strawberry, Apple *Gala,* Pear *Rocha*	Primary producers, Processing, Retailer
	F&V.CS3.ZT-SI	Apples, Onions, Potato, Tomato, Zucchini	Primary production, Processing, Retail
	F&V.CS4.Men-SI	Pumpkin Hokkaido, Turnip, Cabbage, Lettuce, Potato, Tomato, Zucchini, Onions, Apple	Primary production, Processing, Restaurant and food services
	F&V.CS5.LN-DE	Limes, Lemons, Cucumbers, Cherry date tomatoes, Peppers	Primary producer, Wholesaler, Retailer
	F&V.CS6.Ane-ES	Citrus fruits, Persimmons	Primary production, Processing
	F&V.CS7.ILVO-BE	Blueberries, Raspberries, Strawberries, Blackberries	Primary Production, Distributor , Retailer, Match marker
	F&V.CS8.ILVO.BE_NL	Bell pepper, Tomatoes, Lettuce	Primary Production Cooperative, Processing, Wholesaler, Match maker
Meat	M.CS1.Fen-BE	Chicken fillet, Bacon, Cooked ham, Raw ham, Sausages, Pâte, Salami Others *(ready meals, head products, sliced raw salty products, beef fillet, meat loaf)*	Primary Production, Processing and Manufacturing, Retail and Distribution
	M.CS2.AVE-BE_EU	Whole chicken, Breast fillet, Legs, Processed products	Primary Production, Slaughtering, Processing and

			Manufacturing, Retail and Distribution
	M.CS3.Feb-BE	By-products*, Fresh meat, Carcases , Meat preparations, Mechanical separated meat, Minced meat*	Primary Production, Processing and Manufacturing, Retail and Distribution
		*= sub-optimal products coming from parts of meat that do not meet standards after cutting	
Eggs	E.CS1.LF-DK	Egg and egg products	Primary Production, Processing (product factory), Retailer and Distribution (packing station)
	E.CS2.AVE-BE_EU*		Primary Production, Retail and Distribution (Packing station), Processing
Cereals	C.CS1.NN-IT	Soybean + soy, Wheat + soft wheat + wheat flour, Corn + soft corn	Primary Production, Processing, and Distribution
	C.CS2.VN-SI	Wheat + wheat flour , Oat + oat flakes, Spelt + spelt flour, Corn, Barley	Primary Production, Processing, Food Service (Restaurant)
Fish	F.CS1.Opp-ES	Sardine, Anchovy, Alatxa, Bogue, Shrimp, Greater Forkbeard, Mediterranean sand eel, Octopus, Norway lobster, Small spotted catshark, Four spot megrim	Primary Production (fishermen), Wholesaler, Retail (fishmonger), Food Service (Restaurant)

3.2 Step 2 - 5: Data quality check, standardisation, and analysis

Once all data was collected by the different CSs, the **assigned data processors**, responsible for the data pre-processing, conducted quality checks on the raw data, such as handing of missing data, standardisation, outlier management, data anonymization, various data transformation and thematic coding. This step ensured that any inconsistencies or errors were identified and corrected early in the process. The data was then anonymized to protect the privacy of the participants and cleaned to remove any irrelevant or redundant information. This cleaned data was subsequently filled into a standardized reporting template, which facilitated uniformity and ease of analysis across all CSs. Following this, the **assigned data analysts**, who were responsible for data analysis and generating insights, conducted detailed analyses of the standardized data. These analyses involved applying various techniques to uncover patterns, trends, and significant findings related to FW and FMS. The data analysts worked meticulously to ensure that the insights generated were accurate and meaningful. To ensure consistency and alignment across the project, several meetings were held among the data analysts. These meetings provided a platform to discuss challenges encountered during the analysis process, share progress updates, and align methodologies and approaches. This

collaborative effort was crucial in maintaining the coherence of the data analysis, ultimately contributing to the robustness of the project's findings.

4. FINDINGS FROM FRUITS AND VEGETABLES COMMODITY

Eight CSs were conducted within the F&V commodity across 7 EU member state countries: Italy, Portugal, Slovenia, Spain, Germany, The Netherlands and Belgium (Table 1 & 2). The selected countries provided a diverse representation of different market conditions and regulatory environments, allowing for a comprehensive analysis of the factors influencing FW in the F&V sector.

The CSs focused on various stages of the Food Supply Chain (FSC), from production to processing, distribution and retail. This approach ensured that all potential points of FW generation were examined. Key areas of investigation included the effects of aesthetic and size standards on FW, the role of private versus public FMS, and the economic implications of compliance with these standards.

4.1 Italy - Natura Nuova

The Italian fresh fruit sector is a crucial part of the national agricultural and food industry. In 2022, fresh fruit production was valued at €5.21 billion, with the fruit processing industry generating €988 million. Fresh fruits make up about 7% of Italy's agricultural output. The sector saw a 28.4% increase in production value from 2021 to 2022. Italy's fruit production is characterized by small-scale farms, with around 123,890 farms averaging 2.4 hectares each. Italian households spent €18.5 billion on fresh and processed fruit in 2022, with fresh fruit accounting for 25.7% of this expenditure. Italy exported €2.99 billion worth of fresh fruit and imported €1.67 billion, mainly bananas and tropical fruits[5].

Challenges for the sector include rising production costs and climate variability, while opportunities lie in organic production and export market expansion. Natura Nuova (NN), a processor of fruits into fruit purées, operates in Emilia-Romagna and conducted interviews with various supply chain actors. These included farmers, fresh fruit distributors, and processed fruit distributors, all located near NN. The interviewed farms are larger than the national average, and the distributors vary in size and market reach, with some having significant international presence.

4.1.1 Food Marketing Standards

Among 18 identified FMS in the fruit and vegetable sector, 39% are public and 61% are private (Figure 6). Public FMS focus on product safety and quality, while private FMS often extend these standards to stricter levels, particularly for premium products. Public FMS are prevalent in primary

[5] ISMEA (2023). Sector factsheet – Fruit. https://www.ismeamercati.it/ortofrutta/frutta

and distribution sectors, whereas private FMS are more evenly distributed across primary production, processing, and distribution (Table 3).

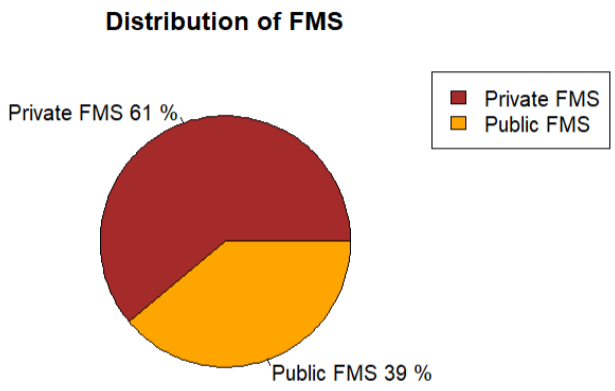


Figure 6: Share of FMS identified in Italy

Public FMS ensure low levels of pesticide residues and guarantee product quality through criteria like imperfections, Brix degree, caliber, and absence of overcolouring. Private FMS, based on public standards, impose stricter criteria for premium classification, including higher caliber, better presentation, and lower imperfections.

The interaction between FMS and FW is crucial, as FMS influence companies' strategies and decision-making. Six out of seven companies interviewed indicated that FMS contribute to FW, but they struggle to quantify this impact. Stricter private standards increase the risk of product rejection and FW generation.

Companies generally view FMS as economically beneficial. Primary producers benefit from higher selling prices and reduced price volatility by meeting FMS for premium products, which helps control supply levels and prevent market oversupply. For processors and distributors, the main advantages are maintaining relationships and reliability in meeting client expectations, aligning with market trends, and ensuring customer satisfaction. However, adopting FMS also brings financial and procedural challenges, especially for primary producers, who face increased fixed costs (e.g., infrastructure investments) and higher production and labour costs. Compliance often requires stricter quality control and more frequent inspections. For processed products, logistics is a major cost driver due to the need for careful planning in purchasing and warehouse management to meet shelf-life requirements. For fresh product distributors, compliance with FMS related to caliber, pesticide residue levels, and brix degree involves significant costs for sampling and analysis, which are essential but expensive.

4.1.2 Suboptimal products

Table 4 provides an overview of the outcomes for products that fail to meet public or private FMS requirements. For primary producers, these outcomes often lead to food loss, as non-compliant products are directly discarded in the field. For processors and distributors, non-compliant products are typically sold at discounted prices, used for alcohol production, or donated, depending on the specific standard and company.

The most frequent destination for fruits and vegetables not complying with FMS is food loss. These products are either left in the field, becoming manure, or discarded if they do not meet public FMS, which are compulsory for market entry. For suboptimal products that do not comply with private FMS but meet public FMS, revalorization strategies include selling them at lower prices to the processing sector for transformation into other food products like purees and juices or for alcohol production. Additionally, processing companies may sell these products at discounted prices to the distribution sector and eventually donate them. Non-compliant products with sufficient remaining shelf life may be discounted further over time and ultimately donated to food banks or other charitable organizations.

The interviews in Italy identified three main destinations for food not complying with FMS: food loss, discounted sales, and revalorization through processing or donation. While food loss is the most common outcome, revalorization strategies provide some financial recovery for companies. However, selling to the industry often results in financial losses, as seen with oranges sold at prices lower than production costs.

4.2 Portugal – MC/MCH

In 2022, Portuguese fruit, vegetable, and flower exports reached a record value of €2.04 billion, marking a 15.6% increase from 2021. Portuguese fruit production is characterized by small to medium-sized family-owned farms, similar to Italy. The sector has seen improvements in efficiency and technological advancements over the past five years[6]. Portugal's annual fruit production is estimated at 1.1 million tons, with key products including oranges, apples, and Rocha pears. The fruit processing industry in Portugal is also significant, with a market size of approximately €1.4 billion[7].

Portuguese households spent a significant portion of their income on food, with food products accounting for 12.9% of total household expenditure in 2022[8]. In addition, Portugal exported €2.04 billion worth of fresh fruit in 2022, with major export destinations including Spain, France, the

[6] Portugal Fresh; Record fruit, vegetable and flower exports - eComercio Agrario
[7] Portugal: Portuguese Fruit Sector Aims to Increase Investments Efficiency and Exports | USDA Foreign Agricultural Service
[8] Statistics Portugal - Web Portal

Netherlands, Germany, the United Kingdom, and Belgium[6]. Imports are not detailed, but the country is not self-sufficient in certain fruits and relies on imports to meet domestic demand[7]. The Portuguese fruit sector faces challenges such as rising production costs, particularly for energy and water management, and climate variability[7].

The MC/MCH CS involved 8 stakeholders across 3 food supply chain stages (Table 1 & 2). Data was collected through structured in-depth interviews, supplemented by internal retailer data. Food waste quantities were self-reported. The study focused on 9 fruits and vegetables (Table 1 & Figure 7).

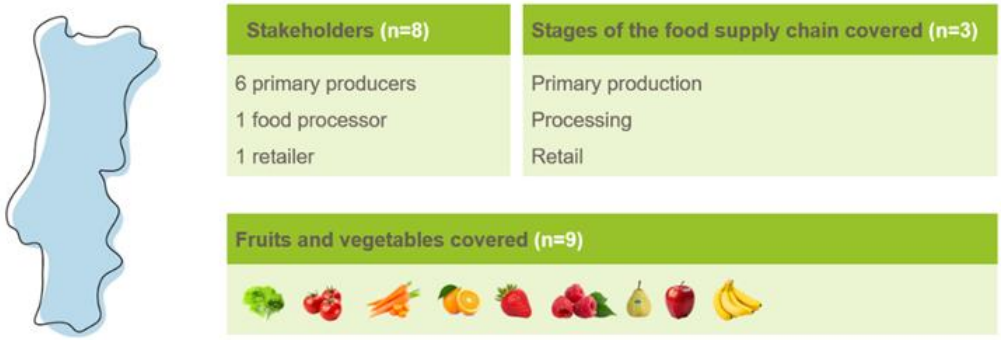


Figure 7: MC/MCH's products and FSC stages

4.2.1 Food Marketing Standards

Portuguese F&V sector implements a couple of public and private FMS (Table 3). Their implementation involves meticulous planning, continuous training, and rigorous quality control measures. Companies, especially primary producers, plan months in advance and select appropriate varieties to meet specific client requirements, which could help reduce FW. Systems like Hazard Analysis Critical Control Points (HACCP) and FMS such as GLOBAL GAP are employed to ensure compliance with hygiene, traceability, and quality standards. Regular audits, both internal and external, along with the use of checklists and technical sheets, are common practices. Investment in machinery and staff training is crucial, and companies maintain quality manuals and fill in various reports to track compliance, especially for certifications like BRCGS and Zerya.

However, the implementation of these FMS presents several challenges. Keeping up with constantly changing legislation and certification requirements is a significant hurdle, often requiring legal or consultancy support. Small and medium-sized enterprises face financial constraints due to the high costs of compliance, including laboratory analyses and audits. The rigorous criteria for product acceptance can lead to increased FW and difficulties in maintaining consistent production levels. Companies also face challenges related to climatic factors, logistical costs, and the need for

continuous employee engagement and training to ensure high standards are consistently met. Human resources costs and the demand for detailed documentation further complicate the process.

Overall, interviewees believe that private FMS are stricter than public FMS. Private standards reflect specific consumer preferences and retailer requirements, which can be more demanding. These standards often lead to more FW due to strict size and quality criteria. The constant changes and higher demands of private FMS, including surprise audits and detailed documentation, make them more challenging to comply with compared to public standards.

Monitoring FW is a common practice among the interviewed companies in Portugal, primarily for financial, production management, and legal traceability reasons. Most companies weigh and record FW to evaluate productivity, profitability, and identify areas for improvement. Some companies, as part of zero-waste initiatives, transform all production waste into other products. Monitoring methods vary, with some companies using precise measurements and others relying on visual estimates.

Several companies reported significant FW due to strict compliance requirements. For instance, one company stated that 90% of their FW is due to FMS, while another highlighted that the challenges of meeting size and quality criteria lead to overproduction and consequently FW. Some companies manage to minimize waste by meticulous planning and using alternative solutions to valorise suboptimal products. However, the rigorous criteria of private FMS often result in higher FW compared to public standards. Despite these challenges, companies strive to adapt and find ways to reduce waste while maintaining compliance with both public and private FMS. For retail, the contribution of products rejected at reception on total products (%) was considered the closest indicator of FW due to FMS (Table 4), despite its weaknesses.

4.2.2 Suboptimal products,

Interviewed companies employ various strategies to enhance the value of foods that are safe for human consumption but do not comply with FMS. These solutions include redirecting out-of-caliber food products to traditional markets, selling non-compliant fruits and vegetables to the puree, frozen food, soup, and ice cream industries, donating to food banks, and using the produce for animal feed. However, selling to the industry often results in financial losses, as seen with oranges sold at a lower price than production costs.

Companies plan to reduce FW by investing in production planning and sales forecasts based on historical data to better align production with demand. Some are developing new products and investing in factories to support these innovations, while others consider implementing mini composting plants or finding more resilient crop varieties. Setting quantitative goals for FW at the start of each campaign and identifying causes of excess waste for future improvement are common

strategies. Despite these efforts, some companies struggle to find large-scale solutions to valorise and reduce FW, highlighting the need for continued innovation and adaptation.

4.3 Slovenia – Zelena Tocka and Mensana

In 2022, Slovenian fruit, vegetable, and flower exports reached a significant value, contributing to the country's overall export growth of 34.2% from the previous year[9]. Slovenian fruit production is characterized by small to medium-sized family-owned farms, similar to Italy and Portugal. The sector has seen improvements in efficiency and technological advancements over recent years[10]. Slovenia's annual fruit production includes key products such as apples, pears, peaches[11], and cherries with the fruit processing industry also notable with a market size of approximately €156.9 million[12].

Slovenian households spent a considerable portion of their income on food, with food and non-alcoholic beverages accounting for 16.8% of total household expenditure in 2022[13]. Slovenia exported a substantial amount of fresh fruit in 2022, with major export destinations including Italy, Croatia, Austria, Germany, and Hungary[14].

