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

- ITALY -

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Contents

1. Executive Summary

1.1. Background and Purpose

Olive oil is a product that holds the Italian economy afloat. However, due to the generation of significant amounts of liquid and solid wastes during the extraction process, it is an activity with remarkable environmental impact as well. The extraction of olive oil in Italy is mostly implemented through two-phase or three phase centrifuge systems, while olive pomace, derived as a by product of olive oil processing, constitutes a raw material for olive pomace oil and wood production. The operation of olive oil mills and olive pomace industries has been connected with the generation of heavily polluted wastewater and solid waste. The present report aims at investigating the current treatment methods and techniques applied for the management of the waste of the olive oil sector in Italy, and evaluating the possibilities of introducing innovative technologies for the valorisation of this waste. The results reveal that there is room for improvement in olive sector's waste treatment in Italy, since many of the currently applied methods comprise only basic level treatment techniques. However, there are still significant barriers to adopting sustainable practices for the residue management that include technological gaps, high costs, legal restrictions and lack of technology and knowledge. General strategies for the adoption of environmentally friendly practices, prevention measures, intensive controls of the production processes and provision of technical assistance and theoritical knowledge to every stakeholder of the sector, is the basic assumption for the transition of the Italian olive oil industry to a circular economy model.

1.2. Key Findings

The responses collected from the questionnaire targeting Italian olive growers and millers (CIRCOLIVE - ANNEX 1: ONLINE SURVEY TARGETING MSMEs IN THE OLIVE SECTOR) and the interviews with 5 entrepreneurs in the olive-oil supply chain (CIRCOLIVE - ANNEX_2_Interview_agro-food experts_professionals) and 5 training course organizers (CIRCOLIVE - ANNEX_3_Interview VET providers) provided valuable information regarding the implementation of circular practices, future trends, and the variables that influence the management and valorization of by-products. The results demonstrated that there is a willingness among technical experts in the olive-oil sector to valorize by-products generated from the olive oil production process. This is also supported by the fact that more than half of those who completed the questionnaire (ANNEX 1: ONLINE SURVEY TARGETING MSMEs IN THE OLIVE SECTOR) expressed interest in staying updated on the progress of the CIRCOLIVE project and participating in future training courses on the valorization of by-products in the olive-oil supply chain.

1.3. Recommendations

To advance the Italian olive sector's shift towards a circular economy, efforts should concentrate on three main areas: promoting the use of waste valorization technologies, streamlining regulations for the utilization of olive by-products, and strengthening education and training on sustainable practices for both farmers and mill operators. These initiatives will boost sustainability, lower environmental impact, and increase the economic resilience of the sector

2. Introduction

2.1. Overview of the Olive Sector

Referring to the 2022/2023 olive oil campaign, Italy is the third European producer and the fourth world producer of extra virgin olive oil (COI, 2024). The Italian olive sector includes about 619,000 farms, with a mean harvested area of 2 ha for each farm (ISMEA, 2024). These data are also linked to the hindering orographic situation of olive groves mostly cultivated in hilly (67%) and mountainous (11%) areas (ISTAT, 2012), where the olive tree represents an integral and characteristic element of the territory (Tiò 1996). Italian olive growing can be generally split between a majority of nonprofessional small-holder farms (generally poorly mechanized, with low input olive growing in steep slopes and terraces, mainly family-run) and a smaller, but significant, number of professional farms, competitive at the international level. The Italian olive oil industry counts 220 companies and over 4000 olive mills. Italy is the world's second exporter and producer of olive oil (following Spain) and the leading olive oil consumer and importer in the world, having always had a negative balance of trade (ISMEA, 2024).

2.2. Objectives of the Report

The objective of the report is to collect information regarding the topic of circularity applied to the olive oil sector, with a focus on the management and valorization of by-products, from the various actors in the olive oil supply chain, starting from those who are directly involved in the olive oil supply chain, namely oil producers (olive growers and oil millers), up to expert providers of training courses.

