BREADCRUMB

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DELIVERABLE 2.6

Estimates of Food Waste Generated due to Marketing Standards, including FW Coefficients

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
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D2.5 – CASE STUDY FOOD WASTE ESTIMATES

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1.0	27/06/2025	Capwell Forbang Echo	Finalising and checking for style and formating

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LIST OF ABBREVIATIONS

Abbreviation	Description
AI	Artificial Intelligence
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
FWC	Food Marketing Coefficient

EXECUTIVE SUMMARY

This report presents a comprehensive examination of food waste (FW) associated with food marketing standards (FMS) across five key product categories: fruit and vegetables, meat, eggs, cereals, and fish studied in the BREADCRUMB project. Developed within the framework of Work Package 2 (WP2) of the BREADCRUMB project, the report focuses on identifying and quantifying food waste attributable to marketing standards and provides methodological guidance for calculating food waste coefficients.

The report begins with an introduction to the BREADCRUMB project, highlighting WP2's role and its connection to other WPs. It provides definitions and concepts critical to understanding food, waste, and suboptimal food, and outlines insights from previous tasks. A detailed section on food marketing standards follows, examining public and private standards across the EU for different food groups. It draws on qualitative evidence from WP1 and integrates waste estimates from case studies for each food category.

The methodology section introduces the data sources and explains the food waste coefficient determination approach using Monte Carlo simulations and ratio method. This is followed by a dedicated section presenting the calculated food waste coefficients for each product at different stages of the food supply chain.

The report concludes by summarizing the findings and offering policy recommendations aimed at reducing food waste linked to marketing standards. Extensive appendices provide supporting data, including case study methodologies, application of food marketing standards across food supply chain stages, and detailed statistical estimates of food waste.

1. 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. 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]

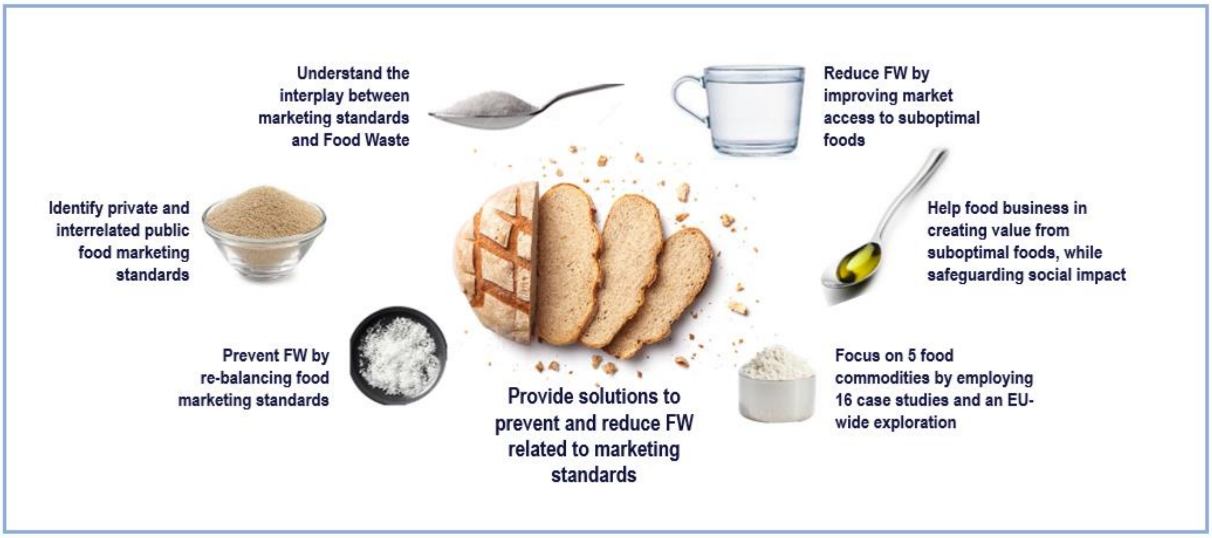


Figure 1: The BREADCRUMB project at a glance

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 employs 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 coordinating institution.

1.2 Overview of BREADCRUMB Work Package 2 and the Case Studies

1.2.1 WP2 and the Case Studies

WP2 in the BREADCRUMB project is strategically positioned with its overall objectives to create evidence based estimates of FW generated and FWC (Figure 2) due to FMS in the five food commodities (fruits and vegetables, meat (poultry, bovine, and pork), eggs, cereals, and fish) for various stages of the FSC targeted by the 16 project case studies of the project (Figure 3). The outputs from WP2 are crucial to feed subsequent work in WP3 and WP4 of the project enabling the overall objectives of the project to be achieved.

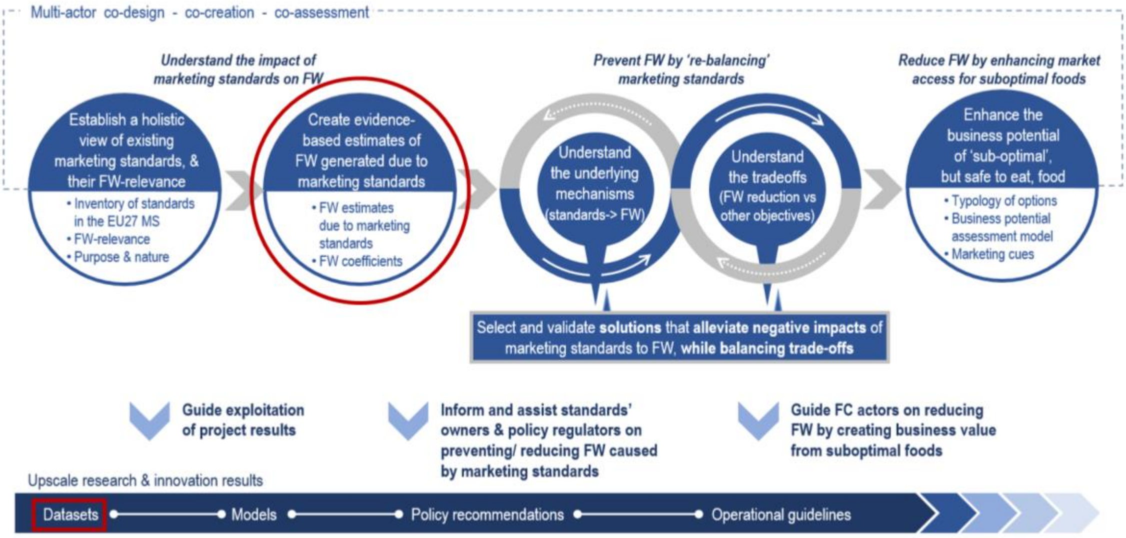


Figure 2: Positioning of WP2 in the BREADCRUMB project

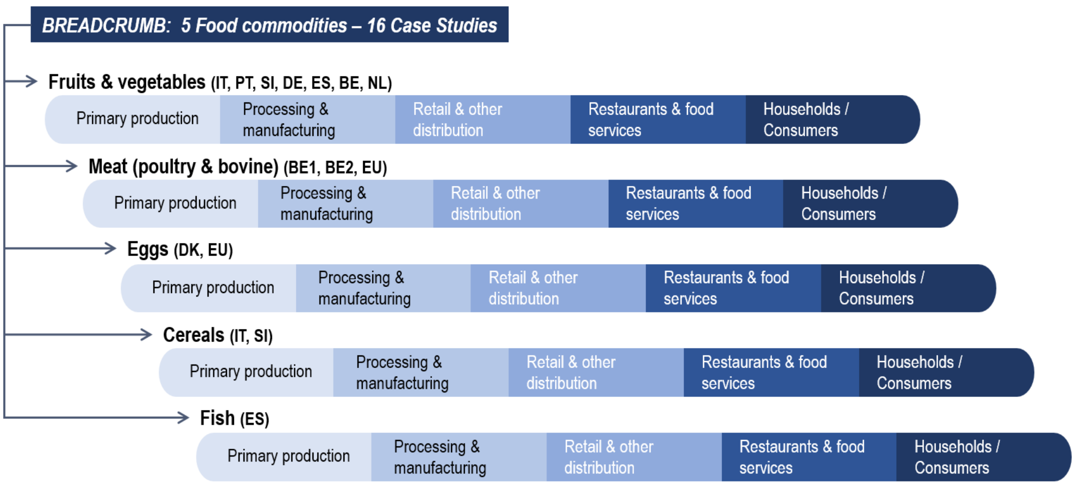


Figure 3: BREADCRUMB Case Studies and food commodities tackled

The CSs are carried out in several EU members states targeting different stages of the FSC to ensure representativeness and enhance comparability of the results obtained. Case studies largely gathered data at company level in the various member states. 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.

