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Sustainability in Agri-food Supply Chains: Food waste in the fruit and vegetables sector

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A B S T R A C T

The present paper aims to characterize and propose collaborative solutions to minimize food waste in agri-food supply chains, with a particular focus on the area of Fruits and Vegetables. To achieve this goal, the present work is broken down into three main axes: (i) development of a conceptual framework for analysis, quantification and mitigation of food waste in the chain, (ii) application of the framework to a case study for consequent validation and interpretation of results, and (iii) proposal of solutions for optimization of waste management along the chain.

Through a literature review it was found the need for a methodology of food waste management across the entities in the supply chains. Then a framework was developed that defines a complete approach to action. Finally, the framework was applied to two related entities, Sonae MC and Greenyard Logistics Portugal, in order to gain detailed knowledge of the respective supply chain, its surplus management process and the identification of hotspots in them. Finally, given the problems identified in the previous steps, a proposal for solutions and recommendations was made, which aims to improve collaboration in managing the levels of food waste generated in the chain, considering current sustainability requirements. It stands out the need to incorporate sustainability practices with a higher degree of commitment, to comply with European guidelines and to prioritize food donation at various levels of the supply chain. To this end, greater involvement between entities can be a key factor.

The following paper is part of a nationwide project, MobFood, which is a research and technological development project that aims to promote better reflection among the various agents of the agri-food sector, making it more sustainable.

KEYWORDS: MobFood Project; Sustainability in the agri-food sector; Food Waste management; Conceptual Framework development; Hotspots identification; Collaborative solutions in the supply chain.

1. Introduction

It is estimated that one third of all food produced is never consumed (FAO, 2011), and several studies have concluded that these levels of Food Waste (FW) represent 8% of global greenhouse gas emissions (FAO, 2015) and cost around $ 1055 billion annually (FAO, 2014) . Clearly, this phenomenon illustrates an obvious paradox with serious ethical, environmental and economic implications.

In this context, there is a need for more initiatives and projects aimed at clarifying and standardizing practices that can be universally recognized and act as a starting point for the renewal of the agri-food sector. In Portugal, this sector corresponds to 4.1% of GDP (FIPA, 2011), resulting from the activity of over 11000 companies in the various levels of the Supply Chain (SC).

In response to these challenges, an inciting project, MobFood, was created, which aims to integrate technological and scientific knowledge in agri-food SCs. Through collaboration between academic institutions and industry-relevant companies such as Sonae MC and Greenyard Logistics Portugal (LP), this project recognizes substantial potential for economic, social and environmental gain in SCs. The two main areas of activity in the **MobFood project** are: (i) the characterization of logistic activities in the agri-food sector, in order to identify motivations, restrictions, constraints and requirements in terms of logistics and sustainability; and (ii) the investigation and development of process management methodologies applied to logistic activities, which allow to base and justify decisions in an integrated and collaborative way.

This paper fits into a specific activity related to the logistics component whose scope lies in the elaboration of the matrix for sustainability and mapping of logistics chains. To address the issue of sustainability in Food Supply Chain (FSC), the phenomenon of FW was stipulated as a priority factor within the project. In this sense, it is envisaged that an improvement in the collaboration of all entities in the chain will be fundamental for the reduction of their waste levels, resulting in a transversally more sustainable agri-food sector.

Recognizing the complexity and, consequently, the need to develop an approach to the issue of FW, it is established as the primary objective of this paper the development of a **Conceptual Framework** that defines the guidelines of action for entities wishing to study FW in a given SC. This framework, besides allowing a holistic understanding of the whole chain, from the entities associated with the direct flow of material to the entities that arise in the waste treatment, also establishes a knowledge base that allows to identify the key-factors for a sustainable waste management.

To this end, this paper evolves around the link between two project promoters, at different stages of the agri-food SC, Greenyard LP and Sonae MC, specifically for fruits and vegetables (FV).

It is evident that this subject is highly relevant and urgent, however, the national FW prevention entity (CNCDA) recognizes that there is no “harmonized and reliable method for measuring FW in the European Union (EU)” (CNCDA, 2018). It also stresses that understanding the magnitude and location of FW is essential for prioritizing approaches, directing preventive and corrective efforts, and monitoring progress.

Concluding, the main objectives of this paper are: (i) the development of a conceptual framework for analysis, quantification and mitigation of FW in the chain, (ii) the application of the framework elaborated to a case study for consequent validation and interpretation. results for future work, and (iii) the proposal of solutions that aim to optimize waste management along the chain, highlighting the importance of collaboration in the agri-food chain in the progress towards sustainability.

The methodology adopted is divided into four main groups, as shown in Figure 1.

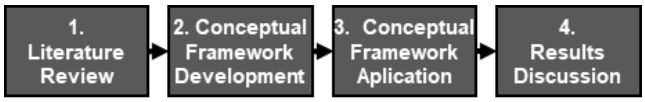

Figure 1 - Methodology

Considering the given methodology, the paper proceeds as follows. Section **2** presents the concept of sustainability applied to agri-food SCs and characterizes the main complexities regarding the phenomenon of FW, which proves to be an extremely relevant topic in this subject. Section **3** presents the framework developed, by characterizing the main five activities required for achieving the intended results. Section **4**, applies the framework in a specific case study, describing the information obtained in all the tasks required. Finally, section **5** aims to briefly discuss the results obtained, concluding the present paper.

2. Literature Review

The concept of sustainability is complex and there is no universal consensus on its meaning or what defines sustainable development. The simplest definition that emerges in the literature, defines sustainability as the ability to meet the needs of the present without compromising the ability of future generations to meet their needs (WCED, 1987). However, such a broad definition may present some difficulties in its practical implementation. In 1994, Elkington creates the concept The Triple Bottom Line Approach (TBL). This approach, despite its simplicity, stood out for the clarification it brought to the concept of sustainability (Elkington, 1994). Here, performance is evaluated based on three distinct dimensions: environmental, economic and social.

Sustainability in agri-food SC

Typically, an agri-Food SC is responsible for producing and distributing agricultural and horticultural products to the final consumer. The main stakeholders in these chains are farmers / producers, food industries, distributors, retailers and consumers. However, there are other indirect partners who do not necessarily participate in chain activities but may have an impact on business, materials and information processes, and financial flows between all entities. These are secondary stakeholders and include government agencies, non-profit organizations, food, industry and financial associations (Prima Dania et al., 2018).

