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The Circular Economy and Food Waste - The Pedagogical Case Study of Jerónimo Martins

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Master in International Management

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Professor Inês Vieira Godinho Medeiro Patrão, Guest Professor, ISCTE Business School.

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BUSINESS SCHOOL

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Resumo

A economia circular oferece uma alternativa sustentável à economia linear, reduzindo o uso de materiais e prolongando a vida útil de matérias-primas nos ciclos de produção. Essa transição apresenta numerosas vantagens, incluindo custos mais baixos para gestão de resíduos e aquisição de materiais, aumento da fidelização de clientes, criação de empregos e potencial para abordar as alterações climáticas e a perda de biodiversidade. Além disso, promove o crescimento económico e a resiliência.

Este Estudo de Caso Pedagógico oferece uma análise aprofundada dos princípios e obstáculos associados à adoção da economia circular. A relação entre a economia circular e o desperdício de alimentos é abordada, com ênfase particular nos esforços da Jerónimo Martins em encarar essa questão. Além disso, investiga a estratégia de aquacultura da Jerónimo Martins, analisando as suas vantagens e benefícios. O estudo também explora o conceito de valorização dos subprodutos de peixe e o seu potencial de implementação na estratégia de aquacultura da Jerónimo Martins. Por fim, é examinado e considerado o potencial impacto do modelo de Aquacultura Integrada Multi-Trófica na estratégia de aquacultura da Jerónimo Martins.

Palavras-chave: Economia Circular, Jerónimo Martins, Desperdício Alimentar, Subproduto de Peixe.

Sistema de classificação JEL:

• Q01 – Desenvolvimento Sustentável

• Q56 – Meio Ambiente e Desenvolvimento; Sustentabilidade

Abstract

The circular economy offers a sustainable alternative to the linear economy by reducing material use and extending the lifespan of raw materials in production cycles. This transition presents numerous advantages, including lower costs for waste management and materials procurement, improved customer loyalty, job creation, and the potential to address climate change and biodiversity loss. Additionally, it promotes economic growth and resilience.

This Pedagogical Case Study provides an in-depth analysis of the principles and obstacles associated with the adoption of the circular economy. It focuses on the relationship between the circular economy and food waste, with a particular emphasis on *Jerónimo Martins'* efforts in addressing this issue. Furthermore, it investigates *Jerónimo Martins'* Seaculture strategy, analysing the advantages and benefits offered by this approach. The study also explores the concept of valorization of fish by-products and its potential implementation within *Jerónimo Martins'* Seaculture strategy. Lastly, the potential impact of the Integrated Multi-Trophic Aquaculture Model on *Jerónimo Martins'* Seaculture strategy is examined and considered.

Key words: Circular Economy, *Jerónimo Martins*, Food Waste, Fish by-product.

JEL Classification System:

• Q01 - Sustainable Development

• Q56 - Environment and Development; Sustainability

Index

Table of Illustrations

Introduction

The Industrial Revolution sparked a linear economy characterized by waste and pollution. However, with population growth and increased resource demand, environmental challenges have emerged. By 2030, the global demand for food, water, and energy is projected to rise significantly (Lieder et al., 2016). Unfortunately, our consumption patterns surpass the generation of resources, resulting in alarming levels of waste. In fact, cities worldwide produce a staggering 1.3 billion tonnes of waste each year, incurring substantial costs (Lacy, 2020). Moreover, resource consumption is predicted to double by 2050, with a significant portion being wasted before products even leave manufacturing plants (Ibn-Mohammed et al., 2021). The consequences of such unsustainable practices include water scarcity, plastic pollution, and the loss of vital habitats (World Health Organization, 2023).

To address these pressing issues, governments have begun implementing waste reduction programs (Korhonen et al., 2018). One promising approach is the concept of Circular Economy (hereinafter referred to as CE), which aims to restore resources, minimize waste, and promote the use of renewable energy (Merli et al., 2018). The significance of CE is underscored by its endorsement by countries like China and the European Union (Lieder et al., 2016). Businesses are also embracing the principles of CE by adopting renewable energy sources and incorporating recycled materials into their operations (Lacy, 2020).

Among the critical areas that require attention is the reduction of food waste (Lacy, 2020). This necessitates the adoption of CE approaches throughout the food supply chain. By embracing the principles of CE, we can move towards a more sustainable and efficient use of resources, ensuring their longevity and reducing waste generation (Lieder et al., 2016).

The agricultural sector is responsible for 80% of global biodiversity loss and contributes to one-third of greenhouse gas emissions, while one-third of all food produced for human consumption is lost or wasted (Pannila et al., 2022; Tamasiga et al., 2022). In order to tackle these challenges and establish a more sustainable food system, the food industry must undergo a transition from a linear economy to a CE (Sadhukhan et al., 2020). By implementing CE models, such as the reuse of food, utilization of by-products and food waste, and promotion of nutrient recycling, economic benefits can be achieved alongside waste reduction (Alexandra et al., 2016). Various initiatives have been introduced to address food loss, ensure food safety and traceability, improve product quality, and tackle environmental concerns. Particularly in developing countries, where hunger affects nearly 0.8 billion people, reducing food waste becomes crucial. Through addressing food waste and embracing CE principles, we can work towards a more sustainable and efficient food sector, mitigating environmental impacts and fostering greater resilience for the future (Zhang et al., 2022).

The Food and Agriculture Organization (FAO) recognizes the unsustainability and inefficiency of current production processes and nutritional models, particularly within the fish industry, where a substantial amount of fish obtained from the sea goes to waste (FAO, 2023).

To tackle this challenge, aquaculture emerges as a promising solution. Aquaculture involves the utilization of processed fish waste as feed, addressing the issue of wastage and improving resource efficiency (Johannessen, 2022). Embracing a CE approach within the fish industry becomes crucial to ensure sustainability, where all by-products are utilized effectively (FAO, 2023). However, with the projected growth in fish demand, sustainable management of aquatic resources becomes critical to ensure long-term food security. Additionally, as seafood demand rises, reducing food loss and waste becomes increasingly important to optimize resource utilization (Helyar et al., 2014).

Aquaculture, the farming of aquatic organisms, including fish, molluscs, crabs, and aquatic plants, has experienced substantial growth in recent decades. It now assumes a crucial position in meeting the world's need for animal protein. The success of the aquaculture industry is directly related to the adoption of sustainable approaches, emphasizing the importance of responsible practices and resource management. Assuring future global seafood access hinges on the industry's ability to embrace sustainability principles and minimize environmental impacts (Stevens et al., 2018; Fraga-Corral et al., 2022).

The Pedagogical Case Study under consideration aims to achieve five objectives:

- Objective 1: Principles and obstacles to adopting the CE.

The first objective of the Pedagogical Case Study is to examine the principles and obstacles associated with adopting the CE. The CE is an economic model that aims to minimize waste and promote the efficient use of resources. It involves principles such as resource recycling, sustainable production, and closing the loop of material flows. The study will explore the challenges and barriers that organizations face when transitioning to a circular economy model, including regulatory constraints, technological limitations, and resistance to change.

- Objective 2: Relationship between CE and food waste and *Jerónimo Martins'* approach.

The second objective is to investigate the relationship between the circular economy and food waste, specifically focusing on how *Jerónimo Martins* (hereinafter referred to as *JM*) addresses this issue.

- Objective 3: *JM* ' Seaculture strategy and its advantages.

The third objective is to analyse *JM* ' Seaculture strategy and explore the advantages it offers.

- Objective 4: Valorization of fish by-products and its potential implementation in *JM* ' Seaculture Strategy

The fourth objective is to define how fish by-products can be valorised and explore the benefits of implementing fish by-products valorization in JM's Seaculture strategy.

- Objective 5: Integrated Multi-Trophic Aquaculture Model and its potential benefits for *JM* ' Seaculture Strategy

The fifth objective is to introduce the Integrated Multi-Trophic Aquaculture (hereinafter referred to as IMTA) Model and assess its potential benefits for *JM* ' Seaculture strategy.

This pedagogical case study is divided into three main chapters, namely the case study, methodology and pedagogical note. These chapters have been carefully arranged to provide a thorough examination of the research topic. The case study chapter delves deep into the specific case under investigation, employing relevant literature, empirical data, and key concepts. It aims to offer a comprehensive understanding of the case and its implications. In the methodology chapter, the research design, data collection methods, and data analysis techniques are outlined. This chapter emphasizes the transparency of the researcher and ensures the credibility and dependability of the study. The pedagogical note chapter explores the practical implications of the research findings, specifically in educational or instructional settings. It discusses how the insights and knowledge gained from the study can be applied to enhance teaching and learning practices. Finally, the conclusion provides a summary of the main findings and their implications. It reflects on the significance of the study, acknowledges any limitations, and suggests potential avenues for future research.

1. Chapter Case Study

1.1 Problem Identification

The Industrial Revolution resulted in a throwaway mentality and linear consumption behaviour causing severe environmental pollution and waste creation. With a projected increase in population growth and middle-class expansion, demand for resources is expected to rise but limited resources cannot meet economic expansion. The global demand for food, water, and energy is estimated to rise by 35%, 40%, and 50% respectively by 2030, posing urgent environmental and resource scarcity problems (Lieder et al., 2016). Lacy (2020) states that we consume 75% more natural resources than we generate each year, with cities globally producing 1.3 billion tonnes of solid waste per year at a cost of $205.4 billion. Ibn-Mohammed et al. (2021) estimates that global resource consumption will double by 2050, with 90% of raw materials creating waste before the finished product leaves the manufacturing plant and 80% of manufactured items discarded in the first six months. By 2025, 785 million people may lack access to safe drinking water, and plastic pollution in the ocean will surpass fish by 2050, warns the World Health Organization. Seven million people die each year due to air pollution, and human activity has caused the loss of 60% of the world's wildlife, 20% of coral reefs, and 13 million hectares of forest since 1970. The 2018 Intergovernmental Panel on Climate Change (IPCC) report states that global warming will result in a $54 trillion economic impact by 2100, with temperatures rising by 1.5°C between 2030 and 2052 (Lacy, 2020).

Governments worldwide are implementing waste reduction and recycling programs due to the unsustainability of the prevailing extract-produce-use-dump economic model (Korhonen et al., 2018). The Chinese government officially acknowledged the concept of CE as a new development strategy in 2002 and passed the first law, the “People’s Republic of China Circular Economy Promotion Law”, which went into effect in January 2009. The European Union (EU) has underlined the CE economic potential, stressing benefits for the industrial sector such as lower material prices and wider profit pools, and has published communications advocating for a CE that maximizes the use of products, materials, and resources while minimizing waste generation (Lieder et al., 2016). CE is an industrial system that aims for restoration and regeneration, shifting towards renewable energy use and eliminating toxic chemicals, to eliminate waste through superior design of materials, products, systems, and business models (Merli et al., 2018). Many powerful corporations have pledged to use only renewable energy, and businesses are adapting to government legislation and consumer behaviour with goals such as using more recycled materials and creating zero waste.