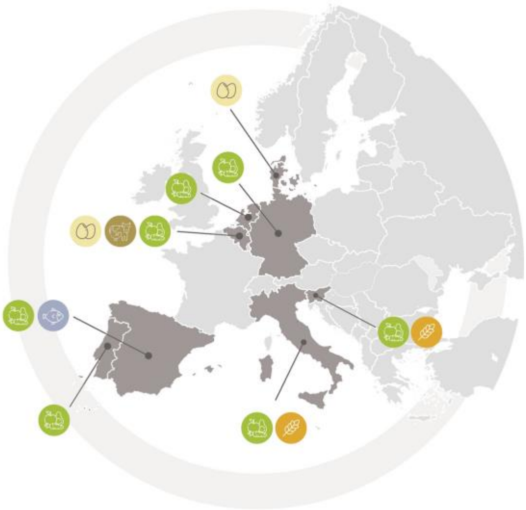


Figure 4: Geographical spread of BREADCRUMB Case Studies

1.2.2 Aim and structure of the report

Deliverable 2.6 (D2.6) presents a comprehensive analysis of FW associated with FMS across a range of product categories within the BREADCRUMB project, with a specific focus on WP2[2] and its case studies. As the final deliverable of WP2, D2.6 is reflective of the work done in T2.4[3], which builds upon previous work under WP2, particularly T2.1[4] and T2.3[5]. Its primary aim is to provide robust, evidence-based estimates of FW generated due to FMS and to translate these estimates into FWCs. The report opens with an introduction to the project's context, objectives, and key definitions, followed by a review of prior findings on the role of FMS in contributing to FW. The methodology section details the data sources and the approach used for calculating FWCs. The main body of the report presents estimated FWCs for fruits and vegetables, meat, eggs, cereals, and fish, highlighting the stages along the FSC where waste occurs. The report concludes with a synthesis of findings, supported by comprehensive appendices containing data tables, calculation methods, and summary statistics.

1.2.3 WP2: T2.4 link with other BREADCRUMB work packages and tasks

Building on WP2-T2.3, which presents the data collection, pre-processing and sensemaking of the 16 CSs, T2.4 and D2.6 focuses on the FWC for a multiple of food products from different food commodities. It also would serve as input to subsequent work in the second half of the project's lifespan. Below is a summary overview of the linkages of T2.4 with the tasks of different WPs. This

[2] WP2 – Evidence-based estimates of FW generated due to marketing standards
[3] T2.4: Evidence-based estimates of FW generated due to marketing standards. This task integrates the results of the FW estimates from the T2.1 and T2.3, providing overall evidence based estimates of FW generated by marketing standards.
[4] T2.1: EU datasets collection, pre-processing and sensemaking. This task identified and collected estimates of FW related to food marketing standards at Eu and National levels.
[5] T2.3 Case studies' datasets collection, pre-processing and sensemaking. This task generated estimates of FW caused by food marketing standards from the project case studies.

interdependency nature ensures comprehensive, cohesive, and impactful outcomes across the project.

- ✓ WP1: T2.4 has benefited from the 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 (surveys and interviews) from T1.3 has been developed and applied to T2.3, ensuring consistency in dataset preparation, processing, and analysis across tasks.
- ✓ WP2: T2.4 has gained from the case study plans (D2.2, D2.3, and D2.4), providing a strategy to closely plan, monitor, and support the CSs in achieving their data collection and research objectives.
- ✓ WP3: T2.4 is synergizing with WP3 by providing essential inputs for developing the agent-based model (ABM) and macro-economic model.
- ✓ WP5: Outputs of T2.4 contribute to the communication, dissemination, and exploitation activities of the project.
- ✓ WP6: The outputs of T2.4 serve as input for WP6 in the overall project evaluation and impact assessment. This alignment ensures that T2.4's results contribute to the broader objectives of the project.

1.3 BREADCRUMB PROJECT: KEY DEFINITIONS, CONCEPTS AND EXPERIENCE FROM PREVIOUS BREADCRUMB TASKS

1.3.1 Food, Waste, and Food Waste

Food or foodstuff can be defined according to the European Commission's (EC) Regulation No 178/2002[6] 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 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[7] as any substance or object which the holder discards or intends or is required to discard while FW varies from the entity defining it and the context in which it is regarded. In the BREADCRUMB project, the EC's definition of FW is adopted which is considered broader and

[6] 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
[7] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

considers all FSC stages. Specifically, Directive 2008/98/EC[7] defines FW as all food that has become waste. For the purposes of the BREADCRUMB project, FW is defined in accordance with the EC definition as any food and its associated inedible parts (such as bones or fruit cores) which do not find their way to human consumption, and rather become discarded. This can occur at all stages of the food supply chain, from farm to fork.

Table 1 provides an overview of various food commodities, detailing the specific CS, targeted products, and the FSC stages involved. It encompasses a diverse range of food categories studied in the BREADCRUMB project namely F&V, meat, eggs, cereals, and fish. Each CS highlights different products within these categories, such as fresh and processed fruits, various types of meat, egg products, grains, and seafood. The stages of the FSC studied include primary production, processing, retail and distribution, and food services, illustrating the comprehensive journey from farm to fork for most commodities. These serves as a useful reference for understanding the complexity and breadth of the FSC across different types of food products and the length to which the BREADCRUMB project diversified its work.

Table 1: Food commodity, food products at some food supply chain stage targeted by case studies

Food Commodity	**Case Study**	**Products targeted**	**Stage of FSC**
F&V	F&V.CS1.NN-IT	Apple (fresh + processed), Pear, Apricot, Peach, Plum, Fruit puree + smoothies, Canned + dried fruit	Primary Production, Processing, Retail and Distribution,
	F&V.CS2.MC-PT	Lettuce, Round tomato, Carrot, Orange, Raspberry, Strawberry, Apple *Gala,* Pear *Rocha*	Primary Production, Processing, Retail
	F&V.CS3.ZT-SI	Apple, Onion, 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	Lime, Lemon, Cucumber, Cherry date tomato, Pepper	Primary Producer, Wholesale, Retail
	F&V.CS6.Ane-ES	Citrus fruit, Persimmon	Primary Production, Processing

	F&V.CS7.ILVO-BE	Blueberry, Raspberry, Strawberry, Blackberry	Primary Production, Distribution, Retail, Match Maker
	F&V.CS8.ILVO.BE_NL	Bell pepper, Tomato, Lettuce	Primary Production Cooperative, Processing, Wholesale, Match Maker
Meat	M.CS1.Fen-BE	Chicken fillet, Bacon, Cooked ham, Raw ham, Sausage, Pâte, Salami Others *(ready meals, head product, sliced raw salty product, beef fillet, meat loaf)*	Primary Production, Processing and Manufacturing, Retail and Distribution
	M.CS2.AVE-BE_EU	Whole chicken, Breast fillet, Leg, Processed product	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 food marketing standards after cutting	
Eggs	E.CS1.LF-DK	Egg and egg products	Primary production, Processing (product factory), Retail 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 Distribution
	C.CS2.VN-SI	Wheat + wheat flour , Oat + oat flake, 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), Wholesale, Retail (fishmonger), Food Service (Restaurant)
*= Alatxa is the Basque name for the Atlantic chub mackerel (*Scomber colias*), a small pelagic fish found in the eastern Atlantic and Mediterranean Sea, resembling the Atlantic mackerel but differing in color and shape.			

1.3.2 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 based on a particular standard, 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 (assumably) remains intact (Aschemann-Witzel et al., 2019; Cao & Miao, 2021; de Hooge et al., 2017).

In the BREADCRUMB project, it was found through previous research activities that stakeholders handle suboptimal food products in different ways for the different food commodities.

- ✓ Non-compliant fruits and vegetables are often repurposed through various methods. They may be sold at discounted prices, used for fermentation and alcohol production, donated to food banks (in some instances with the help of match-making platforms), or redirected to secondary markets such as for puree, frozen food, soup, and ice cream industries. Additionally, these products can be repurposed into sauces, pickles, animal feed, or composted.
- ✓ Suboptimal meat products are typically sold at lower prices, repurposed for animal food production, or degraded to feed or waste. These products may be incinerated, reprocessed, or sold locally at reduced prices. The fate of these products often involves revalorization through processing or repurposing for animal feed.
- ✓ Defective eggs are redirected to the egg processing industry or used in animal feed, and eggshells are repurposed for various applications such as manufacturing tiles and cement mixtures. This approach helps minimize waste and find secondary uses for non-compliant egg products.

- ✓ Non-compliant cereals are either wasted or repurposed for animal feed. This strategy ensures that suboptimal cereal products are utilized in a manner that reduces waste and provides value through secondary uses.
- ✓ Non-compliant fish products are revalorized for other human consumption uses (such as for canned fish, soups etc), although challenges exist due to the unpredictability of catches, short shelf life of catches and diverse catch compositions. Logistical issues can hinder revalorization at other stages, but efforts are made to repurpose these products for human consumption whenever possible.

1.4 Food Marketing Standards and Food Waste Estimates

1.4.1 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 defined by legislation aim to facilitate trade and create a level playing field for EU producers, guaranteeing product quality and accurate labelling (Nes & Ciaian, 2021). 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 international guidelines, developed at different times and under varying conditions, tailored to specific products or entire sectors (European Commission, 2020). Apart from facilitating trade, ensuring 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.