Murphy et al. (2013) found that the food sector is under increasing pressure to adopt sustainability programs, manifested by media exposure and consumer opinion. In fact, a sustainable agri-food CA is an opportunity to attract consumers. Furthermore, not only to win them over, but also to maintain their trust, there must be transparency in the FSC. It is well known that consumers increasingly want to be informed.

2.1 Collaboration

In a collaborative system, the entities involved have a better chance of increasing market shares as well as margins. Greater collaboration reduces conflict and promotes greater responsibility for each stakeholder to maintain sustainability levels. Essentially, collaboration is on the key path to achieving a balance between everyone involved, avoiding individualistic and opportunistic behaviour by some chain stakeholders (Lozano, 2007). In addition, collaboration is essential to support smallholders / farmers. These producers are key entities in the chain and are often limited with respect to business aspects. This makes them focused only on production and neglecting the rest of the SC. Good and efficient collaboration in a sustainable SC will support producers by facilitating access to resources and benefits by matching them with other stakeholders.

Prima Dania et al. (2018) ascertained the 10 factors that directly influence the way stakeholders build relationships, specifically oriented towards sustainability. These are: Joint Efforts, Shared Activities, Coordination, Adaptation, Power, Trust, Commitment, Stability, Continuous Improvement, Collaboration through learning.

Of the various factors identified, Ghosh & Eriksson (2019) recently studied the implications of chain-established power applied to the FW phenomenon.

Relative power

Ghosh & Eriksson (2019) concluded, by studying a real case, that an imbalance in power between entities, specifically in the relationship established between retailers and upstream entities, can have a major impact on FW levels generated along the chain. Based on this evidence, it was considered very relevant to capture this aspect in the present framework. Indeed, a strategic or operational definition should incorporate knowledge of the power relations established in the SC, otherwise it may be inappropriate for the context in question. Recognizing the relevance of power, there is a need to make the concept characterizable in a way applicable to this study.

Cox et al. (2001) define power as the ability of entity A to impose an activity on entity B that would not otherwise be performed. Increased power can then lead to an imbalance in goal achievement, favouring the most powerful entity, at the expense of controlling the behaviour and decision-making of other entities. In addition, the authors add that it may also imply harmful distribution of responsibilities and benefit allocation to the less powerful entity.

Applied to the context in which this framework is inserted, it is essential to investigate the factors that lead to increased levels of FW, derived from an imbalance of power verified between the entities in the chain. For this, the interest will be to characterize the relative power in the established relations and not the absolute power.

From a batch of academic papers, results the determination of a set of factors that allow the characterization of the relative power between the entities in SC. Thus, relative power can be assessed by combining four essential factors: Size, type of contract, decision-making, and dependence. In turn, these are characterized considering the available resources,

market share, bargaining power, available alternatives, requirements, rejection policy, reduction of economic margins and the responsibilities and activities assigned and the respective burden on the costs of the different entities.

2.2 Sustainable Production and Consumption (SPC)

Food and agricultural systems have been changing in recent decades and this has affected not only consumption but also production patterns. SPC is one of the goals of sustainable development and its goal is to have a more profitable and efficient production, while minimizing resources usage and adding value to a product, in a process where pollution and waste are minimized.

According to the United Nations Environment Program (UNEP), one of the most striking examples of production and consumption dysfunction is FW, which is precisely the focus of the present paper.

Food Waste

This phenomenon has highly negative impacts, that can be distinguished in terms of food security, economy and environment.

Food security - In the most developed countries, waste at the end of the SC raises ethical and socially worrying issues, especially when one in ten people are found to be in poor nutrition (World Food Programme, 2017).

Economic - Total lost and wasted food totals US $ 1055 billion annually (FAO, 2014). It is evident that the economic costs associated with this phenomenon are inefficient and a serious problem with direct impacts on the economic sustainability of all entities involved in the chain.

Environmental - The harvesting operation for products that will not be consumed represents a consumption of approximately one quarter of all water used annually in agriculture. Analysing the cultivation area required for this production, it is estimated that it corresponds to China's territorial dimension (FAO, 2013). In addition, this inefficiency accounts for 8% of global GHG gas emissions (FAO, 2015). For a better characterization of the phenomenon, the following factors are distinguished:

- **Definition of concepts**

The definition of FW is complex and not consensual. FAO distinguishes waste from food loss. Describes food loss as the decrease in edible foods over the portion of SC that is behind the creation of food for human consumption. Losses occur in the FSC production, postharvest and processing phases (FAO, 2011). On the other hand, “food losses that occur in the final phase of FSC (retail and final consumption) are referred to as 'food waste', a concept more related to consumer and retailer behaviour.

- **Urge to Reduce Food Waste**

An extremely important milestone in the global recognition of the need to reduce FW levels was the release of the 2030 Agenda for Sustainable Development in 2015, by the United Nations. Concerning FW, the role of objective 12 is highlighted, which portrays the need to “ensure sustainable production and consumption patterns” (United Nations, 2015). Specifically, the third target expresses the need to halve FW levels by 2030.

- **Quantify Food Waste levels**

A consistent methodology requires clarification of some points: definitions and terminology, system boundaries and units of measurement (Caldeira et al., 2017). This is motivated by the lack of a consensual definition of FW and the consequent proliferation of definitions in the scientific literature. The authors Cristóbal et al. (2017) add that, due to this barrier, quantifying FW levels becomes a complex task and that European legislation does not have a binding definition.

- **Food Waste Drivers**

There are numerous reasons for the creation of FW. This factor explains the need for their survey and study so that the most efficient prevention measures can be developed. When it comes specifically to FV, De Laurentiis et al. (2018) justify the large predominance of this group in the FW generated, especially in the consumption phase: (i) the FV correspond, by weight, to approximately 1/3 of the total purchases; (ii) unlike processed products, FV has an inedible component that will always be discarded; (iii) FV is highly perishable (along with meat and fish) and, therefore, when compared to other longer lasting goods, the probability of not being consumed on time is higher; (iv) FV are generally more economical, which makes the consumer less concerned about their waste.