3. Methodology

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

3.1. Data collection methods

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

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

The questionnaire was designed with the aim of collecting quantitative data on a sample of olive grove owners which produce oil in service mills, and a sample of olive mill owners who own or do not own olive groves. The questionnaire (ANNEX 1: Online survey targeting MSMEs in the olive sector) contained multiple-choice questions, closed questions, open questions and questions in the form of a Likert scale. The questions related to numerical production indicators, the use of tillage techniques, the treatment of plant residues in olive groves, methods and capacities of olive processing, the treatment of by-products after olive processing and questions on the circular economy in olive growing. The planned sample size was 20 respondents, but data was collected from 31 respondents, namely 24 respondents for the olive grower's category, 3 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.

Table 1. Decription of the sample of respondents who participated in the online survey (N=31)

Variable	N	Percentage (%)
Gender		
Male	**26**	**83.9**
Female	**4**	**12.9**
I prefer not to answer	**1**	**3.2**
Age		
Up to 36	**4**	**12.9**
37 - 56	**10**	**32.3**
57 and more	**17**	**54.8**
Education		
High school and lower	**23**	**74.2**
Bachelor degree	**3**	**9.7**
Master degree	**5**	**16.1**
Enterprise size		
Micro (<10 employees)	**27**	**87.1**
Small (<50 employees)	**4**	**12.9**
Agriculture is in the household		
The only source of income	**7**	**22.6**
Predominant source of income (>50%)	**5**	**16.1**
Additional source of income (<50%)	**19**	**61.3**

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 Italy (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 face-to-face with respondents and 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.

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

The olive tree (*Olea europea* L.) is a drought-resistant plant, usually grown in areas with limited water resources. In Mediterranean areas characterized by scarce rainfalls, irrigation could influence olives/olive oil production and olives/olive oil quality. Owing to its complex environments, which have been highly modified by humans over thousands of years, the Mediterranean has been defined as a unique ecosystem with multifaceted cultures and landscapes (Barbera and Cullotta, 2016). Olive-based systems, typical of Italy, are characterized by traditional structural traits such as their low planting density (<250 plants ha-1), low yield, and low agronomic input requirements (an absence of irrigation and a low degree of mechanization owing to manual harvest). Italian olive groves contribute to 26% of all EU olive production (Agriculture, forestry and fishery statistics, 2015) and make up 51% of total olive-growing areas in marginal and disadvantaged zones (mountainous and hilly steep slope areas and inner areas). The olive oil production chain in Italy is more fragmented than it is in other Mediterranean countries (619,378 holdings, with an average size of 2 ha). The Italian olive growing is widespread, especially in the southern and island regions, where there is the concentration of about 80% of the total production. The Italian region that has the greatest extent of land dedicated to the cultivation of olives is Puglia with its 342,420 ha, followed by Calabria (184,682 ha) and Sicily (176,596 ha). Other Italian regions are emerging in the olive oil production during the last years, also due to climate change. The total production area reaches an area of around 1,135,837 ha. 30% of the production area is concentrated in Puglia, and the first three Italian regions in this activity (Puglia, Calabria and Sicily) have more than 60% of the production area (ISMEA, 2024). The Italian olive growing is characterized greatly by fragmentation, this is due, in part, to the topography of the country (67% in the hills and 11% in the mountains), and in part to the low mobility of EC assistance (Maroofnezhad, 2013). Southern Italy exhibits a multifaceted olive landscape, with *Olea europaea* being one of the most strongly connotative species and crops of the Mediterranean basin (Allen et al., 2006; Rühl et al., 2011). 30% of Italian olive groves are located in areas with difficult topographic conditions (Modica et al., 2017), such as steep slopes, where many olive orchards are located in Mediterranean areas (Repullo-Ruibérriz de Torres et al., 2018).

4.2. Historical Development of Olive Cultivation

Comprehensive studies of the presence of olive on the Italian peninsula show records of it there since the Early Holocene. The earliest evidence (ca. 6700–5700 bc) comes from Sicily, where Olea sp. pollen is recorded in the pollen sequences from Lago di Pergusa and Gorgo Basso (Sadori and Narcisi, 2001; Tinner et al., 2009) andolive charcoal has been found in the Mesolithic layers of Grotta dell'Uzzo (ca. 6600–6100 bc) (Costantini et al., 1989). Pollen records from Puglia and Toscana show that olive trees were present there from the 5th millennium bc (Caroli and Caldara, 2006; Di Rita and Magri, 2009; Di Rita et al., 2011). In other regions, the cultivation of olives started with the presence of Greek colonies, such as at Agrigento and Selinunte in Sicily and Metapontum in Basilicata (Coppola et al., 1981; D'Alessio, 2004). It is possible that the foundation of the Greek colony of Taranto also promoted olive cultivation in Puglia (Caroli and Caldara, 2006).