1.4.1.1 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 EU, legislation such as Regulation (EU) No. 1308/2013 (CMO Regulation)[8] and the "breakfast directives" (set of European Union regulations that define the composition, naming, and labelling requirements for specific food products commonly consumed at breakfast) 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.

[8] 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

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.

1.4.1.2 EU Food Marketing Standards in Fruits and Vegetables

An overview of FMS of the F&V commodity implemented by the stakeholders and companies studied in the BREADCRUMB project is provided in Appendix I. It outlines various FMS and their specific contexts, detailing both public and private standards. Public FMS are governed by regulations such as Regulation (EU) No 543/2011, which sets criteria for premium products like overcolouring of the peel and absence of imperfections, and Regulation (EC) No 396/2005, which addresses pesticide residue levels. These standards are implemented across primary production, retail, and distribution stages. Private FMS include contracts, certifications, and labels that often exceed public standards, such as higher calibre requirements and stricter pesticide residue levels. Retailers also have their own standards, including those from e.g. ASDA, TESCO, and ALDI, which are applied in distribution and primary production.

1.4.1.3 EU Food Marketing Standards in Meat

For the meat commodity, Appendix II below provides an overview of the various FMS categorized as well into public and private sectors, detailing their application across different stages of the FSC. Public standards include regulations such as EC No. 1308/2013 for carcass classification, EC No. 1069/2009 for handling animal by-products, and Regulation EC No. 543/2008 for poultry meat marketing, which are implemented at various stages including retail and primary production. Private standards encompass certifications like the International Featured Standards (IFS) and Brand Reputation through Compliance Global Standard (BRC) for food safety and quality assurance, as well as specific standards for meat production such as the Global Red Meat Standard (GRMS), Belbeef, and BePork. Additionally, quality schemes (certifications) like Beter Leven focus on animal welfare, while GLOBAL GAP and FSSC 22000 ensure food safety management across multiple stages of the supply chain, particularly at the primary production stage.

1.4.1.4 EU Food Marketing Standards in Eggs

For eggs in the EU, public FMS are governed by various regulations implemented by the European Commission, including Regulations EU No. 1307/2013, EU No. 1308/2013, EU 2017/1185, and EU

2023/2465. These regulations aim to maintain high product quality, protect consumers, and ensure consistency across the EU market. They set detailed rules for marking, grading by quality and weight, packaging, storing, transporting, and displaying eggs for retail sale. Compliance with these standards is essential for market access, with a key focus on the sell-by date, set at 28 days after the laying date. Comprehensive salmonella control measures are implemented at every stage of production, ensuring only eggs from salmonella-controlled herds are delivered to packing plants and sold in the retail market. The egg sorting process involves checking and categorizing eggs based on size, dirt, cracks, leaks, and blood spots, with discarded eggs due to significant leakage or cracking. Packing stations collect eggs from farmers, conduct further grading and quality control, and ensure compliance with marketing standards. Eggs are transported in thermal vehicles within a cold chain in some countries, while others handle eggs at room temperature. Automated machinery classifies eggs by size, weight, and aesthetic quality, with Class A eggs for consumer sales and Class B eggs for the egg processing industry. EU regulations (except in Sweden) prohibit washing eggs but mandate clean eggshells, with excessively dirty eggs removed from the market. Traceability codes stamped on eggs ensure transparency and accountability in the supply chain.

Private FMS are mostly set by retailers and packing stations, imposing additional requirements on farmers. Baseline standards, such as those outlined by Belplume in Belgium or KAT in Germany, serve as foundational standards for market access. Retailers often introduce stricter criteria to distinguish themselves from competitors, such as demanding at least 21 days of shelf life upon delivery and more frequent controls like monthly audits. Recent initiatives, such as EcoVadis audits and Science Based Target Initiative (SBTi) assessments, reflect a shift towards sustainability over animal welfare. The diversity of standards creates complexity and increases workload for quality departments, making it important for actors to determine whether to obtain necessary certifications. This decision often ties closely to price agreements, highlighting the bargaining power of farmers and other actors. Once set, these agreements establish clear expectations regarding actions and quality standards, with actors expected to fulfil these requirements as agreed. Private standards ensure eggs not only comply with public regulations but also exceed them in terms of quality, presentation, and safety, catering to niche markets demanding superior products. By adhering to these private standards, producers can differentiate their products and potentially command higher prices in the market.

1.4.1.5 EU Food Marketing Standards in Cereals

A summary of the application of FMS across different stages of the cereal FSC, highlighting both public and private standards is highlighted in Appendix III. At the primary production stage, public FMS such as Regulation (EC) No. 396/2005 and Regulation (EC) No. 1881/2006 set limits on chemical residues and mycotoxins levels, while private contracts focus on parameters like moisture content, impurity levels, and protein content. Processing standards include mandatory HACCP for food safety and organic certification, with private standards like IFS demanding higher transparency and traceability. In the hospitality sector, public standards are minimal, but private certifications like Green Key emphasize sustainability. Key observations indicate that FW is influenced by strict private buyer requirements and processing inefficiencies, with national public standards having a rare impact on FW.

1.4.1.6 EU Food Marketing Standards in Fish

An outline of the application of public and private standards across different stages of the fish FSC, from fishermen to food service is provided in Appendix IV. Public standards include regulations on legal species, maximum quotas, traceability, minimum calibre, freshness, and adherence to Codex Alimentarius CCFFP, ensuring cold chain maintenance and proper labelling. Private standards emphasize size, homogeneity in size and species, freshness, temperature control, geographical origin, extraction/production methods, proximity, species integrity, and the absence of preservatives. These standards collectively ensure quality, safety, and sustainability throughout the supply chain, from the initial catch by fishermen to the final service in food establishments.

1.4.2 Overview of food waste due to food marketing standards – qualitative evidence from BREADCRUMB WP1

The research from WP1 “Understanding marketing standards and their relevance to FW” highlights that FMS can augment FW through stringent requirements related to appearance, size, labelling, and specific ingredients. Products that do not meet these standards are often rejected, even if they are safe to consume. This leads to over-production and increased costs in the upstream supply chain as producers strive to meet the necessary quantity. Although there are options for dealing with rejected food, such as donation, sale at a lower price, or valorisation, these depend on the resources and motivations of the entity with the surplus.

Conversely, FMS can mitigate FW by providing consistency in perceived quality, which facilitates purchase and helps gain consumer trust. There has been a notable shift towards meeting consumer demands for information on food origin and production processes, with environmental and social concerns becoming more prominent. This shift reflects a broader trend towards transparency and sustainability in food production, which can help reduce FW.

Research from WP1 led to eight hypotheses regarding the relationship between FMS and FW. It was found that standards in Regulation (EU) 1308/2013 - categories D (presentation, labelling, packaging, marking, year of harvest) and E (appearance, consistency, conformation, product characteristics, percentage of water content) are most prevalent and often hypothesized to augment FW. Those related to appearance, however, can also mitigate FW depending on the FSC stage.

Stringent appearance standards for fresh produce can reduce waste by meeting consumer expectations at the retail level, but may cause over-production and waste at the primary production level. For example, retailer requirements for uniform size of fruits and vegetables at the production level for further packaging often lead to the discarding of produce that does not meet these standards, despite being safe and nutritious. This is further exacerbated by misunderstandings about date labels on food products which cause confusion, leading to increased FW at both retail and household levels due to perceptions about safety and quality. Standards related to regional production are hypothesized to mitigate FW; food products with local or regional production labels follow specific requirements, which differentiate them, build consumer confidence, facilitate purchases, and help mitigate food waste.

Research results in WP 1 also found that stringent restrictions on production substances and practices in private organic standards contribute to FW (category K: Type of farming and production method and category G: restrictions as regards the use of certain substances and practices). The ban on synthetic pesticides in organic farming increases vulnerability to pest damage, leading to higher FW. Organic food spoils faster due to the absence of preservatives, and natural cleaning agents are less effective against bacteria and fungi. Without chemical disinfectants, microbial load on surfaces or equipment may rise, increasing spoilage rates. Additionally, the lack of serious heat treatments may fail to eliminate all microorganisms, further contributing to FW. Public FMSs related to size specifications in the fish industry were also hypothesized to augment FW (category B: classification criteria, grading). These standards aim to ensure uniformity and marketability of fish products but result in the discarding of fish that do not meet specific size criteria. Fish outside the accepted size range are often discarded, even if they are edible and nutritious, leading to significant food waste. This practice also contributes to the depletion of fish populations, as undersized fish returned to the sea have low survival rates. Finally, EU public FMS on animal by-products are also hypothesized to contribute to FW due to the categorization process (category M: conditions governing the disposal, the holding, circulation, and use of products). Regulation (EC) No. 1069/2009 categorizes animal by-products based on health risks, with category 3 material considered low risk. However, the regulation's vague criteria for disease signs leads to cautious classification by authorities, often resulting in a higher-risk category 2 classification. This cautious approach increases FW, as products that could be treated and deemed fit for human consumption are instead revalorized as by-products. The regulation's reliance on ante-mortem inspections, rather than post-mortem inspections, further contributes to the misclassification and subsequent FW. The regulation establishes that the checks to determine whether a product is fit for human consumption are done solely through an ante-mortem inspection of the animal, and not a post-mortem inspection.