The Slovenian fruit sector faces challenges such as rising production costs, particularly for energy and water management, and climate variability[15].

4.3.1 Food Marketing Standards

In Slovenia, there is no specific national legislation regulating FMS for fruits and vegetables. Instead, companies must comply with the FMS established at the EU level, which set clear requirements for quality classification, size, labelling, and packaging. These standards apply to key categories such as apples, tomatoes, citrus fruits, and table grapes, ensuring uniform quality and presentation across the EU market. Compliance with these standards is essential for companies looking to sell their fresh produce domestically or export it to other EU countries.

While EU standards provide a consistent framework, companies can further enhance their market position by obtaining certifications like GLOBAL GAP and adhering to good agricultural practices. These certifications ensure the safety, quality, and sustainability of their products through rigorous processes. Although meeting these standards and obtaining certifications may require investments

[9] Exports and imports of goods, December 2022
[10] KIS_Slovensko_kmetijstvo_v_stevilkah_za_leto_2021_EN_spl.pdf
[11] Characteristics of Agriculture in Slovenia
[12] Fruit & Vegetable Processing in Slovenia - Market Research Report (2014-2029)
[13] Correction – Household budget survey, 2022
[14] Slovenia Vegetable Exports by country 2022 | WITS Data
[15] EN-brochure-agriculture-in-numbers-2024.pdf

in quality control, traceability systems, and staff training, these efforts help companies secure competitive advantages, expand their market reach, and enhance their brand reputation.

FW across key commodities such as Hokkaido pumpkin, turnip, cabbage, lettuce, tomato, potato, zucchini, and onion is influenced by product type, FMS, and production scale. Public FMS focusing on appearance, size, freshness, and colour drive significant FW at the primary production stage, especially for fresh products like turnips, cabbage, and lettuce. In contrast, processing stages show relatively lower FW, primarily caused by peeling, trimming, and handling inefficiencies rather than direct FMS enforcement. The Restaurant and other Food Services stage also contributes to FW, driven by customer-focused quality and freshness standards.

At the primary production stage, strict public standards lead to non-compliant products being discarded, left in the field, or diverted to secondary uses such as animal feed or composting. For example, turnips often face rejection due to appearance and size, contributing to high FW levels. Products like tomatoes and zucchini are sometimes repurposed into sauces, pickles, or soups, minimizing losses. In the processing stage, FW arises mainly due to operational inefficiencies, with losses occurring during preparation processes like peeling and trimming. Processing FW is often diverted to secondary uses like animal feed or compost, with potato peels and rejected zucchini being repurposed efficiently. In the Restaurant and Food Services stage, FW is influenced by strict private standards for quality, taste, and freshness.

Generally, primary production remains the most critical point of FW generation, driven by public standards focusing on appearance, size, and freshness. Processing stages experience lower FW, with losses primarily stemming from preparation processes. The Restaurant & Food Services stage represents an additional point of FW generation, driven by private customer demands, but also offers opportunities for waste reduction through repurposing. Effective mitigation strategies, such as repurposing rejected products into sauces, pickles, or animal feed, highlight opportunities for reducing FW, particularly for fresh produce. Smaller producers effectively reduce FW by processing rejected products into compotes or sauces, while larger systems face higher FW due to stricter enforcement of FMS and larger quantities rejected.

4.3.2 Suboptimal products

Suboptimal produce like tomatoes, zucchini, and apples is often repurposed into sauces, juices, or pickles, while items such as onions, potatoes, and pumpkins are more likely to be discarded due to limited reuse options. Restaurants can reduce food waste by creatively using imperfect produce, though severely damaged items are usually thrown away.

4.4 Germany – Lehmann Natur

In 2022, German fruit, vegetable, and flower exports reached a significant value, contributing to the country's overall export growth. German fruit production is characterized by a mix of small to medium-sized family-owned farms and larger commercial operations. The sector has seen improvements in efficiency and technological advancements over recent years[16]. Germany's annual fruit production includes key products such as apples, pears, strawberries, and cherries[17]. The fruit processing industry in Germany is also notable, with a market size of approximately €12.4 billion[18].

German households spent a considerable portion of their income on food, with food and non-alcoholic beverages accounting for 15% of total household expenditure in 2022[19]. Germany imported a substantial amount of fresh fruit in 2022, with major import sources including Spain, Italy, the Netherlands, and France. Imports are essential to meet domestic demand, especially for tropical and exotic fruits[20].

The German fruit sector faces challenges such as rising production costs, particularly for energy and labour, and climate variability. The sector's focus on sustainability and certification also provides a competitive edge in the market[21].

The German case study on F&V was conducted in cooperation with the German organic wholesaler Lehmann Natur (LN) and CSCP. It focused on five key commodities for LN in terms of volume and sales (Table 1 & 2). The study utilized two data sources: internal data from LN's merchandise management system and six interactions through verbal or written questionnaires with international and European F&V suppliers of LN.

4.4.1 Food Marketing Standards

Most of the food produced by the six suppliers was sold in conformity with standards, as LN communicated its specifications and requirements clearly. Suppliers were aware of LN's requirements and EU standards (Table 4), resulting in high compliance rates. The percentage of F&V's sorted out or rejected by retail consumers due to not meeting standards ranged from 30% for limes to 11% for cucumbers. The strict FMS led to significant FW, particularly for products that did not meet specific standards. In some companies, FMS are enforced by sorting the fruit by quality with an AI-supported sorting machine. Non-compliant products were often devalued, repurposed, or

[16] Thünen: Trends in German fruit and vegetable cultivation
[17] Germany: Product Brief Fresh Fruits | USDA Foreign Agricultural Service
[18] Fruit & Vegetable Processing in Germany - Market Research Report (2014-2029)
[19] Consumption expenditure - German Federal Statistical Office
[20] The German market potential for fresh fruit and vegetables | CBI
[21] Exporting fresh fruit and vegetables to Germany | CBI

discarded, contributing to overall FW. The need to meet stringent size, colour, and quality requirements resulted in some produce being used for secondary purposes or left unharvested, highlighting the impact of FMS on FW generation.

4.4.2 Suboptimal products

Despite high compliance, all six suppliers reported some level of "devalorisation" due to FMS. This included produce that could not be exported to the European or German market and had to be sold locally at lower prices or used to produce other products like juice for human consumption (for one company this could amount up to amounting to 4,619,000 kg/year, and revalorizes 7,550,000 kg/year into products like lemon juice from green-coloured lemons). Some limes, tomatoes, and cucumbers were used as animal feed (4,000 kg/year), composted, or left in the field when they did not meet size, colour, or other customer requirements. Additionally, between 0.28% and 2.65% of unsellable produce per commodity was sold by LN to the wholesale market. LN also had to discard between 1.15% and 2.27% per commodity due to defects or rejections by retail customers.

4.4.2.1 Product targeted recommendations to reduce future food waste due to food marketing standards in LN

- ✓ Limes: Allowing for a higher tolerance of discoloured, yellow limes could reduce devaluation and waste upstream in the supply chain.
- ✓ Lemons: The project team suggests discussing with German retailers the possibility of extending the 2024 special agreement to accept a certain share of green lemons due to adverse weather conditions. This could help maintain higher acceptance rates and reduce rejections, while also working on end-consumer acceptance.
- ✓ Cucumbers: The issue of "soft edges" in cucumbers, which occurs more frequently in hot months or at the end of a production cycle, could be mitigated by switching to foil packaging. This would prolong shelf life and reduce the number of cucumbers unsuitable for human consumption.
- ✓ Cherry Date Tomatoes and Peppers: Increasing spoilage tolerance by retail clients from 3% to 5% and implementing a sorting process at the retail site could reduce the need for time-intensive and ecologically questionable transportation of quality products. An annual refund agreement for spoiled goods exceeding 5% could be considered instead of returning the goods. Additionally, the practice of "Drop Shipping" with one organic retailer, where products are sent directly from the producer to the retailer where sorting could be implemented in case of complaints, could be expanded to reduce transportation times and waste.

4.5 Spain – ANECOOP

In 2022, Spanish fruit and vegetable exports reached a significant value, contributing to the country's overall export growth. Spanish fruit production is characterized by a mix of small to medium-sized family-owned farms and larger commercial operations[22]. Spain's annual fruit production includes key products such as oranges, lemons, cucumbers, cherry tomatoes, and peppers[23]. The fruit processing industry in Spain is also notable, with a market size of approximately €13.3 billion[24]. Spanish households spent a considerable portion of their income on food, with food and non-alcoholic beverages accounting for 12.9% of total household expenditure in 2022[25]. Spain exported a substantial amount of fresh fruit in 2022, with major export destinations including Germany, France, the Netherlands, the United Kingdom, and Belgium. Imports are essential to meet domestic demand, especially for tropical and exotic fruits[22].

ANECOOP is a prominent cooperative in Spain, known for being one of Europe's leading suppliers of F&V, and salad products. Established in 1975, ANECOOP has grown to become a significant player in the agricultural sector, with a network that spans across 13 provinces in Spain[26]. ANECOOP offers a diverse range of products, including citrus fruits and persimmons (Table 1 & 2). They are particularly noted for their citrus fruit exports[27]. ANECOOP is committed to sustainable practices such as prevention and reduction of FW and maintaining high-quality standards in their production and distribution processes. ANECOOP's extensive network and commitment to innovation and quality make it a key player in the fruit and vegetable market in Spain and beyond.

4.5.1 Food Marketing Standards

Table 4 compiles the FMS also implemented in Spain. Implementing these FMS presents several challenges, particularly in the context of the F&V sector. These include:

- ✓ Regulatory Compliance: Older members may struggle to understand the field's rules. Regulations are often poorly adapted to the specific needs of the fruit sector, focusing more on general food standards that do not fit well with fruits and vegetables.
- ✓ Quality Standards and Labelling: Quality standards do not consider the size of the company or the unique aspects of the fruit and vegetable sector. There is a need to segregate qualities and manage labelling according to each customer's requirements, which can be inconsistent

[22] The Spanish market potential for fresh fruit and vegetables | CBI
[23] Inside Spain's Citrus Industry - Citrus Industry Magazine
[24] https://citrusindustry.net/2018/07/03/inside-spains-citrus-industry/
[25] Notas de prensa INE (inglés)
[26] Anecoop Group - Anecoop
[27] Agriconsa , Which is, who are, history, Agriconsa, Anecoop, cooperatives, farmers, Valencia, Spain, Europe, EU

and challenging. Also, specific customer demands, such as de-greening oranges for aesthetic purposes, can lead to issues like weight loss, spots, and rot.

- ✓ Economic and Resource Challenges: Increasing regulations require significant economic resources for infrastructure, computer equipment, personnel, and audit fees, which can amount to around €100,000. Customers' demands for pest-free and cosmetically perfect fruit, despite it being grown outdoors, add to the economic burden.
- ✓ Operational and Training Issues: Training staff and controlling production is difficult, especially with many small farms adds to the challenges. In addition, maintaining facilities to meet regulatory standards is economically challenging. Also, adapting standard requirements to the company's characteristics and product is difficult, and measuring necessary parameters for certification is also a challenge.

Overall, the implementation of FMS in the F&V sector involves navigating complex regulations, meeting diverse customer demands, and managing significant economic and operational challenges.

4.5.2 Suboptimal products

Suboptimal products in the Spanish F&V sector are managed through various strategies. Some products are sold to the juice and animal feed industries or second-category markets, even if they do not recover the full cost of handling and collection. In some cases, products are discarded to free the fruit tree. Efforts are made to find customers in local markets for both fresh and juice products. Additionally, there are projects like dehydrated persimmon studies to explore potential sales.

To reduce FW, several measures are being implemented. These include chemical and biological treatments in the field to control pests, thinning to improve fruit calibre, and regular actions by the cooperative's technical team to assist farmers. Post-harvest treatments are being improved to reduce rot, and harvesting colour is optimized to minimize rotting and staining. Farmers receive aid for plantation renovation, and there are ongoing efforts to find customers for low-category products. Training and advice are provided to farmers to enhance pest control and productivity.

4.6 Flanders and the Netherlands – ILVO

Flanders, the northern region of Belgium, is a significant hub for fruit production, particularly for soft fruits like strawberries, raspberries, and blueberries. In 2023, Flanders hosted 1,674 fruit farms, accounting for 7.7% of the region's agricultural producers[28]. However, the number of fruit farmers has been steadily declining over the years. Strawberries are a cornerstone of Flanders' soft fruit

[28] Key Figures on Agriculture 2023 | Statbel

production, with a yield of 51,453 tons in 2023. Major strawberry cultivation areas include Hoogstraten, Roeselare, and Beveren[29]. The popularity of other soft fruits, such as raspberries and blueberries, has also been rising, reflecting changing consumer preferences and market trends[30]. A distinctive feature of fruit and vegetable production in Flanders is the auction obligation. There are three main auctions for vegetables and fruit: Belorta, Reoveiling, and Hoogstraten. The umbrella organization for these auctions, VBT (*Verbond van Belgische Tuinbouwcoöperaties*), provides a platform for knowledge exchange and sector-relevant information. All producers must pass their produce through these auctions, where most products are also packaged. Approximately 85% of strawberries are sold via the auction clock, setting the retail price, while only 5% of berries are sold this way, making them more attractive for promotions.

The Netherlands excels in producing tomatoes and bell peppers, utilizing advanced greenhouse technology to achieve high yields on limited arable land. Regions like Westland and Venlo are known for their state-of-the-art greenhouses, featuring automated climate control, hydroponics, and energy-efficient lighting. Sustainability is a cornerstone of Dutch horticulture, with practices such as closed-loop water systems, carbon dioxide recapture, and renewable energy integration reducing resource use and environmental impact. Integrated pest management (IPM) further supports eco-friendly production by minimizing chemical pesticide use. The Dutch Quality Control Bureau (*Kwaliteits Controle Bureau*, KCB)[31] ensures high standards in Dutch horticulture by enforcing compliance with national and international quality regulations. This bureau monitors the safety, consistency, and presentation of tomatoes and bell peppers for export. These products are key exports, bolstered by the Netherlands' strategic location and efficient logistics. Ongoing research and innovation in genetics, cultivation techniques, and digital farming maintain the country's competitive edge and global leadership in horticulture.

4.6.1 Food Marketing Standards

Public FMS in Flanders and the Netherlands, likewise in many EU countries, are crucial for ensuring consistency, quality, and fair market practices in the trade of fresh fruits and vegetables. These standards have been streamlined from 36 to 10, with specific standards for products like strawberries to ensure uniformity across markets[32]. Public FMS simplify trade by providing clear guidelines, facilitating market integration and competitiveness, especially for export-driven countries like Belgium. The UNECE Standards provide norms for various fruits and vegetables, ensuring consistency in size, shape, colour, and condition across international markets. Regulation 543/2011,

[29] Spatial distribution of fruit cultivation | Agriculture & Fisheries
[30] Fruit | Fruit and vegetables from Flanders
[31] Home | KCB
[32] Fruit and vegetables - European Commission

amongst others (Table 3) outlines marketing standards, quality requirements, and packaging guidelines to maintain the integrity of produce. Private FMS are essential for ensuring food safety, sustainability, and compliance with market-specific requirements. Key certifications like IFS and GLOBAL GAP focus on food safety, quality assurance, and good agricultural practices. Additional modules like SPRING and GRASP address water management and social responsibility. Retail-driven standards often require add-ons to GLOBAL GAP , such as sustainability-focused modules or unique certifications. The implementation of FMS poses challenges due to specific client requirements and diverse packaging needs. Producers must be flexible to meet these demands, which can be time-consuming and lead to increased labour and potential waste. Despite these challenges, compliance with FMS offers opportunities to strengthen partnerships with quality-driven customers and meet growing consumer expectations for safety, sustainability, and ethical sourcing.

FW in soft fruit production in Flanders mainly consists of rot, which cannot be repurposed. Once fruit fails to meet industry standards, its economic value drops significantly, posing challenges for producers who operate on slim profit margins. Strict classification standards exist, with Class 1 and Class 2 having stringent quality criteria, while Class 3 is typically used for frozen fruit with less rigorous standards.