It was during the Roman period that a series of technological improvements led to the spread of olive cultivation (Stika et al., 2008). Oil production peaked in the early period of the Roman Empire, mostly in Campania, Lazio and Puglia, where oil facilities were connected to latifundia, great estates owned by the aristocracy (Stika et al., 2008). Olive growing began again in Puglia in the 12th century ad, where large areas were devoted to the production of olive oil meant for international markets. A century later Campania and Calabria followed this lead, while it took another two centuries for the regions in central Italy to start producing olive oil for exports once more (Cortonesi, 2005).

From the 17th century olive oil sector gained growing importance producing the gradual transformation of arable land into olive groves changing conditions throughout central Italy, providing an important contribution to income from agricultural work, and shaped new landscapes between the woods and villages, thus setting off a process of differentiation in the Apennine areas.

The areas devoted to olive growing almost tripled from 1870 to 1951 (from 68 to about 200 thousand hectares), still prevailing as polycultures over specialized crops in a ratio of 20 to 1 (Ortolani 1964).

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

On the subject of olive oil extraction systems, the main by-products are wastewater and olive pomace. Pomace is a semi-solid mixture that contains oil residues, water, and solid parts of drupes (pulp and woody fragments of the pits) that are left after crushing (Pattara et al., 2010). During olive oil production large quantities of strongly polluted waters, known as olive oil mill wastewaters (OMW), are generated (40-55 L/100 kg of olives processed by traditional batch press or 80-120 L/100 kg of olives processed by continuous solid-liquid centrifuge system). OMW are resistant to biological degradation because of their volatile solids, inorganic matter, and high concentration of phenolic compounds (Assas et al., 2002). Due to these characteristics, which increase the organic load of chemical oxygen demand (COD, 80-200 g/L) and biological oxygen demand (BOD, 50-100 g/L) to values 200-400 times higher than those of a typical municipal sewage (Chiavola et al., 2010), the annual disposal of several million cubic meters of OMW is a major environmental problem for agriculture in the Mediterranean area. Indeed, the discharge of large quantities of this pollutant in the sewage system is not possible without any treatment, and Italian regulations allow its spreading on agricultural soil up to 50 m3/ha for OMW obtained by press and 80 m3/ha for OMW obtained by centrifuge (D.Lvo no. 258, 2000). In many cases, the exhausted olive pomace, due to its high calorific value, is used as fuel in the mills for the production of energy through combustion (Masghouni and Hassairi, 2000). Other less-known uses of olive pomace include its use as an absorbent in treating water contaminated by heavy metals (Pagnanelli et al., 2002; Azbar et al, 2004), and its application to land as a pesticide enhancer (Cox et al., 2004). The review of Rodríguez et al. has highlighted how the olive oil industry produces a precious wood cellulose biomass, the olive pits, which can be used as biofuel (Rodríguez et al. 2008). According to Vitolo et al. (1996), Cordero et al. (2004) and González et al. (2004) olive pits have a low ash and sulphur contents, features that make it a usable renewable energy source. Furthermore, on the basis of its yield of combustion, olive pits represent a valid alternative to traditional pellets (biomass fuel which is having a rapid diffusion in markets) (Miranda et al. 2008). According to García-Maraver et al. (2012), who conducted an "analysis of olive plantation residual biomass potential for electric and thermal energy generation", and as demonstrated by Touš et al. (2011), conversion of that residue into energy can increase the value of waste and reduce the environmental impact of waste elimination.