The present century encounters diverse interdependent challenges, including population growth, resource consumption, waste output, and social inequality, which could result in an unsustainable future if left unattended. To encourage resource-efficient Food Supply Chain (hereinafter referred to as FSC) and decrease waste, the food industry must shift to a CE. Food waste holds substantial environmental, economic, and social ramifications, thus requiring the food sector to reduce it, especially in developing countries (Lacy, 2020).

1.2 Circular Economy and the food sector

The 21st century faces several interconnected challenges, including population growth, resource consumption, waste output, and social inequality that could lead to an unsustainable future if left unaddressed (Sadhukhan et al., 2020). The global population is projected to reach nine billion by 2050, resulting in a 70% increase in food demand and a significant environmental strain (Pannila et al., 2022). Agricultural land development and food production are responsible for an 80% loss of global biodiversity and one-third of global greenhouse gas emissions, with over one-third of all food produced for human consumption being lost or wasted (Pannila et al., 2022; Tamasiga et al., 2022). To reduce waste and create resource-efficient FSC, the food industry must transition from its linear economy to a CE (Sadhukhan et al., 2020). Implementing CE models can benefit businesses economically while reducing waste by reusing food, using by-products and food waste, nutrient recycling, and promoting efficient food patterns (Alexandra et al., 2016). Initiatives have been implemented to address food loss, food safety, production traceability, product quality, and environmental degradation (Zhang et al., 2022). Implementing CE models can promote trust, confidentiality, openness, equality, and cooperation on all geographical scales, mitigating climate change and finite resources (Sadhukhan et al., 2020; Teigiserova et al., 2020).

Rising concerns over food waste have emerged due to its significant environmental, economic, and social implications, including the use of substantial natural resources like agricultural water and farmland and contribution to global greenhouse gas emissions (Teigiserova et al., 2020). Though food waste can occur throughout the FSC, it is prevalent during consumption (56%) and food processing (around 38%) (Cristobal et al., 2018). Nevertheless, food waste generated during the food manufacturing phase has a high level of compositional uniformity and can be used to extract high-value goods. Reducing food waste is critical to achieving food sector sustainability, particularly in developing nations, where chronic hunger affects nearly 0.8 billion individuals (Zhang et al., 2022).

1.3 The Global Fisheries and Aquaculture Scenario

The world's population is growing exponentially, and by 2050, it is projected to reach 10 billion, leading to significant challenges in meeting the global food demand sustainably (Fraga-Corral et al., 2022). The FAO[1] (2023) acknowledges that current production processes and nutritional models are unsustainable and inefficient, particularly in the fish industry, where a significant amount of fish obtained from the sea is wasted. To address this challenge, aquaculture, which utilizes processed fish waste as feed, is seen as a promising solution (Johannessen, 2022). Adopting a CE approach to the fish industry, where all by-products are utilized, is necessary to ensure sustainability. The global fishery and aquaculture sector has seen significant growth, with an estimated output of over 200 million tonnes by 2030 (FAO, 2023). Fish consumption has increased dramatically in recent years and is recognized as an important component of a balanced diet and a healthy lifestyle (Coppola et al., 2021). Fish accounts for around 17% of total animal protein intake worldwide, and per capita consumption is estimated at more than 20 kg. The fish and fish products industry employs about 200 million people globally, with women accounting for a significant proportion of those employed in processing operations in poor nations (FAO, 2023). However, given the forecasted growth in demand for fish, sustainable management of aquatic resources is critical in providing food security. Decreasing food loss and waste is becoming increasingly important as demand for seafood grows. Overall, the challenge of meeting the global food demand sustainably requires a CE approach to the fish industry and the adoption of sustainable management practices to ensure food security for the growing world population (Helyar et al., 2014).

Small-scale and artisanal fishing, conducted by both men and women, contribute to half of the world's fish catch and two-thirds of the catch for human consumption. They provide food and income for local and national economies, yet often lack visibility and support from policymakers, despite their significant role in supporting river-side communities (FAO, 2023). Large-scale fishing impacts food security and sustainable resource use, covering the entire fishing value chain and supplying food to local, national, and international markets. Run by established businesses with access to advanced technology and infrastructure, the sector

[1] Food and Agriculture Organization of the United Nations

includes various types of fishing vessels and employs both men and women, mainly in processing activities (FAO, 2023).

Aquaculture is the farming of aquatic organisms such as fish, molluscs, crabs, and aquatic plants. Individuals or companies own the species being produced, and the process includes deliberate activities to increase productivity such as stocking, feeding, and predator protection (FAO, 2023). Aquaculture has grown considerably in recent decades (see Table 2.1), and it is now crucial to providing the world's need for animal protein (Fraga-Corral et al., 2022). This is an important industry for assuring future global seafood access and it is becoming increasingly obvious that the adoption of more sustainable approaches is directly related to the success of aquaculture output (Stevens et al., 2018).

Table 1.1 The yearly increase in aquaculture output across various geographic locations

	Thousands of tonnes (%)					
Regions/ countries	1995	2000	2005	2010	2015	2018
Europe	1581 (6.5%)	2053 (6.3%)	2137 (4.8%)	2527 (4.4%)	2949 (4.0%)	3083 (1.6%)
Norway	278 (1.1%)	491 (1.5%)	662 (1.5%)	1020 (1.8%)	1381 (1.9%)	1355 (1.6%)
Spain[a]	224 (0.9%)	309 (1.0%)	219 (0.5%)	252 (0.4%)	290 (0.4%)	348 (0.4%)
Galicia	n.a.	n.a.	221[b] (0.5%)	223 (0.4%)	275 (0.4%)	290 (0.4%)
Asia	21677 (89%)	28421 (88%)	39186 (88%)	51229 (89%)	64592 (89%)	72812 (89%)
China	15856 (65%)	21522 (66%)	28121 (63%)	35513 (61%)	43748 (60%)	47559 (58%)
India	1659 (6.8%)	1942 (6.0%)	2967 (6.7)	3786 (6.6%)	5260 (7.2%)	7066 (8.6%)
Indonesia	6411 (2.6%)	788 (2.4%)	1197 (2.7%)	2305 (4.0%)	4342 (6.0)	5427 (6.6%)
Viet Nam	381 (1.6%)	498 (1.5%)	1437 (3.2%)	2683 (4.6%)	3462 (4.8%)	4134 (5.0%)
Bangladesh	317 (1.3%)	657 (2.0%)	882 (2.0%)	1308 (2.3%)	2060 (2.8%)	2405 (2.9%)
Africa	110 (0.4%)	400 (1.2%)	646 (1.5%)	1286 (2.2%)	1777 (2.4%)	2196 (2.7%)
Egypt	718 (0.3%)	340 (1.0%)	540 (1.2%)	920 (1.6%)	1178 (1.6%)	1561 (1.9%)
America	920 (3.8%)	1423 (4.4%)	2177 (4.9%)	2515 (4.3%)	3275 (4.5%)	3799 (4.6%)
Chile	157 (0.6%)	392 (1.2%)	724 (1.6%)	701 (1.2%)	1046 (1.4%)	1266 (1.5%)
Total	24382	32418	44298	57744	72771	82095

N.a.: not available data.
[a] Including Galicia data.
[b] Data from 2007.

Source: Fraga-Corral et al. (2022)

JM, a portuguese food distribution company, has incorporated CE principles into its business practices and has adopted a seaculture strategy based on these principles to tackle food waste.

1.4 The Organization

1.4.1 *Jerónimo Martins* Group Presentation

JM Group is an international organization headquartered in Portugal founded in 1792, by a young Galician man named *Jerónimo Martins*. With over 230 years of experience, the company specializes in food distribution and is a leader in Poland through its Biedronka chain and in Portugal through its *Pingo Doce* supermarkets and *Recheio* Cash & Carry outlets. *JM* also operates in Colombia through its Ara neighborhood stores. The company operates specialized retail chains such as Hebe in Poland, which focusses in health and beauty, as well as *Jerónimo* coffee shops and Hussel chocolates in Portugal.[2]

In addition, the company has created *JM Agro-Alimentar* in 2014 to support its food distribution operations in Portugal. The primary aim of this business area is to ensure the sustainable supply of strategic products, thereby guaranteeing food safety and availability. *JM Agro-Alimentar* operates in three business areas, including dairy products (*Terra Alegre*), Angus beef production and fattening (Best Farmer), and aquaculture (Seaculture), and it cooperates with the group's retail companies to develop its businesses.[3]

As of December 31, 2021, *JM* had sales of €20,889 million, employed 123,458 individuals, generated an EBITDA of €1,585 million, recorded a net profit of €463 million, and maintained a total of 4,908 stores.[4]

The *JM* Group achieved an "A" score in the Carbon Disclosure Project’s climate programmes[5] and maintained an "A-" score for three consecutive years for commodities related

[2] *Jerónimo Martins*. 2022. *Jerónimo Martins* Corporate Presentation. https://www.jeronimomartins.com/wp-content/uploads/01-DOCUMENTS/Corporate-Presentations/JM_Corporate-presentation_MAR2022.pdf

[3] *Jerónimo Martins*. 2023. About Us. Agribusiness. https://www.jeronimomartins.com/en/about-us/what-we-do/agribusiness/

[4] *Jerónimo Martins*. 2022. Jerónimo Martins Corporate Presentation. https://www.jeronimomartins.com/wp-content/uploads/01-DOCUMENTS/Corporate-Presentations/JM_Corporate-presentation_MAR2022.pdf

[5] The Carbon Disclosure Project. 2023. About us. https://www.cdp.net/en/info/about-us The Carbon Disclosure Project. 2023. What we do. https://www.cdp.net/en/info/about-us/what-we-do The Carbon Disclosure Project (CDP) is a non-profit organisation that oversees the global environmental

to deforestation, including palm oil, soy, and beef. The *JM* Group earned a "B" score for paper and timber. In addition, the group was among the first to sign the EU Code of Conduct on Responsible Business and Business Practices, and 80% of food purchases made by the group's companies are sourced locally. A molecular microbiology laboratory was established to ensure food safety and analyse Private Brand and fresh food products in Portugal, Poland, and Colombia.[6]

1.4.2 Food Waste Problem: Identification and its relevance to the company

The *JM* Group believes that it has an increased responsibility in combating food waste through improving its processes, promoting responsible primary production, and partnering with suppliers, employees, and charitable institutions. By involving and cooperating with all stakeholders in the value chain, the group has been working for several years to reduce food waste in its supply chains while simultaneously meeting the goals of the United Nations, such as fighting hunger and inequality, promoting food safety and nutrition, and positive synergies with the natural capital we depend on: respecting and efficiently managing terrestrial and marine biodiversity and combating climate change. In line with Sustainable Development Goal 12.3 on Responsible Consumption and Production, *JM* has committed to reducing its food waste associated with its activities by half by 2030.[7]

JM is the first food retail chain in Portugal to receive the *Produção Sustentável Consumo Responsável*[8] *seal from the Comissão Nacional de Combate ao Desperdício Alimentar*[9] *(CNCDA).* This recognition was the result of a set of good practices that were implemented, with the aim of fulfilling their commitment to reduce food waste by half by 2030.[10] *JM* was

disclosure system used by investors, corporations, cities, states, and regions to manage their environmental impacts. Every year, CDP assists a large number of businesses, cities, states, and regions in assessing and managing their risks and opportunities related to climate change, water security, and deforestation.

