Developing skills for introducing circular business models and digital technologies in olive oil sector

D2.1 National Report on current situation in the olive oil sector

- Portugal -

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National Report on current situation in the olive oil sector - Portugal

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Contents

1. Executive Summary

Olive oil production is a very important agricultural activity in Portugal, in particular in the northern region of Trás-os-Montes and Alto Douro, central-north region of Beira and southern region of Alentejo. By-products and waste from the olive oil production sector in Portugal represent significant environmental challenges, but also offer opportunities for innovation and sustainability. By adopting integrated waste management strategies and investing in research and development, Portugal can improve the sustainability of its olive oil industry and contribute to the circular economy.

This report presents the current circular practices and technological gaps in the olive sector in Portugal and analyses the potential of developing a program for vocational education and training on circular business skills in the olive sector in order to adapt the provision of vocational education and training to the emerging needs of circular business skills.

1.1 Background and Purpose

The areas under olive groves, both in Portugal and in the world, are constantly increasing. During olive production and the processing of olive fruits into olive oil, large amounts of by-products and waste are created, such as pruning residues, olive pits, olive pomace and waste water, which should be valorized by circular business practices.

With the aim of reducing the negative impact of the mentioned by-products on the environment, the CIRCOLIVE project will support the EU's transition to a circular economy by improving/strengthening circular business skills in the olive oil sector in Spain, Italy, Greece, Portugal and Croatia, in order to promote the adoption of circular business models for the valorization of waste and by-products from the entire olive sector.

The project will encourage the adaptation of the provision of vocational education and training to the emerging needs for circular business skills in the olive sector by developing transnational curricula.

This National Report will identify the current state and needs of the olive sector for the transition to a circular economy in Portugal.

1.2. Key Findings

This report presents the research results of primary and secondary sources of data on the state of the circular economy in the olive sector and olive oil production in Portugal. Primary sources included field data collection on a planned sample of respondents through a survey and interviews with relevant stakeholders in the olive sector, olive oil production and education providers in Portugal. Secondary data included the analysis of available literature related to this topic. Data was collected on the numerical indicators of olive production, the technologies used in the olive grove, the handling of residues after pruning in the olive grove, the methods and capacity of processing olives into olive oil, and handling of by-products/waste after olive processing. It was possible to check that data regarding the quantities of by-products/waste after olive processing isn´t available in the country. What is more, data on the prevalent circular economy practices in the olive growing sector and oil industry in Portugal was collected, as well as potential portuguese institutions that could provide vocational education and training in the area of the

circular economy. Therefore, the obtained research results provide an insight into the current state of the circular economy in Portugal, and provide an overview of the opportunities, strengths, weaknesses and threats of the implementation of the circular economy in the olive sector and olive oil production.

1.3. Recommendations

Sustainable practices in the olive sector and olive oil production are key to minimising the environmental impact of the olive industry in Portugal. Evidence shows that producers in Portugal already adopt ecological agriculture, and efficient use of water. However, much more has to be done in terms of energy-efficient technologies and strategies for effective management of olive by-products/waste, in order to ensure that in Portugal, olive oil production remains environmentally responsible and economically viable for future generations. The recommendation for a more successful development of the olive by-product/waste market is to establish uniform terminology and legislation in the sector. It is also necessary to support the development of innovative projects in the sector of utilisation and valorization of olive by-products/waste, and to design and offer vocational education and training in the area of circular economy that would motivate and provide the necessary knowledge and skills for implementing circular business models in the olive sector in Portugal. By adopting integrated waste management strategies and investing in research, development and education, Portugal could improve the sustainability of olive oil production and contribute to the circular economy in the olive sector.

2. Introduction

2.1. Overview of the Olive Sector

Portugal represents 6% of Europe's olive grove area and 3% of the world's olive grove area. Despite this, and due to the type of olive grove and production efficiency, Portugal offers 6.42% of its olive oil to the market. In the last 4 harvests (2020-2024), Portugal has doubled its weight in relation to the world and Europe. It is currently among the world's top 10 olive oil producers, with the best proportion of virgin olive oil and extra virgin olive oil in relation to total production. If the current development of the sector continues, both in terms of surface area and production, Portugal will soon become the third largest olive oil producer in the world. If we consider the olive oil sector and the average for the last three years (2020-2022), we can estimate a turnover of more than 850 million euros, approximately double the turnover for the three years 2014-2016 (Olivum, Consulai & Vilar, 2024). By 2022, the sector would account for close to 10% of the value of agricultural production (PORDATA, 2023), reversing the high dependence on imports.

From an environmental point of view, modern olive groves in Portugal are managed according to environmentally sustainable agricultural practices, including plant carbon management, favouring biodiversity, preventing soil erosion, increasing plant mass and, consequently, boosting carbon sequestration and increasing ecosystem services. The initial motivation for triggering growing circularity in the olive sector was undoubtedly economic, due to the problem of pomace and extraction companies. However, thinking has evolved and companies are beginning to understand the social motives (sustainability, collaborative economy, etc.) and the demand for innovation, technology and research as

extremely important, cementing this demand for the transformation of by-products/waste in the sector, which are increasingly generated in greater quantities, given the high level of olive oil production in Portugal.

2.2. Objectives of the Report

The aim of this report is to analyse and investigate current circular practices and technological gaps in the olive oil sector in Portugal, and to encourage adaptation of the provision of vocational education and training to the emerging needs of circular business skills. The report is part of Work Package 2 (Identification of olive sector circular needs and emerging skills and/or professions for transition of the olive oil sector to a circular economy in the 5 countries) of the CIRCOLIVE project (Developing skills for introducing circular business models and digital technologies in the olive oil sector) and represents deliverable D2.1. (National Report on the current situation in the olive oil sector - Portugal).

The review of the available literature and the analysis of the collected data determined the current state of the olive growing sector in Portugal, which will be used in the further work of the project and the creation of a curriculum for vocational education and training on circular business skills in the olive growing sector in Portugal.

3. Methodology

The chapter "Methodology" describes the methods of data collection and their analysis. The aim of the chapter is to inform the reader about the methodology used and the possibility of repeating the study using the same methodology.

3.1. Data collection methods

The data was collected from two data sources: primary and secondary data sources.

Primary data collection involves the process of preparing tools for data collection and collecting data from a planned sample of respondents. Three data collection instruments were prepared for the purposes of this study: a questionnaire and two interview reminders.

The questionnaire was designed with the aim of collecting quantitative data on a sample of olive grove owners which produce oil in service mills, and a sample of olive mill owners who own or do not own olive groves. The questionnaire (ANNEX 1: Online survey targeting MSMEs in the olive sector) contained multiple-choice questions, closed questions, open questions and questions in the form of a Likert scale. The questions related to numerical production indicators, the use of tillage techniques, the treatment of plant residues in olive groves, methods and capacities of olive processing, the treatment of by-products after olive processing and questions on the circular economy in olive growing. The planned sample size was 20 respondents, but data was collected from 25 respondents, namely 16 respondents for the olive grower's category, 6 respondents for the olive grower's and olive mills owners' category and 3 respondents for the olive mill owner category. The questionnaires were collected online via Google forms.

Two interview reminders were also prepared for the qualitative data collection. One interview reminder was prepared for experts in the agri-food sector (ANNEX 2: Structured

interview with circular business agro-food experts/professionals). The other one for providers of education in Portugal (ANNEX 3: Structured interview with VET providers). The reminders contained open questions with sub-questions so that the interview could be conducted as efficiently as possible. The planned sample size was 5 respondents for experts in the agri-food sector and 5 respondents for providers of education, but 6 interviews for experts in the agri-food sector were carried out. Interviews were conducted with respondents through online meetings.

The interviews were recorded and a transcript of the conversation was made. Each respondent has voluntarily and expressly consented to the collection and further processing of personal data and has voluntarily agreed to answer questions for the purpose of research within the CIRCOLIVE project. Each respondent has confirmed this with their signature in the documents: a) Statement related to giving consent for the processing of personal data and b) Information form for participation in research – personal informed consent.

It should be noted that the major olive-growing regions in Portugal are in Alentejo (southern Portugal), Trás-os-Montes and Alto Douro (northeastern Portugal) and Beira Interior (north-central Portugal). For this reason, contact was made with a larger number of olive producers and mill owners in the Alentejo region, followed by those in Trás-os-Montes and, to a lesser extent, Beira Interior, for the purposes of answering the questionnaire and conducting interviews. Nevertheless, the questionnaires were sent to olive producers and mill owners all over the country.

The graph provided shows that the majority of the questionnaire respondents for MSMEs in the olive sector is from the Alentejo (44%), followed by respondents from the north of the country (32%) and the centre (24%).

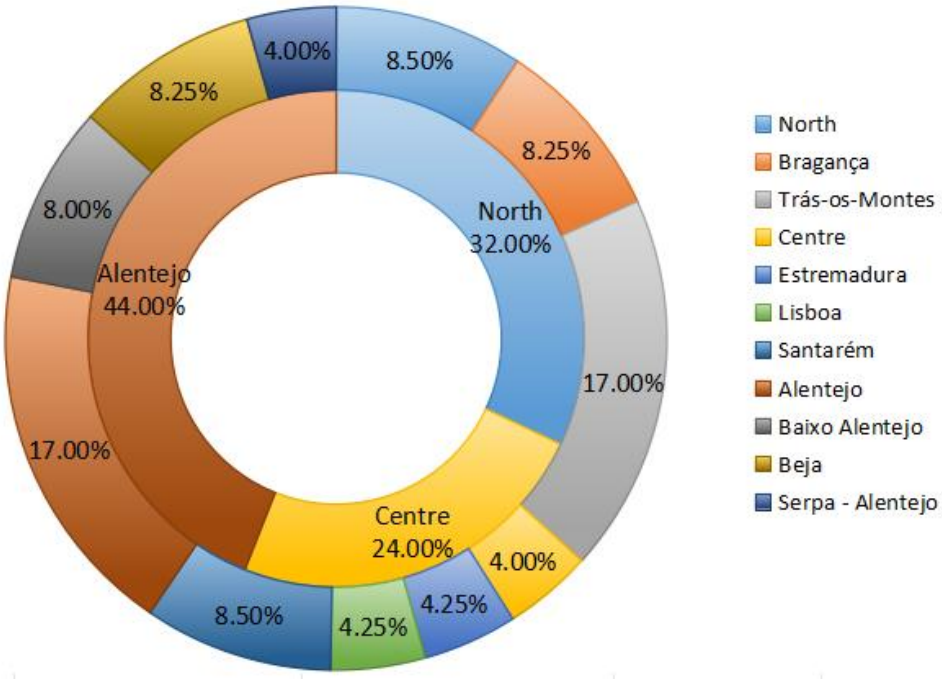

Fig. 1. Region and company location of respondents. The 100% universe corresponds to a sampling of 25 surveys (16 olive producers; 3 olive mill owners and 6 olive producers who are mill owners).

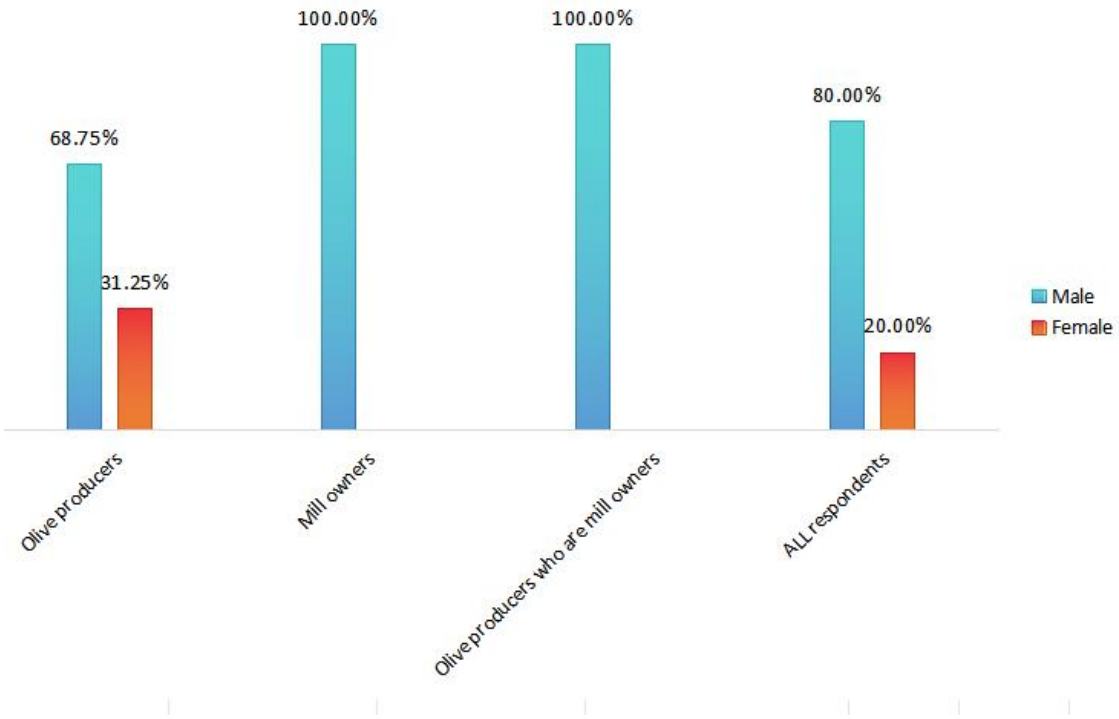

Fig. 2. Respondents gender type. The 100% universe corresponds to a sampling of 25 surveys (16 olive producers; 3 olive mill owners and 6 olive producers who are mill owners).

With regard to the age of the respondents, it can be seen that these professionals in the olive and olive oil production sector are between 40 and 50 years old.

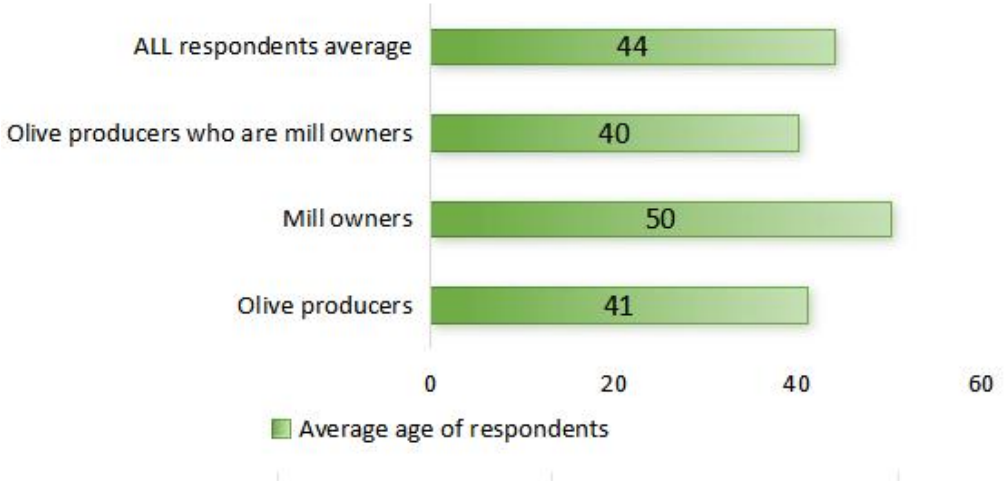

Fig. 3. Average age of respondents by type of respondent. The 100% universe corresponds to a sampling of 25 surveys (16 olive producers; 3 olive mill owners and 6 olive producers who are mill owners).

As for the experts and professionals interviewed from the agri-food sector of circular economy companies, it should be noted that 4 of these professionals are from Alentejo region and 2 of them from Trás-os-Montes region. The 6 interviewees were male and aged between 40 and 58, representing small and medium-sized companies in the sector.

Secondary data is ready-collected data that comes from various sources, e.g: statistical yearbooks, available studies, databases, scientific papers, technical literature, etc. When

using this data, the source is always cited in the report and the list of references used can be found in chapter 13 of this report.

3.2. Data analysis methods

After the data collection was completed, the data analysis was carried out.
Quantitative data collected through questionnaires were analysed using descriptive analysis and response frequencies. The data are presented in the form of tables, graphically through graphs and descriptively.
The data collected through the interviews were processed through a content analysis. The interviewees' answers are presented in the form of a description with reference to the type of interviewee in the interview (example: Interview with education stakeholder; Interview with by-products/waste from olive sector stakeholder; Interview with olive growing and oil production stakeholder).

4. National Context

4.1. Geographic and Climatic Overview

Portugal, with its geographical and climatic diversity, offers unique conditions for olive growing and is one of the main producers of olive oil in Europe. In this regard, the following is a detailed analysis of Portugal's geographical and climatic panorama, with a specific focus on the cultivation of olive trees (Olivum, Consulai & Vilar, 2019).

A. Portugal Geography and Distribution of Olivet

Portugal is situated on the south-western tip of Europe, on the Iberian Peninsula. The country's geography is varied, with a combination of plains, mountains, valleys and plateaus. This topographical diversity directly influences the regional climate and, consequently, the cultivation of olive trees, particularly in the following regions of the country (Vasconcelos, M. F. P. (2008). *Contribution to the study of the characterisation of the olive and olive oil sectors in mainland Portugal* (Master's dissertation). Technical University of Lisbon, Higher Institute of Agronomy.):

- **North and Centre:** They are characterised by a more rugged topography, with mountains and deep valleys. These regions have less favourable soils for traditional olive growing, due to higher acidity and wetter climatic conditions. However, in inland areas, such as Trás-os-Montes and Alto Douro and Beira Interior, where the soils are predominantly limestone and granite, olive growing is viable, especially for varieties that tolerate more extreme climatic conditions.
- **South (Alentejo and Algarve):** The Alentejo, in particular, is a vast region of plains and gentle hills, with soils rich in limestone and clay. This area is the most productive in terms of olive growing in Portugal, accounting for a large proportion of national olive oil production. The Algarve, with its even hotter and drier climate, is also suitable for growing olive trees, albeit on a smaller scale.

B. Portugal's Climate and Its Influence on Olive Growing

Portugal has a Mediterranean climate, characterised by hot, dry summers and mild, wet winters. However, the country is also influenced by the Atlantic Ocean, which moderates temperatures and increases humidity in coastal areas, especially in the north. The following main characteristics of the country's climate can therefore be identified:

- **Mediterranean climate:** Predominant in the centre and south of the country, the Mediterranean climate is ideal for olive growing. Olive trees need long periods of sunshine and little water during the growing season, conditions that are perfectly catered for in the Alentejo and Algarve regions. The hot summers, with average temperatures that can exceed 30°C, and the rainy winters (with average annual rainfall of between 400 and 800 mm) create the ideal environment for cultivation.
- **Atlantic influence:** In the coastal areas of the north and centre, the climate is more temperate and humid, which can limit the expansion of olive groves due to the higher occurrence of fungal diseases associated with humidity. Lower winter temperatures and less sunlight are also limiting factors.
- **Continent interior:** In the more inland regions, the climate is more extreme, with very hot summers and cold winters, but with low annual rainfall, which favours varieties that are resistant to drought.
- **Semi-arid climate:** In the Alentejo and parts of the Algarve, rainfall is low and summer temperatures are high, which creates almost ideal conditions for large-scale olive growing, provided there is efficient water management.

C. Climate Challenges and Impacts of Climate Change

Climate change represents a growing challenge for olive growing in Portugal, especially in the Alentejo, which already faces extremely dry and hot summers. Therefore, in the future, the olive sector in the Alentejo will have to face the following challenges (Branquinho, S. S. (2020). *Definition of adaptation measures to climate change in the irrigation of super-intensive olive groves in the Alentejo region* (Master's dissertation). University of Lisbon, Higher Institute of Agronomy):

- **Global Warming:** Studies indicate that global warming is causing a gradual increase in average annual temperatures in Portugal. Projections show that by 2080, temperatures could rise by up to 2°C in southern olive-growing regions such as the Alentejo. This could lead to greater evapotranspiration, reducing the availability of water in the soil, which is crucial for olive trees during the dry season.
- **Reduced Rainfall:** A significant decrease in rainfall is expected, especially during the summer months, further exacerbating the water stress on olive trees. Annual rainfall could fall by up to 90 mm, increasing the need for efficient irrigation systems to maintain olive grove productivity.

D. Adaptation and Sustainability Measures

To mitigate the impacts of climate change, irrigation is an essential adaptation measure, especially in the Alentejo. Applying water at critical times, through drip irrigation systems, can help compensate for productivity losses caused by water stress. The following must therefore be guaranteed:

- **Water efficiency:** Due to the scarcity of water resources, it is essential to implement efficient irrigation strategies, where irrigation is applied in such a way as to minimise water use while maximising efficiency in the use of available resources.

- **Sustainability:** Sustainability is a pillar of modern Portuguese olive growing. Practices such as soil conservation, the choice of more resistant varieties and integrated water management are essential to guarantee the long-term viability of olive growing in Portugal.

In short, Portugal, with its diverse geography and predominantly Mediterranean climate, offers ideal conditions for olive growing, especially in the Alentejo and Algarve regions. However, climate change imposes significant challenges, particularly in relation to rising temperatures and reduced rainfall. Adaptation measures, such as efficient irrigation and sustainable management, will be crucial to ensuring that Portugal remains a global leader in the production of high-quality olive oil. The Alentejo, with its focus on innovation and sustainable practices, continues to lead olive growing in Portugal, and the production of high-quality olive oil in the country is fundamental for the economy and the consumer.

4.2. Historical Development of Olive Cultivation

The history of olive growing in Portugal is rich and deeply rooted in the country's agricultural traditions, so it's important to take a brief look at its historical evolution, from ancient times to modern times (Soares, I. C. (2022). *The impact of sustainable tourism on environmental conservation in coastal regions* (Master's dissertation). Polytechnic Institute of Leiria).

The introduction of the olive tree to Portugal dates back to ancient times, probably brought by the Phoenicians or the Greeks during the first millennium BC. However, it was during Roman rule (around 200 BC to 400 AD) that olive growing really took hold in the Iberian Peninsula, spreading to the Alentejo and Algarve regions, where climatic conditions and soils were particularly favourable.The Romans were masters of agriculture and quickly recognised the potential of the olive tree, cultivating it extensively for the production of olive oil, an essential product for food, lighting and medicinal uses. The olive oil produced in Lusitania (the Roman province that included a large part of present-day Portugal) was exported to other parts of the Roman Empire, demonstrating the economic importance of this crop from an early stage.

After the fall of the Roman Empire, olive growing in Portugal suffered a period of stagnation, but never completely disappeared. During the Middle Ages, under the influence of the Christian kingdoms and the Muslim incursions into the Iberian Peninsula (18th century), olive oil production continued, but on a smaller scale, focused mainly on local consumption. It should be noted that the Arabs introduced new irrigation and cultivation techniques, which improved the productivity of the olive groves.

With the arrival of the Age of Discovery in the 15th century and Portugal's subsequent maritime expansion, Portuguese agriculture, including olive growing, began to diversify. During the 17th and 18th centuries, demand for olive oil grew, driven by its use in cooking and lighting, as trade expanded. However, it wasn't until the 18th century that olive growing in Portugal began to gain momentum again, with the introduction of more modern farming practices and a greater emphasis on the quality of the product. Olive oil became a more important commercial product, both for the domestic market and for export.

The 19th century marked a turning point for olive growing in Portugal, as industrialisation began to influence agriculture. Olive oil production began to be organised along more industrial lines, with the creation of modern mills and the introduction of new extraction techniques, as well as improvements in cultivation techniques.

The 20th century brought both opportunities and challenges for olive growing in Portugal. The two world wars and subsequent economic instability affected agriculture in general, including olive growing. However, after the Second World War, there was a renewal of agriculture in Portugal, with the then government encouraging the intensification of agricultural production, namely the cultivation of olive trees, especially in the traditional regions of Alentejo and Trás-os-Montes. Olive growing benefited from new planting and irrigation techniques, although it also faced challenges such as competition from other producing countries and fluctuations in the global olive oil market.

Finally, Portugal's accession to the European Community in 1986 brought new incentives and subsidies that helped modernise Portuguese agriculture, making it possible to plant 30,000 new hectares of olive groves (Olivum, Consulai & Vilar, 2019). Olive growing, in particular, saw a significant renewal, with the introduction of new varieties of olive trees, advanced cultivation technologies through the approval of the National Plan for Olive Growing and a focus on olive oil quality to compete in the European market.

In the 21st century, olive growing in Portugal has become an example of innovation and sustainability. The introduction of canopy and hedgerow cultivation techniques, which allow for a higher density of olive trees per hectare, and the use of drip irrigation systems, combined with major investments in technology, have made it possible to increase productivity and efficiency in the use of resources. The Alentejo, with its vast areas of plains and dry climate, has become the main olive oil producing region in Portugal, accounting for a significant part of national and international olive oil production by leading the way in modern olive growing.

With increasing environmental concerns and climate change affecting global agricultural production, Portugal has been investing in sustainable olive growing practices, such as the efficient use of water and the choice of more climate-resistant olive tree varieties. These efforts are essential to ensuring the long-term viability of olive growing in Portugal, facing climate challenges and maintaining the quality and competitiveness of Portuguese olive oil on the global market.

To summarise, olive growing in Portugal has a long history that reflects the social, economic and climatic transformations the country has faced over the centuries. From its origins in Roman times to its current status as a leading producer of high-quality olive oil, Portugal has shown a continuous capacity to adapt and innovate. The history of olive growing in Portugal is therefore a narrative of resilience and evolution, with a promising future as the country continues to face the challenges and opportunities of the 21st century.

4.3. Regulatory Framework and Government Policies related to olive production by-products

The regulatory framework and government policies related to the by-products of olive production in Portugal are an integral part of a broader strategy of sustainability, circular economy and compliance with European Union directives. Let's take a look at some of the regulatory aspects and policies in force that influence the sector in Portugal ((APA. (2023). *Declassification of Waste - Clarification Session, 1 February 2023*. Portuguese Environment Agency.) ; (APA. (2020). *Waste Classification Guide (Version 2.0)*. Portuguese Environment Agency.)).

National legislation (Portugal)

- **Law no. 52/2015 - Water Law:** Transposes the Water Framework Directive into the Portuguese context, requiring agricultural and industrial activities, including the olive sector, to implement measures to protect water quality. This is particularly relevant for the management of wastewater from olive mills (Portugal. (2015). *Law No. 52/2015, of June 9*. Diário da República, 1st series, No. 110. - https://diariodarepublica.pt/dr/detalhe/lei/52-2015-67442930).
- **Decree-Law 73/2011 - General Waste Management Regime:** Establishes the rules for waste management in Portugal, including agricultural by-products (Portugal. (2011). *Decree-Law No. 73/2011, of 17 June*. Diário da República, 1st series, No. 116. - https://diariodarepublica.pt/dr/detalhe/decreto-lei/73-2011-670034).
- **Rural Development Programme (PDR 2020):** This programme includes specific measures to support the modernisation and sustainability of agricultural activities in Portugal. Among its various lines of action, there are incentives for investments in technologies to valorise olive by-products, such as energy cogeneration systems and wastewater treatment technologies (http://www.pdr-2020.pt/).