5. Olive Production Analysis and Olive Oil Processing

5.1. Cultivation Practices and Varieties

Italy is currently the leading country for cultivar biodiversity, accounting for over 800 varieties (International Olive Oil Council, 2019; Rotondi et al., 2013). Since monovarietal extra virgin olive oils (MEVOOs) are products reflecting the characteristics of a country beyond genetics, their systematic sensory and chemical characterization has a pivotal role in order to identify quality oils with remarkable diversity and clear identity. A detailed description of the chemical and sensory traits of MEVOO produced with olive cultivars among the most widespread in Italy, such as Frantoio, Leccino and Moraiolo, was reported by several authors (Campus et al., 2013; Portarena et al., 2015; Blasi et al., 2019; Klikarová et al., 2020). Additionally, the features of MEVOO from cultivars typical of different Italian regions producing appreciated oils were also highlighted, with different sensory characteristics particularly related to specific attributes such as almond, artichoke, red fruits and tomato (Piscopo et al., 2016; Firdousse Laincer et al., 2016; Rotondi et al., 2017).

However, it is known that the same cultivar grown in different pedoclimatic conditions (altitude, latitude, climatic conditions, soil composition, etc.) shows different values in fatty acid composition, phenolic content, and oxidative stability (Vichi et al., 2007; Campestre et al., 2017). Since pedoclimatic aspects, olive ripeness, harvesting time, and the extraction system, strongly impact on the chemical composition and sensory properties of oils (Bruno et al., 2019), it is recommended to control these factors.

Conventional techniques are the most widely used for olive cultivation, followed by ecological methods that lack eco-label certification (Fig. 1: Technology used in the olive grove).

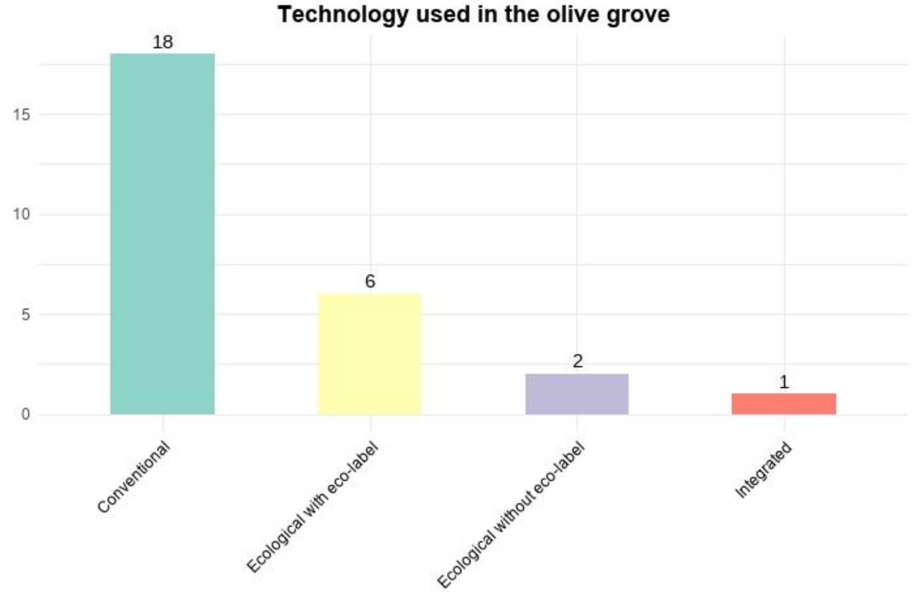


Fig. 1: Histogram representing the technologies used by olive producers for olive cultivation.

Among the circular economy practices reported by respondents, 'grass cutting' is the most prevalent (22 responses), followed by the use of organic fertilizers (13 responses), 'inert plant cover from cut grass' (12 responses), and incorporation of pruning residues into the soil (10 responses) (Fig. 2: Interventions related to circular economy applied in olive grove).