- **Common destinations for Food Waste**

As a result of consulting two of the most relevant documents in this context, the usual FW destinations are: Animal Feed, Biological Raw Material / Biochemical Processing, Composting , Not harvested, Anaerobic Digestion, Bioenergy, Cogeneration, Incineration, Sewer and Landfill (Hanson et al., 2016; Tostivint et al., 2016).

Destination enumeration is a relatively simple task and can be described in a limited number of groups. However, prioritizing these destinations, and consequently defining a hierarchy of FW treatment, is a particularly complex task. To this end, the EC presented in 2008 Directive 2008/98/EC (Comissão Europeia, 2008), which sets out the first binding clauses concerning waste prevention and treatment. This document, recognized as the 'Waste Framework Directive' (WFD) presented the key principles for waste management, establishing a hierarchy of destinations for the European context.

The proposed WFD Hierarchy should be considered as a general principle of waste prevention and management legislation and policy. It defines 5 main methods for dealing with FW, which are presented in order of preference: (1) Prevention and reduction (2) Preparation for reuse (3) Recycling (4) Other types of recovery and (5) Disposal. Considering the different methods, an efficient FW reduction approach involves quantifying data and recording results separately. This approach will allow an entity to recognize all food flows and have the ability to expose or share results. There is another approach to the study of FW which, when combined with sustained quantification, provides a holistic understanding of the whole problem, enabling the creation of effective indicators and prevention and reduction strategies. This approach consists of investigating the drivers of FW, which has only recently received more attention (Caldeira et al., 2017).

3. Framework Development

The Framework developed may be applied whenever a particular entity wishes to identify any collaborative

improvements in SC, regardless of the associated reasons (academic research, waste management optimization, sustainability concerns)

The section begins by clarifying the definitions to be used on the framework, a step that was found to be essential in the literature review. This is followed by the characterization of the constituent activities of the conceptual framework, ending with a final conceptualization where an overview of the developed framework is provided.

3.1 Relevant definitions' prior clarification

There are four concepts that must be clarified and differentiated: Food Waste, By-product, Waste and Surplus:

- **Food Waste**

As introduced by CNCDA, FW is "any processed or partially processed or unprocessed substance or product intended for human ingestion or reasonably likely to be of which the holder (primary producer, agri-food industry, trade and distribution and families) is disposed of or has the intention or obligation to do so, assuming the nature of residue "(CNCDA, 2018). The case of human donation, animal feed, use as a biological raw material and biochemical processing are excluded from this definition, which implies they are not FW.

- **Residue**

It is defined by the EC as "any substance or object that the holder discards or intends or is required to discard" (Comissão Europeia, 2008).

- **By-product**

The products resulting from a production process whose main objective differs are considered by-products and not waste (Comissão Europeia, 2008).

- **Surplus**

In a study focused on FW applied to the business context, it is essential to consider that a product has different flow options prior to be considered as residue. In this sense, the concept of surplus is introduced.

A surplus in an entity then corresponds to a group of foods purchased in the normal course of business that, for various reasons, were not traded at the economic value originally intended for that product. This concept is strictly associated with the entity under analysis, and for this reason, whenever used, it intends to portray the perspective of that company.

Introducing the concept of surplus, it is essential to understand the relationship between the various concepts and how they differ. The diagram, Figure 2, clarifies the distinction of concepts

3.2 Framework activities

Before developing the five main activities, there is an **initial step** to consider in order to safeguard future work as well as allocated resources.

Initial step

It corresponds to the clarification of the **scope** and **boundaries** of study. The **scope** refers to the environment of the study, which includes specifying the motivation and purpose inherent. The boundary definition refers to the clarification of the SC levels and entities implied in the study. It is necessary to define the study boundary due to the very characteristics of the agri-food SCs (extensive, dispersed and with many involved entities). Having clarified the initial step, the core of the framework is now described.

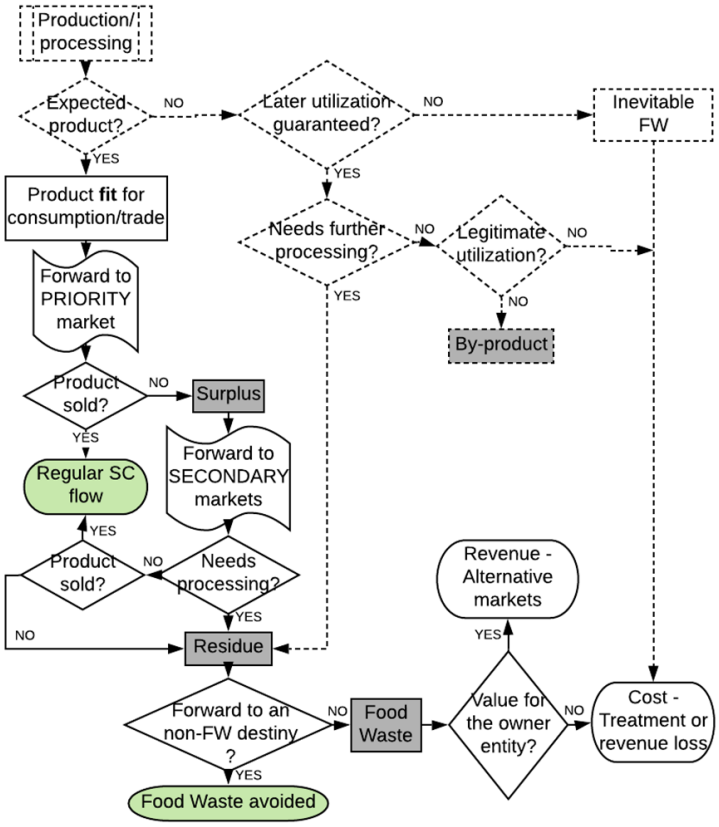

Figure 2 - Relationship between concepts diagram

To achieve the defined purpose, the Conceptual Framework is divided into **five** main activities. Each one is decomposed into several tasks and intermediate results that make it possible to link the activities on the Framework.

Figure 3 provides an overall macroscopic view of the Conceptual Framework, where all tasks and intermediate results are identified with a numbering sequence, according to the activity they belong to. This macroscopic presentation is followed by the description of each activity and therefore it is recommended to consider reanalysing Figure 3 whenever a new activity is described. Additionally, it is clarified that the arrows shown in the figure illustrate the necessary tasks to obtain a certain result and which sequence of tasks to perform to properly apply the framework.