Government Policies and Initiatives

- **National Waste Strategy (ENR 2020):** ENR 2020 aims to promote waste recovery and reduce the environmental impact of waste management in Portugal. In the olive sector, the strategy encourages practices that enable the reuse of olive pomace and the reuse of wastewater.
- **Biomass Valorisation Initiatives:** The Portuguese government, in partnership with private entities and agricultural cooperatives, has been promoting the use of biomass (including olive pomace) for energy production. This is encouraged through subsidies and funding programmes for the installation of cogeneration units in mills.
- **National Sustainable Agriculture Policy:** As part of the National Plan for Sustainable Agriculture, this policy covers the management of olive by-products, promoting agricultural practices that minimise environmental impact and encourage the recovery of waste. It is important to mention the recent Resolution of the Council of Ministers no. 97/2021 (Portugal. (2011). *Decree-Law No. 73/2011, of 17 June*. Diário da República, 1st series, No. 116.

https://diariodarepublica.pt/dr/detalhe/decreto-lei/73-2011-670034), which deals with the recovery of agricultural by-products and waste from the agri-food industry, prioritising the recovery of olive pomace, namely through composting and integration into the process of recovering livestock effluents.

Support and Funding Initiatives

- **Tax Incentives:** Some tax policies in Portugal offer deductions and tax benefits for companies that invest in waste treatment and recovery technologies. Plants that adopt sustainable practices may qualify for these incentives.

Participation in Networks and Partnerships

- **Cooperation Networks:** The olive sector in Portugal has benefited from cooperation networks and partnerships, both at national and European level, which facilitate the sharing of good practices and access to new technologies for valorising by-products.
- **Public-Private Partnerships:** The Portuguese government has encouraged public-private partnerships for by-product management, promoting innovation and the adoption of cutting-edge technologies through collaboration between public entities, universities and private companies.

This regulatory and government policy landscape reflects an ongoing effort to make the olive sector in Portugal more sustainable, innovative and competitive on the global stage. The waste management hierarchy, established by the European Union and applied in Portugal, prioritises prevention, reuse and recycling before disposal. The valorisation of by-products is a central part of this strategy, which aims not only to comply with environmental standards, but also to create new economic opportunities and promote more sustainable agriculture, but there is no consensus when it comes to the olive pit. The **olive pit** can be classified **as either a by-product or waste**, depending on how it is treated after it is generated. The distinction between by-product and waste is made on the basis of the criteria established by **Decree-Law 73/2011**, which regulates waste management in Portugal.

- **Sub-product:** If the olive pit is reused directly, without the need for additional treatment, in processes such as **biomass production**, biofuels or composting, it is classified as a **sub-product**. This classification is possible when the material results from a production process and is destined for viable and sustainable reuse, taking into account quality and safety criteria (Portuguese Environment Agency: https://apambiente.pt/residuos/subprodutos).
- **Waste:** On the other hand, if the olive pit has no immediate useful application and is discarded or sent for disposal treatment (such as landfill), it will be classified as **waste**. In this case, it needs to be managed in accordance with agricultural waste regulations, complying with environmental directives on storage and treatment (Rural Network: https://inovacao.rederural.gov.pt/grupos-operacionais/13-

projectos-groupos-operacionais/98-tecnicas-e-tecnologia-para-valorizacao-de-subprodutos-em-olivicultura-tecolive) (Liferay DXP: https://agricultura.gov.pt/olivicultura-e-azeite).

Classification therefore depends on the i**ntended use** and **subsequent treatment** of the pit. If it is reused efficiently, it is a **sub-product**; if it is discarded without useful application, it becomes **waste**.

The olive sector's preference for classifying olive pits as by-products reflects a combination of practical, economic and regulatory considerations. Although the circular economy offers a vision of long-term sustainability, the immediate challenges faced by producers, such as costs, saturated markets, and regulatory complexity, may lead the sector to look for a classification that offers greater flexibility and economic viability in the short term and that simplifies regulatory and logistical processes, decreases recovery obligations and reduces economic burdens through access to subsidies and incentives and tax exemptions.

5. Olive Production Analysis and Olive Oil Processing

5.1. Cultivation Practices and Varieties

The major olive-growing regions in Portugal are located in Trás-os-Montes (north-east of the country), Beira Interior (north - centre of the country), Ribatejo, Oeste and Alentejo (south of Portugal). According to 2019 data, traditional olive groves occupy a total area of 140,000 hectares (37.2% of the total area), with a greater expression in the regions of Beira Interior and Trás-os-Montes. Modern canopy olive groves occupied a total area of 125,000 hectares (33.2% of the total olive grove area) and were represented in all regions of the country (Olivum, Consulai & Vilar, 2019), although in 2024 they were most prevalent in the Alentejo region. It should be noted that in 1999, only 2% of the total olive grove was modern, meaning that over the last 20 years, Portuguese olive groves have undergone a profound transformation, i.e. from a traditional and uncompetitive olive grove to a modern and efficient olive grove, with all the direct and indirect benefits that this generates. Modern irrigated olive groves (hedgerow production systems with high planting densities), which exist most prominently in the region covered by the irrigation perimeter of the Alqueva barrage in the Alentejo region, have sparked some public discussion about the environmental sustainability of these modern olive grove management systems, particularly when compared to the traditional crops grown (characterised by lower planting densities) in the rainfed and traditional olive groves of the Trás-os-Montes and Beira Interior region.

Despite this discussion, various studies have identified good practices to promote soil conservation in olive groves, including the incorporation of crop residues into the soil, particularly pruning residues, frequent applications of organic matter to the soil in order to increase its water retention capacity and avoiding inter-row tillage in order to reduce the accelerated mineralisation of organic matter and promote carbon sequestration in the soil

(AGRO.GES – Sociedade de Estudos e Projetos, Lda. (2022). *Sustainability of olive groves in Portugal: Challenges and responses*. Princípia Editora).

In the questionnaire sent to the PMES in the olive sector, the producers' responses highlight some of these practices, addressing issues that are central to understanding agricultural practices in the cultivation of olive groves and their preferences regarding technology, soil management and pruning.

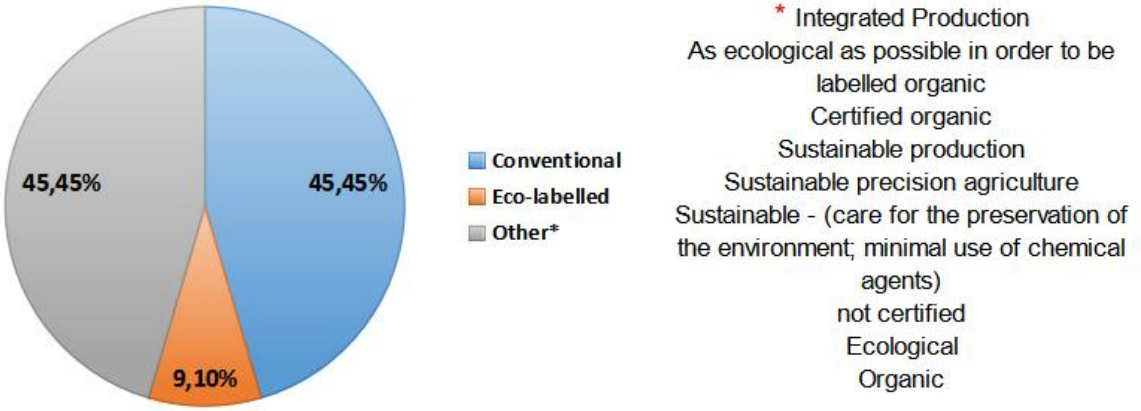

Fig. 4. Technology used in olive groves. The 100% universe corresponds to a sampling of 22 surveys (16 olive producers and 3 olive mill owners).

The following preferences were noted:

- **Conventional (45.45%):** The majority of producers surveyed use conventional cultivation methods, the main aim of which is to maximise olive yields. This indicates that although there is growing concern about sustainable practices, the quest for greater productivity still prevails.
- **Other (45.45 %):** A considerable group adopts ecological practices, which prioritise environmental preservation and the minimal use of chemical agents. This group reflects a growing trend towards more sustainable olive growing, possibly motivated by market and regulatory demands.
- **Ecological/Organic (9.10 %):** Despite a lower level of adherence, this group focuses on certified practices and eco-labelling, indicating a concern for the authenticity and quality of the products on offer.

With regard to the type of land management, there are the following preferences:

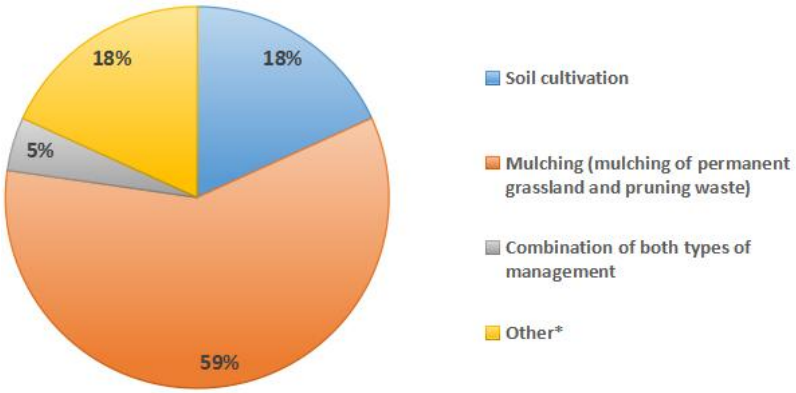

Fig. 5. Type of soil management in your olive grove. Where it says Other*, the respondents answered: At the moment nothing; Annual mobilisation; weed cutting; inter-row sown grass. The 100% universe corresponds to a sampling of 22 surveys (16 olive producers and 3 olive mill owners).

Mulching (59 %): Most producers favour mulching, which involves covering the soil with pruning waste or permanent grassland. This practice is beneficial for retaining moisture in the soil, controlling weeds and improving soil fertility, reflecting a more ecological and sustainable approach.

Soil cultivation (18 %): There is still significant adherence to traditional ploughing, which involves direct cultivation of the soil. Although effective for some operations, it may be less sustainable in the long term due to the possible impact on soil structure and increased erosion.

Combination of Methods (5%): Some producers choose to combine different soil management techniques, possibly in order to optimise the benefits of each method and minimise their negative impacts.

Other (5%): A small percentage of producers mention another type of approach, such as: nothing at the moment; annual tillage; mowing; inter-row sown grass. These options may reflect a more diversified and adaptable approach to soil management. Producers who opt for these practices may be responding to specific conditions in their soil and environment, or experimenting with methods that they consider more suitable for their particular needs. Each of these practices has its pros and cons, and the choice depends on multiple factors, including climatic conditions, soil type, and production objectives. It should be noted that inter-row tillage is the most effective soil management system, significantly reducing soil erosion and improving soil structure, and it plays a key role in weed control in olive groves.

With regard to the practice of pruning, the producers who responded said the following:

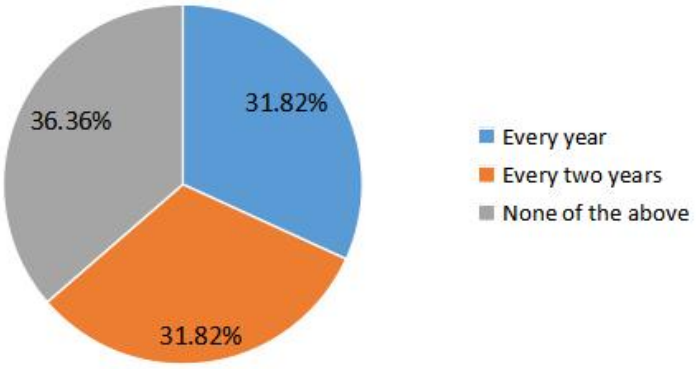

Fig. 6. Intensity of Winter pruning in olive groves. The 100% universe corresponds to a sampling of 22 surveys (16 olive producers and 3 olive mill owners).

- **Annual pruning (31 %) and biennial pruning (31 %):** Pruning is a common practice, with an even split between those who do it annually and biennially. Regular pruning is essential to maintain the health of the tree, control growth and improve fruit production.
- **No Regular Pruning (36 %):** A significant proportion of producers do not follow a fixed pruning regime, which may indicate different management strategies or even challenges in the regular maintenance of olive groves.

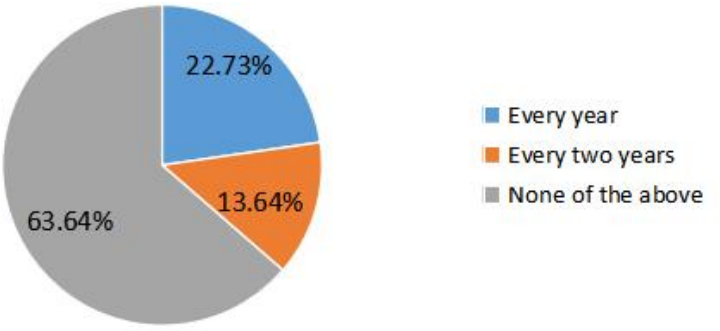

Fig. 7. Intensity of Summer pruning in olive groves. The 100% universe corresponds to a sampling of 22 surveys (16 olive producers and 3 olive mill owners).

- **No summer pruning (63 %):** Most growers choose not to carry out summer pruning, which is lighter and focussed on removing new shoots. This may be due to prioritising more robust winter pruning practices, or simply a management strategy that minimises summer interventions.
- **Annual pruning (22 %) and Biennial pruning (13 %):** Those who carry out summer pruning do so consistently, either annually or every two years. This practice helps to improve air and light circulation, which is beneficial for tree health.

These results show an olive sector in Portugal that is still largely dominated by conventional practices, but with a growing presence of sustainable and ecological methods. Soil management through mulching is predominantly adopted, reflecting an environmental awareness. However, pruning practices vary significantly, which may indicate different regional approaches or grower-specific challenges. The diversification of practices and the adoption of more sustainable techniques are trends that are likely to continue to grow, especially with the pressure to reduce the environmental impact of agricultural production.

5.2. Olive Oil Extraction Methods

According to data from INE - Portugal's National Statistics Institute (2023), there are a total of 455 olive oil mills in Portugal, of which 69% are industrial mills, almost 21% are cooperative mills and 10% are private mills. In recent years there has been a downward trend in the number of mills - in 2018 there were 462 - demonstrating the need to invest in structures with greater capacity and greater production efficiency.

Portugal's mills are distributed throughout the country, with almost 46% in the Centre, 26% in the Alentejo, 25% in the North, 2% in the Algarve and just 1% in the Lisbon Metropolitan Area. In the particular case of the Alentejo, it should be noted that around 50 per cent of the region's mills are located in the Alqueva area.

Despite the continuing downward trend in the number of mills over the years, there has been an increase in the quantity of olive oil produced and an improvement in the quality of the oil. This is due to greater industrial investment in technology, making mills more efficient, and modernisation and production techniques, such as the introduction of irrigation, resulting in greater olive profitability (INE, 2023). In other words, the hedgerow olive grove, from the start of research and planting in 1995, led to a transformation in olive growing, but also in the processing industry, especially in the Alentejo, where its prosperity was very significant. This has led to the emergence of mills with larger capacity models, greater versatility and more functionalities, enabling Portugal to house the most

innovative mills in the world. It should be noted that eight of the ten mills in the world that mill the largest volume of olives are located in Portugal, with capacities of between 60 and 110 million kilos of olives per campaign. Each of these mills has several production lines, which include receiving the fruit, prior collection, milling, separation, filtration and storage.

This development has also been boosted by the environmental problems associated with the discharge of raw water (a continuous three-stage extraction system dating back to the early 1970s) and increased regulatory pressure, especially the legislation of 2000, which has led to the search for new olive oil production technologies and, consequently, the closure of many units, as well as the modernisation of some mills or the construction of new units from scratch. In response to environmental requirements, consumer demands and technological advances, the installation of two-stage continuous extraction processes has grown significantly. In 2022, this two-stage extraction system became the most installed, with 270 mills in operation (59% of the total), four times more than the number of mills in operation in 1997. A two-stage continuous extraction system makes it possible to produce high-quality olive oil, which is highly valued on the market, as it allows olives to be processed more quickly, reducing exposure to factors that can degrade the quality of the oil while preserving its organoleptic characteristics (Olivum, Consulai & Vilar, 2024).

The respondents to the questionnaire applied to olive growers and olive oil producers will therefore show that two-stage centrifugation is the predominant extraction method, and is considered the most efficient type of mill with the best environmental performance.

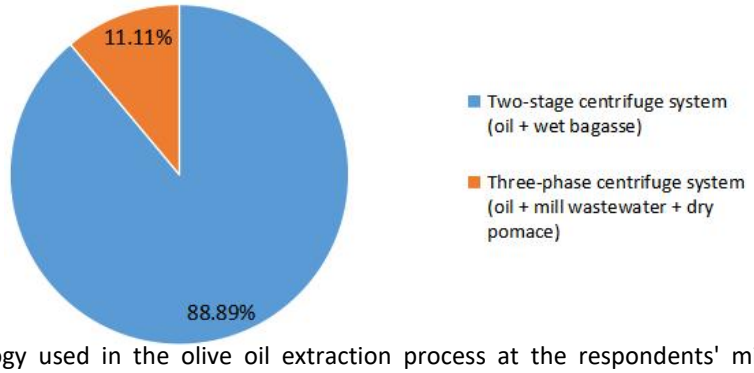

Fig. 8. Technology used in the olive oil extraction process at the respondents' mill. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

It should also be noted that no other olive oil extraction technology was found, apart from the two presented.

It is also worth mentioning the possibility of olive oil extraction returning to a three-stage system, making it possible to utilise wastewater once again. An indicator of this possibility is the prototype of a very innovative decanter presented by Gea Westfalia at the World Olive Oil Congress held in Madrid from 26 to 28 June in 2024. The prototype of this equipment, whose technology has been patented, will allow water to be separated from its organic compounds, resulting in concentrated syrups rich in tyrosol, hydroxytyrosol and polyphenols. The possibility of separating the different components and marketing them to different industries, i.e. the cosmetics industry, the agri-food industry and the pharmaceutical industry, will give the once undervalued raw water another kind of importance, providing an additional source of income for the mills.

5.3. Cultivation area, Yield Trends and Production Statistics

Over the years, we have seen a slight increase in Portugal's olive grove area, which in 2020 reached a maximum of 380,852 hectares, corresponding to an increase of 7% in relation to the olive grove area 20 years ago (Olivum, Consulai & Vilar, 2024).

As indicated in the previous chapter, the major olive-growing regions are in the Alentejo (southern Portugal), Trás-os-Montes and Alto Douro (north-eastern Portugal) and Beira Interior (north-central Portugal), although olive groves can be found throughout Portugal. In recent years, there has been an increase in the Alentejo area, which currently accounts for around 55% of the total national olive grove area.

It should also be noted that in terms of the evolution of the olive grove area in Portugal, there has been an increase in the modern area (mainly in the Alentejo) and a decrease in traditional olive groves (mainly in Trás-os-Montes and Beira Interior), which have in many cases been abandoned or transformed into modern olive groves. This demonstrates the country's commitment to modernising the crop and making it more profitable, and it was the first country to start converting modern canopy olive groves into modern hedgerow olive groves.

Currently, and as a result of the modernisation of olive groves and mills, national olive oil production has been growing, reaching 1,350,238 tonnes in 2021. In 2022, production was 74% lower than in 2021, due to the fact that this was a year of counter-harvest and drought. In 2022, the Alentejo accounted for 87% of national olive oil production (Olivum, Consulai & Vilar, 2024).

In **Table 1.** we can see the national production of olive oil in 2023 and its distribution by region.

Table1. Olive production (tonnes) by place of origin (Agrarian Region); Annual - INE, annual survey of olive oil production. Data reference period: 2023. Data last updated on: 13th July 2024.

Place where the olives come from (agricultural region)	Olive production (t) by place where the olives come from (agricultural region); Annual
	Data reference period
	2023
	t
Portugal	1176087
Between Douro and Minho	1312
Trás-os-Montes	93520
Coastline	20496
Inland Coast	36795
Ribatejo and Weast	45247
Alentejo	972357
Algarve	6360
Açores	0
Madeira	0

It should be noted that the evolution of production in Portugal by type of olive grove shows the entry of hedged olive groves in the last four marketing years, allowing for an increase in the pace of production, thus made possible by the application of technology in modern, efficient irrigated olive groves. This situation is most noticeable in the Alentejo region, mainly due to the Alqueva Multipurpose Development on the River Guadiana.

With regard to the data obtained during the online survey of MSMEs in the olive sector, the following can be seen:

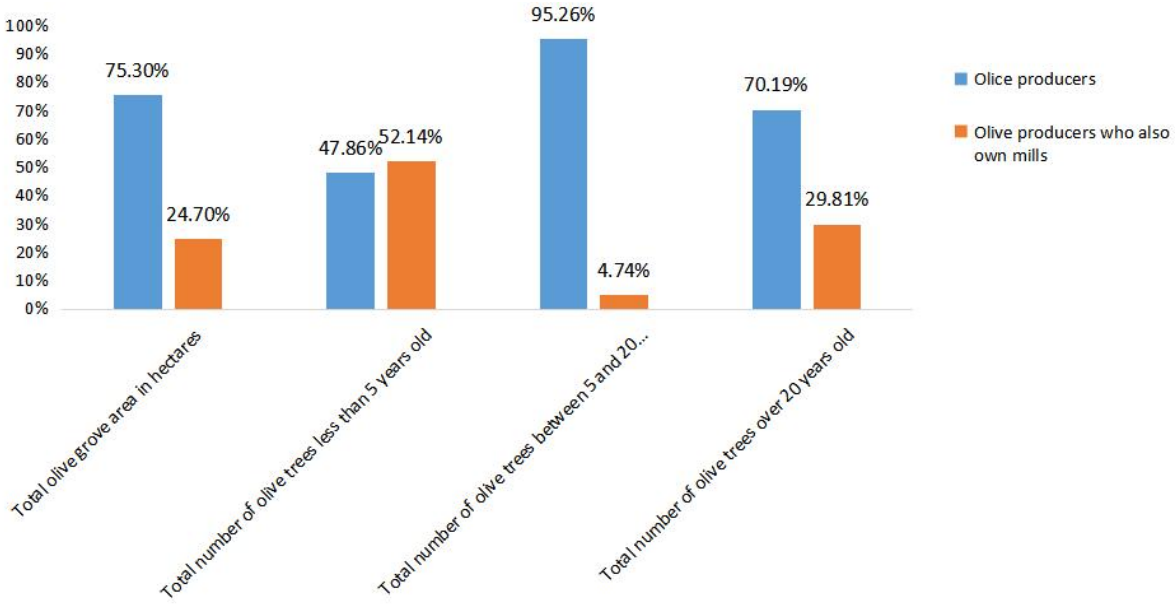

Fig. 9. Volume and characteristics of the company's olive production. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

The majority of the cultivation area is dominated by olive producers, with 75.30 % of the total olive grove area belonging to this group. This suggests that most production is concentrated in large olive groves dedicated exclusively to olive production. Despite having a significant presence, the majority of producers who also own mills have smaller cultivation areas, possibly because part of their focus is on processing the olives.

The predominance of olive trees less than 20 years old indicates a dynamic sector that invests in renovating and modernising olive groves. The age distribution of the trees may be strategic, with young trees guaranteeing long-term continuity of production, while older trees contribute a stabilised yield.

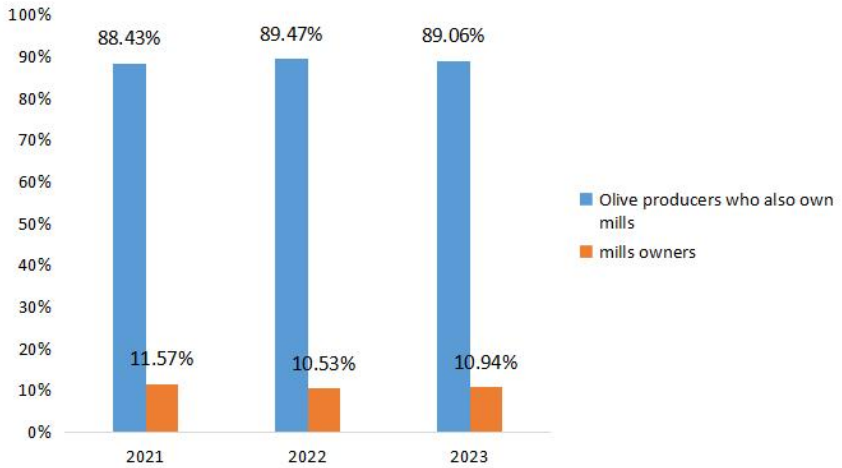

Fig. 10. Graph of the quantity of olives processed in the last 3 years, with a comparison between mill owners and olive producers who also own mills. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

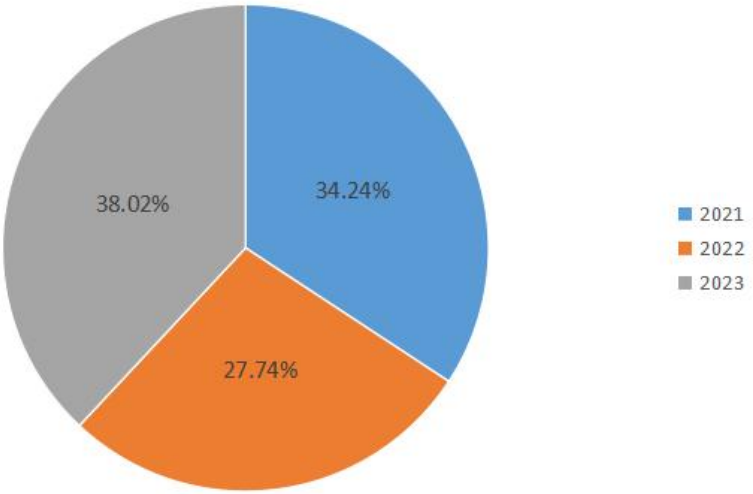

Fig. 11. Graph comparing the quantity of olives processed over the last 3 years, not making a distinction between owner/producer. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

The amount of olives processed by the "olive mill owners" group has remained stable over the last three years, suggesting consistency in production, which may be the result of efficient management of olive groves and processing, but could also be an indication that they have reached saturation point in processing capacity or that production is influenced by external factors such as weather conditions and labour shortages. In the "olive producers who also own mills" group, there has been an increasing amount of olives processed, with a slight increase from 0.34 to 0.38 over the last three years. This indicates a positive trend in yields, possibly due to improvements in cultivation practices, favourable conditions for the sector, the expansion of its cultivation operations or greater efficiency in the processing of olives.

In conclusion, analysing the data confirms that the olive sector in Portugal is constantly evolving, with a strong trend towards the renewal of olive groves and an increasing focus on improving yields and efficiency. The predominance of young olive groves suggests continued investment in modern cultivation practices, while production statistics show general stability with potential for growth. These indicators are promising for the long-term sustainability of the sector, especially if combined with sustainable cultivation practices and the efficient use of resources.

With regard to the information obtained through interviews with experts and professionals (4 from the Alentejo region and 2 from the Trás-os-Montes e Alto Douro region) in the agri-food sector from circular economy companies, it is worth noting that the Alentejo has the largest area of modern olive groves, allowing for less time-consuming harvesting, carried out at the right time and in a mechanised way, contributing to an improvement in the quality of the olives and the oil produced. For this reason, the weight of extra virgin olive oil is significant in Portugal, not only because of the high percentage of modern, mechanised olive groves, but also because of the considerable development of olive oil mills, with the largest modern, high-capacity industrial park in the world.