[6] *Jerónimo Martins*. 2023. Investidor. Apresentações e Relatórios. https://www.jeronimomartins.com/wp-content/uploads/01-DOCUMENTS/Investor/Results-Presentations/2021FYResults_Presentation.pdf

[7] Biblioteca Casos de Estudo BCSD Portugal. 2020. Casos de Estudo. Economia Circular. Jerónimo Martins. https://bcsdportugal.org/wp-content/uploads/2020/12/Caso-de-Estudo-Economia-Circular-Jeronimo-Martins-20201116.pdf

[8] Free translation of the original: Sustainable Production, Responsible Consumption.

[9] Free translation of the original: National Commission to Combat Food Waste.

[10] *Pingo Doce*. 2023. *Sobre Nós*. *O Combate ao Desperdício Alimentar no Pingo Doce*. https://www.pingodoce.pt/sobre-nos/noticias/combater-o-desperdicio-alimentar/

the first retailer in Portugal to calculate and publicly disclose their food waste footprint, in accordance with the methodology of the World Resources Institute's Food Loss and Waste.[11]

1.4.3 *Jerónimo Martins* Food Waste Indicators

In 2021 (see Table 2.2), *JM* Group's food waste increased to 17.6 kg of wasted food per ton of food products sold. This 4.1% increase is mostly related to the growth of perishable products in Biedronka, as these products are more sensitive to handling, temperature, and have shorter expiration dates. Waste in the perishable categories represents about 70% of the total food waste generated by *JM* Group.[12]

Table 1.2 Food Waste Indicators

kg of wasted food /tonnes of food sold	2021	2020	2021/2020
Food Waste	17,6	16,9	+4,1%
Destination			
• Animal feed and biological processing	2,2	2,5	-12,0%
• Anaerobic digestion, composting and controlled combustion	10,8	10,3	+4,9%
• Landfill disposal, incineration and wastewater treatment systems	4,6	4,1	+12,2%
Quantity per units per business			
• Biedronka	18,5	17,1	+8,2%
• Pingo Doce	21,3	22,7	-6,2%
• Recheio	4,7	6,4	-26,6%
• Ara	11,4	11,6	-1,7%

Source: *Jerónimo Martins*. 2021. Food Waste Indicators

11 *Jerónimo Martins*. 2023. *Responsabilidade*. *Gestão de Resíduos*. https://www.jeronimomartins.com/pt/responsabilidade/respeitar-o-ambiente/gestao-de-residuos/

12 *Jerónimo Martins*. 2021. *Indicadores de Desperdício Alimentar*. https://www.jeronimomartins.com/wp-content/uploads/01-DOCUMENTS/Responsibility/Environment/PT/Indicadores_de_Desperdicio_Alimentar_2021.pdf

1.4.4 Food Loss and Waste Accounting and Reporting Standard

In order to measure food waste in *JM* Group operations, the group adhere to the methodology defined in the Food Loss and Waste Accounting and Reporting Standard (version 1.0)[13], which considers the following assumptions:

- Definition of Food Waste: food (edible parts) and their corresponding inedible parts, removed from the FSC and managed as waste or by-products of animal origin;
- Types of Materials: the majority of the material is made up of edible parts of processed food products (including beverages) considered unsuitable for human consumption. In the case of some perishable products, non-edible parts were also considered;
- Destinations of Materials: the final destinations of food products considered unsuitable for human consumption in 2021 are: animal feed and biological processing; anaerobic digestion, composting, and controlled combustion and landfill and disposal through wastewater treatment systems;
- Time Horizon of Analysis: annual, 12 months, between January and December;
- Covered Operations: operations owned by *JM* Group, in the context of Food Distribution: Biedronka (Poland), *Pingo Doce* and *Recheio* (Portugal), and Ara (Colombia). This includes distribution centers, logistics platforms, production units, and stores (including restaurants and cafeterias when present in the brands);
- Calculation Method and Sources of Uncertainty: the use of internal accounting systems of all business units allows us to calculate the weight of food waste throughout the *JM* Group and maintain traceability of food product categories that contribute the most to waste. However, in certain cases, some estimates are used to determine the net weight of products when this is not available in the standardized unit (kilogram). For beverages, for example, net weights are defined according to specific physical densities - generally assuming that 1litter corresponds to 1 kilogram, for instance. The risk associated with estimates is mitigated through a more in-depth, manual, and individual

[13]The Food Loss & Waste Protocol. 2016. https://flwprotocol.org/wp-content/uploads/2017/05/FLW_Standard_final_2016.pdf

analysis of the products and categories that contribute the most to waste. 6.7% of the total value obtained comes from estimates.[14]

1.4.5 *Jerónimo Martins* Circular Economy projects and initiatives

The *JM* Group has developed an integrated strategy to combat waste, from the source to the final consumer.[15] The company purchases imperfect fruits and vegetables and integrates them into their value chain instead of abandoning them in the fields. These "ugly" vegetables are used in soups, cut and washed vegetables, and sold at a reduced price in their stores. They are also used to feed cattle and goats.[16] These actions have allowed for the collection of food that was previously abandoned in agricultural fields and wasted, resulting less waste and therefore, lower greenhouse gas emissions.[17] From 2015 to 2021, a total of 127,800 tonnes of unattractive or "ugly" fruits and vegetables were repurposed.[18]

The company sells discounted food products that are close to their expiry date and makes it easier for consumers to manage expiration dates[19], easily identifiable through an orange-colored label.[20] Unsold roasted chicken and suckling pig are shredded and used for pizzas, salads, and sandwiches or sold in trays. Larger fruits are cut in half to reduce waste, and packaging is adjusted to actual consumption. From 2015 to 2021, a total of 13,800 tonnes of products were sold at a discounted price. The company promotes food waste reduction through the book *Desperdício Zero à Mesa* and *Sabe Bem* magazine that provide tips and recipes shared on social media[21], encouraging the use of leftover food, thereby enabling a reduction in wastage

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[14] *Jerónimo Martins*. 2021. Indicadores de Desperdício Alimentar. https://www.jeronimomartins.com/wp-content/uploads/01-DOCUMENTS/Responsibility/Environment/PT/Indicadores_de_Desperdicio_Alimentar_2021.pdf

[15] *Biblioteca Casos de Estudo BCSD Portugal*. 2020. *Casos de Estudo*. *Economia Circular*. *Jerónimo Martins*.https://bcsdportugal.org/wp-content/uploads/2020/12/Caso-de-Estudo-Economia-Circular-Jeronimo-Martins-20201116.pdf

[16] *Jerónimo Martins*. 2023. *Responsabilidade*. *Desperdício Alimentar*. https://www.jeronimomartins.com/pt/responsabilidade/desperdicio-alimentar/

[17] Biblioteca Casos de Estudo BCSD Portugal. 2020. Casos de Estudo. Economia Circular. Jerónimo Martins. https://bcsdportugal.org/wp-content/uploads/2020/12/Caso-de-Estudo-Economia-Circular-Jeronimo-Martins-20201116.pdf

[18] *Jerónimo Martins*. 2023. *Responsabilidade*. *Desperdício Alimentar*. https://www.jeronimomartins.com/pt/responsabilidade/desperdicio-alimentar/

[19] ib.

[20] *Pingo Doce*. *2023*. *Sobre Nós*. *O Combate ao Desperdício Alimentar no Pingo Doce*. https://www.pingodoce.pt/sobre-nos/noticias/combater-o-desperdicio-alimentar/

[21] *Jerónimo Martins*. 2023. *Responsabilidade*. *Desperdício Alimentar*. https://www.jeronimomartins.com/pt/responsabilidade/desperdicio-alimentar/

in consumers' kitchens.[22] Surpluses that cannot be sold but meet safety standards are donated to solidarity institutions, with priority given to entities that work with the elderly, disadvantaged children, and youth. Biedronka's food donation program exceeded expectations, and Pingo Doce and Recheio networks in Portugal donate food. Between 2015 and 2021, a total of 98,100 tonnes of food products were donated and 140 institutions were supported by Biedronka.[23] In Colombia, the project was launched simultaneously with the Ara in 2013. In 2021, *Pingo Doce* donated food items that were equivalent to over 6,200 tons and is currently providing regular support to over 500 institutions such as Refood, *Comunidade Vida e Paz*, *CASA (Centro de Apoio ao Sem Abrigo)*, and *Cáritas*.[24]

All of these initiatives enable combating food waste on all fronts, reflecting the principles of a circular and cross-cutting economy throughout the entire value chain.[25]

1.4.6 *Jerónimo Martins* Seaculture strategy

JM recognizes that almost 90% of global fish stocks are either fully exploited or overexploited. For this reason, the *JM* has initiated two major sea-based fish production projects in Portugal: one in Sines for sea bass production, and another in Madeira for sea bream production. The Sines project is expected to produce over 500 tonnes of sea bass from 2018 onwards, while the Madeira project is being developed in three stages.

The first stage aims to harvest 550 tonnes of sea bream, with an expected increase to 1,200 tonnes in the second stage and ultimately up to 2,400 tonnes annually in the third stage. In both locations, aquaculture is practiced through open sea production rather than tanks, enabling the fish to grow in their natural habitat and preserving the biodiversity of the ecosystems. Furthermore, handling of the fish is minimized until they are caught to avoid stress. This is part of a 10-year plan to increase the production of this and other species preferred by consumers in Portugal, particularly at *Pingo Doce* stores, within appropriate maritime waters that are highly efficient and sustainable. This approach aims to address one of the major problems being

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[22] *Pingo Doce*. 2023. *Sobre Nós. O Combate ao Desperdício Alimentar no Pingo Doce*. https://www.pingodoce.pt/sobre-nos/noticias/combater-o-desperdicio-alimentar/

[23] *Jerónimo Martins*. 2023. *Responsabilidade*. *Desperdício Alimentar*. https://www.jeronimomartins.com/pt/responsabilidade/desperdicio-alimentar/

[24] *Pingo Doce*. 2023. *Sobre Nós. O Combate ao Desperdício Alimentar no Pingo Doce*. https://www.pingodoce.pt/sobre-nos/noticias/combater-o-desperdicio-alimentar/

[25] *Biblioteca Casos de Estudo BCSD Portugal*. 2020. *Casos de Estudo. Economia Circular. Jerónimo Martins*. https://bcsdportugal.org/wp-content/uploads/2020/12/Caso-de-Estudo-Economia-Circular-Jeronimo-Martins-20201116.pdf

faced worldwide, which is the depletion of natural fish stocks.[26] Seaculture has access to the Marine Sciences Laboratory's facilities, equipment, and materials through strategic partnerships. This allows them to study fish pathologies and conduct research on the preservation of natural and man-made environments.[27]

As of December 31, 2021, the volume of seaculture fish produced was 1,400 tonnes.[28] *JM* is committed to ensuring that their fresh, frozen, and canned fish products do not contribute to the overexploitation, depletion, or extinction of fish species. They have been regularly assessing the conservation status of all the species they sell every three years since 2016. Based on their findings, they adjust their sustainable fishing strategy, taking into account the threat levels of different species according to the International Union for Conservation of Nature's Red List of Threatened Species.