Activity 1: Supply Chain Definition

The authors (Gunasekaran et al., 2001) point out that in order to characterize a SC, it is necessary not only to capture the various levels through transverse measures but also to include products and processes. Thus, it is necessary to acquire a global perception and to understand, primarily, which entities are directly involved in the SC and what is their role / importance in the SC, which are the main flows of material and information. as well as the general processes involved in the SC. This activity addresses the entities that define as **direct entities**, as they are responsible for the normal functioning of the SC, that is, for the direct flow that occurs in products from the moment of production to the moment of consumption. This activity excludes entities that

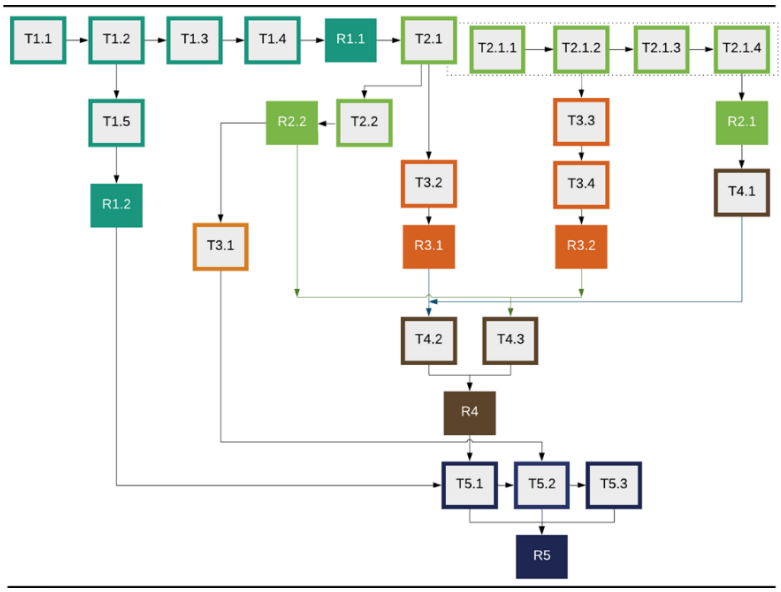

Figure 3 - Conceptual Framework Macroscopic View

arise in the treatment of surplus in the chain (s), called **indirect entities**, which will only be addressed in the subsequent activity. The main components of the first activity are described in Table 1. The numbering used refers to Figure 3. To obtain the result **R1.1**, it is necessary to perform tasks T1.1 to T1.4, which involve:

- Choosing a product to analyse and clarify the implied reasons;
- Map all direct entities in order to restrain the study to those specific entities;
- Characterize all process involved in the resulting SC;
- Characterize material and information flows.

Table 1 - Activity 1: Focus, Tasks and Results

Act. 1	Supply Chain Definition	
Focus	Direct SC –direct entities, SC flows and processes	
Tasks	Product definition	T1.1
	Direct entities mapping	T1.2
	SC processes characterization	T1.3
	SC flows characterization	T1.4
	Direct entities analysis	T1.5
Results	Case Study Definition	R1.1
	Direct entities characterization - Relative Power	R1.2

To obtain **R1.2**, the task T1.5 requires the characterization of a set of factors retrieved from the literature review: available resources, market share, bargaining power, available alternatives, requirements, rejection policy, reduction of economic margins and the responsibilities and activities assigned and the respective burden on the costs of the different entities.

Activity 2: Surplus Management Definition

As stated in the literature review, collaboration between entities reduces conflicts by increasing accountability and consequent motivation to maintain sustainability levels (Pomeroy et al., 2007). However, there is no guide that explicitly helps to improve the collaborative system (Prima Dania et al., 2018). Thus, it is understood that the characterization of the relationships established between the entities in the studied context is a fundamental initial step to later enhance collaboration in a whole. The main components of the second activity are described in Table 2. This activity marks the beginning of the Surplus management study

Table 2 - Act.2: Focus, Tasks and Results

Act. 2	Surplus Management Definition	
Focus	SC Surplus management – indirect entities, levels, destinies and relationships in the SC	
Tasks	Surplus management process mapping	T2.1
	▪ Surplus definition per entity	T2.1.1
	▪ Surplus possible destinies mapping	T2.1.2
	▪ Surplus management-related entities mapping	T2.1.3
	▪ Surplus management process characterization	T2.1.4
	Surplus quantification-related data collection	T2.2
Results	Holistic View of the Surplus Management Process	R2.1
	Quantification of FW/Surplus	R2.2

Activity 3: Surplus Management Critical Analysis

This activity marks the beginning of the critical component of the Framework. To this end, it must be analysed the information obtained from previous activities or collect information from a more analytical perspective. The main components of the third activity are described in Table 3.

Table 3 - Activity 3: Focus, Tasks and Results

Act. 3	Surplus Management Critical Analysis	
Focus	Surplus Management - Types, Causes, and Destinations	
Tasks	Analysis of the representativeness of the data collected / processed	T3.1
	Collection of analytical information on FW drivers	T3.2
	Surplus type characterization for each entity	T3.3
	Surplus Destinations Analysis by Entity (3 sustainability dimensions)	T3.4
Results	FW drivers (holder's perception) mapping	R3.1
	Surplus/FW destinations characterization	R3.2

The result **R3.1** pretends to incorporate the perspective of direct entities in the study of Surplus/FW drivers. To obtain **R3.2**, every destination should be analysed considering the sustainability dimensions (economic, environmental and social). This analysis allows for an understanding of the best surplus treatment options and introduces the need for solutions that seek the combination of the three dimensions addressed, imposing the need to potential trade-offs.

Activity 4: Hotspots Identification

The identification of hotspots is directly linked with the critical analysis of the Surplus management process. The term hotspot is defined as the activities identified in the product life cycle that have an impact on the environmental and social aspects. In this paper, this definition includes the factors that also impact the economic aspect and that influence the collaborative perspective in the chain. The main components of the fourth activity are described in Table 4.

It is expected that the result R4 provides a critical understanding of the current SC Surplus management, clearly identifying the factors that need to be optimized most urgently.

