Circular economy in the meat value chain – waste and by-product recovery opportunities

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Abstract – The work herein developed is under the scope of the MobFood project, which promotes strategies based on technological and R&D development in order to obtain innovative results, acting along the whole value chain and promoting the collaboration between entities.

The Case study aims to contextualize, as it presents the MobFood Project, the project where the present dissertation is inserted in, and, more specifically, the PPS-7 and all the constituent entities. The literature review aims to provide a background regarding the most used methods for meat by-products recovery, as well as some notions related with collaboration. In addition, concepts related to VRP and waste collection problems are presented in order to display some knowledge that is used as a theoretical background to the collection process developed in this dissertation.

The aim of this paper is to highlight the need for reducing the waste of pork by-products and to propose a solution that adds value to them. More specifically, the proposed solution is to collect pork by-products from slaughterhouses located throughout Lisbon, Tagus Valley and the central region of Portugal and export them to China, a country where these are highly valued. The methodology is divided into two phases: the first phase, which refers to how by-products are collected and treated in national territory; and the second phase, referring to the international transport of such by-products. All costs incurred are demonstrated, explained and then balanced with the expected revenues, in order to comprehend if the entire process of export is financially viable.

Keywords: By-products recovery; Sustainable collaboration; VRP; Waste Collection problem; Air freight costs; Ocean freight costs.

1.Introduction

1.1 – Problem background and motivation

Food is and will always be a central need for all human beings. Population growth and the consequent demand growing for food and drinks are occurring at speeds never before observed. Therefore, global trends are shaping the demands that modern agriculture and food production must meet, meaning that a rising global population requires access to safe and reliable sources of nutrition. However, a rise in food production is not enough, considering the limited resources we have on earth. With that in mind, we must act in a sustainable way.

This is the starting point and the main motivation for the **MobFood Project** - Mobilization of scientific and technological knowledge in response to challenges, more specifically, for the working package PPS- 7 - Logistics - Sustainable Collaborative Agro-Food Logistics Chain. Two main acting pillars can be highlighted: the characterization of logistic activities regarding the agri-food sector so that motivations, constrains and requirements related to sustainability can be identified and; the research and development of process management methodologies applied to logistic activities which make it possible to base and justify decisions in an integrated way while fostering collaboration between FSC stakeholders. The present work is being developed within IST (Instituto Superior Técnico), which is another entity belonging to PPS-7.

1.2 – Objectives

Within the work plan of PPS-7, the objective of this work is to build a decision support framework based on the meat supply chain that shows a possible attractive valuation opportunity in the occurrence of breakage, waste or by-product.

More specifically, the goal of the present work will be to explore the possibility of exporting pork by-products to China, a country where such by-products will surely be properly valued, thus not being wasted, due to the main features of the Chinese pork by-products' market which make such products so valuable. This process can be divided into two operations: the collection and storage of the pig meat by-products; and then the transport of such products to China.

2.Case study

This chapter aims to contextualize the reader, explaining the problem being studied and how important is the chosen theme. Firstly, the national meat sector will be characterized in order to contextualize the reader by exhibiting the main constrains and opportunities of this sector. Then, the MobFood project will be explained, more specifically the PPS-7, which is dedicated to the logistics topic of the within overall project. ETSA and Greenyard (two of the co-promoters) will then be described, since their core activities are the collection and storage of goods, respectively. Finally, the problem statement will be exhibited.

2.1 – Meat supply chain characterization

The entities operating within this sector, whose flow of products and information through collaboration constitute the meat supply chain, are presented in figure 1. The main picture basically shows us how cattle becomes consumable meat products for citizens, as well as all the stages which meat must go through.

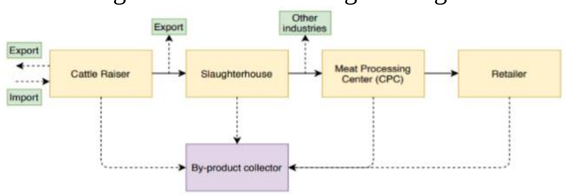

Figure 1 - Meat Supply Chain

The sector is highly concentrated and fragmented. This means that explorations belong to few entities but each exploration, due to its location, is managed differently. This is a big obstacle for collaboration between entities in the meat sector. The sector under study also requires long trust relationships between the entities involved. This can be a hard goal to accomplish, since all the entities involved are spread across the country and they are sometimes far away from each other [1]. The meat sector is highly regulated. It is very important that all meat must be properly regulated in order to guarantee the quality of the meat. Any flaw in this step can harm the consumers and jeopardize their health. On the other hand, this is a clear obstacle for possible collaborations between entities. The lack of labour and the technological delay are some of the main problems faced by the sector [4].

2.2 – The MobFood project

MobFood is the result of a joint mobilization project entailed by many agri-food sector actors who seek to respond to challenges related the promotion of a more competitive food industry. The main goal is to promote new strategies based on technological and R&D development in order to obtain innovative products, services and processes, acting along the whole value chain and promoting the collaboration between the business sector and non-business entities. The MobFood consortium is composed by 47 entities that include companies who act on different agri-food subsectors and non-business companies that complement the research by providing specific knowledge that other companies do not have [2].

2.3 – PPS-7 (Logistics - Collaborative Sustainable Agri-Food Logistics Chain)

The main objective of this PPS is to investigate and develop innovative logistics processes and management methodologies [3]. The present work will focus on the meat sector.

2.3.1 – ETSA Group

All ETSA Group companies focus their activities on environmental issues by offering global, safe and sustainable answers. Through their services, they look for the best solutions to value all by-products and all products that contain animal substances. To do so, the companies guarantee specialized and integrated answers by using collection devices and respecting all regulations.