The company's strategy is underpinned by three commitments, which are re-evaluated whenever assessments identify areas for improvement. A review was conducted in 2020, based on an evaluation of more than 200 fish and shellfish species carried out in 2019.

- Critically Endangered Species: prohibit the acquisition and trade of species categorized as “Critically Endangered” in the absence of any specific special permits granted for such purposes;
- Endangered Species: prohibit the vending of species categorized as 'Endangered' unless they are obtained from aquaculture, sustainably managed stocks, or possess a sustainability certification such as Marine Stewardship Council or Aquaculture Stewardship Council;
- Vulnerable Species: restrict marketing efforts of species classified as 'Vulnerable' in the event that they are not obtained from aquaculture or sustainably managed stocks, or lack a sustainability certification like Marine Stewardship Council or Aquaculture Stewardship Council.

JM continued to meet its commitments in 2021 and recognized the need for improved monitoring of Atlantic tuna stocks to maintain stock integrity in the future. A new assessment

[26] Be the Story. 2023. Environment. Aquaculture on its way to feed the world. https://www.be-the-story.com/en/environment/aquaculture-on-its-way-to-feed-the-world/

[27] *Jerónimo Martins*. 2023. About Us. Agribusiness. https://www.jeronimomartins.com/en/about-us/what-we-do/agribusiness/

[28] *Jerónimo Martins*. 2022. *Jerónimo Martins* Corporate Presentation. https://www.jeronimomartins.com/wp-content/uploads/01-DOCUMENTS/Corporate-Presentations/JM_Corporate-presentation_MAR2022.pdf

of the fish and shellfish used in *JM*'s perishable and Private Brand products will be conducted in 2022. *JM*'s analysis of 'Critically Endangered' species identified only the European eel, which is farmed but depends on wild glass eels, leading to its removal from *JM* stores in 2016.[29] In order to promote sustainable fishing practices, *JM* stores do not sell species categorized as "endangered" unless they come from aquaculture or sustainably managed fishing reserves. Similarly, species categorized as "vulnerable" are not included in any promotional activities by *JM* companies, unless they come from aquaculture or sustainably managed fishing reserves.

JM recognizes that farmed fish species, such as salmon, sea bream, and sea bass, are acknowledged for their nutritional and gustatory qualities. *JM* advocates for the consumption of these aquaculture-raised fish as they provide a sustainable alternative to wild-caught fish, thereby reducing the pressure on their populations. *Pingo Doce* sells fish only from capture zones that comply with the best practices for the sustainable management of fish stocks, such as Norway and Iceland, to ensure that they are meeting the needs of their customers who are among the largest consumers of cod in the world.[30]

1.5 Problem Review

Sustainable Development Goal 12 was established by the United Nations to decrease food waste and losses in the FSC, including post-harvest losses, by 50% per capita by 2030 (UN, 2015). The significant environmental, economic, and social implications of food waste, such as the use of a substantial amount of natural resources like agricultural water and farmland, and its contribution to global greenhouse gas emissions, have led to increasing concerns (Teigiserova et al., 2020). While food waste occurs at every stage of the FSC, it mainly occurs during consumption (56%) and food processing (about 38%). However, food waste generated during the food manufacturing stage has a high degree of compositional uniformity and can be utilized in the extraction of high-value goods. It is crucial to reduce food waste for achieving food sector sustainability, especially in developing countries, where chronic hunger affects around 0.8 billion people (Cristobal et al., 2018).

CE principles provide potential for reducing food waste and providing higher-quality and safer food to customers. Techniques based on CE principles such as technology-based

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[29] *Jerónimo Martins*. 2023. Responsibility. Sustainable Fishing. https://www.jeronimomartins.com/en/responsibility/sourcing-responsibly/sustainable-fishing/

[30] Be the Story. 2023. Environment. Cherishing the oceans. https://www.be-the-story.com/en/environment/cherishing-the-oceans/

solutions, social and behavioural improvements, and legislative suggestions offer a way to tackle food sector issues. Food waste valorisation solutions that align with the objectives of the CE concept, which are based on the principles of reusing, reducing, and recycling, provide an effective approach to addressing food waste concerns (Zhang et al., 2022).

2 Chapter Methodology

Case studies as a teaching tool have grown in popularity across all academic disciplines, with roots in law, administration, medicine, and public policy. The primary goal of educational case studies is to provide a foundation for discussion and debate among students, without requiring the rigorous empirical analysis required for research-based case studies (Yin, 2001). According to Barney and Hesterly (2014), the case method of instruction is essential in many strategic management courses. This method entails examining and discussing actual business challenges, as well as identifying the opportunities and challenges they present. Students improve their ability to analyse and synthesise data by applying their theoretical knowledge to real-world situations (Barney & Hesterly, 2014).

The methodology adopted for this Pedagogical Case Study will be qualitative since the data being analysed is non-numerical and does not require statistical methods. The study is descriptive and will follow a qualitative and interpretative investigation strategy. Its descriptive nature aims to interpret and analyse the qualitative features of the CE principles in the company being studied, as well as to describe the situations that arise, and the effects on the company, society, and the environment. The essential steps in conducting this Pedagogical Case Study include describing the company under study, reviewing several documents related to its operations, defining the issues to be addressed in the case study, and conducting a literature review.

JM was chosen as the company for this study due to its size and prominence in Portugal as a major international food distribution company with a history spanning over two centuries. In addition, the company is notable for its commitment to circularity in its operations, making it a suitable choice for this study. The case questions were formulated with the objective of enabling students to apply their understanding of the CE concept to a practical scenario. Specifically, the questions address the issue of food waste within *JM*'s core business of food distribution, analyse the advantages and benefits offered by *JM*'s Seaculture strategy, explore the concept of valorisation of fish by-products and its potential implementation within *JM*'s Seaculture strategy, and lastly, examine the potential impact of the Integrated Multi-Trophic Aquaculture Model on *JM*'s Seaculture strategy. The questions were designed to facilitate the systematic application of conceptual frameworks and theoretical knowledge relevant to the topic of the CE and food waste. Ultimately, the aim was to equip students with the skills to support their ideas by effectively applying their existing knowledge to the context of *JM*.

In order to prepare this case study, a detailed depiction of the company and its activities was compiled by examining information from official reports including the Full Year Financial Results and Food Waste Indicators from 2021, as well as data from credible sources. The literature review began with an exhaustive search for articles using specific keywords in the ISCTE Discovery Data Base, including " CE concept," " CE business models," " CE implementation," " CE obstacles," " CE and food waste," " FSC," " CE and fish waste," "Fish Supply Chain," " CE and Aquaculture," "Fish waste types," and "Fish by-product valorisation." Additionally, relevant articles cited in other bibliographic reviews were considered. The search and reading of articles concluded once no new or significant information that could aid the proposed case was discovered.

Regarding the development of the case questions, a combination of information gathered from the case study and theoretical knowledge about CE applied specifically to the management of food waste, particularly fish waste, enabled the fulfilment of the pre-determined objective and the provision of responses to the proposed queries.

3 Chapter Pedagogical Note

3.1. Case Study Target Audience

The target audience for this case study is undergraduate and graduate students of International Management and Sustainable Development or related fields. Furthermore, professionals seeking to learn from a practical example of addressing food waste, through circularity in a food distribution company would also benefit from this case study.

3.2. Pedagogical Objectives

This case study serves as a practical tool for examining the existing problem and potential changes in the prevailing economic paradigm, the linear economy. It accomplishes three primary objectives: first, consolidating theoretical knowledge regarding the CE; second, applying this knowledge to an actual company's example through the most relevant frameworks and concepts; and third, assessing if these concepts are being put into practice in the specific case study and how it can create a favourable impact on the company, environment, and society. In addition to these goals, this pedagogical case study provides valuable insights into addressing CE challenges for organisations operating in the fish sector. It enables individuals who work in this sector to transfer this analysis to comparable situations and apply these methods and strategies to their own cases.

3.3. Literature Review

3.3.1. The Circular Economy Concept

The CE concept can be traced back to Rachel Carson's book "Silent Spring" and K. Boulding's essay "The Economics of the Coming Spaces" in 1966 (Roleders et al., 2022). D. Pierce and R. Turner expanded on the closed-loop economy concept in 1989 and used the term "CE" in their 1990 research on the interrelationships between the environment and economic activity (Merli et al., 2018). CE is based on the understanding that economic expansion leads to environmental deterioration and over-exploitation of natural resources, affecting the biosphere's reproductive potential (Merli et al., 2018). The concept has been applied differently across the world, influenced by cultural, social, and political systems (Winans et al., 2017). CE is widely regarded as a solution for balancing economic growth and environmental preservation, addressing issues like waste creation, resource scarcity, and long-term economic benefits (Lieder et al., 2016). However, there is no widely recognized definition of CE, as it is a newish subject of study with origins in several areas and schools of thought (Merli et al., 2018). Kirchherr et al. (2017) argue that a more holistic definition of CE is needed to achieve sustainable development at micro, meso, and macro levels.

The Ellen MacArthur Foundation has outlined three primary principles of the CE through various studies. The first principle emphasizes the importance of conserving and enhancing natural capital by using renewable resources and controlling finite stocks. The second principle highlights the need to optimize resource yields by keeping technical components and materials in circulation and encouraging the reuse of biological nutrients. The third principle emphasizes promoting system effectiveness by reducing harm to various systems and managing externalities. To enhance system resilience and reduce resource dependence, the energy required to power this cycle should be renewable. (Ellen MacArthur Foundation, 2015b; Moreno et al., 2016)

3.3.2. The Obstacles to Adopting Circular Economy in a Sustainable Food Supply Chain

Pannila et al. (2022) identifies seven primary reasons influencing the adoption of CE in the sustainable FSC:

1. **Cost efficiency**: The main challenge to CE in the food industry is cost efficiency. Businesses are hesitant to invest in new and costly goods/services with uncertain outcomes. Addressing this requires recognizing the impact of FSC on sustainability, then improving financial capacity to invest in circular products/services for long-term economic and environmental benefits.

2. **Less enforcement of legislation and regulations:** A significant challenge to implementing CE techniques in the food industry is the weak enforcement of rules and regulations, with no penalties for policy violations. This constrains CE business models further, and there are no rules governing single-use plastic food packaging. A lack of food quality control and procedures also makes it hard for CE businesses to ensure product quality. Governments and national authorities must collaborate, and supply

chain partners must adopt a long-term vision and expanded producer responsibility to overcome these barriers and promote CE activities.