Table 4 - Activity 4: Focus, Tasks and Results

Act. 4	Hotspots Identification	
Focus	Surplus management inefficiencies	F4
Tasks	Inefficiencies between direct and indirect entities analysis	T4.1
	FW/Surplus Drivers justified clearance	T4.2
	Correlation between Surplus destination and the Waste Hierarchy	T4.3
Results	Supply chain's Hotspots Identification	R4

Activity 5: Solutions / Recommendations Proposal

This activity concludes the holistic analysis of the FW phenomenon for the defined case study as it considers all stages from information gathering, treatment and analysis, to hotspots identification, in order to design solutions and recommendations as tailored as possible to the SC specifications. The main components of the fifth activity are described in Table 5.

Table 5 - Activity 5: Focus, Tasks and Results

Act. 5	Solutions / Recommendations Proposal	
Focus	SC Surplus management improvement	F5
Tasks	Solutions design for prevention/reduction of the Surplus/FW levels	T5.1
	Proposed solutions characterization	T5.2
	FW reduction potential characterization	T5.3
Results	Final solutions and recommendations and SC's application analysis	R5

The designed solutions must fit not only the hotspots identified, but also the entities and the relative power that each entity has in the chain. In fact, while Liljestrand (2016) notes the importance of adapting solutions based on SC characteristics, other authors argue that the integration of stakeholders in the analysis enables a most effective approach, also adapted to the specificities of each entity involved (Diaz-Ruiz et al., 2019). Despite its subjectivity, this factor is important because it considers that different positions in the chain play different roles with greater or lesser impact to change global practices and consequently influence FW levels (Ghosh & Eriksson, 2019).

Additionally, the designed solutions should be characterized based on their corresponding SC level addressed, required steps and entities involved, as proposed by Diaz-Ruiz et al. (2019).

4. Framework Application

Since this paper is part of the MobFood project, the application of the Conceptual Framework developed is based on the entities involved in the project. To this end, Greenyard LP and its business relationship with Sonae MC are used as a starting point to study the FW phenomenon. Considering this, it is relevant to introduce both entities before the desired application.

4.1 Main Entities presentation

Greenyard LP

This company is focused on providing logistics services for food products such as fruits, vegetables, cold and fresh meats, dairy products, fresh and frozen fish. Recently began operating in the **FV importation and distribution**. However, the latter market only accounts for about 5% of its total operations. As a logistics operator, a Greenyard LP had a turnover of 6 million euros in 2017, which corresponds to a market share of 1.1%, being in 27th position in this market. Portugal. With two facilities in the country, the headquarter located in *Riachos*, *Torres Novas*, and a support platform in *Leixões*, the company provides logistics, transportation and value-added services.

As a FV **distributor,** this operation began with the importation of organic bananas from Peru and rapidly evolved to the distribution of 19 national and international biologic FV (e.g. carrots, sweet potato). This operation included, in a 7-month period, a volume of 555.921,01 kg, distributed to 24 clients and 43 delivery points, across 8 districts.

Sonae MC

Sonae MC is one of the biggest retail players in Portugal. It owns approximately 500 stores, with a market share of 19.4%.

Currently, this company includes a diversified portfolio in the food retail model, which extends from small proximity stores to large urban hypermarkets. In addition to the traditional food retail format, the company has other adjoining formats including the Go Natural brand, an organic supermarket and restaurant company, that is also supplied by Greenyard LP.

Sonae MC's supply chain includes a wide network of suppliers as well as some intermediate infrastructures. For food logistics, the company has 4 logistics platforms that precede distribution to retail areas: two warehouses, in *Maia* and *Azambuja*; a distribution centre (DC) in *Madeira*; and a Hub in *Maia*, especially for cross-docking operations. These infrastructures make it possible to store and prepare orders, adapting distribution to the needs of the wide store grid.

4.2 Framework activities

This section is strictly associated with section 3.2, as it corresponds to the direct application of the activities proposed. This said, in this paper, due to space constraints, the results of the research done are briefly exposed.

Initial Step (scope and boundary definition)

Scope: The **purpose** is the identification of collaborative methodologies among agri-food entities aiming to reducing the FW generated along the chain.

Boundary: The aim is to cover the largest number of entities and perspectives that can be explored, provided that the information obtained is sufficient to identify problems and suggestions that are adaptable to the studied context. Despite this, the study of the last level in the supply chain, consumption, is immediately excluded. Although this has a very large weight on the amount of FW generated, it does not fall within the scope defined for the present study, as they do not correspond to specific entities capable of establishing collaborative methodologies.

Activity 1: Supply Chain Definition

Firstly, to define the Case Study (**R1.1**), 4 tasks are required:

- **T1.1** - Product definition

To this end, three criteria were defined: (i) Autonomy in the Surplus Management process, (ii) Access to different levels in the chain and (iii) Representativeness / impact of the business. Considering this combination, and restricting the research to a single product, due to resource's constraints, the product chosen was: **BIOLOGICAL CARROTS.**

- **T1.2** - Direct entities mapping

Figure 4 shows the additional entities in the SC, both associated to the production level. The brown one, ***Producer Pegões,*** is a very small producer with about 15 Ha of biologic carrot production and operates exclusively for Greenyard LP. The blue one, ***Producer Comporta***, is the largest organic producer in Portugal, presenting dimensions significantly larger than the previously, with an estimated production area of over 100 Ha. As shown, this producer owns a processing center in *Almeirim*, where the products collected in the fields are sent and the shipments are prepared.

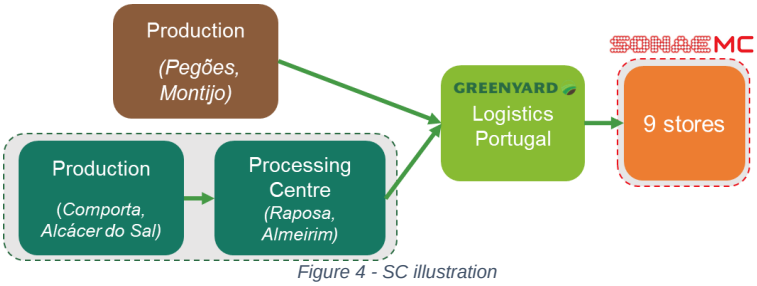

Figure 4 - SC illustration

- **T1.3** - SC processes characterization

Excluding distribution and storage, the main processes in the SC are production; collection; treatment and washing; sorting and packaging, all occurring at an early stage of the chain. **Producer *Pegões*** performs manually the production, collection, treatment and washing and sorting, it does not perform the packaging. This task is left to Greenyard LP, which occurs in the main warehouse using a semi-automated packaging line. **Producer *Comporta***, on the other hand, incorporates all operations in its processing centre, through an automated infrastructure.