As a result, Portugal's production went from 24,600 tonnes in the 2000/01 harvest year, representing 1% of world production, to producing around 210,000 tonnes, with a world weight of 4%, in the 2021/2022 marketing year, representing growth of 320%, which is higher than the world average (140%) (Olivum, Consulai & Vilar, 2024).

The increase in productivity of Portuguese olive groves was therefore much greater than that of other producing countries, allowing Portugal to go from ninth to sixth producer in just four marketing years.

The type of production model also affects the productivity of olive groves. While traditional olive groves are more affected by drought and climatic conditions, modern irrigated olive groves, predominant in Portugal's Alentejo region, benefit from extra water and are better protected from rainfall, tending to have more stable productivity.

6. By-products and Waste Production in the Olive Sector

Between 2019 and 2024, Portugal's olive sector has made significant progress in terms of producing and valorising by-products and waste. Olive oil production in Portugal generates a series of residues and by-products, the most common of which are olive pomace, wastewater (alpechins, alperchins or aqua-ruça) and olive pits. These residues and by-products have been the target of new strategies and technologies to mitigate their environmental impact and economically valorise the sector.

The increase in the national olive grove area (377.000 hectares) and the growing conversion of traditional olive groves into modern potted and hedgerow olive groves, which already occupy more than 1/5 of the olive grove area for olive oil, provide an ever-increasing availability of by-products resulting from this crop (INE, 2021). The olive oil extraction industry also produces huge quantities of by-products and waste. Only 20% of the weight of olives can be extracted into oil, and the waste represents four times more than the product of interest. In 2021, more than 900.000 tonnes of olives were processed per harvest, giving rise to huge volumes of by-products, which had to be converted into new resources (INE, 2021).

During the research carried out for this report, it emerged that there is no survey in Portugal of the quantity of by-products and waste produced and marketed throughout the country, although in the Alentejo region, given the existence of modern mills and larger bagasse drying companies, this task is more easily achievable. To this end, some of the main producers and agents in the sector were contacted in order to provide an estimated figure for this production and commercialisation in 2023 and 2024. However, since no timely response was received, which is necessary for presenting this data in this report, this survey is presented in the document as a recommendation.

Notwithstanding the above, it is important to mention the provisional data presented by the National Statistics Institute (INE) in Portugal, regarding the amount of olive oil produced from 1995 to 2019, and the amount of pomace commercialised in that period, as well as the amount of pomace produced between 2004 and 2019.

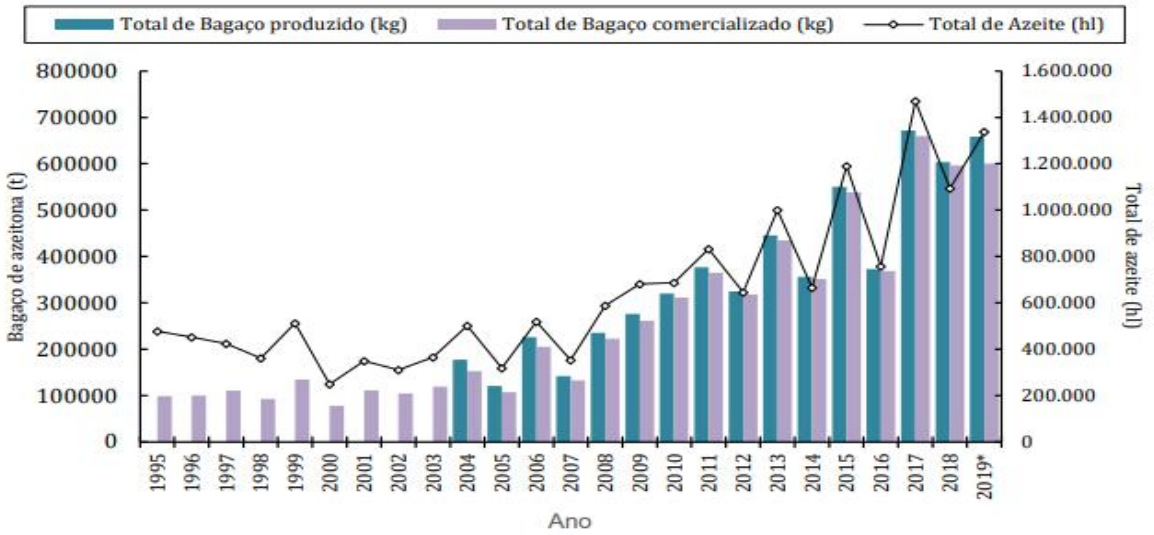

Fig.12. - Total production of olive oil and olive pomace produced and commercialised. Source: INE, 2020. (* provisional data according to INE). Legend to consider: Bagaço de azeitona (t) - Olive Pomace (t); Ano - Year; Total de azeite (hl) - Total olive oil (hl); Total de Bagaço produzido (Kg) - Total olive pomace produced (Kg); Total de Bagaço comercializado (Kg) - Total olive pomace commercialised (Kg).

There has thus been a growing increase in the production of pomace, but the data for 2019 is provisional, according to INE. The production record was reached in 2021 as a result of the high quantity of olives produced that year. It should be noted that this situation led to constraints on olive oil production by the mills, given that the high amount of pomace directed to the pomace reception and extraction units led to the exhaustion of their maximum installed capacity and, consequently, to the suspension of the reception of pomace, forcing the mills to stop working, limiting the olive harvest.

The problem is expected to worsen in the coming years, and it is necessary to study how to increase the storage and processing capacity of these by-products in the mills, as well as how new industrial units should be authorised and built (Olivum, Consulai & Vilar, 2024). However, this situation has led producers to invest more in composting, allowing them to put pomace to other uses and to anticipate future problems in its disposal to pomace reception and extraction units. Despite the above, in the regions with the highest pomace production, which is likely to increase in the coming years, in parallel with the rise in olive oil production, investment in biogas companies is the way to guarantee a circular industry with zero waste.

The main by-products and waste in the olive sector are listed below:

1. Olive leaves and branches: coming mostly from the pruning of olive groves and the olive harvest, their use as inert mulch demonstrates that this is a mitigating practice and is part of a strategy that can improve soil properties, reduce CO2 emissions and increase the soil's capacity to store carbon. (Olivum, Consulai & Vilar, 2019).
2. Olive pits: Largely used as a biofuel, olive pits are gaining popularity as a sustainable source of renewable energy. Some estimates indicate a growth in the

use of pits for industrial and residential heating between 2019 and 2024, especially in rural areas (Liferay DXP: https://agricultura.gov.pt/valorizacao-subprodutos).

3. Olive pomace: Both the two-phase and three-phase olive oil extraction systems produce this by-product. The pomace has great potential to be used as a source of biomass for energy, organic compost for fertilisation, and even in animal feed after proper treatment. It is estimated that olive pomace has been valued with increasing efficiency in agro-industrial composting and biogas production projects (Rede Rural: https://inovacao.rederural.gov.pt/grupos-operacionais/13-projectos-groupos-operacionais/98-tecnicas-e-tecnologia-para-valorizacao-de-subprodutos-em-olivicultura-tecolive; Agência Portuguesa do Ambiente: https://apambiente.pt/residuos/subprodutos).
4. Wastewater (Alpechins): This water from olive oil extraction contains high levels of organic compounds and is often treated in Wastewater Treatment Plants (WWTPs) before being disposed of. Recent projects aim to reuse this water for irrigation after treatment, or to integrate it into industrial processes to reduce the use of fresh water (Rede Rural: https://vozdocampo.pt/2024/09/04/digitalizacao-e-agricultura-4-0-aplicadas-a-pequenos-olivicultores-e-lagares-em-portugal/).

Within the framework of the interviews carried out with 6 experts/professionals in the agri-food sector from circular economy companies, there is clear experience in transforming by-products and waste in the sector, and an interest in expanding the activity of transforming them. They all unanimously agree that what they consider to be a by-product of the sector is incorrectly labelled “waste”, given that there is an added value, a usefulness, and there is no waste. According to them, waste is destroyed or channelled into a landfill, which is not the case in the olive sector.

6.1. Olive Leaves and Branches

Olive tree pruning generates a significant amount of waste, including leaves and branches. This waste can be managed in various ways, both to minimise the environmental impact and to maximise the economic value by converting it into useful by-products.

The online survey of small and medium-sized companies in the olive sector revealed the following regarding pruning practices:

Considering **Fig. 6.** and **Fig. 7.** we can verify that Winter pruning seems to be a more regular practice, with approximately two thirds of producers following an annual or bi-annual schedule, while Summer pruning is much less structured, with the majority of producers not following a specific routine, suggesting that this is a less prioritised or occasional practice.

From **Fig. 13.** and **Fig. 14.** below, we can conclude that the use of leaves and branches as by-products in olive production is essential to maximise agricultural efficiency. The intensity of pruning, particularly during the Winter, determines directly the amount of by-products generated and also helps to maintain tree health. However, care must be taken

in this procedure, as very aggressive pruning can reduce the capacity to produce olives in the following cycle. The balance between healthy pruning and maximising by-products is therefore critical.

More intense pruning results in more biomass available to be utilised in the following ways, according to the respondents' preferences:

1. **Composting:** the biomass generated can be converted into high-quality compost used as a natural fertiliser, promoting a circular economy within the farm itself.
2. **Mulching:** shredded leaves and branches can be used as mulch to retain moisture in the soil and control weeds, improving soil quality in the long term.
3. **Energy production:** Another emerging use involves converting olive biomass into biofuels, a sustainable energy alternative.

When small and medium-sized companies in the olive sector were surveyed about the procedures they adopt with regard to olive tree pruning waste, the following was found:

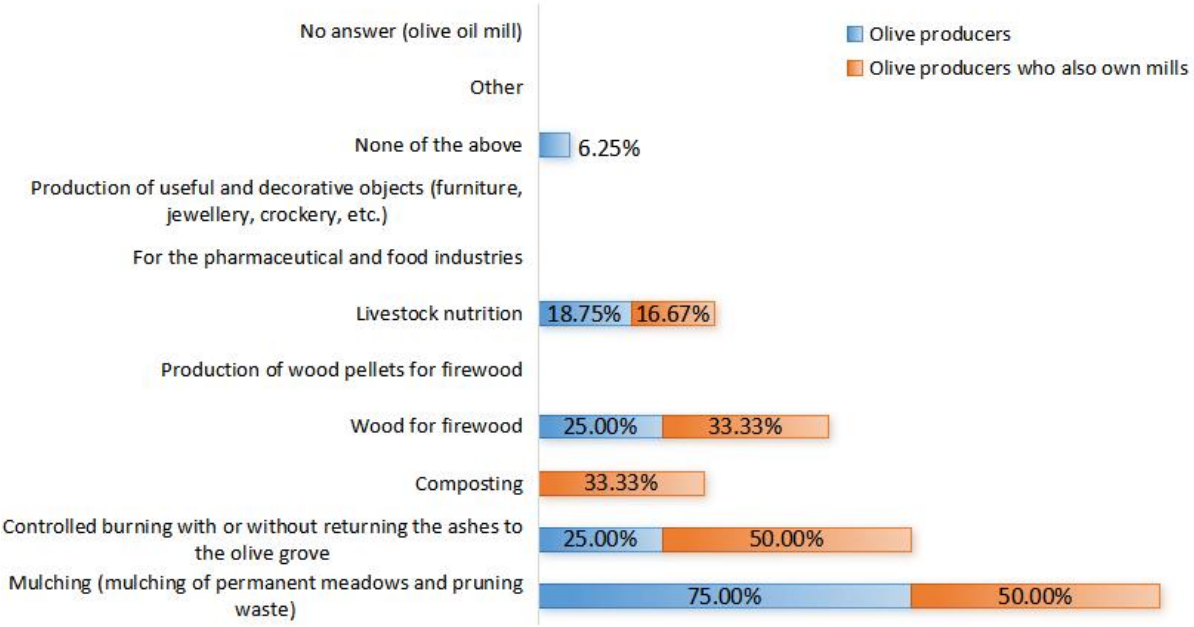

Fig. 13. In the graph of this figure it is possible to compare the procedure with olive pruning waste that is adopted in the olive grove by those who are olive producers, with those who are olive producers and who also own a mill.

The majority of olive producers, 75%, use pruning waste for mulching.

The mulching procedure is even the one that both exclusive olive producers and olive producers who also own mills choose to put olive pruning waste to good use, as can be seen in the following graph:

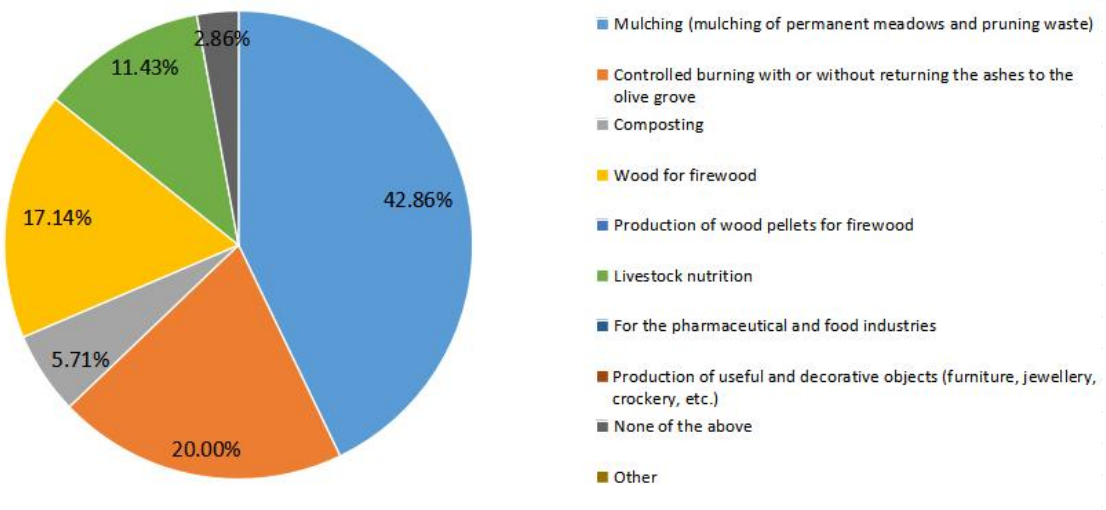

Fig. 14. Graph reflecting the respondents' preferences regarding the procedures adopted in the olive grove with olive pruning waste. A universe of 100 percent should be considered, corresponding to a sample of 22 surveys (6: olive producers who also own olive mills, 16: olive producers). The options of: Production of useful and decorative objects (furniture, jewellery, crockery, etc.), For the pharmaceutical and food industry, Production of wood pellets for firewood and other were not chosen, corresponding to a null percentage.

According to the results of the SustainOlive project (https://sustainolive.eu, 2023), it can be seen that when the soil receives no addition of organic carbon, apart from natural leaf fall, soil organic carbon (SOC) drops to 80 percent of its initial rate after 30 years. Thus, when tree pruning is shredded and applied to the soil, along with the fallen leaves, carbon is lost by around 2%.

The 6 interviews conducted with experts/professionals in the agri-food sector from circular economy companies revealed that the majority of olive leaves and branches are used for animal feed, for rabbits and cows, composting, shredding for mulching, or burning on site or for heating purposes, mostly in the north of the country.

Given the above, we can conclude that the challenges related to olive leaves and branches include: the cost associated with collecting, processing and storing these by-products.

However, opportunities such as the production of bioenergy or the creation of bioproducts are being explored, particularly in large-scale olive groves. For small producers, composting and mulching represent more practical and accessible solutions. This approach reflects a technical and strategic vision of utilising olive leaves and branches as by-products, promoting more sustainable and efficient agriculture.

6.2. Olive Leaves Pits

Olive pits are a valuable and underutilised by-product of olive production. Although a growing number of producers are exploring their potential, there is still a long way to go for the widespread adoption of technologies that can facilitate the separation and valorisation of this waste. In addition to biofuel, the pits have potential for:

- **Charcoal production:** Pits can be carbonised to create a more sustainable alternative fuel.

- **Use in animal feed:** In some cases, after processing, they can be used as a feed supplement.

In the future, it is expected that further technological innovations will allow greater integration of pits into circular economy systems, especially with the increased demand for renewable energy sources and sustainable agricultural practices.

As part of the online survey aimed directly at small and medium-sized companies in the olive sector, the following emerges:

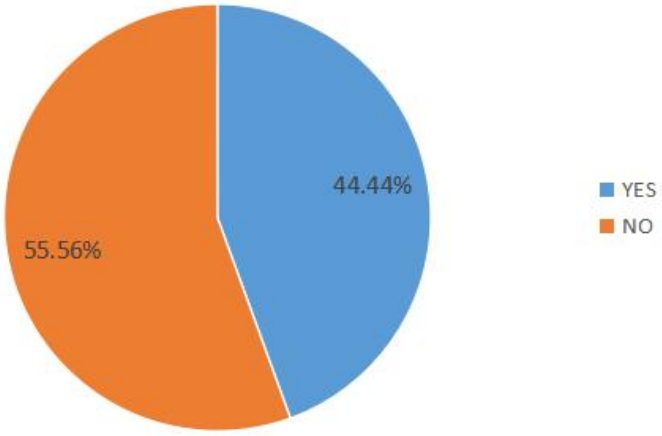

Fig. 15. Are the pits separated at your mill? The graph reflects the respondents' preferences regarding the separation of the pits in their mill. A universe of 100% corresponds to a sample of 9 surveys (6: olive producer who also owns a mill and 3: mill owner).

Approximately 44% of those surveyed separate the pits at their mill, while 56% don't. This suggests that the use of pits as a by-product is still in the process of being adopted, possibly due to technological and monetary limitations, or the lack of infrastructure for biomass utilisation.

Its separation can have two main purposes:

1. **Energy use:** Olive pits are an excellent source of biomass due to their high thermal power of around 4,500 kcal/kg, which can be used as biofuel in both industrial and residential heating systems. This is particularly relevant in olive oil producing regions, where the waste can be converted into energy for the mill itself or the farming community. In this way, CO2 emissions into the atmosphere are reduced, there is less dependence on fossil fuels, the environment is more respected and the olive oil production cycle is closed with zero waste (OLIVUM, Consulai & Vilar, 2019).
2. **Raw material for composting:** Another possibility for using olive pits is to include them in composting processes, although they are slower to degrade due to their rigid structure. Its use depends on local practices and technological acceptance in the producing regions.

Regarding the stage of processing at which the pits are being separated, the responding producers provided the following insights into operational practices in the mills:

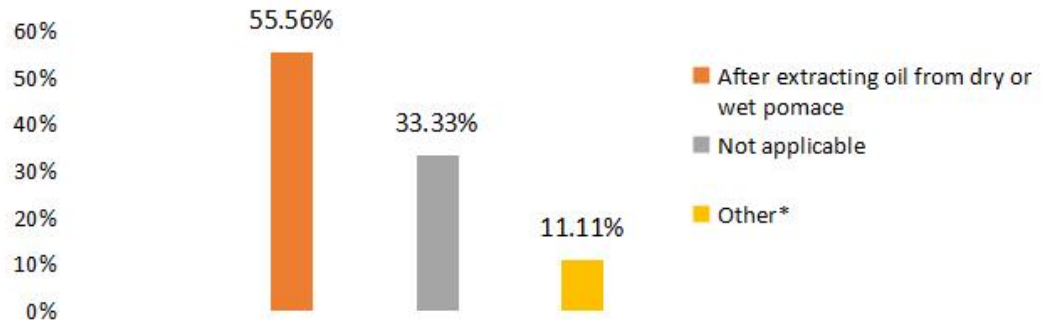

Fig. 16. Graph reflecting the stage at which the pits are being separated. A universe of 100% corresponds to a sample of 9 surveys (6: olive producer who also owns a mill and 3: mill owner).

The data obtained shows that none of the respondents separates the pits before milling. This suggests that, in most of the processes analysed, the pits end up in the pomace and are treated as a residual by-product that can be used for composting or energy.

The 6 interviews with agri-food sector experts/professionals from circular economy companies revealed a trend towards investment in the acquisition of technology that will allow the pit to be extracted before the olives are milled, such as the Moragri group (Alentejo region) and the Acushla company (Trás-os-Montes and Alto Douro region). The first company emphasises the increase in the percentage of pits removed as the most valuable aspect of this investment. In the case of the second company, the installation of a very modern ginnery on the property in 2024 will make it possible to use the olive pits for biofuel. According to its owner, he believes they will be able to obtain around 100.000kg of olive pits this year, with part of this by-product going to the estate for self-consumption and the rest for sale.

All of the interviewees mention that their companies use olive pits as biomass, to run the boilers and heat the water in the mill, and at the same time commercialise part of this by-product.

This data thus corroborates the trend of mills implementing pit separation equipment, allowing them to have another source of income from the sale of pits. It should be noted, however, that 4 of the respondent producers represent companies from the Alentejo region, where olive production is higher than in the rest of the country, and the remaining 2 respondent producers are, in one case, representatives of a company from Trás-os-Montes and Alto Douro that is investing in modernising its equipment and, in the other case, representatives of an Association of Integrated Protection Producers from the Trás-os-Montes and Alto Douro region (*Associação de Produtores em Protecção Integrada da região de Trás-os-montes e Alto Douro)*, with more than 10 hundred producers and many decades of experience in processing by-products.

6.3. Olive Pomace (2-phases and 3-phases)

Olive pomace is an unavoidable by-product of the olive oil extraction process, and there are two main extraction systems:

1. **Two-phase system:** Produces a pomace with higher humidity, containing both solids and liquids in a single phase. The two-phase system is more environmentally sustainable as it reduces the volume of wastewater generated. The main advantage of the two-phase system is the reduction in liquid effluents, but the resulting bagasse needs additional treatment due to its moisture content.
2. **Three-phase system:** This system separates the oil, water and solids, resulting in three distinct by-products. Although more efficient at separating the components, it generates large volumes of wastewater (alpechim, alperchim or água-ruça, which is a liquid residue from the manufacture of olive oil, acidic and phytotoxic, with a dark colour and unpleasant smell), which needs to be treated before disposal, representing a significant environmental challenge.

Depending on how it is treated, olive pomace can be a valuable source of energy and fertiliser, with the following characteristics:

1. **Use as a fertiliser:** After the composting process or appropriate treatment, the pomace can be applied directly to the soil as a fertiliser, promoting moisture retention and improving soil quality. Composting can thus reduce spending on mineral fertilisation and be an alternative to it, improving poor soils and solving erosion problems. It should be noted, however, that direct use without treatment can cause phytotoxicity problems due to the phenolic compounds present.
2. **Biomass production:** Olive pomace can also be dried and used as biomass in heating systems or to generate electricity, taking advantage of the high calorific value of the waste.

Taking into account the graph in **Fig. 8.** in section 5.2 and the graph in **Fig. 18**. below, as well as the data obtained during the online survey of PMES in the olive sector, it can be verified that, with regard to the use or disposal of olive pulp or dried pomace by the responding olive sector companies, the majority do not spread the pomace on agricultural soil immediately after its production, which suggests that prior treatment, such as drying or composting, is the predominant practice. The preference for treatment before application to the soil avoids possible negative environmental impacts.

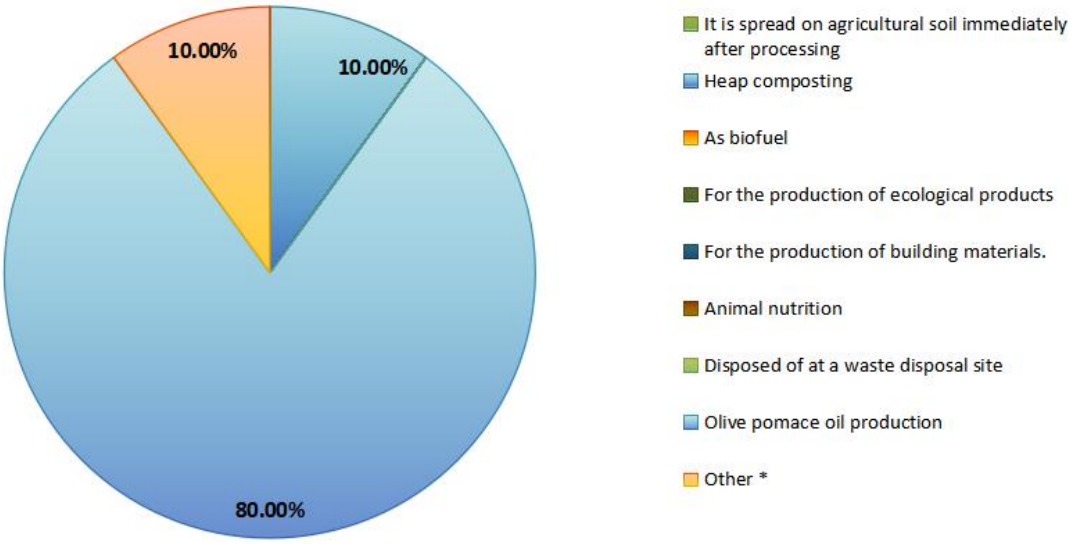

Fig. 17. - Graph showing how olive pulp or dried pomace is used or disposed of in the respondents' companies, 80% of which is for the production of pomace oil, 10% as heap composting and 10% for other purposes (Delivered to another mill for transfer). To be considered a universe of 100 percent corresponds to a sample of 9 surveys (6: olive producer who also owns a mill and 3: mill owner).

It is also worth mentioning the existence of tests being carried out by the Academy in Portugal on the application of olive grove by-products/residues to the soil, in the two ways mentioned above, i.e. the application of pomace directly to the soil and the application of compost to the soil.

In this regard, the *SustainOlive project* (https://sustainolive.eu, 2023), should be mentioned. Its results showed that soil organic carbon (SOC) levels improved with the application of composted olive pomace and manure, although to a lesser extent than with herbaceous cover. It was also estimated that after 30 years, soil organic carbon is 55% higher in olive groves with organic soil application (53 tonnes per hectare), compared to the control where conventional practices were followed (34 tonnes per hectare). As you might expect, in olive groves whose soils are relatively unchanged and where there is a wide variety of types of organic matter (olive pomace compost and crushed pruning waste, among others), a much more diverse and biologically active soil microfibre develops (similar to that of a forest), having enormous value for the farmer in ecological, productive and economic terms.

In the interviews with 6 experts/professionals in the agri-food sector from circular economy companies, the following points were noted:

- Their mills use a two-phase olive oil extraction process;
- Most of them have installed second and third extraction lines in order to obtain remilled olive oil, given that the pomace has a high oil content, and this practice constitutes an additional source of income for the mills;
- Part of the olive pomace is simultaneously used on the property of the companies of the professionals interviewed, and the other part is commercialised. In the case of Herdade da Poupa (Alentejo region), some of the pomace produced is used as organic fertiliser to feed the cows they keep on the property. In the case of the Acushla company (Trás-os-Montes and Alto Douro region), it uses around 3,000kg

of wet pomace for dyeing clothes, as its owner has businesses in the textile and olive sectors. Herdade da Figueirinha (in the Alentejo region) invested in 2024 in setting up a composting unit, with a size of 1.5 hectares, and plans to increase its area this year. The main aim of this project is to avoid sending pomace to the pomace oil extractors, since, according to the owner, his company was penalised three years ago when the pomace extractors no longer had the capacity to receive pomace. In addition, this professional interviewee felt that the by-product pomace was not put to a decent use. According to him, the activity of the extractors causes an unpleasant odour and smoke, so he finds it difficult to defend their work, which is poorly regarded by the population. On top of this, and in line with the European 'Farm to Fork' strategy, which will require the use of 50% organic fertilisers by 2030, and given that there is not enough organic matter on the Portuguese market, let alone of the quality required to achieve this goal, he decided to invest in setting up a composting unit and in the future commercialisation of the compost it will produce;

- Most producers in the north of the country send 99% of the pomace they produce to the olive pomace oil extraction industry. Only a very residual percentage is used for composting, which indicates the need for greater awareness of the adoption of this circular practice in this region of Portugal.