3. **Lack of information on sustainable processes**: The lack of information on sustainable processes entails the absence of production and cost data for life cycle assessment; lack of information on materials used in manufacturing, limiting the possibility to recycle materials that have not been combined with other substances; difficulty in getting data from numerous FSC participants and finally, insufficient process data and a need of a comprehensive technique for estimating food waste.

4. **Technological difficulties and R&D deficiency**: The inefficient utilization of technology for labour-intensive tasks, such as the sorting of plastic waste, and the low level of technological readiness in FSC and laboratories, pose challenges in the field. Additionally, difficulties in determining the quality and hygiene of CE-related products, as well as a lack of advancement in product designs and processes, hinder progress.

5. **Lack of societal acceptance and demand**: The failure to recognise the environmental and economic benefits of CE food products and services has led to scepticism about the quality of these products and potential health risks linked with CE methods. Furthermore, current CE business models are insufficient in meeting consumers' cultural, social, and psychological needs.

6. **A lack of awareness and expertise**: There exists an inadequate knowledge regarding the value of waste, and limited information about labelling systems such as "best before" dates. Furthermore, professionals involved in the implementation of CE initiatives require additional training and education to develop the necessary knowledge and skills. A limited awareness of environmental issues, as well as insufficient knowledge of quality standards and safe handling procedures, also pose barriers to the successful implementation of CE initiatives.

7. **Insufficient subsidies and incentives**: One of the main hindrances to promoting CE is the lack of subsidies, tax incentives, and ease of access to grant funding for CE products and business models. Despite subsidizing farmers, innovative technologies that support CE are not being adopted, which is likely due to the uncertain nature of incentives provided by governments. The authors assert that establishing sustainable partnerships,

eco-industrial parks, biorefineries, waste valorisation, and eco-innovations are crucial in overcoming barriers to the adoption of CE in the FSC. Starting from agriculture and continuing through post-harvest, food processing, packaging, distribution, and consumption, the implementation of CE practices is essential in addressing global food insecurity.

3.3.3. Food Waste

CE principles offer potential for reducing food waste and ensuring the provision of higher-quality and safer food to customers. Popular CE based techniques for addressing food sector concerns include technology-based solutions, social and behavioural improvements, and legislative suggestions. Food waste valorisation solutions, which are based on the principles of reusing, reducing, and recycling, align with the CE concept's objectives (Zhang et al., 2022).

According to FAO, the causes of food waste vary by country and are influenced by local circumstances. Low-income countries have food loss during the production, postharvest handling, storage, and processing stages. This waste is mostly the result of managerial and technical restrictions. Food waste and loss are caused by a variety of factors, including inadequate infrastructure, outdated technologies, and economic limits. Overproduction is another form of food waste. Food waste occurs in high- and middle-income nations during the distribution and consumption phases of the food value chain (Tamasiga et al., 2022). On the basis of Borrello et al, (2017) research, some of the waste generated is from non-edible food, such as meat bones or egg shells ("unavoidable food waste"). Some waste comes from food that some people eat but others do not, such as bread crusts, or from food that can be eaten when cooked one way but not another, such as potato skins ("possibly avoidable" food waste). However, families throw out a large volume of food that was perfectly edible at some time prior to disposal ("avoidable food" waste).

As stated by Alexandra et al. (2016) research, approximately 30%-50% of food meant for human consumption is wasted at various stages of the food chain. These authors list, analyses, and proposes solutions for the various stages of the food chain, namely: Food Production, Food Consumption and Food Waste and Surplus Management:

1. **Food Production**: The increasing demand for phosphorus (P) due to meat-based diets is outpacing population growth, and recycling and reusing P as fertiliser is

crucial for food security and efficient agricultural practices. Measures such as raw material origin passports, extraction certifications, and labelling the origin of fertilizer-P in food products can help promote sustainable sources of P. Localised food systems that prioritize nutrient cycling and waste reduction also offer a potential solution to improve sustainability and reduce food waste (Alexandra et al., 2016).

2. **Food Consumption**: The western diet's overreliance on industrially produced meat poses significant health and environmental challenges, including high fertiliser and energy demands, greenhouse gas emissions, and other pollutants. Consumers, including individuals, the hospitality sector, and government agencies, can speed up the transition to a CE by making more sustainable choices and advocating for them. To encourage sustainable food choices, supermarkets, food service, and public catering must participate in efforts to increase plant-based foods and reduce meat portion sizes while introducing meatless days, regional and cultural dishes, and trustworthy labelling. Educating customers about labelling and promoting openness about their trustworthiness is also crucial in helping customers select sustainable food choices (Alexandra et al., 2016).

3. **Food Waste and Surplus Management**: Food surplus is edible food that is not consumed for various reasons, while food waste refers to inedible waste that could have been avoided. The primary strategy for reducing food surpluses is prevention, followed by the re-use of surplus food for human consumption via redistribution networks and food banks. When food is no longer fit for human consumption, it can be recycled into animal feed or composted. In retail, food quality requirements, labelling standards, and food safety legislation need to be reconsidered to reduce wasteful waste. Policies that incentivize producers and merchants to redistribute unwanted food and foster industrial symbiosis in food processing can also help cut food waste. More education and awareness are needed to encourage individuals to use food that might otherwise go to waste. Developing solutions for food waste reduction and prevention requires examining the hurdles (Alexandra et al., 2016).

3.3.3.1. Food Loss and Waste in Fish Value Chains

Around 200 million people are employed from harvesting through distribution, with 59.6 million directly working in fisheries and aquaculture, and approximately one out of every ten people rely on fisheries and aquaculture for a living. A value chain is the whole process through which a sector or a company adds value to their ultimate output (FAO, 2018). Fishing, aquaculture, processing, shipping, wholesale and retail marketing are all part of the fishing industry's value chain (FAO, 2023). As mentioned previously, food waste can be defined as waste created at the end of the FSC, primarily during marketing and consumption, however food loss and waste occur at all stages of the fisheries and aquaculture value chain (Borrello et al., 2017).

The FAO (2023) considers that is essential to comprehend the reasons behind it and pinpoint the locations where it happens to equip policymakers with data that can help minimize and avert it. As the demand for fish as a food source grows, decreasing food loss and waste is becoming more significant.

Fishery by-products hold the potential of being a valuable resource, and they offer opportunities for value addition and sustainability (Al Khawli et al., 2019; Stevens et al., 2018). Therefore, the issue of waste generation by the aquaculture industry and the potential reuse of fishery by-products need attention. To address this problem, the IMTA model could be employed (Guerrero & Creamades, 2012).

3.3.3.2. Fish by-product valorisation

Al Khawli et al. (2019) report that fish are highly nutritious and that global fish production in 2016 was approximately 171 million tons, with 91 million tons coming from fishing and 80 million tons from aquaculture, being China the largest producer. Norway and Spain are the largest producing countries for capture fisheries in Europe. The ratio of food fish to by-product varies by fishing zone, season, fish size, and species, with heads making up 9% to 12%, viscera 12% to 18%, skin 1% to 3%, bones 9% to 15%, and scales around 5% of the total fish weight. Stevens et al. (2018) suggest that although some by-products are restricted for human consumption, marine by-products have been shown to contain essential minerals, vitamins, protein, and lipid components, with potential for use in various applications (see table 4.2 and figure 4.1).

Rather than being considered waste, marine by-products have the potential to be a valuable resource. In summary, fish by-products offer valuable opportunities for value addition and sustainability (Al Khawli et al., 2019; Stevens et al., 2018).

3.3.3.3. Aquaculture and fish by-product valorisation

Aquaculture has expanded rapidly to meet the worldwide demand for animal protein, but the current production process is not sustainable in the long term. The process produces a significant amount of waste that can have a notable environmental impact, but this impact can be mitigated by reusing the waste. In terms of fish grown in aquaculture, around 45% is directly used, while the remaining 55% is classified as a sub-product, primarily composed of the fish's head, frames, viscera, skin, belly flaps, trimmings, and blood. The head and frames make up the largest proportion of the sub-products at 20%, followed by viscera at 12.5%, skin and belly flaps at 5%, and trimmings and blood at 4% (Stevens et al., 2018). The efficiency of different sea creatures in terms of their body weight and edible portions has also been studied. Crabs have a shell and head that make up 60% of their total body weight, while the flesh used for food accounts for 40%. Molluscs are the most efficient organisms since their flesh constitutes 70% and their shell 30% of total body weight. The sub-products from these animals also need to be considered, including the estimated 4% of killed animals during the growth phase in each production system (Iñarra et al., 2018).

Accordingly, to Nawaz et al. (2020), fishery by-products are divided into two categories: organic waste and inorganic waste. To Fraga-Corral et al. (2022), aquaculture waste can be divided into four categories. The first category is solid waste, which contains suspended particles derived primarily from unconsumed animal food. The second category is dissolved organic compounds, which are mostly nitrogen and phosphorus. The third type of substance is dissolved chemical compounds, which are derived from drug therapies. Pathogens are the fourth and last group.

Table 3.1 The global market for biomolecules derived from aquaculture fish by-products

Biomolecules	Application	Market size (year)	Reference
Proteins	Food and nutraceutical	$52.5 billion (2020)	("Protein Ingredients Market," 2020)
Collagen	Food, nutraceutical, medical, and cosmetics	$3.5 billion (2019)	(S. S. Kunal Ahuja, 2019)
Gelatine	Food, nutraceutical, and cosmetics	>$1.5 billion (2019)	(S. S. Kunal Ahuja, 2019)
Chitosan	Food, food industry, cosmetics, and water treatment	$1.5 billion (2017)	(Kiran Pulidindi, 2017)
Astaxanthin	Nutraceutical, cosmetics, aquaculture and animal feed	>$0.6 billion (2018)	(A. R. Kunal Ahuja, 2018)
β-carotene	Food, nutraceutical, pharmaceutical, cosmetics, and animal feed	>$0.5 billion (2019)	(A. R. Kunal Ahuja, 2020)
Ω3 PUFAs	Food, infant formula, nutraceutical, pharmaceutical and animal feed	$2.2 billion (2020)	("Omega 3 PUFA Market," 2020)

Source: Fraga-Corral et al. (2022)

Nawaz et al. (2020) research depicts that the fisheries sector generates a substantial quantity of naturally occurring by-products, including fish skin, viscera, red and white meat, and some scales, bones, and fins. All of these substances have the potential to be used as collagen sources. Fish-derived collagen and gelatin avoid religious and safety concerns associated with mammalian sources, such as pathogen transfer. Following fillet processing, red fish meat is the second most abundant organic component, after collagen, found in the organic section.

Fish oil, a by-product of the fishing industry, is another type of organic waste that could have value as a high-quality source of nutrition (Herpandi et al., 2011). It contains omega-3 fatty acids, which have been shown to have the potential to prevent cardiovascular diseases and enhance the immune system (see Table 4.1) (Herpandi et al., 2011; Kadam & Prabhasankar, 2010).

