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

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National Report on current situation in the olive oil sector – Spain

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1. Executive Summary

1.1 Background and Purpose

Olive oil is a fundamental product for the Spanish economy, representing more than 47% of global production. However, the extraction of oil generates large amounts of liquid and solid waste, leading to considerable environmental impact. In Spain, the extraction process is mainly carried out using two or three-phase centrifugal systems. These processes generate by-products such as alpechín (olive mill wastewater) and olive pits, which can be reused in the production of pomace oil or biomass.

Despite its economic importance, the olive oil sector faces significant challenges in managing its waste. In many production regions, the current waste management practices include basic methods that do not fully mitigate the environmental impact. For example, liquid waste is often discharged into evaporation ponds or treated using rudimentary techniques, which can lead to soil and groundwater contamination. Additionally, using these residues in agriculture, if not properly managed, can cause eutrophication in nearby water bodies. This report aims to investigate the current waste management techniques in the olive oil sector in Spain and evaluate the opportunities for introducing innovative technologies for waste valorization. The findings reveal that there is room for improvement, as many of the current methods only provide a basic level of treatment. However, significant barriers remain in adopting sustainable practices, such as the lack of infrastructure, high costs, technological gaps, and insufficient technical knowledge among many operators.

1.2. Key Findings

The report reveals that Spain's olive oil sector, while showing a strong commitment to managing by-products sustainably, faces several barriers to fully integrating circular economy practices. These include a lack of innovation, high costs, fragmented practices, low social and environmental awareness, and regulatory challenges. One major issue identified is the significant gap in educational programs specifically focused on circular business practices, which prevents the sector from maximizing the added value of these sustainable solutions. Additionally, the absence of a strong market for these innovations presents a key challenge.

The report also highlights shortcomings in Spain's vocational education and training (VET) programs for the olive oil sector. While these programs are strong in addressing olive oil production and general sustainability, they often fail to meet the specific needs of circular economy practices. Some training providers incorporate elements of sustainability and waste management into their curricula, but most lack a comprehensive approach to circularity. Furthermore, the lack of a standardized curriculum across institutions creates inconsistencies in the depth and breadth of training. Regional disparities are also evident, with Andalusia more advanced in circular economy initiatives compared to Catalonia, where such practices are less developed.

1.3. Recommendations

To improve the integration of circular economy practices in Spain's olive oil sector, the report recommends the development and implementation of a standardized and comprehensive curriculum across educational institutions. This curriculum should focus on key areas such as waste valorization, resource efficiency, sustainable production processes, and circular business models. Investment in educator training is also crucial, equipping teachers with the necessary knowledge to effectively teach these principles, in collaboration with universities, research institutions, and industry experts.

Moreover, practical training opportunities, such as internships and workshops in companies that have already adopted circular practices, should be increased to provide students with hands-on experience. Promoting regional collaboration to share best practices, especially allowing regions like Catalonia to benefit from Andalusia's successful models, is also essential. Lastly, the report stresses the importance of supporting research and innovation in circular economy technologies through partnerships between educational institutions, research centers, and industry stakeholders, fostering new developments and knowledge dissemination.

2. Introduction

2.1. Overview of the Olive Sector

According to the Ministry of Agriculture, Fisheries, and Food of Spain, Spain is positioned as the leading country in the production, commercialization, and export of olive oils, with average sales of 1,400,000 tons per year in recent seasons, 62% of which are destined for the export market. The sector is one of the most dynamic in the Spanish agri-food system and serves as a key driver of our economy. In fact, olive oils are the third most exported agri-food product from our country, accounting for 10% of the total sales of our agro-industry. This is only possible thanks to the deep-rooted olive-growing tradition and the vast fields dedicated to this purpose: 2,500,000 hectares of the most diverse and productive olive groves in the world, with 340 million olive trees, making it the largest olive-growing area on the planet (Ministry of Agriculture, Fisheries, and Food of Spain, 2024).

Recent data highlights the sector's resilience facing climatic and economic challenges, maintaining a commitment to quality on the global stage. Olive oil consumption reflects Spain's culinary traditions, with the sector holding significant economic, environmental, cultural, and gastronomic importance. Spain's leadership in olive cultivation underscores its pivotal role in the global market, particularly in sustainable practices.

The rise of circular economy principles offers an opportunity to enhance sustainability in olive oil production. By advocating for renewable resource production and transforming byproducts into value-added resources, circular models align with the Mediterranean diet's health benefits and economic significance.

2.2. Objectives of the Report

This report aims to identify circular economy practices and needs in Spain's olive oil sector and pinpoint emerging skills and professions essential for transitioning towards circular practices. Objectives include assessing current practices, identifying areas for improvement, recognizing necessary skill sets, evaluating potential impacts, and providing recommendations for stakeholders. Through these efforts, the report seeks to advance sustainable practices in the Spanish olive oil industry, fostering resilience, innovation, and economic growth in line with circular economy principles.

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 30 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 sample size was 30 respondents, namely 14 respondents for the olive grower's category, 12 respondents for the olive growers and olive mills owners' category and 4 respondents for the olive mill owner category (Table 1). 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 Spain (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. Interviews were conducted through an online meeting. 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.

Secondary data are ready-collected data that come 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.

Table 1. Decription of the sample of respondents who participated in the online survey (N=30)

Variable	N	Percentage (%)
Gender		
Male	**18**	**60**
Female	**10**	**33.33**
Prefer not to answer	**2**	**6.67**
Age		
Up to 36	**4**	**13.3**
37 - 56	**16**	**53.3**
57 and more	**10**	**33.3**
Education		
High school and lower	**13**	**41.9**
Bachelor degree	**14**	**48.4**
Master degree	**2**	**6.5**
PhD	**1**	**3.2**
Enterprise size		
Micro (<10 employees)	**28**	**93.5**
Small (<50 employees)	**2**	**6.5**
Medium sized (<250 employees)	**0**	**0**
Agriculture is in the household		
The only source of income	**10**	**32.3**
Predominant source of income (>50%)	**9**	**29**
Additional source of income (<50%)	**11**	**38.7**

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 (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

Spain is the world leader in surface area, production, and foreign trade thanks to the olive-growing tradition of our country and to a technologically advanced and professional industry capable of producing high-quality oils. Spanish olive oil production accounts for 70% of EU production and 45% of global production (International Olive Council, 2024).

The sector not only has undeniable economic importance but also has significant social, environmental, and territorial impacts. More than 350,000 farmers are dedicated to olive cultivation, the sector maintains around 15,000 jobs in the industry and generates over 32 million workdays per campaign. Additionally, the processes of transformation and distribution of its products, including its by-products, constitute the main activity of numerous municipalities and an associated industry that structures and unifies, in many cases, the rural environment where it is based, relying on a strong grassroots cooperative movement.

The olive grove covers 2.75 million hectares, of which 2.55 million hectares are dedicated to olive oil production (93% of the total olive grove area). The cultivation is present in 15 of the 17 autonomous communities, with a distribution in the central-southern and eastern parts of the peninsula. Andalusia is the largest producing region with 1.67 million hectares, mainly concentrated in Jaén, known for its characteristic "sea of olives" (Ministry of Agriculture, Fisheries and Food, 2024).

Regarding production, olive cultivation is characterized by its marked biennial bearing nature, resulting in significant production alternation between campaigns. As table 2 shows, regionally, olive oil production is mainly located in Andalusia, accounting for 80% of the total, with Jaén being the principal producing province with approximately 37% of the total, followed by Castilla-La Mancha with 8%, and Extremadura with 4% of the national total.

Table 2. Olive oil production in the regions of Spain (Ministry of Agriculture, Fisheries and Food, 2024)

Region	Hectares of Olive Groves
Andalucía	1.679.412
Castilla La Mancha	451.994
Extremadura	296.190
Cataluña	114.101
C. Valenciana	945.05
Aragón	614.94
Madrid	29.811
Reg. Murcia	29.069
Navarra	10.211
Baleares	9.307
Castilla y León	7.427
La Rioja	3.587
Canarias	578
País Vasco	335
Galicia	63
Asturias	0
Cantabria	0
Spain	**2.788.084**

The primary reason Spain leads the world in olive oil production is its favourable climate. Much of the Spanish territory enjoys a Mediterranean climate, ideal for olive cultivation, characterized by long hours of sunlight and mild temperatures, especially in regions like Andalusia and Extremadura. The diverse topography also contributes to a variety of olive types, each imparting unique flavours and aromas to the oil. However, other olive-producing countries like Italy, Greece, and Tunisia share similar climatic and topographical features. What sets Spain apart is its millennia-old tradition of olive cultivation. The introduction of olive trees to the Iberian Peninsula by the Phoenicians dates to around the 8th century BCE. This long history has allowed olive farming to become deeply rooted in the culture and economy of Spain (Food and Agriculture Organization of the United Nations, 2024).

4.2. Historical Development of Olive Cultivation

The historical development of olive cultivation in Spain can be traced back to ancient times. Introduced by the Phoenicians around the 8th century BCE, olive farming has flourished over the centuries, becoming an integral part of Spanish agriculture. Today, Spain boasts 2.75 million hectares of olive groves, representing 57.3% of its agricultural area, followed distantly by cereals at 9.1%, according to the integrated production statistics from the Ministry of Agriculture, Fisheries, and Food (MAPA, 2024). Of these olive groves, 93% are dedicated to olive oil production, with the remaining 7% used for table olives (CaixaBank Research, 2024).

Nowadays, the olive oil sector in Spain is heavily reliant on a robust grassroots cooperative movement, which plays a crucial role in the industry's success. Cooperatives, which are widespread in olive oil-producing regions like Andalusia, serve as a foundation for the sector's economic and social structures. They help small and medium-sized producers pool their resources, gain market access, and improve their bargaining power, which is essential for dealing with both domestic and international markets (CaixaBank Research, 2024).

These cooperatives have evolved over time to become more than just production entities. They often engage in processing, marketing, and even exporting olive oil, thus ensuring that the added value of olive oil production stays within the local economy. They also invest in technological innovations and sustainable practices, helping members adopt environmentally friendly techniques that contribute to the broader goals of circular economy initiatives.

Moreover, cooperatives support rural development by providing employment and stabilizing rural populations, which is vital in regions suffering from depopulation. This grassroots model is also instrumental in maintaining traditional agricultural practices while simultaneously embracing modern advancements in production and processing (Government of Spain, 2024).

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

The olive oil industry also generates substantial waste and by-products that can negatively impact the environment if not properly managed. In recent years, there has been a growing interest of the Ministry of Agriculture of Spain in implementing circular economy practices in the olive oil sector to reduce waste and promote sustainability

(Donner & Radić, 2021; MAPA, 2024).

In terms of policy, Spain has several relevant regulations and strategies in place to promote the circular economy in the olive oil sector. The Royal Decree 553/2020, for example, regulates the transfer of waste within Spain. Additionally, the CE Action Plan I includes measures to incorporate circular economy principles into other policies and areas at the national level, such as the More Food, Less Waste Strategy and the Biogas Roadmap.

Additionally, the Order TED/92/2022, of February 8, establishes the conditions for considering fatty pomace from olive mills as by-products when destined for the extraction of crude olive pomace oil. This regulation aims to harmonize the classification of these residues across different autonomous communities in Spain. According to this order, fatty pomace is considered a by-product if it will be used without further processing other than what is typically industrial, produced as part of an integrated production process, and meeting all relevant health and environmental requirements (Real Decreto 553/2020; Orden TED/92/2022).

The regulation sets specific requirements for the storage and handling of these by-products to prevent contamination and ensure their safe use. For example, fatty pomace must be stored in appropriately isolated facilities to avoid contact with soil and surface water. Producers must also notify the relevant regional authorities if they intend to manage fatty pomace as a by-product.

The results of the interviews indicate that the primary regulation in the sector pertains to the use of residual water. The extraction of oil from olives results in a liquid effluent composed of the washing waters of the olives and the washing waters of the oils obtained through the two-phase extraction system. These effluents are resources that can be used on agricultural soils to restore part of the nutrients extracted by cultivation.

The Ministry of Agriculture, Fisheries, and Rural Development, through Decree 4/2011 of January 11, which regulates the use of olive mill liquid effluents as agricultural fertilizer on agricultural plots, and the Order of February 18, 2011, which regulates the authorization regime for the use of liquid effluents resulting from olive oil extraction in olive mills as fertilizer on agricultural soils, has established limitations for the use of these liquid effluents as agricultural fertilizers. They can be used under a series of conditions that ensure they do not affect the environmental quality of the area where they are applied (MAPA, 2024).

The limitations for the use of this washing water resulting from the virgin olive oil extraction activity establish a maximum volume that can be applied, which in no case will exceed 50 cubic meters per hectare per year. Furthermore, it designates exclusion areas for the use of these effluents, which include surfaces located less than 500 meters from urban centres; “the police zone” (a legal and technical term that refers to a strip of land adjacent to a river, lake, reservoir, or other body of water that is subject to special regulations to protect the public water domain) of 100 meters regarding hydraulic public domain; and the protection easement zone of 100 meters regarding maritime-terrestrial public domain. According to the new regulations, the application of effluents will be adjusted to the infiltration capacity of the soil to avoid surface runoff, thus excluding their application on saturated, flood-prone, or frozen soils. Applications must be carried out in such a way that they do not produce nutrient and salt leaching or invade the groundwater level of the soil, as stipulated by the norm.

Additionally, the use of effluents is prohibited on saline or sandy soils, on plots with slopes greater than 15% for woody crops and 10% for herbaceous crops, percentages that can be increased up to 35% for woody crops as long as there is a vegetative cover with a minimum width of 1 meter. In the case of applications by localized irrigation, the percentages will not be considered. In any case, both the effluents to be used and the soils where they are intended to be applied must be analysed by authorized laboratories (agricultural-livestock laboratories, agri-food laboratories). Similarly, the maximum permissible limits for the analytical parameters of the effluent for its application on agricultural soils are established (Actualidad Jurídica Ambiental, 2022).

5. Olive Production Analysis and Olive Oil Processing

5.1. Cultivation Practices and Varieties

According to Oriva.es (2024), in Spain, olive cultivation is a major agricultural activity characterized by diverse practices tailored to local conditions. Table 3 shows the distribution of Olive Varieties Across Different Zones in Spain. The country primarily grows two main olive varieties: 'Picual,' renowned for its high oil yield and robust flavour, and 'Arbequina,' which is valued for its mild taste and high adaptability. Cultivation practices vary regionally, with Andalusia, Castilla-La Mancha, and Extremadura being the primary olive-growing areas. In recent years, there has been an increasing trend toward sustainable practices, including the use of integrated pest management and organic farming methods to improve both yield and environmental impact.