1.4.3 Food Waste Estimates from BREADCRUMB Case studies

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 is to go a step further from generating FW estimates for various products of the five food commodities to determining FWC, which is a crucial step in understanding the magnitude of FW along the FSC as a result of FMS and the development of mitigation strategies.

1.4.3.1 Fruit and Vegetables Food Waste Estimates

Estimates of FW in F&V across different countries due to FMS can be seen in Appendix VI. It highlights the commodities with the highest and lowest FW percentages due to FMS and compares the same products in different countries. From these data, FW due to FMS seems to vary significantly across different products and countries. The highest estimates are seen in limes from Germany; primary production (*data from one lot*), with 30.0% potential waste due to colour requirements and spoilage, followed by carrots in Portugal at 24.2% due to appearance standards. Persimmons in Spain showed considerable waste at both primary production (22.47%) and processing stages (13.69%). Conversely, the lowest estimates are found in Slovenia, with tomatoes at 0.05%, potatoes at 0.08%, and onions at 0.24% all at the primary production stage due to public FMS related to size, shape, and quality. Still at the primary production stage, comparing apples, Italy has higher waste (13.0% - 20.0%) due to stricter aesthetic and size standards compared to Slovenia (10.0%). For tomatoes, Portugal's primary production waste is 10.0% with no FMS influence, whereas in Slovenia waste is 1.22% with 0.05% due to FMS, indicating other factors play a larger role in Portugal. These results align and confirm the hypothesis from previous WP1 work of the project that food marketing categories D (presentation, labelling, packaging, marking, year of harvest) and E (appearance, consistency, conformation, product characteristics, percentage of water content) of Regulation (EU) 1308/1203 can augment FW (highlighted in the previous section).

1.4.3.2 Meat Food Waste Estimates

Appendix VII 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.

1.4.3.3 Egg Food Waste Estimates

Interviewees from the Danish, Belgian and Italian egg industries reported general compliance with EU FMS, despite differences in interpretation, particularly regarding egg washing and date marking. While FMS are not seen as major drivers of FW, they can lead to financial losses, especially for producers. Allowing egg washing, for instance, could increase usable output by 3 – 4%, enabling some Class B eggs to be sold as Class A, hence adding to the potential economic gain.

Most FW results from cracks, leaks, and handling damage, not from FMS. Reported FW levels are low, around 0.5% in packing stations and distribution. This is because packing stations have very good valorisation routes (class B eggs) for 'suboptimal eggs' and therefore the low FW estimates. Still, there is frustration with standards that emphasize appearance over functionality, which can hurt economic viability. Interviewees called for greater flexibility in categorizing and marketing eggs to reduce waste and improve revenue. They emphasized that meaningful reductions in waste will likely require regulatory changes.

1.4.3.4 Cereals Food Waste Estimates

Based on the figures of the FW estimates due to FMS in Appendix VIII for both Italy and Slovenia, Italy reported some of the highest FW estimates due to FMS for cereals and derived products, with wheat flour at 12%, corn at 3.46%, and soy at 1.51%. This was primarily due to quality requirements such as mycotoxin levels, seed appearance, protein content, and GMO restrictions. These standards, while intended to ensure food safety and consistency, often lead to the rejection of otherwise edible products, particularly in the retail, distribution, and processing stages.

In contrast, Slovenia shows minimal FW linked to FMS, with about 0.03% for oat flakes mainly due to certification and packaging inefficiencies. At the primary production stage, Slovenia's wheat waste is estimated at 1.20% due to protein and mycotoxin standards, whereas Italy's FW for wheat in this stage is unreported. Overall, the data highlights stark contrasts between the two countries, with Italy facing greater losses from stricter and more varied FMS criteria.

1.4.3.5 Fish Food Waste Estimates

As with other commodities, not all FMS identified in the fish CS contribute to FW. Appendix VIX highlights the most relevant FMS generating FW, summarized at each stage of the fish FSC. The highest FW estimates due to FMS were reported at the wholesaler and food service levels. At the wholesaler stage, Alatxa experienced 30% FW, primarily due to issues with species value, size, integrity, freshness, and labelling. At primary production, Alatxa saw 12% FW for similar reasons, including minimum calibre and legal species constraints. In the food service sector, Greater

Forkbeard had 15% FW, mainly driven by requirements for freshness, size, integrity, and species preference.

Conversely, the lowest FW levels were observed in food service (Mediterranean sand eel, 1.0%), retail fishmongers (1.5%), and wholesalers (shrimp, 1.5%), where losses were limited to factors like freshness and integrity. Overall, FW tends to be higher at the end of the FSC, particularly in wholesale and food service, likely due to product deterioration during handling and fluctuating customer preferences. These conditions increase the burden of meeting strict private FMS, especially for high-valued but inconsistently demanded species like Norway lobster.

1.5 Food Waste Coefficient Determination methods

Several methods have been implemented in different studies to determine FWCs. Depending on the context, nature of data, and resources available, these methods have differing strengths and weaknesses.

- ✓ The JRC publication: Building a balancing system for food waste (FW) accounting at the national level (De Laurentiis et al., 2021) employed a "balancing system" approach to estimate FW by reconciling food supply and waste data across sectors using mass balance. The method was based on official and standardized national data for EU member states, enabling system-wide FW tracking across the food supply chain (FSC). However, this approach relied heavily on the availability of extensive and harmonized datasets across the FSC; a requirement that is often difficult to meet in practice. As a result, the analysis tended to produce low-resolution data, meaning that the data was aggregated at a broad level (e.g., national or sectoral), making it difficult to identify specific sources or patterns of waste at more detailed levels such as individual products, sub-sectors, or supply chain stages. This lack of granularity limits the ability to design precise and targeted FW reduction interventions.
- ✓ Mass Flow Analysis is another approach commonly used. By being a system-based accounting method that models inputs, outputs and losses through different stages of the FSC, this approach is most useful for macro-level FW estimation. It nonetheless is data intensive requiring comprehensive, high-quality data which is often not available (Caldeira et al., 2019; Dong et al., 2022).
- ✓ Waste Composition Analysis involves physical sampling and sorting of waste streams to identify and quantify FW. This method ensures high accuracy and it is very useful for household and retail waste characterization(Hanson et al., 2016).
- ✓ The ratio method estimates FW by applying fixed percentages (waste coefficients) to total production or processing volumes. These ratios are often drawn from prior studies or expert

judgment. While this method is simple, quick, and useful when data is scarce, it lacks precision and can be prone to bias or outdated assumptions. It is generally more suitable for initial approximations rather than robust or context-specific analyses (Hanson et al., 2016).

- ✓ Statistical regression analyzes the relationship between FW and influencing factors such as sales volume, shelf life, or seasonality. It can reveal key drivers of waste and offer predictive insights. However, it requires large, high-quality datasets and careful model selection to avoid overfitting (model has learned the training data too well, including its noise, outliers, or random fluctuations, rather than just the underlying patterns) or misinterpretation. In contexts with limited or inconsistent data, this method is typically unreliable (Qi & Roe, 2016).
- ✓ Life Cycle Assessment (LCA) assesses the environmental impacts of food waste across its lifecycle; from production to disposal. Though valuable for sustainability analysis, LCA is not a method for determining food waste coefficients directly. It is data-intensive and more suitable for evaluating the consequences of food waste rather than quantifying it at specific supply chain points.
- ✓ Benchmarking and literature synthesis is an approach that uses existing studies and regional comparisons to estimate food waste coefficients based on similar products or systems. It is especially helpful when primary data is lacking, offering a reference point for expected waste levels. However, it depends heavily on the comparability of source data and may not reflect unique local or sector-specific conditions. It is best used as supplementary input alongside other methods. This method is not per se useful in the context of the BREADCRUMB project case study data, since data and studies on the impact of FMS on FW are extremely limited.
- ✓ The Monte Carlo simulation is particularly well-suited for contexts with limited or uncertain data. By generating probability distributions from repeated random sampling, it accounts for uncertainty and provides confidence intervals for FWCs. Think of it as running thousands of "what-if" scenarios using random inputs to see all the possible outcomes and how likely each is. This method allows the use of a range of inputs—including expert estimates or benchmark data—and produces more nuanced, risk-aware outcomes. It does not require large datasets, making it ideal for small samples or variable conditions. Even when precise data is unavailable, Monte Carlo helps estimate how a system might behave by simulating many plausible versions of reality.

Among the available methods, the Monte Carlo simulation stands out as the most appropriate for the project's context, where sample sizes are small and data quality is variable. Unlike more data-dependent methods such as regression or mass flow analysis, Monte Carlo accommodates uncertainty, enhances transparency, and yields statistically sound estimates. Used effectively, it can support better decision-making and policy design by reflecting the real-world variability in FW generation.