4.6.2 Suboptimal products,

In Flanders, surplus soft fruits like avocados are sent to oil processors, while rejected blueberries are frozen and sorted for use in yogurt and frozen goods. Retailers use innovative technologies, such as organic peel coatings, to extend the shelf life of avocados. Surplus products unsuitable for fresh markets are processed into concentrated purees or frozen goods, enhancing sustainability and reducing waste. While in the Netherlands, matchmaking platforms connect producers with processors to turn surplus agricultural products into long-lasting items. These platforms facilitate the streamlined food supply chain by packing and delivering surplus items directly to members' homes. Misfit vegetables like tomatoes and bell peppers are processed into purees, providing new revenue streams for producers. Regular communication with producers ensures feasible product transformation, balancing economic viability and waste reduction.

In Flanders and the Netherlands, the following were advanced as possible pathways for future planning to prevent and reduce FW.

- ✓ Technological advances: By 2027, a new Enterprise Resource Planning (ERP) system will be implemented by a Belgian distributor of soft fruits to enhance tracking and reporting of food waste, aiding in meeting Corporate Sustainability Reporting Directive (CSRD) standards. The Dutch matchmaking platform is exploring tools like *'Overschot Spot'* to connect surplus producers with potential users.

- ✓ Semi-finished products and flexibility: A Belgian distributor plans to work with semi-finished products, allowing for finalization based on market quality and requirements, increasing flexibility and reducing waste.
- ✓ Carbon accounting and certifications: Carbon accounting will become mandatory for growers supplying retail, with certification systems like GLOBAL GAP incorporating carbon metrics to align practices with environmental expectations.
- ✓ Reforming certification landscape: Future plans include redefining FMS to encourage acceptance of non-standard produce, reducing rejections, and adding value for growers. Shorter supply chains and closer collaboration with producers can drastically reduce waste.
- ✓ Acceptance of imperfect produce: The goal is to ensure no produce is wasted by fostering societal acceptance of imperfect produce and building robust networks for collaboration across the supply chain.

4.7 General overview of Food Marketing Standards in Fruits and Vegetables

Table 3 below outlines some FMS implemented in the F&V commodity, detailing both public and private FMS. It includes specific contexts, stages of the FSC where they are applied, and the EU countries (the case studies) where these standards are implemented.

Table 3: Overview of FMS in BREACRUMB F&V case studies, member states, and stages of FSC where they are applied

Type of FMS	FMS	Specific FMS (context)	FSC implemented	EU countries implemented
Public	Regulation (EU) No 543/2011	✓ Premium product: Overcolouring of the peel >40%	✓ Primary production	✓ Italy ✓ Portugal ✓ Slovenia ✓ Germany ✓ Spain ✓ Belgium ✓ The Netherlands
		✓ Absence of imperfections (10% tolerance)	✓ Primary production ✓ Retail ✓ Distribution	
		✓ Caliber	✓ Primary production ✓ Retail ✓ Distribution	
		✓ Brix degree (sweetness)	✓ Primary production ✓ Retail ✓ Distribution	
	Regulation (EC) No 396/2005	✓ Pesticide residues level	✓ Primary production ✓ Retail ✓ Distribution	

		✓ Phytosanitary products levels	✓ Primary production	
	Regulation (EU) 2018/848	✓ Less chemical residues for organic production	✓ Primary production ✓ Retail ✓ Distribution	
	Regulation (EU) 2016/2031	✓ Protects against pests of plants. ✓ Establishes phytosanitary measures to reduce pest risks.	✓ Primary production	
	Regulation (EC) No 852/2004	✓ Ensures food safety ✓ Hygiene requirements for food business operators.	✓ All stages of production.	
	Commission Delegated Regulation (EU) 2019/428	✓ Amends marketing standards for fruits and vegetables. ✓ Aligns with UN/ECE revised standards.		
	Regulation regarding bio products	✓ Organic production and labelling.	✓ Primary production ✓ Processing	
	IGP - National	✓ Protects names of products with specific geographical origin.	✓ Primary production	Portugal
	Regulation (EU) No 1169/2011	✓ Labelling : covers labelling, allergens, nutrition information, and product origin.	✓ Processing ✓ Retail and distribution	ALL
	HACCP – International	✓ Food safety	✓ Primary production ✓ Processing ✓ Food services	

	UNECE Standards[33]	✓ Size ✓ Shape ✓ Colour ✓ Condition	✓ Primary production	
Private	Private contracts, certifications and Labels	✓ Caliber higher than public standard	✓ Primary production	
		✓ Absence of imperfections (5% tolerance)	✓ Primary production	
		✓ Pesticide residue levels below 40-70% of legal levels	✓ Primary production	
		✓ Specific acidity/ sugar levels	✓ Primary production	
		✓ Remaining shelf life	✓ Processing	
		✓ Product presentation	✓ Processing	
		✓ Firmness	✓ Distribution	
		✓ Standard International Featured Standard (IFS)	✓ Distribution	
		✓ BRC(G) certification – International	✓ Distribution	
		✓ GLOBAL GAP – International	✓ Primary production	
		✓ ISO 22005	✓ Distribution	
		✓ ZERYA® Certification – European	✓ Primary production ✓ Processing	
		✓ Kosher Certification – International		
		✓ Client's technical sheets – Regional		
		✓ Demeter	✓ Primary production ✓ Wholesaler	

[33] Fresh Fruit and Vegetables - Standards | UNECE

			✓ Retailer	
		✓ BIO Suisse	✓ Primary production ✓ Wholesaler ✓ Retailer	
		✓ Naturland		
		✓ PGI (Protected Geographical Indication)	✓ Primary production	
	Retailers standards	✓ ASDA ✓ TESCO Manufacturing ✓ NURTURE ✓ ALDI	Distribution	
		✓ LEAF	Primary production	
		✓ Farmers and nature (Boer & Natuur)	Primary production	Flanders – Belgium

4.8 Estimates of Food Waste in Fruits and Vegetables targeted in the study

Table 4 provides estimates of FW in F&V across different countries, focusing on the impact of FMS on FW generation. The table highlights the commodities with the highest and lowest FW percentages due to FMS, as well as a comparison of the same products in different countries.

Highest estimates of FW/produce sorted out due to FMS

- ✓ Limes (Germany, Primary Production): **30.0%** sorted out due to colour requirements and spoilage.
- ✓ Carrot (Portugal): **24.2%** due to standards related to appearance (broken carrots, size, and deformation).
- ✓ Persimmons (Spain, primary production): **22.47%** due to FMS at primary production.
- ✓ Persimmons (Spain, Processing): **13.69%** due to FMS at processing stage (ware houses).

Lowest estimates of FW due to FMS:

- ✓ Tomato (Slovenia): 0.05% due to public FMS related to size, shape, and quality.
- ✓ Potato (Slovenia): 0.08% due to public FMS standards related to shape, size, or quality.
- ✓ Onion (Slovenia): 0.24% due to public FMS related to size, shape, and quality.

Comparison of the same products in different countries:

- ✓ Apples: In Italy, FW at the production level due to FMS ranges from 13.0% to 20.0%, primarily due to aesthetic and size standards. In Slovenia, primary production waste is 10.0% due to appearance, shape, and quality standards. This indicates stricter standards in Italy leading to higher waste.
- ✓ Tomatoes: In Portugal, primary production waste is 10.0% with no waste attributed to FMS. In Slovenia, primary production waste is 1.22% with 0.05% due to FMS. This suggests that Portugal's tomatoes waste is more influenced by factors other than FMS compared to Slovenia.

Table 4: Estimate of total production, average FW and average FW due to FMS for various F&V products

Case study	Country	FSC	Food Product	Total Production (Tons/year)	(Weighted) Average FW Estimate (%)	(Weighted) Average FW Estimate due to FMS (%)	FMS causing FW
F&V.CS1.NN-IT	Italy	Primary production	Apples (fresh)	Not provided	15.0	13.0 – 20.0	✓ Premium product: overcolouring of the peel > 40% ✓ Absence of imperfections (10% tolerance) ✓ Caliber ✓ Pesticides residues level ✓ Caliber higher than public standard ✓ Absence of imperfections (5% tolerance) ✓ Pesticide residue levels below 40 – 70% legal levels ✓ Aesthetic appearance
			Pears		5.0	5.0	✓ Absence of imperfections (10% tolerance) ✓ Caliber ✓ Brix degree (sweetness) ✓ Pesticides residues level ✓ Caliber higher than public standard ✓ Absence of imperfections (5% tolerance) ✓ Pesticide residue levels below 40 – 70% legal levels
			Apricots		5.0	5.0	✓ Absence of imperfections (10% tolerance) ✓ Brix degree (sweetness) ✓ Pesticides residues level ✓ Caliber higher than public standard

							✓ Absence of imperfections (5% tolerance) ✓ Pesticide residue levels below 40 – 70% legal levels
			Peaches		20.0	7.0 – 8.0	✓ Caliber ✓ Aesthetic appearance
			Plums		10.0	2.0 – 2.5	✓ Caliber ✓ Aesthetic appearance
		Retail and distribution (fresh distributors)	Apples	Not provided	1% of total revenue	1% of total revenue	✓ Caliber ✓ Aesthetic appearance ✓ Brix degree ✓ Pesticide residue level 50 – 70%
			Pears				
			Plums				
		Processing	Fruit purees	Not provided	0.5 – 1.0	0.5 – 1.0	✓ Remaining shelf life ✓ Product presentation
			Fruit smoothies				
F&V.CS2.MC-PT	Portugal	Primary production	Lettuce	165.0	1.8	0	✓ Decay
			Round tomato	200,000.0	10.0	0	
			Carrot	70,000.0	25.5	24.2	✓ Standards related appearance (broken carrots, size and deformation)
			Orange	200,000.0	15.0	13.5	✓ Standards related to aesthetic effects
			Raspberry	9,300,000.0	15.0	0	
			Apple Gala	33,590.07	11.1	1.2	✓ Standards related to colour, size and epidermic defects

			Pear Rocha	16,276.05	20.3	3.7	✓ Standards related to colour, size and epidermic defects
		Retail	Lettuce	2,322.113	0.9	0.6	✓ Standards related to labelling, size, appearance (un-fresh and brownish leaf tips)
			Round tomato	8,386.65	0.5	0.5	✓ Standards related to labelling, size, colour and epidermal defects
			Carrot	5,056.18	0.8	0.7	✓ Standards related to labelling, size, dehydration, appearance – poor for commercial purposes and packaging, weight
			Orange	9,668.237	0.4	0.2	✓ Standards related to labelling, size, organoleptic characteristics and epidermal defects.
			Strawberry	3,960.533	3.2	2.0	✓ Standards patterning to labelling, colouring, appearance, size – undersize, sugar content and packaging
			Apple Gala	621.904	4.3	0.1	✓ Standards related to labelling, packaging, size, hardness, appearance
			Banana	29,178.991			✓ Standards related to ripening, appearance – bruising and epidermal effects
F&V.CS3.ZT-SI	Slovenia	Primary production	Apples	10.0	20.0	10.0	✓ Standards related to appearance, shape, and quality
			Onion	21.0	9.76	0.24	✓ Public FMS related size, shape, and quality

			Potato	62.0	1.94	0.08	✓ Public FMS standards related to shape, size, or quality
			Tomato	9.8	1.22	0.05	✓ Public FMS related size, shape, and quality
			Zucchini	0.7	7.14	2.86	✓ Public standards on quality (freshness)
		Processing	Onion	11.0	15.0	0	
		Retail	Apples	30.0	10.0	9.6	✓ Public standards on appearance, shape and quality
			Apple strips	2.0	0	0	
			Onion	10.0	10.0	2	✓ Public standards on appearance and quality
			Potato	10.0	10.0	2.0	✓ Public standards on appearance (size and shape) and quality (freshness issues)
			Tomato	10.0	10.0	3.0	✓ Public standards on appearance, shape and quality
			Fresh Zucchini	2.0	2.5	0.5	✓ Public FMS regarding the appearance and quality
F&V.CS4.Men-SI	Slovenia	Primary production	Pumpkin *Hokaido*	40.0	5.0	0.45	✓ Public standards on size and freshness
			Turnip	100.0	10.0	5.0	✓ Public standards on appearance and size
			Cabbage	30.0	1.0	1.0	✓ Public standards on appearance and colour

			Lettuce	50.0	1.0	0.24	✓ Public standards on freshness and size especially those related to perishability and cosmetics
			Tomato	20.0	1.0	0.9	✓ Public standards on appearance and size
			Potato	50.0	1.0	0.12	✓ Public standards on size and quality
F&V.CS5.LN-DE	Germany	Primary production	Limes	6,714	NA	30	✓ Non-conformity to several standards
		Wholesale		2,055 (products bought)	228	11.11 (of complaint reasons related to FMS, excluding spoilage)	✓ Colour (customer requirement) ✓ Spoilage (EU Norm)
		Primary production	Cucumber	60,000	NA		
		Wholesale		2,323	1.61	11.24 (of complaint reasons related to FMS, excluding spoilage)	✓ Soft-ends / spoilage
		Primary production	Cherry date tomatoes	25,300.563	NA	Not indicated	
		Wholesale		492	1.28	9.01 (of complaint	✓ Too low spoilage tolerance

						reasons related to FMS, excluding spoilage)	✓ Quality deviations, freshness defects and maturity level
		Primary production	Peppers	650	5 – 11	Not indicated	✓ Aesthetic defects such as silvering, small size or differences in shape
		Wholesale		2,579	1.30	7.63 (of complaint reasons related to FMS, excluding spoilage)	✓ Quality deviations maturity level growth deficiencies, not meeting customer specifications, wrong calibre or discolouration (0,38%)
F&V.CS6.Ane-ES	Spain	Primary production	Citrus fruits	435	7.25	7.23	✓ Aesthetic appearance (caused by pests, hail, wind, wounds due to harvesting operations) ✓ Decay ✓ Overmature
			Persimmons	90	22.48	22.47	
		Primary production & processing	Citrus fruits	86,142	2.0	0.52	
			Persimmons	113,835	32.47	13.69	
F&V.CS7.ILVO-BE	Belgium	Primary production	Strawberries	51.453 [34]	14.0	Not indicated	
F&V.CS8.ILVO.BE_NL	The Netherlands	Primary Production	Bell peppers	67.69	4.0	Not indicated	
			Tomatoes	85.52	2.5		

[34] www.flandersfruitsandvegetables.com

		Processing (class II)	Bell peppers	1,100,000	0.7		
			Tomatoes	1,995	14.29		

4.9 Solutions to suboptimal fruit and vegetable products and their fate

Suboptimal products in the F&V sector are managed through various strategies. Public FMS often result in FW due to strict criteria such as overcolouring of the peel, absence of imperfections, caliber, brix degree, pesticide residues, and phytosanitary product levels. These products, including apples, pears, apricots, plums, and peaches, may also be directed to alcohol production. Private FMS impose even stricter standards, leading to products being sold at lower prices or resulting in FW. For instance, products not meeting caliber, absence of imperfections, pesticide residue levels, and specific acidity/sugar levels are sold at reduced prices. Additionally, products like fruit purees, smoothies, canned fruit, and dried fruit with limited remaining shelf life are often discounted or donated. Firmness and various certifications (IFS, BRC, Global GAP, ISO 22005:2007) also influence the fate of products, with many directed to alcohol production (Table 5).