- **T1.4** - SC flows characterization

Material flows: the correspond to the transportation process and they are represented by the green arrows in Figure 4. Greenyard LP is responsible for all flows (except the transportation between the production and processing centre of **Producer *Comporta).*** All transports are refrigerated and consolidated, if possible, with other products.

Information flows: Every Monday, Greenyard LP receives from producers lists indicating the sales price of the products along with the quantity available. In the following days, the quantity to be ordered is defined, the information is registered in the internal system and the order of collection is given to the transport department, and for national suppliers the registration needs a day in advance to organize the transport. When it comes to Greenyard-Sonae interaction, Greenyard LP sends a price list weekly on Wednesday. Between Thursday and Friday an agreement of prices and quantities is reached. Although there is a standard Greenyard LP table in relation to Sonae MC, the latter has a specific table, which implies a dedicated padding.

Lastly, to characterize the relative power (**R1.2**):

- **T1.5** - Direct entities analysis

Sonae MC, as a retailer, has significant power in the chain, influencing the decisions of upstream entities to meet the demanding requirements imposed. These include Greenyard LP, which, being responsible for most of the chain's intermediate activities, adapts operations and transmits requirements along the chain.

As regards carrot producers, the large grower has greater relative power given the independence of procedures, the resources available, and the various market channels. Small producer, on the other hand, is more dependent on the chain and therefore its power is greatly reduced.

These conclusions were based on a wider research regarding all factors presented in the literature. The research is excluded from this paper due to space constraints.

<u>Activity 2: Surplus Management Definition</u>

Firstly, to understand the surplus management (**R2.1**):

- **T2.1** - Surplus management process mapping

The results are shown per entity for three subtasks. Subtask T2.1.4 is highly descriptive and for that reason is excluded from the present paper due to document constraints. Tables 6 to 9 demonstrate the surplus types (T2.1.1), destinies (T2.1.2) and indirect entities involved in the process (T2.1.3) for each direct entity, respectively Greenyard LP, Sonae MC, Producer *Pegões* and Producer *Comporta*.

Table 6 - Greenyard LP: Task T2.1 results

T2.1.1	T2.1.2	T2.1.3
▪ Products out of retailer Sonae MC standards ▪ Product rejected in quality control ▪ Product out of any retailer standards ▪ Products out of minimum consumption standards	▪ Secondary markets ▪ External donation ▪ Internal donation ▪ Composting	▪ Other retail clients (less demanding ▪ Private Charity Institutions (IPSS) ▪ Internal workers ▪ *Componatura* (waste management entity)

Table 7 - Sonae MC: Task T2.1 results

T2.1.1	T2.1.2	T2.1.3
▪ Products exposed and not sold (in store) ▪ Products in distribution centre out of store standards	▪ External donation ▪ Internal donation ▪ Composting ▪ Revaluation (processing) ▪ Composting ▪ Landfill	▪ IPSS (through an external entity *Phenix)* ▪ Internal workers ▪ Internal structure plus processing entities ▪ Waste management system (SGRU)

Table 8 - Producer Pegões: Task T2.1 results

T2.1.1	T2.1.2	T2.1.3
▪ Products out of retailer Sonae MC standards ▪ Products out of minimum consumption standards	▪ Secondary markets ▪ Animal feed	▪ Local markets final client ▪ Livestock industry

Table 9 - Producer Comporta: Task T2.1 results

T2.1.1	T2.1.2	T2.1.3
▪ Products out of retailer Sonae MC standards ▪ Products out of minimum consumption standards	▪ Revaluation (processing) ▪ Animal feed	▪ Processing industry ▪ Livestock industry

The present activity is completed with the surplus quantification for each entity (**R2.2**). To this end, follows:

- **T2.2** - Surplus quantification-related data collection

Considering the direct entities, it was possible to obtain exact values from Greenyard LP, estimates from both Producers (directly from the producer manager) and macroscopic values from Sonae MC (i.e. not specifically related to the product studied). Considering this, Table 10 presents the information related to Greenyard LP and both Producers.

Table 10 - Surplus quantification per entity

	Greenyard LP	Producer *Pegões*	Producer *Comporta*
Total Sales	**87,8 %**	**40 %**	**35 %**
Production Losses	-	12 %	-
Total Surplus	**12,2 %**	**48 %**	**65 %**
- Internal donation	1,7 %	-	-
- Composting	10,5 %	-	-
- Secondary markets	-	40 %	-
- Revaluation (processing)	-	-	60 %
- Animal feed	-	8 %	5 %

When it comes to Sonae MC, it is relevant to highlight that its higher dimensions and fragmented infrastructures (stores and DC) were the main reasons that prevented a detailed quantification. Nevertheless, some relevant data was found:

- 29% of the total stores employ a waste separation process in its regular operations, which means the other 71% treats waste inferentially.
  - Where there is separation, the residues are collected by 2 SGRU, depending on location.

- The entity *Phenix*, intermediate for the external donations process is active in 40 stores and reaches 280 different IPSS.
- The revaluation process generates 7 new products (Cake and chutneys) from FV surplus.

Activity 3: Surplus Management Critical Analysis

Even though task '**T3.1** - Analysis of the representativeness of the data collected / processed' is important, its results are omitted in the present paper as they are not critical.

Task '**T3.2** - Collection of analytical information on FW drivers' is omitted from the present paper. The drivers obtained in this activity are consolidated in task '**T4.2** - FW/Surplus Drivers justified clearance', which, in turn, in contribute directly to the hotspot's identification.

Considering the information above, in the present activity two tasks are addressed:

- **T3.3** - Surplus type characterization for each entity

Figure 5 demonstrates the corrected definition of all surplus destinies (introduced earlier), verified in each entity.