It could therefore be said that olive pomace, whether from a two-phase system or a three-phase system, offers significant opportunities for the production of valuable by-products such as biomass and organic fertilisers. However, proper management is mandatory to avoid environmental impacts, especially with regard to the management of wastewater and phenolic compounds. With appropriate technologies and sustainable management practices, olive pomace can be transformed into a valuable resource, rather than a problematic waste product, contributing to the circular economy in olive growing.

6.4. Wastewater

Wastewater is one of the most critical by-products of the olive oil extraction process, especially in the three-phase system. These effluents have a high load of organic compounds, including fatty acids, phenolic compounds and other pollutants, which require specific treatment to minimise environmental impacts, systematised as follows:

1. **Environmental impact of wastewater:** Due to its high content of phenolic compounds, wastewater is toxic to aquatic fauna and flora and can contaminate groundwater if not properly managed. Effective treatment of this waste is therefore essential to avoid environmental degradation and guarantee the sustainability of olive oil production.
2. **Treatment and disposal:** Solutions vary according to the capacity of the mill and the technology available. Some options include:
    - **Treatment in wastewater treatment stations:** Wastewater treatment stations that process industrial effluents are essential for removing the pollutants present in the wastewater.
    - **Controlled land application:** In some regions, wastewater is applied to agricultural land after dilution and strict monitoring, as it has fertilising

properties. However, this practice requires attention so as not to affect soil and groundwater quality.

- **Evaporation ponds:** large open basins that contain the wastewater and allow the water to evaporate naturally over time, concentrating the solids and contaminants at the bottom. With the heat, the water evaporates, significantly reducing the volume of liquid effluent that needs treatment or final disposal.

The reuse of wastewater is a sustainable strategy that aims to transform problematic waste into a useful resource:

Recycling in olive transformation: One of the most advanced options involves recycling wastewater for other processes within the mill. This can include reusing the water for washing olives, or in cooling systems, or even in the extraction of the oil itself, after filtering and appropriate treatment.

Use in irrigation: Although the practice of reusing wastewater in irrigation is restricted due to the toxicity of wastewater, some technological innovations mean that, after treatment, this water can be applied in a controlled manner to agricultural crops. This reduces the need for fresh water and can help manage water scarcity.

With regard to the data obtained during the online survey of the olive sector's PMES, the following can be seen:

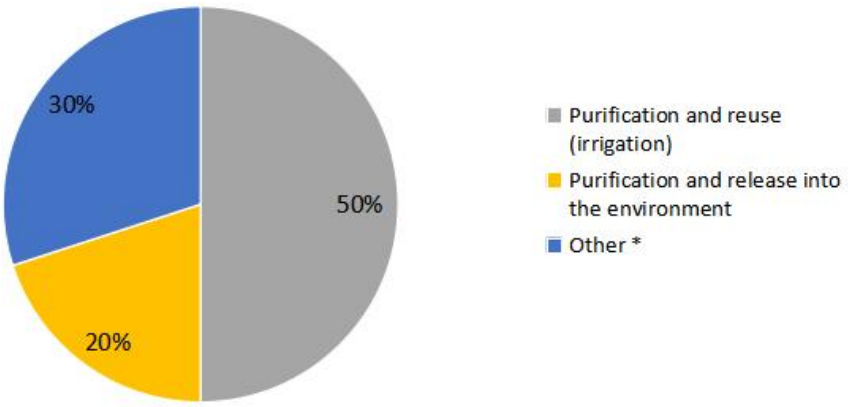

Fig. 18. - Graph showing how wastewater is utilised on the respondents' mills. 50% for purification and reuse; 20% for purification and release into the environment and 30% for other methods such as Evaporation pond and after treatment it goes to the WWTP. To be considered a universe of 100 percent corresponds to a sample of 9 surveys (6: olive producer who also owns a mill and 3: mill owner).

Most producers do not use wastewater recycling directly in olive processing. This reflects the technological difficulties and lack of adequate infrastructure for the efficient reuse of this resource. However, the global trend towards the circular economy could drive the development of new technologies that promote the recycling and reuse of wastewater on a larger scale.

As part of the interviews carried out with 6 experts/professionals in the agri-food sector from circular economy companies, the following points were noted:

- The wastewater in their mills results from the olive oil extraction process, in a two-phase system;
- They mostly use evaporation ponds to store wastewater. Even so, some producers report that grease films sometimes form on the surface of the pond, blocking the evaporation process and affecting their preparation for the following season;
- The spokesman for the Olibest olive mill says that he intends to use the wastewater from his mill to irrigate the olive groves, but points out that the law limits the amount of cubic litres per hectare and that the pH must be corrected before it is applied;

It can therefore be said that the wastewater generated in the olive oil extraction process represents a significant challenge for olive producers and for the environmental management of growing regions. Adopting sustainable practices, such as appropriate treatment in wastewater treatment plants, controlled recycling or the use of evaporation ponds, can minimise the impact of these effluents, the latter being the most widely used in the olive sector in the Alentejo region. The advantages of this practice are its low cost, simplicity and reduced volumes. The disadvantages of this practice lie in its environmental risk, dependent climate and solid waste management. The future of wastewater management in olive growing depends on technological innovation, with an increasing focus on reuse and the development of extraction systems that generate lower volumes of effluent. Possible government support could serve as an incentive for the acquisition and implementation of modern technology to help with this management. The treatment and recycling of wastewater is thus a key component in ensuring that olive oil production is compatible with the principles of sustainability and respect for the environment.

Finally, the majority of producers agree that these waters have important biological activities, which are of interest to the pharmaceutical and food industries due to their antioxidant and antimicrobial properties. However, the extraction process is still at an early stage.

6.5. Other residues (table olives residues, lampante olive oil, etc.)

It is important to mention in this section of the report that in recent years many mills in Portugal have installed what is known as a lampante line, removing the remaining percentage of oil from the olive pomace, which means that pomace extraction companies have less chance of obtaining pomace oil. The mills thus start to obtain lampante olive oil, which does not fulfil certain internationally defined quality parameters, and sell it to the olive oil refining industry, which is another source of income. Together with the sale of olive pits, the mills thus acquire two additional sources of income, compared to around five years ago in the country. In the most modern 4.0 technology mills in the Alentejo region, this transfer line has already been replaced by decanters with NIR sensors and Artificial Intelligence software, which allow the decanter's operating parameters to be adjusted in real time, without human intervention, allowing the loss of fat to the ‘wet’ pomace to be minimised.

The olive pomace thus arrives at the olive pomace extraction companies, tending to be pitted and with a much lower percentage of fat, thus increasingly valorising by-products and waste.

In addition to the production of lampante olive oil, the mill also produces another by-product, the olive oil lees, which are deposited at the bottom of the vats containing tens of

thousands of litres of olive oil and are used to make soap in the cosmetics sector and to produce candles. Once again, all the by-products and waste from the mill are utilised, making this a circular business.

In the context of the interviews carried out with 6 experts/professionals from the agri-food sector of circular economy companies, the following aspects stand out:

- In the 2023/2024 olive oil harvest, the Moragri Group's olive oil business identified the production of 42 tonnes of olive oil from a second extraction line and 40 tonnes of olive oil lees. In the same harvest, the Olibest company reported production of 630 tonnes of olive oil, and this mill not only harvests its own olives, but also those of other producers. It's important to note that these two companies are from the Alentejo region, and the mills in this part of the country are characterised by their commitment to making the most of all their by-products;
- The majority of producers in the Trás-os-Montes e Alto Douro region commercialise the olive pomace they produce, with a high percentage of fat in it, thus providing the three pomace oil extraction companies in the north of the country with a good source of income from this extraction.

With regard to pomace oil, which is extracted from olive pomace by extraction companies using chemical processes, it should be noted that this product is not sold directly to consumers in Portugal, but is mostly exported to the Spanish market for the purposes of industrial frying and even sold to the general public as a low-quality fat.

7. Sustainability and Environmental Impact

The increase in the volume of production in the olive sector in Portugal over the last 20 years has been made possible by the professionalisation of a large part of the sector, using very intensive, irrigated olive cultivation based on highly productive varieties, and more recently, supported by the use of a great deal of innovation and technology.

In this regard, the need for efficient use of production factors, i.e. water, fertilisers and agricultural pesticides, has meant that in the last decade (2014-2024), innovative sensors and techniques have been used to monitor the state of olive groves. This has led to the emergence of probes to measure soil moisture content to support irrigation management, largely driven by "measure 7.5 - Efficient use of water" of the 2014-2020 Rural Development Programme. Soil, foliar and water analyses have also become routine, as a result of the obligation to carry them out periodically in order to receive aid from sustainable production methods, such as Integrated Production, leading to fertilisations calculated for each plot, rather than uniformly for the whole farm, as was previously the case. This is how "Precision Olive Growing" (Santos, S. (2023). *Analysis of the environmental and economic sustainability of olive oil production in Portugal* (Master's thesis). University of Lisbon, School of Agronomy; Voz do Campo. (2024, April 7). *Precision olive growing: Current state and future perspectives*; Agriterra. (2022). *The structural transformation of Portuguese olive groves*.) began to be adopted , which has very recently taken hold with some expression in the Alentejo region, with the determination of variability in olive groves and the application of production factors based on this variability. The aim of the "Precision Olive Farming" concept is to apply the amount of resources (water, fertiliser, pesticides, etc.) that are really needed, where they are needed and at the right time, reducing costs and reducing environmental impact.

In this chapter we will look at some of the most common sustainable practices in olive growing and olive oil production in Portugal, which reflect the development of the production sectors, agricultural machinery, industrial machinery, and the commitment to new technologies and innovation, which are essential for implementing the principles of the circular economy and improving environmental sustainability.

7.1. Sustainable Practices in Olive Farming and Olive Oil Producing

Since 2022, Portugal has been intensifying the implementation of sustainable practices in olive growing and olive oil production, especially in the most productive regions, such as the Alentejo, which has led the transformation of olive growing not only in the country, but internationally. These practices aim to reduce environmental impact and improve resource efficiency, especially in response to the growing pressures of climate change. Below are some of the main sustainable practices adopted in the country:

1. **Efficient Irrigation and Water Management**
   - Drip Irrigation Systems: a widely adopted practice is the use of drip irrigation, which allows for the precise application of water, minimising waste. This system is particularly effective in regions such as the Alentejo, where drought is a constant challenge.
   - Integrated Water Management: projects such as the Alqueva Barrage, which guarantee the availability of water for irrigation all year round, are essential for sustaining olive growing, especially in years of intense drought (Olive Oil Times: https://www.oliveoiltimes.com/production/olive-oil-production-in-portugal-set-to-rebound/124707).
2. **Use of Resilient Olive Varieties**
   - Selection of Adapted Varieties: farmers have been selecting olive varieties that are more resistant to drought and high temperatures, which reduces the need for irrigation and increases the resilience of olive groves in the face of climate change (Delices Olivier: https://delicesolivier.com/en/blog/post/59-olive-oil-production-2023-2024).
3. **Sustainable Agricultural Practices**
   - Conservation Agriculture: the adoption of practices such as tilling, not mobilising the soil and mulching, which helps maintain soil moisture and reduces erosion and improves soil quality, have very positive effects in terms of soil organic matter and are regularly used by modern olive growers.

In this respect, it is important to note that the implementation of good management practices in modern olive groves allows them to become one of the most significant carbon sinks, while also providing multiple and valuable environmental and social services. However, olive growers are not economically rewarded for these services. If such a payment existed, the carbon sequestration potential of Mediterranean olive groves, and therefore their ability to mitigate climate change, would probably increase significantly (Olivum, Consulai & Vilar, 2024).

According to estimates made by the Life Sustainolive project (https://sustainolive.eu/,2023), olive growers who maintain tillin over the entire

surface of their holdings could earn between 50 % and 125 % more in compensation for this service than those who maintain herbaceous strips in the row or remove vegetation under the canopy, respectively. Regardless of the payment model or certification system to be adopted, these results seem to be very encouraging for modern olive growing, which has already popularised tilling in its work routines.

- Reducing the use of chemical products: there is an ongoing effort to reduce the use of pesticides and chemical fertilisers, promoting integrated pest management practices and the use of organic fertilisers.

4. **Energy Production from By-Products**
   - Valorisation of by-products: olive pits and pomace are often used to produce biomass, which can be converted into energy, reducing dependence on non-renewable energy sources (Olive Oil Times: https://www.oliveoiltimes.com/production/olive-oil-production-in-portugal-set-to-rebound/124707).
   - Wastewater treatment: treatment systems are implemented to reuse wastewater from olive oil extraction units, minimising pollution and allowing water to be reused in agricultural processes.
5. **Certification and Quality**
   - Sustainability certifications: many cooperatives and olive oil producers have been working towards achieving certifications such as ISO 14001 and Organic Farming, which guarantee the adoption of sustainable farming practices and respect for the environment.
   - Focus on Olive Oil Quality: in addition to sustainable practices, there is a growing focus on producing high-quality olive oil, which is often associated with environmentally friendly cultivation and production methods.

With regard to the data obtained during the online survey of MSMEs in the olive sector, several of the aforementioned practices were adopted: 68.18% of respondents mulched their olive groves; 54.55% of respondents adopted integrated agriculture and reduced the use of chemical pesticides. Similarly, 54.55% of respondents use organic fertilisers and 45.45% of farmers use drip irrigation and water control.

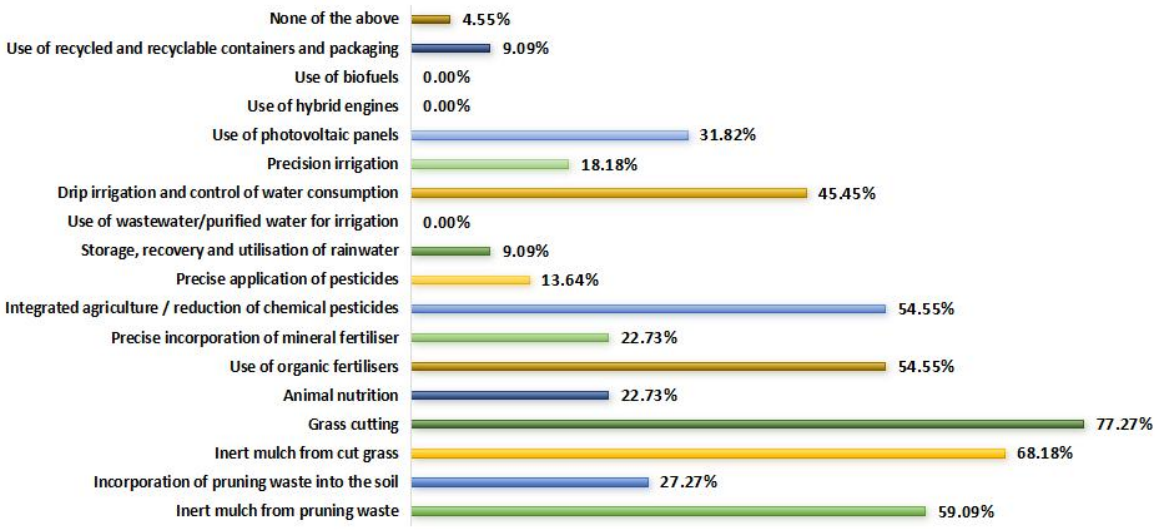

Fig. 19. Graph that shows Technological interventions related to the circular economy applied to respondent's olive groves. The technological interventions: Use of wastewater/purified water for irrigation, use of hybrid engines and use of biofuels were not chosen by any of the respondents, thus obtaining 0% in the graph above. Each percentage was calculated based on a universe of 117 responses, obtained from a sample of 22 surveys (6:producers who also are mills owners and 16: olive producers).

It can be seen that the practices identified reflect a growing effort to incorporate circular economy principles, improving sustainability through actions such as reducing pesticides, using renewable energies, recycling and efficient water management, among others.

The following aspects emerged from the interviews with 6 experts/professionals from the agri-food sector of circular economy companies:

- His companies' mills have two-phase extraction systems (German Westfalia technology) and a machine that washes and cleans the olives, as well as separating the leaves from the olives; in addition, there is a blade and hammer mill, i.e. mixed technology, and the use of Westfalia mixers, decanters, centrifuges and rapid decanting tanks;
- In the case of the 5 agri-food sector experts / professionals from small and medium-sized circular economy companies, the olives are processed in their mills in a short space of time, so from the moment they are picked from the tree until they are transformed into olive oil, it takes no more than 6 hours;
- The leaves and branches from pruning their olive groves are shredded with shredders and used for composting, along with other farm by-products such as straw. In the case of the Acushla company, in the Trás-os-Montes and Alto Douro region, its owner uses straw taken from the sheepfold where he has 300 sheeps, and also adds organic almond shells from a local partner. He also collects vegetable waste from other neighbouring producers; the Herdade da Figueirinha company in the Alentejo region uses various by-products in its composting, which makes for better quality compost. When their compost is ready (they set up a Composting Unit just six months ago), part of it will be used on the property, and the rest of the organic compost will be channelled for sale, in bulk, in big bags;
- In the case of Herdade da Figueirinha (Alentejo), wastewater from the mill is used to irrigate wheat;

- Herdade da Figueirinha and the Acushla company use olive pomace for composting purposes, as they consider pomace oil extractors to be polluting, and also fear that in campaigns of high olive oil production, they will no longer have the capacity to collect pomace and will paralyse the sector, as happened in 2021;
- The Acushla company also uses 3,000kg of olive pomace for the textile sector, to make a natural dye for clothes. It also uses olive leaves to sell tea in its own commercial space in the city of Porto, in the north of the country;
- The companies that carry out composting in greater quantities use machines to stir the compost, while the olive groves of the professionals interviewed from companies in the Alentejo, which are characteristically modern, use water measuring probes, automatic irrigation systems, image collection via drones, among other types of technology;
- However, all the interviewees said that investing in new technology for the mills implies a certain rationality, since these are large investments for industrial areas that only work for three months a year. They therefore invest according to their production needs. It should be noted that the company Acushla will be making an investment in 2025, which will allow for an olive oil extraction process in which the olives will have as little contact with oxygen as possible;
- The Olibest mill spokesman says that in terms of technology, there have been innovations in terms of sensing and monitoring the process, which, applied at various stages, makes it possible to check the loss of oil in the pomace, as well as a better indication of the speeds and temperatures to be adopted. This advance will make it possible to control and act more quickly than a few years ago. He also points out that the trend towards three-stage extraction has reappeared, due to the problem of handling the pomace. However, he believes that this option implies the problem of the wastewater, and that there is still no defined and inexpensive process for cleaning it. He says there is still a lot of interest in being able to use this water to irrigate olive groves, for example, or even to water cattle, but this process has not yet been resolved. He also mentions the challenge that the pomace factories have set up their entire structure and logistics based on wet pomace. And so, once most mills go back to having the three phases, the extractors will have a problem, because the way they treat wet bagasse differs from the way they treat less wet bagasse. The move to a three-stage mill will therefore have to be better studied, and not all of these players in the olive mill sector are convinced yet. He reiterates, however, that wastewater does indeed have a lot of value, and that a revolution in the extraction system would bring added value to the olive sector, although this is still an expectation, for which there are European funds for research. In his opinion, the olive sector in Portugal is very comfortable with the value of olive oil and doesn't need to make a big effort for this business to be profitable. However, he points out that there should be a greater effort to attribute greater value to each of the stages of olive oil production.

From the information gathered, we can see that there are increasingly environmentally sustainable practices that enable olive oil producers to earn a higher income by incorporating all the by-products and waste from the olive groves and mills into their holdings. As we have seen, the olive groves and mills in the Alentejo region reflect the use of advanced technology, even though it is not available to everyone, and requires rationally managed investments. The sector is looking forward to more effective responses in the management of the olive pomace produced and to a better return on wastewater.

8. State of Circular Business Practices in the Olive Sector

8.1. Trends and Preferences

As part of the online survey aimed at small and medium-sized companies in the olive sector, it is possible to trace trends and preferences in the sector.

Thus, the main reasons for implementing new technologies and practices in the olive sector are related to:

1. **Increased production efficiency:** producers see innovation as a way of increasing the profitability and sustainability of their operations.
2. **Cost reduction:** producers are looking to implement practices that reduce resource consumption, such as water and energy, and this is a priority for most of those surveyed.
3. **Sustainability:** environmental preservation is a growing focus, and the adoption of practices aimed at minimising waste and improving the management of by-products is widely recognised.

On the other hand, the most common barriers indicated include:

1. **High initial costs:** many producers point to initial investments as a major obstacle to adopting new technologies.
2. **Lack of technical knowledge:** the need for specialised training and the lack of accessible information are obstacles to implementing innovations.

When it comes to technologies related to the use of by-products and waste, producers show a strong preference for:

1. **Composting technologies:** The recovery of solid waste, such as pomace, is a priority, with many producers adopting composting techniques that turn this waste into organic fertiliser.
2. **Bioenergy:** The use of olive pits and pomace to produce renewable energy is one of the emerging trends in the sector

Here are the main advantages of composting olive pomace as indicated by the respondents: 18% consider this compost to be a high-value organic fertiliser, 15% identify composting as the best available way to use olive pomace and 18% agree that compost improves the structure and biological activity of the soil. However, 18 % of the respondents mentioned the fact that composting olive pomace takes 1 year to complete.

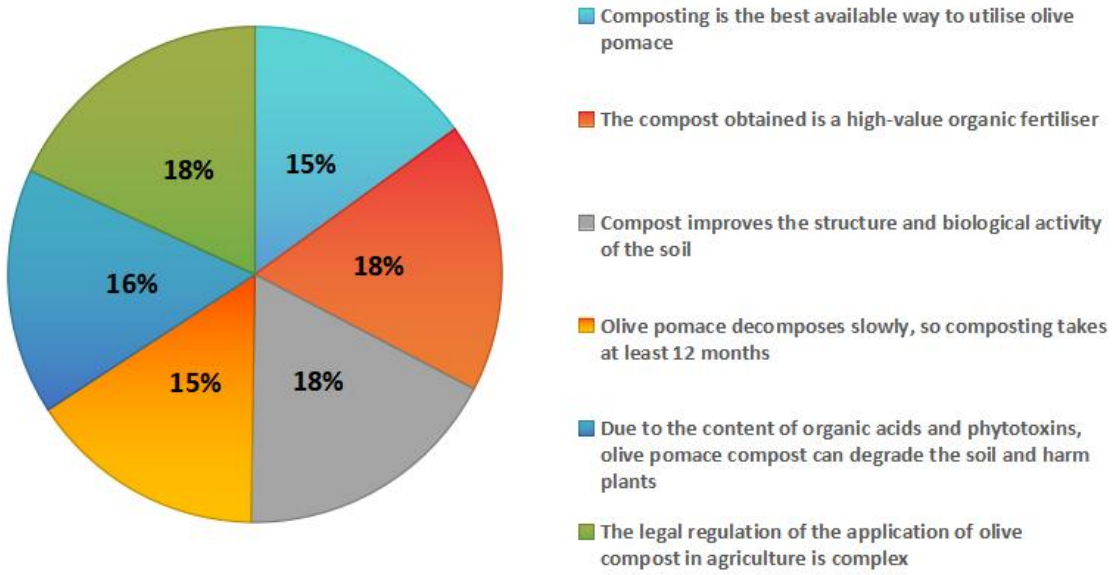

Fig. 20. Graph that shows Agreement with the statements about the advantages and disadvantages of composting olive pomace. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

With regard to the use of olive pomace as a biofuel, here are the main advantages and disadvantages identified by the respondents:

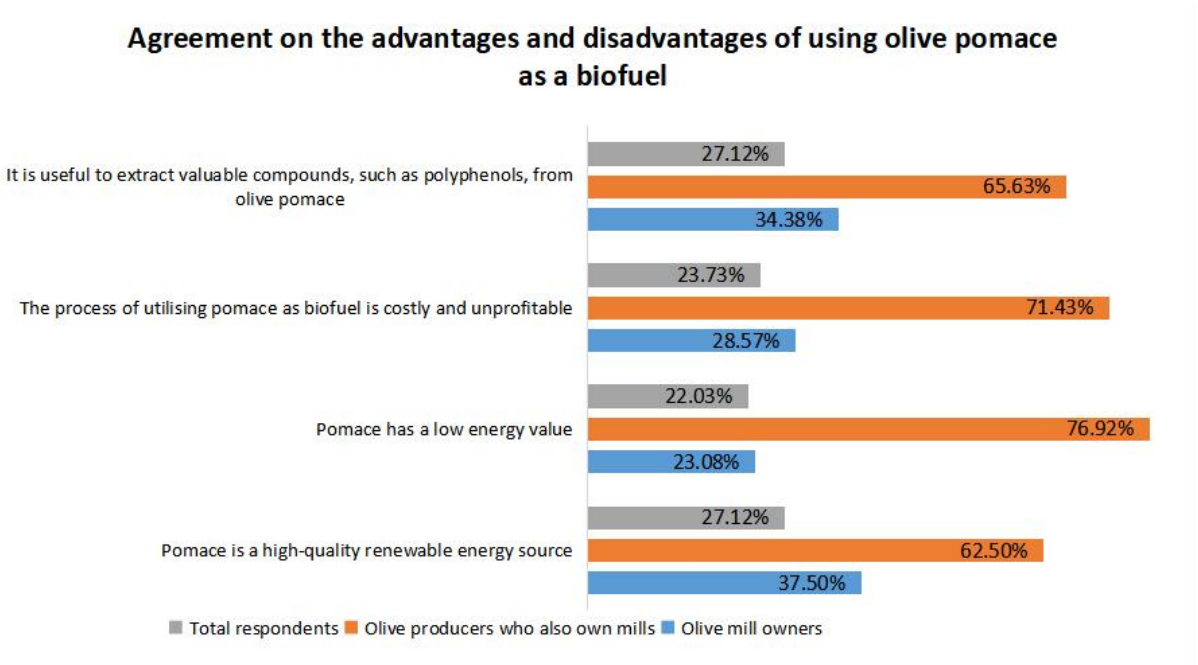

Fig. 21. Graph that shows Agreement on the advantages and disadvantages of using olive pomace as a biofuel. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

It should also be noted that olive producers in Portugal are increasingly aware of the importance of adapting their practices to environmental regulations. There is thus a growing trend towards:

1. **Wastewater treatment:** Many producers implement **treatment systems in wastewater treatment stations** or **controlled soil application practices,** especially in regions with high production.
2. **Circular economy:** The reuse of by-products within the farm itself, such as the use of pomace and pits for fertilisation or energy, is on the rise.