In the context of the present work, Abapor is the ETSA Group's most relevant component, since this is the company that is accountable for the collection, transport, sorting and unpacking of edible meat by-products. All the information related to ETSA's operational activities provided in this dissertation is based on the work developed by Marta Lopes in 2018, in collaboration with Abapor. This entity, which belongs to the ETSA group, is dedicated to the collection, transport, sorting and unpacking of animal-based by-products [5].

Abapor collects meat by-products throughout the modern distribution, municipal markets, industries and so on, always recording all products' traceability. In the case of the present work, only the collection of meat by-products from meat processing centers and slaughterhouses will be considered. Abapor operates under four collection points throughout mainland Portugal, located in Vila Nova de Gaia, Loures, Coruche and Tunes. All four infrastructures operate in different ways and complement each other in terms of activities performed by each point and their respective flows in order to maximize the efficiency of the entire process and to minimize the total cost.

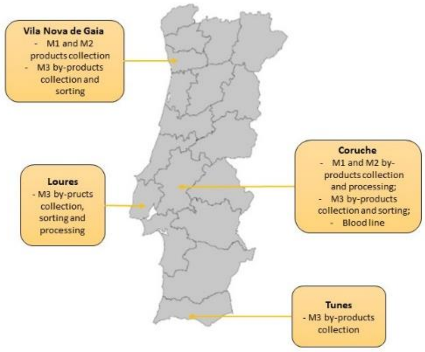

Figure 2 - Abapor's four collection points

2.3.2 – Greenyard

Greenyard Logistics, which has been in Portugal since 2001, operates in the market of providing logistics services and transportation of food products, being more focused on perishable food products, and in the importation and marketing of Fruits and Vegetables. Greenyard Logistics Portugal is located in the center of Portugal and it has a 17.000 m^2 platform which satisfies all the needs that requires temperatures between -25ºC and 18ºC and is constantly supported by cross-docking hubs [6].

2.4 – Problem statement

The problem to address is to find opportunities and legitimate methods to reduce pig meat waste or, at least, direct it to proper destinations, thus adding value to it. In the context of the present dissertation, collaboration is required to enable the collection of all the unused meat products that otherwise would be wasted, as well as to implement the necessary treatment on such products.

The present work will be exclusively focused on pig meat by-products from slaughterhouses. This is because of two main reasons. Firstly, there are less collecting points to be considered (and, therefore, a higher quantity of fresher by-products to collect in each point) than there would be in the case of by products' collection from stores. Secondly, and most importantly, such pork by-products that can be found in larger quantities in slaughterhouses are the most commercialized and consumed ones in China.

The goal will be, therefore, to collect pig meat by-products from slaughterhouses and add value to them. In the context of this work, those infrastructures that will serve as collecting points are located in Lisbon, Tagus Valley and in the central region of mainland Portugal. This is because, as there is a large airport and also a maritime port in Lisbon, only the Abapor's infrastructure that is located in Loures will be considered. In this work, the value will be added through the export of pig meat by-products to China, a country whose culture will enable a better destination to such products, which otherwise would be wasted.

3.Literature review

The aim of this chapter is to expose all the necessary knowledge and theoretical basis to understand and face the problem that is being analyzed in this dissertation, which will be based on the potential benefits resulting from meat by-products recovery and waste collection.

3.1 – Meat by-products recovery

The meat industry generates large volumes of by-products that are costly to be treated and disposed ecologically. These costs can be balanced through innovation to generate added value products that increase its profitability. The residuals contain proteins and other essential nutrients with potentially bioactive properties, eligible for recycling and upgrading for higher-value products, such as for human consumption, pet food and feed purposes and non-food and non-feed purposes [7]. However, the past crisis related to outbreaks of foot-and-mouth disease have shown the consequences of the improper use of certain animal-based products for public and animal health [8]. Since then, the European Commission published many regulations to prevent the reoccurrence of those crisis, which resulted in significative economic losses for the entire sector. Strict legislations regulate the utilization of various animal-based by-products and represent a major hurdle if not addressed properly [7]. This means that adequate disposal of by-products may increase the cost to processors and makes it necessary to produce new substances or products capable to cover the disposal costs [9]. Despite all the possible benefits that the use of animal by-products can bring, it is often hard to implement them due to the existent difficulties to combine the use of innovative technology, processing methods, and adequate marketing of the product [10]. There are three main ways of adding value to meat by-products: they can be used in human food, for animal feed applications or for non-food and non-feed applications (see Figure 3) [9,11].

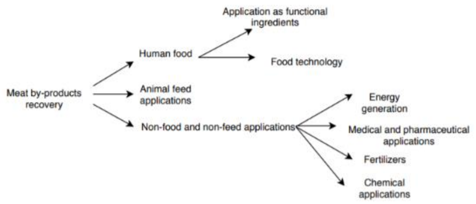

Figure 3 - Possible ways of recovering meat by-products

3.1 – VRP for waste collection

The Vehicle Routing Problem (VRP) is highly used in the operational research context and is basically a problem where customers who have known demands must be supplied by one or several depots. The main goal when solving this problem is to find the set of routes that satisfy the imposed constraints and minimize the total cost of travelling The sector which the present work will be more focused on is the waste collection, since the focus of the present study starts with the collection of unused meat by-products.

In a classical VRP, the customers, as well as their respective locations, are previously known. The driving time between the customers and the service times at each customer are also often known. When presenting a VRP, the customers' locations are described within a graph composed by vertices and a set of arcs. Each arc (i, j), where i is always different than j, is always linked with a distance, or, in some cases, with a travelling cost or traveling time. Moreover, it is assumed that there are a certain number of vehicles available, being that number represented by a fixed constant. Sometimes, mainly in the cases where the number of available vehicles is not fixed or limited, a cost of using a vehicle is imposed in the model. With all this data in mind, when solving the VRP, the main goal is to design a set of vehicle routes that minimize the total cost while knowing that: each customer is visited exactly once, by exactly one vehicle; all vehicle routes start and end at the depot; all other constrains imposed in the mathematical model must be satisfied [12,13].