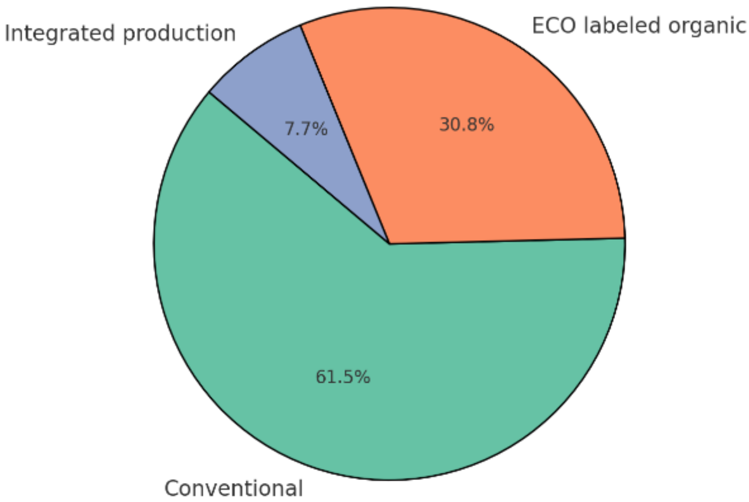
Table 3. Distribution of Olive Varieties Across Different Zones in Spain (Source: Oriva.es,2024).

Zone	Regions	Main Varieties
Zone 1	Entire province of Jaén, North of Granada, East of Córdoba	Picual
Zone 2	Large part of Córdoba, Antequera, Loja, Estepa	Hojiblanca, Picual, Carrasqueña de Córdoba (Picudo), Chirrío, others
Zone 3	Huelva, Cádiz, Seville	Hojiblanca, Verdial de Huévar, Manzanilla Serrana
Zone 4	Province of Almería, part of Granada, Málaga	Lechín de Granada, Verdial de Vélez-Málaga, Aloreña, others
Zone 5	Extremadura, Ávila, Salamanca, Zamora	Manzanilla Cacereña, Manzanilla or Corresgueña de Badajoz, Morisca, Verdial de Badajoz, Cornicabra
Zone 6	Castilla La Mancha, Madrid	Cornicabra
Zone 7	Levante area	Blanqueta
Zone 8	Ebro Valley (Aragón, La Rioja, Navarre, Álava)	Empeltre
Zone 9	Tortosa - Castellón area	Farga, Morrut, Servillenca, Empeltre, others
Zone 10	Catalonia (mostly Lleida province) except Lower Ebro - Montsià, Balearic Islands	Arbequina

5.2. Olive Oil Extraction Methods

According to Olive Oils from Spain (2023), olive oil extraction in Spain employs both traditional and modern methods. The most common technique is the mechanical cold-pressing process, which involves crushing olives and extracting oil without the use of heat, preserving the oil's quality and flavour. Additionally, some producers use centrifugal separation techniques to enhance extraction efficiency. The use of advanced technology and innovation in extraction methods has been growing, focusing on improving oil quality and operational efficiency while adhering to stringent quality control standards.

For instance, according to the results of the questionary applied to olive oil producers and mill owners, in the first chart, representing olive producers, (Fig. 1) the majority



(61.5%) rely on conventional farming methods. A significant portion (30.8%) uses ECO labelled organic practices, while a smaller fraction (7.7%) employs integrated production techniques. This distribution indicates that while there is a growing interest in organic practices, conventional methods still dominate among olive producers

Fig 1. Technology used in the olive grove (Olive producers).

The second chart (Fig. 2), which represents producers who also own mills, shows a more diversified approach. It highlights that nearly half (46.2%) utilize conventional methods, while others incorporate sustainable approaches such as organic farming with ecological labels (7.7%) and biodynamic practices certified by Demeter (7.7%). A notable segment combines conventional techniques with integrated production (7.7%) to minimize environmental impacts. Additionally, some producers manage dual operations of organic and conventional olive growing, reflecting a versatile approach to market demands and agricultural sustainability. The chart emphasizes a shift towards environmentally friendly practices, including the use of recyclable and biodegradable packaging (7.7%). This indicates that mill owners, who may have more resources or different market demands, are more inclined to adopt a variety of sustainable practices compared to olive producers alone.

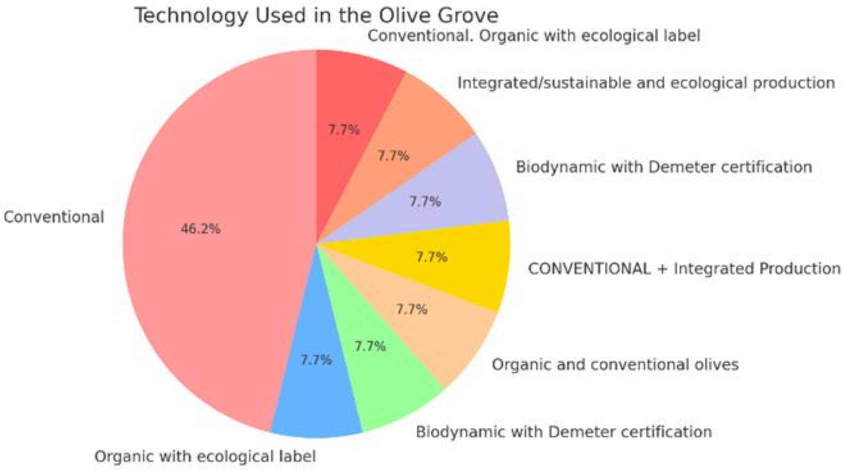


Fig 2. Technology used in the olive grove (olive producers and mill owners).

5.3. Cultivation area, Yield Trends and Production Statistics

According to the Olive Oil Market Report (2023), Spain is the largest olive oil producer globally, with a total cultivation area of approximately 2.8 million hectares. The country's olive groves are primarily concentrated in Andalusia, which accounts for most of the cultivation area. Yield trends have shown a steady increase in recent years due to advancements in cultivation techniques and improved varieties. The province of Jaén has more than 60 million olive trees, covering over 80% of the arable land. Therefore, olive oil is the economic backbone of the province of Jaén, accounting for more than 50% of the total production at the national level (International Olive Council, 2024). The total olive oil production in Spain for 2023 is estimated to be around 1.8 million tonnes. This represents a slight increase from previous years, reflecting ongoing improvements in cultivation practices and favourable climatic conditions (Ministry of Agriculture, Fisheries, and Food of Spain, 2024).

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

6.1. Olive Leaves and Branches

A common practice in rural areas of Spain consists of burning branches and leaves in large piles in the open air. However, although burning pruned olive branches may seem like an acceptable and common practice, it can have serious consequences for both human health and the environment. Also, the droughts and lack of rainfall make it even more urgent to regulate the burning of pruned olive branches, as there can be a fire risk even in autumn and winter in areas of Andalusia such as Córdoba or Jaén, and specifically where we are located, in the Sierras Subbéticas Natural Park in Córdoba (Ministry of Agriculture, Fisheries, and Food of Spain, 2024).

Table 4. Procedure with Olive Pruning Residues in the Olive Grove

Procedure with olive pruning residues	Olive Producers %	Olive Producers and Mill Owners %
Mulching (pasture mulching)	**46.2**	**75**
Controlled burning with or without residue retrieval	**46.2**	**25**
Composting	**23.1**	**25**
Firewood	**69.2**	**58.3**
Pellet production	**0**	**0**
Animal nutrition	**7.7**	**16.7**
For the pharmaceutical industry	**0**	**0**
Production of useful articles	**0**	**0**
None of the above options	**7.7**	**8.3**
Soil incorporation trenching	**7.7**	

6.2. Olive Pits

The olive is composed of 85% pulp and 15% pit, and the olive pit can be utilized in two fundamental ways: to generate energy and to obtain non-energy chemical products. Today, numerous studies are underway to develop methods for the energy recovery of biomass, particularly lignocellulosic materials. Traditionally, the olive pit has been used in boilers in olive-related industries, such as oil mills and extractors, as well as in other sectors like ceramics and farms. In Spain, the number of companies dedicated to utilizing this material and transforming it into eco-friendly fuel has significantly increased in recent years, becoming a highly profitable business.

Table 5. Use of olive pits the Olive Grove

Purpose	Producers	Mill Owners
Energy source in its original form	**46.2%**	**100.0%**
For pellet or briquette production	**15.4%**	**25.0%**
For biomaterial production	**0.0%**	**25.0%**
For organic fertilizer production	**23.1%**	**0.0%**
We do not pit the olives	**7.7%**	**-**
Not used	**7.7%**	**-**
None	**7.7%**	**-**

Table 5 compares the purposes for using olive pits between producers and mill owners, and mill owners. Mill owners predominantly use olive pits as an energy source in their original form, with 100% of respondents selecting this option, compared to 46.2% of olive producers. This highlights a strong preference for energy generation among mill owners. Conversely, olive producers are more diverse in their usage, with 23.1% using olive pits for organic fertilizer production, a purpose not selected by any mill owners. Additionally, while mill owners do consider the production of pellets or briquettes (25%) and biomaterials (25%), these options are less prevalent among olive producers. Interestingly, a small percentage of olive producers (7.7%) indicate that they do not pit their olives or do not use the pits at all, options not chosen by mill owners. This suggests that mill owners have more specialized or consistent practices for utilizing olive pits, primarily focused on energy production.

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

In the last 30-35 years, the process of oil extraction in the mill in Spain has undergone various and very significant technological changes. From the traditional press with baskets, the process evolved to continuous extraction using a three-phase decanter (oil, pomace, and olive mill wastewater), and in recent years, to a two-phase decanter (oil and wet greasy pomace), and occasionally to a second centrifugation.
The following pie charts (Fig. 3 and Fig.4) compare the olive oil extraction technologies used by two groups: olive producers and mill owners, and mill owners. The majority of both groups use the two-phase centrifugation system, but it's more prevalent among olive producers and mill owners at 84.6%, compared to 75% among mill owners. This system produces less liquid waste (wastewater), which can be beneficial for the environment. Additionally, the wet pomace can be used for composting or for biogas extraction. In the first group (fig. 3) A smaller portion (7.7%) use a three-phase centrifugation system, which results in oil, wastewater, and dry pomace. Additionally, another 7.7% of this group employs a combined approach, starting with two-phase extraction and following up with a three-phase extraction. This indicates a strong preference for the two-phase system among these producers, likely due to its efficiency and lower water usage compared to the three-phase system.

Fig. 4, which represents mill owners only, shows a slightly different pattern. While the majority (75%) still favor the two-phase centrifugation system, a significant 25% of mill owners use the three-phase centrifugation system. The three-phase centrifugation system is used by 25% of mill owners, whereas only 7.7% of olive producers and mill owners use this method. This indicates a preference for the two-phase system across both groups, but mill owners show a higher adoption rate of the three-phase system, possibly due to different operational needs or resource management strategies.

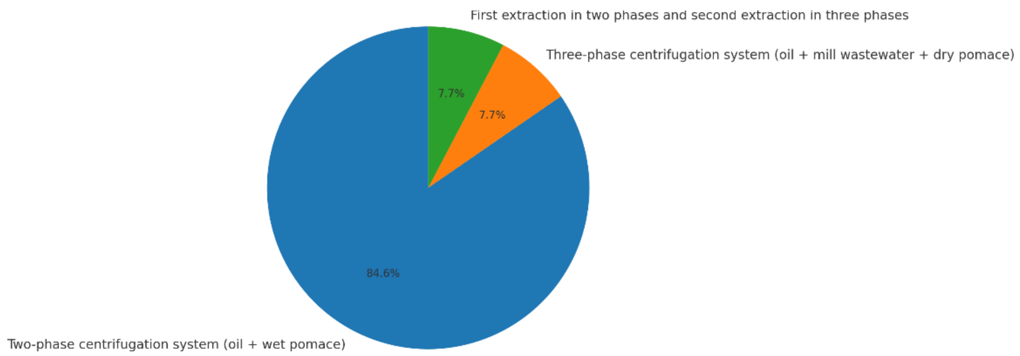


Fig. 3 olive oil extraction technologies used by olive producers and mill owners

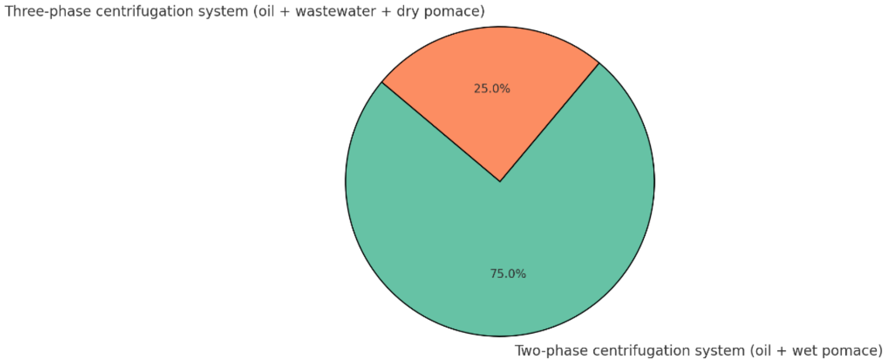


Fig. 4 olive oil extraction technologies used by mill owners

Table 6 shows Use or disposal methods of olive pulp or dry pomace between olive producers and mill owners who are also producers. Producers who are also mill owners demonstrate a variety of approaches to managing these by-products. Their responses indicate a spread of activities, including composting in piles and using the pomace as biofuel, each selected by 15.4% of respondents. Additionally, 61.5% of this group sends the pomace-to-pomace oil extractors, reflecting a significant reliance on this method. Interestingly, 7.7% of these producers spread the pomace on agricultural soil, dispose of it in a landfill, or use it for product production, showcasing a diverse range of practices.

In contrast, mill owners who do not engage in olive production are more focused in their approach. A full 100% of this group sends the pomace to, pomace oil extractors, making this the predominant method of utilization. Only 25% of mill owners report disposing of pomace in a landfill, indicating limited variation in their practices compared to the more diverse methods employed by those who are both producers and mill owners.

This suggests that mill owners prioritize the efficiency and profitability of sending pomace to extractors, whereas producers who are also mill owners might explore a broader spectrum of uses, likely influenced by their dual role in production and processing.