2. METHODOLOGY

2.1 The Data

Figure 5 illustrates the three key data sources used to determine the FWC reported in this deliverable. The primary data originated from the work conducted in Task 2.3, which included general FW estimates and FW generated due to FMS across the five commodity groups studied in the BREADCRUMB project. This core dataset was derived from 16 case studies, providing detailed, context-specific evidence on how FMS affect FW across various points in the FSC. These case studies offered empirical insights into real-world business practices, waste patterns, and the impact of regulatory requirements, forming the foundation for calculating the coefficients.

To complement and validate the case study findings, two additional data streams were considered. First, WP1 synthesized existing literature on FW and its links to FMS, offering a conceptual framework and data-informed hypotheses that guided the analytical approach. Second, D2.1 contributed EU-level estimates of FW and FW-FMS, offering a macro-scale perspective to benchmark and cross-check the findings at company level. These sources complemented each other across both spatial and temporal dimensions. While the case studies offered recent and highly localized data, D2.1 provided broader geographical coverage at the national/EU level. WP1, by drawing on a wide body of literature across time, added a longitudinal and theoretical dimension to the analysis. Together, they enabled a robust triangulation of evidence and enhanced the validity of the coefficient estimates. However, aligning these datasets also presented challenges. Differences in data granularity, timeframes, and definitions requires reconciliation, particularly when mapping qualitative insights to quantitative models. These discrepancies were addressed through sensitivity checks and expert judgement to ensure consistency in coefficient estimation. Despite these challenges, D2.5 remained pivotal by anchoring the analysis in measurable, industry-grounded outcomes, while the additional sources strengthened the analytical framework and external validity of the results.

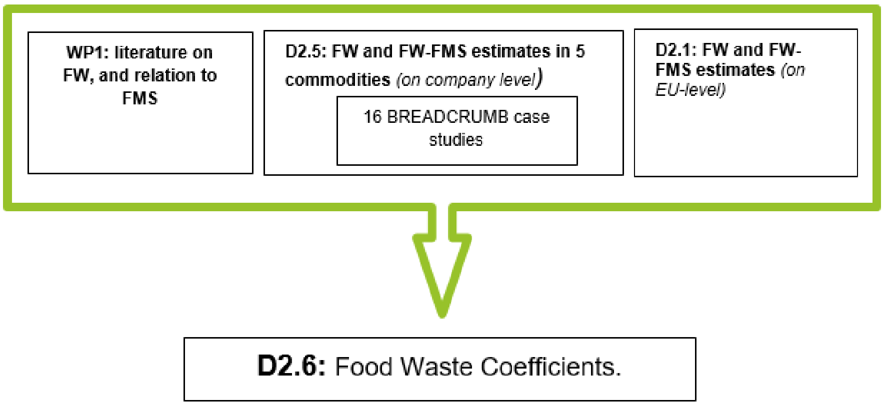


Figure 5: Data sources used in the determination of FWC

2.2 BREADCRUMB Food Waste Coefficient determination Approach using Monte Carlo Simulations

The most crucial steps to statistically determine FWC with the implementation of Monte Carlo simulations are outlined below.

- ✓ Define the FSC of interest, here looking at where reliable data is available
- ✓ Compile the necessary data for all products at all FSC
- ✓ Calculate the FWC, usually expressed as a fraction or a percentage. It can be calculated using the following formula.

$$FWC = \frac{Q_{waste}}{Q_{in}}$$

Where

Q_{waste} = total food waste generated at a stage of the *FSC*

$Q_{waste,i}$ = total food waste generated at a stage of the FSC_i

Q_{in} = total food quantity entering the stage of the *FSC*

- ✓ Simulate more FWC data using the Monte Carlo simulation or bootstrap approach. This is a simulation process (10,000x) with replacement to model the distribution of FWC of each product at different FSC stage. For products with 3 to 6 data points, a triangular distribution is appropriate, allowing the estimation of minimum and maximum and a most likely value (mode). This gives a more realistic representation of uncertainty when some outcomes are more common than others.

- ✓ For products with only 2 data points, uniform distribution was assumed as it defines a simple range (min and max) where both values are equally likely. [9]

[9] The Monte Carlo simulations in this analysis are based on small datasets (2, 3, or 6 data points per product-stage group). While these simulations help estimate variability and uncertainty, the limited data may not fully capture the true distribution of food waste. Results should be interpreted with caution and seen as indicative rather than definitive.

3. FOOD WASTE COEFFICIENTS

To account for uncertainty and variability in the data, a Monte Carlo simulation; a method that uses repeated random sampling to model a range of possible outcomes was used. FWCs for several products were determined through a Monte Carlo simulation approach as explained in Section 2. For the remaining products, where running a simulation was not possible, the coefficients were provided directly by the industry representatives (gotten through the ration approach).

3.1 Fruit and vegetable food waste coefficients

Table 2 presents FWCs of F&V as percentages across various products and FSC stages. The percentage of FW due to FMS varies widely across products and stages. At the primary production stage, values range from 0.000% (raspberry, round tomato) to a maximum of 30.67% (limes; results from 1 lot studied), with carrot (24.19%) and persimmons (17.11%) also notably high. At the packaging stage, FW due to FMS ranges from 1.37% (citrus) to 12.26% (persimmons). In the retail/wholesale stage, values range from 0.16% (orange) to 11.11% (limes), with cucumber (11.24%) and red peppers (8.33%).

Table 2: Food Waste percentages for F&V Products on different Food Supply Chain Stages

product	stage	% of FW due to FMS (%)
persimmons	packaging	12.26
apples	primary	3.74
citrus	packaging	1.37
potato	primary	0.14
tomato	primary	0.30
apples	retail	4.89
cherry_tomato	primary	0.97
citrus	primary	9.13
cucumber	wholesale	11.24
lettuce	primary	0.12
onion	primary	2.50
persimmons	primary	17.11
banana	primary	0.003
cabbage	primary	1.00
carrot	primary	24.19
carrot	retail	0.67
lettuce	retail	0.58
limes	primary	30.67
limes	wholesale	11.11
orange	primary	13.50
orange	retail	0.16
pear_rocha	primary	3.69
pumpkin_hokaido	primary	0.45

raspberry	primary	0.000
red_peppers	wholesale	8.33
round_tomato	primary	0.000
round_tomato	retail	0.46
strawberry	retail	1.99
turnip	primary	5.00
zucchini	primary	2.86

Figure 6 and 7 further shows FWCs distribution for various fruits and vegetables across different FSC stages. Most FW occurs at the primary production and packaging stages, especially for persimmons, citrus, and cucumbers. In contrast, for the other products processing and retail stages show lower and more consistent FWCs. The variability across products and stages highlights critical points for targeted waste reduction interventions.

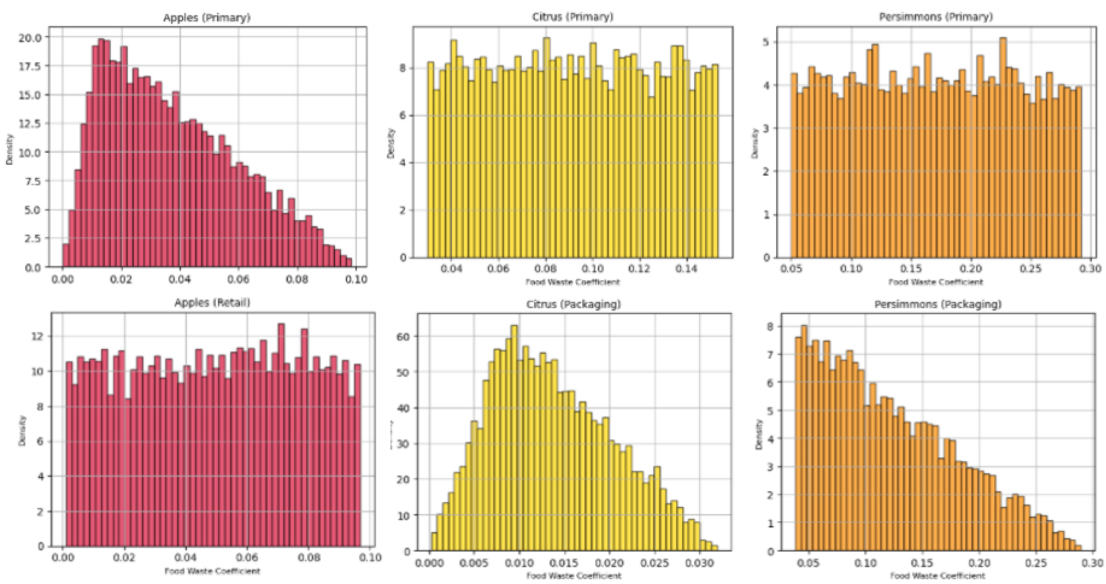


Figure 6: Distribution of Food Waste in Fruits across the Food Supply Chain Stages (for detailed table see Appendix)