4.Methodology

The entire process can be divided into two main phases: the collection and storage phase, which refers to how by-products are collected and treated in national territory; and the export phase, referring to the transport and arrival of such by-products to China. The first part of the present chapter will present the first phase. It consists of the collection of pig meat by-products from multiple slaughterhouses located in Lisbon and Tagus Valley and also in the central region of mainland Portugal. The problem enclosed in this first phase can be formulated as a VRP and it is intended to be solved through the optimization of a mathematical model. The goal is to determine the best set of pairs trajectory-trucks which return the minimum collection cost. Then, the by-products will be stored until they are ready to be exported, which leads us to the second phase. The second part of the chapter will present the methodology to address the second phase of the problem. Firstly, the main features that make the Chinese pig meat market such a promising opportunity to be explored when it comes to the export of pig meat by-products will be presented. Then, the most critical challenges when it comes to choosing the best way of exporting meat by-products will be exposed. Many topics must be discussed, such as the way of transportation (air freight or ocean/sea freight), the incoterm to be established, the quantity to be exported, and much more. The main purpose of this analysis is to provide a framework which helps a potential exporter to decide which is the best way of transportation, considering the established requirements.

The chapter's scheme is presented in figure 4.

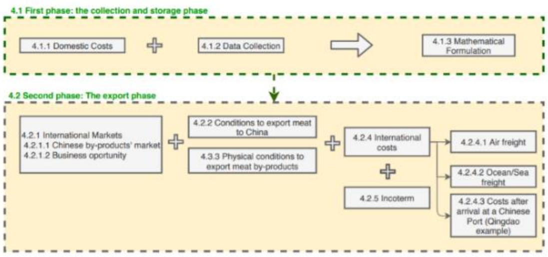

Figure 4 - Methodology's scheme

4.1 – The first phase: the collection and storage of by-products

The process suggested by the author begins with the collection of large quantities of pork by-products, performed by a company specialized in meat products logistics. These by-products are found in several slaughterhouses located throughout Lisbon, Tagus Valley, and the central region of mainland Portugal. The main goal will be to collect all the by-products from those slaughterhouses while minimizing the total travelling costs. To do so, a VRP is being solved by formulating a MILP model to find the best set of trajectory-trucks which find the minimum cost.

4.1.1 – Domestic costs

In the context of this work, domestic costs represent all the costs incurred in the process of collecting from the desired slaughterhouses and MPCs and storing them. All considered costs are the following ones:

- **Salaries -** The sum of all workers' wages who drive the trucks so that the by-products can be collected.
- **Tolls -** Charges payable to drive on bridges or certain roads.
- **Fuel costs -** Total fuel expenditure to travel the necessary distances to collect by-products from all collection points.
- **Warehousing costs -** They are referred to the total cost of holding inventory. Inventory costs usually include costs such as rent, utilities, salaries, opportunity costs, and costs related to perishability, shrinkage and insurance.

One must note that the costs herein presented are a simplification of reality. In the context of this dissertation, the author decided to assume that the collected products are not purchased from the companies that own the slaughterhouses. Therefore, the entire collection process represents an act of collaboration between several companies, including Abapor. Hence, it was admitted that, if there are no purchasing costs, the profit resulting from the final sale of all by-products will be distributed according to the costs incurred by each company involved.

4.1.1 – Mathematical formulation

There are n slaughterhouses and k vehicles to be considered in this model. Each slaughterhouse is represented by i and j, where i is always different than j. In this case, 0 is the depot. The other vertices represent the slaughterhouses that must be visited by a truck. A set of vehicles k is initially stationed at the depot. All parameters are presented in table 1.

Table 1 – Model's parameters

Parameter	Description
Cap	Capacity of each vehicle (kg)
H	Worker's salary (€/h), knowing that there is only one worker driving each vehicle.
d	Transportation cost (€/km)
v	Average speed (km/h) of every truck
$dist_{ij}$	Absolute distance (km) of arc (i,j)
$time_{ijk}$	Travel duration (h) for each vehicle, associated with traversing arc (i,j).
c_i	Quantity (kg), of by-products in slaughterhouse i
T_{ij}	Toll value (€) that must be paid in order to traverse arc (i,j)

The mathematical formulation is presented as follows. First, the decision variable is defined in the following way:

$$X_{ijk} = \begin{cases} 1, if\ vehicle\ k\ goes\ through\ arc\ (i,j) \\ 0, otherwise \end{cases}$$

The objective function is described by equation (1), whose main goal is to minimize total travelling costs.

$$Min\ \sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=1}^{K}(dist_{ij} * X_{ijk} * d + T_{ij} * X_{ijk} + 2 * H * t_{ijk} * X_{ijk}) \quad (1)$$