Table 6. Use or disposal methods of olive pulp or dry pomace between olive producers and mill owners who are also producers

Usage of Olive Pulp or Dry Pomace	Producers and Mill Owners (%)	Mill Owners (%)
Spread on agricultural soil	**7.7**	**0**
Composted in piles	**15.4**	**0**
Used as biofuel	**15.4**	**0**
Used for product production	**7.7**	**0**
Used for material production	**0**	**0**
Used for animal feed	**7.7**	**0**
Disposed of in a landfill	**7.7**	**25**
Sent to pomace oil extractors	**61.5**	**100**

6.4. Waste Water

Years ago, a study at the University of Granada identified the feasibility of using olive mill wastewater, or "alpechín," as a fertilizer for olive groves. In fact, this study led to a 2014 regulation allowing the discharge of alpechín from olive mills as a fertilizer, provided it is applied at a dose of 500 m³ per hectare per year and on farms located away from municipal boundaries and watercourses. More recently, research from the University of Córdoba has proposed using industry effluents to reduce their environmental impact and compensate for the decline in rainfall (elmundo.es, 2024).
Regarding the wastewater, table 7 compares the answers of the questionary regarding the wastewater usage methods between producers and mill owners, and mill owners. Producers who are also mill owners predominantly focus on purification and release into the environment, with 53.8% of respondents selecting this method. This is followed by 30.8% who choose purification and reuse for irrigation. Interestingly, none of these producers use recycling and reuse in the processing of olives, and only a small portion (7.7%) use the residual water for biofuel production or as an organic amendment. Additionally, 7.7% indicated that they do not use water in their process.
In contrast, mill owners show a more varied approach. Half (50%) of them focus on purification and reuse for irrigation, which is consistent with some of the practices of the producers who are also mill owners. However, 25% of mill owners recycle and reuse water in the processing of olives, a method not used by the first group. Similarly, 25% of mill owners purify and release water into the environment. Unlike the producers who are also mill owners, none of the mill owners use residual water for biofuel production or as an organic amendment.
This analysis suggests that mill owners are more likely to implement recycling and reuse practices within their processes, while producers who also own mills are more focused on purification and environmental release, indicating different priorities or resource allocations between the two groups.

Table 7. Wastewater usage methods between producers/mill owners, and mill owners

Usage of Residual Water from the Olive Mill	Producers and Mill Owners (%)	Mill Owners (%)
Recycling and reuse in the processing of olives	**0**	**25**
For the production of biofuel (biomethane)	**7.7**	**0**
Purification and reuse (irrigation)	**30.8**	**50**
Purification and release into the environment	**53.8**	**25**
Application as organic amendment	**7.7**	**-**
We do not use water in our process	**7.7**	**-**

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

Table Olives – Curing companies
The second agro-industrial utilization line of the olive tree is the table olive processing sector, where table olives are produced in curing companies (a facility where olives are processed and treated, typically through fermentation or brining, to produce table olives) through fermentation or brining processes.
According to The Ministry of Agriculture, Fisheries, and Food of Spain, the olive groves

in Spain cover 2.75 million hectares, of which 197,335 hectares are dedicated to table olives (77,650 hectares for table olive groves and 119,685 hectares for dual-purpose groves). Table olive groves represent 7% of the total olive-growing area, and it is estimated that 40% of these are irrigated. Spain is the world leader in table olive production. Spanish production accounts for an average of 62% of the EU's production and 17% of global production.
In terms of variety, the most notable are: Hojiblanca with 46% of the national total production, Manzanilla with 36%, Gordal Sevillana with 7%, Manzanilla Cacereña with 4%, and Carrasqueña with 3% (Ministry of Agriculture, Fisheries and Food of Spain).

Regionally, production is concentrated in Andalusia, which accounts for 80% of the total, and Extremadura with 13%. Seville, as the main producing province, accounts for approximately 58% of the national total production.
By-products generated in these agro-industries include leaves and olive pits.
Leaves from curing companies are produced similarly to mills during the olive cleaning process before processing. The number of leaves generated is less than in mills because table olives are harvested manually, whereas olives for oil are harvested using mechanical shakers or vibrators, which produce more leaves. The uses of leaves in this case are similar to those from mills Olive pits from curing companies are generated during the pitting process for producing pitted table olives. Most of these pits are sent to mills, along with rejected olives, integrating them into the olive oil extraction line (Mercacei, 2023)

According to Spanish regulations, olive oil must meet specific acidity requirements. For olive oil to be classified as "lampante" (a type of olive oil not suitable for direct consumption and typically used for refining), the free fatty acid content must exceed 2.0%. In contrast, "refined olive oil" and "olive pomace oil" have different standards. Refined olive oil must have a maximum acidity of 0.3%, while olive pomace oil, which is extracted from the residue left after the first extraction, must have an acidity level of less than 1.0% to be commercially acceptable (Ministry of Agriculture, Fisheries and Food, 2024, Reglamento (UE) No 2568/91).

According to the Junta de Andalucia, in their report called Evaluation of the Production and Uses of By-products from the Olive Agro-industries in Andalusia (2015), the by-products of the olive agro-industries have a wide variety of uses. These uses include animal feed, direct incorporation into the soil, composting, and bioenergy production. Figure 5 describes the Use Model of the Circular Economy in the Olive Agroindustry in Spain.

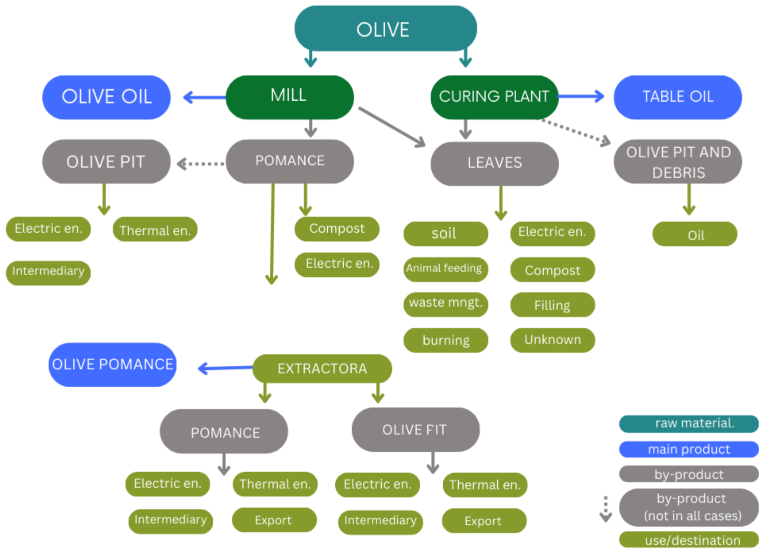


Fig. 5 Cascading Use Model of the Circular Economy in the Olive Agroindustry in Spain (Junta de Andalucía, 2015)

Olive oil-Mills

In Andalusia, the most important region in Spain in terms of olive oil production, the primary and most significant transformation process by production volume is olive oil extraction, which processes approximately 90% of the total olives transformed in the region. Olive oil is produced through physical processes in olive oil-mills. The by-products generated in these agro-industries include leaves, pomace/alperujo, and olive pits (Junta de Andalucía, 2020).

Leaves are composed of the remnants of leaves and fine branches produced during the cleaning of olives before processing. The primary uses or destinations for this by-product include direct soil incorporation by farmers, electric generation or cogeneration, animal feed (mainly for goats and sheep), composting, waste management, and filling erosion furrows.

Pomace/alperujo is the by-product resulting from the olive oil extraction process. It consists of the paste of crushed olives from which the oil has been extracted and is characterized by a high moisture content (60-65%). Pomace/alperujo is primarily used to produce pomace oil in extractors and, to a lesser extent, for compost production and electric generation or cogeneration.

Olive pits, a component of pomace/alperujo, are extracted through a physical process in many mills due to their value as a biofuel. These pits are used to generate process heat within the mill (self-consumption), and the surplus is sold for electric generation or cogeneration in biomass plants, thermal applications in industries, domestic heating, and to intermediaries or processors who distribute and/or transform them. The transformation process involves separating the pulp from the pit to create a higher-quality biofuel, mainly used for domestic heating. The separated pulp can be used in animal feed.

Pomace Olive Oil – Extractors

Pomace/alperujo generated in mills is primarily used to produce pomace oil, a process carried out in extractors or pomace oil plants. By-products generated in these agro-industries include olive pits and pomace, though their production depends on the type

of extractor and the extraction processes used (physical and/or chemical).
Olive pits in extractors are obtained similarly to mills, through a physical process from pomace/alperujo before processing to obtain pomace oil. The extracted pit is used in the extractors for drying pomace/alperujo, and/or sold for thermal uses in industries, electric generation or cogeneration, intermediaries, and export.

Pomace is the by-product of the pomace oil extraction process using a chemical method (hexane as a solvent). This type of extraction requires prior drying of pomace/alperujo to 10% moisture. Pomace is used to generate process heat within the extractors for drying pomace/alperujo, and/or sold for electric generation or cogeneration in biomass plants, thermal applications in industries, intermediaries, and export.

7. Sustainability and Environmental Impact

7.1. Sustainable Practices in Olive Farming and Olive Oil Producing

Like all industries, the agri-food industry for olive oil produces a range of waste that must be managed to prevent contamination. Challenges such as water availability, sustainable food production, and climate change mitigation can be addressed within the framework of such strategies. Olive oil production generates a wide variety and amount of waste and by-products that must be managed properly in compliance with current legislation to ensure environmental protection and conservation (ecoprolive.com).
At the same time, it is possible to consider alternatives that create new business opportunities for olive growers under the bioeconomy paradigm. This approach aims to optimize the use of resources, materials, and products, maintaining their value in the economy for as long as possible and ultimately minimizing the final generation of waste. In this sense, many of the previously misnamed "wastes" become by-products or new raw materials, transforming problems into opportunities.
One by-product of olive oil production in mills in Spain, is the wastewater from washing olives, which can also include water from washing patios and machinery. These wastewaters must be managed appropriately under the principles of legality, sustainability, and profitability. Currently, there are various alternatives such as anaerobic digestion or evaporation, processes that are costly or require significant investment but are necessary due to the unavoidable need for managing this effluent, both from a regulatory perspective and because of the volume generated in a short period and the limited space available in mills for its storage.

In this context, an innovative alternative is the direct use of this by-product through localized irrigation systems. The organic and variable nature of this fluid, commonly known as "alpechín," makes this valorisation option a challenge, showing that it is an effective and advantageous option when the appropriate technology is used (Tratamiento de alpechines, Ministery of Agriculture, Fisheries, and Food of Spain, 2024).
In Spain, mills are increasingly focused on optimizing both water and energy resources. New machinery being installed in the extraction process uses water more rationally and controlled, as water is an increasingly scarce resource. This includes not only its consumption but also the discharge of that water, which previously ended up in evaporation ponds. The installation of more efficient motors in machinery is leading to

a reduction in energy consumption, allowing mills to gradually adapt to the new scenario of fighting climate change (Elmundo.es/andalucia/2024).
Most of the technology is used for less consumption of water. The sector is using modern machinery that is increasingly efficient and consumes less water, using only 1 litter of water for every 100 kg of olives processed. But not only are measures being taken in oil extraction to mitigate climate change, but also in the use of by-products generated by the mill. These include using olive pits as biofuel (once treated and certified) and alpeorujo (a less valued by-product) primarily as compost. This approach helps close a circular economy around olive farming (smallops.com, 2022).
According to the information gathered trough the questionary applied, figure 6 shows the technological interventions related to circular economy practices mostly applied in olive grove.

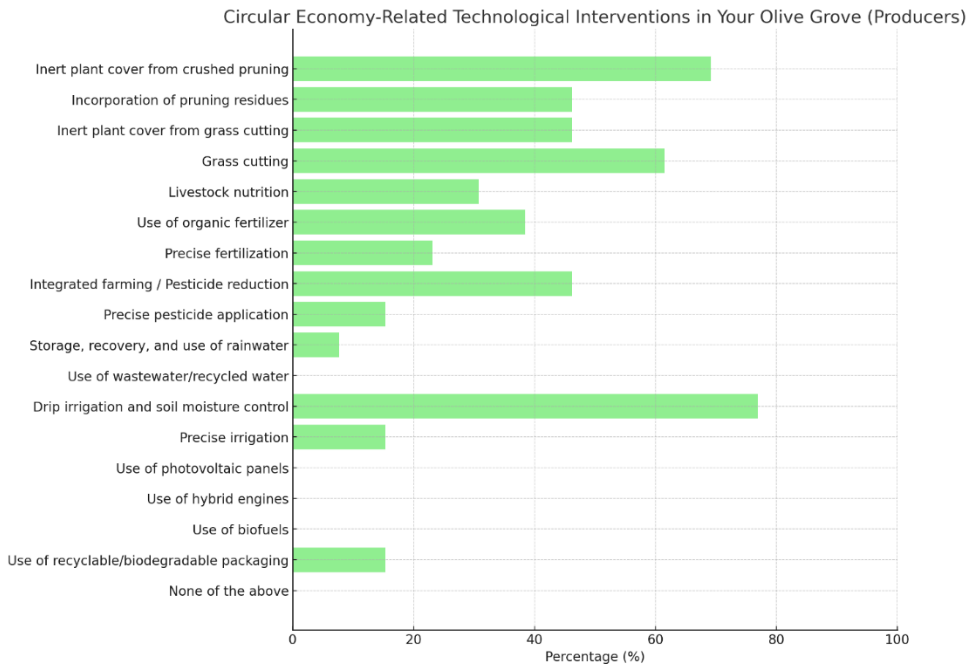


Figure 6. Technological interventions related to circular economy mostly applied in olive grove by producers.

As can be observed, the responses from olive producers indicates a strong preference for the use of circular economy-related technologies in their olive groves. The most common practice, with 76.9%, is drip irrigation and water consumption control, highlighting a significant focus on efficient water use. This is closely followed by the use of inert plant cover from pruning residues, which 69.2% of producers implement. This practice, along with grass cutting (61.5%) and the incorporation of pruning residues into the soil (46.2%), reflects an emphasis on soil health and sustainability. The adoption of organic fertilizers is also notable at 38.5%, demonstrating an inclination toward sustainable agriculture. However, advanced technologies such as the use of photovoltaic panels, hybrid engines, or biofuels are not widely adopted, showing limited integration of renewable energy sources. The absence of any respondents indicating the use of recycled or recyclable packaging suggests that waste management practices might not be as prioritized.

Responses changed when the same variables were asked to mill owners that are also producers as showed in Figure 7.