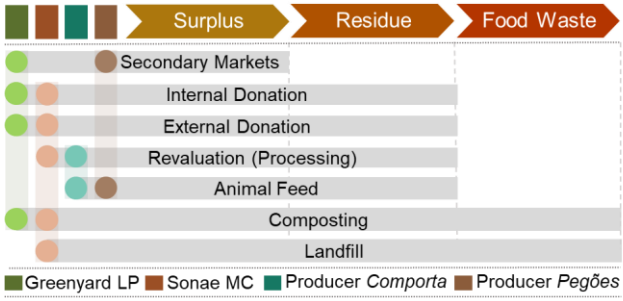

Figure 5 - Surplus destinies correct definitions

- **T3.4** - Surplus Destinations Analysis by Entity

Equivalently to task **T1.5,** the present task is also composed by a broader research, which was excluded from the present paper. The purpose is to classify every existing surplus destiny in all three dimensions of sustainability. the **economic** dimension is divided into costs and revenues. Total costs are characterized by a combination of (i) Rejection costs, (ii) Profit losses e (iii) Treatment costs. Total revenues consider (i) tax benefits e (ii) Trading revenues. The **environmental** dimension is characterized by a hierarchy proposed from Champions 12.3, an extremely relevant entity in the FW context that clarified the hierarchy of destinies, considering their environmental impacts. Lastly, the **social** dimension considers both the local impact and the possibility to fight world hunger (Sustainable Development Goal 2).

Considering all factors, Figure 6 presents 4 radar graphics, one per direct entity, that provide the relative characterization of each destiny in the three dimensions considered.

Activity 4: Hotspots Identification

The present activity consists in an inefficiencies' analysis (**T4.1**) and the identification of FW drivers (**T4.2**). Even though these tasks are essential to identify the hotspots in the SC, the identification itself acts as a sum up of the results of both tasks. This said, in the present paper the inefficiencies and the FW drivers were deliberately omitted, considering that the hotspots were primarily a result of that analysis. Considering the above information, Figure 7 presents the hotspots identified in each entity through all entities in the SC.

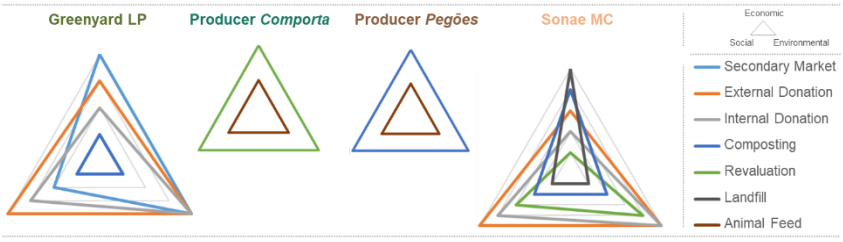

Figure 6 - Relative Characterization of all Surplus Destinies

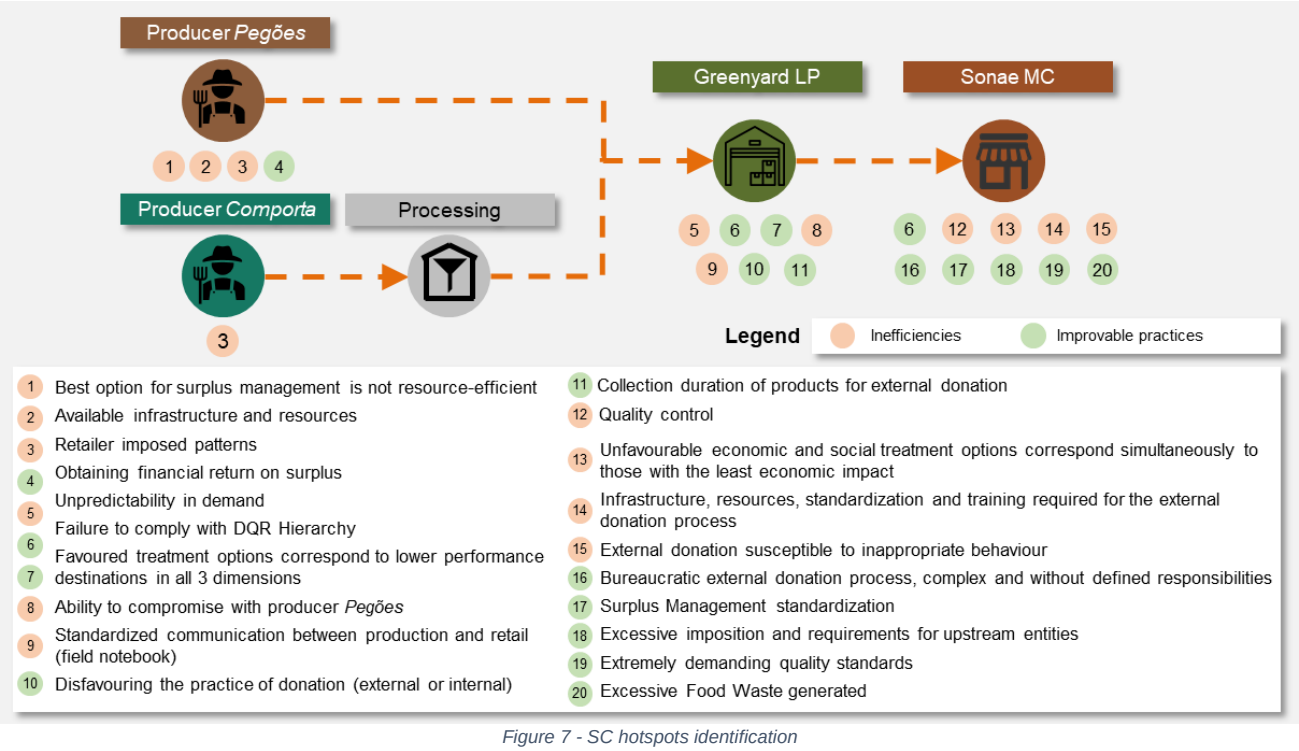

Figure 7 - SC hotspots identification

Activity 5: Solutions / Recommendations Proposal

The present activity begins with:

- **T5.1** - Solutions design for prevention/reduction of the Surplus/FW levels

To address the hotspots identified, a set of 18 solutions was designed. Table 11 presents the designed solutions (first column, numbered from S1 through S18) for different entities involved. In the respective entity columns, the critical points associated with the solution and the entity are identified - e.g. the second solution 'S2 - Digitalization to alleviate burden' impacts Greenyard LP at Critical Point 9 - 'Standardized Communication between Production and Retail', and Producer *Pegões* at critical point 2 - 'Available infrastructure and resources'.