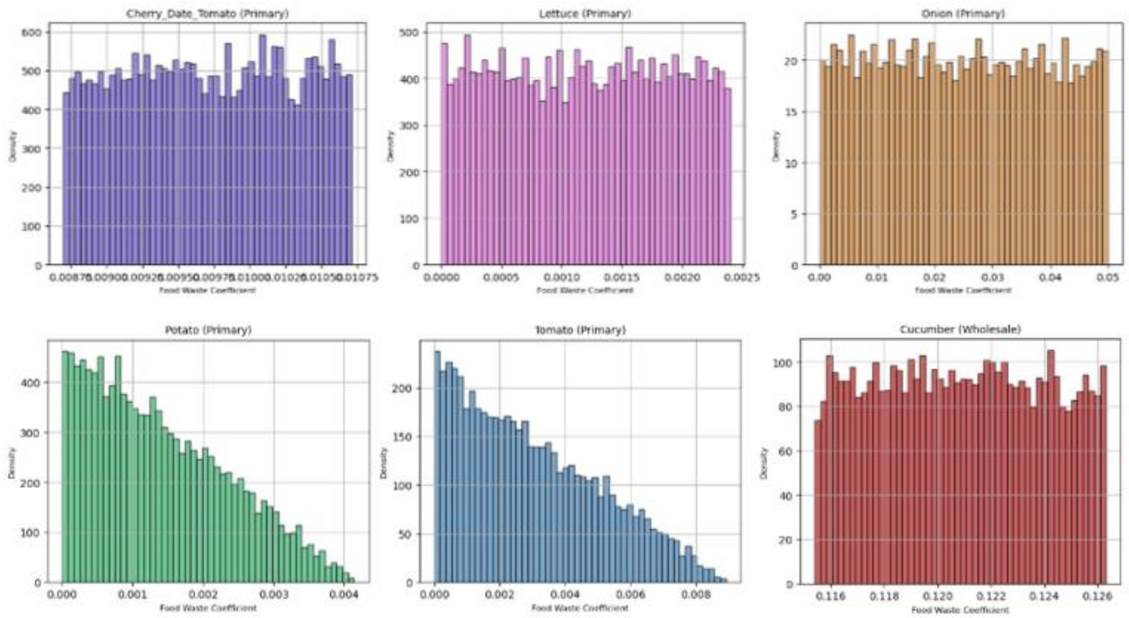


Figure 7: Distribution of Food Waste in Vegetables across the Food Supply Chain Stages (for detailed table see Appendix XI: Full Summary Statistics of F&V Products and Food Supply Chain Stage)

3.2 Meat food waste coefficients

For the meat products, Monte-Carlo simulations could not be executed due to fewer than 2 data points. Here, the ratio method to determine the FWC was implemented (Table 3).

Table 3: Food Waste percentages for Meat Products on different Food Supply Chain Stages

Product	Stage	% of FW due to FMS (%)
Cooked ham	Primary production, processing and manufacturing, & retail and distribution	0.15
Whole chicken	Primary production, slaughtering, processing and manufacturing	1.01
Breast Fillet		0.31
Legs		0.56
Processed products		0.12
Slaughtered pig carcasses	Processing and manufacturing	8.69
Pig Carcass + meat → offal (waste cat III)		7.2
Pig Carcass + meat → offal (cutting losses)		0.49
Whole beef	Processing & Manufacturing, Retail and distribution (wholesale)	12.5
Slaughtered beef carcasses		9.0

Deboned beef carcasses	9.8
Degraded (wasted) whole carcasses	0.06

3.3 Egg food waste coefficients

For the egg products, Monte Carlo simulations could not be executed due to fewer than 2 data points. Here, the ratio method to determine the FWC was implemented. See section 1.4.3.3 for more details on FWC (or FW estimates) of egg products.

3.4 Cereal food waste coefficients

Table 3 presents the FWC estimates for cereals and cereal products across two FSC stages. For cereals FW due to FMS at the primary production stage ranges from 0.500% (barley) to 1.749% (corn and oat), showing relatively consistent values across grains. At the processing stage, FW percentages are significantly lower, ranging from 0.002% (soy) to 0.028% (oat flakes), with wheat flour at 0.006%. These results highlight that most cereal waste occurs early in the supply chain, reinforcing the importance of targeting interventions at the primary production stage.

Table 4: Food Waste Coefficients and their confidence interval for Cereal Products along different Food Supply Chain Stages

product	stage	% of FW due to FMS (%)
corn	primary	1.749
oat	primary	1.749
spelt	primary	1.741
wheat	primary	1.737
wheat_flour	processing	0.006
barley	primary	0.500
oat flakes	processing	0.028
soy	processing	0.002

Figures 8 goes a step further to show cereal FWCs by product and FSC stage. At the primary stage, most cereals including corn, oat, spelt, and wheat, cluster around an average FWC of 1.75%, with some variability up to 3.0%. This suggests that the bulk of cereal waste occurs during cultivation and harvest. In contrast, at the processing stage, products like wheat flour and oat flakes show near-zero FWCs, indicating highly efficient processing with minimal losses. Overall, the figures emphasize that FW in cereals is concentrated at the primary production level, with much lower downstream losses.

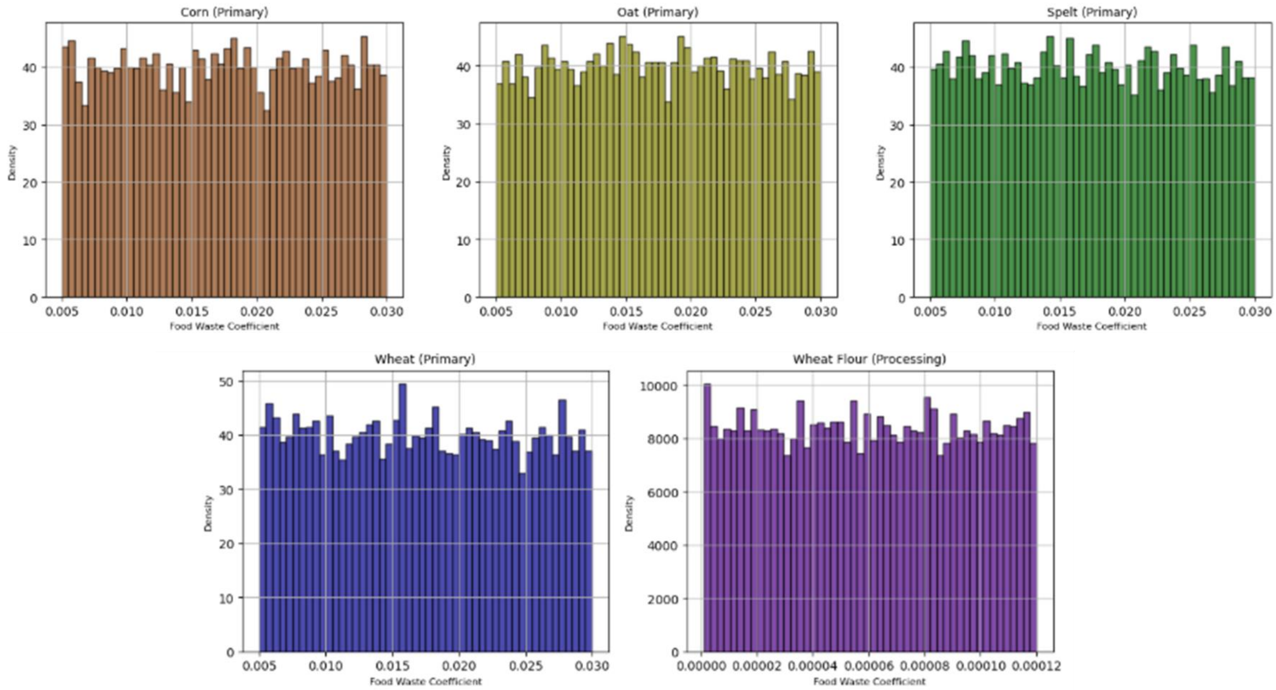


Figure 8: Distribution of Food Waste in Cereal across the Food Supply Chain Stages (for detailed table see Appendix XI: Full Summary Statistics of Cereal Products and Food Supply Chain Stage)

3.5 Fish Food Waste Coefficients

For the fish products, Monte-Carlo simulations could not be executed due to fewer than 2 data points. Here, the coefficients were provided directly by the industry representatives.

For fish, at the primary production stage, FW percentages range from 1.7% (sardine, anchovy) to a high of 12.0% (alatxa), with alatxa showing notably greater waste despite lower volume. In the wholesale stage, FW ranges from 1.5% (shrimp) to 30.0% (alatxa), indicating significant variation. In the food service stage, FW ranges from a minimal 1.0% (sand eel) to 15.0% (greater forkbeard), with most species like octopus and megrim showing moderate levels around 7 – 8%, highlighting diverse waste impacts depending on product and stage.

4. CONCLUSION

4.1 Conclusion

This report provides a comprehensive and data-driven examination of the intricate relationship between FMS and FW generation across various stages of the FSC. Leveraging Monte-Carlo simulations and empirical evidence from 16 case studies, the analysis reveals that FMS - both public and private - play a pivotal role in shaping FW outcomes, with impacts varying significantly by commodity type and FSC stage.