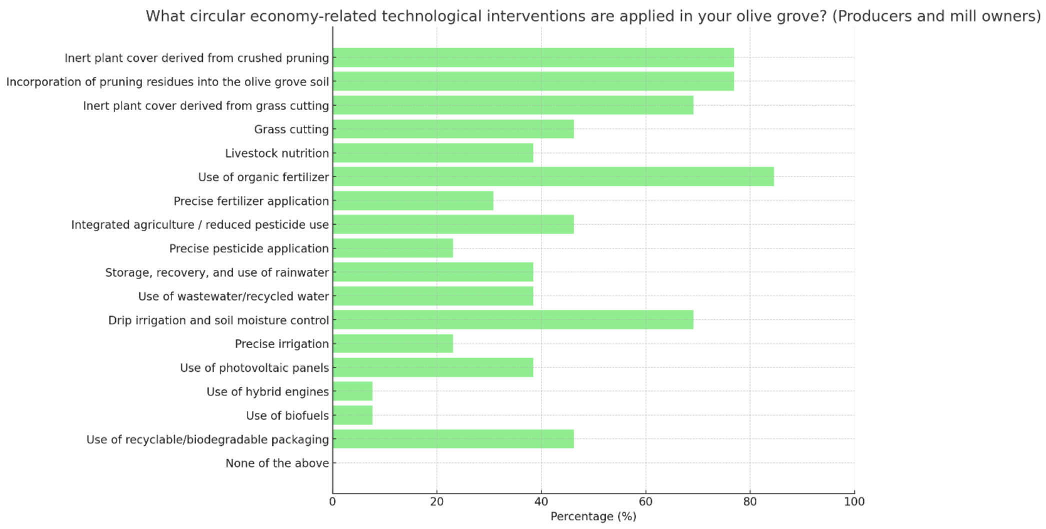


Figure 7. Technological interventions related to circular economy mostly applied in olive grove by mill owners who are also producers

The chart for producers who are also mill owners (Fig. 7) shows a slightly different distribution of technological interventions. The most prevalent practice is the use of organic fertilizers, with 84.6% of respondents indicating its use, which underscores a strong commitment to sustainable and organic agriculture. The use of inert plant cover derived from crushed pruning, the incorporation of pruning residues is also widely practiced (76.9%), drip irrigation and water consumption control and inert plant cover derived from grass cutting (69.2%) show that these producers are equally concerned with water efficiency and soil health. Interestingly, this group shows some engagement with renewable energy technologies, with 7.7% using hybrid engines and biofuels. This might indicate a gradual shift towards more innovative, energy-efficient practices. Also, there is reported use of photovoltaic panels (38.5%), and 46.2% are using recycled or recyclable packaging. The data suggests that while traditional sustainable practices are strongly embraced, the adoption of newer, more advanced technologies is still relatively limited among these producers and mill owners.

8. State of Circular Business Practices in the Olive Sector

8.1. Trends and Preferences

The table 8 provides an overview of olive producers' motivations and perceptions regarding the treatment of by-products from olive cultivation in Spain. The responses highlight various opinions on composting pruning residues, burning pruning residues, mulching pruning residues, and utilizing olive pomace and pits. For composting pruning residues, a significant number of respondents agree that it improves soil health, reduces the need for chemical fertilizers, and reduces waste management costs. However, there is also a notable percentage that neither agree nor disagree with these benefits. Regarding burning pruning residues, many find it a quick way to dispose of waste and believe it provides necessary nutrients back to the soil yet concerns about pollution and the danger of wildfires are prevalent, with high disagreement rates on its usefulness and safety. Mulching pruning residues is widely recognized for improving soil moisture retention, adding organic matter, and promoting microbial activity, though opinions on its effectiveness in increasing soil organic carbon content and water infiltration vary. When considering motivations for utilizing pruning residues, reducing costs and increasing income, and awareness of sustainability are strong drivers, alongside legal obligations and the availability of technology and knowledge. For olive pomace, respondents generally agree that composting it improves soil fertility, reduces waste volume, and contributes to nutrient cycling, although there is some ambivalence regarding these benefits. Finally, the use of olive pits as an energy source is largely seen as positive for providing clean energy and being renewable, with some respondents highlighting the minimal processing required and the potential for heating and power generation.

Table 8. Olive producers' motivations and perceptions regarding the treatment of by-products from olive cultivation in Spain

Question	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
The composting of pruning residues improves soil health.	Low	Medium	Low	High	Low
The composting of pruning residues reduces the need for chemical fertilizers.	Low	Medium	Low	Medium	Low
The composting of pruning residues reduces waste management costs.	Low	High	Low	Medium	Medium
Not having to burn pruning residues reduces pollution.	Low	Low	Medium	High	Medium
The composting of pruning residues increases crop yield.	Low	Medium	Low	Medium	Medium
The composting of pruning residues improves soil structure.	Low	Medium	Medium	Medium	High
Burning pruning residues is a quick way to dispose of waste.	Low	Medium	Low	High	Low
It provides necessary nutrients back to the soil.	Low	Medium	Medium	Medium	Low
Extracting residues through burning helps in pest control.	Medium	Low	Medium	Medium	Low
It is not useful to burn residues because it destroys nutrients.	Medium	Low	Low	High	Low
It is dangerous to burn residues because it can cause wildfires.	Low	Medium	Low	Medium	Medium
Mulching of pruning residues improves soil moisture retention.	Low	Medium	Medium	Medium	High

An effective way to manage pruning residues is through mulching.	Low	Low	Medium	High	Medium
It provides organic matter to the soil through mulching.	Low	Low	Medium	Medium	Medium
It promotes microbial activity in the soil through mulching.	Medium	Low	Low	Medium	Medium
Increases the organic carbon content in the soil through mulching.	Medium	Low	Low	Medium	Medium
Improves water infiltration in the soil through mulching.	Low	Low	Medium	Medium	Low
Reduce costs and increase income.	Low	Medium	Low	Low	Low
Legal obligation and support for the utilization of pruning residues.	Low	Low	Medium	Medium	Low
Technology, knowledge, and available experiences for pruning residue utilization.	Low	Low	Low	Medium	Low
Awareness of sustainability in pruning residue utilization.	Low	Low	Low	Low	Low
Not applicable.	Low	Low	Low	Low	Low
The composting of olive pomace improves soil fertility.	Low	Medium	Medium	High	Medium
The composting of olive pomace reduces the volume of waste.	Low	Medium	Medium	Medium	Low
The composting of olive pomace contributes to nutrient cycling.	Low	Low	Medium	High	Low
Olive pomace can be used as an organic fertilizer.	Low	Medium	Low	Low	Medium
Due to its properties, olive pomace is suitable for composting.	Low	Low	Medium	Low	Medium
Regulates soil pH through composting of olive pomace.	Low	Medium	Low	Low	Low
Olive pits as an energy source are renewable.	Low	Medium	Medium	Medium	Low
It provides a sustainable way to dispose of olive pits.	Low	Low	Low	Low	Medium
Olive pits generate clean energy.	Low	Low	Low	Low	Medium
They require minimal processing before use as biofuel.	Low	Medium	Low	Medium	Low
I can use olive pits for heating and power generation.	Low	Low	Low	Low	Medium

In terms of the motivations and preferences of mill owners and producers, the data in table 9 suggest that the primary reasons for utilizing pruning residues as by-products among olive producers who are also mill owners revolve around cost reduction, income generation, and heightened awareness of sustainability. Legal obligations and support, alongside technology, knowledge, and available experience, also play crucial roles in their decision-making. When assessing the pros and cons of mulching pruning residues, respondents largely agree that mulching enhances soil health and significantly reduces soil erosion, with additional benefits including the addition of organic matter and the promotion of microbial activity. There is also moderate consensus that mulching contributes to increased soil carbon and improved soil moisture. In contrast, burning pruning residues is valued for its effectiveness and speed, with pest control also being seen as a notable advantage. Composting is recognized for its contributions to soil health and waste reduction, though there are some concerns about its labor-intensive nature and potential costs. Overall, the preferences lean strongly towards sustainable practices such as mulching and composting, motivated by economic gains and environmental consciousness, while also acknowledging the practical benefits and challenges associated with burning residues.

Table 9. Olive producers and mill owners' motivations and perceptions regarding the treatment of by-products from olive cultivation in Spain

Question	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
Reduce costs and increase income	Low	Low	Low	Medium	High
Legal obligation and support	Low	Medium	Low	Low	Low
Technology, knowledge, and available experiences	Low	Low	Medium	Medium	Low
Awareness of sustainability	Low	Low	Low	Medium	Medium
Not applicable	High	Low	Low	Low	Low
Mulching improves soil health	Low	Medium	Low	Medium	High
Mulching reduces soil erosion	Medium	Low	Low	Medium	Medium
Mulching adds organic matter	Low	Low	Low	Medium	High
Mulching promotes microbial activity	Medium	Low	Medium	Medium	Low
Mulching increases soil carbon	Low	Low	Low	Medium	Medium
Mulching improves soil moisture	Low	Low	Medium	Medium	Medium
Burning residues is effective	Low	Medium	Low	Medium	Low
Burning residues is quick	Medium	Low	Low	Medium	Medium
Burning residues controls pests	Low	Low	Medium	Medium	Medium
Burning residues is not useful	Medium	Medium	Low	Medium	Low
Burning residues is dangerous	Low	Low	Medium	High	Medium
Composting improves soil health	Low	Low	Medium	High	Low
Composting reduces waste	Low	Medium	Low	Medium	Medium
Composting reduces chemical use	Low	Medium	Low	Medium	Low
Composting is labor-intensive	Low	Medium	Low	Low	Medium
Composting is costly	Medium	Low	Medium	Medium	Low
Composting is beneficial	Low	Medium	Low	High	Low

Below, the responses from both olive producers and mill owners are expanded upon, regarding the advantages and disadvantages of adopting certain circular practices.

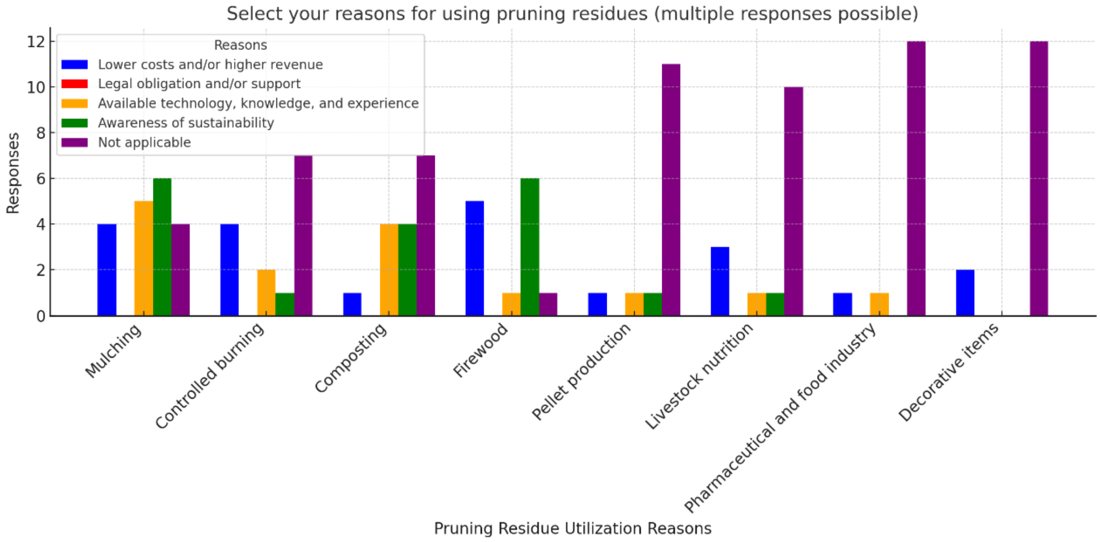
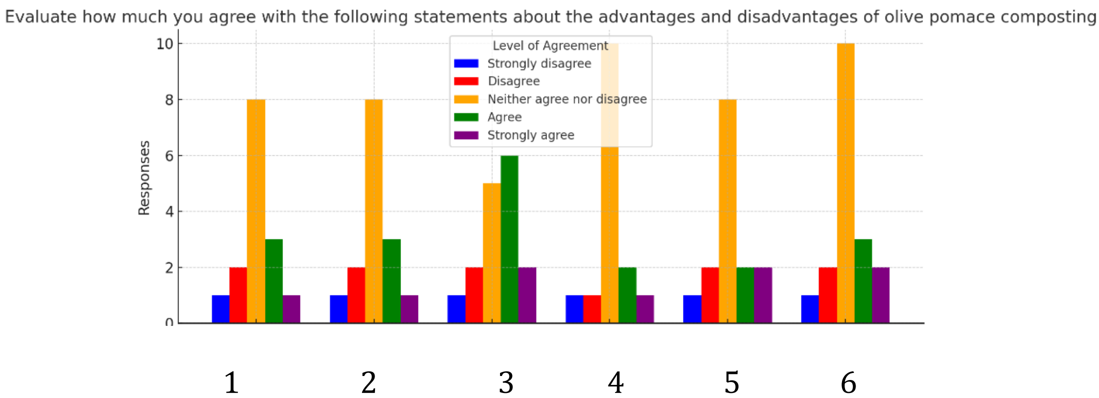


Figure 8. Olive producers' reasons for using pruning residues

Figure 8 shows the reasons for using pruning residues, with multiple responses allowed. "Not applicable" was the most selected response, especially for categories like pellet production, livestock nutrition, and use in the pharmaceutical and food industries. For categories like mulching, composting, and firewood, respondents cited "Available technology, knowledge, and experience" and "Awareness of sustainability" as significant reasons. Interestingly, "Lower costs and/or higher revenue" was a prominent factor in firewood and mulching. Meanwhile, "Legal obligation and/or support" had no responses, indicating it wasn't a driving factor for the utilization of pruning residues. Overall, economic and technological reasons seem to drive decisions in certain categories, while others are considered less relevant.



1. Composting is the best available method for utilizing olive pomace.
2. The compost obtained is a high-value organic fertilizer.
3. Compost improves the structure and biological activity of the soil.
4. Olive pomace decomposes slowly, so composting takes at least 12 months.

5. Due to its low content of organic acids and phytotoxins, soil amendment with olive pomace compost does not pose an environmental risk.
6. The legal regulation of the application of olive compost in agriculture is complex.

Figure 9. Responses from olive producers regarding advantages and disadvantages of olive pomace composting.

Figure 9 presents the distribution of responses of olive producers regarding the advantages and disadvantages of olive pomace composting. The majority of respondents fall into the "Neither agree nor disagree" category, suggesting a largely neutral perspective on the subject. However, there is notable support for specific statements, such as "The best available way to use olive pomace is composting" and "Due to the low content of organic acids and phytotoxins, amending soil with olive pomace compost does not pose an environmental risk." These statements reflect positive views on the environmental and practical benefits of composting olive pomace. On the other hand, disagreement levels are consistently low across all statements, indicating that few respondents view the practice negatively. Overall, the chart reflects a general ambivalence with pockets of support for the advantages of composting, while opposition to these views is minimal. This suggests that although many respondents are uncertain, those with an opinion lean towards recognizing the benefits of composting olive pomace.