Subject to:

$$\sum_{i=1}^{n} X_{jik} \leq 1 \quad \forall j = 0; k = 1,2, \dots K \quad (2)$$

$$\sum_{i=1}^{n} X_{ijk} \leq 1 \quad \forall j = 0; k = 1,2, \dots K \quad (3)$$

$$\sum_{i=1}^{n}\sum_{k=1}^{K} X_{ijk} = 1 \quad \forall j = 1,2, \dots n \quad (4)$$

$$\sum_{i=1}^{n}\sum_{k=1}^{K} X_{jik} = 1 \quad \forall j = 1,2, \dots n \quad (5)$$

$$\sum_{j=0}^{n} X_{ijk} = \sum_{j=0}^{n} X_{ijk}\ \forall i = 0, \dots n; k = 1, \dots K \quad (6)$$

$$\sum_{i=1}^{n} c_i X_{ijk} \leq Cap \quad \forall j = 0, \dots, n; \ k = 1, \dots K \quad (7)$$

$$t_{ij} = \frac{dist_{ij}}{v} + 0.5 \quad \forall k = 1,2, \dots, K \quad (8)$$

$$\sum_{i=0}^{n}\sum_{j=1}^{n} t_{ijk} * X_{ijk} \leq 16h \quad \forall k = 1,2, \dots, K \quad (9)$$

$$u_i - u_j + N * X_{ijk} \leq N - 1 \quad \forall k = 1,2, \dots, K; 1 \leq i \neq j \leq N \quad (10)$$

The first two constraints, presented by equations (2) and (3), specify all conditions related to the depot. Equation (2) states that each truck must leave the depot at the start of the tour, whereas equation (3) states that each vehicle must enter the depot at the end of the tour. According to equation (4) and (5), each slaughterhouse must be visited and left exactly once, respectively. Then, equation (6) ensures the continuity condition, meaning that, if vehicle k enters a node (slaughterhouse), it must also leave that same node. Then, equation (7) shows that the total collected by-products from all the visited slaughterhouses by each vehicle must not exceed the capacity of the vehicle. Equation (8) defines the duration any vehicle in the model takes in order to travel arc (i,j). Note that the value 0.5 (30 minutes) represents the time the worker driving the vehicle takes in order to perform the collection itself within any slaughterhouse the driver passes by [5]. Equation (9) imposes a time limitation of 16 hours of transport for each vehicle (it is considered that each truck contains two workers) [5]. Equation (10) represents the Miller, Tucker and Zemlin (MTZ) constrain, which prevents every vehicle to drive in closed circuits that do not contain the depot.

4.2 – The second phase: the export of by-products

After all by-products are collected, stored at the depot and then taken to the port or airport of departure, they are ready to be exported and commercialized. This second half of the chapter has two main purposes. The first one is to demonstrate the business potential of the Chinese meat products' market that led the author to believe that the export of pork by-products to China would be a sustainable business opportunity. The second one is to present two means of transportation for exporting meat products to China: air freight and ocean/sea freight. First, all necessary physical conditions that must be put into practice in order to guarantee the export of meat products to China will also be mentioned. Then, a demonstration and explanation of all the costs that are usually incurred in the export of meat products, in the cases of both air freight and ocean/sea freight are exposed. Finally, the section ends with the demonstration of the chosen incoterm.

4.2.1 – Business opportunity

There are several Chinese pork market characteristics that show how exporting pig by-products to China can be a real business opportunity [14].

First, it can be less costly for Chinese pig meat industry entities to import directly from other countries than to produce domestic pig meat. Therefore, with the rise of domestic pork prices, the less expensive foreign pork becomes more competitive in the Chinese market. However, to be cost competitive in China, foreign pig meat must be comparable in cost or cheaper than Chinese pork after accounting for freight costs, tariffs, value-added taxes and so on.

Lastly, the EU countries and Chinese consumers have complementary tastes that encourage pork trade between both groups. European consumers prefer muscle meats, while Chinese consumers prefer offal and variety meats that have low value in the EU countries.

These features of the Chinese variety meats' market are what makes it such a promising opportunity for exporters, importers and all the stakeholders involved.

4.2.2 – Physical conditions to export meat products

Meat by-products are extremely vulnerable to microbiological hazards, since their moisture, pH levels, and high protein content provide the kind of environment that best allows the growth of bacteria. Due to these characteristics, the products must be carefully monitored in order to prevent their exposure while being stored during transportation [15].

Generally, frozen meat is stored under a temperature of -18ºC so that the activity of micro-organisms and enzymatic degradation are properly suppressed (the temperature can be lower as long as it is maintained, in order to avoid re-crystallization, which originates the degradation and discolouration of the meat). For that temperature, edible offal has a practical storage life of 4 months. The temperature must be kept constant in order to avoid re-crystallization on the product's surface, which reduces the utility value [16,17].

Regarding the package, sides of pork are usually packaged in stockinet and boned portions are wrapped in film and then packaged in cartons. Offal is often vacuum-packed. The protective coverings must always be clean and dry, meaning without blood stains, since they are a sign of previous thawing [16,17].

4.2.3 – International costs

In the present dissertation, two transportation options will be considered: air freight and ocean/sea freight. The main cost components related to the movement of goods from the exporting to the importing countries will be discussed, both in the cases of air freight and ocean freight.

4.2.3.1 – Air freight

Air freight pricing is usually based on the weight of goods being moved. However, if particularly large or oddly shaped objects are being shipped, this might incur some surcharges related to low levels of stowability. Using a consolidated freight route is usually the cheapest arrangement, although it might take a few days longer than a direct service. Air freight costs vary significantly depending on what it is being moved and where. The following considerations must be considered when defining the cost of air freight [18,19]:

• Base rate - Carriers use a shipment's weight when calculating cost. There are two options regarding the type of weight to use when computing the base rate: the actual weight, that is, how much the item actually weighs (gross weigh); volumetric weigh (or dimensional weigh) which is calculated by dividing the volume of the item by the density of the item.

• Fuel surcharge (FSC) – it is a fee that is related with the fluctuation and seasonality associated with fuel costs. This cost component is one of the top expenses for carriers. Fuel surcharges depend on the fuel's price and are calculated as a percentage of the shipment's weight.