The findings highlight that FW is not uniformly distributed but is instead highly dependent on the nature of the product, the specific FMS applied, and the operational context. In the F&V sector, persimmons emerge as the most waste-prone commodity across the commodities studied by project case studies, with exceptionally high FWCs at the packaging stage (18.4%) and during primary production (17.12%). Cucumbers also exhibit substantial waste at the wholesale stage (11.24%), while citrus fruits show notable losses during primary production (9.16%). Apples experience moderate waste at both primary production (3.74%) and retail (4.89%). In contrast, tomatoes, potatoes, and cherry date tomatoes demonstrate minimal waste, with mean FWCs consistently below 1%, suggesting either less stringent FMS or more effective valorisation strategies.

In the cereals category, the primary production stage is a consistent point of FW generation, with corn, oat, spelt, and wheat each showing a mean FWC of 1.7%. However, the processing stage for wheat flour stands out for its efficiency, with a negligible mean FWC of just 0.01%, indicating minimal losses during milling and processing.

For meat, eggs, and fish, the analysis relied on the ratio method due to limited data availability. Despite this constraint, the report identifies significant FW in specific contexts such as whole beef and egg during processing, where strict standards and handling protocols contribute to elevated waste levels.

Crucially, the report does more than quantify waste; it contextualizes these figures within the broader objectives of FMS, such as ensuring food safety, maintaining consumer trust, and supporting trade. This dual perspective enables a nuanced understanding of the trade-offs involved and highlights the importance of balancing regulatory goals with sustainability imperatives.

Overall, the study underscores the need for targeted interventions that consider both the variability and reliability of FW estimates. By pinpointing high-impact areas such as packaging standards for persimmons or wholesale practices for cucumbers, stakeholders can design more effective waste reduction strategies. The insights also advocate for the dissemination of best practices, particularly in sectors like cereal processing, where efficiency is demonstrably high. This evidence-based approach lays the groundwork for harmonizing FMS with sustainability goals, ultimately contributing to a more resilient and resource-efficient food system.

4.2 Policy Recommendations

Building on the insights derived from the FWCs and the qualitative evidence gathered throughout the BREADCRUMB project, the following policy recommendations aim to address the root causes of FW linked to FMS. These recommendations are designed not only to mitigate waste but also to preserve the core objectives of FMS ensuring food safety, quality, and market transparency. By targeting both systemic inefficiencies and behavioural drivers, the proposed actions seek to foster a more sustainable, inclusive, and circular food system. The recommendations are structured to support stakeholders across the FSC, from primary producers to policymakers, and are grounded in the empirical realities uncovered through the project's case studies and analytical work.

- ✓ **Revise Food Marketing Standards**

Revising FMS is widely seen as necessary, particularly due to outdated or overly strict standards; especially those related to appearance that contribute significantly to food waste. However, some stakeholders argue revisions should be context- and commodity-specific. Simplification and alignment with sustainability goals are key drivers for this recommendation.

- ✓ **Promote Suboptimal Food Utilization**

There is strong consensus that repurposing or selling suboptimal produce (e.g., misshapen or blemished but safe food) should be actively promoted to prevent unnecessary waste. It also offers opportunities for product innovation and market diversification.

- ✓ **Enhance Consumer Awareness**

Raising awareness is viewed as crucial. Many believe consumer perceptions about food aesthetics and quality must shift to support the acceptance of suboptimal food and reduction of food waste. However, some note that awareness alone isn't always enough without structural and market-level changes.

- ✓ **Support Technological Innovations**

Technology is important but secondary to structural and behavioural shifts. Innovations (e.g., AI, gentle processing, measurement tools) to better or improve food waste data collection amongst others can help reduce waste and improve the handling of suboptimal food. Still, barriers like cost, resource limitations, and slow adoption must be addressed.

- ✓ **Implement Regulatory Changes**

There is a strong call for regulatory reforms to reduce administrative burden, limit excessive private standards, and align food systems with sustainability goals. While public FMS are necessary for safety and trade, many argue that private standards, often stricter should be moderated.

- ✓ **Standardize Data Collection and Reporting**

Standardized and transparent data is considered essential to understand, monitor, and reduce food waste effectively. However, some note practical challenges in data collection, especially at the business level, due to complexity, cost, and lack of prioritization.

- ✓ **Harmonize Standards**

Harmonizing public and private standards across the EU can reduce confusion and inefficiencies, particularly in cross-border trade. Some warn, however, that harmonization must not limit flexibility or innovation, and must be carefully balanced.

- ✓ **Enhance Coordination and Collaboration**

Improved collaboration among supply chain actors, policy makers, and regions is essential. Clearer communication, joint initiatives, and data sharing are needed to align efforts and scale food waste reduction solutions.

Supporting food waste reduction is a fundamental objective that underpins all other recommendations. By promoting good practices, incentives, storytelling, and short-term actions across the supply chain, stakeholders can reduce food waste while still aligning with the goals of food marketing standards. This balanced approach contributes to a more sustainable, efficient, and resilient food system.

5. REFERENCES

Aschemann-Witzel, J., de Hooge, I., & Almli, V. (2019). Suboptimal food? Food waste at the consumer–retailer interface. *Saving Food*, 347–368.

Caldeira, C., De Laurentiis, V., Corrado, S., van Holsteijn, F., & Sala, S. (2019). Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis. *Resources, Conservation and Recycling*, *149*, 479–488. https://doi.org/10.1016/j.resconrec.2019.06.011

Cao, Y., & Miao, L. (2021). Consumer responses to suboptimal food products. *Appetite*, *163*. https://doi.org/10.1016/j.appet.2021.105205

de Hooge, I. E., Oostindjer, M., Aschemann-Witzel, J., Normann, A., Loose, S. M., & Almli, V. L. (2017). This apple is too ugly for me! *Food Quality and Preference*, *56*. https://doi.org/10.1016/j.foodqual.2016.09.012

De Laurentiis, V., Caldeira, C., Biganzoli, F., & Sala, S. (2021). *Building a balancing system for food waste accounting at National Level*. https://doi.org/10.2760/316306

Dong, W., Armstrong, K., Jin, M., Nimbalkar, S., Guo, W., Zhuang, J., & Cresko, J. (2022). A framework to quantify mass flow and assess food loss and waste in the US food supply chain. *Communications Earth and Environment*, *3*(1). https://doi.org/10.1038/s43247-022-00414-9

European Commission (2020). *European Commission (2020a), Commission staff working document – Executive Summary of the evaluation of marketing standards (contained in the CMO Regulation, the 'Breakfast Directives' and CMO secondary legislation), SWD(2020) 230 final.*

Hanson, C., Lipinski, B., Robertson, K., Dias, D., Gavilan, I., Gréverath, P., Tran, B., Leach, B., & Quested, T. (2016). *GUIDANCE ON FLW QUANTIFICATION METHODS Supplement to the Food Loss and Waste (FLW) Accounting and Reporting Standard, Version 1.0 FLW Protocol Steering Committee and Authors Other Contributing Authors*.

Nes, K. ., & Ciaian, P. . (2021). *Marketing standards for food products : a review of literature*. Publications Office of the European Union.

Qi, D., & Roe, B. E. (2016). Household food waste: Multivariate regression and principal components analyses of awareness and attitudes among u.s. consumers. *PLoS ONE*, *11*(7). https://doi.org/10.1371/journal.pone.0159250

6. APPENDICES

6.1 Appendix I: Overview of FMS in BREACRUMB F&V case studies and stages of FSC where they are applied

Type of FMS	FMS	Specific FMS (context)	FSC Implemented
Public	Regulation (EU) No 543/2011	✓ Premium product: Overcolouring of the peel >40%	✓ Primary Production
		✓ 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
	Regulation (EU) No 1169/2011	✓ Labelling : covers labelling, allergens, nutrition information, and product origin.	✓ Processing ✓ Retail and Distribution
	HACCP – International	✓ Food safety	✓ Primary Production ✓ Processing ✓ Food Services
	UNECE Standards[10]	✓ 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 ✓ Retailer
		✓ BIO Suisse	✓ Primary Production

[10] Fresh Fruit and Vegetables - Standards | UNECE

			✓ 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

6.2 Appendix II: Overview of FMS in BREACRUMB Meat case studies and stages of FSC where they are applied

Category	**Food Marketing Standard Name**	**Description**
Public	Regulation EC No. 1308/2013	✓ Carcass classification
	Regulation EC No. 1069/2009	✓ Handling of animal by-products
	"Detailhandel" (Retail)	✓ Governmental standards for food sold in the retail sector
	Regulation EC No. 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