Table 5: Suboptimal F&V and their fate

FMS category	Product	FMS applicable	Fate of the product
Public	Apples	Premium product: Overcolouring of the peel >40%	✓ Food loss
	Apples, Pears, Apricots	Absence of imperfections (10% tolerance)	✓ Food loss ✓ Alcohol production
	Apples, Pears, Plums	Caliber	✓ Food loss ✓ Sold at lower price ✓ Alcohol production
	Pears, Apricots, Apples, Plums	Brix degree (sweetness)	✓ Food loss ✓ Alcohol production
	Apples, Pears, Apricots, Plums, Peaches	Pesticide residues level	✓ Food loss ✓ Alcohol production
	Apples, Peaches, Plums	Phytosanitary products levels	✓ Food loss
	Apples for processing	Less chemical residues for organic production	✓ Food loss ✓ Alcohol production
Private	Apples, Pears, Apricots, Peaches, Plums	Caliber higher than public standard	✓ Sold at lower price
	Apples, Pears, Apricots, Peaches, Plums	Absence of imperfections (5% tolerance)	✓ Sold at lower price
	Apples, Pears, Apricots	Pesticide residue levels below 40-70% of legal level s	✓ Sold at lower price
	Apples, Peaches, Plums	Specific acidity/sugar levels	✓ Sold at lower price

			✓ Food loss
	Fruit purees, smoothies, canned fruit, dried fruit	Remaining shelf life	✓ Increasing discounts; Donation
	Fruit purees, smoothies, canned fruit, dried fruit	Product presentation	✓ Sold at lower price
	Apples, Pears, Plums	Firmness	✓ Alcohol production
	Apples, Pears, Plums	Standard IFS	✓ Alcohol production
	Apples, Pears, Plums	BRC certification	✓ Alcohol production
	Apples, Pears, Plums	Global GAP	✓ Alcohol production
	Apples, Pears, Plums	ISO 22005:2007 for traceability	✓ Alcohol production

5. FINDINGS FROM MEAT COMMODITY

Three CSs were conducted in the meat commodity, FENEVIAN and FEBEV are focused on Belgium and AVEC is focused on EU27. Each CS focused on different meat products (Table 1 & 2).

5.1 Belgium - FENAVIAN

FENAVIAN is the Belgian Federation of the Processing Industry of Meat, other proteins, and ready meals which focuses on maintaining high standards in the meat processing industry, ensuring food safety, quality, and sustainability. Through its members data to support this study was collected. The major of stakeholders operate at an international scale engaging in Business-2-Business (B2B) models.

5.2 Belgium - FEBEV

The Belgian beef sector plays a vital role in the country's agricultural and food industry, with a strong focus on quality and export. Its most renowned breed, the Belgian Blue, is globally recognized for its leanness and fine texture, making it ideal for premium markets. The sector encompasses farmers, slaughterhouses, cutting plants, and processors, working together to meet strict standards in food safety, animal welfare, and sustainability. At the same time, the sector faces challenges such as rising costs, stricter environmental regulations, and shifting consumer preferences toward sustainable and plant-based alternatives.

FEBEV, the Federation of Belgian Meat, represents the interests of slaughterhouses, cutting plants, and meat processors in Belgium. Acting as a spokesperson to policymakers, the federation promotes innovation and quality systems while supporting its members in areas such as sustainability and export. FEBEV contributes to a forward-looking and resilient sector, balancing economic interests with societal expectations.

5.3 Europe - AVEC

AVEC is the voice of the European poultry meat sector. The association facilitates communication and exchange between international organizations and decision-makers, and focuses on key areas like animal health and welfare, food safety and quality, trade and sustainable development.

AVEC acts as a reliable, open and credible partner for all stakeholders in the poultry meat sector, media and institutions. By advocating for coherent European policies which will work on the global stage, AVEC is ensuring the development of a solid and thriving European poultry meat sector.

Poultry is the most widely consumed meat in the world, and is enjoyed by many as part of a balanced diet. For years, the European poultry meat sector has provided the world with nutritious and safe

poultry meat. As part of this, the sector is highly integrated and has kept its focus firmly on science and critical innovation to engage and develop trade.

The ongoing success of the sector is defined by its collective knowledge and commitment to these core aims:

- ✓ To provide EU citizens with healthy, sustainable, safe and affordable meat
- ✓ To contribute to a healthy EU economy by creating jobs and supporting trade
- ✓ To defend and uphold EU food safety, animal welfare and environmental protection standards

5.4 Food Marketing Standards in Meat

Table 7 categorizes the identified FMS in the meat sector into public and private ones, detailing the specific standards and stages of the FSC at which they are implemented.

Table 6: Several Food Marketing Standards in the EU meat sector

Category	Food Marketing Standard Name	Stage of Food Supply Chain
Public	Regulation EC 1308/2013	✓ Carcass classification
	Regulation EC 1069/2009	✓ Handling of animal by-products
	"Detailhandel" (Retail)	✓ Governmental standards for food sold in the retail sector
	Regulation 543/2008 Poultry Meat Marketing Standards	✓ Poultry meat marketing
Private	International Featured Standards (IFS)	✓ Food safety and quality assurance for retail and wholesale suppliers
	Brand Reputation through Compliance Global Standard (BRC)	✓ Food safety and quality for retail supply chains
	Global Red Meat Standard (GRMS)	✓ Meat production
	Belbeef	✓ Beef production in Belgium
	BePork	✓ Pork production in Belgium
	FEBEV+	✓ Meat production

	Meesterlyck	✓ Artisanal meat production
	Beter Leven	✓ Animal welfare in food production
	FSSC 22000	✓ Food safety management based on ISO standards
	National/Local Schemes	✓ Various stages of food supply chain
	GLOBAL GAP	✓ Various stages of food supply chain especially at the primary production stage

5.4.1 Creation, adherence, and implementation

The creation and adherence to FMS are crucial for gaining market access, meeting customer demands, and remaining competitive. Compliance is essential to avoid market exclusion as regulatory demands rise. In the Belgian meat industry, a multi-layered approach is used to gain market access through certification of multiple FMS. Key points include customer-centric development, broadening the customer base, and interconnected standards. Compliance with multiple standards expands market reach but also requires additional certifications to meet specific client requirements and compete in limited-supplier markets. Limited certifications, like Approved Retail Consortium (ACS) alone, restrict market access, necessitating further compliance.

Implementing FMS like IFS, BRC, and Global Red Meat Standard (GRMS) is essential for market access and meeting customer requirements. In Belgium, standards like Belbeef and BePork are valuable for retail but lack international added value. Compliance with FMS enables companies to meet strict customer-imposed requirements, though some flexibility is allowed. Carcass classification, mandated by legislation such as EC 1308/2013, provides assurance to farmers and influences pricing. Meeting multiple FMS requirements increases costs due to additional staffing and compliance measures. Non-compliant products are investigated and destroyed to maintain quality.

5.4.2 Challenges

Implementing FMS presents several challenges, including stringent customer and regulatory requirements. Major customers often perform additional audits, and failure to achieve Global Food Safety Initiative (GFSI) certification has significant consequences. Product specifications can be restrictive, and strict interpretations of FMS or legal regulations create additional obstacles. Delays in food safety testing can lead to food waste if products spoil while awaiting clearance.

Associated costs

The implementation of FMS results in varying cost increases depending on the area of expense. The highest cost increases are associated with certification and administrative expenses, particularly for the IFS standard. Personnel costs are another notable contributor, reflecting the rigorous requirements for compliance. Moderate cost increases are observed in IT development and additional administrative tasks. The lowest cost increases are typically seen for standards like BePork and Meesterlyck. Overall, while ongoing costs may stabilize, the implementation phase represents a significant financial commitment.

Relevance and Sustainability

The creation, adherence, and implementation of FMS are driven by mandatory requirements set by the retail sector and specific obligations imposed by customers. These standards are crucial for maintaining reputation, complying with legal obligations, and meeting pricing expectations. While FMS are essential for ensuring safety and quality, their relevance to sustainability varies. Companies report limited consumer interest in sustainability metrics, with price and quality remaining dominant factors. However, retailer pressure for sustainability is increasing, pushing companies to integrate ecological and social considerations into their practices.

Compliance and Market Impact

Compliance with FMS influences the pricing outcomes of products, albeit variably across standards. For GLOBAL GAP Standards, National/Local Schemes, and "Other" standards, compliance is universally perceived to result in better product prices. In contrast, compliance with ISO Standards leads to improved pricing for only a minority of respondents. The implementation of FMS poses several challenges, including increased costs and additional bureaucracy. Despite these challenges, most respondents believe that products associated with FMS would not perform better in the market if these standards were removed or relaxed. Removing or relaxing FMS could lead to significant potential consequences, including a decline in quality and reduced consumer confidence.

5.5 Estimate of Food Waste

Table 7 gives an overview of the total FW and FW due to FMS for the targeted meat products. The highest FW estimates due to FMS are observed in whole beef (12.5%), deboned beef carcasses (9.8%), and slaughtered beef carcasses (9.0%), primarily due to standards like Discarded Cat III and IFS. The lowest FW estimates are found in cooked ham (0.15%), processed products (0.12%), and degraded whole carcasses (0.06%), with minimal impact reported from FMS. These figures highlight the significant variation in FW across different products and stages of the FSC, influenced by specific FMS requirements.

Table 7: Estimate of total FW and FW due to FMS for various Meat products

Case study	Country	FSC	Food Product	Total Production (Tons/year)	(Weighted) Average FW Estimate (%)	(Weighted) Average FW Estimate due to FMS (%)	FMS causing FW
M.CS1.Fen-BE	Belgium	Primary production, processing and manufacturing, & retail and distribution	Chicken filet	Not indicated	2.0	Not indicated	
			Bacon	0.3	2.0	Not indicated	
			Cooked ham	676.06	0.15	0.15	
			Raw ham	Not indicated	2.0	Not indicated	
			Sausages	Not indicated	2.0	Not indicated	
			Pâté	5,600	5.41	Not indicated	
			Salami	484.3	0.25	Not indicated	
M.CS2.AVE-BE_EU	EU	Primary production, slaughtering, processing and manufacturing	Whole chicken	172,704.95	1.01	1.01	✓ Regulation Animal By-Products 1069/2009
			Breast Fillet	158,025.81	0.31	0.31	
			Legs	130,791.07	0.56	0.56	
			Processed products	844,358.33	0.12	0.12	
M.CS3.Feb-BE	Belgium		Whole pig	0.092	5.40	Not indicated	

		Processing and manufacturing	Slaughtered pig carcasses	51,800	8.69	8.69	✓ Bepork ✓ IFS
			Pig Carcass + meat → offal (waste cat III)	3,470.726	7.2	7.2	
			Pig Carcass + meat → offal (cutting losses)	3,470.726	0.49	0.49	
		Processing & Manufacturing, Retail and distribution (wholesale)	Whole beef	Not provided	12.5	12.5	✓ Discarded Cat III
			Slaughtered beef carcasses	500	9.0	9.0	✓ IFS
			Deboned beef carcasses	6809.4	9.8	9.8	
			Degraded (wasted) whole carcasses	13,737.98	0.06	0.06	

5.6 Suboptimal products,

According to the respondents, suboptimal products, particularly Category III (Cat III) products, are often sold at a lower price (57.89%) or demoted to the production of animal food (15.79%). The fate of Cat III products points out different management practices, with the most common approach being degradation to feed (54.55%), followed by degradation to waste (45.45%). Selling at a lower price and incineration each accounts for 18.18%, while reprocessing methods are the least common, representing 9.09%.

Future plans to reduce FW and optimize the handling of suboptimal food focus on several key initiatives:

- ✓ Process Optimization Initiatives:
  - Intestinal improvements: Enhancing the cleaning process to reduce water consumption and improve hygiene.
  - Gut washing: Prioritizing improvements in gut washing procedures to enhance product quality and reduce waste.
- ✓ Product Utilization Strategies:
  - Fat and skins management: Improving tracing and processing to allow for potential human consumption, such as producing gelatine.
  - Valorisation of downgraded products: Processing by-products in countries with lower labour costs for additional valorisation.
- ✓ Flexibility in Specification Management and Customer Relations:
  - Retail customer flexibility: Addressing strict selection criteria to minimize waste and improve marketability.
  - Processing alternatives: Redirecting products for processing into lower-value products if they cannot be sold under specific conditions.
- ✓ Regulatory Considerations:
  - Legislative Reviews: Reviewing existing legislation to ensure it accommodates modern sustainability practices and faster turnaround times on analyses.
- ✓ Continuous Improvement Focus:
  - Ongoing Process Optimization: Emphasizing continuous efforts to optimize processes and adapt to market needs.
  - Market Adaptation: Exploring alternative markets that value products differently.
- ✓ Collaboration Opportunities:
  - Cooperation with other companies: Collaborating with other businesses to reduce food waste and enhance efficiency in the value chain.

These initiatives underscore the commitment to addressing FW challenges by improving efficiency, innovating processes, and repurposing materials where feasible. However, a majority of companies did not report specific plans or strategies, highlighting the need for more unified efforts to address FW comprehensively.

6. FINDINGS FROM EGG COMMODITY

In D2.5, only the Danish Egg case study was considered. The AVEC egg case study was not analysed at the time of writing this report due to delays in data collection. The data that came later will be incorporated in T2.4 - D2.6 to have a broader picture for the egg commodity.

FW is also concern in the egg sector. A study by Caldeira et al., (2019) indicated that approximately 29% of eggs are wasted throughout the FSC, from production to consumer consumption, due to a complex interplay of regulations, consumer behaviour, and perceptions of food quality and safety. In this sector, an important concern is the prohibition of washing Class A eggs, which are the only ones available for retail sale. This regulation is intended to ensure hygiene standards, but technological advancements offer new alternative methods for safety and cleanliness. Companies in Sweden are exempted[35] from this rule which suggests an opportunity to reassess washing practices to reduce FW.

The EU's FMS are further complicated by numerous voluntary labelling schemes, whose effects on FW are not well understood. Regulation (EU) 2022/2258[36], which extended the sell-by date for eggs from 21 to 28 days, has also sparked discussions about FW, as ambiguities in these provisions may lead consumers to discard eggs prematurely. The aim of the interviews was to explore the impact of public and private marketing standards on FW in the egg sector, focusing on producers, packing stations, and product factories, while highlighting necessary reforms and awareness to reduce FW.

6.1.1 Food Marketing Standards in Egg sector in Denmark

In Denmark, there are approximately 4.5 million egg-laying hens at around 120 professional and registered egg producers, along with an increasing number of "barn door and backyard hens." These hens produce about 80 million kilograms of eggs annually. Egg production in Denmark includes four types: battery, organic, free-range, and caged, with regulations ensuring high standards of food safety and traceability.

Eggs are regulated by several EU (public) marketing standards, including Commission Implementing Regulations (EU) 2017/1185[37], No 1307/2013, No 1308/2013[38], and EU 2023/2465[39]. These standards ensure that all eggs are quality sorted at authorized packing stations. Class A eggs, which are of impeccable quality, are sold in retail stores, while Class B eggs are used to make egg products.

[35] https://www.foodnavigator.com/Article/2005/11/09/Eggs-washed-or-unwashed/
[36] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R2258
[37] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1185
[38] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1185
[39] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302465

Eggs are sorted by weight into sizes XL, L, M, and S, and undergo extensive quality control, including salmonella checks, x-ray inspections, and cold chain storage.

Danish eggs are marked with a traceability code that indicates the production method and country of origin, ensuring they can be traced back to the farmer. This comprehensive system ensures that only high-quality eggs reach consumers, maintaining Denmark's reputation for food safety and quality.

6.1.1.1 Egg sorting process complexity and waste generation

The egg sorting process begins on farms, where eggs are categorized based on size, leaks, cracks, and blood spots. Eggs outside the standard size or with blood spots are sold directly to consumers on-farm, while those with significant leaks or cracks are discarded. After initial sorting, eggs are transported to a packing facility for further grading and quality control using automated machinery. Eggs are stamped with production details and Class A eggs are packaged with expiry dates for retail. Class B eggs are processed into egg products, generating FW like eggshells and residuals.

Waste quantification helps monitor production efficiency, with waste often repurposed for animal feed or fertilizer. Interviewees highlighted efforts to track and reduce waste, indicating a culture of continuous improvement in waste management.

6.2 Food Marketing Standards and Estimate of Food Waste in the Danish Egg sector

Table 8 summarizes FW estimates in the egg production and processing industry in Denmark. Interviewees agreed on implementing EU FMS in their operations, despite some variations in interpretation, such as egg washing and date marking. They noted that these standards do not significantly increase FW (Table 8) but can cause financial losses, especially for producers. Allowing egg washing could potentially increase sales of class A eggs by 3 - 4% and reduce financial losses on Class B egg that are sold as Class A after washing.