• Security surcharges – it refers to any additional fees for security measures required at airports. The cost associated with security surcharges applies to evaluation processes that certain goods must go through in accordance with the Airline Security Regulations. The fee is charged at the points of origin and destination and are exclusively applied to air freight rates

• Container freight station (CFS) – it is a fee that is related to cargo that is temporarily stored in third-party warehouses or other facilities when entering a country. Once all necessary customs documentation is provided, all cargo is released.

• Airline terminal handling fees – these are charged in order to compensate all costs associated with cargo handling at the origin and destination ports.

• Custom clearance fees – these are referred to charges paid to customs brokers in order to allow the entrance of the exported goods into the country of destination.

• Associated trucking fees – they are charged when cargo is picked up from the airport and transported to the next stop. These fees are charged in order to cover fuel costs and drivers' wages.

• Cargo insurance – typically arranged through a freight forwarder and covers all cargo being exported. Cargo insurance is highly recommended, since liability falls on the shipper, not on the carrier or forwarder.

4.2.3.1 – Ocean/sea freight

Ocean/sea freight transport is the shipping by sea or ocean via of goods inserted in shipping containers and it is currently the most common mode of transport that importers and exporters use [20]. Ocean and sea freight can be divided into the two following options: a full container load (FCL) and a less than container load (LCL). One important factor is the choice between FCL or an LCL. With LCL, several shipments are put into one container, which usually means more work for the forwarder. In the cases of LCL, there is more paperwork involved, as well as the physical work of consolidating various shipments into a container before the main transport and the shipments' de-consolidation at the destination port. The LCL shipments contain three main disadvantages:

- LCL takes more time to deliver than an FCL shipment, due to all the extra work involved.
- The risk of damaging, misplacing, and losing the goods is higher.
- The cost per cubic meter is higher.

Ocean freight quote is dependent on factors such as the form of cargo, the mode of transportation, the weight of the cargo, and the distance between the ports of departure and destination. Some of the costs of shipping sea freight are related to where the goods come from and where they go to. Freight costs are often broken down into three main categories: pre-carriage, carriage and post carriage. Pre-carriage costs include all those inherent to the inland movement (often close to the port) that are incurred before the container is loaded at the port of departure. The carriage costs refer to the ones incurred while moving the cargo between the port of loading and the port of discharge. Lastly, the post carriage costs refer to any inland movement that occur after the container is off-loaded [21].

4.3 – Incoterm

As it is known, there is no standard Incoterm that can be applied to all situations that involve international commerce. Instead, the exporting and importing entities must negotiate an Incoterm that satisfies both, thus meeting the requirements of each one.

Regarding the exporting side, sometimes the exporter wants to control and keep track of international shipping costs all the way to the destination port, since this way provides the exporter flexibility to implement cost-effective shipping options. However, when the exporter does not feel too familiar with the laws and trading regulations of the country of destination, it is better to transfer the responsibility for the goods to the importer at the terminal of destination. On the other hand, the greater the control one company has over the international trade, the greater the responsibility and the greater the risk for that same company. The same logic can be applied for the importer. When negotiating, both parties must reach an agreement that is beneficial for both and they must guarantee that all responsibilities are properly defined in order to avoid future problems.

In the context of this dissertation, DAT (Delivery at Terminal) was the chosen Incoterm so that the author can put into practice all the costs referred throughout the previous sections of the present chapter. This Incoterm is used when it is the seller's responsibility to fully deliver the goods at the port of destination [22,23]. The seller is accountable for all the expenses, risks and insurance incurred until the goods are unloaded at the port of destination. On the other hand, the buyer pays for customs clearance and taxes at destination. The seller is still responsible for any destination terminal handling charges [22,23].

5.Implementation and results

The main goal of the present chapter is to implement the methodology which was proposed in the previous chapter. The structure of this chapter is similar to the last chapter's, as it is also divided into two phases: the collection of by-products from the slaughterhouses and their storage; and the export of the collected by-products to China. The main objective of this chapter will be to finally implement a cost/benefit analysis on the methodology which was proposed by the author in the previous chapter, by using all the necessary data related with the value of the collected by-products, as well as with all the costs incurred in the processes of collecting, storing and exporting such products.

5.1 – The volume and value of the collected goods

After analyzing the quantities of by-products produced by all slaughterhouses, as well as the distances between all of them, three scenarios were created:

• **Scenario 1** – All slaughterhouses are considered, meaning that all by-products generated by all 50 slaughterhouses after three working days are collected by the trucks;

• **Scenario 2** – Only the slaughterhouse that is located the furthest from the depot is rejected. All the other 49 slaughterhouses are considered;

• **Scenario 3** – Only the slaughterhouses located in the Lisbon/Tagus Valley zone are considered. All slaughterhouses located in the central zone of Portugal are rejected.

Naturally, rejecting and including slaughterhouses in the VRP route have implications on the quantity of collected by-products that will later be exported and, therefore, on the revenues generated by the sale of such by-products in China. For the case of scenario 1, exactly **100 420** kilograms of pork by-products are being collected to later be sold in China, thus generating a revenue of **31 954 €**. For the case of scenario 2, **98 743** kilograms are being collected to later be sold at a total price of **31 420 €**. Finally, for the case of scenario 3, **81 910** kilograms are being collected, thus generating a future revenue of **26 066** €.

5.2 – The first phase: the collection and storage of by-products

The purpose of the present section is to explain how the model presented in section 4.1.1 was implemented in the software GAMS, as well as to present all the relevant results.

5.2.1 – Implementation of the model in GAMS

The mathematical model which was demonstrated in section 4.1.1 was implemented in the software GAMS. To do so, values had to be attributed to scalars, as well as to all the parameters. Table 2 demonstrates the value that was given to each scalar.