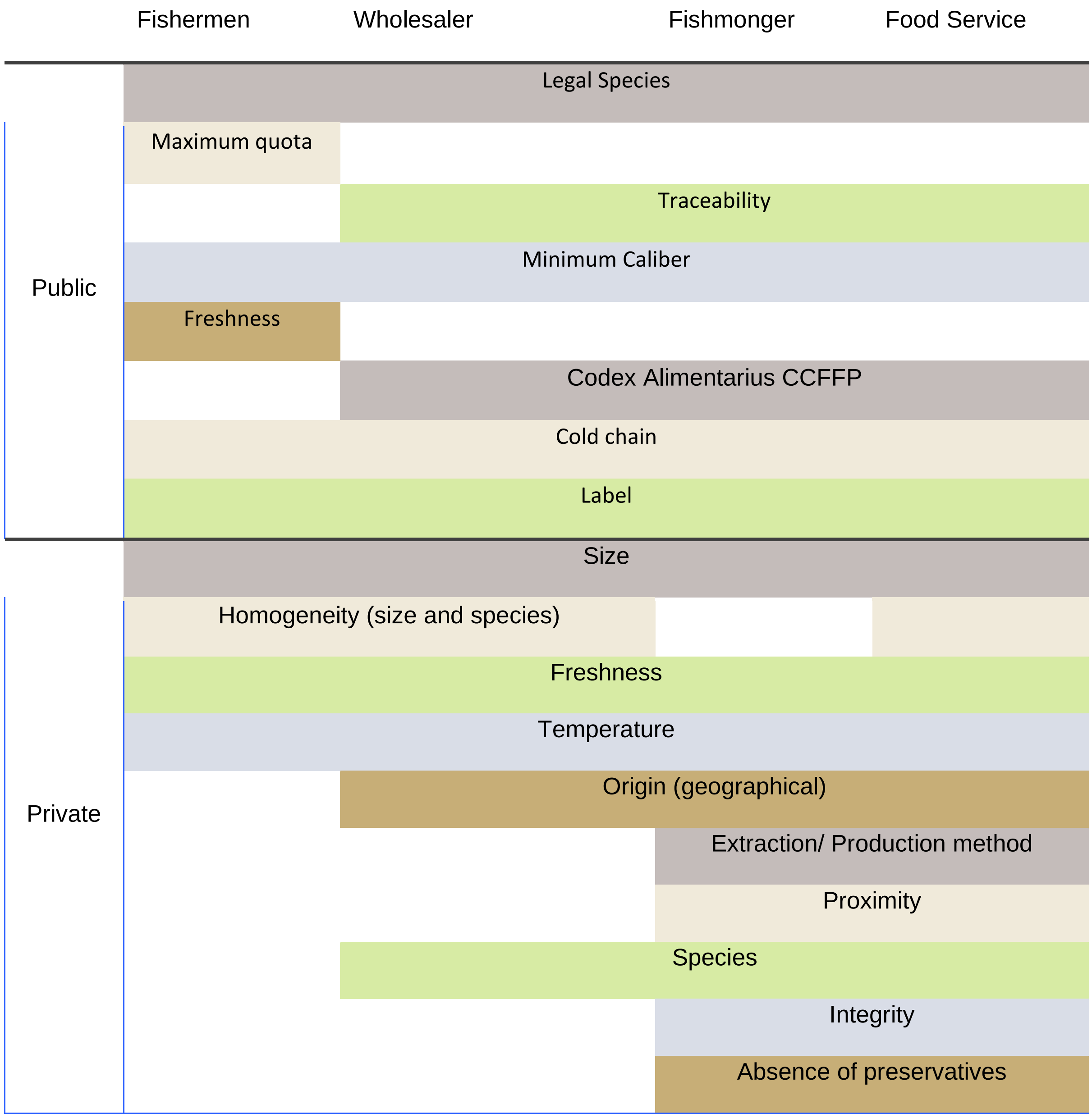
	Beter Leven	✓ Animal welfare in food production
	FSSC 22000	✓ Food safety management based on ISO standards
	National/Local Schemes	✓ Various stages of food supply chain
	GLOBAL GAP	✓ Various stages of food supply chain especially at the primary production stage

6.3 Appendix III: Overview of FMS in BREACRUMB Cereal case studies and stages of the FSC applicable

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 (Corn, Wheat, soft corn, wheat flour) ✓ Regulation (EC) No. 1829/2003: Limited level of GMO (Soybean)	✓ 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) ✓ Private contracts: Vitreous seeds (Corn) ✓ Private contracts: Origin of raw	✓ 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 ✓ FW largely driven by strict private buyer requirements

	✓ Regulation (EU) No.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)	material (Wheat flour) ✓ Private contracts: Organic production (Wheat flour) ✓ Private contracts: Technical and rheological parameters (Wheat flour) ✓ Private contracts: Type of milling (Wheat flour)	
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

6.4 Appendix IV: Overview of FMS in BREACRUMB Fish case study and stages of the FSC applicable



6.5 Appendix V: 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

6.6 Appendix VI: 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 (complaint reasons related to FMS)	✓ 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)	✓ Soft-ends / spoilage

		Primary production	Cherry date tomatoes	25,300.563	NA	Not indicated	
		Wholesale		492	1.28	9.01 (of complaint reasons related to FMS)	✓ Too low spoilage tolerance ✓ 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)	✓ 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 [11]	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		
			Bell peppers	1,100,000	0.7		

[11] www.flandersfruitsandvegetables.com

		Processing (class II)	Tomatoes	1,995	14.29		

6.7 Appendix VII: 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,	Whole chicken	172,704.95	1.01	1.01	✓ Regulation Animal By-Products 1069/2009
			Breast Fillet	158,025.81	0.31	0.31	

		processing and manufacturing	Legs	130,791.07	0.56	0.56	
			Processed products	844,358.33	0.12	0.12	
M.CS3.Feb-BE	Belgium	Processing and manufacturing	Whole pig	0.092	5.40	Not indicated	
			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	

6.8 Appendix VIII: 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***					

6.9 Appendix IX: 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	

6.10 Appendix X: 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 * = annual catches	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	

6.11 Appendix XI: Full Summary Statistics of F&V Products and Food Supply Chain Stage

product	stage	n	Min	Max	Mean	Median	Std Dev
apples	primary	3	0.0027	0.09962	0.03739	0.03391	0.02214
apples	retail	2	0.00107	0.09666	0.04886	0.04890	0.02777
banana	primary	1	0.00003	0.00003	N/A	N/A	N/A
cabbage	primary	1	0.01000	0.01000	N/A	N/A	N/A
carrot	primary	1	0.24186	0.24186	N/A	N/A	N/A
carrot	retail	1	0.00667	0.00667	N/A	N/A	N/A
cherry_tomato	primary	2	0.00870	0.01071	0.00970	0.00970	0.00058
citrus	packaging	3	0.00013	0.03174	0.01368	0.01285	0.00677
citrus	primary	2	0.02983	0.15332	0.09126	0.09129	0.03574
cucumber	wholesale	2	0.11539	0.11241	0.11241	0.12089	0.00316
lettuce	primary	2	0.00000	0.00240	0.00119	0.00120	0.00070
letus	primary	1	0.00000	0.00000	N/A	N/A	N/A
letus	retail	1	0.00575	0.00575	N/A	N/A	N/A
limes	primary	1	0.30666	0.30666	N/A	N/A	N/A
limes	wholesale	1	0.1111	0.1111	N/A	N/A	N/A
onion	primary	2	0.00001	0.04999	0.02496	0.02487	0.01438
orange	primary	1	0.13500	0.13500	N/A	N/A	N/A
orange	retail	1	0.00162	0.00162	N/A	N/A	N/A
pear_rocha	primary	1	0.03686	0.03686	N/A	N/A	N/A
persimmons	packaging	6	0.03817	0.29057	0.12259	0.11626	0.05955
persimmons	primary	2	0.05001	0.29226	0.17106	0.17007	0.05901
potato	primary	3	0	0.00413	0.00138	0.00121	0.00038
pumpkin_hokaido	primary	1	0.00450	0.00450	N/A	N/A	N/A
raspberry	primary	1	0.00000	0.00000	N/A	N/A	N/A
red_peppers	wholesale	1	0.08333	0.08333	N/A	N/A	N/A
round_tomato	primary	1	0.00000	0.00000	N/A	N/A	N/A
round_tomato	retail	1	0.00463	0.00463	N/A	N/A	N/A
strawberry	retail	1	0.01994	0.01994	N/A	N/A	N/A
tomato	primary	3	0	0.00895	0.00301	0.00265	0.00212
turnip	primary	1	0.05000	0.05000	N/A	N/A	N/A
zucchini	primary	1	0.02857	0.02857	N/A	N/A	N/A

6.12 Appendix XII: Full Summary Statistics of Cereal Products and Food Supply Chain Stage

product	stage	n	Min	Max	Mean	Median	Std Dev
barley	primary	1	0.005000	0.005000	N/A	N/A	N/A
corn	primary	2	0.00500	0.03000	0.01749	0.01753	0.00723
oat	primary	2	0.00500	0.03000	0.01749	0.01746	0.00716
oat flakes	processing	1	0.000278	0.000278	N/A	N/A	N/A
soy	processing	1	0.000015	0.000015	N/A	N/A	N/A
spelt	primary	2	0.00500	0.03000	0.01741	0.01739	0.00721
wheat	primary	2	0.00501	0.02999	0.01737	0.01729	0.00723
wheat_flour	processing	2	0.00000	0.00012	0.00006	0.00006	0.00003