Interviewees highlighted that the majority of FW is caused by leaks, cracks, and handling damage, rather than by marketing standards. They reported minimal FW, approximately 0.5% in retail and distribution. The consensus is that marketing standards do not significantly contribute to FW, but there is frustration with standards that prioritize appearance over usability, impacting economic viability. There is a call for revising these standards to allow more flexibility in categorizing and marketing eggs, potentially reducing waste and increasing revenue. Interviewees also noted that significant innovations in waste reduction will require regulatory changes.

Table 8: Estimate of total FW and FW due to FMS for various Egg products

Case study	Country	FSC	Food Product	Total Production (Tons/year)	(Weighted) Average FW Estimate (%)	(Weighted) Average FW Estimate due to FMS (%)	FMS causing FW
E.CS1.LF-DK	Denmark	Primary production	Eggs	3,708.364	3.35	3.35	
		Retail and distribution (Packing station)		62,997.088	0.8	0.5	✓ Standards related to appearance and quality (after sorting)
		Processing (product factory)		1,774.160	9.64	6.84	
E.CS2.AVE-BE_EU*	EU	**** = taken up in T2.4***					

6.2.1 Handling of food waste and opportunities and challenges for valorisation

This section explores how eggs classified as food waste (FW) or downgraded to Class B are managed within the industry. Defective eggs that are unsuitable for retail or liquid production are typically redirected for use in animal feed. Additionally, eggshells are repurposed for various industrial applications, including the manufacturing of tiles and cement mixtures.

Some companies collaborate with specialized organizations, such as Symrise, to extract valuable proteins from discarded materials; effectively turning waste into a resource. These innovative uses of eggshells exemplify circular economy practices and contribute to enhanced sustainability across the sector.

Despite these efforts, regulatory barriers remain a significant obstacle. Interviewees expressed frustration with the lengthy approval processes required by the European Union, which delay the adoption of new by-product applications. Economic considerations also play a role; while companies acknowledge that reducing food waste can benefit their bottom line, such efforts are often only feasible if the required investments are reasonable.

In summary, the industry is actively pursuing sustainable waste management strategies but continues to face regulatory and logistical challenges that must be addressed to unlock the full potential of by-product utilization.

7. FINDINGS FROM CEREAL COMMODITY

In the BREACRUMB project, two cereal CSs were deployed in Italy and Slovenia.

7.1 Italy – Natura Nuova

The Italian cereal sector is a vital part of the national agricultural economy, with wheat, corn, and soybeans as key crops. In 2023, the sector's production was valued at €5.29 billion, making up 14.4% of agricultural output. Wheat alone contributed €1.84 billion, or 35% of the cereal sector's value, while corn accounted for €1.51 billion (29%), and soybeans also made a significant contribution.

Wheat production focuses on both durum and soft wheat, with 3.5 million tons of durum and 3.081 million tons of soft wheat produced in 2023. The milling industry processed over 4 million tons of soft wheat into flour, driven by demand from the bakery and pastry sectors.

Soybean production, concentrated in northern regions like Emilia-Romagna and Lombardy, is important for animal feed and industrial uses. In 2023, the sector saw notable growth, with Italian soybeans in demand within the EU for non-GMO and sustainable products.

Corn production, central to livestock feed and bioenergy, reached approximately 6 million tons in 2023. Despite challenges like increased production costs and competition from imports, Italian corn remains valued for its high quality, especially in niche markets like organic feed[40].

Natura Nuova uses cereals and grains for plant-based protein products, such as seitan, tofu, and tempeh. The company conducted five interviews with primary producers and millers, covering wheat and soybean farms and mills involved in flour production. The interviews, held between September and November 2024, provided

Public FMS baseline:

Most of the public FMS in the cereal sector are intended to preserve the safety of the product, while no public FMS related to the aesthetic characteristics of the product were found. FMS aiming at guaranteeing the safety of products are related to:

- ✓ Presence of diseased and broken seeds
- ✓ Specific weight
- ✓ Levels of chemical residues
- ✓ Mycotoxins levels

[40] ISMEA (2023). Sector factsheet – Cereals https://www.ismeamercati.it/seminativi/cereali

- ✓ Limited level of GMO
- ✓ Levels of allergen
- ✓ Absence of physical contaminants and foreign bodies
- ✓ Classification of flour

Private baseline

Private FMS that are extending and/or making public FMS stricter are mainly related to the safety of products. However, also private FMS related to quality and aesthetics can be found.

Concerning private FMS with a public baseline related to food safety of product, the interviews highlighted:

- ✓ Lower moisture content, impurity levels, weight
- ✓ Higher protein level

Concerning aesthetic and quality levels, private FMS for cereals include:

- ✓ Absence of aesthetic imperfections (foxing; discoloration and brownish spots, dark colour, teguments, damaged seeds, vitreous seeds)
- ✓ Compliance with technical and rheological parameters

7.1.1.1 Costs, Benefits, and Challenges

Benefits:

- ✓ Companies adopt FMS primarily for economic benefits, aiming to stay competitive, sell products, and position them as premium-quality offerings sold at higher prices.
- ✓ Adhering to FMS enhances product value, ensuring competitiveness and profitability.

Costs:

- ✓ Financial investments and procedural adjustments are required.
- ✓ Primary producers need standardized fertilization and plant protection plans, modern production techniques, higher-quality plant products, increased labor, higher fuel consumption, and extended working hours.
- ✓ Processors and distributors face costs for extensive testing (e.g., mycotoxins), removing unfit seeds, separating homogeneous batches, and maintaining advanced storage facilities.
- ✓ High raw material management costs involve detailed document analysis for traceability and compliance, necessitating rigorous and frequent quality checks.

Challenges:

- ✓ Relaxing FMS could decrease food safety and lead to unpredictable processing performance.
- ✓ Despite the costs, adherence to FMS ensures consistent quality and predictability.

7.1.2 Food Waste estimates

Table 11 demonstrates the estimated FW due to FMS for cereal products in Italy. Primary producers in Italy most often sell all their produce, with some however subjected to price reduction due to quality issues. For the products not complying with FMS, two main pathways are followed: they are either wasted or repurposed for animal feed.

Appendix 11.4 further indicates the FMS at each stage of the cereal FSC that contributes to FW generation.

7.2 Slovenia - Vila Natura

In Slovenia, the quality of cereals and cereal-based products is regulated by both EU-wide general FMS for cereals and specific national regulations. These include the Rules on the Quality of Cereal Products, Fine Bakery Products, and Bakery Products. These rules provide detailed guidelines for producing, processing, and marketing cereals to ensure consistency, safety, and high-quality standards.

The milling industry, a key player in the cereal supply chain, enforces stringent quality criteria tailored to processing and end-use needs. Critical parameters include moisture content (for safe storage and stability), purity (to assess foreign materials or impurities), and mycotoxin levels. Protein content is emphasized for its role in determining the baking properties of wheat and other cereals. Additional factors like falling number, hectoliter weight, and gluten content help classify cereals into distinct grades, determining their suitability for various applications.

This grading system is crucial for setting purchase prices, with higher-quality grades fetching better market value. By adhering to these comprehensive standards, Slovenia ensures the competitiveness of its cereal products in both domestic and international markets, while maintaining consumer trust and food safety.

7.2.1 Food Marketing Standards and Food Waste

Variations in FW across cereals at company level in Slovenia (Table 9) are influenced by private buyer-imposed standards (e.g., protein content, cleanliness, moisture levels) and private and public regulations (e.g., GLOBAL GAP, Slovenian Cereals Quality Regulation respectively). Producers manage FW by selling non-compliant products as animal feed. FW is most significant at the primary production stage, driven by private standards (Table 9). Wheat and oat are most impacted due to

low protein content, high moisture, and mycotoxin contamination. Processing generates minimal FW, mainly from packaging and raw material cleaning inefficiencies.

Strict compliance with private standards on protein, moisture, and cleanliness heavily influences FW. Standards like GLOBAL GAP contribute to sustainability but play a minor role in FW generation. Plans to reduce FW are limited, as compliance with FMS is crucial for market access.

In summary, FW in cereals varies across supply chain stages, with private standards posing significant challenges at primary production. Investments in technology and flexibility in buyer-imposed standards (mandatory – private standards) could further minimize FW in cereals.

7.3 Food Marketing Standards in Cereals overview

This table integrates the public and private FMS details with the stages and key observations, providing a comprehensive overview.

Table 9: Overview of FMS in Cereals

Stage	Public FMS	Private FMS	Key Observations
Primary Production	✓ Italian Commodities Exchange: Presence of diseased seeds under 5% (Soybean) ✓ Italian Commodities Exchange: Presence of broken seeds under 20% (Soybean) ✓ Italian Commodities Exchange: Specific weight (Soft wheat, wheat) ✓ Regulation (EC) No. 396/2005: Levels of chemical residues (Soft Wheat, Soybean, Wheat flour) ✓ Regulation (EC) No. 1881/2006: Mycotoxins levels	✓ Private contracts: Moisture content (Soft wheat, Soybean, Wheat flour) ✓ Private contracts: Impurity level (Soybean) ✓ Private contracts: Minimum weight lower than public FMS (Soybean) ✓ Private contracts: Protein level (Soft wheat) ✓ Private contracts: Absence of aesthetic imperfections (Wheat, corn, soy)	✓ Slovenian Regulation: National-level standards on cereal quality ✓ Rare impact of national public standards on FW ✓ Quality Standards for cereals (milling industry): Imposed by buyers, focus on protein content, moisture, and mycotoxins ✓ High compliance with GAP and Slovenian Regulation

	(Corn, Wheat, soft corn, wheat flour) ✓ Regulation (EC) No. 1829/2003: Limited level of GMO (Soybean) ✓ EU Regulation 1169/2011: Levels of allergen (Wheat flour) ✓ Regulation (EU) No. 852/2004 + (Italian) Presidential Decree DPR 187/2001: Absence of physical contaminants and foreign bodies (Wheat flour) ✓ Italian Law No. 580/67: Classification of flour (Wheat flour)	✓ Private contracts: Vitreous seeds (Corn) ✓ Private contracts: Origin of raw material (Wheat flour) ✓ Private contracts: Organic production (Wheat flour) ✓ Private contracts: Technical and rheological parameters (Wheat flour) ✓ Private contracts: Type of milling (Wheat flour)	✓ FW largely driven by strict private buyer requirements
Processing	✓ HACCP: Mandatory EU-level standard ensuring food safety ✓ Organic Certification (EU) ✓ Labelling and Expiry Dates: Required for all processed products	✓ IFS Certification: Focused on traceability, safety, and compliance with retailer demands	✓ FW caused by processing inefficiencies rather than FMS ✓ Private standards (IFS) demand higher transparency and traceability, leading to increased costs and investments
HoReCa (Restaurant)	✓ No specific public standards directly affecting operations	✓ Green Key Certification: Private standard (Slovenia) emphasizing sustainability and environmental goals	✓ FW largely unrelated to FMS

7.4 Food Waste estimations

Based on the figures of the FW estimates due to FMS in Table 10 for both Italy and Slovenia:

The three highest FW estimates due to FMS include:

- ✓ Italy - Corn (Retail, distribution, and processing): 3.465% FW due to vitreous seeds, absence of teguments, and light-coloured seeds.
- ✓ Italy - Wheat flour (Retail, distribution, and processing): 12% FW due to mycotoxin levels, foxing or weathering, specific weight, residues of plant protection products, absence of foreign bodies, organic production, and type of milling.
- ✓ Italy - Soy (Retail, distribution, and processing): 1.509% FW due to the absence of damaged seeds and limited levels of GMO.

The three smallest FW estimates due to FMS:

- ✓ Slovenia - Wheat flour (Processing): 0% FW.
- ✓ Slovenia - Spelt flour (Processing): 0% FW.
- ✓ Slovenia - Oat flakes (Processing): 0.03% FW due to IFS certification and packaging inefficiencies.

Country Comparison: Italy vs. Slovenia (Wheat at Primary Production):

- ✓ Italy: Soft wheat, FW data not provided, FMS causing FW include minimum test weight, protein content, moisture content, and mycotoxin levels.
- ✓ Slovenia: Wheat, 1.20% FW due to standards on protein content (low < 11.5%) and presence of mycotoxin levels.

In summary, Italy's corn at the retail, distribution, and processing stage has the highest FW estimates due to FMS, while Slovenia's wheat flour at the processing stage has the least FW. Comparing wheat at the primary production stage, Slovenia has a specific FW estimate of 1.20%, while Italy's data is not provided.

Table 10: Estimate of total FW and FW due to FMS for various Cereal products

Case study	Country	FSC	Food Product	Total Production (Tons/year)	(Weighted) Average FW Estimate (%)	(Weighted) Average FW Estimate due to FMS (%)	FMS causing FW
C.CS1.NN-IT	Italy	Primary production	Soft wheat	Not provided	Not provided	Not provided	✓ Minimum test weight of 76 kg/hectare ✓ Protein content of at least 11% ✓ Moisture content > 13 – 16% ✓ Mycotoxin levels
		Retail, distribution and processing	Wheat flour	8,000.0	12.0	12.0	✓ Mycotoxin levels ✓ Foxing or weathering ✓ Specific weight ✓ Residues of plant protection products ✓ Absence of foreign bodies ✓ Organic production ✓ Type of milling
			Corn	80,000.0	31.5	3.465	✓ Vitreous seeds ✓ Absence of teguments ✓ Light coloured seeds
			Soy	15,000.0	8.2	1.509	✓ Absence of damaged seeds ✓ Limited levels of GMO
C.CS2.VN-SI	Slovenia	Primary production	Wheat	270.0	1.20	1.20	✓ Standard on protein content (low < 11.5%) and presence of mycotoxin levels
			Oat	160.0	0.697	0.697	✓ Standards related to protein content and mycotoxin levels

							✓ Standards related to quality (cleanliness)
			Spelt	120.0	0.517	0.517	✓ Private standards (imposed by buyers) on moisture and protein levels
			Corn	110.0	0.482	0.482	✓ Quality standards related to moisture content, protein content, presence of mycotoxins, and appearance
			Barley	60.0	0.5	0.5	✓ Private standards (imposed by buyers) on moisture and protein levels
		Processing	Oat flakes	180.0	0.42	0.03	✓ IFS certification ✓ Packaging inefficiencies
			Wheat flour	300.0	0.2	0	
			Spelt flour	200.0	0.3	0	
		Retail	Pasta	2.0	5.0	0	

8. FINDINGS FROM FISH COMMODITY

The fish case study is located in Spain (Figure 10), the leading European country in wild-caught fish, contributing 1% to global fish consumption. Given the broad nature of the fish category, the scope was narrowed to formulate accurate hypotheses.

The baseline actor for this study was Catalonian fishermen, focusing on the Purse Seine fishery, which primarily targets oily fish. Their activities are regional, covering the North East coast of Spain, specifically the North West Mediterranean (FAO zone 37.1), centering the geographical scope of the study in this area.

This CS examines the entire value chain with six stakeholders across four supply chain stages, each with fewer than 15 workers. It includes two fishermen from key Catalonian ports (Blanes and Vilanova i la Geltrú), two wholesalers supplying fish regionally, nationally, and internationally, one fishmonger with regional coverage, and one local restaurant. The retail and food service stakeholders emphasize sustainable practices and high quality.

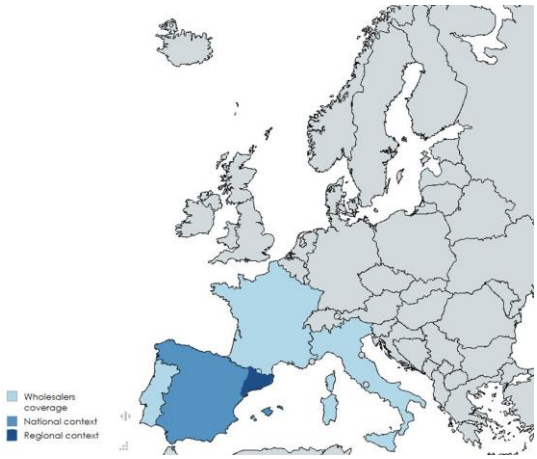


Figure 8: Fish case study geographical context

8.1 Food Marketing Standards

A total of 18 FMS were identified throughout the entire FSC in the study, with 56% being private standards (Figure 9). Some of these private standards are based on mandatory public standards but can be extended to become stricter private marketing standards (Table 12).