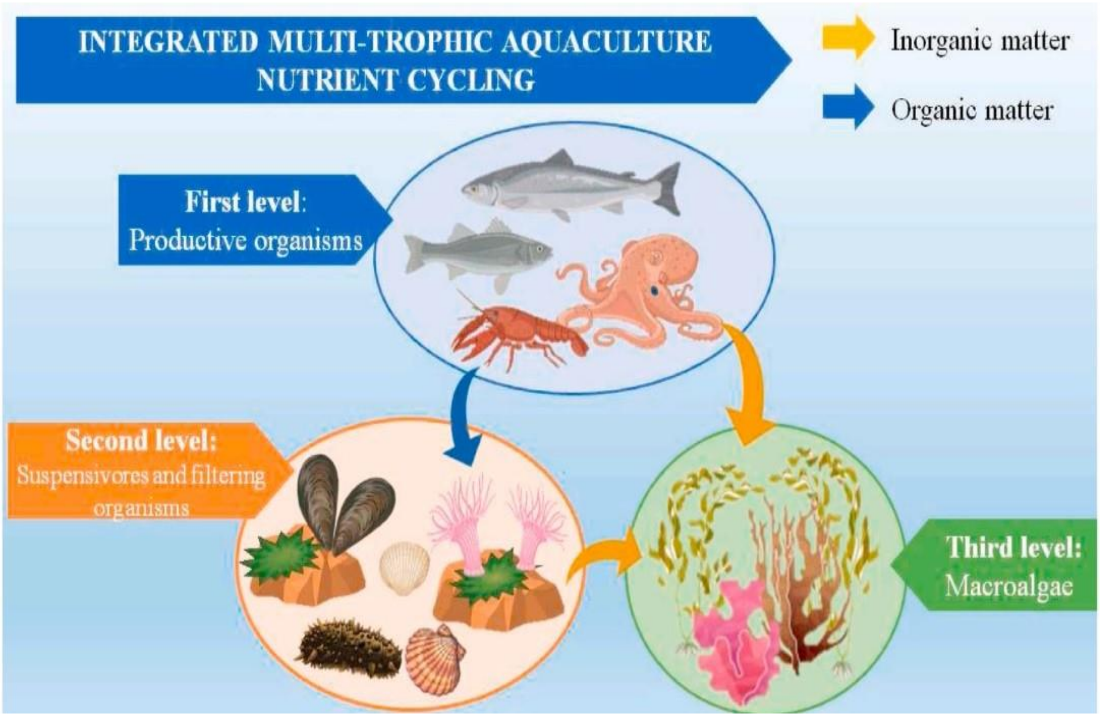
Figure 3.1 Aquaculture products and by-products (re-) use based on the waste hierarchy model

Source: Fraga-Corral et al. (2022)

3.3.3.4. The Integrated Multi-Trophic Aquaculture Model

Aquaculture in Europe, for example, is attempting to meet European laws while also becoming a substantial contributor to animal protein production by developing cost-effective and ecologically friendly technologies. Waste formed from metabolic products or wasted food should be seen as a useful source of minerals, vitamins, proteins, and lipids in order to reduce environmental impact and enhance efficiency, and recycling this waste is regarded as a viable strategy to achieve these goals. (Lee et al., 2019; Stevens et al., 2018). The IMTA is regarded as a model adopted by many countries capable of meeting all of these needs (Guerrero & Creamades, 2012).

Figure 3.2 The Integrated Multi-Trophic Aquaculture Model



Source: Fraga-Corral et al. (2022)

The procedure of IMTA involves using organic matter produced at the initial level to nourish organisms at the subsequent level (see figure 4.2). Additionally, the inorganic matter generated at both the first and second levels is utilized to feed organisms at the third level (Fraga-Corral et al., 2022). This production design suggests the culture of several species from varying trophic levels, where waste produced by those from higher levels serves as resources for species from lower levels, just like what happens in natural ecosystems. (Guerrero & Creamades, 2012; Jeronimo et al., 2020). IMTA systems enable the creation of diverse valuable species using fewer resources and minimising the adverse environmental effects. Thus, production systems modelled on IMTA principles promote the responsible utilisation of natural resources and sustainable productivity (Cranford et al., 2013; Guerrero & Creamades, 2012).

3.4. Case Study Lecture Plan

Session	Description of Activity	Time
Preparation	• Analyse and understand the issue before the class. • Additionally, it is recommended to research and gather supplementary details regarding the organization and the subject matter of the case.	Around 30 min.
Session 1	• The class should be divided into five groups consisting of approximately 3 to 5 students in each group. • An overview of the case study and an introduction to the presentation of *Jerónimo Martins* shall be provided (play video[31]).	10 min.
	• Question 1: What are the principles and obstacles to adopting the Circular Economy? • The students presented and deliberated on the key findings of Question 1.	20 min.
Session 2	• Question 2: What is the relationship between Circular Economy and food waste, and how is *Jerónimo Martins* addressing the issue of food waste? • The students presented and deliberated on the key findings of Question 2.	30 min.
Session 3	• Question 3: What is *Jerónimo Martins'* Seaculture strategy and the advantages it offers? • The students presented and deliberated on the key findings of Question 3.	30 min.
Session 4	• Question 4: The *Jerónimo Martins'* Seaculture strategy does not contemplate fish by-products valorization. What does the valorisation of fish by-products entail and how could its implementation in *Jerónimo Martins'* Seaculture strategy prove advantageous? • The students presented and deliberated on the key findings of Question 4.	30 min.
Session 5	• Question 5: *Jerónimo Martins'* aquaculture strategy is solely centred on the commercialisation of fish, without taking advantage of the potential benefits that the organic matter obtained from the fish could provide. What is the Integrated Multi-Trophic Aquaculture Model and how could its adoption benefit *Jerónimo Martins'* Seaculture strategy? • The students presented and deliberated on the key findings of Question 5.	30 min.

[31] Jerónimo Martins. 2022, agosto 23. 2021: a year of growth and increased profitability. YouTube https://www.youtube.com/watch?v=k8e54XBOsVI

3.5. Faculty Case Study Lecture for Students

This case study aims to accomplish two main goals: firstly, to provide a comprehensive definition of the CE and its fundamental principles, explore the available strategies for developing innovative business models, examine the associated benefits and drawbacks, and most significantly, examine how it addresses the issue of food waste, particularly in the fish sector. Secondly, it aims to equip students with the ability to articulate and appraise the approach taken by the *JM* Group to incorporate CE principles in tackling food waste, with an emphasis on their efforts to overcome challenges within the global fisheries and aquaculture domain.

- Question 1: What are the principles and obstacles to adopting the Circular Economy?

- Question 2: What is the relationship between Circular Economy and food waste, and how is *Jerónimo Martins* addressing the issue of food waste?

- Question 3: What is *Jerónimo Martins'* Seaculture strategy and the advantages it offers?

- Question 4: The *Jerónimo Martins'* Seaculture strategy does not contemplate fish by-products valorization. What does the valorisation of fish by-products entail and how could its implementation in *Jerónimo Martins'* Seaculture strategy prove advantageous?

- Question 5: *Jerónimo Martins'* aquaculture strategy is solely centred on the commercialisation of fish, without taking advantage of the potential benefits that the organic matter obtained from the fish could provide. What is the Integrated Multi-Trophic Aquaculture Model and how could its adoption benefit *Jerónimo Martins'* Seaculture strategy?

3.6. Resolution analysis of the data

Question 1: What are the principles and obstacles to adopting the Circular Economy?

The Ellen MacArthur Foundation has delineated three primary principles of the CE. The first principle stresses the significance of safeguarding and improving natural capital through the employment of renewable resources and finite stock management. The second principle underscores the importance of maximising resource efficiency by promoting the recycling of technical components and materials, and encouraging the reuse of biological nutrients. The third principle accentuates the need to augment system efficiency by minimising harm to various systems and managing externalities. In order to fortify system resilience and reduce resource dependence, it is recommended that the energy required to drive this cycle should be sourced from renewable sources.

CE is facing several challenges that hinder its adoption. These obstacles can be grouped into seven categories. One of the main challenges is cost efficiency. Many businesses are hesitant to invest in new and potentially costly goods or services that may have uncertain outcomes. To overcome this obstacle, it is necessary to recognize the impact of FSC on sustainability and to improve financial capacity to invest in circular products and services for long-term economic and environmental benefits.

Another obstacle is the weak enforcement of rules and regulations, with no penalties for policy violations. This constrains CE business models further, and there are no rules governing single-use plastic food packaging. A lack of food quality control and procedures also makes it hard for CE businesses to ensure product quality. Governments and national authorities must collaborate, and supply chain partners must adopt a long-term vision and expanded producer responsibility to overcome these barriers and promote CE activities.

Lack of information on sustainable processes is another obstacle, including the absence of production and cost data for life cycle assessment, lack of information on materials used in manufacturing, and difficulty in getting data from numerous FSC participants. There is a need for a comprehensive technique for estimating food waste.

Technological difficulties and R&D deficiency are also challenges in the field. The inefficient utilization of technology for labour-intensive tasks, such as the sorting of plastic waste, and the low level of technological readiness in FSC and laboratories pose challenges in the field. Additionally, difficulties in determining the quality and hygiene of CE-related products, as well as a lack of advancement in product designs and processes, hinder progress.

Lack of societal acceptance and demand is another obstacle, which has led to skepticism about the quality of CE products and potential health risks linked with CE methods. Furthermore, current CE business models are insufficient in meeting consumers' cultural, social, and psychological needs.

A lack of awareness and expertise poses another challenge, with insufficient knowledge of quality standards and safe handling procedures. There is also a limited awareness of environmental issues, and professionals involved in the implementation of CE initiatives require additional training and education to develop the necessary knowledge and skills.

Finally, the lack of subsidies, tax incentives, and ease of access to grant funding for CE products and business models hinders the adoption of CE in the sustainable FSC. Despite subsidizing farmers, innovative technologies that support CE are not being adopted, likely due to the uncertain nature of incentives provided by governments.

Overcoming these obstacles to the adoption of CE in the FSC is crucial in addressing global food insecurity. Establishing sustainable partnerships, eco-industrial parks, biorefineries, waste valorization, and eco-innovations are crucial in promoting the adoption of CE in the FSC.

Question 2: What is the relationship between Circular Economy and food waste, and how is *Jerónimo Martins* addressing the issue of food waste?

The 21st century faces several challenges such as an expanding global population, linear resource consumption, and unsustainable waste output. The food industry recognizes the need to establish a CE to address the problem of food waste, as one-third of all food produced for human consumption is lost or wasted. The CE in the food system involves reducing waste, reusing food, using by-products and food waste, nutrient recycling, and promoting diversified and efficient food patterns. The United Nations has set a Sustainable Development Goal 12 to reduce global food waste by 50% per capita by 2030. Reducing food waste is critical for sustainable food production, especially in developing nations with a high number of people suffering from chronic hunger. Solutions for the different stages of the food chain include food production, consumption, and waste management. Developing CE models can help eliminate waste from value chains and rely on climate change impact and finite resources.