The following aspects emerged from the interviews with 6 experts/professionals from the agri-food sector of circular economy companies:

- The majority of producers consider social, political-legal and technological reasons to be the main drivers for achieving the best economic result in the transformation of olive by-products/waste. Even so, they emphasise the economic motivation as paramount in defining any investment, so that it is profitable and, if possible, constitutes good environmental practice;
- The use of olive pomace, through its compost, for internal consumption by olive-producing estates makes it possible to reduce costs by eliminating the need to buy external fertilisers. According to the spokesperson for Herdade da Figueirinha, selling quality compost is a profitable business, as it fulfils a market need.
- Herdade da Figueirinha has teamed up with OLIVUM - Associação de Olivicultores e Lagares de Portugal, as part of a pilot group for a sustainability programme, and with the INOVCircolive project, promoted by the University of Évora, so that the work carried out by the estate in its recently created Composting Unit can have some scientific and technical support from the Academy;
- All the experts/professionals interviewed pointed to the need to invest in more training for producers in composting so that the process can be more efficient, allowing a path towards sustainability, social, environmental and economic solidarity.

The olive sector in Portugal is evolving towards greater sustainability, with a focus on production efficiency and intelligent waste and by-product management. However, there are still challenges related to implementation costs and technical training, which need to be overcome for more widespread adoption of innovative practices and technologies.

8.2. Technological Gaps in the Implementation of Circular Practices in the Olive Oil Sector

Based on the responses of MSMEs in the olive sector to the online survey carried out, it is possible to identify several **technological gaps** in the implementation of circular practices in Portugal's olive sector. Here are the main weaknesses preventing a more effective transition to a **circular economy** in olive growing:

1. **Limited infrastructure for waste treatment:** one of the major barriers to the implementation of circular practices in the olive sector is the lack of **adequate infrastructure** for the treatment and valorisation of by-products such as olive pomace and wastewater. Although some farms have implemented **composting** and **biogas production systems**, there is still a lack of accessible and efficient facilities for small and medium-sized producers. Many olive farms lack **local wastewater**

treatment stations or advanced technologies that allow for the in-situ treatment of wastewater.

2. **Lack of Access to Bioenergy Technologies:** although the use of **olive pits** and pomace to produce **biomass and biofuels** has shown great potential, the adoption of these technologies is still limited, and the lack of understanding of how to classify pits as waste or by-products means that the sector has difficulty disposing of pits properly. The main gap lies in the **lack of technical knowledge** and the **absence of specific equipment** to efficiently transform these by-products into energy. This scenario is particularly challenging for small olive producers, who don't have enough scale to justify the necessary investments in energy generation equipment.
3. **Insufficient technical knowledge:** Technical knowledge about circular practices, such as **by-product management** and **wastewater reuse**, is not yet sufficiently widespread among olive producers. **Training** on advanced composting, bioenergy systems and waste reuse technologies is still scarce, limiting producers' ability to adopt these practices efficiently. Many report difficulty in accessing up-to-date information or obtaining technical assistance to integrate these systems into their farms.
4. **Low digitalisation and monitoring:** Another weakness is the **low level of digitalisation** in the sector, specifically with regard to effective monitoring of waste flows and their recovery. Digital technologies, such as **sensors for monitoring soil quality** and the **efficiency of composting processes**, are essentially used by large producers. The lack of digitalised management of circular processes prevents the optimisation and efficient use of resources, compromising the implementation of sustainable practices.
5. **Dependence on Traditional Solutions:** Many producers still rely on conventional solutions, such as simply applying waste to the soil without proper treatment or monitoring. Although practices such as **applying wastewater to the soil** can be a viable solution, the **lack of dilution and monitoring technologies** makes this practice risky for the environment. There is also a reluctance to invest in cutting-edge technologies, due to the perception that traditional solutions are sufficient to maintain productivity.

Here are some of the responses from the MSP producers in the olive sector who were consulted, regarding the advantages and disadvantages of using olive oil mill wastewater:

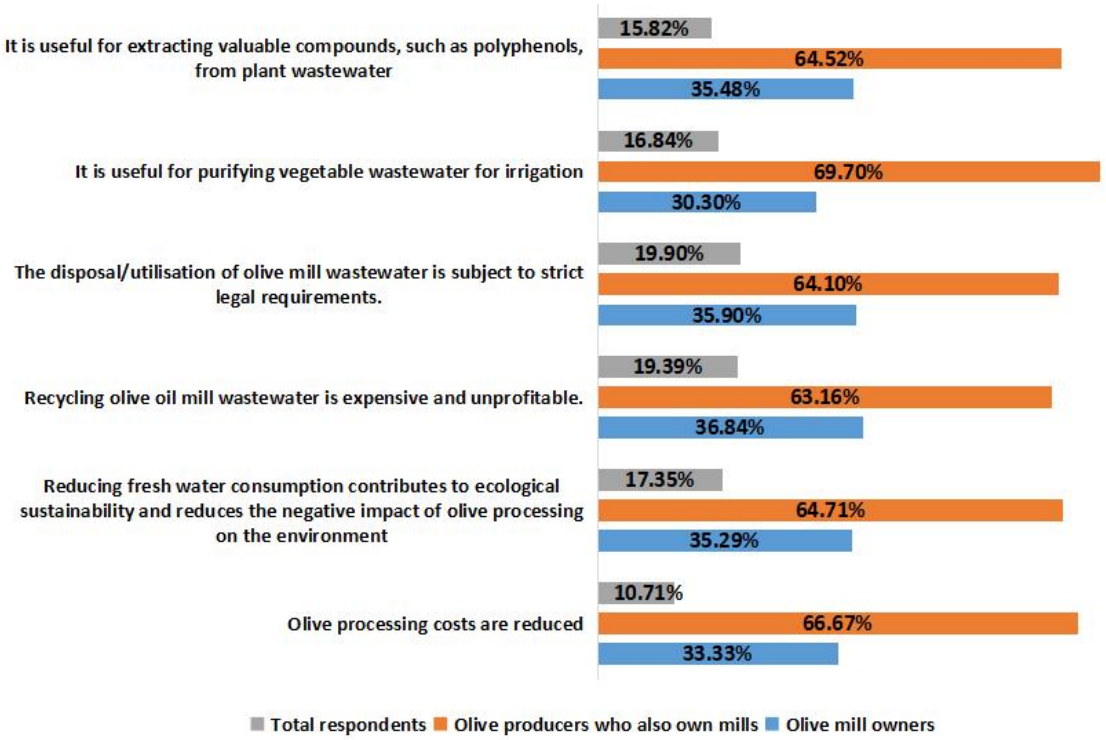

Fig. 22. Graph that shows Agreement on the advantages and disadvantages of using olive oil mill wastewater recycling and its potential utilisation. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

It is noteworthy that 63.16 % of respondents consider the recycling of olive oil mill wastewater to be a costly and unprofitable process, and that 64.10 % of respondents consider the legal requirements for the utilisation or disposal of wastewater to be strict.

The response of the MSMEs producers in the olive sector who were consulted regarding the use of olive pits as an energy source was also the subject of this report. Thus, 25 % of the MSMEs agree that olive pits are a natural and renewable energy source with growing demand.

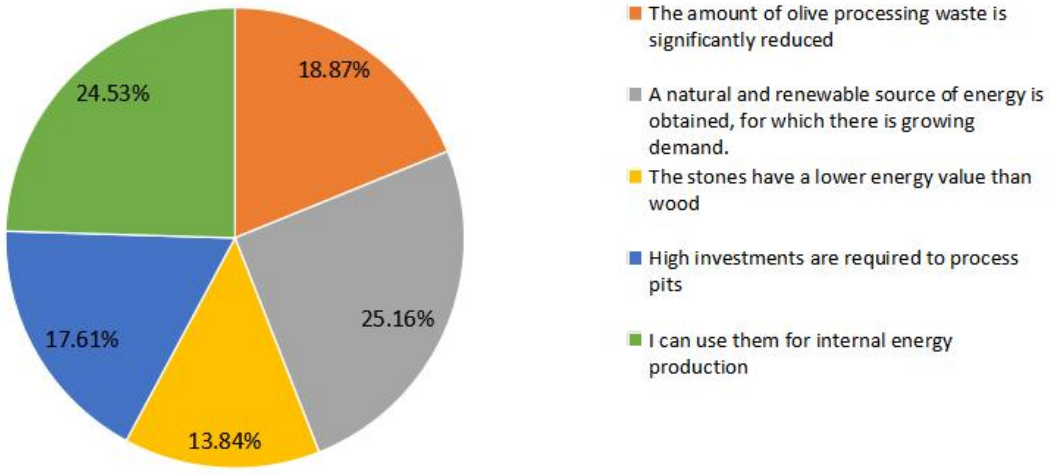

Fig. 23. Graph that shows Agreement on the advantages and disadvantages of using olive pits as an energy source. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

The information obtained from interviews with 6 experts/professionals in the agri-food sector from circular economy companies also confirms the data obtained from the online survey of MSMEs in the olive sector.

Lastly, we should mention the European project *OIL4MED*, implemented by the Instituto Superior de Agronomia of the University of Lisbon and funded by the Prima Programme through the Portuguese Foundation for Science and Technology, which aims to promote digitalisation among small and medium-sized olive producers and mills in Portugal, since only large farms have taken advantage of the technological possibilities available in the sector.

It could therefore be said that the technological gaps in implementation in the olive sector in Portugal are mainly related to a **lack of suitable infrastructure, insufficient technical knowledge, legislation and low digitalisation**, especially among small producers. The implementation of circular practices, such as the valorisation of by-products and the treatment of wastewater, still encounters many obstacles due to the lack of accessible technology and the resistance to change of various players in the sector. To overcome these shortcomings, a coordinated effort between the public and private sectors is needed, focusing on **technical support, investment in infrastructure and ongoing training for producers** to ensure an effective transition to the circular economy in the olive sector, as well as a better understanding and/or rectification of current legislation.

8.3. Best Practices of the Implementation of Circular Practices in the Olive Oil Sector

Some of the good circular practices in Portugal's olive sector that this report has been able to identify are as follows:

By-products valorisation

One of the best practices implemented in the sector is the valorisation of by-products from the olive oil extraction process, such as olive pomace. Many producers have adopted technologies that transform these by-products in particular as sources of energy:

- Biomass production, for home heating, bakeries and various institutions, particularly in the northern region of the country, which has a harsh winter
- Composting pomace and olive pits

The data obtained during the online survey of MSMEs in the olive sector shows that the majority of olive producers and mill owners (80 %) use olive pits in their original form as pellets or briquettes, taking advantage of their high calorific value as a source of energy.

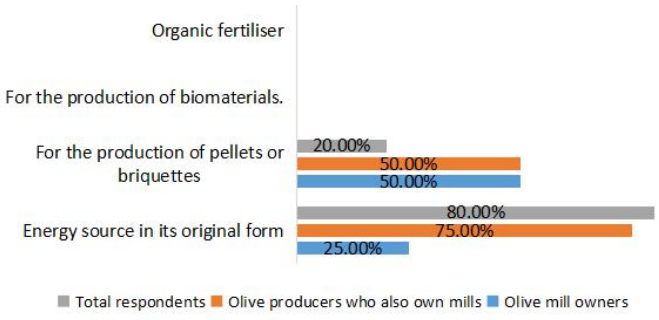

Fig. 24. Graph showing the preferences of olive millers for the channelling and treatment of olive pits at their mills. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

Wastewater Treatment and Reuse

The proper treatment and reuse of wastewater has been a focus area for circularity in the olive sector:

- Local wastewater treatment stations
- Controlled reuse in soil

Integration of Digitalisation and Monitoring Technologies

Good circular practices in the sector also include the use of digital technologies to monitor and optimise production processes:

- Sensors and monitoring systems
- Management software

Partnerships and Collaborative Projects

The adoption of circular practices in the olive oil sector has been driven by collaborative projects between producers, universities and industry associations. A significant example is the *Alentejo Olive Oil Sustainability Programme (PSAA)*, which aims to promote circular practices throughout the production chain. Collaboration between the private and academic sectors has been essential for implementing technological innovations and developing economically viable solutions. This chapter will also look at other examples of partnerships and collaborative projects.

Energy Efficiency and Emissions Reduction

In addition to valorising by-products, mills are investing in energy efficiency as part of good circularity practices, in particular:

Renewable energy - many mills are integrating solar energy to power their operations, reducing dependence on non-renewable energy sources and carbon emissions.

Efficient extraction technologies - the use of more efficient technologies for olive oil extraction, such as the two-phase system, has made it possible to reduce the volume of wastewater generated and, at the same time, increase production efficiency.

Waste Reduction and Integrated Management

The data obtained from the online survey of PMES in the olive sector shows that another good practice adopted in the sector involves integrated waste management and waste reduction, i.e. Pruning Planning.

The information obtained from the interviews carried out with 6 experts/professionals in the agri-food sector from circular economy companies also confirms the above information, with all the interviewees stating that current agronomic practices are much more positive when compared to 20 years ago. According to the interviewees, current producers want their activity to have as little impact as possible on the olive grove ecosystem.

The following good practices for implementing Circular Practices in the olive oil sector in Portugal were identified:

Alentejo Olive Oil Sustainability Programme - project led by OLIVUM - Association of Olive Producers and Olive Oil Mills of Portugal, in partnership with the Évora University, and started in 2022. It recognises, strengthens and values the environmental, social, economic and cultural performance present throughout the olive oil value chain, from olive production to the end consumer (https://psaalentejo.com/pt-pt/). It defines clear sustainability criteria and provides a guide for producers to improve their practices and correct others.
URSA Project - Alqueva By-product Recirculation Units - a project promoted by EDIA - Alqueva Development and Infrastructure Company, S.A., whose main objective is to increase the soil's organic matter content by incorporating compost resulting from agricultural by-products from different producers (http://www.edia.pt/ursa/).
Figueirinha Farm Composting Unit - Creation of a composting unit (1.5 hectares) 6 months ago (https://figueirinha.pt/sustentabilidade/), joining the **Continente Producers Club** (Continente is a supermarket chain belonging to the Sonae Sierra group) (https://clubedeprodutores.continente.pt/pt/), composting not only its by-products (olive leaves, almond leaves, almond tops and olive and grape pomace), through collecting, using Herdade da Figueirinha's own trucks, by-products from other agro-industrial units that have no way of dealing with their by-products, even paying other organisations to collect their by-products, when they are surpluses that are ideal for composting. The idea will be to distribute organic compost to the producers from whom their by-products have been collected. It should be noted that this project has the technical support of Beja Polytechnic Institute and Évora University, and is being studied by master's and doctoral students. They also aim to be a reference for other producers to start composting in the future, sharing the knowledge and experience they are acquiring with this project. At the moment, they have made some interesting discoveries, such as the fact that cattle manure contains between 25 and 27 % organic matter. Olive pomace has 88 % organic matter. They also discovered that it is possible to use wastewater for composting, and came to the conclusion that there is no problem with this. In addition, they discovered that olive pomace is compostable in itself and does not need animal manure, as was initially thought, to lower the ratio of carbon to nitrogen.
ESPORÃO Composting Project - on this property, all the organic by-products generated by its activity (wine masses, olive leaves, olive pomace and pruning waste) (https://www.esporao.com/pt-pt/sobre/praticas-agricolas/compostagem.html/). In the end, the compost is used on their land, maintaining soil fertility and reducing dependence on chemical fertilisers.
InovCircolive Project – The aim of the project is to recover olive oil surpluses from the perspective that waste is a resource, prioritising activities linked to agricultural recovery and introducing a strong research component. The project consortium is led by the University of Évora and includes 13 entities, including universities, skills centres, laboratories, associations and MSMEs, and is funded by Portugal's Recovery and Resilience Plan. (https://www.inovtechagro.pt/projects/inovcircolive-la-5-1/)
Entogreen Case Study - project that use insects (black soldier fly) as a bioconversion tool for olive pomace, allowing the transformation of a by-product of the olive grove into organic fertiliser for the soil, but also oils and proteins for animal feed (https://www.entogreen.com/). ome properties are being receptive to this possibility and are starting protocols with this company, incorporating this resource into their properties and avoiding the need to transport olive pomace from producers to other locations.
LiFE SUSTAINOLIVE Project (2019-2023) - a consortium of 22 organisations from Spain, Portugal, Italy, Greece, Tunisia and Morocco (https://sustainolive.eu/), with the aim of promoting sustainability in the olive sector by implementing and promoting solutions based on agro-ecological concepts. To this end, it has established a set of Sustainable Technological

Solutions, adapted to the great diversity of conditions in olive groves in the Mediterranean basin. In Portugal, the project has 3 partners: the University of Évora, CEPAAL and Esporão.
Axpo and Goldenergy Biomethane Project - this project aims to produce biomethane from agricultural waste from a company located in northern Portugal. (https://goldenergy.pt/blog/energia-verde/projeto-biometano-axpo-goldenergy/)
Biogas production - several large mills in Portugal are studying technological solutions that will allow them to stop sending 'wet' pomace to the pomace dryers and extract the maximum revenue from it, in facilities adjacent to the mills. We are referring to the production of biogas, to be produced in biodigesters, which have made it possible to obtain biogas (with a high biomethane content) by biodigesting the 'wet' pomace, which would then be injected into the national natural gas grid.

Good circular practices in Portugal's olive sector reflect a growing awareness of the importance of **sustainability** and **efficient resource management**. By valorising by-products, treating wastewater, integrating digital technologies and collaborative partnerships, olive oil producers have managed to reduce the environmental impact of their activities and promote a more circular and sustainable economy in the sector.

9. Technological Advancements

We are currently in the middle of a boom and development of precision agriculture, agriculture 4.0. Another step will be the processing of the thousands, millions of data exchanged and analysed by the different data sources, in other words, the management of large volumes of data for decision-making. All this will have to be brought together in a single cyber-physical system that brings together all these elements of the farm, processing them in real time and providing perfectly interpretable analysis results that can be applied to decision-making.

The next stage, of which there are already several examples, will be data management and actions carried out entirely by autonomous robotic systems. In other words, agriculture 5.0 will involve fleets of robots with different functions, sharing data and acting together in a coherent way for the overall management of the farm.

Due to the rapid and recent expansion of olive groves in Portugal, they have the most sophisticated systems and are a permanent testing ground for the implementation of state-of-the-art, world-class technology, making it possible for them to host the world's first 5.0 olive press in the short term, with the integration of artificial intelligence (Olivum, Consulai & Vilar, 2024).

In this way, the following points show examples of innovation in the production and processing under study, as well as examples of future technological trends.

9.1. Innovations in Production and Processing

PROJECTS		
Project name	**Period**	**Website**
Técnicas e tecnologia para valorização de subprodutos em olivicultura (Techniques and technology for the recovery of by-products in olive growing)	**2019 – 2022**	https://inovacao.rederural.gov.pt/grupos-operacionais/13-projectos-groupos-operacionais/98-tecnicas-e-tecnologia-para-valorizacao-de-subprodutos-em-olivicultura-tecolive https://www.uevora.pt/investigar/projetos?id=3691 e http://mecanizacao.der.uevora.pt
NUTRIOLEA - Nutrição e fertilização do olival superintensivo (Nutrition and fertilization of super-intensive olive groves)	**2017 – 2022**	https://www.iniav.pt/projetos/nutriolea-grupo-operacional-nutricao-e-fertilizacao-do-olival-superintensivo
GreenEcoRoxo - Utilização de leitos flutuantes para melhoria da qualidade de massa de água superficial (Use of floating beds to improve the quality of surface water mass)	**2017 – 2021**	http://green-ecoroxo.pt/
OLIVEMEC - Poda mecanizada e colheita em contínuo de olivais de variedades portuguesas (Mechanized pruning and continuous harvesting of olive groves of Portuguese varieties)	**2019 - 2021**	https://www.uevora.pt/investigar/projetos?id=3685 http://mecanizacao.der.uevora.pt
FitoFarmGest - Gestão sustentável de fitofármacos, em olival, vinha e culturas arvenses, na área de influência do EFMA (Sustainable management	**2018-2022**	https://www.fitofarmgest.com/

of phytopharmaceuticals in olive groves, vineyards and arable crops in the EFMA area of influence)		
SustentOlive - Olivicultura e Azeite: Melhoria das práticas de rega e fertilização nas explorações olivícolas em Trás-os-Montes para a sustentabilidade do olival (Oliviculture and Olive Oil: Improving irrigation and fertilization practices on olive farms in Trás-os-Montes for the sustainability of olive groves)	**2018-2023**	https://sustentolive.utad.pt/
OliveBIOextract – Aproveitamento sustentável do bagaço de azeitona numa cadeia de valorização integrada utilizando processos inovadores. (OliveBIOextract - Sustainable use of olive pomace in an integrated recovery chain using innovative processes.)	**2020-2023**	https://morecolab.pt/inicio/projetos/projetos-olivebioextract/
BIOMA – Soluções integradas de Bioeconomia para a mobilização da cadeia agroalimentar (Integrated Bioeconomy solutions for mobilising the agri-food chain)	**2020-2023**	https://projetobioma.pt/
BisOlive	**2021-2023**	https://morecolab.pt/inicio/projetos/projetos-bisolive/
SCIENTIFIC ARTICLES		

References	Article name	DOI/URL
Olga M. C. C. Ameixa et al., 2023.	Bioconversion of olive oil pomace by black soldier fly increases eco-efficiency in solid waste stream reduction producing tailored value-added insect meals	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0287986
Patanita et al., 2021.	OLIVE GROWING – THE CHALLENGE OF SUSTAINABILITY	https://repositorio.ipbeja.pt/server/api/core/bitstreams/467f3652-f4da-4bd3-a7ec-b437c7e33f30/content
Damacena et al., 2021.	Value Co-creation as a Strategy for Value Creation in the Rural Tourism Sector: a study applied to the context of oliviculture.	10.11606/issn.1984-4867.v32i2p249-271
Correia Miguel, M, et al., 2024.	Clima e olivicultura. Potencialidades locais na região de Alvega	https://doaj.org/article/60bceabcac0a427484d692ab170e0b53
A. Alcazar-Ruiz et al., 2021.	Valorization of olive oil industry subproducts: ash and olive pomace fast pyrolysis	https://doi.org/10.1016/j.fbp.2020.10.011
Guise Inês et al., 2010.	Climate change is expected to severely impact Protected Designation of	https://doi.org/10.1016/j.agsy.2024.104108

	Origin olive growing regions over the Iberian Peninsula	
Paula Cabo et al., 2020.	**Conhecimentos, preferências e hábitos de consumo relativamente ao azeite em Portugal**	http://hdl.handle.net/10198/28383
Ana Caroline Royer et al.	**Preliminary analysis of the bacterial community in different phases of the olive pomace composting process**	https://doi.org/10.19084/rca.28558
Luísa Coelho et al., 2009	**Valorização do bagaço de azeitona por compostagem, para utilização agrícola**	10.13140/2.1.4819.5361
Miriam Sofia da Silva Dourado, 2023	**Azeite, compostos fenólicos e alegação de saúde: os azeites nacionais**	http://hdl.handle.net/10451/62822

9.2. Future Technological Trends in the Sector

According to Portuguese research, the following approaches and solutions were considered for the valorisation of olive by-products:

- **Composting**

  The use of microbial inoculants to improve olive pomace composting

- **Olive pomace**

  Use of olive pomace in the feeding of Bisaro pigs (Effect of the Inclusion of Olive Cake in the Diet on the Physicochemical Characteristics of Dry-Cured Loin and Dry-Cured “Cachaço” of Bísaro Pig; Ana Leite et al., 2023; Did the Addition of Olive Cakes Obtained by Different Methods of Oil Extraction in the Finishing Diet of Bísaro Pigs Affect the Volatile Compounds and Sensory Characteristics of Dry-Cured Loin and “Cachaço”?, Ana Leite et al., 2023; Can the Introduction of Different Olive

Cakes Affect the Carcass, Meat and Fat Quality of Bísaro Pork?, Ana Leite et al., 2022)

- **Biochar production**

  Production of certified biochar for organic farming. The aim is to produce a soil restructuring agent in a single application, with the aim of capturing carbon in the soil and improving its physicochemical properties (Resposta da oliveira à aplicação de biochar e fertilização orgânica, Garmus, Taís Gabriele, 2019)

- **Sugars production**

  Enzymatic production of sugars from olive pomace and pits (Produção de açúcares por via enzimática, a partir de bagaço e de caroço de azeitona, Vicente Maria et al., 2019)

- **Preparation and characterisation of LDPE composites**

  Preparation and characterisation of LDPE composites reinforced with cork and olive pit powder, for applications in civil construction (Ferreira, João Daniel Teixeira, 2013)

- **Heating**
  - Different proportions of RA (2, 4 and 8% v/v) in codigestion with Mixed Sludge produced in the WWTP in the codigestion process and biogas and methane yield (OTIMIZAÇÃO DA CODIGESTÃO DE LAMAS MISTAS DE ETAR COM DIFERENTES PROPORÇÕES DE ÁGUAS RUÇAS, Liliana Soares, 2022)
  - Biogas Production (Otimização da Produção de Biogás por Co-digestão Anaeróbia, Alexandre Deodato, 2019)

- **Olive leaf utilisation**

  Used as a resource for natural additives to improve olive oil quality

In Portugal, it has been the practice to compile information on studies that are being developed, projects that are being implemented, good practices or experimental work with application in the field, with presentation in symposium proceedings, in magazines in the field (e.g. Revista de Agricultura e Pesca) rather than in the form of a scientific article, which is prioritised by academia. There is also a lot of information written and described in theses, both master's and doctoral, since they allow for an interconnection between academia and work in the field.

Taking into account all the information mentioned above, which also includes the studies and papers presented, it can be concluded that efforts are being made in Portugal to make the most of olive oil mill waste, with composting, biochar production, the introduction of olive pomace into animal feed and heating being some examples of the various approaches that are being explored. Areas such as the pharmaceutical, chemical, polymer and even civil engineering and construction industries could play a leading role in the success of the circular economy associated with the management of waste such as olive pomace and wastewater.

10. Market Analysis

10.1. Market Forces

Using the data presented above in subsections 6.3, 8.1 and 8.2, plus the information obtained from the online survey aimed at MSMEs in the olive sector, converted into the graphs in the figures below, and as part of the interviews carried out with experts/professionals in the agri-food sector, it is possible to analyse market forces in terms of prices, distribution channels and the main producers and agents of by-products and waste from the olive sector, reflecting a constantly evolving environment driven by the growing demand for sustainability, technological innovation and economic efficiency.

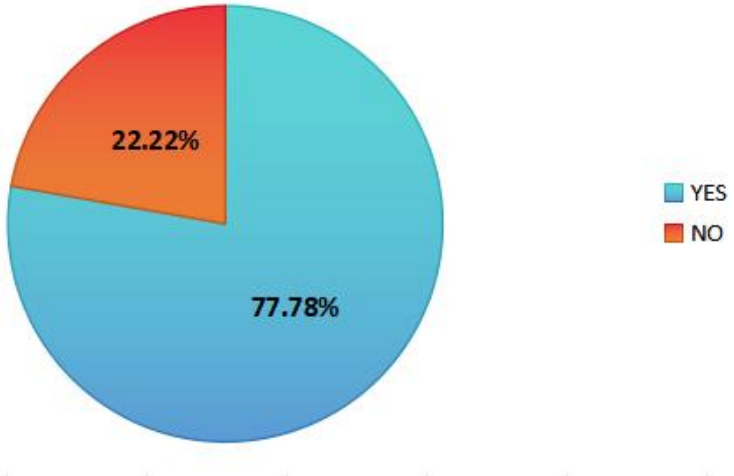

Fig. 25. Graph showing the percentage of respondents that sell by-products/or olive waste obtained in the olive sector. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

This shows that 77.78% of the respondents sell the by-products and/or waste from the olives they produce. The companies of the 6 agri-food sector experts/professionals interviewed also sell by-products and waste.