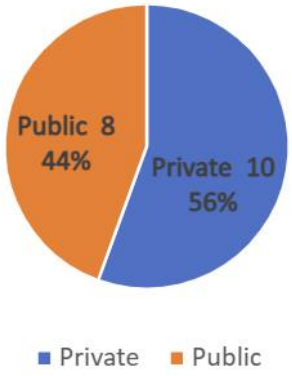
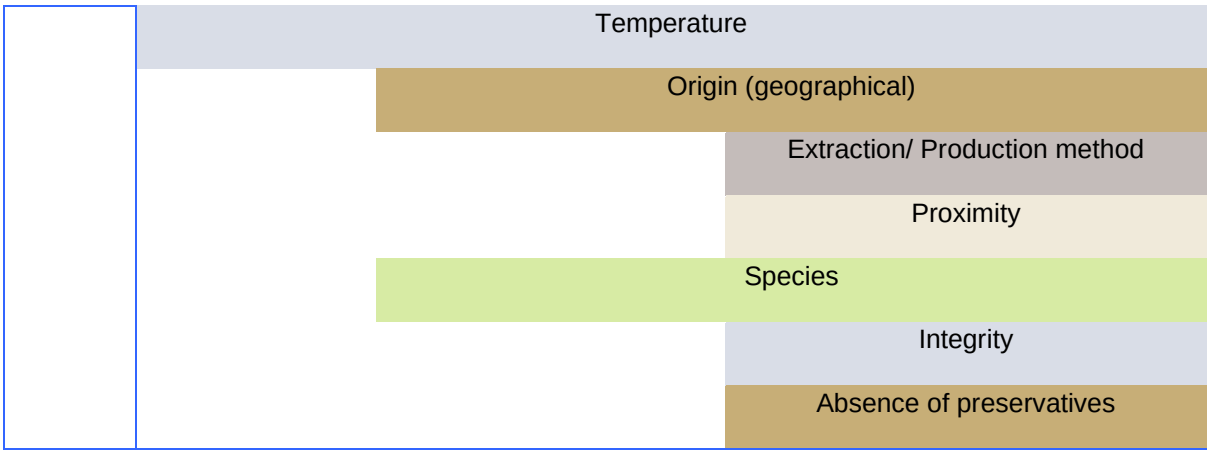


Figure 9: Share of public and private FMS implemented by Spanish fish sector stakeholders

These FMS are typically shared along the FSC stages, as shown in Table 11. This dynamic is explained by retailers, as the final stage of the supply chain, demanding FMS that must be met starting from the primary production stage - in this case, the fishermen stage – and continue through the rest of the supply chain.

Table 11: Public and private FMS detected in case study and its extension along the fresh fish Supply Chain.

	Fishermen	Wholesaler	Fishmonger	Food Service
Public	Legal Species			
	Maximum quota			
		Traceability		
	Minimum Caliber			
	Freshness			
		Codex Alimentarius CCFFP		
	Cold chain			
	Label			
Private	Size			
	Homogeneity (size and species)			
	Freshness			



Most public standards aim to set a baseline, enhance food safety and FSC efficiency, while others focus on sustainable exploitation of natural resources (e.g., maximum quota, minimum size, and species). The regulations and laws providing the legal framework for public FMS include:

- ✓ Legal sizes, minimal freshness, and legal species at the primary production level are established by **Council Regulation (EC) No 2406/96**.
- ✓ Traceability and labelling are mandatory under **Regulation (EU) No 1379/2013**.
- ✓ Cold chain requirements are based on the ATP agreement (Refrigerated transport at controlled temperature) from Geneva 1970, with Spain following **Real Decreto (Royal Decree) 1202/2005.**
- ✓ Maximum quota (TAC) is regulated by **Regulation (EU) 2019/472**.
- ✓ **Codex Alimentarius (CCFFP)** corresponds to the Codex Committee on Fish and Fishery Products established by FAO and WHO.

Some private standards are developed building upon public standards. These focus on freshness, temperature, and avoiding substances like sulphites to extend shelf life and maintain quality, addressing food safety concerns. Other private standards aim to improve FSC efficiency, increase economic profit, and reduce rejection rates. These can be divided into aesthetic reasons (e.g., homogeneity and integrity) and enhancing perceived quality and sustainability. Proximity, geographical origin, and extraction/production methods are FMS that promote sustainability and quality, supported by mandatory traceability, creating market differentiation (Table 13).

Species and size are regulated by the European Commission, but the market also has private "regulations" for more desirable and high-value sizes. Some species and sizes are less available or more preferred by consumers, driving up prices and stakeholder interest.

Table 12: Private marketing standards with a public standard as baseline.

Public baseline	Extended Private FMS
Traceability	Geographical origin Extraction/production method Proximity
Freshness	Absence of preservatives Extra freshness is required
Cold chain	Temperature
Legal Species	High value Species
Caliber	Size

8.2 Food Marketing Standards

This section evaluates the sustainability of FMS by examining their potential economic impact and interaction with FW. It highlights that food not complying with FMS often becomes FW due to food safety, short shelf life, and logistical barriers, especially in the fresh fish market.

There are eight FMS that produce FW, while 10 prevent it (Table 13). Public standards mainly aim to increase food safety and FSC efficiency, reducing FW. However, incorrect labelling and bycatch regulations can cause FW. Private standards, while sometimes stricter, may also lead to avoidable FW if products do not meet perfect conditions. Homogeneity in FMS helps reduce FW by ensuring consistency, while integrity standards can increase FW by rejecting products with minor defects. Valued sizes and species can also lead to FW when less desirable ones are left behind or when high-value species are not purchased by consumers.

Overall, the interaction between FMS and FW is complex, with both positive and negative impacts on sustainability.

Table 13: Private and Public Marketing standards and its interaction with Food Waste and Cost-Benefits

	Fresh Fish MS	Preventing FW	Producing FW	Increasing cost	Economic profit
Public	Legal Species		X	X	
	Maximum quota	X		X	
	Traceability	X		X	
	Minimum caliber		X	X	
	Freshness	X			
	Codex Alimentarius CFFP	X		X	

	Cold chain	X		X	
	Label	X	X		
Private	Size		X	X	X
	Homogeneity	X		X	X
	Freshness	X	X	X	X
	Temperature	X		X	X
	Geographical origin	X		X	X
	Extraction/production method	X		X	X
	Proximity	X		X	X
	Species		X	X	X
	Integrity		X	X	X
	Absence of substances	X	X	X	X
	Total	**13**	**8**	**14**	**10**

Table 13 highlights the economic impact of public and private FMS. Public FMS are mandatory, often involving costs but no direct economic benefit as they provide a uniform framework for all markets. Private FMS, while also costly, offer economic benefits and builds customer confidence. Non-compliance with private FMS can lead to customer loss, reduced payback, market exclusion, and increased FW.

Interviews revealed that private FMS are more significant for stakeholders, driven primarily by customer demands. Key concepts include quality, freshness, safety, traceability, and labelling, all crucial for preventing FW. Implementing FMS involves control, additional work, and personnel, but these costs are minor compared to the benefits of meeting standards and increasing profits.

Waste was not a major focus in the discussions (Figure 10), as the wild-caught fish sector is just beginning to address FW issues, making tracking and measuring FW an area in development.

Figure 10: Major concerns of Fish stakeholders

8.3 Food Waste estimates

Not all of the FMS identified in the fish CS contribute to FW. Figure 11 highlights the most relevant FMS generating FW, summarized at each stage of the fish FSC. Also, Table 14 presents the FMS causing the most and least FW in the fish FSC.

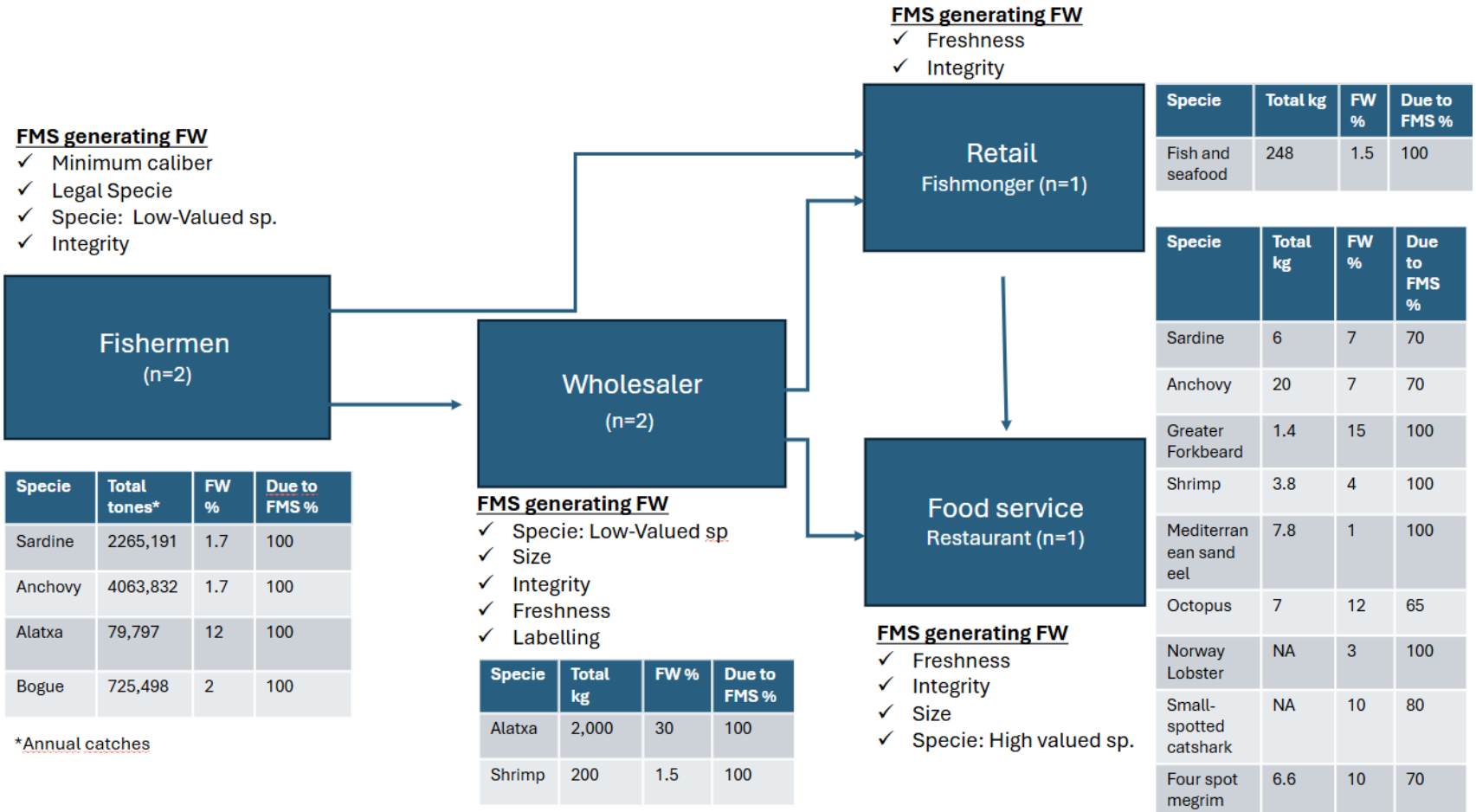
Three FMS causing the most FW:

- ✓ Wholesaler (Alatxa): 30% FW due to species (low-valued), size, integrity, freshness, and labelling issues.
- ✓ Primary production (Alatxa): 12% FW due to minimum caliber, legal species, low-valued species, and integrity.
- ✓ Food service (Greater Forkbeard): 15% FW due to freshness, integrity, size, and high-valued species.

Three FMS causing the least FW:

- ✓ Food service (Mediterranean sand eel): 1% FW due to freshness and integrity.
- ✓ Retail (fishmonger): 1.5% FW due to freshness and integrity.
- ✓ Wholesaler (Shrimp): 1.5% FW due to species (low-valued), size, integrity, freshness, and labelling issues.

It is noticeable how FW estimates are low for most stages, with whole sale and food service having higher ratios. This may be due to the position at the end of the supply chain, mainly caused by the loss of product integrity and freshness during handling, as well as irregularity in customers' demands and expectation, increasing the pressure over some private FMS, as high-valued species that are not always demanded (e.g. Norway lobster).



Specie	Total tones*	FW %	Due to FMS %
Sardine	2265,191	1.7	100
Anchovy	4063,832	1.7	100
Alatxa	79,797	12	100
Bogue	725,498	2	100

*Annual catches

Specie	Total kg	FW %	Due to FMS %
Alatxa	2,000	30	100
Shrimp	200	1.5	100

Specie	Total kg	FW %	Due to FMS %
Fish and seafood	248	1.5	100

Specie	Total kg	FW %	Due to FMS %
Sardine	6	7	70
Anchovy	20	7	70
Greater Forkbeard	1.4	15	100
Shrimp	3.8	4	100
Mediterranean sand eel	7.8	1	100
Octopus	7	12	65
Norway Lobster	NA	3	100
Small-spotted catshark	NA	10	80
Four spot megrim	6.6	10	70

Figure 11: Distribution of FW (+ FW due to FMS) across fish FSC, Case study - Spain

Table 14: Estimate of (weekly) total production, average FW and average FW due to FMS for various Fish products

Case study	Country	FSC	Food product	Total production (tons)	Average FW estimate (%)	Average FW estimate due to FMS (%)	FMS causing FW
F.CS1.Opp-ES	Spain	Primary production (fishermen)	Sardine	2,265,191*	1.7	1.7	✓ Minimum caliber ✓ Legal species ✓ Species: low-valued sp. ✓ Integrity
			Anchovy	4,063,835*	1.7	1.7	
			Alatxa	79,797*	12	12	
			Bogue	725,498*	2	2	
		Wholesaler	Alatxa	2	30	30	✓ Specie: low-valued sp. ✓ Size ✓ Integrity ✓ Freshness ✓ Labelling
			Shrimp	0.2	1.5	1.5	
		Retail (fishmonger)	Fish and seafood	0.25	1.5	1.5	✓ Freshness ✓ Integrity
		Food service (restaurant)	Sardine	0.006	7	4.9	✓ Freshness ✓ Integrity ✓ Size ✓ Specie: high-valued sp.
			Anchovy	0.02	7	4.9	
			Greater Forkbeard	0.0014	15	15	
			Shrimp	0.0038	4	4	

			Mediterranean sand eel	0.0078	1	1	
			Octopus	0.007	12	7.8	
			Four spot megrim	0.0066	10	7	
*** = annual catches**							

8.4 Challenges

Interviews across the FSC reveal that the revalorization of products is minimal or nearly non-existent. The fishermen stage presents an opportunity to revalorize products that do not meet private FMS for other human consumption uses. However, the unpredictability of catches, forecasting difficulties, and diverse catch compositions make it challenging to establish stable value chain relationships to enhance product value and reduce food waste. At other stages, revalorization is more difficult due to short shelf life and the need to maintain the cold chain, creating logistical issues. Wholesalers could facilitate revalorization, but bureaucratic and legal requirements significantly hinder this process.

9. CONCLUSION

9.1 Conclusion

In this report D2.5, the analysis of FMS and their influence on FW and FW estimates collected by the 16 CSs across five food commodities (fruits and vegetables, cereals, meat, fish and eggs) are presented. This work uncovered the complex relationship between FW and FMS at the company level. A six-step approach was used for data collection, pre-processing, and sensemaking, ensuring a smooth workflow and allowing for the immediate identification and management of any inconsistencies or errors.