Table 2 - Value attributed to each model's scalar

Scalar	Symbol	Value
Capacity of each vehicle (Kgs)	Cap	32 000
Transportation cost (€/km)	d	1.15
Average speed of every truck (km/h)	v	80
Salary of each worker (€/hour)	H	5.54

Regarding the values that were given to all parameters, all of them, except for $time_{ij}$ (see section 4.1.1), were read and imported to GAMS from Excel. Basically, while all the information related with the distances between all slaughterhouses ($dist_{ij}$), the tolls that must be paid in order to move from one slaughterhouse to another (T_{ij}), as well as the quantity of by-products generated by each slaughterhouse (c_i), were presented in Excel files through tables, a function that is able to read and import all that information was implemented in GAMS so that the program could run the model using the appropriate values. All vehicles were available started their routes at the depot, which is the ETSA's meat by-products collection point located in Lisbon (observe figure 2).

5.2.1.1 – Scenario 1

The results came out after running the model in GAMS for 14 400 seconds (equivalent to 4 hours). Five trucks were used. Each truck had 1 worker, if the route took less than 8 hours from and two otherwise. In that sense, it was considered that, when needed, in each vehicle there were two workers so that they could both drive and help each other in carrying the collected by-products from the slaughterhouse to the truck. Given that all trucks leave at the same time, the duration of the entire collection process corresponds to the duration of the truck which took the longest time to complete its route. Therefore, in this case, the duration of the collection process as a whole is 15 hours and 20 minutes. The result of the model's objective function, whose main goal was to minimize the total cost of the entire collection process, was **3 182 €**.

5.2.1.2 – Scenario 2

Just like in the previous scenario, the results came out after running the model in GAMS for 14 400 seconds (equivalent to 4 hours). Four trucks were used. Once again, each truck had 1 worker if the route took less than 8 hours and, otherwise, two workers. By the same logic as the one used in the previous scenario, given that all trucks leave at the same time, the duration of the entire collection process is 15 hours and 30 minutes. The result of the model's objective function, whose main goal was to minimize the total cost of the entire collection process, was **2 913 €**. By analyzing the resulting cost and duration, one can understand that, timewise, the duration of scenario 1 is slightly lower than the duration of scenario 2, by a margin of 10 minutes. Cost wise, the present scenario is better than scenario 1 by a margin of 269 €.

5.2.1.3 – Scenario 3

The main goal of this third scenario is to provide an alternative for a case of an urgency, that is, a case in which, for some reason, the exporter was not able to collect the planned quantity of by-products (weather it was because of the collector, who was not able to start the collection process earlier and must ship the goods on a previously agreed date, or because some slaughterhouses were not able to provide the pre-agreed quantity of by-products). In this scenario, all slaughterhouses located outside the Lisbon/ Tagus Valley zone are rejected so that the collection duration can be lower than 8 hours. This process will, not only be shorter in terms of duration, but it will also be much cheaper, because, in this case, there is only one worker driving the truck. Just like in the previous scenarios, the program run in GAMS for 14 400 seconds (equivalent to 4 hours). Only three trucks were needed. By the same logic as the one used in the previous scenario, given that all trucks leave at the same time, the duration of the entire collection process is 8 h. The result of the model's objective function, whose main goal was to minimize the total cost of the entire collection process, was **879 €**. By analyzing the resulting duration, one can understand that the duration of scenario 3 is much lower than the duration of the two previous scenarios, by a margin of 7 hours and 20 minutes when comparing to scenario 1. Cost wise, the present scenario is also much cheaper than the previous two scenarios, by a margin of 2 034 € when compared to scenario 2.

5.2.2 – Warehousing costs and transportation of the collected goods to the port or airport of departure

In order to obtain an estimate regarding the cost of storing the collected pork by-products, the author contacted Greenyard, a company which was described in section 2.3.2. This company is well known for their expertise when it comes to storing frozen goods. When contacting Greenyard, the author was told that the main costs vary according to the number of pallets being handled and stored. Knowing that each pallet can carry between 600 and 750 Kgs of frozen meat products, the author decided to use the average of the two weights: 675 Kgs. By observing the quantities generated in each scenario in section 5.1 and by dividing such quantities by the capacity of a pallet, the number of used pallets were calculated. For scenario 1, 149 pallets were needed, for scenario 2, 147 were used and 122 pallets were necessary for scenario 3. There are three costs to consider when storing pallets of frozen goods: the pallet's entrance cost (3.5 € per pallet), the storage cost (0,55€ per pallet, per day) and the pallet's leaving cost (3.5 € per pallet). Then, two scenarios were created. These scenarios are based on how long the goods are stored in the warehouse. In the **optimist case scenario,** the goods are stored for two days, whereas in the **pessimist case scenario** the goods are stored for seven days. With all that in mind, the warehousing costs for the three scenarios are the following ones: for **scenario 1,** the cost is **1 207 €** in the optimistic case scenario and **1 617 €** in the case of the pessimist case scenario; for **scenario 2**, the cost is **1 191 €** in the optimist case scenario and **1 595 €** for the pessimist case scenario; for **scenario 3**, the cost is **988 €** in the optimist case scenario and **1 324 €** in the pessimist case scenario.

Then, regarding the transportation costs from the depot to the port or airport of departure, these depend on the following factors: the number of vehicles transporting the goods; the number of workers driving the trucks; the distance between the depot and the airport or port of departure and the existence of tolls to be paid. The calculation that must be made in order to calculate this cost is the following one:

$$Cost\ of\ moving\ the\ goods\ to\ the\ (air)port = number\ of\ trucks * (d * distance + H * time) + T$$

Regarding the number of trucks being driven for scenario 1 and 2, in order to be the most efficient as possible, four trucks must be used (three FTL, with a load of 32 tons, and one LTL, with a load of 4 420 Kgs). Then, the scalars d and H can be directly obtained from table 2. Finally, the distance and time parameters can be easily obtained through Google Maps.