The growing demand for phosphorus in food production due to the shift towards meat-based diets requires the recovery and reuse of phosphorus as recycled fertilizer to increase efficiency and ensure food security. To reduce food waste and promote sustainability, alternatives such as raw material origin passports, labelling the origin of fertilizer-P in food products, and creating local food systems can be utilized. The overreliance on industrially produced meat in the western diet imposes environmental costs and health risks, and consumers can accelerate the transition to a CE by making sustainable choices and advocating for them. Supermarkets and food service providers should promote plant-based foods, reduce meat portion sizes, and introduce meatless days. To manage food waste, retail food quality requirements, labelling standards, and food safety legislation should be reconsidered. Policies promoting industrial symbiosis in food processing and more education and awareness in families are also necessary.

JM recognizes its increased responsibility to combat food waste by improving its processes, promoting responsible primary production, and collaborating with suppliers, employees, and charitable institutions. *JM* has been working for several years to reduce food waste in its supply chains while simultaneously achieving the objectives of the United Nations, such as fighting hunger and inequality, promoting food safety and nutrition, and maintaining positive synergies with the natural capital we depend on, such as respecting and effectively managing terrestrial and marine biodiversity and fighting climate change. *JM* has committed to reducing its food waste related to its operations by half by 2030 in line with Sustainable Development Goal 12.3 on Responsible Consumption and Production. *JM* has become the first food retail chain in Portugal to be awarded the [32]*Produção Sustentável Consumo Responsável* seal from the *Comissão Nacional de Combate ao Desperdício Alimentar*[33]. This recognition was achieved through a series of good practices implemented by the company to fulfil their commitment to reducing food waste by half by 2030. *JM* was also the first retailer in Portugal to disclose publicly its food waste footprint, following the methodology of the World Resources Institute's Food Loss and Waste. In 2021, the *JM* Group's food waste increased to 17.6 kg of wasted food per ton of food products sold, a 4.1% increase mainly attributable to the growth of perishable products in Biedronka, which are more susceptible to handling, temperature, and have shorter expiration dates. Waste in the perishable categories accounts for around 70% of the total food waste generated by the group. To measure food waste in *JM*'s operations, the group adheres to the methodology defined in the Food Loss and Waste Accounting and Reporting Standard (version 1.0).

The *JM* Group has formulated an integrated strategy to combat waste, from the source to the final consumer. The company acquires imperfect fruits and vegetables and incorporates

[32] Free translation of the original: Sustainable Production, Responsible Consumption.
[33] Free translation of the original: National Commission to Combat Food Waste.

them into its value chain rather than abandoning them in the fields. These "ugly" vegetables are used in soups, cut and washed vegetables, and sold at a reduced price in their stores. They are also utilized to feed cattle and goats. These actions have resulted in the collection of food that was previously abandoned in agricultural fields and wasted, resulting in less waste and, as a result, lower greenhouse gas emissions.

From 2015 to 2021, a total of 127,800 tonnes of unattractive or "ugly" fruits and vegetables were repurposed. The company sells discounted food products that are close to their expiration date and makes it easier for consumers to manage expiration dates by labelling them with an orange color. Unsold roasted chicken and suckling pig are shredded and used for pizzas, salads, and sandwiches or sold in trays. Larger fruits are cut in half to reduce waste, and packaging is adjusted to actual consumption. From 2015 to 2021, a total of 13,800 tonnes of products were sold at a discounted price.

The company promotes food waste reduction through the book *Desperdício Zero à Mesa* and *Sabe Bem* magazine, which provide tips and recipes shared on social media, encouraging the use of leftover food, thereby reducing wastage in consumers' kitchens. Surpluses that cannot be sold but meet safety standards are donated to charitable institutions, with priority given to organizations that serve the elderly, disadvantaged children, and youth. Biedronka's food donation program exceeded expectations, and *Pingo Doce* and *Recheio* networks in Portugal donate food. In Colombia, the project was launched simultaneously with the Ara in 2013. During the period between 2015 and 2021, Biedronka donated a total of 98,100 tonnes of food products and supported 140 institutions. In 2021, *Pingo Doce* donated food items amounting to more than 6,200 tons and is currently providing regular assistance to more than 500 institutions, including Refood, *Comunidade Vida e Paz*, *CASA (Centro de Apoio ao Sem Abrigo)*, and *Cáritas*. All of these initiatives are aimed at combating food waste on various fronts, and they reflect the principles of a circular and integrated economy throughout the entire value chain.

Question 3: What is *Jerónimo Martins'* Seaculture strategy and the advantages it offers?

JM acknowledges that almost 90% of the world's fish stocks are fully exploited or overexploited, and as a result, the *JM* Group has launched two significant sea-based fish production projects in Portugal. One project, located in Sines, is focused on producing sea bass, while the other, situated in Madeira, aims to produce sea bream. The Sines project anticipates yielding more than 500 tonnes of sea bass annually from 2018 onwards, while the Madeira project is being developed in three phases. The first phase intends to harvest 550 tonnes of sea bream, with an expected increase to 1,200 tonnes in the second phase, and eventually up to 2,400 tonnes per year in the third phase. Both locations employ open-sea aquaculture methods rather than tanks, allowing the fish to develop in their natural habitats while preserving the biodiversity of the ecosystems. Furthermore, the handling of the fish is kept to a minimum until they are caught to prevent stress.

This is a component of a ten-year plan to increase the production of this and other species that are popular with consumers in Portugal, particularly at *Pingo Doce* stores, within appropriate and sustainable maritime waters. This approach aims to address one of the significant challenges faced globally, namely the depletion of natural fish stocks.

Through strategic partnerships, Seaculture has access to the Marine Sciences Laboratory's equipment, materials, and facilities, enabling them to investigate fish pathologies and conduct research on preserving natural and human-made environments. As of December 31, 2021, Seaculture had produced 1,400 tonnes of fish.

JM is dedicated to ensuring that their fresh, frozen, and canned fish products do not contribute to the overexploitation, depletion, or extinction of fish species. Since 2016, they have been regularly evaluating the conservation status of all the species they sell every three years. Based on their findings, they adjust their sustainable fishing approach, taking into account the threat levels of different species according to the International Union for Conservation of Nature's Red List of Threatened Species. The company's strategy is founded on three commitments that are reviewed and improved as needed. In 2020, they conducted a review based on an evaluation of over 200 fish and shellfish species conducted in 2019. For Critically Endangered species, the acquisition and trade are prohibited without specific special permits. In relation to Endangered species, vending is prohibited unless they come from aquaculture, sustainably managed stocks, or possess a sustainability certification such as Marine Stewardship Council or Aquaculture Stewardship Council. With regards to Vulnerable species, marketing efforts are restricted if they are not obtained from aquaculture or sustainably managed stocks or lack a sustainability certification.

JM has continued to meet its commitments in 2021 and acknowledged the need for improved monitoring of Atlantic tuna stocks to preserve stock integrity in the future. In 2022, they will carry out a new assessment of the fish and shellfish used in *JM*'s perishable and Private Brand products. *JM*'s analysis of 'Critically Endangered' species identified only the European eel, which is farmed but depends on wild glass eels, leading to its removal from *JM* stores in 2016. In order to promote sustainable fishing practices, *JM* stores refrain from selling species categorized as "endangered" unless they come from aquaculture or sustainably managed fishing reserves. Similarly, *JM* companies do not include species categorized as "vulnerable" in any promotional activities, unless they come from aquaculture or sustainably managed fishing reserves. *JM* acknowledges that farmed fish species, such as salmon, sea bream, and sea bass, are well-known for their nutritional and gustatory qualities. They advocate for the consumption of these aquaculture-raised fish as a sustainable alternative to wild-caught fish, thereby reducing the pressure on wild fish populations. *Pingo Doce*, among the world's largest consumers of cod, ensures that they meet the needs of their customers by selling fish only from capture zones that comply with the best practices for the sustainable management of fish stocks, such as Norway and Iceland.

Question 4: The *Jerónimo Martins'* Seaculture strategy does not contemplate fish by-products valorization. What does the valorisation of fish by-products entail and how could its implementation in *Jerónimo Martins'* Seaculture strategy prove advantageous?

Fish are an important source of animal protein and are highly nutritious, with essential minerals, vitamins, protein, and lipid components. In 2016, approximately 171 million tons of fish were produced globally, with 91 million tons from fishing and 80 million tons from aquaculture. China is the largest producer of fish, followed by Norway and Spain, which are the largest producing countries for capture fisheries in Europe.

The ratio of food fish to by-product varies based on factors such as fishing zone, season, fish size, and species. Heads make up 9% to 12% of the total fish weight, viscera 12% to 18%, skin 1% to 3%, bones 9% to 15%, and scales around 5%. These by-products have the potential for use in various applications due to their high nutritional content.

Aquaculture, for example, is an essential source of animal protein, but it generates a significant amount of waste that can have a notable environmental impact. Around 45% of fish grown in aquaculture are directly used, while the remaining 55% are classified as a sub-product, primarily composed of the fish's head, frames, viscera, skin, belly flaps, trimmings, and blood. The efficiency of different sea creatures in terms of their body weight and edible portions has also been studied. Crabs have a shell and head that make up 60% of their total body weight, while the flesh used for food accounts for 40%. Molluscs are the most efficient organisms since their flesh constitutes 70% and their shell 30% of total body weight.

Fishery by-products can be divided into two categories: organic waste and inorganic waste. Aquaculture waste can be divided into four categories: solid waste, dissolved organic compounds, dissolved chemical compounds, and pathogens. Naturally occurring by-products from the fisheries sector, such as fish skin, viscera, red and white meat, and some scales, bones, and fins, have the potential to be used as collagen sources.

Fish oil, a by-product of the fishing industry, contains omega-3 fatty acids, which have been shown to have the potential to prevent cardiovascular diseases and enhance the immune system. Therefore, the fishery and aquaculture industries have an opportunity to extract additional value from these by-products while simultaneously promoting sustainability.

By integrating the valorisation of fish by-products into its Seaculture strategy, *JM* could reap several advantages. These benefits include the potential to generate supplementary revenue streams, minimise the environmental impact of its operations, and create a self-sustaining system that enhances resource efficiency. The adoption of this approach could involve the transformation of fish waste into valuable commodities, such as fish meal, fish oil, or fish hydrolysate, which have diverse applications in industries like agriculture, cosmetics, and aquaculture. Embracing this technique could significantly bolster *JM '* sustainability efforts and enhance its reputation as a socially responsible entity that is dedicated to preserving the environment.

Question 5: *Jerónimo Martins'* aquaculture strategy is solely centred on the commercialisation of fish, without taking advantage of the potential benefits that the organic matter obtained from the fish could provide. What is the Integrated Multi-Trophic Aquaculture Model and how could its adoption benefit *Jerónimo Martins'* Seaculture strategy?

The IMTA involves using organic matter produced at the initial level to nourish organisms at the subsequent level. Additionally, the inorganic matter generated at both the first and second levels is utilized to feed organisms at the third level. IMTA systems enable the creation of diverse valuable species using fewer resources and minimizing the adverse environmental effects. As a result, by reusing and recycling by-products from aquaculture industries, we can reduce environmental impacts, promote sustainability, and extract additional value from these resources. The IMTA system is one example of how cost-effective and ecologically friendly technologies can be developed to meet these needs.