During data collection, through interviews and surveys, the CSs faced several challenges such as stakeholder reluctance, small sample size due to rejection in answering (response rate), claims of not monitoring FW, and some interviewees found difficulties in understanding questions due to the complex nature of the subject matter. These limited sample sizes may not fully represent the broader industries, potentially affecting the generalizability of the findings. Additionally, the definition of FW is not uniform across all commodities, making alignment over the different CSs challenging before starting data collection. Monthly meetings with the CSs provided opportunities to reflect on, and find solutions for these challenges. Conducting interviews helped explore and understand the difficulties when FW and FW-FMS estimates were not shared.

During sensemaking, different trends and patterns were uncovered using the filled-out reporting templates of the 16 CSs, who worked closely with the assigned data processors and data analysts. However, there were substantial data limitations, particularly concerning incomplete information on FW for certain products. For example, total production volumes and FW amounts for some items were not provided, limiting the ability to make precise calculations or draw robust conclusions about FW generation across these products. This lack of comprehensive data may skew the analysis of FW patterns and hinder the development of effective recommendations for waste reduction strategies. It also became clear that FW monitoring was not a key priority for some companies, or they were unwilling to share the data. Additionally, obtaining estimates on FW-FMS was challenging because different companies did not measure and monitor FW caused by specific reasons such as FMS. This made it difficult to receive data on FW-FMS from various companies along the food supply chain (FSC) in different sectors.

To highlight some key results on food waste estimates due to food marketing standards;

Cereals (Italy and Slovenia):

- ✓ Corn (Retail, distribution, and processing): 3.5% FW due to vitreous seeds, absence of teguments, and light-coloured seeds.

- ✓ Wheat flour (Retail, distribution, and processing): 12% FW due to mycotoxin levels, foxing or weathering, specific weight, residues of plant protection products, absence of foreign bodies, organic production, and type of milling.
- ✓ Soy (Retail, distribution, and processing): 1.509% FW due to damaged seeds and limited levels of GMO.
- ✓ Wheat (Primary production): 1.20% FW due to standards on protein content (low < 11.5%) and presence of mycotoxin levels.
- ✓ Oat flakes (Processing): 0.03% FW due to IFS certification and packaging inefficiencies.

Fish (Spain):

- ✓ Alatxa (Wholesaler): 30% FW due to species (low-valued), size, integrity, freshness, and labelling issues.
- ✓ Alatxa (Primary production): 12% FW due to minimum caliber, legal species, low-valued species, and integrity.
- ✓ Greater Forkbeard (Food service): 15% FW due to freshness, integrity, size, and high-valued species.

Eggs (Denmark):

- ✓ Eggs (Primary production): 3.35% FW due to standards related to appearance and quality.
- ✓ Eggs (Retail and distribution): 0.5% FW due to standards related to appearance and quality after sorting.
- ✓ Eggs (Processing): 6.84% FW due to standards related to appearance and quality.

Meat (Belgium and EU):

- ✓ Whole beef (Processing and manufacturing, retail and distribution): 12.5% FW due to discarded Category III standards.
- ✓ Deboned beef carcasses (Processing and manufacturing, retail and distribution): 9.8% FW due to IFS standards.
- ✓ Slaughtered beef carcasses (Processing and manufacturing, retail and distribution): 9.0% FW due to IFS standards.
- ✓ Cooked ham (Processing and manufacturing): 0.15% FW due to FMS.
- ✓ Processed products (Processing and manufacturing): 0.12% FW due to FMS.

Fruits and Vegetables:

- ✓ Organic Limes (Primary Production): 30% FW due to colour requirements and spoilage.

- ✓ Organic Limes (Germany, Wholesale): 11,1% FW due to not meeting customer specifications such as colour requirements and size.
- ✓ Carrot (Portugal, Primary production): 24.2% FW due to standards related to appearance (broken carrots, size, and deformation).
- ✓ Persimmons (Spain, Primary production): 22.47% FW due to various standards.
- ✓ Tomato (Slovenia, Primary production): 0.05% FW due to public FMS related to size, shape, and quality.
- ✓ Potato (Slovenia, Primary production): 0.08% FW due to public FMS standards related to shape, size, or quality.
- ✓ Onion (Slovenia, Primary production): 0.24% FW due to public FMS related to size, shape, and quality.

These estimates illustrate the significant variation in FW across different products and stages of the food supply chain, influenced by specific food marketing standards requirements.

To conclude, FW is a problem encountered in all commodities, yet measuring FW is for some companies not a priority. Additionally, no distinction is made between FW and FW-FMS in several companies. In this fast-changing reality, there are significant differences between companies; some are front runners already tracking FW and FW-FMS, and finding solutions, while others prefer to hold off until action is required, as they do not yet see the added value. However, as of 2026, CSRD requires companies, with more than 250 employees to report transparently on their environmental impact, social responsibility and governance. This will definitely bring changes in the near future.

9.2 Limitations of the study

A key limitation of the study is the relatively small sample size for most case studies in the various food commodities. The CSs indicated that motivation to participate in interviews, fill out surveys and share data was limited. These limited sample sizes may not fully represent the broader industries, potentially affecting the generalizability of the findings. Additionally, there are considerable data limitations, particularly concerning precise information on FW for certain products. For example, production volumes and waste amounts for some cereals were not provided, limiting the ability to make precise calculations or draw robust conclusions about FW generation across these products. This lack of comprehensive data may skew the analysis of FW patterns and hinder the development of effective recommendations for waste reduction strategies.

9.3 Research and Policy Considerations

9.3.1 Research Recommendations

- ✓ Expand Sample Size: Conduct broader studies involving diverse stakeholders across regions and scales of operation to enhance representativeness.
- ✓ Analyse Specific Standards: Investigate the unique challenges and benefits associated with each type of FMS, focusing on their direct and indirect impacts on food waste.
- ✓ Quantify Waste Reduction Impact: Develop metrics to assess the effectiveness of interventions aimed at reducing food waste attributable to FMS compliance.

9.3.2 Policy Recommendations

- ✓ Harmonize Standards: Align public and private standards to reduce inconsistencies and operational burdens on companies.
- ✓ Support Waste Reduction Initiatives: Provide financial or technical assistance to companies implementing waste-reduction strategies, such as process optimization and circular practices.
- ✓ Facilitate Coordination: Promote national and sectoral-level coordination to address gaps in food waste management and enhance alignment of FMS with sustainability goals.
- ✓ Encourage Innovation: Incentivize technologies like blockchain for traceability and revalorization of suboptimal products to reduce waste and maximize resource use.

9.3.3 General Recommendations

- ✓ Expand Data Collection and Monitoring: Invest in robust tracking systems for food waste across all product categories to improve the accuracy of waste assessments.
- ✓ Enhance Cost Management for FMS Implementation: Streamline the process of adhering to FMS by leveraging automation and improving internal documentation systems to reduce administrative and certification costs.
- ✓ Increase Focus on Sustainability Metrics: Incorporate more sustainable practices into operations, increasing consumer awareness and demand for sustainable products.
- ✓ Promote Waste Reduction Initiatives: Share best practices and collaborate with industry peers to create more efficient production processes, optimize recipes, explore alternative processing methods, and develop new products from waste materials.
- ✓ Broaden Retailer Engagement on Sustainability: Work closely with retail partners to align on sustainability goals, develop joint initiatives to reduce environmental impact, improve product packaging, and reduce food waste during production transitions.

- ✓ Invest in Training and Knowledge Sharing: Provide ongoing training for staff in compliance, documentation, and waste management to mitigate costs and promote efficient practices.
- ✓ Research on Waste Fate and Recovery: Explore innovative waste management strategies beyond degradation to feed or incineration, such as reprocessing waste into new products or exploring more sustainable disposal methods. Conduct research into the long-term environmental impacts of current waste management practices to make more informed decisions.

These recommendations aim to address the key challenges of food waste, FMS compliance costs, and sustainability within the industry, while encouraging more effective practices and collaboration.

10. REFERENCES

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11. APPENDICES

11.1 Participant Information Sheet and Consent Form

BREADCRUMB

Annex 1: Information sheet + informed consent

Template: Information Sheet for BREADCRUMB

This is a template for informed consent when collecting and processing personal data in BREADCRUMB. It can be used for surveys, observation, interviews, sound recording, etc. When you provide your own text, please, use clear and simple language, headings, and bullet points, active (not passive) language, and avoid foreign words.

Please change all text market in yellow. *Omit the italics*

Information sheet

Dear participant,

You are invited to voluntarily participate in BREADCRUMB's research activity, **"Generating estimates of food waste caused by food marketing standards in different food commodities on a local level".** Before you agree to participate in this study, it is important that you read this information form carefully. If anything is not clear, please do not hesitate to ask questions, contact information can be found at the bottom of this document.

What is the purpose of the project

BREADCRUMB aims to provide an empirical evidence-based understanding and purpose of food marketing standards, along with their influence on the generation of food waste (FW). Its goal is to suggest interventions that strike a balance between the aim of FW reduction and other standards-related objectives, while assisting food chain participants in maximizing the commercial viability of less-than-optimal food products.

To achieve these goals, the project will address 16 case studies in five different food commodities (fruit & vegetable, meat, eggs, cereals, and fish).

Who is responsible for the research project?

ILVO is the responsible for project (i.e. the project coordinator).

What is the purpose of the research activity?

Briefly describe the research activity (e.g., survey, interview, observation, etc.), and the purposes for data collection and data processing. Use the example below, as per case of activity, and adjust the text accordingly.

Our purpose with the [name the activity, i.e., survey, interview, observation] is to gain more detailed information and deeper insight into [include here the objectives of the activity]

To avoid information being lost during the interview, a sound recording of the interview will be made - if you agree to this. The sound recording will be erased within 3 months (if applicable)

Who is responsible for the data-collection in this research activity?

Breadcrumb has the following project partners VLTN, UNIBO, Natura Nuova, CREDA, UCPH, ITC, AINIA, CSCP, AVEC, Vila natura, Zelena Tocka, Anecoop, LF, Lehman Natur, FEBEV, FENEVIAN, PNO, MC and Mensana.

ILVO is responsible for the data collection in this research activity. Contact details can be found on the last page of this document."

Why are you being asked to participate?

Describe how the sample has been selected (population, selection criteria and how many people have been asked to participate), so that it is clear why the person is receiving this inquiry. If applicable, indicate whether you have received the person's contact details from another (and indicate any approval/permission obtained in order to do this), or whether another has sent out this information letter on your behalf.

What does participation involve for you?

Describe the methods (online/paper-based survey, interview, observation, etc.), what type of information will be collected and how the information will be recorded (electronically, on paper, sound/video recording), also including the expected duration of the activity. Use the example below, as per case of activity, and adjust the text accordingly.

If you chose to take part in the research activity, this will involve that you [fill in an online survey, answer to some questions of an interview, etc.]. Your participation is expected to last approximately [add here the duration - XX hours/minutes]. The [survey, interview, etc.] includes questions about [describe the most important questions/topics]. Your answers will be recorded [electronically, using pen and paper, sound recording, etc.].

For the case of interviews, please also add the following text as is: In case translation between different languages is needed, the interview may last a little longer. If you permit, the interview will be recorded. If you are not comfortable with sound recording, detailed notes will be taken.

Potential benefits or risks of participation

Your involvement contributes to advancing scientific understanding, developing evidence-based solutions to combat food waste, and benefiting society. There are no direct benefits from your participation and there are no foreseeable risks in the participation.

Participation is voluntary

Your participation is completely voluntary. You have the right to refuse to answer any questions you are uncomfortable with or to skip any sections. If you chose to participate, you can withdraw your consent at any time without giving a reason. There will be no negative consequences for you if you chose not to participate or later decide to withdraw. If you do not wish to continue participating, you will be given the choice of having the data already collected erased or give your consent to the researcher to

continue processing the results already acquired from the research However, deleting your data is no longer possible once the data has been anonymised, as anonymous data cannot be traced back to you.

Confidentiality & Privacy

Your identity and responses will remain confidential. Any personal data obtained will be handled securely. It will not be disclosed to anyone outside of the BREADCRUMB research team without your explicit consent. Only the involved researchers and authorized personnel from their own institutions will have access to the research data collected during the study. Partners of the project will have access to the anonymised data. The research results and analysis will only ever be communicated in *anonymised* form and be made available to the public via the website of BREADCRUMB, relevant publications, or other exploitation outcomes of the project. We will use your personal data only for the purpose(s) specified in this information letter.

The project will end in December 2026. All personal data will be stored only for the minimum period required to complete the research activities, which is foreseen 2 years after the project end, and in accordance with the accounting rules that apply under Horizon 2020, no longer than five years from the end of the project, when it will be deleted.

In accordance with the General Data Protection Regulation (GDPR), your privacy will be respected. As already indicated, you may withdraw your consent at any time and without giving any reason. This means that your data will not be further processed from the moment of withdrawal.

You have the right to access the data collected about you and may also request a copy, if this does not infringe the rights and freedoms of others. Any incorrect data about you may be corrected at your request. Furthermore, you have the right to be forgotten: this means that, after withdrawing your consent, you may ask for your personal data to be deleted. However, deleting your data is no longer possible once the data has been anonymized, as anonymous data cannot be traced back to you.

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Contact information

"For questions about the project, please contact rani.vangompel@ilvo.vlaanderen.be or capwellforbang.echo@ilvo.vlaanderen.be or sofie.deman@ilvo.vlaanderen.be or anna.twarogowska@ilvo.vlaanderen.be

For withdrawal of your consent or questions regarding the use of your personal data, please contact [insert name and contact details of the data protection officer at the institution responsible for the data collection]

If you believe that we are improperly processing your data, you can complain to [inset name and contact details of National Data Protection Authority]

Kind regards,

Researcher responsible for data collection

Consent form

Selecting "I Agree" below indicates that:

- You have received and read the information in the BREADCRUMB Information sheet;
- You give permission to be recorded;
- You understand the procedures described above and the expected duration of the storage of the data;
- You have been given the opportunity to ask questions;
- You voluntarily agree to participate, and you are free to withdraw at any time without giving a reason and without consequences;
- You understand that your personal information will be treated and handled in accordance with the provisions of the EU General Data Protection Regulation (Reg. 2016/679);
- You are at least 18 years of age.

o I Agree

If you consent to the use of your personal data for the processes outlined in this notice, under the BREADCRUMB project activities, please check accordingly:

I give consent:

- o to participate in this BREADCRUMB research activity
- o for my personal data to be processed, as described in the information letter
- o for making a sound recording of the [interview/ focusgroup] to avoid information being lost during the interview – *if applicable*

Participant's Signature: _____ Date: _____

Researcher's Signature: _____ Date: _____

11.2 Guiding questions / template used by case studies

Question guides for case study partners

All partners can adapt these questions according to their own context. Make sure that you can answer the reporting template with the interviews. Each interviews is a new entry, so a new Microsoft form. For the surveys, you can send the structured excel file, with your codebook.

Company level

1. In what stages of the supply chain is your business operating? (Primary Production, Processing & Manufacturing, Retail and distribution (wholesale), restaurant and food services)
2. What is the size of your company? *(SMEs, large enterprise, micro enterprise, mid-sized enterprise, …)* and what is the geographical coverage of your company? (*Local, national, international, …)*
3. Which food commodity does your company operate? (*Fruit & vegetables, meat, fish, cereals, eggs)*
4. What specific products do you focus on? (*Try to be as specific as possible. E.g. not only say tomatoes, but rather cherry tomatoes).*

Depending on what type of actor (Farmer, processors, retailers or food services), include the following

Food marketing standards (FMS)

5. Which food marketing standards (FMS, public and/or private) does your company implement or which FMSs are more relevant for your company? (you can always add a few examples as an interviewer in IDI or FGI, or a drop-down list for surveys can be made possible such as those outlined in Regulation (EU) 1308/2013 with a last option of "others" to be listed by the respondent.)
   - ➔ 5a. Which FMS are public (i.e. government mandated)? Are they on European level or national level?
   - ➔ 5b1. Which FMS are private? what is the nature i.e. voluntary or imposed? Which entity created it/where does it come from?
   - ➔ 5b2. If they are private food marketing standards, Why did your company commit to participating in this?
6. How is/are X standard(s) implemented?
7. What factors influence your decision to adhere to private marketing standards? (e.g., access to the market, good reputation) or
8. What is the implication/requirement for your organization to implementing the private FMS? Think about the costs and benefits: financial, social, environmental, different procedures, new machinery, logistics, quality controls). Explain (in case of IDI)
9. Do you face any challenges when implementing these food marketing standards?