In this case, because the distance between the depot and the Lisbon airport is 11.3 Km, the duration is approximately 0.27 hours (equivalent to 16 minutes) and no tolls must be paid, the cost of moving the products is **58 €.** For the case of the Lisbon port, because the distance is 19.7 Km, the duration is approximately 0.42 hours (equivalent to 25 minutes) and no tolls must be paid, the cost of moving the products from the depot to the port of Lisbon is **100 €.**

For scenario 3, the cost of moving the goods from the depot to the port or airport of departure is lower, because, for the quantity of by-products generated in this scenario, only three vehicles are needed: 2 FTL with a capacity of 32 tons and a LTL, with a load of 17 910 Kilograms. Therefore, the cost of moving the products from the depot to the Lisbon airport is **43 €** and the cost of moving the products from the depot to the port of Lisbon is **75 €.**

5.3 – The second phase: the export of by-products

This section aims to demonstrated involved in the transportation of the collected by-products from Lisbon (Portugal) to Qingdao (China). As it was stated in section 4.2, two means of transportation are being considered: air freight and ocean/sea freight. The costs of air freight are presented in section 5.3.1 and the costs of ocean/sea freight are presented in section 5.3.2. For both cases, all the costs incurred in the process of transportation are presented.

5.3.1 – Air freight

By analysing reference [24], which presents the Boeing 747-400F's cargo structure, it was possible to find the load capacity of the plane, which is 112 900 Kgs, meaning that it was possible to move all the goods in just one flight. It is also known that there is space for 23 (244 x 317,5 x 300) cm pallets. Each pallet supports a M1-H reefer container. Each of these containers can support 6 800 Kgs of cargo and has 21,2 m^3 of intern cubic capacity. Regarding scenario 1, it is possible to distribute the 100 420 Kgs of goods for 14 full pallets and a semi-full pallet, giving a total of 15 utilized pallets. Regarding scenario 2, it is possible to distribute the 98 743 Kgs of goods for 14 full pallets and a semi-full pallet, too, thus being necessary a total of 15 utilized pallets. Finally, regarding scenario 3, it is possible to distribute the 81 910 Kgs of goods for exactly 12 full pallets. With that in mind, all the costs of moving all the goods from the Lisbon airport to the Qingdao airport were found and calculated. The air freight costs are **245 131 €**, **251 869 €** and **209 089 €**, for scenarios 1,2 and 3, respectively.

Just by observing the total cost of all presented scenarios, it is clear that this mode of transportation is too expensive, considering the total price for which the goods are being sold for. The base rate is the most expensive cost, accounting for approximately 78.41% of the total cost of transportation for the case of scenario 1, for instance. It is fair to say that this mean of transportation is so expensive because there are many charges which vary according to the weight being handled. In that sense, because many tons of goods are being exported, those charges turn out to be quite expensive.

5.3.2 – Ocean/sea freight

As it was done with air freight, the first task that must be completed is to set out the conditions under which the goods are being exported. In the case of ocean/sea freight, it was decided that the goods would be exported in 40 feet reefer containers. Each of these containers has a payload capacity of 27700 Kgs and a cubic capacity of 59.3 m3 [25]. For scenarios 1 and 2, the quantity of frozen meat products being transported, four 40 feet reefer containers are needed. However, for scenario 3, only three 40 feet reefer containers are needed. In addition, knowing that the distance between the Lisbon port and the Qingdao port is approximately 9689 nautical miles, via the Suez Canal. With that in mind, all the costs of moving all the goods from the port of Lisbon to the port of Qingdao were searched and calculated.

Two scenarios related to the magnitude of ocean/sea freight costs being studied: a **base case scenario** and a **worst-case scenario**. This distinction in scenarios was made so that the reader can understand how greatly the total cost can vary according to seasonality, thus showing how much fuel price fluctuations and variations in demand can increase the cost of ocean/sea freight. The resulting ocean/sea freight costs were the following ones: **17 678 €** in the base case scenario and **58 040 €** in the worst-case scenario, for scenario 1; **17 677 €** in the base case scenario and **57 403 €** in the worst-case scenario, for scenario 2 and; **13 540 €** in the base case scenario and **46 341 €** in the worst-case scenario, for scenario 3. As one can understand from these results, for the base case and for the worst-case scenarios, the final costs of transporting ocean/sea freight are very similar in scenarios 1 and 2, as there are very few costs that vary according to weight or value. Because in scenarios 1 and 2, the same number of containers is needed, the total cost of ocean/sea freight do not vary much. However, when comparing scenario 3 with the other two scenarios, the cost of ocean/sea freight drops to 13 540 € in the case of the base case scenario and to 46 341 € in the case of the worst-case scenario. This bigger variation in cost is mostly due to the fact that in the latter scenario, only three containers are used.

5.4– Cost/benefit analysis

The goal of this section is to balance all the costs discussed throughout this entire chapter with the revenues generated by the sale of the exported by-products (mentioned in section 5.1). By balancing such values, the profits generated in each possible scenario can be obtained.

As it was expected, the cost of moving the goods under study by plane are too high when compared to their value, that is, to their generated revenues. The air freight costs, alone, are already much higher than the expected generated revenues. To go even further, the air freight base rate, knowing that it is 2 € per kilogram and that in all three scenarios, over 80 tons are being transported, reaches the 160 000 € mark, at least. Knowing that the generated revenues, in the case of the three studied scenarios, go as far as 31 954 €, it can be easily concluded that the costs of air freight are much higher than the expected revenues. As a result, the generated profits are negative for all the scenarios which were studied in the context of the present dissertation.