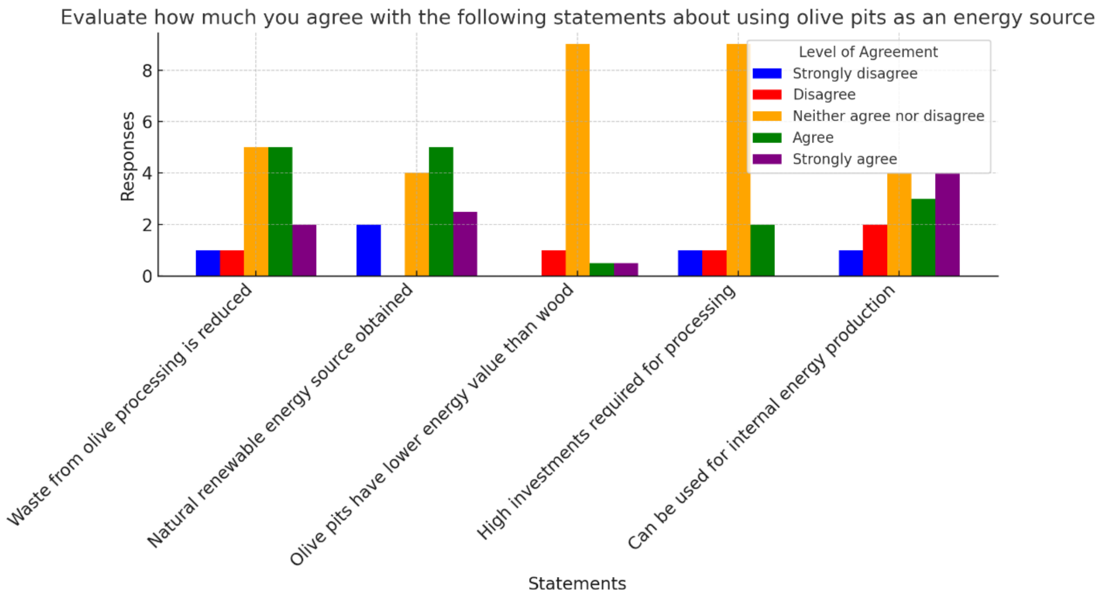


Figure 10. Responses from olive producers regarding the use of olive pits as an energy source.

Figure 10 illustrates olive producers' levels of agreement with statements about the use of olive pits as an energy source. A significant number of respondents neither agreed nor disagreed with the statement that olive pits have a lower energy value compared to wood and that high investments are required for processing, indicating a neutral stance on these points. However, many agreed that olive pits provide a renewable energy source and reduce waste from olive processing. There is also strong support for using olive pits for internal energy production. Overall, the results show a generally positive view of olive pits as a sustainable energy option, though there is some uncertainty in areas like energy value and processing costs.

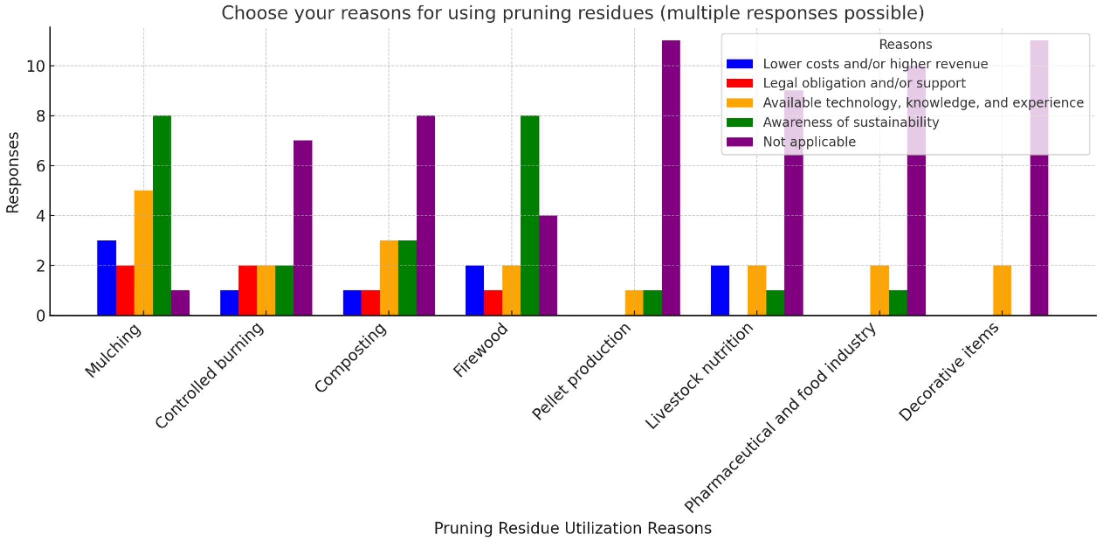


Figure 11. Responses from olive oil producers and mill owners regarding their reasons for using pruning residues.

Figure 11. presents the responses of olive oil producers and mill owners regarding their reasons for using pruning residues. "Not applicable" was the most common answer, particularly for pellet production, livestock nutrition, and the pharmaceutical and food industry, indicating that these uses may not be widely relevant. For categories like mulching and firewood, respondents highlighted "Awareness of sustainability" and "Available technology, knowledge, and experience" as key drivers. "Lower costs and/or higher revenue" was a motivating factor primarily for mulching and firewood. Interestingly, "Legal obligation and/or support" had minimal influence across all categories, showing that economic and environmental considerations, rather than legal factors, are more significant in driving the use of pruning residues.

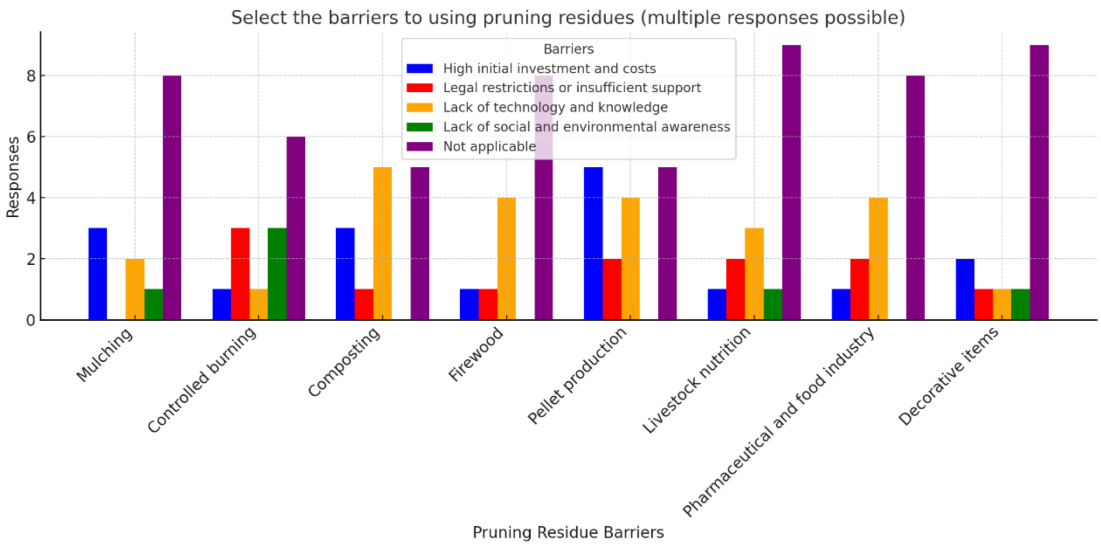


Figure 12. barriers faced by olive oil producers and mill owners when utilizing pruning residues

Figure 12 illustrates the barriers faced by olive oil producers and mill owners when utilizing pruning residues. "Not applicable" was the most frequently chosen option, particularly for pellet production, livestock nutrition, and decorative items, suggesting that these uses may not be relevant to many respondents.
"High initial investment and costs" was a significant barrier for pellet production and composting but less so for other uses. "Legal restrictions or insufficient support" played a role in controlled burning and pellet production but had minimal impact on other categories.
"Lack of technology and knowledge" was notably a barrier for composting, firewood, and pellet production, highlighting the need for better tools or expertise in these areas. Interestingly, "Lack of social and environmental awareness" was not considered a major barrier, with only controlled burning and mulching receiving some responses in this category.

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

Despite the progress made, several barriers to implementing circular economy practices in the olive oil sector remain. These include the need for a common regulatory framework, public financial measures, new circular business models using innovative technologies, multi-actor collaboration, and increased consumer awareness. Additionally, there are technological gaps in the efficient valorization of olive oil waste and by-products, particularly in terms of scalable and cost-effective methods for converting these materials into high-added-value products.
The responses from the interviewed experts highlight several technological barriers in the treatment of residues in the olive oil sector. Access to technology is a significant issue, as it is not always available to everyone. Additionally, there is limited training and knowledge regarding new technologies. The lack of technical knowledge and environmental awareness further exacerbates the problem, with many producers lacking the skills to operate machinery and insufficiently understanding the importance of environmental sustainability. Interviewees noted that innovation in the olive by-products sector is not always profitable, which can be a barrier to implementing new technologies. As one expert mentioned, "nobody engages in excessively innovative practices when they are not yet profitable and there is a profitable, safe, and simple alternative available." This sentiment underscores the economic realities that often dictate the pace and extent of technological adoption.
Moreover, the speaker pointed out that although collaboration between different links in the value chain is crucial, the collaborative economy and sustainability are not always fully integrated into business practices, which could be a shortcoming in the sector. The sector's atomization is another challenge, as it is highly fragmented in Spain, with many small operations and few large, solvent companies. This fragmentation can hinder negotiation and collaboration, posing a barrier to growth and efficiency in the by-products business. The speaker also acknowledged that while there is always room for more training, greater education in circular economy practices could benefit the sector.
Additionally, European and Spanish legislation is strict, which can be a barrier for companies that must quickly adapt to new regulations. However, the speaker also recognized that this same legislation could drive companies to innovate and adopt more sustainable practices. The technological gaps, coupled with regulatory challenges

and the need for increased training and collaboration, continue to present significant hurdles for advancing circular economy practices in the olive oil sector.

Respondents of the applied questionnaire olive producers perceived several barriers in adopting various methods for handling olive cultivation by-products (see tables 8 and 9).

For olive producers, significant barriers include high initial investment and costs, and a lack of social and environmental awareness. The data indicate that a large percentage of producers see high costs as a major barrier, making it difficult to implement sustainable practices like composting and mulching. Additionally, there is a notable lack of social and environmental awareness, which suggests that more education and awareness campaigns are needed to highlight the benefits of these practices. Legal restrictions and insufficient support, along with the lack of technology and knowledge, are also mentioned but to a lesser extent. These barriers indicate that while producers might be willing to adopt more sustainable practices, the financial and educational resources required are not sufficiently available.

For producers who are also mill owners, the barriers are similar but with some differences in emphasis. High initial investment and costs are again a major barrier, but there is also a significant mention of legal restrictions and insufficient support. This group highlights the need for better regulatory frameworks and support systems to facilitate the adoption of sustainable practices. Lack of technology and knowledge is another important barrier, indicating that mill owners may need more access to modern technologies and training to implement effective by-product management strategies. Lack of social and environmental awareness is also a significant barrier for this group, suggesting that, similar to olive producers, more education and awareness campaigns are necessary.

Both groups identify legal obligations and support as less significant motivators compared to other factors like reducing costs and increasing income, or awareness of sustainability. This indicates a possible gap in policy effectiveness or support mechanisms that are not sufficiently encouraging these sustainable practices. The perception of technology, knowledge, and available experiences being moderate to low suggests that there is room for improvement in providing the necessary tools and education to make these practices more accessible and feasible.

Andalusia, along with Castilla-La Mancha and Extremadura, are the only autonomous communities significantly increasing their olive grove areas (Ministry of Agriculture, Fisheries, and Food of Spain, 2024).

In the autonomous community of Extremadura, less than 450 million kilos of pomace are managed, and in the coming years, close to 500 million with the launch of at least one new industry. Currently, there is a question of whether it will be the capacity to unload all the trucks at these pomace plants in the future. It should be noted that pomace plants begin managing pomace from the start of the campaign, and during the 100 days of the campaign, they are already "managing" the pomace and producing various products derived from it (ESAO, 2023; Xtra Food Magazine, 2024).

However, this risk or problem is not unique at the regional level; nationally, more than 6,250 million kilos are managed, although it must be considered that in a good campaign, more than 7 billion kilos of olives can be produced (Ministry of Agriculture, Fisheries, and Food of Spain, 2024). So, there is a need for industries to manage this by-product. Even a single well-constructed industry could alleviate the pressure that might arise during a "good start to the campaign." At the very least, it would be necessary to invest in storage ponds to cushion this punctual influx and make it more organized to avoid a sudden saturation peak. A temporary problem due to campaign circumstances cannot be allowed to become a structural issue for the olive oil production sector (Mercacei, 2022).

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

Before the term "Circular economy" was coined, there was already a comprehensive utilization of olive by-products, although it was not well known or disseminated and even had a bad reputation, giving the impression that it was about "placing" things in other value chains. But nothing could be further from the truth, as pomace industries have been utilizing alperujo by commercializing all its components and even turning their by-products into added value products for various destinations.

It is important to note that Spain generates the highest amount of alperujo per liter of oil in the world. This trend is exacerbated by the increasing use of hedge cultivation. Hedge cultivation is a modern farming technique where olive trees are planted closely together in dense rows, resembling a hedge. This method increases the number of olives produced per hectare; however, these olives tend to be smaller and have a higher water content compared to olives from traditional cultivation methods. It leads to lower industrial yields, meaning that more alperujo is created relative to the amount of oil produced. As a result, at the beginning of the harvesting season, it is possible to generate as much as 7-8 kilograms of alperujo for every kilogram of oil produced (ecomercioagrario.com).

Table 10. Quantities of products generated from the current utilization of pomace-by-pomace mills. Own elaboration based on ANEO data.

Category	Yield	Million kg
Crushed Olives	-	6
Olive Oils	20%	1.2
Wet Pomace	80.00%	4,8
Water Vapor	48.00%	2.304
Dry Pomace	22.00%	1.056
Pit	6.40%	307
Raw Pomace Oil	1.60%	77
Olive Pulp	1.44%	69
Ash	0.56%	27

Of the total national production of pomace, 90% is used to extract pomace oil. Table 10 provides a simulation of how different products are generated from pomace in pomace-processing mills. The raw pomace oil extracted accounts for only 1.6% of the total. After removing a significant portion of the water vapor, which constitutes 48% of the pomace, the remaining dry and defatted pomace is used for various purposes. This includes energy generation, using part of the olive pulp for animal feed, and using the ash in construction or as a fertilizer.
The olive oil industry is gradually shifting towards a circular bioeconomy model. This approach focuses on maximizing the value of byproducts, making the industry more competitive, sustainable, and self-sufficient. It also has the potential to create rural employment and retain more added value within local communities (BioCycle, 2024; Biltekin, 2022).