Below are the specific by-products commercialised by the olive producers and mill owners surveyed:

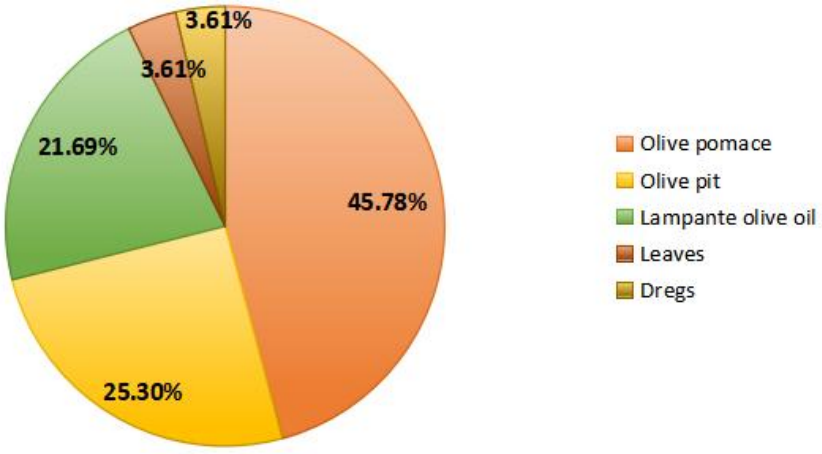

Fig. 26. Graph showing the type of sub-products that respondents sell. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

We should also highlight the first product selected by the respondents according to their business type - olive oil production and production of olives and olive oil at the same time:

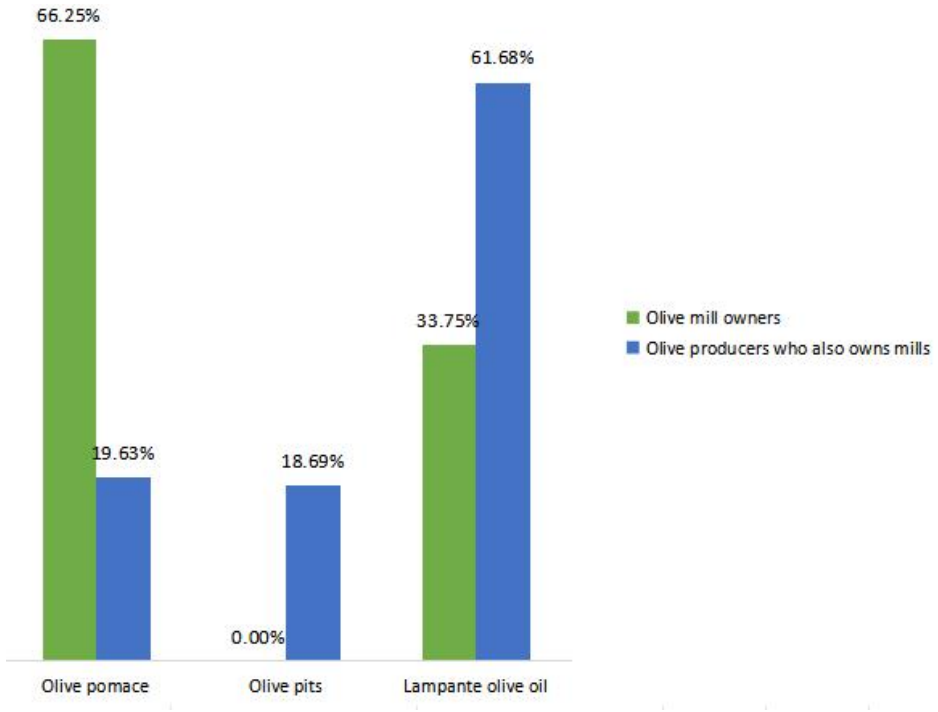

Fig. 27. Graph showing the choice and respective percentage by type of respondent (olive mill owner or olive grower who also owns a mill) of the first product, i.e. the one that respondents use most in their type of business. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

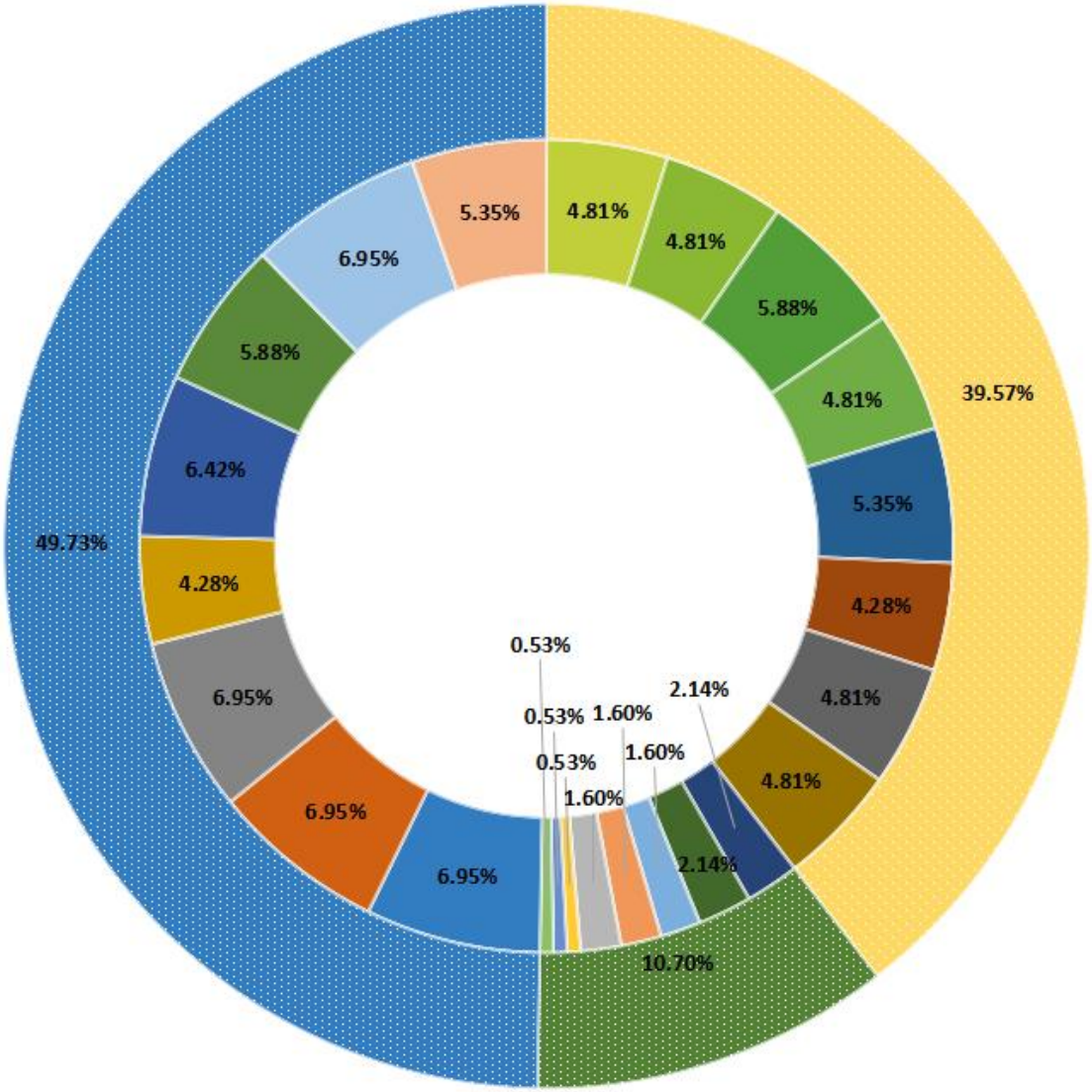

Fig. 28. The following graph should be read in the following way: outer ring: **olive pomace** with 39.57%; **passed olive oil** with 49.73% and **olive pit** with 10.70%. Inner ring, **Olive pomace section:** I have no problem with the placement of this product with 4.81%; I am satisfied with the selling price with 4.81%; I intend to increase production with 5.88%; Most customers are within a 50 km radius with 4.81%; The national market does not yet recognise this product with 5.35%; I need to improve the production technology of the product for the market with 4.28%; It is necessary to educate customers about the benefits of the product with 4.81% and I need to invest a lot in marketing and advertising with 4.81%; Inner ring, **Passed Olive oil section**: I have no problem with the placement of this product with 6.95%; I am satisfied with the selling price with 6.95%; I intend to increase production with 6.95%; Most customers are within a 50 km radius with 4.28%; The national market does not yet recognise this product with 6.42%; I need to improve the technology of producing the product for the market with 5.88%; It is necessary to educate customers about the benefits of the product with 6.95% and I have to invest a lot in marketing and advertising with 5.35%; Inner ring, **Olive pit section**: I have no problem with the placement of this product with 2.14%; I am satisfied with the selling price with 2.14%; I plan to increase production with 1.60%; Most customers are within a 50 km radius with 1.60%; The national market still doesn't recognise this product with 1.60%; I need to improve the technology for producing the product for the market with 0.53%; I need to educate customers about the benefits of the product with 0.53% and I need to invest a lot in marketing and advertising with 0.53%. The 100% universe corresponds to a sampling of 9 surveys (3 olive mill owners and 6 olive producers who are mill owners).

The radial graph shows three olive by-products - **olive pomace**, **lampante olive oil** and **olive pits**. Each outer ring represents the market share of these products, while the inner rings reveal the perceptions and challenges associated with the commercialisation and production of each by-product, according to the producers.

The analysis of each of these by-product categories shown in the graph will be analysed in more detail below.

Olive pomace (39.57%)

Olive pomace, which makes up 39.57% of the by-products identified, plays an important role, not only for its use in biomass plants, but also for its transformation into fertilising compounds.

Challenges and Opportunities (Inner Ring):

- **Technological improvement (4.28%):** the need to invest in technology is a crucial point. Although pomace is widely used, many producers feel that extraction and drying equipment needs to be updated to increase efficiency.
- **Consumer Education and Marketing (4.81%):** awareness of the benefits of olive pomace is still limited. Many producers recognise that educating consumers is vital to increasing demand, and investment in advertising appears to be a priority.
- **Recognition in the National Market (5.35%):** the gap in the recognition of pomace in the national market highlights the lack of effective strategies to highlight its advantages, whether as a source of renewable energy or as a raw material for composting.
- **Expanding Production (5.88%):** the desire to expand production is clearly associated with bagasse's potential, but for this to happen, it is essential that the domestic market recognises the value of this by-product.

Lampante olive oil (49.73%)

Lampante olive oil, which occupies a significant share of 49.73 %, is usually extracted after the first pressing and still contains a considerable amount of oil. This category is well established among producers and is seen as a viable and valuable product.

Challenges and Opportunities (Inner Ring):

- **Satisfaction with Price (6.95%):** high satisfaction with the selling price of olive oil is a positive indicator, suggesting that this by-product is well accepted in the market.
- **National Market Recognition (6.42%):** even so, a significant proportion of producers believe that the national market does not yet adequately recognise this product, which may be linked to the lack of differentiation between virgin olive oil and lampante olive oil.
- **Consumer Education (6.95%):** as with pomace, consumer education is essential, as many are unaware of the benefits of lampante olive oil, particularly for industrial uses or in the production of processed foods.
- **Production Expansion (6.95%):** the intention to increase production demonstrates confidence in the market for this product, but also depends on growing acceptance and demand, both nationally and internationally.

Olive pits (10.70%)

Olive pits, at 10.70 %, represent a smaller part of the equation, but have great potential, especially for the production of biofuels and biomaterials. This use is gaining prominence as renewable energies and alternative fuels take on a greater role.

Challenges and Opportunities (Inner Ring):

- **Technological Improvement and Marketing (0.53%):** the olive pit section reveals the greatest technological and marketing challenges, with low percentages (0.53%) for each of these factors. This suggests that there is still plenty of room to invest in technological innovations and improve communication about the benefits of the pit.
- **Satisfaction with Price (2.14%):** Satisfaction with the selling price is relatively lower than in the case of lampante olive oil, reflecting that the market value of the kernels has not yet reached its full potential.
- **National Market Recognition (1.60%):** Similar to lampante olive oil, the national market does not yet widely recognise the value of olive pits, despite the fact that they are a sustainable alternative for energy production.
- **Production Expansion (1.60%):** Despite the energy potential, few producers intend to expand the production of pits, perhaps due to technological barriers or the lack of a consolidated market for this by-product.

The analysis of this graph indicates that **lampante olive oil** is the most well-established by-product in terms of production and commercialisation, with a positive perception of the price and potential for expansion. **Olive pomace** plays a big role in the sector, but still faces technological and market recognition challenges, especially in the national context. Finally, **olive pits**, although the smallest of the three in terms of utilisation and production, have significant potential, especially for energy and biofuel production, but need more investment in marketing and technology in order to gain a foothold in the market.

This analysis reflects current trends in the Portuguese olive sector, where sustainability and technological innovation are crucial to maximising the value of olive by-products. If these barriers are overcome, the sector could not only increase its efficiency, but also generate more revenue and open up new markets.

The following are the major market forces for by-products and waste in the olive sector:

1. Prices: Volatility and Market Influences

The prices of the main products (olive oil and olives) and by-products (olive pomace, pits and wastewater) are influenced by various factors:

- **Supply and demand:** the price of olive oil, the sector's main product, is highly dependent on global supply, climatic conditions and annual productivity. Limited supply due to droughts or bad harvests tends to increase the price, while abundant harvests or rising international production can lead to a reduction. It should also be noted that when supply is greater than demand, yield values increase towards the packaging stage, and in the opposite case, when demand is greater than supply, yield is more concentrated in the first stages.
- **Sustainability and added value:** by-products such as olive pomace and pits have grown in value as they are recognised as valuable resources for the production of biomass and biofuels. The price of these by-products is directly linked to their

valorisation as renewable energy sources, and is generally higher in areas with a strong demand for sustainable energy solutions.

It is important to include, with regard to the by-product of olive pomace and olive pits, additional information obtained in the context of interviews with 6 experts/professionals in the agri-food sector from circular economy companies, some of whom highlighted the fact that the price of olive pomace is cartelised by the refining companies. This situation has encouraged the sector to rethink the delivery of pomace to extractors. It should be noted, however, that some mills have been able to negotiate the value of the pomace with the pomace extraction industry by analysing the pomace and checking the percentage of olive oil it contains. The higher the percentage of oil in the pomace sold, the greater the possibility of the producer receiving a higher sum. With regard to the olive pit, it was reiterated that its price fluctuates according to supply and demand trends.

The spokesperson for the Moragri Group and the Olibest company mentioned selling olive pits at €60 a tonne in 2021, selling them at €170 a tonne in 2022 and selling them at €110 a tonne in 2023. They believe that the rise in value in 2022 is due to the start of the war in Ukraine and fears of gas shortages in northern Europe. They also point to the fact that the olive pit is valorised when it is packaged, thus giving the packaging industry a higher percentage of profit when selling this by-product to the public. Most of the interviewees also mentioned the prospect of growth in the olive pit market, given its energy potential, with a more competitive price than pellets or other types of product for use in boilers, and it is also considered a green fuel, due to the retention of carbon by olive groves.

Finally, it is important to mention the valorisation of olive pomace in composting, which, despite being a recent development, has significant business potential. All the interviewees emphasised the future market potential of by-products, given their ecological footprint and the fact that future market valorisation cannot be based on more polluting responses than those that currently exist.

- **Treatment and disposal costs:** in the case of waste, such as wastewater, the cost is related to the need for appropriate treatment. Environmental legislation obliges producers to adopt specific practices, such as the use of WWTPs (Wastewater Treatment Plants) or soil reuse solutions, which can increase operating costs and, consequently, the prices associated with managing this waste.

2. Distribution Channels: Local and Global Integration

The distribution channels for products and by-products in the olive sector are broad and segmented:

- **Domestic market and olive oil exports:** Portuguese olive oil, especially from the Alentejo, is widely distributed both nationally and to international markets. The main distribution channel includes producer co-operatives, which guarantee direct and large-scale commercialisation, as well as large national and international distributors. Portugal exports a significant part of its production to Europe, North America and Asia, with export channels being key to the growth of the sector.
- **By-products and waste:** olive pomace and pits are increasingly being integrated into distribution channels for energy production. There are specialised operators who buy these by-products directly from the mills, process them and sell them as

biomass. For small producers, the distribution channel is generally more local, with direct sales to regional bioenergy companies.

- **Waste market:** as far as wastewater is concerned, distribution or treatment usually takes place within local systems, where producers turn to companies specialising in effluent management or adopt their own solutions for agricultural reuse. This channel is more restricted, as it depends heavily on environmental regulations and the infrastructure available in the region.

3. Main Producers and Sector Agents

The olive sector in Portugal is made up of a diverse mix of producers, from small olive growers to large companies with industrial capacity, such as mills and co-operatives:

- **Large producers and cooperatives:** in the Alentejo, where most olive oil production is concentrated, cooperatives play a central role in the commercialisation of both olive oil and by-products. These cooperatives bring together the production of many small olive growers, enabling them to compete on international markets and obtain better sales conditions. Co-operatives are also leading the way in introducing technologies to valorise by-products, such as the production of biomass from pomace and pits.
- **Technological innovation agents:** companies specialising in waste treatment technology are playing an increasingly important role. They are responsible for developing and implementing solutions for efficient waste management, such as composting systems or biological wastewater treatments. The growing pressure to adopt sustainable practices is positioning these companies as key players in the value chain (Rede Rural) (Liferay DXP).

  The following companies are reference points in the national market for by-products and waste from the olive sector:

  - **UCASUL - Southern Co-operative Union -** Olive pomace drying plant in the Alentejo region (https://www.faaba.pt/associacoes-filiadas/28);
  - **AZPO** - Olive pomace drying plant in Alentejo region (https://www.ccip.pt/en/members/members/produtos-alimentares-bebidas-e-tabaco/azpo-azeites-de-portugal-sa)
  - **CASA ALTA** – Olive pomace utilisation plant in the Alentejo region (https://casa-alta.pt/quem-somos/). This company is studying the utilisation of wastewaters with the Polytechnic Institute of Portalegre, in order to verify the possibility of extracting polyphenols from them;
  - In the northern region of Portugal there are 3 olive pomace extractors in the towns of Mirandela, Valpaços and Pocinho (Vila Nova de Côa).
  - **Pit Evolution** – biomass company (https://pitevolution.com/).

    It should be noted that several companies in Spain buy olive pits from olive pits from producers in Portugal when their harvests are strong.

- **Bioenergy companies:** With the increased interest in renewable energy solutions, **bioenergy companies** have become important buyers of **olive pomace** and **pits**, which are turned into pellets or biomass for industrial and domestic heating systems. This market is expanding as the demand for clean energy increases, both domestically and in export markets (Revista do Setor Agrario).(Agricultural Sector Magazine).

As a result, the market for olive by-products and residues in Portugal is dynamic and is being shaped by various forces. Prices are influenced by supply and demand, as well as the costs of treating and valorising waste. Distribution channels are expanding, with increasing integration of by-products into bioenergy networks, while waste is managed through local treatment solutions. The main producers and agents, such as co-operatives, technology companies and bioenergy operators, are leading the transformation of the sector, promoting sustainability and circularity in the olive production cycle.

10.2. SWOT Analysis

This section attempts to systematise the set of factors that influence the development of the by-products and waste business in the **Portuguese olive sector**, namely the strengths, weaknesses, opportunities and threats (swot analysis), reflecting the contributions of the olive and olive oil producers consulted. The aim was not only to take into account the point of view of the olive sector, but also the impact on national society and the economy:

INTERNAL FACTORS

Strengths:

1. **Growing Sustainability:** The adoption of more sustainable practices, such as the reuse of wastewater and composting, has contributed to the environmental improvement of the sector.
2. **Valorisation of by-products:** The sector has shown a growing capacity to valorise by-products, such as olive pomace and pits, which are being used to produce biomass and renewable energy. The production of organic compost will also make it possible to fulfil the protocol with the European 'Farm to Fork' strategy (https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en), as part of the *European Green Deal*.
3. **Growing Sustainability:** The adoption of more sustainable practices, such as the reuse of wastewater and composting, has contributed to the environmental improvement of the sector.
4. **Strong Cooperation:** Olive cooperatives play a crucial role in aggregating production and integrating innovative technologies, allowing small producers to benefit from economies of scale.
5. **Favourable climatic conditions:** Portugal's Mediterranean climate, especially in the south, is ideal for growing olives, which guarantees a continuous supply of raw materials.

Weaknesses:

1. **Lack of Treatment Infrastructure:** Many small and medium-sized producers lack adequate waste treatment infrastructure, such as wastewater treatment plants (WWTPs).
2. **High Initial Costs:** The implementation of technologies to valorise by-products, such as bioenergy or composting systems, and the area to allocate them, imply high initial investments, which can be prohibitive for small-scale producers.

3. **Limited Technical Knowledge:** There is a lack of training and technical assistance, especially in areas such as waste management and the integration of new technologies for treating and valorising by-products.
4. **Dependence on Traditional Techniques:** Many producers still resort to traditional waste disposal methods, such as direct application of by-products to the soil, without proper treatment or monitoring.

EXTERNAL FACTORS

Opportunities:

1. **Increased Demand for Renewable Energy:** The growing demand for sustainable energy solutions offers an opportunity to expand the use of olive by-products, such as biomass, in heating and energy production systems.
2. **Government Incentives:** There are support programmes, both national and European, that encourage the adoption of circular and waste management practices in the agricultural sector, e.g. the acquisition of carbon credits by companies that fail to reduce or avoid emissions of polluting gases or that seek to value their investments in projects or solutions developed to reduce or eliminate their carbon footprint (Voluntary Carbon Market).
3. **Expansion into new markets:** The growing popularity of sustainable and ecological products, especially in the food sector, opens up new opportunities for Portuguese olive oil and its by-products in international markets.
4. **Technological Innovations:** Technological advances in waste management, such as biological wastewater treatment and automation in composting, can increase efficiency and reduce long-term costs for producers.
5. **Circular Economy:** The growing focus on the circular economy offers opportunities for reusing by-products into high-quality fertilisers (boosting quality products), bioenergy and new materials.
6. **Climate change mitigation**
7. **Employability in the sector:** the expansion of new business opportunities in the by-products and waste sector will require specialised labour, which will be more employable.

Threats:

1. **Climate Change:** Extreme weather conditions, such as prolonged droughts or storms, could affect olive production and the stability of the sector.
2. **International Competition:** Other olive oil producing countries, such as Spain, Italy and Greece, represent strong competition on the international market, which could put pressure on prices.
3. **Strict Environmental Regulations:** As environmental regulations become more restrictive, compliance costs for waste management and the implementation of sustainable practices may increase. In addition, olive and olive oil producers have identified the existence of regulatory/legislative obstacles, namely the fact that the olive pit can be classified as both a by-product and waste, depending on how it is treated after it is generated (most producers consider the olive pit to be only a by-product); regulatory obstacles to incorporating the pomace directly into the land; incorporating the wastewater in evaporation ponds into irrigation water requires expensive treatment and lengthy licensing; many producers fear European directives to achieve environmental sustainability at any cost.

4. **Lack of Innovation on Small Farms:** Small producers who fail to adopt technological innovations and sustainable practices run the risk of losing competitiveness, both in terms of costs and production efficiency.
5. **Market Price Volatility:** Fluctuations in international olive oil prices, influenced by global supply and climatic factors, can affect the profitability of the Portuguese olive sector.
6. **Partnerships with the scientific community:** Some producers feel that the industry in Portugal and the academy are often not in the right harmony, and that there is no fluid connection. There has been a rapprochement, but it's still not enough, in order to promote further development in the sector, and it's essential for research projects to involve companies. There should also be a greater focus on higher education, with a research component in the area;
7. **There are not enough olive pomace extraction companies in the region:** given the high production of pomace (especially in the Alentejo), producers fear that the sector will be paralysed in years of high production.

The Portuguese olive sector has great potential for growth, driven by its international reputation and the valorisation of by-products. However, it faces challenges such as limited infrastructure and high technological implementation costs. Taking advantage of technological opportunities and government incentives will be crucial to overcome market threats, international competition and climate change. To maintain its competitive position, the sector needs to continue investing in sustainability and innovation, adopting practices that promote the circular economy. The interviewees from the olive oil agri-food sector believe that the business of by-products and waste will flourish in Portugal, given that the national olive oil sector stands out among the world's players, given the existence of cutting-edge technology in the Alentejo region, with modern olive groves and some of the most productive in Europe. In this sense, producers, especially in the Alentejo region, are the first players in the sector to be interested in finding the best solutions for by-products and waste.

10.3. Regulatory Challenges and Barriers

The challenges and regulatory barriers in the Portuguese olive sector are multiple and complex. Compliance with environmental laws and waste management represent a significant burden for many producers, especially smaller ones. Regulations, while necessary to protect the environment, often require high investment and specialised infrastructure, which creates a barrier to their implementation. In addition, the lack of adequate technical and financial support increases the risk of non-compliance and limits the potential of many olive growers to implement more sustainable and circular practices.

In this way, through the data obtained from the online survey of MSMEs in the olive sector, we can obtain relevant information regarding regulatory challenges and barriers in the field of composting, using pruning waste and olive pomace, as well as utilising olive pits as an energy source.

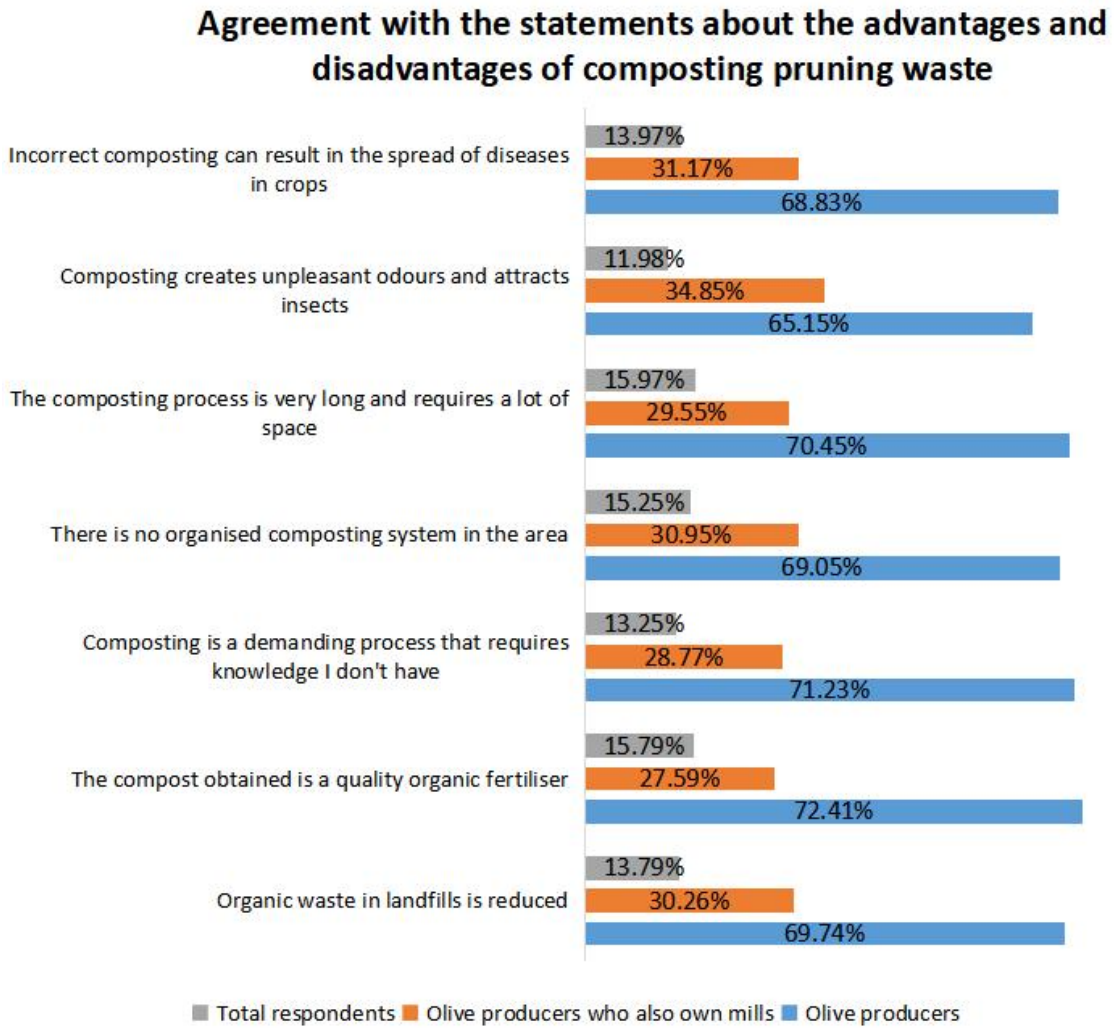

Fig. 29. The graph shows the advantages and disadvantages of composting pruning waste. The 100% universe corresponds to a sample of 22 surveys (6: olive producers who also own olive mills and 16: olive producers).