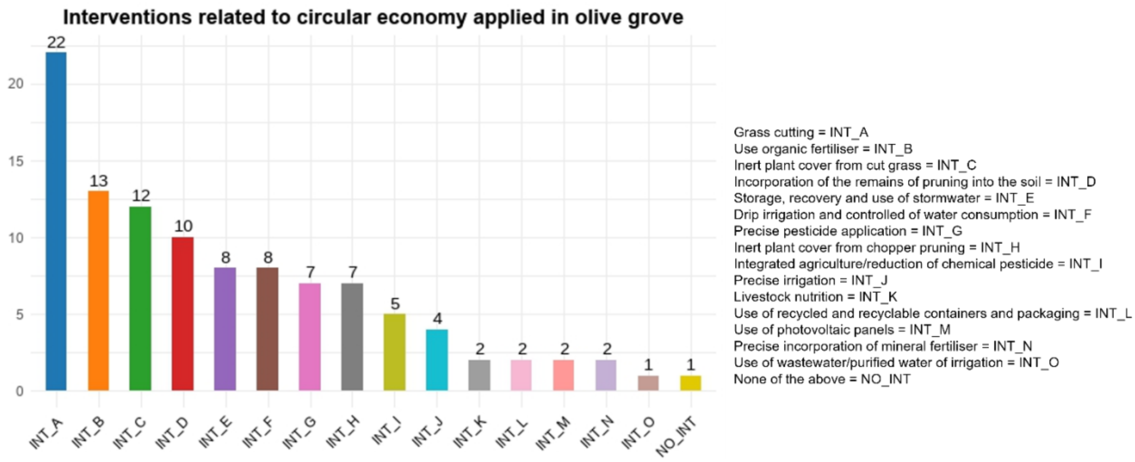


Fig. 2: Histogram representing the circular economy interventions applied by respondents to olive cultivation.

Mulching, which includes the use of permanent mulching, grassland, and pruning residues, is the most commonly practiced soil management technique (Fig. 3: Soil management).

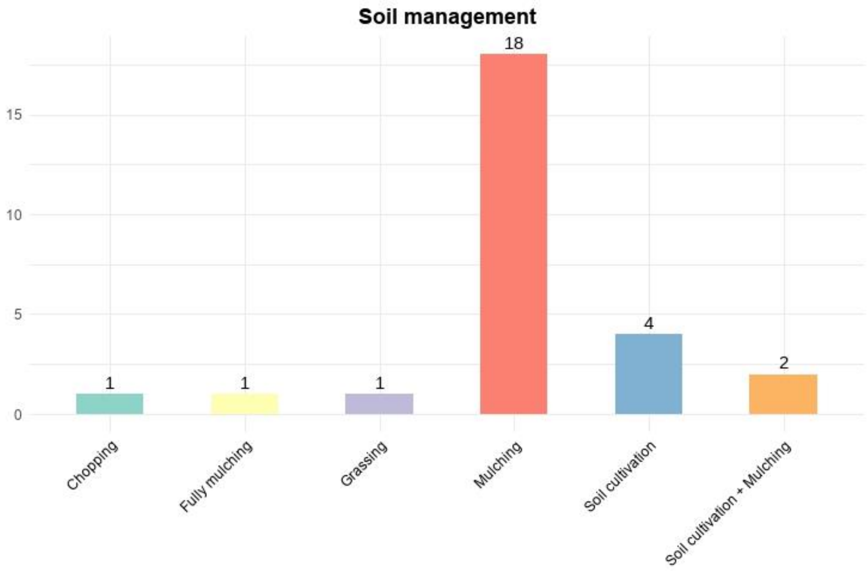


Fig. 3: Histogram representing the soil management interventions applied by respondents.

Additionally, the majority of respondents report that the most common pruning frequency for olive groves is annual, covering both summer and winter seasons (Fig. 4: Frequency of winter and summer pruning).