These proposals to give new uses or outlets to olive by-products can be grouped into two directions or purposes:

1. Utilizing the substances of nutritional interest they contain (for example, polyphenols)
2. Using them as "nutrients" or "resources" to generate another different product, taking advantage of the good aspects of their composition (for example, biofertilizers)

Most of the participants in this research agreed the most commons uses are showed in table 11.

Table 11. Participant Responses Regarding the Uses of By-products from Olive Oil Production.

Byproduct	Processing	Uses
Leaves, Branches, Sprouts	Collected by a denting machine.	Animal feed, fertilizer, or organic matter.
Pomace	Separation of the oil from the pulp using a centrifuge. The pulp is sent to a refinery to extract the remaining oil, producing pomace oil that is not extra virgin.	Culinary, biodiesel production, soap production.
Pit	Separation of the pulp using a depitting machine.	Combustion in biomass boilers, own use, or sale.
Wastewater	Dumped in fields.	Presumably for use as fertilizer or for its environmental management.
Low-grade Oil	Used to make pastes.	Manufacturing creams. Sold to companies specializing in extracting the remaining oil (a company in Tortosa that refines the oil to obtain refined olive oil).

There are also other uses:

Leaf

We should consider healthy pruning leaves, not those from the reception of olives, which are sick or dead leaves. An example of this utilization is the NATAC industry, with pioneering and unique facilities at the European level, located in Hervás (Cáceres). This company already markets products rich in olive antioxidants, oleuropein, its derivatives, terpenes, etc. However, exploiting substances of nutritional and commercial interest requires complex technology, solvent extraction facilities, and substantial investment in fixed assets. In addition to extraction, another notable result in terms of technology innovation in the by-products industry is the one from the AGROMATTER project (a Spanish initiative, coordinated by the CERVERA AGROMATTER Group. It involves multiple technology centers in Spain, including AITEX, ANDALTEC, ITENE, and CTNC, focusing on agriculture, biotechnology, and materials science) It consist in the use of leaves for their pigments in "non-woven" fabrics, which can also contain up to 50% olive pits (redagromatter.com, 2023).

Olive mill wastewater

The extraction of hydroxytyrosol from olive mill wastewater is a reality, with various industries having the technology to extract and commercialize it. This also makes the by-product of this extraction very suitable for use as a fertilizer, as it would have reduced the high phenol content that prevented its direct use as a fertilizer (Donner, 2021; Ministry of Agriculture, Fisheries and Food, 2024). One hypothesis for a more sustainable future for olive groves is to "return" to the three-phase system and self-manage this olive mill wastewater. In this regard, some companies offer a drying system without smoke generation from the resulting pomace and evaporation-concentration of olive mill wastewater for use as fertilizer, due to its high content of humic acids, fulvic acids, potassium, etc. This system is gradually being implemented thanks to some corporations, which are installing olive mill wastewater evaporators that produce concentrated wastewater with high levels of fulvic and humic acids, making it of great interest as a fertilizer. However, phenols remain the limiting factor for direct use. Once a method is developed to "remove" and utilize these phenols, olive mill wastewater could become a high-quality natural fertilizer (Donner et al., 2021).

In Spain, the extraction and utilization of these polyphenols have garnered attention due to their potential applications in the pharmaceutical, cosmetic, and food industries. For instance, studies have shown that polyphenols extracted from Olive Mill Wastewater. can enhance the nutritional quality and shelf life of olive oil without altering its organoleptic properties. This extraction process not only adds value to what would otherwise be waste but also aligns with circular economy principles by reducing environmental pollution and promoting sustainability (MDPI, 2022).

Utilizing Pomace for Other Value Chains

According to Oliveoiltimes.com and ecomercioagrario.com after utilizing leaves and olive mill wastewater, pomace in Spain is starting to being employed in other fields: For electric power generation, as done by the TROIL Vegas Altas cooperative, a unique company worldwide, pioneering in many uses and destinations for its members' pomace.

- In 2023, there was a significant increase in the demand for collaboration with industries for biomethane generation through anaerobic digestion. The realization and viability of these projects could create another destination or use for pomace, potentially becoming an important client for "placing" pomace (World Economic Forum, 2023).
- More traditionally, but no less importantly, 5% of the national pomace volume is used for compost production. Pomace compost is not only a significant outlet for the pomace problem but also has important nutritional value for the fields:
    - Up to 55% of its composition can be pomace, and it requires "process water" for maturation.
    - It is a source of potassium (K, phosphorus (P), organic matter, builds soil, retains water..., providing short-term soil vitality and reducing the need for P, K, and N applications in the medium to long term (SoilQuality.org.au, 2023).
- Including pomace or dry pomace in animal feed is not new, but its use should be increased in the future. Research indicates that up to 12% of pomace can be included in pig diets. Its use in cattle is more limited, although some projects by El Encinar de Humienta have shown a reduction in greenhouse gas emissions. This destination for pomace is crucial because Spain produces 37.5 million tons of animal feed; the dry pomace generated would represent only 1 million (2.6%).

Experts interviewed for this research also agreed that another growing use in recent years is for the generation of proteins and fats for animal feed. These products are obtained through aerobic biodigesters where black soldier fly larvae are "cultivated." The resulting residue can be used as compost. More recently, pomace also has been used to generate nanoparticles for filtering and absorbing toxins in effluents.

9. Technological Advancements

9.1. Innovations in Production and Processing

Recent innovations in olive oil production and processing in Spain reflect a significant shift towards technology-driven improvements and efficiency enhancements. Some of those innovations are displayed in the following research articles:

Authors	Article Title	Publication Year	Abstract
Domingo Sanchez-Martinez, Jose; Carlos Rodriguez-Cohard, Juan; Garrido-Almonacid, Antonio; Jose Gallego-Simon, Vicente	Social Innovation in Rural Areas? The Case of Andalusian Olive Oil Co-Operatives	2020	This work sets out to determine whether innovations carried out by Andalusian olive oil cooperatives can be described in terms of social innovation and if they could run a main role as rural development actors preserving the competitive capacity of farmers and the living conditions in rural Andalusia.

Parra-Lopez, Carlos; Reina-Usuga, Liliana; Garcia-Garcia, Guillermo; Carmona-Torres, Carmen	Functional analysis of technological innovation systems enabling digital transformation: A semi-quantitative multicriteria framework applied in the olive sector	2024	The objective of this article is twofold: 1) to provide a comprehensive methodological framework for the functional analysis of a TIS, which allows a semi-quantitative assessment of the performance of a TIS at subfunctional, functional and global levels; and 2) to illustrate the application of this framework to the case of the TIS for the DT of the olive sector in Andalusia.
Reina-Usuga, Liliana; Parra-Lopez, Carlos; Carmona-Torres, Carmen	Knowledge Transfer on Digital Transformation: An Analysis of the Olive Landscape in Andalusia, Spain	2022	This paper analyses the role of KT in the framework of digital transformation (DT) in the Andalusian olive landscape. Thus, from the perspective of knowledge-generating agents, the main knowledge emitting and receiving actors in the DT are identified by using Social Network Analysis techniques (SNA). Subsequently, the performance of the Technological Innovation System (TIS) in KT is evaluated by using the multi-criteria Analytic Hierarchy Process (AHP) method.
Mozas Moral, Adoracion; Bernal Jurado, Enrique; Fernandez Ucles, Domingo; Medina Viruel, Miguel Jesus; Puentes Poyatos, Raquel	Second degree cooperativism and ICT adoption	2020	The article highlights the importance of innovation and investment in R&D as key drivers of economic growth and job creation. It emphasizes that companies that fail to adapt to technological changes will not survive in the market. The study focuses on Spanish olive cooperatives, which are global leaders in olive oil production, with over 70% of this production coming from cooperatives. The analysis examines the factors that promote technological innovation in second-degree olive oil cooperatives, including ICT training, CSR commitment, internationalization, organic production, and business integration.

Hamelin, Lorie; Borzecka, Magdalena; Kozak, Malgorzata; Pudelko, Rafal	A spatial approach to bioeconomy: Quantifying the residual biomass potential in the EU-27	2019	This study presents a geo-localized methodology in order to quantify the overall (theoretical) residual biomass potential for each NUTS-3 region of the EU-27 + Switzerland (NUTS-3 is the smallest regional division in Eurostat's Nomenclature of Territorial Units for Statistics). Estimates were made for biomass residues stemming from 4 main activities: i) agriculture (straw, manure, residues from pruning permanent plantations); ii) forestry (forestry residues); iii) urban greenery management (residues from managing urban green areas and roadside vegetation); and iv) food waste (agri-industrial food process waste and municipal biodegradable waste). A review of earlier assessments using a variety of spatial coverages is also presented.
Torrecillas, Celia; Martinez, Catalina	Patterns of specialisation by country and sector in olive applications	2022	The aim of this paper is to present an analysis of country specialisation patterns across different sectors using olive applications. We compare the number of planted hectares of olive crops across countries with their revealed comparative advantages in terms of olive products exports and with their revealed technological advantages in terms of olive related patent applications.
Goncalves, Alexandra Rodrigues; Dorsch, Laura Lou Peres; Figueiredo, Mauro	Digital Tourism: An Alternative View on Cultural Intangible Heritage and Sustainability in Tavira, Portugal	2022	Regarding this fractional environment, and as a by-product of the international EU funded iHERITAGE project, (B_A.2.1_0056), the goal is to create, through an innovation-driven growth process and technological transfer, brand strategies for the affirmation and better knowledge of intangible realities in the Mediterranean region. The Sicilian Tourism Department in Italy is the project's lead beneficiary, with representative partners throughout six Mediterranean countries (Italy, Egypt, Spain, Jordan, Lebanon, Portugal). The research based on the cultural experience, the history of the landscape and the sense of identity and continuity of knowledge is reassigned into a digital platform-the creation of apps and, within this, the design of a virtual route that navigates key geographical places.
Carrillo-Labella, Rocio; Fort, Fatiha; Parras-Rosa, Manuel	Motives, Barriers, and Expected Benefits of ISO 14001 in the Agri-Food Sector	2020	This paper presents a qualitative study with semi-structured interviews to analyze the perceptions that managers, employees, and quality managers have about the concept of sustainability and, given that environmental management systems are considered as motivational

			factors, it also analyzes the perceptions they have about the motivations, barriers, and expected benefits of their adoption in the olive food industry in southern Spain.
Gonzalez-Yebra, Oscar; Aguilar, Manuel A.; Aguilar, Fernando J.	A first approach to the design component in the agri-food industry of southern Spain	2019	This work raises the need to open new research lines to bring closer Design and Agri-food Industry, understanding design as a structured and multidisciplinary working process headed up to create products, images, spaces, etc. Within this framework, the following objectives have been outlined: i) Identification of the major design areas with regards to the agri-food sector, ii) Estimation of the importance of the Design component and iii) Definition of the possible lines of action.

Additionally, other technologies have been adopted within the sector, some of which are still in their early stages. Research centers and companies are actively working on their improvement. These technologies are described as follows:

- *Advanced Extraction Technologies:* Innovations in extraction methods, such as the use of advanced centrifugal separation and innovative cold-pressing techniques, have improved the efficiency and quality of olive oil production. These methods reduce the need for traditional heat-based processing, preserving the oil's delicate flavours and nutritional qualities.
- *Artificial Intelligence and Automation:* The integration of artificial intelligence (AI) and automated systems into olive oil production has revolutionized the industry. AlI algorithms are used to monitor and control various production stages, from olive harvesting to oil extraction, optimizing processes and ensuring consistent quality. Automated systems also enhance operational efficiency by reducing human error and labour costs (Envero, 2024).
- Digital Olive Oil Monitoring: Digital technologies are transforming olive oil production through real-time monitoring and data analysis. Sensors and IoT (Internet of Things) devices track factors such as olive ripeness and oil quality, allowing producers to make data-driven decisions and improve overall product consistency. These technologies facilitate a more precise and controlled production environment.
- Circular Economy Approaches: The adoption of circular economy principles in olive oil processing is gaining traction. This approach involves utilizing by-products and waste materials from olive oil production to create new value streams. For example, olive pomace can be repurposed as biofuel or compost, reducing environmental impact and enhancing resource efficiency.
- Innovative Packaging Solutions: The development of sustainable and smart packaging solutions is also noteworthy. Olimerca (a Spanish publication specializing in news and analysis about the olive oil industry, including market trends, production, and trade insights) reports on innovations in packaging that

include features like freshness indicators and tamper-evident seals, enhancing both product safety and consumer trust.

9.2. Future Technological Trends in the Sector

Looking ahead, several technological trends are expected to shape the future of the olive oil industry:

Enhanced AI Integration: As AI technology continues to advance, its role in olive oil production will expand. Future AI applications may include more sophisticated predictive analytics for crop yield forecasting, disease detection, and automated quality control systems. This will further enhance production efficiency and product quality (Oleo Revista, 2023).

Blockchain for Traceability: Blockchain technology is anticipated to play a crucial role in improving traceability and transparency in the olive oil supply chain. By providing a secure and immutable record of each step in the production process, blockchain can help combat fraud, ensure product authenticity, and enhance consumer confidence (MuyInteresante, 2023).

Advanced Data Analytics: The use of big data and advanced analytics will become increasingly prevalent. Ecoprolive (a Spanish company dedicated to producing sustainable, high-quality olive-derived products using eco-friendly processes) is already utilizing advanced data analytics to optimize the management of olive pomace and other by-products, making the production process more efficient and sustainable (Ecoprolive, 2023).

Sustainability Innovations: Future technological trends will likely focus on further advancing sustainability in olive oil production. Innovations in water and energy management, as well as new methods for recycling and reusing by-products, will help reduce the environmental footprint of olive oil production. Technologies aimed at minimizing waste and improving resource efficiency will become standard practices (Ciudades del futuro, 2024).

Precision Agriculture: The application of precision agriculture technologies, including drones and remote sensing, will enhance olive grove management. These technologies will allow for more precise monitoring of crop health, soil conditions, and irrigation needs, leading to optimized yields and reduced resource consumption (Olimerca, 2022).

Smart Processing Facilities: The development of smart processing facilities equipped with IoT devices and real-time analytics will revolutionize how olive oil is produced. Coto Bajo is an example of a facility integrating smart technology to better control every aspect of the production process, from raw material handling to final product quality (Oleo Revista, 2023).