Pruning waste composting in olive growing in Portugal is a potentially beneficial practice, but it faces several significant barriers to its implementation. Concerns about the spread of disease, a lack of organised infrastructure and a lack of technical knowledge are the main difficulties pointed out by producers and mill owners. For composting to become a more common and efficient practice in the sector, it is essential to invest in education, technical training and regional composting infrastructure. With adequate support, producers can turn pruning waste into a valuable source of organic fertiliser, promoting more sustainable and resilient olive growing.

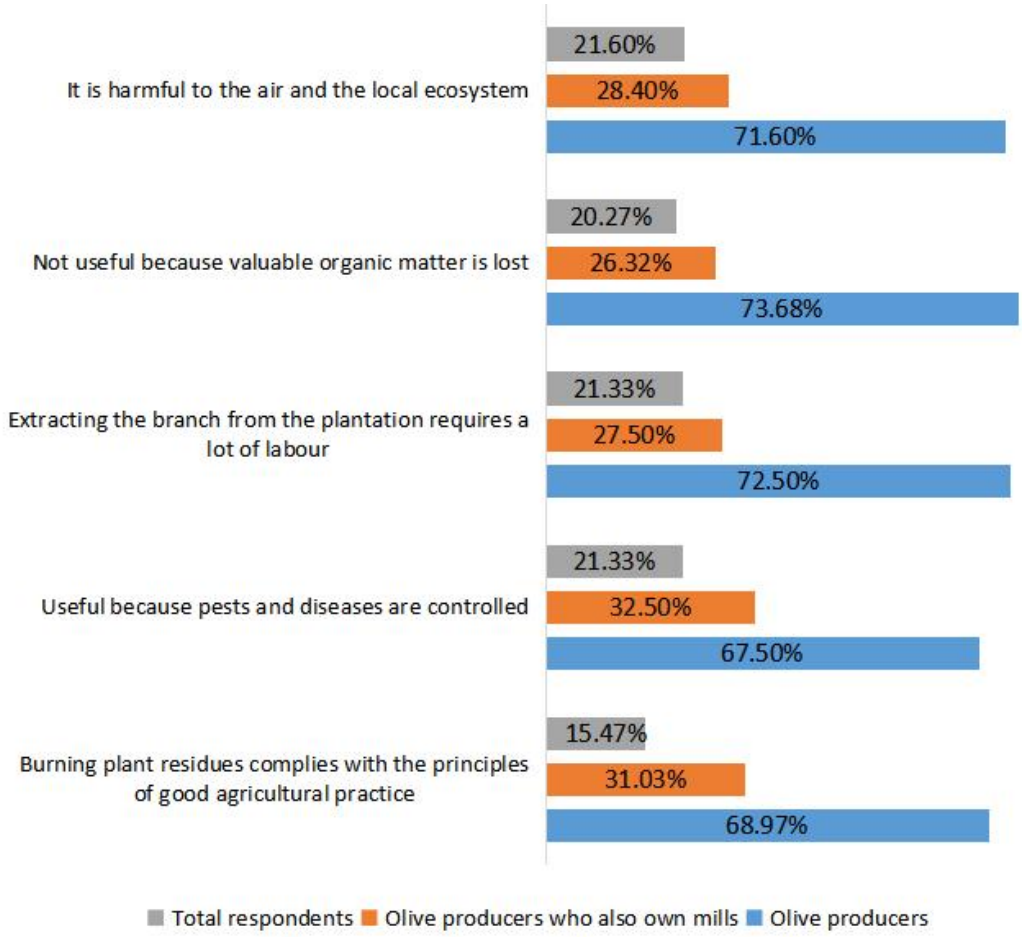

Fig. 30. The graph shows the advantages and disadvantages of burning pruning waste. The 100% universe corresponds to a sample of 22 surveys (6: olive producers who also own olive mills and 16: olive producers).

This point indicates the need to comply with laws restricting the burning of plant waste, a common practice but one that is increasingly regulated due to concerns about air pollution and public health. Many producers recognise that burning does not always comply with environmental requirements, and replacing it with more sustainable methods such as composting involves investment and operational changes.

This point, taking into account the above and **Fig. 20.** of this document, addresses the utilisation and disposal of waste and by-products, such as olive pomace and wastewater, which are some of the biggest challenges in the sector in regulatory terms. There are significant barriers to implementing sustainable management systems for this waste and/or by-products. Through the data presented in the graph in **Fig. 29.** we can conclude that there is an even split in perceptions about the advantages and disadvantages of composting olive pomace, with a clear recognition that the compost generated from this by-product can be valuable for improving soil quality, but there are legitimate concerns around the slowness of the decomposition process and the regulatory complexity associated with agricultural use. In addition to the above, the presence of phytotoxins in olive pomace emphasises the need for rigorous composting techniques to ensure that the end product is safe.

According to the head of the URSA project - Alqueva By-product Recirculation Units, promoted by the Alqueva Development and Infrastructure Company, the licensing process for farmers to be able to compost their by-products and thus fertilise the soil and the crops they grow is extensive and involves different entities:

- National Agricultural Reserve Authority which, according to the current understanding, does not consider composting to be a complementary activity to agricultural activity;
- National Irrigation Authority, since composting is not an activity provided for in the Regulations for Hydro-agricultural Enterprises;
- General Directorate of Food and Veterinary;
- The local town council for the respective area, in order to assess compliance with current land management instruments.

There is also a new legal process that is considerably complex if the farmer wants to sell some of the compost produced. Therefore, according to the URSA project manager, the state doesn't encourage people to take a path towards sustainability, due to the regulatory difficulties in accessing this path. Similarly, the spokesperson for the Herdade da Figueirinha Composting Unit, when interviewed by experts/professionals in the agri-food sector from circular economy companies, mentioned the need for a clearer definition of licences for composting units.

The Portuguese Environment Association (APA) currently has in force (January/2023) a set of *General Rules for Composting Agricultural, Livestock and Agro-Industrial Waste in Dynamic Piles with Turning*, which do not provide a clear response to the needs of producers, creating many obstacles. Producers thus aim to achieve a green life for composting.

The spokesman for the Association of Integrated Protection Producers of Trás-os-Montes and Alto Douro region also warns of the need for legislation that more clearly regulates composting, i.e. what kind of matter from other crops can actually be added to compost without committing any offences, since few farms have all the material needed for composting. He also points out that there is a great lack of organic matter in the soil, which is being wasted due to regulatory obstacles, when it could be used for composting. According to him, legislation needs to keep pace with developments in these agricultural sectors.

With regard to the use of olive pits as a source of energy, it can be seen that this question, posed in the direct survey to MSMEs, explores the application of circular practices in the sector, such as the reuse of by-products and their integration into the olive farm economy.

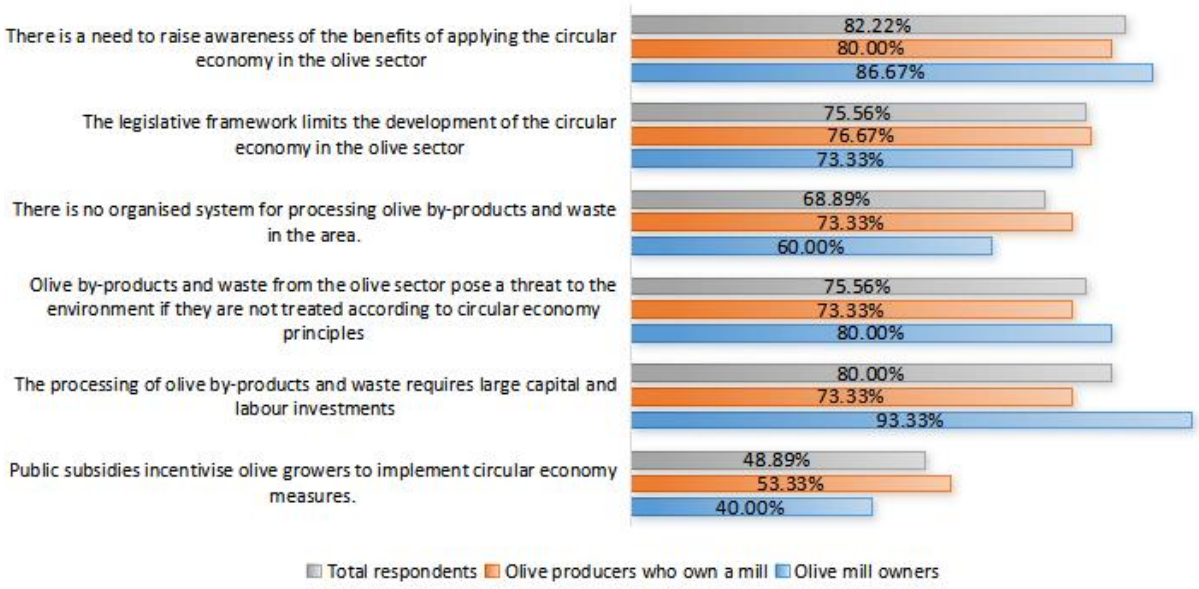

Fig. 31. Graph showing respondents' agreement with statements about the opportunities and threats of the circular economy in the olive sector. The 100% universe corresponds to a sample of 22 surveys (6: olive producers who also own olive mills and 16: olive producers).

Thus, 82.22% of respondents say there is a need to raise awareness of the benefits of the circular economy in the olive sector; 75.56% agree that the legislative framework limits the development of the circular economy in the sector; 68.89% agree with the statement: "Lack of by-product transformation systems in production areas"; 75.56% agree that transforming olive pits as an energy source reduces environmental impact; 80.00% mention that investment costs for transforming by-products are high and, finally, 48.89% say that public subsidies incentivise circular economy measures.

The data obtained reflects a generally positive perception of the environmental and operational advantages of turning olive pits into a source of energy in the olive sector. However, it could be said that the main barriers are legislative, financial and logistical. Although producers and mill owners recognise the value of the circular economy, many are hesitant to implement these practices due to the lack of suitable infrastructure and high initial investment costs.

In order for the Portuguese olive sector to maximise the potential of olive pits as an energy source, it is crucial that there is greater awareness of the benefits of this practice, as well as government incentives to facilitate the implementation of technological solutions. In addition, improving the legislative framework and creating regional by-product processing infrastructures are key to an effective transition to a more circular and sustainable economy.

11. Vocational Training (VET)

It should be noted that only since 2023 has the subject of the Circular Economy in the olive sector been considered relevant in the training needs of a large part of the country's educational institutions and training organisations. The information in the following subsections of this report highlights this issue.

11.1. Existing VET on Circular Business Practices in the Olive Sector

The need for more qualified people in the agricultural sector, and its growing modernisation, has led to the emergence of more higher education training in the area, and in this sense, an increase in higher education graduates in the area of agriculture. Similarly, because the new paradigm of more productive, irrigated olive production has generated a set of new circumstances, investment in training professionals in the olive sector could not be ignored, both in higher education and in professional training.

In this sense, you can sometimes find some curricular units or seminars in higher education institutions in the regions with the highest olive and olive oil production in Portugal, aimed at circular practices in the olive sector, in the following courses:

Northern Region of Portugal - Trás-os-Montes and Alto Douro

- *Bragança Polytechnic Institute - Agricultural Superior School of Bragança*

  .Degree in Agricultural Engineering

  .Higher vocational technical course (VET) in Agricultural Production and higher vocational technical course in Agricultural Management

North Region - Centre of Portugal - Castelo Branco

- *Castelo Branco Polytechnic Institute - Agricultural Superior School*

  .Degree in Agronomy

  .Higher vocational technical course (VET) in Agricultural Production

  .Master's Degree in Agricultural Engineering

Centre of Portugal - Lisbon

- *University of Lisbon - Higher Institute of Agronomy*

  .Agricultural Engineering Degree

  . Master's in Agricultural Engineering

Southern Portugal - Alentejo (Portalegre, Évora and Beja)

- *Portalegre Polytechnic Institute - Elvas School of Biosciences*

  . Agronomy degree

  .Master's degree in sustainable agriculture

- *Évora University - School of Science and Technology*

  . Degree in Agronomy

  . Master's Degree in Agronomic Engineering

  . Master's Degree in Oliviculture and Olive Oil

  . PhD in Agricultural and Environmental Sciences

- *Polytechnic Institute of Beja - Superior School of Agriculture*
  . Agronomy Degree
  . Higher vocational technical course in olive growing, olive oil and table olives
  . Master's Degree in Agronomy
  . Postgraduate Diploma in Sustainable Management of the Olive Sector.

We should also highlight the identification of 3 courses in the Alentejo region specifically geared towards the olive sector: a master's degree in Oliviculture and Olive Oil at the University of Évora; a higher vocational technical course (VET) in olive growing, olive oil and table olives and a postgraduate course in Sustainable Management of the Olive Sector at the Polytechnic Institute of Beja.

In addition to education and training in higher education institutions, it is important to mention the existence of training courses on different themes in the olive sector, carried out by different training organisations, particularly in the Alentejo region, where olive and olive oil production is much higher than in other regions of Portugal, as already noted in this report, of which the following stand out:

Southern Farmers' Association - ACOS

- Fertilisation and Irrigation in the Olive Grove
- Growing Olives in Organic Production - Programming, Organisation and Guidance | B-Learning
- The Quality of Table Olives
- Olive Oil Quality

Despite this, none of the education and training organisations listed above provide training specifically on circular commercial practices in the olive sector.

Likewise, in interviews with five representatives of organisations providing vocational education and training, it emerged that their organisations do not provide training in circular practices in the olive sector, and they also said that they did not know of any higher education organisations or vocational training organisations that provide training in these areas.

Nonetheless, it's worth mentioning, on behalf of the university professor responsible for the Master's in Sustainable Agriculture and the degree in Agronomy at *Portalegre Polytechnic Institute - Elvas School of Biosciences*, in Alentejo, the fact that this institute recently submitted, together with Évora University, an application for a PhD in Circular Economy in Agriculture to A3ES - the Higher Education Assessment and Accreditation Agency. If this application is approved, this course will, in the 2025/2026 academic year, address circular practices in the olive sector, namely the issue of its by-products and waste.

In the same way, the Association of Farmers of the South - ACOS, a training entity certified by the Directorate-General for Employment and Labour Relations, has indicated, through the coordinator of its training centre, that it will carry out training in 2025 on the recovery of olive grove by-products, and another training course on the sustainability of olive mills, both in partnership with the Évora University.

In the context of the interviews carried out with 6 experts / professionals from the agri-food sector in circular economy companies, it emerged that only one of the interviewees has training in circular practices, i.e. a postgraduate qualification in the Management of

By-Products from the Olive Press, through the UNIA - Universidad Internacional de Andalucía, in Spain, in partnership with the University of Évora. However, this programme is no longer available. It should be noted that two other interviewees mentioned that they had been trained in circular practices, however, this subject was covered in the post-graduate programme in Sustainable Management of the Olive Sector at Beja Polytechnic Institute, or in the master's degree in Agronomic Engineering at the Lisbon Higher Institute of Agronomy.

With regard to the responses from producers of SMP in the olive sector, in relation to training in circular practices that they have had, the following can be seen:

Table 2. Information on the type of respondent, the name of the course they attended in the field of organic farming, the organisation responsible for the course, the duration, the teaching method (the options could be: hybrid method; face-to-face method; 100% online method) and if there was a title awarded and if so, the name of it.

Please enter the following information about teaching:					
Type of respondent	Name of course	Responsible organisation (VET provider)	Duration in months	Realisation method	Title obtained
Olive growers who own a mill	Organic farming + olive oil tasting	ISA and other	Days	Hybrid method	None
Olive growers who own a mill	Training in organic production in olive groves	Farmers' association	1	Face-to-face	Training certificate

Only two of the respondents identified as having had training in organic farming, although it was not clear that they had been in contact with training content in circular practices. Only one of the respondents reported that he had received a training certificate.

In conclusion, by consulting the websites of the several institutes and universities in the country, as well as national training organisations, it was not possible to identify the existence of training on circular commercial practices specifically in the olive sector in the country. The data obtained from the 11 interviews conducted confirms this.

11.2. Training Methods and Techniques, Recognition Paths/Qualification Validation Methods Used

Although we have not identified any existing professional training on circular commercial practices in the olive sector in Portugal, here are some of the contributions drawn from the interviews with five representatives of organisations providing vocational education and training.

To this end, we'll begin by outlining the main characteristics of the postgraduate course in Sustainable Management of the Olive Sector at the Beja Polytechnic Institute in Alentejo region, identifying several aspects that make it attractive to its students/trainees, and which could be used as a reference for future courses on circular practices in the olive sector. One of the coordinators of this course was interviewed for the Circolive project.

This postgraduate programme will have its 4th edition in the 2024-2025 academic year. It is characterised by 114 face-to-face hours, with one course - Eco-efficiency in the Olive Oil Sector - more focused on the circularity theme in the olive sector. Each course includes national and international guests who will address different topics for 2 hours or more each. This type of approach allows for networking, not only between the trainees, but also with their teachers, trainers and external guests. During this postgraduate programme,

they also made several technical visits to mills in Alentejo region, to olive sector companies, and also visited the URSA project - Alqueva By-product Recirculation Units, promoted by EDIA - Alqueva Development and Infrastructure Company. At the end of the postgraduate programme, there is always an international trip to one of the olive and olive oil producing countries. In previous editions of the postgraduate programme, they have already had the opportunity to go to Morocco, Italy and Greece. One of the postgraduate coordinators interviewed for this report said that one of the great advantages of this type of trip was the chance for students/trainees to visit farms in these countries, as well as mills, marketing companies and research centres that specifically carry out research into olive groves and olive oil, and sometimes also into technology and industry. With regard to the validation method for this postgraduate programme, students are evaluated through the realisation of many assignments, presented in class, which generate discussion and debate among everyone. There are also some written tests. However, the coordinators of each course unit decide how they want to carry out the assessment for their course unit. This postgraduate coordinator also says that this is the best way to run a course that is essentially aimed at student workers, many of whom work in agriculture, but also in other areas. This postgraduate course does not confer an academic degree, although it does award a final certificate. It is also important to point out some relevant aspects for the organisation of future courses on circular practices in the olive sector, according to the 5 representatives of VET providers interviewed for the Circolive project:

Teacher profile

- Agronomists and environmental engineers who have experience in the field to carry out shorter training courses. Some economics or management skills will also be necessary, as farmers are always looking to know the economic benefits and costs associated with composting.
- Agronomists linked to the production and processing sector, environmental engineers, industrial engineers, since current processes are increasingly industrial, as well as teachers in the field of food technology and economists, for longer courses, so that students/trainees can realise the economic benefit of circular practices.

Training methods and techniques

A training response that combines a theoretical component with a practical component, and some visits.

The theoretical component is necessary in order to have a good understanding of the technical fundamentals, particularly in terms of soil microbiology. The interviewees also said that it was important to know the legislative framework for the sector.

The practical component will involve field or laboratory work.

Visits make it possible to see good examples and make contact with real cases. One of the university lecturers interviewed gives the example of the importance of visiting composting and biogas plants that are in operation, where you can talk to the workers responsible for the process or the equipment.

One of the postgraduate coordinators in Sustainable Management of the Olive Sector at Beja Polytechnic Institute also said that, according to her experience, people who are already in the labour market are more interested in short courses, rather than long courses, i.e. a few modules of 4 hours each.

Competences that students/trainees should have at the end of the training in circular commercial practices in the olive sector

- Farmers or agricultural workers:

  Recognition of the importance of the circular economy and its advantages, since, according to some of the representatives of organisations providing Vocational Education and Training interviewed, farmers over the age of 60 are already beginning to be more aware of circular economy issues, but they certainly don't know all its advantages, particularly composting;

- Professionals in the olive-growing sector and/or professionals retraining:

  Training to work in companies where they will fulfil roles with varying degrees of responsibility, such as the head of an industry, the director of the by-product recovery department, or the worker responsible for the circular economy in the company. There are also opportunities to work in consultancy firms, or on investment projects for new facilities, i.e. the design and industrial layout of new mills, or in public administration, for the state, given the lack of qualified professionals in these areas.

Training method

All six of the experts/professionals in the agri-food sector from circular economy companies interviewed are fans of face-to-face training, due to the interactions that are created and the relationships that are formed between the trainees, although they indicated the possibility of distance learning, online, for courses and training in cities in Portugal that are far from their cities of residence or place of work. They also indicate that they are interested in attending future training courses on circular commercial practices in the olive sector.

11.3. Best Practices Identified Regarding the Education Programs on Circular Business Practices in the Olive Sector

After carrying out a search for good practices in education programmes on circular commercial practices, we were unable to find any programme aimed solely at the olive sector.

The only two references identified in the interviews with five representatives of organisations providing vocational education and training are listed below. However, these good practice references are not exclusive to the olive sector:

- **Tangocircular Project** - the aim of the TANGO-Circular Project (https://tango-circularproject.eu/), promoted by Évora University, is to explore innovative training methods and implement cutting-edge solutions with a view to valorising natural waste and seeking new opportunities for economic growth in agriculture by implementing the Circular Economy concept. One of the means of achieving this goal is to make the training material developed under the TANGO-Circular project accessible through ICT tools.

- **Exclusive E-book with more than 50 cases of circular companies -** this teaching resource was developed by the Bee Circular association (https://www.beecircular.org/beethefuture-capacitacao), which only works on the Circular Economy.

11.4. Potential Institution that Could Offer Courses on Circular Business Practices in the Olive Sector

According to the research carried out and in the framework of the interviews carried out with 5 representatives of organisations providing Vocational Education and Training, there are three different types of organisations that could potentially carry out courses on circular commercial practices in the olive sector, depending on the type of course to be held:

Institutions

Universities and polytechnic institutes: for longer courses with a more academic focus, conferring a degree at the end.

- *Bragança Polytechnic Institute - Agricultural Superior School of Bragança (*https://portal3.ipb.pt/index.php/pt/ipb/quem-somos/escolas/esa)

This institute has been responsible for organising a national olive-growing symposium for many years. In 2024, this symposium will take place from 23th to 24th October and will be on the theme of "Innovating for Sustainability in Olive Growing".

- *Castelo Branco Polytechnic Institute - Agricultural Superior School* (https://www.ipcb.pt/esacb/escola-superior-agraria)
- *ISA - Lisbon Superior Institute of Agronomy* (https://www.isa.ulisboa.pt/en/education/grade-plan
- *Portalegre Polytechnic Institute - Biosciences Elvas School* (https://esbe.ipportalegre.pt/pt/escola-agraria-de-elvas/)

In the 2024-2025 academic year, the Master's programme in Sustainable Agriculture will have a 28-hour curricular unit on the circular economy in agriculture, addressing aspects more targeted at the olive sector.

- *Évora University - School of Science and Technology* (https://www.uevora.pt/unidades/organicas/ect)
- *Beja Polytechnic Institute - Agricultural Superior School (https://www.ipbeja.pt/UnidadesOrganicas/ESA/Paginas/default.aspx)*

Vocational schools

For medium-length courses that enable students/trainees to complete secondary education, i.e. the minimum mandatory schooling defined in Portugal. Several organisations of this nature can be identified in Portugal.

Training centres

For shorter certified courses aimed at professionals in the labour market and/or the unemployed, without the attribution of an academic degree.

- *Confederation of Portuguese Farmers* (https://www.cap.pt/)

- *Young Farmers' Association of Portugal* (https://formacao.ajap.pt/)
- *Association of Integrated Protection Producers of Trás-os-montes and Alto Douro* (https://appitad.com/)
- *More colab* - Collaborative Mountain Research Laboratory, a non-profit organisation associated with Lisbon's Polytechnic Institute. Bragança (https://morecolab.pt/en/home/)
- *Southern Farmers' Association - ACOS* (https://www.acos.pt/)

This organisation consults companies in the Alentejo region on their training needs and then builds its training plan accordingly. For this reason, they began to organise shorter training courses, making it possible for company workers to attend them. ACOS usually works with the National Qualifications Catalogue in order to get funding for training. However, this type of training lasts around 25 to 50 hours, making it impossible for many workers to combine it with their working hours. During the interview, the coordinator of the ACOS training centre also referred to the efforts the organisation has made to bring the academy closer to farmers, inviting several university professors to train in the courses they run. In 2025, they intend to start training in circular practices in the olive sector.

- *Baixo Alentejo Farmers' Association* (https://aabaformacao.pt/)
- *Bee Circular Association* (https://www.beecircular.org/sobre)

There are four different types of target audience for courses on circular practices in the olive sector, depending on their age, educational situation and professional experience:

Course recipients:

Professionals in the olive sector with a university degree, i.e. a bachelor's or master's degree preferably in agricultural and agri-food sciences, or at least professional training in the area. Knowledge of soil microbiology, soil chemistry and fertilisation is required.

Farmers or agricultural labourers, with less training, who may only have the minimum mandatory schooling, but have professional experience.

Undifferentiated professionals with no previous training or who are unemployed but want to work in the area of valorising by-products from the olive oil industry.

Young students/trainees who are finishing their mandatory schooling or are looking to study at university in order to work in the olive oil sector afterwards.

12. Conclusion

12.1. Summary of Key Insights

The main key insights to be highlighted are the following:

A.Growing Sustainability: The olive oil sector in Portugal has increasingly adopted more sustainable practices, such as wastewater reuse and composting. The valorization of by-products, such as olive pits and pomace, has also gained prominence, with uses including biomass production and organic compost.

It should be noted that the northern region of Portugal, where the quantity of by-products is much lower than the Alentejo region in the south of the country, is not

under the same pressure in terms of managing the production of by-products and their commercialisation. In the north of the country, circular practices will continue in terms of bagasse composting and drying. In the south of the country, composting will certainly not be enough to cope with the large amount of bagasse produced, so the biogas route will be one of the most likely options.