Food marketing standards influencing food waste

Note: focus on products that were mentioned in question 4

10. Is the food waste that is generated in your company monitored/tracked/ recorded/weighed? If yes, why and how?
11. Does your company face food waste in relation to the marketing standards of the products it deals with? (Yes/no)
12. Please provide all information in this table below:

a. What is the estimated food waste generated by your company per product mentioned? (Provide the absolute numbers (kg/year) of each product. If % is provided, ensure to provide total production, or amounts so that an absolute value can be calculated)
b. Is the FW generated mentioned above associated with a FMS? (*Yes/No*)
c. What proportion of the estimated FW generated is due to FMS? *(Provide the absolute numbers (kg/year) of each product that you are talking about.*

Table 1 (related to Q12)

	Product	**Estimated FW (kg/year) (Q12a)**	**FW Associated with FMS? (yes/no) (Q12b)**	**Estimated FW generated is due to FMS (kg/year) (Q12c)**
1				
2				
3				

13. On a scale from 0 to 100%, to what extent do you believe you comply with each FMS, on average? (Table 2) Can you mention what specific activities you do as part of compliance to the FMSs?
14. uan What would be the consequences of relaxing these standards? What impact would it have on products q tities? (Qualitative and Quantitative) (Table 2)

Table 2 (related to Q13-Q15)

Product	FMS complied with	Rate of compliance to this MS (scale: 0 to 100%) (Q13)	Consequences of having FMS relaxed n terms of products' quantities (Q15)

Suboptimal food/product (definition above in introduction)

15. What are you doing with food that doesn't comply with food marketing standards? (*Think about the suboptimal food, that is still sold, such as apples for apple juice, but has a negative economic impact on your company).*
16. What solutions are implemented regarding this suboptimal food, to avoid food waste?

The future

17. Are there some plans in the pipeline for reducing food waste? (Maybe related to FMS)

If you are interviewing retail actors:

18. If you inform your customers that the supermarket is trying to reduce food waste by selling product X not satisfying a particular MS with a 10% reduction in price, how much of the waste rate (%) produced within your shops do you think would decrease? (Table 3)

19. Do you think these marketing standards are relevant for the consumers? *(Qualitative) (Table 3)*

20. What would be the consequences of having FMSs standards relaxed in terms of products' quantities offered to consumers? (*Quantitative) (Table 3)*

Table 3 (related to Q19-Q21)

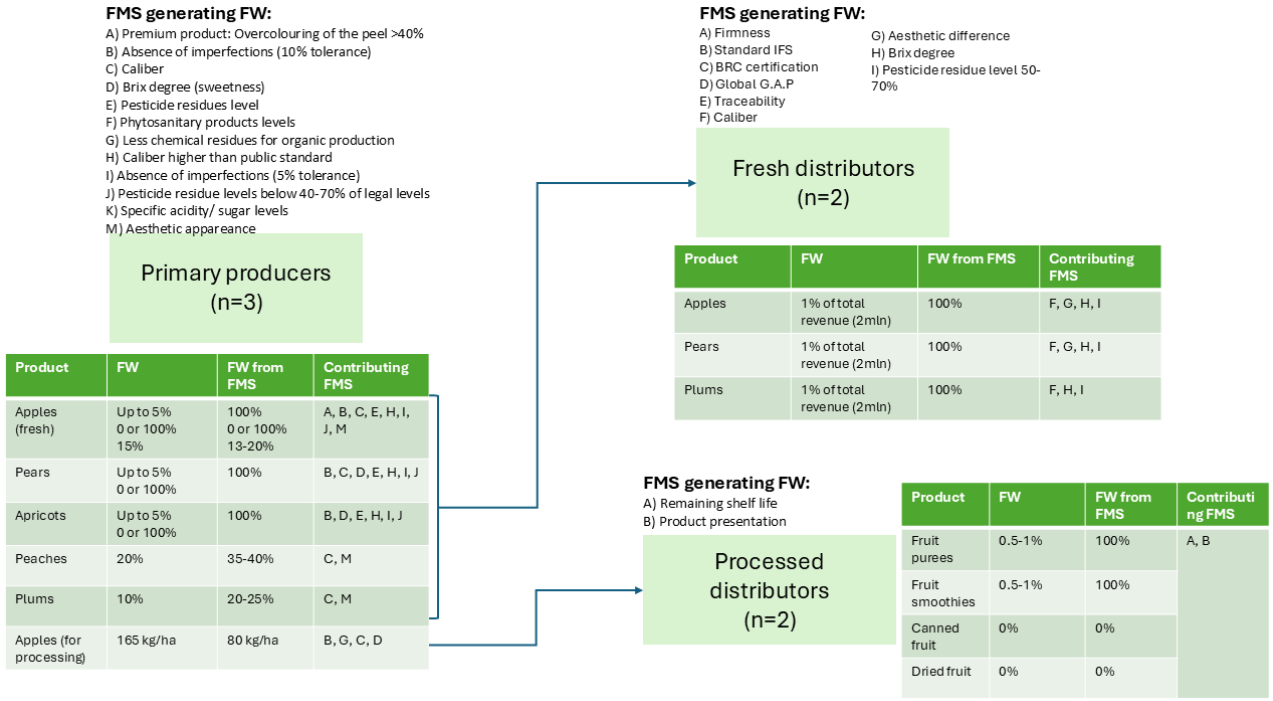
Product	FMS complied with	Do you think the MS is relevant for consumers? (Q20)	Consequences of having FMS relaxed in terms of products' quantities (Q21)

Table 4 (for all supply chain actors contacted)

Food product	Relevant marketing standards (MS)	Do you comply with this MS? 1=Yes; 0=No	If yes, how do you rate your level of compliance with this MS? 1=Very low 2=Low 3=Average 4=High 5=Very high	Do you think the compliance level with this MS leads to food waste? Yes=1; No=0	If yes, how do you rate (in percentage terms) the level of FW due to the current compliance level of this MS? (%)

11.3 Overview of FMSs influencing FW at each stage of the supply chain in F&V in Italy.

The figure highlights the affected products and corresponding waste outcomes. The values in "FW from FMS" columns refer to the percentage of total FW caused by FMS (e.g. Apples for fresh distributor: FW is 1% of total revenue and it is totally caused by FMS, thus FW from FMS is 100%)

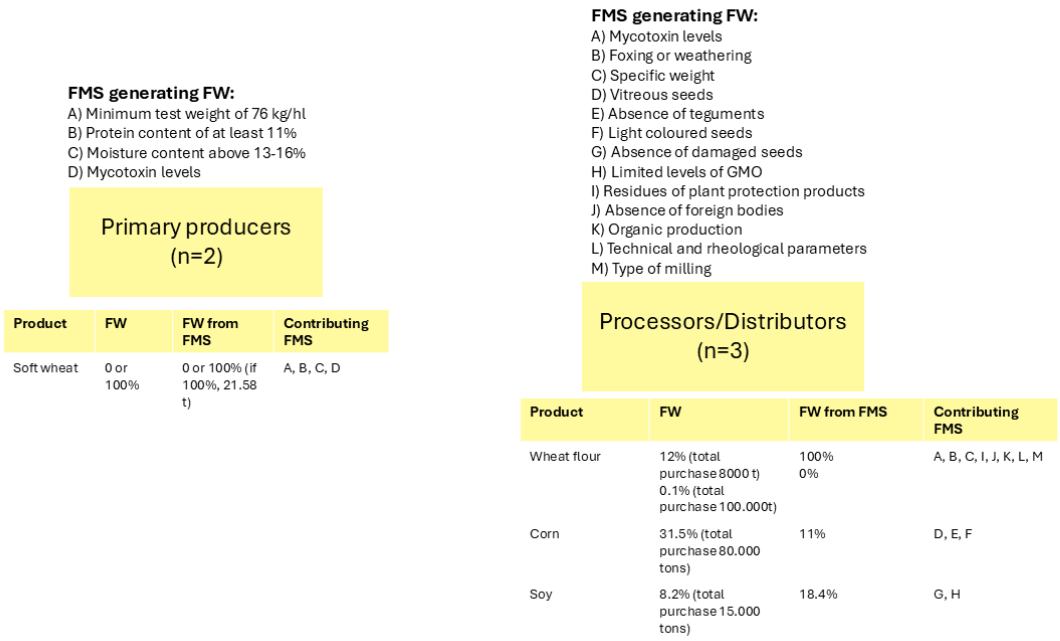


Product	FW	FW from FMS	Contributing FMS
Apples (fresh)	Up to 5% 0 or 100% 15%	100% 0 or 100% 13-20%	A, B, C, E, H, I, J, M
Pears	Up to 5% 0 or 100%	100%	B, C, D, E, H, I, J
Apricots	Up to 5% 0 or 100%	100%	B, D, E, H, I, J
Peaches	20%	35-40%	C, M
Plums	10%	20-25%	C, M
Apples (for processing)	165 kg/ha	80 kg/ha	B, G, C, D

Product	FW	FW from FMS	Contributing FMS
Apples	1% of total revenue (2mln)	100%	F, G, H, I
Pears	1% of total revenue (2mln)	100%	F, G, H, I
Plums	1% of total revenue (2mln)	100%	F, H, I

Product	FW	FW from FMS	Contributing FMS
Fruit purees	0.5-1%	100%	A, B
Fruit smoothies	0.5-1%	100%	
Canned fruit	0%	0%	
Dried fruit	0%	0%	

11.4 Overview of FMSs influencing FW at each stage of the supply chain in the cereal sector in Italy.



Product	FW	FW from FMS	Contributing FMS
Soft wheat	0 or 100%	0 or 100% (if 100%, 21.58 t)	A, B, C, D

Product	FW	FW from FMS	Contributing FMS
Wheat flour	12% (total purchase 8000 t) 0.1% (total purchase 100.000t)	100% 0%	A, B, C, I, J, K, L, M
Corn	31.5% (total purchase 80.000 tons)	11%	D, E, F
Soy	8.2% (total purchase 15.000 tons)	18.4%	G, H

11.5 Contribution of FW due to FMS on total FW in the Portuguese case study

PRODUCT	PRIMARY PRODUCTION				PROCESSING			RETAIL			
	FW %	FW DUE TO FMS %	CONTRIBUTION OF FW DUE TO FMS ON TOTAL FW (%)	FMS GENERATING FW	FW %	FW DUE TO FMS %	FMS GENERATING FW	REJECTED AT RECEPTION (%)	REJECTED AT RECEPTION DUE TO FMS (%)	CONTRIBUTION OF PRODUCTS REJECTED AT RECEPTION ON TOTAL PRODUCTS REJECTED AT RECEPTION (%)	FMS GENERATING FW
Lettuce	1,8%	0,0%	0,0%	None. The existing FW is due to overstocks and difficulty in predicting sales				0,9%	0,6%	66,1%	Labeling, size, poor commercial appearance, Unfresh appearance, brownish leaf tips
Round Tomato	10,0%	0,0%	0,0%	None because of efforts made in investment and planning in production				0,5%	0,5%	88,9%	Labeling, size, no consistency, color, epidermal defects
Carrot	25,5%	24,2%	95,0%	Appearance (Broken carrots, size and deformation)	0,01%	0%	NONE	0,8%	0,7%	83,2%	Labeling, size, dehydrated, poor commercial appearance, packaging, weight
Orange	15,0%	13,5%	90,0%	Epidermic defects	0,01%	0%	NONE	0,4%	0,2%	40,5%	Labeling, size, organoleptic characteristics, epidermal defects
Raspberry	15,0%	0,0%	0,0%	None because there are several channels to valorize raspberries	0,01%	0%	NONE				
Strawberry					0,01%	0%	NONE	3,2%	2,0%	62,4%	Labeling, coloring, poor commercial appearance, undersize, sugar content, packaging
Apple Gala	11,1%	1,2%	11,0%	Colour, size and epidermic defects	0,01%	0%	NONE	4,3%	0,1%	2,5%	Labeling, packaging, size, bruising, hardness, changes in the polp, poor commercial appearance
Pear Rocha	20,3%	3,7%	18,0%	Colour, size and epidermic defects	0,01%	0%	NONE				
Banana								0,0%	0,0%	26,3%	Ripening, bruising, epidermal defects

11.6 Calculation of per year% estimate of FW and FW-FMS in the Danish egg sector

IDI Identity	FSC	Interview data							Estimated/Calculated			Remarks	Estimated FW (%)	Estimated FW-FMS (%)
		Production					FW (kg)	FW-FMS (Kg)	Production	FW	FW-FMS			
		Time Frame	Number	kg	Cost	Income			Kg/year	Kg/year	kg/year			
Breadcrumb_IDI_Egg_producer_DK01	Producer	per month		78,120.00			400.00		937,440.00	3,650.00	3,650.00	10 kg per day	0.39	0.39
Breadcrumb_IDI_Egg_producer_DK04	Producer	Per day		600.00	75,000.00 kr.		30.00		219,000.00	10,950.00	10,950.00		5.00	5.00
Breadcrumb_IDI_Egg_producer_DK05	Producer	Per month	2,900,000.00	174,000.00	2,053,200.00 kr.				2,088,000.00	104,400.00	104,400.00	Weight is calculated as 0,06 kg per egg	5.00	5.00
Breadcrumb_IDI_Egg_producer&packing-station_DK03	Producer	2024 Q2		115,981.00	1,792,000.00 kr.		1,300.00		463,924.00	5,200.00	5,200.00		1.12	1.12
Breadcrumb_IDI_Egg_producer&packing-station_DK03	packing station	2024 Q2		245,522.00	3,918,394.00 kr.	8,463,731.00 kr.	1,798.00	623.00	982,088.00	7,192.00	2,492.00	623 kg is the waste after sorting out.	0.73	0.25
Breadcrumb_IDI_Egg_packing-station&product factory_DK06	packing station		400,000,000.00	25,000,000.00			206,000.00		25,000,000.00	206,000.00	23,000.00	184 tons of liquid products during processing + 23 tons of egg shells	0.82	0.09
Breadcrumb_IDI_Egg_packing-station&product factory_DK07	packing station			36,015,000.00			290,000.00		36,015,000.00	290,000.00	290,000.00	*0,7-0,8 percentage	0.81	0.81
Breadcrumb_IDI_Egg_product-factory_DK02	Product factory			6,000,000.00					6,000,000.00	30,000.00	84,000.00	*FW is less than half percent * Company no longer cracks the eggs, they only buy liquid products. The FW-FMS is calculated based on 12% of Shell waste of their 700 tonnes of egg beings processed	0.50	1.40
Breadcrumb_IDI_Egg_packing-station&product factory_DK06	Product factory			15,000,000.00					15,000,000.00	1,670,000.00	1,100,000.00	570 tonnes of liquid waste + 1100 tons of eggshell. Liquid waste are not calculated as food waste. Thus, shell of eggs are taken a FW	11.13	7.33
Breadcrumb_IDI_Egg_packing-station&product factory_DK07	Product factory			4,918,000.00			798,000.00		4,918,000.00	798,000.00	590,160.00	12% shell of eggs + 4,2% in processing	16.23	12.00

11.7 Liquid waste during the processing of egg products, an example from a company

		Liquid egg white	Powder per 4,7 mT EWP
01	Flushout from Roadtanker (Foam)	2-5 kg / 25 mT	1 kg / Batch
02	Flushout from storage tank	2-5 kg / 50 mT	0,5 kg / Batch
03	Precipitation at pH change	10-50 kg / 40 mT	3,5 kg / Batch
04	Clarifyer loss	10-20 kg / 40 mT	1,5 kg / Batch
05	Extraction loss in Resin	150-250 kg / 40 mT	25 kg / Batch
06	Flushout from storage tank	2-5 kg / 50 mT	0,5 kg / Batch
07	Sieve residue		1,5 kg / Batch
08	Floor and Dust waste		1,5 kg / Batch
		Total Waste	35 kg / Batch
			< 1 %