10. Market Analysis

10.1. Market Forces

During the interviews and questionnaires conducted for this project, several key themes emerged regarding the market dynamics and marketing strategies for olive oil by-products:

Market Pricing: Interviewees indicated that pricing for these products is primarily influenced by market conditions and the prices set by refineries. Competitive pricing is

essential to remain viable, especially in the energy and industrial sectors where cost efficiency is a critical factor. Recently, and due to the financial aid from the EU, more and more Spanish energy companies are setting their sights on olive oil mills.
Product Value Proposition: The value proposition of olive oil by-products lies in their sustainability and environmental benefits. Products like biofuels and biogas are particularly attractive due to their potential to reduce carbon emissions and reliance on non-renewable energy sources.
Distribution Channels: Effective distribution is crucial for market penetration. Supermarkets and export markets are vital for olive pomace oil, while industrial by-products find their niche in the packaging industry and eco-friendly retailers. Agricultural products like proteins and fertilizers benefit from direct engagement with farmers through agricultural markets and fairs.

Promotional Strategies: The promotion of these products leverages themes of sustainability, clean energy, and natural quality. B2B, Social media and trade fairs are effective platforms for reaching target audiences. Conferences and ecological media are also important for connecting with industry professionals and eco-conscious consumers.

10.2. SWOT Analysis

10.2. SWOT Analysis
Based on the interviews and surveys with olive producers and mill owners and experts in circular economy in the olive oil sector, a SWOT analysis for the development of the olive by-products and residues business reveals the following insights (table 12).

As can be observed, strengths include the rich content of valuable compounds like polyphenols in olive by-products, which have high demand in various industries and support sustainable practices. Weaknesses are mainly due to limited access to advanced technology and insufficient training among producers, coupled with high initial costs and labour intensity of processes. Opportunities arise from EU financial aid and technological advancements that offer more efficient extraction methods. However, threats include regulatory, climate, innovative practices and social challenges.

Table 12. SWOT analysis

Strengths	Weaknesses
Technological innovation improving efficiency and quality	High initial investment, higher costs, lower profitability
High caloric and nutritional value of by-products with good preservation. Use of poliphenols.	Cyclical nature of campaigns, price volatility
Assured demand, added value	Lack of a circular industry design; each company operates independently without a strong complementary industry.
Abundant by-product generated every year, which provides long-term returns once the olive grove is planted. It is produced in large quantities and has excellent properties.	Sector is not highly professionalized (there are qualified people, but they have limited access to the current sector system, and cooperatives tend to "close off" to non-members).
	Producers are more interested in the main products than the by-products. There is no vision for better utilization of these by-products.
	Limited access to advanced technology
	Atomized sector
Opportunities	**Threats**
Technological innovation improving efficiency and quality	Dependence on olive availability and climate fluctuations
Opportunities in emerging markets with environmental awareness	Variable environmental and health regulations
Growing sector with significant caloric and nutritional potential in by-products	Social factors: lack of environmental awareness, tradition, and deficiencies in collaborative economy networks
Assured demand, added value	Political-legal-institutional factors: regulatory limitations, lack of institutional support, and insecurity regarding incentives and aids
Incentives and aids from the European Union.	Innovation and technology challenges: obsolescence, lack of development/access to technologies, and lack of technical knowledge.
Political and legislative environment encourages companies to move towards more sustainable and circular practices.	Significant competition from other countries
Public-private collaboration	Unfavourable weather conditions.
	Sudden political changes, legal adjustments, or reconstructions.

10.3. Regulatory Challenges and Barriers

The Olive By-Product Industry

The olive by-product industry faces several challenges and regulatory barriers that hinder its growth and efficiency. These challenges span across various areas, such as legislation, economic factors, technology, social awareness, and institutional support. Below is a detailed analysis based on interviews with key industry stakeholders.

Legislation and Wastewater Management

One of the main regulatory challenges is the strict legislation governing wastewater management. Royal Decree 553/2020 and Order TED/92/2022 regulate waste management and the classification of fatty pomace as a by-product in the olive oil sector in Spain. While these regulations aim to standardize by-product treatment at the regional level, they could hinder the circular economy by imposing stringent criteria and regional harmonization requirements. This may reduce the flexibility of mills to reuse or recycle waste, creating inconsistencies in implementation and limiting innovation in waste management practices. Additionally, the Water Law (Consolidated Water Law, Royal Legislative Decree 1/2001) imposes further obligations regarding water resource management, complicating compliance.

Economic Barriers

Economic factors present substantial barriers for the industry. High operational costs are a significant problem, primarily due to the large initial investments required for specialized technology and machinery, such as boilers and adequate infrastructure. This need for substantial capital outlay makes it difficult for smaller operations to compete and expand.

The industry is affected by high initial investment requirements and maintenance costs. Acquiring specialized machinery and developing the necessary infrastructure demand large financial resources, making it challenging for many companies to enter or expand in the market.

Innovation and Technology

Access to advanced technology is not uniformly available across the industry, creating disparities in operational efficiency and product quality. Furthermore, there is limited training and knowledge dissemination regarding new technologies. This knowledge gap prevents the industry from innovating and adopting more efficient and sustainable practices.

The lack of technical knowledge and environmental awareness further complicates the situation. Many operators are not adequately trained to use advanced machinery, and there is a general lack of awareness of the environmental benefits of effectively using by-products.

Social Factors

Social factors also play a crucial role in the challenges faced by the industry. There is limited adoption of sustainable practices due to a lack of awareness and understanding of the benefits of using by-products. For example, the medicinal properties of olive leaves are not widely recognized or exploited. Additionally, there is a general shortage of technical knowledge required to operate specialized machinery effectively.

Institutional Barriers

Institutional barriers, such as inaccessible financial aid and technical support, are exacerbated by bureaucratic hurdles. In Spain, Law 38/2003, of November 17, General Law on Subsidies, regulates public aid, but accessing these funds can be difficult due to administrative complexity. Companies often find it challenging to obtain the necessary financing and assistance, hindering their ability to innovate and expand their operations.

Access to financial and technical support is often difficult due to bureaucratic processes. This inaccessibility to aid makes it difficult for companies to take advantage of available resources to improve their operations and adopt sustainable practices.

Industry Outlook

1. **Innovation and Profitability**: Innovation in the olive by-product sector is not always profitable, creating a barrier to adopting new technologies. Industry stakeholders mentioned that there is little incentive to invest in overly innovative solutions when simpler, more reliable, and cost-effective alternatives exist.
2. **Collaborative Economy**: Despite the recognized importance of collaboration along the value chain, collaborative economy and sustainability practices are not fully integrated into business operations. This gap presents an area for improvement to increase efficiency and sustainability in the industry.
3. **Sector Size and Fragmentation**: The sector in Spain is highly fragmented, with many small-scale operations and few large, solvent companies. This fragmentation hinders negotiation and collaboration efforts, posing a barrier to the sector's growth and efficiency.
4. **Training and Knowledge**: There is a persistent need for more extensive training, particularly in circular economy practices. Greater training and knowledge dissemination could significantly benefit the sector, improving operational efficiency and sustainability.

Regulations and Legislation

Strict European and Spanish regulations pose a challenge for companies needing to quickly adapt to new standards. However, these regulations are also recognized for driving improvements in environmental and operational standards. For example, Regulation (EU) 2019/1009 related to fertilizers and Regulation (EC) No. 1069/2009 on animal by-products are examples of European regulations that directly impact olive by-product management. In Spain, Royal Decree 506/2013 on fertilizers and Law 22/2011, of July 28, on waste and contaminated soils set frameworks for handling organic waste and environmental protection, complicating compliance but also pushing the sector towards sustainability.

11. Vocational Training (VET)

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

In Spain, the olive sector is increasingly recognizing the importance of circular business practices to promote sustainability and efficient resource management. Vocational Education and Training (VET) programs are critical in equipping industry professionals with the skills needed to implement these practices. As a result of the interviews made during this research some programs related to the olive oil sector raised.

<u>Technical Training in Olive Oil and Wine</u>

In Spain, vocational training programs for olive oil and wine are widely available, reflecting the country's significant agricultural sector. One such program is the "Technical Training in Olive Oil and Wine", which provides comprehensive training in various aspects of olive oil and wine production. This program encompasses modules that cover critical areas such as olive oil extraction, wine production, and the conditioning of olive oils, along with other beverages and derivatives.

The training also includes essential topics such as food safety and hygiene, electromechanical maintenance, and sales and marketing of food products. Students gain skills in warehouse operations, sensory analysis, and understanding raw materials and products specific to the olive oil, wine, and beverage industries. Additionally, the curriculum addresses occupational training, business and entrepreneurial skills, technical English, and synthesis, culminating in practical workplace training. Despite its broad scope, this program does not specifically address circular economy practices.

<u>Specialized Training Programs</u>

There are several specialized programs aimed at enhancing sustainability in the olive sector:

- **IRTA's Sustainability and Organic Waste Management Program**: The Institute of Agrifood Research and Technology (IRTA) in Spain provides specialized training on sustainability in biosystems and the integrated management of organic waste. IRTA is a leading research institution focused on advancing agricultural and food technologies, including circular economy practices in the olive sector.
- **Elaioleg Program**: This program, focused on olive oil expertise, covers aspects such as production, quality, tasting, and commercialization. It is particularly renowned in Andalusia, where the role of the master miller (maestro almazarero) is highly prestigious. This program attracts professionals from around the world, emphasizing the importance of high-quality olive oil production.
- **Training in Agrarian Schools**: Agrarian schools offer courses on olive oil tasting and milling, explaining the operation of mills and the processes required to produce high-quality oil. However, these programs do not specifically focus on circular economy practices.

<u>Advanced and University-Level Training</u>

- **Master's Program in Oliviculture and Elaiotechnics**: There is a two-year master's program in Córdoba dedicated to oliviculture and elaiotechnics. This program is highly regarded and attracts participants from across the globe. However, it is based on the Andalusian perspective, which may not fully reflect the practices and challenges faced by other regions of Spain.
- **Master's Degree in Circular Economy:** offered by Campus Iberus is a multidisciplinary official program aimed at providing advanced training in circular economy principles and practices. This master's program is designed to equip students with the knowledge and skills needed to develop sustainable business models, reduce waste, and optimize resource use across various industries. Campus Iberus, a consortium of universities in northeastern Spain, delivers its programs in collaboration with several prestigious institutions, including the University of Zaragoza, the University of Lleida, the Public University of Navarre, and the University of La Rioja.
- **University Programs**: The University of Jaén, the University of Seville and the University of Lleida offer relevant programs in agricultural sciences and environmental management. Additionally, the Institute of Fat-CSIC and IFAPA (Institute of Agricultural and Fisheries Research and Training) provide specialized research and training in olive oil production.
- **Private Enterprises**: A few private companies, including one in Valencia, offer courses similar to those provided by agrarian schools. These courses focus on milling and oil tasting, reflecting the practical aspects of olive oil production.

Regional Training Challenges

In Catalonia, there was an attempt to implement specialized training in olive oil production. However, a course was discontinued due to a lack of student enrolment. This reflects a lower regional emphasis on this training compared to Andalusia, where the role of the master miller is highly esteemed and contributes significantly to the industry.

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

To que question concerning to the education level (fig. 13) results of the questionary among olive producers and mill owners show that the majority, 48.4%, have a university degree, followed by 41.9% who have completed secondary education or lower. A smaller portion, 5.0%, have attained a master's degree, while 4.7% hold a PhD. This indicates a fairly diverse range of educational backgrounds, with a significant number having pursued higher education.

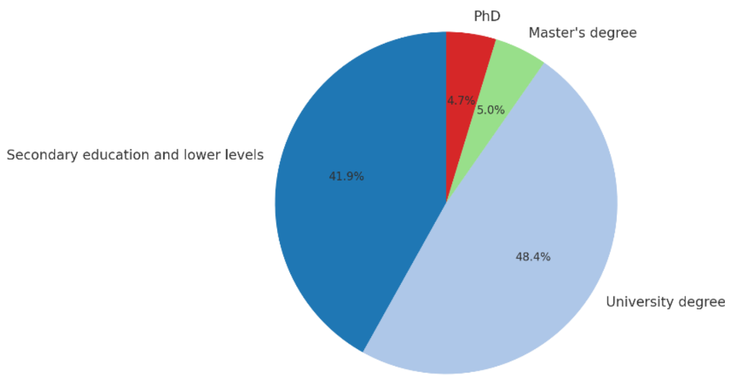


Figure 13. Education level of the respondents

Figure 14. shows that the majority of respondents, 74.2%, have received education in the field of agriculture, while 25.8% have not. This indicates that a significant portion of the surveyed sample has some formal background or training in agriculture, although a notable minority lacks this specific educational experience.

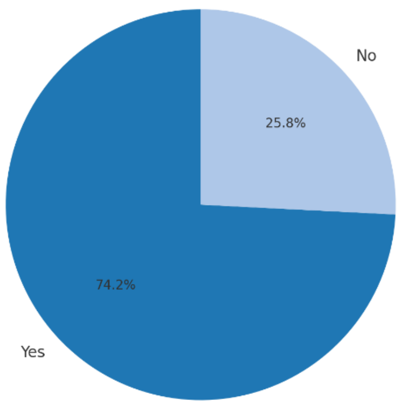


Figure 14. Education of the respondents in the field of agriculture

Figure 15. illustrates the results of the question asking whether respondents have completed any course, training, or education on the circular economy in the olive and/or agriculture sector. Here, unlike in the question about agricultural education, a significant majority, 77.4%, indicated that they have not received such education, while only 22.6% of respondents reported that they have. This suggests that most participants lack formal training or education in circular economy practices related to the sector.

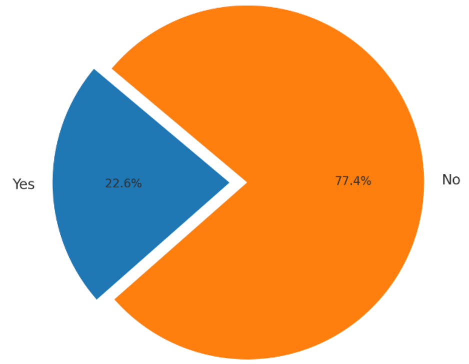


Figure 15. Education on circular economy of the respondents.

Regarding the method of implementation for completed education (fig. 16) the majority, 57.1%, completed their education in-person, while 28.6% followed a hybrid mode, combining both in-person and online methods. A smaller portion, 14.3%, completed their education fully online. This data suggests that traditional in-person education remains the most common method, although a significant number of respondents have experienced hybrid or online learning formats.