B.Technological and Infrastructure Challenges: Small and medium producers face challenges related to the lack of proper infrastructure for waste treatment, such as wastewater treatment plants, as well as limited technical knowledge to implement circular practices.

C.High Initial Investment: Implementing technologies for by-product valorization and composting systems requires high upfront investment, which becomes a significant barrier for small producers.

D.Favorable Climate: Portugal benefits from Mediterranean climatic conditions that are ideal for olive cultivation, particularly in southern regions, ensuring a continuous supply of raw materials.

E.Improved Production Efficiency: Investments in technological innovation, particularly in modernising mills and mechanising harvests, have significantly improved production efficiency. As a result, Portugal has increased its olive oil output in recent years and is becoming a leader in the sector.

F.Legislation as a Barrier: Despite initiatives to increase circularity in the sector, the legislative framework in Portugal still poses a barrier to the development of a circular economy in olive farming. The complexity of licensing processes, particularly for composting and waste reuse, prevents many producers from implementing more sustainable solutions.

G.Importance of Education and Training: There is a growing need for vocational training programs that address the circular economy in the olive sector. A lack of technical knowledge, particularly in waste management practices, remains a challenge for small and medium producers.

At the moment, the existence of educational programs or education that deal exclusively with the topic of the circular economy in olive growing has not been established in Portugal. However, there are certain types of education in which the topic of the circular economy is covered only in a small part. Almost all respondents in this research are interested in attending an education that would deal exclusively with this topic. From this research, it can be concluded that with proper education and adequate financial support, the mentioned respondents could start or improve their application of sustainable practices in the olive sector. The review of existing

institutions dealing with education in Portugal identified potential institutions that could provide vocational education and training on the topic of the circular economy in olive growing.

12.2. Recommendations for the implementation of circular practices in olive sector

The following are recommendations for implementing circular practices to improve the sustainability and efficiency of the sector:

A. By-product valorisation

- **Survey of the volume of by-products produced and commercialised in the country:** providing this up-to-date information will make it possible to identify, in a sustained manner, the challenges that exist in each region of Portugal and to define the priorities and investments that will be necessary there.
- **Olive pomace and pits:** Encouraging the use of technologies to transform olive pomace and pits into biomass. These by-products have a high calorific value and can be converted into energy for on-farm use or even commercialised.
- **Composting:** Promote the composting of agricultural waste, such as leaves and pomace, to produce high-quality organic fertilisers that can be used in the olive groves themselves, reducing the need of external chemical fertilisers.

B. Wastewater Treatment

- **Create local treatment plants:** Establish wastewater treatment plants in areas with high production to reuse water on farms, especially in drought-prone regions such as the Alentejo.
- **Controlled reuse in the soil:** Implement technologies that allow the controlled application of wastewater to the soil, minimising the risk of contamination and promoting the saving of water resources.

C. Digitalisation and Monitoring

- **Sensors and management software:** Integrate digital technologies on a regular basis, such as sensors to monitor soil quality and composting efficiency, to optimise the use of resources and reduce waste. Digitalisation can facilitate data-based decision-making, increasing production efficiency.

D. Training and Education

- **Vocational training programmes:** Develop specialised training programmes in circular practices, with a focus on composting, valorisation of by-products and wastewater management. Lack of technical knowledge is one of the main obstacles to implementing these practices on a large scale.
- **Partnerships between academia and the private sector:** Promote collaborations between universities, producer associations and technology companies to disseminate best practices and technological solutions.

E. Infrastructure and Investment

- **Regional by-product valorisation infrastructures:** Create regional infrastructures that can process the by-products of small and medium-sized producers, facilitating access to circular economy solutions.
- **Financial incentives:** Investment costs are high for small farms. It is necessary to increase access to public subsidies and credit lines favourable to the acquisition of technologies that support the transition to a circular economy. These subsidies should be easy to access and include technical support for their implementation.

Large companies will be able to solve the challenges inherent in working in the olive sector in terms of the ever-increasing adoption of circular practices and digital technologies, while the challenge lies with small producers. The answer could be for agricultural associations, agricultural cooperatives and farmers' groups to invest in the purchase of machinery and equipment that is essential to the sector, at a price that is affordable for their members, together with the provision of training in digital technology and circular practices. The existence of support measures for this purpose, namely within the scope of

the 2023-2027 Common Agricultural Policy Strategic Plan (PEPAC) for Portugal, for this type of acquisition, together with the possibility of selling the services of these associations, cooperatives and groups of farmers to other clients at market prices, will boost the sustainability of this investment.

F. Legal and Regulatory Support

- **Revision of the legislative framework:** Simplify legislation related to by-product management and composting to facilitate the implementation of these practices on farms. Bureaucracy and complex legal requirements are barriers for many producers.
- **Certification of good practices:** Encourage certifications that recognise circular economy practices in the sector, valuing producers who implement sustainable solutions.

12.3. Policy Implications and Recommendations

The main policy implications and recommendations are the following:

A. Waste Treatment Infrastructure

- Policy Implications: The lack of adequate infrastructure for waste treatment, such as wastewater treatment stations, prevents the sustainable use of by-products. It is crucial for the government to financially support the creation of infrastructure so that small and medium-sized producers can adopt effective waste management practices.
- It is recommended the implementation of government subsidies, to support the creation of regional waste treatment infrastructure, enabling the valorisation of by-products for biomass or composting.

B. Financial Support and Tax Incentives

- **Policy Implications**: The high upfront cost of implementing by-product valorisation technologies, such as bioenergy and composting, limits the adoption of circular practices in the sector. Small producers face financial challenges in investing in these technologies.
- It is recommended the definition of a system of tax incentives and subsidies aimed at small and medium-sized producers investing in sustainable technologies. This system should include tax exemptions for by-product recovery technologies and waste treatment.

C. Legislation and Process Simplification

- Policy Implications: The complexity of licensing processes for the reuse of wastewater and by-products, such as olive pomace, creates barriers to innovation in the sector. Strict and rigid regulations increase compliance costs for producers, especially small-scale ones.
- It is recommended the simplification of environmental licensing processes and the creation of a more flexible legal framework for the reuse of waste, facilitating the implementation of innovative circular economy technologies.
- Creation of a single support structure for farmers to implement new agricultural projects, making it easier to obtain the authorisations needed to set up and manage permanent crops, particularly olive groves, as this role is still carried out only by agricultural consultancy firms.

D. Technical Training and Knowledge Transfer

- Policy Implications: The lack of technical knowledge regarding circular practices, such as waste management and by-product reuse, is a significant barrier to their adoption. Specialised technical training is limited, especially for small producers.
- It is recommended the development of technical training programmes in partnership with universities and local associations to train producers. The government should fund educational initiatives that promote knowledge transfer in sustainable practices.

E. Integration of Digital Technologies

- Policy Implications: Digitalisation of operations is limited in the olive oil sector, hindering efficient monitoring of waste management and composting processes. The lack of monitoring prevents resource optimisation and the effective use of circular economy technologies.
- It is recommended the promotion of the digitalisation of the sector by using sensors to monitor soil quality and composting processes. The government should provide financial support for the adoption of these technologies through subsidies and incentives.

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14. Appendices

14.1. Glossary of Terms

Olive Grove: A plantation where olive trees are grown, primarily for producing olives used in oil extraction.

Olive Mill: A facility where olives are crushed and processed to extract virgin olive oil.

Pomace: The solid residue left after the extraction of olive oil, consisting of olive skins, pulp, seeds, and stems.

Technological water: potable water used in processes. In production of virgin olive oil is used for washing of fruits, but also for washing of machinery and the facilities, and in three-phase extraction is added to the olive paste for facilitating centrifugal extraction, becoming part of virgin olive oil extraction residues.

Two-Phase Centrifugation: A method of olive oil extraction with minimal addition of technological water that separates the oil from the residues, resulting in two phases: oil and wet pomace.

Three-Phase Centrifugation: A method of olive oil extraction with addition of significant amount of technological water that separates the oil, from the residues, resulting in three phases: oil, dry pomace and the residual liquid phase, also called wastewater from the olive mill, constituted mostly from technological and vegetable water.

Wet Pomace: The solid by-product from the two-phase extraction process, having a high moisture content.

Dry Pomace: The solid by-product from the three-phase extraction process, containing less moisture than wet pomace.

Olive Pit: The hard stone inside an olive that contains the seed. It is often separated after the oil extraction process and can be used for various purposes like energy production.

Biomethane: A type of biofuel that can be produced from organic materials, including olive pomace, through anaerobic digestion.

Organic Fertiliser: A natural fertiliser made from organic matter, such as composted olive pomace, that is used to enrich soil fertility.

Composting: The process of decomposing organic matter, such as olive pomace, to create nutrient-rich compost for soil amendment.

Purification and Reuse (Irrigation): The process of treating residual water from olive mills to make it safe for use in irrigation.

Purification and Release: The treatment of residual water from olive mills before releasing it into the environment to prevent pollution.

Circular Economy: An economic system aimed at eliminating waste and the continual use of resources, often implemented in olive oil production by reusing by-products and minimising environmental impact.

Mulching: A technique where organic materials, like olive pruning residues, are spread over the soil surface to improve moisture retention, soil fertility, and reduce weed growth.

Pellet Production: The process of compressing organic materials, such as olive pits or pomace, into small, dense pellets used as fuel.

ECO Labelled Organic: Products certified and therefore labelled as organic, produced under specific environmental and organic farming standards, ensuring they are produced without synthetic pesticides or fertilisers.

Integrated Production: A farming system that combines the best of conventional and organic practices to reduce chemical inputs and enhance environmental sustainability.

Oil refinery: A facility that processes low-grade olive or olive pomace oils, producing edible refined oils from olives or olive pomace.

Landfill Disposal: The practice of disposing of olive by-products in designated landfills, typically for waste that cannot be reused or recycled.

14.2. Survey Questionnaires and Interviews

14.2.1. ANNEX 1: Online survey targeting MMSMEs in the olive sector

ANNEX 1: ONLINE SURVEY TARGETING MMSMEs IN THE OLIVE SECTOR

QUESTIONNAIRE ABOUT METHODS AND POSSIBILITIES OF USING OLIVE BY-PRODUCTS AND WASTE IN OLIVE SECTOR

This survey is launched as the first consultation activity of the project ***"Developing skills for introducing circular business models and digital technologies in olive oil sector (CIRCOLIVE)"***, a three-year project co-funded by the European Union under the Erasmus+ Programme.

The project aims to support the EU transition to the Circular Economy by improving/enhancing the circular business skills in the olive oil sector in Spain, Italy, Greece, Portugal and Croatia, in order to promote the adoption of circular entrepreneurial models for waste and by-product valorisation of the whole olive value chain.

The answers to this survey will help us in developing of skills for introducing circular business models and digital technologies in olive oil sector.
In this survey definition of ***Circular Economy*** presents methods and possibilities of using olive by - products and waste in olive sector.

The survey takes **about 10 - 20 minutes**. Responses will be treated **anonymously** and the results will be used for **CIRCOLIVE project purposes only**.

Your answer is valuable to us and we thank you in advance for your time and effort.

- questions for olive producers

- questions for olive producers

1. Volume and characteristics of olive production on the enterprise
    - Total area under olive groves _____ ha
    - Total number of olive trees by age
        - Olive groves until 5 years _____ trees
        - Olive groves between 5 to 20 years _____ trees
        - Olive groves older than 20 years _____trees

2. Technology used in your olive grove (one answer)
    a) Conventional
    b) Ecological with eco-label

c) Other

3. Which technological interventions related to circular economy you apply in olive grove:

	Yes-No
Inert plant cover from chopped pruning	
Incorporation of the remains of pruning into the soil	
Inert plant cover from cut grass	
Grass cutting	
Livestock nutrition	
Use organic fertiliser	
Precise incorporation of mineral fertiliser	
Integrated agriculture /reduction of chemical pesticide	
Precise pesticide application	
Storage, recovery and use of stormwater	
Use of wastewater/purified water for irrigation	
Drip irrigation and controlled of water consumption	
Precise irrigation	
Use of photovoltaic panels	
Use of hybrid motors	
Use of biofuels	
Use of recycled and recyclable containers and packaging	
None of the above	

4. Type of soil management in your olive grove
   a) Soil cultivation
   b) Mulching (mulching permanent grassland and pruning residues)
   c) Combination of the first two ways
   d) Other:

5. Intensity of winter pruning in your olive grove
   a) Every year
   b) Every couple of years
   c) None

6. Intensity of summer pruning in your olive grove

   a) Every years

   b) Every couple of years

   c) None

7. Select the procedure with olive pruning residues in your olive grove (multiple answers is possible)

	Procedure
a)	Mulching (mulching permanent grassland and pruningresidues)
b)	Controlled burning with or without returning the ashes to the olive grove
c)	Composting
d)	Firewood
e)	Production of firewood pellets
f)	Livestock nutrition
g)	For pharmaceutical and food industry
h)	Production of useful and decorative items (furniture, jewellery, dishes, etc.)
	None of the above
i)	Other (specify):

8. Choose your motives and barriers for utilisations of pruning residues

		Types of procedure						
		a)	b)	c)	d)	e)	f)	g)
Motives for implementation	Lower costs and/or higher incomes							
	Legal obligation and/or support							
	Available technology, knowledge and							

	experience
	Awareness of sustainability
Barriers for implementation	High initial investment and costs
	Legal restrictions or insufficient support
	Lack of technologies and knowledge
	Lack of social and environmental awareness

9. Rate your agreement with the following statements about the advantages and disadvantages of mulching pruning residues in an olive grove:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
The most cost-effective way of using pruning residues	1	2	3	4	5
A positive effect on the structure and content of organic material in the soil	1	2	3	4	5
Useful because it prevents the growth of weeds and erosion and conserves moisture in the soil	1	2	3	4	5
Disease development and pest attack are encouraged	1	2	3	4	5
Increases the danger of fire outbreaks	1	2	3	4	5
Negative impact on soil pH value	1	2	3	4	5

10. Rate your agreement with the following statements about the advantages and disadvantages of burning pruning residues:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
The plant residues burning is in accordance with the principles of good agricultural practice	1	2	3	4	5
Useful because pests and disease are controlled	1	2	3	4	5
Extracting the branch from the plantation requires a lot of work	1	2	3	4	5
It is not useful because valuable organic material is lost	1	2	3	4	5
It is harmful to the air and the local ecosystem	1	2	3	4	5

11. Rate your agreement with the following statements about the advantages and disadvantages of composting pruning residues:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Organic waste in landfills is reduced	1	2	3	4	5
The obtained compost is a quality organic fertilizer	1	2	3	4	5
Composting is a demanding procedure that needs knowledge that I do not have	1	2	3	4	5
There is no organized composting system in the area	1	2	3	4	5
The composting process is very long and requires a lot of space	1	2	3	4	5

Composting creates unpleasant odors and attracts insects	1	2	3	4	5
Improper composting can result in the spread of disease in the plantations	1	2	3	4	5

12. Rate your agreement with the following statements about the advantages and disadvantages of producing firewood pellets from pruning residues:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Pellets have a high energy value	1	2	3	4	5
Pellets are an ecological energy source	1	2	3	4	5
Equipment for pellets production is expensive	1	2	3	4	5
The production of pellets requires a large consumption of energy, so their production is not ecologically justified	1	2	3	4	5
There is no organized system for the production of pellets in the area	1	2	3	4	5
The price of pellets is high compared to other energy sources	1	2	3	4	5

- questions for olive mill owners

13. Installed olive mill capacity:_____ kg/hour

14. Amount of processed olive fruits in the last 3 years:

2021 year - _____ olive fruit tons

2022 year - _____ olive fruit tons

2023 year - _____ olive fruit tons

15. Which technology is used in the olive oil extraction process in your olive mill:

a) Two-phase centrifuge system (oil + wet pomace)

b) Three-phase centrifuge system (oil + olive mill wastewater) + dry olive pomace)

Other_____

16. Is the extraction of pits carried out in your olive mill?

Yes - No

17. In witch phase are pits being separated?

a) Before milling the fruits

b) After oil extraction, from dry or wet pomace

c) Not applicable

Other_____

18. How is olive wet or dry pomace used or disposed of in your enterprise?

a) It is scattered on agricultural soil immediately after processing

b) Heap composting

c) As biofuel

d) For production of ecological products.

e) For the production of construction materials.

f) Livestock nutrition

g) Is disposed of at a waste disposal site

Other (specify):_____

19. If is implemented in your enterprise, how long does the composting process last _____ months

20. Rate your agreement with the following statements about the advantages and disadvantages of composting olive pomace:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Composting is the best available way to use olive pomace	1	2	3	4	5
The obtained compost is a high-value organic fertilizer	1	2	3	4	5
Compost improves the structure and biological activity of the soil	1	2	3	4	5
Olive pomace decomposes slowly, so composting takes at least 12 months	1	2	3	4	5
Due to the low content of organic acids and phytotoxins soil amendment with olive pomace compost is not an issue of environmental risk	1	2	3	4	5
The legal regulation of olive compost application in agriculture is complex	1	2	3	4	5

21. Rate your agreement with the following statements about the advantages and disadvantages of using olive pomace as biofuel:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Pomace is a high-quality renewable energy source	1	2	3	4	5
Pomace has a low energy value	1	2	3	4	5
The process of using pomace as biofuel is	1	2	3	4	5

expensive and unprofitable

22. How is used olive mill wastewater in your olive mill?

a) Recycling and reuse in the olive processing
b) For production of biofuel (biomethane)
c) Purification and reusing (irrigation)
d) Purification and release into the environment
e) Other (specify):_____

23) Rate your agreement with the following statements about the advantages and disadvantages of using olive mill wastewater for recycling and the potential use

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Olive processing costs are reduced	1	2	3	4	5
Reducing fresh water consumption contributes to ecological sustainability and reduces the negative impact of olive processing on the environment	1	2	3	4	5
Recycling olive mill wastewater is expensive and unprofitable	1	2	3	4	5
The disposal/use of recycled olive mill wastewater is subject to strict legal requirements	1	2	3	4	5
It is useful to purify vegetable wastewater for irrigation	1	2	3	4	5
It is useful to extract valuable compounds, such as polyphenols, from vegetable wastewater	1	2	3	4	5

24) For which purpose are olive pits used in your olive mill?

a) Energy source in its original form

b) For the production of pellets or briquettes

c) For the production of biomaterials. Organic fertilizer

d) Other (specify):_____

25) Rate your agreement with the following statements about the advantages and disadvantages of using olive pits as an energy source:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
The amount of waste from olive processing is significantly reduced	1	2	3	4	5
A natural, renewable energy source is obtained, for which is an increasing demand	1	2	3	4	5
Pits have a lower energy value compared to wood	1	2	3	4	5
High investments are required in a pits processing	1	2	3	4	5

26) Do you sell olive by-products and/or waste obtained in the olive sector?

No – Yes, _

Please list all the products you sell and mention as first the most important one according to your opinion.

27) (If the previous answer is YES) Rate your agreement with the following statements related to the placement and sale of the previously mentioned first product:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
I have no problem with the placement of this product	1	2	3	4	5
I am satisfied with the selling	1	2	3	4	5

price					
I plan to increase production	1	2	3	4	5
Most of the customers are within a radius of 50 km	1	2	3	4	5
The domestic market does not yet recognize this product	1	2	3	4	5
I need to improve the production technology of product for the market	1	2	3	4	5
It is necessary to educate customers about the benefits of the product	1	2	3	4	5
I have to invest a lot in marketing and publicity	1	2	3	4	5

28) Rate your agreement with the statements about the opportunities and threats of the circular economy in the olive sector

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Public subsidies stimulate olive growers to apply circular economy measures	1	2	3	4	5
The processing of olive by-products and waste requires large capital and labor investments	1	2	3	4	5
Olive by-products and waste from the olive sector pose a threat to the environment if they are not processed according to the principles of the circular economy	1	2	3	4	5

There is no organized olive by-products and waste processing system in the area	1	2	3	4	5
The legislative framework limits the development of circular economy in olive sector	1	2	3	4	5
It is necessary to raise awareness about the benefits of implementing circular economy in olive sector	1	2	3	4	5

Questions for both groups: Socio-economic characteristics of respondents

29) Respondent's gender

a) Male

b) Female

c) I don't want to answer

30) Respondent's age _____ year

31) Enterprise location

Country _____

Region _____

32) Respondent's education

a) High school and lower

b) Bachelor degree

c) Master degree

d) PhD

33) Education in the field of agriculture

Yes - No

34) Do you completed a course, training or education of circular economy in olive sector and/or agriculture?

Yes - No

35) If YES, enter the following information about education:

a. Education name _____

b. Organization in charge (Vocational Education and Training (VET) provider).

_____

c. Duration

_____

d. Method of implementation

Online

In presence

Hybrid mode

e. Obtained title _____

36) Enterprise size:

1. Micro (<10 employees)
2. Small (<50 employees)
3. Medium sized (<250 employees)
4. Large size (>250 employees)

37) Agriculture is for my household

a) The only source of income
b) Predominant source of income (> 50%)
a) Additional source of income (< 50%)

38) I am interested in attending a training course focused on how to valorise olive by-products and waste

Yes - No

39) Select the preferred method for attending a training course focused on how to valorise olive by-products and waste

a) Online

b) In presence

c) Hybrid mode

40) Dear responded,

Thank you for your time and contribution to Circolive project

41) I consent to have the information stated above used by the CIRCOLIVE project partners solely for meeting the purposes of this survey.

Yes – No

In case you want receive information about the project and activities, please enter your e-mail

14.2.2. ANNEX 2: Structured interview with circular business agro-food experts/professionals

ANNEX 2: Structured interview with circular business agro-food experts/professionals

Date:

Location:

Enterprise name:

Enterprise email address (in case you want receive further information about the Circolive project):

Enterprise size:

1. Micro (<10 employees)
2. Small (<50 employees)
3. Medium sized (<250 employees)
4. Large size (>250 employees)

Type of enterprise (possible multiple choice):

1. Olive producer
2. Olive mill owner
3. Olive by-products/waste recycle facility owner
4. Other: _____

Interviewees' business role:

1. Executive
2. Manager
3. Operations and production

Interviewees' years:

Interviewees' educational level:

1. Main information about your enterprise.
- length of business, number of employees,
- description of olive production (total number of olive trees, production area etc…)
- total amount of processed olive fruits per year
- oil mill capacity per hour
- all types of olive by-products/waste being processed
- all types of products obtained
- years of experience of by-products and waste processing
- total amount of each type of olive by-products/waste processed per year
- Other information

2. Describe the olive processing technology
- Describe the olive by-products and waste processing technology also if you know future technology trends if you know
- Describe the normative of each olive by-products and waste obtained from 100 kg of olive fruits (percentage of olive oil, wet/dry pomace, olive mill wastewater, pits)
- In case you use just one type of olive by-products and waste please explain the reason why you didn't use other olive by-products and waste

3. How are the obtained product/products from olive-by products and waste being used?
- Reusing by the enterprise or in the field, selling on the market, other
- If you sell on the market, describe the marketing mix 4P (price, product, place, promotion for each new product/products)
- Identify the major producers and industry players in the olive waste sector
- Try to predict market development of olive waste products (risk/challenges and opportunity/potential)
-

4. Which is your motives/drivers/preferences for processing olive by-products/waste?
- Social motives (more sustainable awareness/practice, social benefits/cohesion, culture/tradition, collaborative economy)
- Economical (cost savings – shared use, cheaper resource, resource of greater efficiency, higher income – additional income from products, increased sales, increased price from differentiation)
- Political-legal-institutional (legal obligations, systems of certification, institutional support)
- Innovation and technology (technology, knowledge, training)

5. Did you have any barriers or gaps when starting the olive by-products/waste business?
- Social (lack of environmental – social awareness, culture -tradition, deficiencies in collaborative economy networks)
- Economic (high initial investment, higher costs, lower profitability)

- Political-legal-institutional (regulatory limitations, lack of institutional supports and insecurity regarding incentives and aid)
- Innovation and technology (obsolescence, little development – access to technologies, lack of technical knowledge)

6. Describe the current situation in the context of barriers or gaps?
- Comment off all barriers from the previous question.

7. Do you plan remaining in olive by-products/waste business in the future?
- Expand business - increase the amount of olive by-products/waste processing capacity, add new types of olive by-products/waste processing or reduce/give up…)

8. Which is the Strengths, Weaknesses Opportunities, and Threats and for further developing the olive by-products/waste business?

Strengths (Strengths describe what an organization excels at and what separates it from the competition)
Weaknesses (Weaknesses stop an organization from performing at its optimum level)
Opportunities (Opportunities refer to favorable external factors that could give an organization a competitive advantage)
Threats (Threats refer to factors that have the potential to harm an organization)

- Can you identify any other best practices in your country regarding circular economy in the olive sector?

9. Do you have any education in the field of circular economy?

If yes, who is the provider of this education, duration of education, way of conducting the education (In presence, online, hybrid mode)
If no, do you plan participating in an educational program on the circular economy in the olive sector?

10. Are you interested in participating in the educational program on the circular economy in the olive sector which will be final results of the CIRCOLIVE project?

Which way of conducting the education (In presence, online, hybrid mode) you prefer?

14.2.3. ANNEX 3: Structured interview with VET providers

ANNEX 3: Structured interview with VET providers

Date:

Location:

VET name:

VET email address (in case you want receive further information about the CIRCOLIVE project):_____

Type of VET:

1. University
2. Polytechnic
3. Institute
4. Public Open University
5. Private provider
6. Other (specify):_____

Interviewees' role:

1. Executive
2. Manager
3. Lecturer
4. Other_____

Interviewees' years:

Interviewees' educational level:

1. Main information about VET provider
    - Length of business
    - Number and type of employees by role (teaching, training, administrative…)
    - Area of provided education (agronomy, forestry, economy, other)
    - Other information

2. Do you offer courses on circular business practices in the olive sector?

If - YES (question no. 3), If – NO (question no. 4)

3. Main information about available educational courses related to circular business practices in the olive sector:
    - Name and number of courses per year
    - Duration of each course in hours
    - Average number of participants who successfully passed the courses (per courses and per year)
    - Method and techniques used for training
    - Obtained title after course finishing
    - What are the recognition paths/qualification validation methods used by the offered trainings?
    - According to your knowledge, is the concept of circular business practices in the olive sector taught in other Institutions (regular (higher) education programs, in vocational training (VET) or in adult training in general)?

4. Which institutions offer courses on circular business practices in the olive sector (Universities, VET providers, adult training institutions, private institutes/schools, etc.)?
   - If there isn't any, which institutions could potentially offer courses on circular business practices in the olive sector in the future (universities, vocational education and training providers, adult training institutions, private institutes/schools, etc.)?

5. What training methods and techniques are mostly used and are suitable for circular business agro-food professionals' training? Theory + practices, Practices + educational visits, combination or something else, please describe.

6. What are the identified best practices in your country regarding the education programs in the context of circular business practices?
- offered trainings, training methods, recognition paths/qualification validation methods

7. In your opinion, which lecturer profiles (specialties) should have an institution offering courses on circular business practices? - agronomy (or a specialist in olive growing), ecology, food technology, economist, others

8. Do participants of the circular economy course in the olive sector need any prior specific degree or knowledge/skills?

9. If yes, which ones?

10. What skills the participants will have after passing the circular economy course in olive sector, and where they can apply their knowledge

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