Table 11 - Categorization of solutions by impacted entity and critical point

Solutions	Greenyard LP	Sonae MC	Produtor Comporta	Produtor Pegões
S1 - Leveraging Existing Channels	[1]		[1]	1,2,4
S2 - Digitalization to alleviate burden	9			2
S3 - Adaptation of quality standards		19	3	3
S4 - Emphasis on Commitment	5	[1]	[1]	[1]
S5 - Donation-oriented Inventory Management	6			
S6 - Incentives in Donation	6, 10	14		
S7 - Application of global guidelines	6,7, 10	20		
S8 - Avoid landfill		13		
S9 - Autonomous transport to external donation	11			
S10 - Digital donation platforms	10			
S11 - Support production phase	8			[1]
S12 - Optimization of Order Receiving locations		12,18		
S13 - Awareness		15		
S14 - Consider non-financial return on investment in sustainable options		13		
S15 - Standardization, training and proximity		14,17		
S16 - Optimization for external donation		16,17		
S17 - Focus on global SC over individual focus		18		
S18 - Holistic prevention of FW		20		

[1]Impacts entity even though it does not correspond to a critical point

Both tasks **T5.2** and **T5.3** are omitted from the present paper as they are shortly addressed in the conclusion section. The present activity is thus concluded by a set of recommendations concerning the central entities:

- Greenyard LP: Use inventory management tools exclusively dedicated to product donation (S5), preventing these products from evolving into FW. In the interaction with the IPSS entities that receive the donations, try to minimize the collection time (S9), considering the possibility of delivering the products in the IPSS. At the threshold of product quality, one day may be decisive in making them obsolete. With a potential growth in activity, IPSS absorption capacity limitations should be considered. Therefore, it is recommended to diversify the relationships established by using digital donor-recipient matching platforms (S10).

- **Greenyard LP with Producer *Pegões***: The reduced amount of resources available to this producer implies a difficulty in issues extra-production. In this regard, it is recommended to study tools (S2) that simplify the activity and are easily accessible to Greenyard LP (e.g. digital platforms). Additionally, the specific relationship with this producer would benefit from high levels of cooperation and support, allowing for a relief in the production phase (S11).

- Greenyard LP with both carrot growers: In line with the previous recommendation, considering access to secondary markets is a problem for smaller growers (*Pegões*), it is recommended to take advantage of both growers' surplus volume (S1), where Greenyard LP would be intermediary.

- **Greenyard LP with upstream and downstream entities**: Seek greater involvement of both upstream and downstream entities by making volume commitments to producers and retail customers (S4), ensuring product outlets in the priority market, avoiding any surplus for lack of demand.

- Sonae MC: As noted, awareness raising is estimated to play a key role with consumers and employees. Recognizing this factor, the entity should consider being an active presence at a national level (S13). However, it is important to consider the economic sustainability of these investments. In this sense, a search for non-financial benefits (S14), such as consumer trust and consequent increased consumer adhesion, which may be reflected in an increase in overall sales volume, is recommended. The size of this entity exponentiates the complexity of standardization of practices across all stores. Nevertheless, it is recommended an increased effort from the upper levels of company management that should be disseminated in the values transmitted to employees. The act of external donation in store entails costs and complications in activities and planning, which must be constantly optimized (S16). For this reason, proximity with all entities involved (employees and IPSS) in the process (S15) is justified.

- Sonae MC with upstream entities: The high-quality standards required by Sonae MC for upstream entities in SC mean that producers are not able to sell a considerable portion of products that are nutritionally fit but aesthetically distinct from traditional forms. This issue has a greater impact on organic production due to the difficulties inherent in production. Thus, a study of the target consumer of these products is recommended, allowing to capture their preferences and adapt the imposed standards accordingly (S3), avoiding the creation of surplus along the chain. In addition, when faced with the reality that the requirements imposed on other entities may be detrimental to their activities and may even be a cause of FW, the motivation to seek mutual benefit is quite high. That said, the entire chain would benefit from an optimization of activities that could generate upstream entropy (S12). Sonae MC, holding the highest relative power, should thus seek a cross-chain performance improvement rather than an individual one, reducing the levels of FW holistically (S17, S18).

- Greenyard LP and Sonae MC: For both entities, a strict application of the European guidelines (S7) is recommended, preventing surplus firstly and strongly rejecting landfill (in the case of Sonae MC - S8). This will require considering aspects of SC performance optimization whose impact on the FW may be positive. Additionally, it is relevant to mention that both entities would benefit from donation incentives (S6), as this activity may entail considerable financial effort which makes it less appealing. In this sense, this recommendation is addressed to regulators, whose focus should be on stimulating donation practices in the agri-food sector.

5. Conclusions

This paper is motivated by the study the phenomenon of FW in the agri-food chains, as an essential concern for their sustainability, and develops, for that purpose, a framework proposing an integrated approach that allows characterizing the study context, analysing the information from a critical perspective and proposing collaborative solutions aimed at optimizing FW management in SC. Given its involvement in the MobFood project, it is possible to apply the framework to a SC resulting from the commercialization of organic carrots between Greenyard LP and Sonae MC.

Among the entities studied, there are factors or practices that prevent a fast, efficient and standardized external donation, especially for Sonae MC. It is also concluded that relative power in the chain can promote some practices that clearly favour the most powerful entity, implying a complexification of tasks in the other entities in the chain. From the inefficiency's analysis, it was concluded that these can have a significant impact on the creation of surplus and consequently FW in the chain. Based on these factors, a set of critical points in the chain is identified (inefficiencies and incorrect practices) It is noteworthy that most of the critical points are attributed to downstream entities, which may be justified by the increased complexity of operations at SC levels closer to consumption. Overall, there is a high margin of progress in sustainable surplus management in accordance with global guidelines, especially for Greenyard LP and Sonae MC.

Regarding the framework limitations, there is a lack of quantitative methods which would be necessary to prioritize a further qualitative valuation and analysis. Although the focus deviates from the development of numerical and exact methods or mathematical models, it is recognized that these, when properly incorporated, can add precision and objectivity to the study. Thus, this map should be considered as a tool that allows to acquire considerable knowledge about a given context and that stimulates both the identification of areas of greatest impact on the FW phenomenon as well as the research for synergies or more favourable situations in the SC. Furthermore, the limitations found in the Case Study include some factors such as data collection, resources available for the research and limited availability of corporate entities.

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