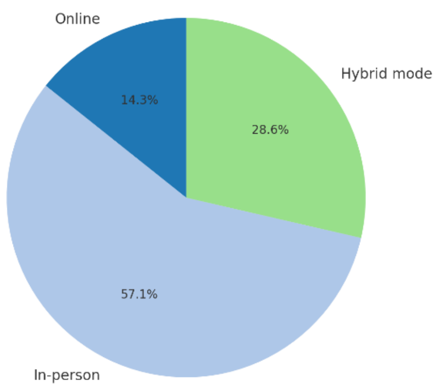


Figure 16. Method of implementation for completed education

According to feedback from interviewed and surveyed professionals, the most effective training approach is dual education, which combines theoretical learning with practical, field-based experiences. This method allows students to gain hands-on experience in olive mills, thereby deepening their understanding of the production process and the operational realities of the industry. For topics related to circular economy, which are relatively new to the sector, a solid theoretical foundation is essential. However, it is equally important for students to engage in practical applications of this knowledge. This approach ensures that learners not only understand the principles of circular economy but also can implement these practices effectively in real-world scenarios. Research centres and agricultural institutions in Spain play a crucial role in bridging the gap between theoretical knowledge and practical application. They are instrumental in transferring cutting-edge research and innovations to the olive oil industry. These institutes work on various aspects of olive oil production, including the management of by-products and waste. By involving students in ongoing research and development projects, these institutions provide valuable exposure to the latest advancements in the field. Additionally, training programs benefit from collaboration with industry stakeholders to ensure that educational content remains relevant and up to date. This involvement helps to align training with current industry needs and trends, particularly in the context of sustainability and circular economy practices.

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

Unfortunately, as previously mentioned, there are very few educational programs specifically focused on Circular Business Practices in the Olive Sector. While various educational programs in circular economy are offered by technological centres, research institutes, and universities in the region, none are specifically tailored to the olive oil sector.

From the surveys and questionnaires conducted, it is evident that Spain has highly advanced technological and research centres, staffed by well-trained professionals. These institutions play a significant role in knowledge transfer, particularly in sectors like agro-industry. Their efforts are not limited to agricultural schools; they also collaborate closely with universities and vocational training centres. Spanish universities are also strong in theoretical fields. However, there has always been a significant gap between universities and the private sector, which hinders students' access to practical experience.

Regarding vocational training, Spain stands out for offering a wide range of programs across various sectors, with a strong emphasis on practical learning. An example of this is dual vocational training, which combines classroom education with on-the-job training in companies.

Most interviewees agreed that an internship program focused on circular economy practices in the olive oil sector should be aimed at individuals who already have prior education in the field. Additionally, they emphasized that the program should prioritize theoretical knowledge before moving on to practical experience. The format of this training should be designed as a specialization or a master’s program, developed by a research centre or a university. Regarding the required skills, the individual responsible for developing this training should have a strong theoretical background in circular economy and, importantly, a deep understanding of the various possibilities for transforming a by-product, preferably with a focus on product technology.

As for the application of these skills, there is significant potential today in utilizing by-products from olive cultivation in sectors such as food, animal feed, packaging materials, agriculture, and cosmetics.

Interviewees agreed that online training programs in Spain are experiencing significant success in terms of student enrollment. These programs offer flexibility and accessibility, making them an attractive option for many learners. However, to maximize their effectiveness, it is crucial to combine online training with practical, hands-on experience, which allows students to apply theoretical knowledge in real-world settings, bridging the gap between learning and application.

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

Several respondents and interviewees agreed that vocational training centres and agricultural schools would be well-suited to offer courses on circular business practices in the olive sector. These institutions are already equipped to provide specialized training in various aspects of olive oil production and could effectively integrate circular economy principles into their curricula. Furthermore, it would be highly beneficial if these institutions collaborated closely with technological centres or research institutes. Such partnerships could enhance the programs by incorporating cutting-edge research and technology, thereby providing a more comprehensive and up-to-date education in circular business practices.

Universities are also mentioned as potential institutions for offering such courses. For instance, universities in southern Spain offer master's programs in Oliviculture and Oil Technology. However, upon reviewing their curricula, it becomes evident that there are no specific modules dedicated to circular economy practices. This gap suggests that while existing programs are robust, they do not yet fully address the emerging importance of circular economy concepts.

Some participants have proposed that circular economy training should be developed into a full undergraduate degree. Given the significance and potential of the olive sector in Spain, a dedicated degree program could provide more comprehensive education on circular economy practices. Such a program would offer ample time and resources to delve deeply into these practices, preparing graduates to implement and innovate within the sector effectively.

Additionally, the incorporation of circular economy principles into academic programs could also benefit from collaboration with industry experts and research centres. These partnerships would ensure that the training remains aligned with current industry needs and advancements, thus enhancing the relevance and impact of the educational offerings.

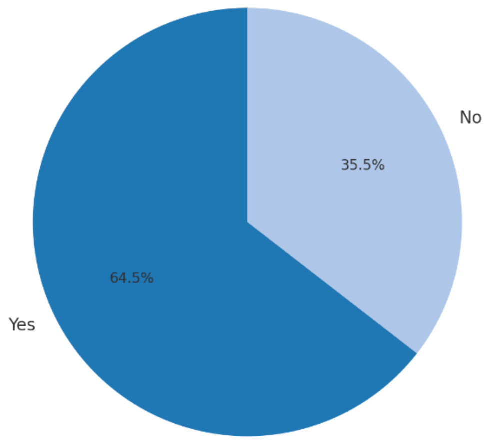


Figure 17. Respondents' interest in attending a training course focused on olive by-products and waste valorisation

Figure 17 illustrates respondents' interest in attending a training course focused on olive by-products and waste valorisation. The majority, 64.5%, expressed interest in participating, while 35.5% indicated they were not interested. This suggests a strong overall willingness to engage in educational opportunities related to sustainability and resource optimization in the olive industry, although a significant minority remains uninterested.

12. Conclusion

12.1. Summary of Key Insights

The olive oil production industry is crucial to Spain's economy, being the world's largest producer and a significant source of employment, particularly in rural areas. It also plays a key role in preserving Spain's cultural heritage and enhancing its global culinary reputation. In terms of the circular economy, producers and mill owners find both advantages and disadvantages within the sector. Producers are driven by the need to reduce costs and increase income, recognizing that the effective management of by-products can lead to significant financial benefits. There is also an awareness of sustainability, with many motivated by the desire to minimize environmental impact and promote more sustainable agricultural practices. The availability of technology and knowledge plays a crucial role, as access to modern solutions makes it easier for producers to implement efficient by-product management practices. Legal obligations and support mechanisms, while not the strongest motivators, still influence decision-making, particularly when there are clear regulations and incentives in place. Also, the growing interest in research and development of new technologies offers a pathway to improved efficiency and added value in by-product management. For instance, producers are exploring the potential to enhance the value of by-products through the production of compost or derivative products like cosmetic creams. There is also a recognized opportunity to tap into emerging markets that prioritize environmental sustainability. Moreover, the cooperative system in the Spanish olive oil industry offers significant advantages. It enables small producers to pool resources, reducing costs and increasing their bargaining power in the market. Cooperatives also facilitate knowledge sharing and innovation, allowing members to adopt more sustainable and efficient practices. This collaborative approach enhances the overall competitiveness and sustainability of the industry.

However, results also show that the olive oil sector in Spain faces some challenges, particularly concerning the management of by-products and waste. Results of the survey confirm that the olive oil production industry in Spain demonstrates engagement with the principles of the circular economy, particularly in the management of by-products. The types of by-products generated—such as olive pits, pomace, leaves, branches, and wastewater—are being utilized in various ways that contribute to both environmental sustainability and economic efficiency. Olive pits are predominantly used as biomass or sold as biofuel, while pomace is often sent to refineries for further oil extraction. Leaves and branches find secondary uses as compost or animal feed, and wastewater is typically applied as fertilizer in agricultural fields, although its management is subject to strict regulatory control. This fact shows that most olive oil producers, especially the smaller ones, manage their waste in a similar manner, with very little innovation in the treatment of by-products. Also, results indicate a preference for the two-phase system between mill owners due to its environmental benefits, such as reduced liquid waste and potential for wet pomace utilization. However, the continued use of the three-phase system by some mills suggests that there is still progress to be made in advancing and adopting more sustainable extraction technologies across the sector.

Another barrier in the olive oil industry is the lack of a strong complementary market for by-products. This absence of a robust secondary industry discourages investment in the production and innovative use of by-products, as producers have limited opportunities to profit from these materials. Although there are some pioneering companies exploring innovative methods, such as polyphenol extraction, these initiatives are still in their infancy and have not yet seen widespread adoption. The primary by-product remains pomace oil, and rather than viewing waste as an opportunity, many companies see it only as a problem. Instead of investing in treatment and valorization, they often choose to sell the waste to third parties who handle its processing. This lack of innovation and vision limits the potential of olive oil waste to become valuable resources within a circular economy model. Another strong barrier is the strict regulatory framework for wastewater management, which requires substantial investments in advanced infrastructure and technology to meet stringent environmental standards. This is particularly difficult for smaller operations that often lack the capital to comply. Additionally, high initial investment costs and ongoing maintenance expenses for specialized equipment further strain financial resources. These economic factors make it challenging for many producers and mill owners to invest in innovative practices and technologies. Additionally, many industry stakeholders lack sufficient training to use new technologies or fully grasp the environmental benefits of managing by-products effectively. This leads to the underutilization of these valuable resources. The sector's fragmentation, characterized by numerous small-scale operations and a limited number of large solvent companies (mostly in Catalonia), hinders collaboration and the implementation of sector-wide improvements. While there have been advancements in by-product utilization—such as in biofuels, animal feed, and cosmetics—the economic viability of these innovations is still uncertain due to high costs and regulatory constraints. As a result, many producers are unwilling to invest in new waste treatment technologies. Given the high initial costs and the nascent state of the industry, they prefer to stick with traditional methods rather than risk investing in unproven innovations. In some regions, commercial challenges also arise, particularly in the sale of by-products like olive pomace, where producers often lack the bargaining power to influence pricing, being dependent on a limited number of buyers.

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

To advance the implementation of circular practices in the olive oil sector, the following recommendations are made:

1. Enhance By-Product Utilization: Promote the exploration and adoption of innovative uses for by-products. This includes expanding research into new applications for olive pits, pomace, leaves, branches, and wastewater that go beyond traditional uses, such as developing new products or energy sources.
2. Adopt Advanced Technologies: Encourage the transition to more sustainable

extraction technologies. The two-phase system should be adopted more widely due to its environmental benefits, while efforts should be made to phase out the less sustainable three-phase system.
3. Support Innovation and Research: Increase support for research and development in by-product management technologies. Partnerships between industry stakeholders, research institutions, and universities can drive innovation and lead to the creation of new circular economy solutions.
4. Improve Training and Education: Enhance vocational training programs to include specialized education on circular economy practices and by-product management. This will equip industry professionals with the skills needed to implement and advance sustainable practices effectively.
5. Strengthen Regulatory Support: Advocate for policies that support the development and implementation of advanced by-product management technologies. This includes providing incentives for adopting innovative practices and easing regulatory barriers for smaller producers.

Regarding the existing vocational education and training (VET) programs in the olive oil sector in Spain, although comprehensive in areas like olive oil production and sustainability, they often fail to address the specific needs of circular economy practices. This gap in training highlights the necessity for more specialized and integrated educational programs that can better equip industry professionals with the skills required to implement and advance circular economy practices effectively.

To advance the integration of circular economy practices in the olive oil sector, it is recommended to develop and implement a standardized, comprehensive curriculum across educational institutions, covering key areas such as waste valorization, resource efficiency, sustainable production processes, and the integration of circular business models.

It is crucial to invest in training educators to equip them with the necessary skills and knowledge to effectively teach these principles, through partnerships with universities, research institutions, and industry experts.

Additionally, increasing practical training opportunities such as internships, workshops, and hands-on projects in companies already implementing circular practices is essential to provide students with real-world experience and a deeper understanding of how these principles can be applied.

Promoting regional collaboration to share best practices and resources is also recommended, enabling institutions in regions like Catalonia to benefit from successful models in areas such as Andalusia.

12.3. Policy Implications and Recommendations

Policy implications regarding by-product management in the olive oil sector suggest several areas for improvement:

- Standardize Practices: Develop and enforce standardized guidelines for by-product management across the industry. This will help ensure consistent and effective practices and reduce disparities between larger and smaller producers.
- Promote Circular Economy Principles: Incorporate circular economy principles into policy frameworks to encourage more sustainable management of by-products. This includes supporting initiatives that enhance the value of by-

products and integrate them into circular business models.
- Enhance Support for Small Producers: Provide targeted support for smaller producers to help them adopt more sustainable practices. This can include financial assistance, technical support, and access to innovative technologies that may otherwise be out of reach.
- Facilitate Collaboration: Foster collaboration between producers, cooperatives, and research institutions to share best practices and resources. Regional and sector-wide partnerships can accelerate the adoption of circular economy practices and drive collective improvements in by-product management.

Concerning the engagement in circular economy practices among training providers in the olive oil sector, results show that it is varied. While some institutions incorporate elements of sustainability and waste management into their curricula, there is a general lack of comprehensive and dedicated training programs focused explicitly on circular economy principles. The concept of circularity is often addressed indirectly, with more emphasis on sustainability and waste reduction rather than a holistic circular economy approach. Another finding is the lack of standardized curriculum. There is no standardized curriculum across institutions for circular economy practices in the olive oil sector. Training programs tend to be fragmented, with some institutions offering more in-depth training in sustainability and others focusing on practical skills without a clear framework for circularity. Results also show that the sector lacks specialized educators with expertise in circular economy practices. There are also regional disparities in how circular economy practices are taught and implemented, particularly between Catalonia and Andalusia. Andalusia appears to be more advanced in terms of resources and recognition of the importance of circular practices, whereas in Catalonia, such initiatives are less developed and less formally integrated into training programs.

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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 Fertilizer: A natural fertilizer 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 minimizing 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 Labeled Organic: Products certified and therefore labelled as organic, produced under specific environmental and organic farming standards, ensuring they are produced without synthetic pesticides or fertilizers.

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 MSMEs in the olive sector

ANNEX 1: ONLINE SURVEY TARGETING MSMEs 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	1	2	3	4	5

and attracts insects					
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 expensive and unprofitable	1	2	3	4	5

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 price	1	2	3	4	5
I plan to increase production	1	2	3	4	5
Most of the customers are	1	2	3	4	5

within a radius of 50 km					
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	1	2	3	4	5

olive sector					
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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