Adopting the IMTA model could improve *JM* Seaculture strategy in a variety of ways. To begin, an IMTA system uses fish waste to grow seaweed or other organisms, reducing the environmental impact of fish farming. This is accomplished by reducing waste and improving water quality, thereby mitigating the negative environmental effects of aquaculture.

Second, growing multiple species in an IMTA system can boost productivity. *JM* will benefit from higher yields and profitability because the nutrients and organic matter from one species can be used to support the growth of another. Furthermore, by diversifying production and reducing reliance on a single species, the system becomes more resilient to market fluctuations and environmental stresses.

Thirdly, incorporating different species in an IMTA system can contribute to the diversification of *JM '* Seaculture strategy. This would result in a more robust and resilient system that is better able to cope with market fluctuations and environmental stresses.

Lastly, introducing seaweed or other organisms in an IMTA system can significantly improve water quality, enhancing the health and growth of fish and resulting in higher-quality products for consumers.

In conclusion, adopting the IMTA model has the potential to significantly enhance *JM '* Seaculture strategy by improving sustainability, productivity, diversification, and product quality. This, in turn, could lead to greater market competitiveness, profitability and improve the company's standing as a socially responsible entity.

Conclusion

In conclusion, this Pedagogical Case Study conducted a comprehensive analysis of the principles and challenges involved in adopting the circular economy. It specifically focused on exploring the correlation between the circular economy and food waste, with a strong emphasis on *JM* ' notable efforts to address this pressing issue. The study also delved into the detailed examination of *JM* ' Seaculture strategy, thoroughly analysing the advantages and benefits it offers. Furthermore, the concept of valorising fish by-products and its potential integration within *JM* ' Seaculture strategy were explored in depth. Lastly, the study carefully examined the potential impact of the IMT Model on *JM* ' Seaculture strategy. To address these five objectives, corresponding questions were formulated, providing a structured framework for the research analysis.

The findings of this Pedagogical Case Study reveal that the Ellen MacArthur Foundation has established three fundamental principles for the CE. These principles involve safeguarding natural capital through renewable resources and finite stock management, maximizing resource efficiency by recycling technical components and materials and reusing biological nutrients, and enhancing system efficiency by minimizing harm to various systems and managing externalities. The adoption of the CE faces several challenges that hinder its widespread implementation. The challenges in adopting the CE include cost efficiency, weak enforcement of rules and regulations, lack of information on sustainable processes, technological difficulties and R&D deficiency, lack of societal acceptance and demand, lack of awareness and expertise, and lack of subsidies, tax incentives, and ease of access to grant funding.

The challenges confronted in the 21st century, encompassing population growth, resource consumption, and waste, underscore the necessity of a CE in the food sector. The CE endeavours to tackle food waste by diminishing waste, reusing food, utilizing by-products, recycling nutrients, and advocating for efficient food practices. Adopting CE models can eradicate waste, minimize environmental impact, and conserve resources. Furthermore, the retrieval and reuse of phosphorus as recycled fertilizer play a crucial role in enhancing efficiency and ensuring food security. Encouraging sustainable choices, promoting plant-based foods, and reassessing food quality requirements and labelling standards are significant measures. Policy backing for industrial symbiosis, education, and awareness are also imperative for proficient food waste management. *JM* has implemented various strategies to tackle food waste and it is committed to reducing its food waste by half by 2030 through responsible primary production, collaborating with suppliers, employees, and charitable institutions, and improving its processes. The *JM* Group has developed an integrated strategy to tackle waste at all stages of the supply chain, from sourcing to the end consumer. One initiative involves acquiring imperfect fruits and vegetables that would have otherwise been abandoned in fields and incorporating them into their value chain. The company sells discounted food products that are close to their expiration date and labelling them with an orange colour to help consumers manage expiration dates. The *JM* Group promotes food waste reduction through various initiatives such as *Desperdício Zero à Mesa* and *Sabe Bem* magazine that provide tips and recipes shared on social media to encourage the use of leftover food. Surpluses that cannot be sold but meet safety standards are donated to charitable institutions, with priority given to organizations that serve the elderly, disadvantaged children, and youth. These efforts have resulted in significant reductions in food waste and have demonstrated the positive impact of the circular economy approach.

JM has undertaken two significant sea-based fish production projects in Portugal, with a specific focus on sea bass and sea bream. These projects aim to enhance the production of sustainable fish by utilizing open-sea aquaculture methods that enable the fish to develop naturally while safeguarding biodiversity. *JM*'s dedication to sustainability is evident through their regular assessments of fish species conservation status, which inform adjustments to fishing practices. By promoting farmed fish as a sustainable alternative to wild-caught varieties and partnering with the Marine Sciences Laboratory, *JM* underscores their commitment to responsible sourcing and environmental preservation. This comprehensive approach contributes to the overarching objective of combatting the pressing issue of overfishing in the long term.

The utilization of fish by-products presents a valuable opportunity for the fishery and aquaculture industries. By-products such as fish skin, viscera, red and white meat, scales, bones, and fins can be effectively utilized as collagen sources. Fish oil, a by-product rich in omega-3 fatty acids, holds promising potential for preventing cardiovascular diseases and enhancing the immune system. The extraction of additional value from these by-products not only benefits the industries but also promotes sustainability by reducing waste and maximizing resource utilization. This underscores the importance of considering the untapped potential of fishery and aquaculture by-products in achieving a more sustainable and efficient approach.

The integration of fish by-product valorisation into *JM'* Seaculture strategy offers numerous advantages. By leveraging this approach, the company can unlock additional revenue streams, minimize environmental impact, and establish a self-sustaining system that improves resource efficiency. Transforming fish waste into valuable commodities like fish meal, fish oil, or fish hydrolysate opens up diverse applications in sectors such as agriculture, cosmetics, and aquaculture. Embracing this technique not only strengthens *JM*" sustainability efforts but also enhances its reputation as a socially responsible entity committed to environmental preservation. This comprehensive approach underscores the company's dedication to maximizing value from by-products while fostering a more sustainable and efficient operational framework.

The aquaculture industry faces significant challenges related to sustainability, including ecological degradation, resource depletion, and economic inefficiency. To address these issues, the IMTA model has emerged as a promising approach for sustainable aquaculture. By utilizing organic matter and inorganic resources produced at different levels, IMTA systems utilize resources efficiently, minimizing adverse environmental impacts at the same time. By cultivating diverse species in an integrated manner, resources can be conserved and environmental burdens reduced. Aside from reducing environmental impacts and promoting sustainability, IMTA also extracts additional value from aquaculture by-products by reusing and recycling them. IMTA's innovative cost-effective and ecologically friendly technologies demonstrate the importance of meeting the escalating demands of the aquaculture industry responsibly. In order to make aquaculture more environmentally conscious and responsible, IMTA's comprehensive and innovative approach can significantly enhance efficiency and sustainability.

The adoption of the IMTA model presents numerous advantages for *JM'* Seaculture strategy. By implementing IMTA, the company can effectively address environmental concerns associated with fish farming, reduce waste, and improve water quality. The integration of multiple species within the IMTA system enhances productivity, leading to higher yields and increased profitability. Moreover, the diversification of production through IMTA provides resilience against market fluctuations and environmental challenges. The introduction of seaweed or other organisms in the IMTA system further enhances water quality and promotes the growth of healthier fish, resulting in higher-quality products for consumers. Overall, embracing the IMTA model not only enhances sustainability, productivity, and diversification but also strengthens *JM'* position in the market and establishes the company as a socially responsible entity committed to sustainable aquaculture practices.

The primary limitation of this pedagogical case study lay in its exclusive reliance on secondary sources, which can impose certain constraints that hinder the thoroughness and originality of the research. Secondary sources, being interpretations and analyses of primary sources by other authors, may not offer the necessary level of depth and analysis required for a comprehensive investigation.

To address these limitations, the incorporation of primary sources, such as interviews, could play a crucial role in enhancing the understanding of the subject matter. Interviews provide direct access to first-hand information from individuals who possess direct experience or expertise in the field. This direct engagement empowers students to gather unique insights, perspectives, and personal narratives that are not readily available in secondary sources.

Nonetheless, it is worth noting that the main objectives outlined in this pedagogical case were successfully achieved. This accomplishment can be attributed to the sufficient inclusion of secondary sources, which enabled students to answer the questions arising from the case study. While the reliance on secondary sources proved satisfactory in this instance, the integration of primary sources, particularly interviews, would have further enriched the research process. Such sources would have provided additional depth, authenticity, and first-hand experiences, contributing to a more comprehensive analysis and enhancing the originality of the study.

The primary contribution to academia, particularly for the students, is their acquisition of comprehensive knowledge regarding the principles and challenges associated with adopting the circular economy. They have developed a profound understanding of the interconnectedness between the circular economy and food waste, along with *J.M.'s* commendable efforts in tackling this urgent issue. Additionally, students have become well-versed in *J.M.*'s Seaculture strategy, comprehending its advantages and the benefits it offers. The exploration of the concept of valorising fish by-products and its potential integration within *J.M.*'s Seaculture strategy has been conducted meticulously, alongside an analysis of the impact of the IMT Model on J.M.'s Seaculture strategy.

For researchers, these aforementioned insights manifest as an opportunity to delve further into relatively unexplored concepts, such as the valorisation of fish by-products. Moreover, there exists a noticeable gap in the examination of models that share similar objectives to the IMT Model. This pedagogical case study serves as an enduring foundation for future research and analysis within this specific field. It presents researchers with the prospect of venturing into uncharted territory, uncovering novel perspectives, and expanding the current understanding of these subjects. Building upon the findings of this study, researchers can address existing gaps, conduct comprehensive investigations, and make significant contributions to the advancement of knowledge in this domain.

The contribution of this pedagogical case study to *J.M.* is noteworthy, as it highlights the potential for undertaking a feasibility study to evaluate the viability of implementing circular economy (CE) practices specifically related to fish waste and fish by-product valorisation. By collaborating with industry experts, J.M. can identify best practices and develop tailored approaches that align with their operations. Furthermore, investing in research and development can facilitate the exploration of new technologies employed by models such as the IMT Model. These strategic initiatives have the potential to position *J.M.* as a trailblazer in sustainable practices and significantly contribute to the advancement of circular economy principles within the fish industry.

It is worth noting that other companies within the same realm as *J.M.* can follow similar steps to enhance their efficiency and sustainability. By adopting the findings and recommendations from this case study, these companies can embark on their own feasibility studies, engage with industry experts, and invest in research and development to explore innovative solutions. Such initiatives can propel them towards becoming leaders in sustainable practices within the fish industry and contribute to the wider adoption of circular economy principles.

By embracing a proactive approach and implementing the lessons learned from this case study, *J.M.* and other companies can drive positive change, reduce waste, and foster a more sustainable future for the industry as a whole.

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