Nevertheless, table 3 exhibits the profit demonstration for the case of ocean/sea freight. At the top of the table, the two scenarios related to the warehousing costs are presented. Then, in the row below, the three scenarios presented in the first section of the present chapter are presented as well. Finally, on the left side of the table, the two scenarios presented in section 5.3.2, the one where all the ocean/sea freight costs are demonstrated, are presented. This way, the profits resulting from all scenarios can be properly exposed and compared.

Unexpectedly, scenario 3 proved to be more profitable than the other two scenarios, for all scenarios related to warehousing costs and sea freight costs. There is a plausible explanation for that. Although the increase regarding the quantity of exported by-products results in an increase in expected revenues, such revenue increase is not high enough to offset the resulting increase in costs, due to the added trucks (for the collection process) and to the added 40 feet reefer container (in the exporting process). Thus, it is more profitable to export three almost full containers than to export four (three full containers and a less-than-full container).

Table 3 – Profit demonstration for the case of ocean/sea freight

		Optimist case scenario	Pessimist case scenario	Optimist case scenario	Pessimist case scenario	Optimist case scenario	Pessimist case scenario
		Scenario 1		**Scenario 2**		**Scenario 3**	
Both scenarios	**Revenue**	**31 954**		**31 420**		**26 066**	
	Collection cost	3 182		2 913		879	
	Warehousing costs	1 207	1 617	1 191	1 595	988	1 324
	Moving the goods to the port of Lisbon	100		100		75	
	Subtotal – Domestic costs	**4 489**	**4 898**	**4 204**	**4 608**	**1 943**	**2 278**
Base case Scenario	Ocean/sea freight costs	17 678		17 677		13 540	
	Total costs	**22 167**	**22 577**	**21 880**	**22 285**	**15 483**	**15 819**
	Profit	**9 788**	**9 378**	**9 539**	**9 135**	**10 583**	**10 247**
Worst case scenario	Ocean/sea freight costs	58 040		57 403		46 341	
	Total costs	**62 528**	**62 938**	**61 607**	**62 011**	**48 284**	**48 619**
	Profit	**-30 574**	**-30 984**	**-30 187**	**-30 592**	**-22 218**	**-22 554**

Additionally, it is proved that it is better to exclusively move full containers than to move a less-than-full container because most of the costs depend on the number of containers being moved and not on the actual weight being moved. In addition, it is known that, for scenarios 1 and 2, the same number of containers are needed (four) to transport the required quantity of by-products. That results in very little variation between the ocean/sea freight costs of those two scenarios, although there is a difference of 1 678 Kgs in weight being moved between scenarios 1 and 2. On the other hand, the generated revenues directly vary with the quantity of goods being traded, thus being the variance in revenues much higher than the variance in ocean/sea freight costs. This results in a lower profit for scenarios 2 when compared to scenario 1. This may lead one to conclude that the fuller the containers being transported, the higher the final profit, if only the ocean/sea freight costs are being considered, since revenues grow more according to the weight being transported than ocean/sea freight costs.

Unlike the case of air freight, there are some scenarios that generate positive profits. All profits resulting from the base case scenario are positive, regardless of any scenarios related with warehousing costs or quantity being transported. Naturally, the highest profit corresponds to the base case scenario combined with the good case scenario. In the case of scenario 3 (the one that resulted in the highest profit), the profit is **10 583 €.** This result shows that exporting by-products by ocean and sea might be a viable option, financially. On the other hand, the worst-case scenario demonstrates how profits can drop if the exporting procedure is not properly planned or if unpredictable events which increase the shipping costs occur, thus generating negative profits. For the worst-case scenario, all profits are negative, regardless of any scenario related to warehousing costs or volume being exported. Naturally, this is because of the big difference between the ocean/sea freight costs in the base case scenario and in the worst-case scenario.

6. Conclusions

The main motivation for this dissertation was to highlight the need for reducing meat waste, or, at least, reducing the meat quantity that goes to improper destinations. Because pig meat proved to be the most wasted meat; it was decided that pig meat would become the focus of this work. The main objective throughout the entire work was, therefore, to search for opportunities to reduce the quantity of pig meat and add value to pig meat would otherwise be unsold. Although the presented methodology did not provide any new technologic nor scientific innovation insights towards the utilization of wasted meat products, it presented a new market opportunity for pig meat by-products. More specifically, the goal of the present dissertation was to explore the possibility of exporting pork by-products to China, a country where such by-products are surely valued, thus not being wasted. China was chosen to be the importing country for the context of this dissertation because of all the features of the Chinese variety meats' market that makes it such a promising opportunity for all the stakeholders involved.

The main conclusion to take regarding the results of the methodology imposed by the author is that, under certain external scenarios which cannot be controlled, exporting pig meat by products from Lisbon (Portugal) to Qingdao (China) by ship can be a financially viable option. Considering the scenarios presented throughout the entire chapter, the highest profit one can get is 10 583 €. However, as it can be again observed it table 3, under certain circumstances, ocean/sea freight costs can increase up to a point where it is not profitable to export the same goods by ship anymore. Then, air freight turned out to be the least financially viable option for exporting meat by-products from Portugal to China, although it is the fastest mean of transportation.

The main point is that, as the author initially suspected, the idea of exporting pig meat by-products from Portugal to China is a promising opportunity to all stakeholders involved. The work presented so far may be seen as an estimate of how the exporting process might proceed and, although a deeper and more accurate analysis is needed, it is still a good starting point, as it provides the main insights regarding the conditions and costs involved.

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