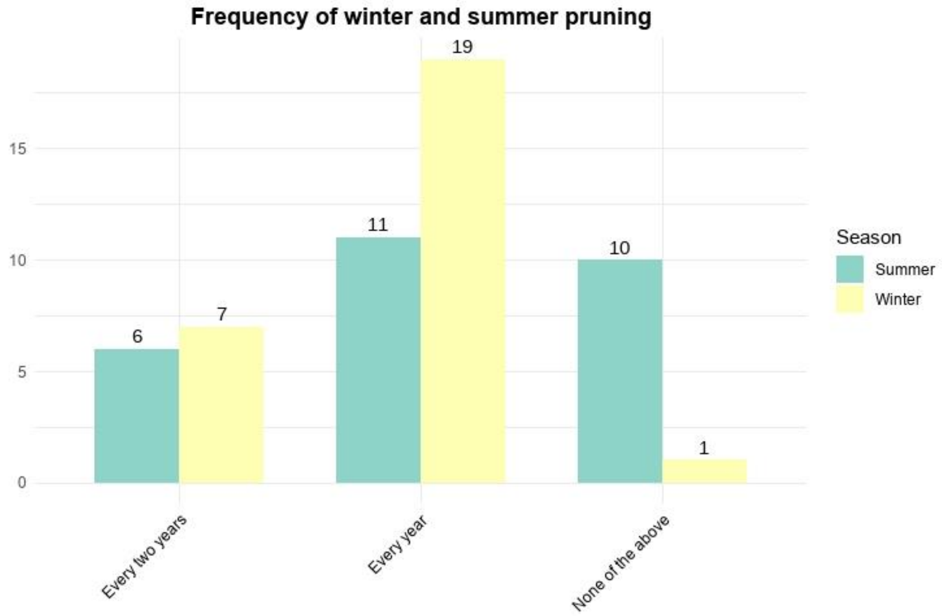


Fig. 4: Histogram representing the frequency of summer and winter pruning applied to the olive trees of the respondents.

5.2. Olive Oil Extraction Methods

The high number of oil mills (more than 4000), present in almost all Italian regions and, especially, in the Southern regions where most of olive production is concentrated, makes the olive processing possible also in the zones where the production is small, but widespread and fragmentary. More than 90% of oil mills process less than 1000 tons of olives but produce only 44% of oil, with the remaining big mills accounting for 56% of total production (ISMEA, 2024). The cause is that live processing to mechanically extract virgin olive oil is carried out in many small-medium sized oil mills equipped with the pressing system (about

30%), or with the three-phases centrifugation system (about 70%). Therefore, the oil mill sector has high costs, also due to the following reasons: the daily olive processing capacity of many oil mills is very small, lower than 15 t/day; the requirement to process separately each olive lot of different farmers; the reduced quantity of each lot, commonly lower than 1 t; the use of the pressing system which is more expensive for the manpower cost; the use of the three-phases centrifugation system which requires the addition of water to olive paste and produces, as by-products, olive mill wastewater (OMW) and a wet olive pomace (WOP), that has a low content of oil and high content of moisture and, therefore, a low market value. However, in the regions at high olive production, like Apulia region, oil mills have a higher size, and some of them are equipped with two-phase centrifugal decanters having a loading capacity higher than 5 t/h. The use of the two-phase centrifugal decanter, very widespread in Spain, doesn't need the addition of water to olive paste but requires the reduction of the loading capacity of the decanter, to obtain satisfying oil extraction yields. Besides, it allows to avoid the production of OMW but causes the production of high amount of de-oiled olive paste (80–85% of the processed olives) containing the whole not extracted oil and so wet (66–72%) as to be refused by the Italian olive pomace oil industry. To reduce the negative influence of the mentioned disadvantages and to increase the income of the process, some big-sized oil mills have adopted a complex diagram of olive processing based on the double extraction of oil and on the recovery of olive stone fragments (SF). The technology of the double extraction of olive oil was already used in the past, when the pressing system was used (Petruccioli, 1965; Leone et al., 1977; Di Giovacchino et al., 2016) but also in more recent years, when oil mills have adopted the more effective new centrifugal decanter at two- and three-phases (Di Giovacchino, 1991; Alba Mendoza et al., 1996; Di Giovacchino, 2002; Canamasas and Ravetti, 2014; Caponio et al., 2015). In addition, the same oil mills have improved the value of the solid by-product by the use of a stoner machine, useful to separate and recover part of SF from olive pomace (Serio et al., 2011; Leone et al., 2015).

Among the olive mill operators who completed the questionnaire, the average mill capacity is 1,404 kg per hour. Five out of seven operators use a two-phase centrifugal extraction system (yielding oil and wet pomace), while two use a three-phase centrifugal system (producing oil, olive mill wastewater, and dry pomace) (Fig. 5: Technology used in oil extraction).

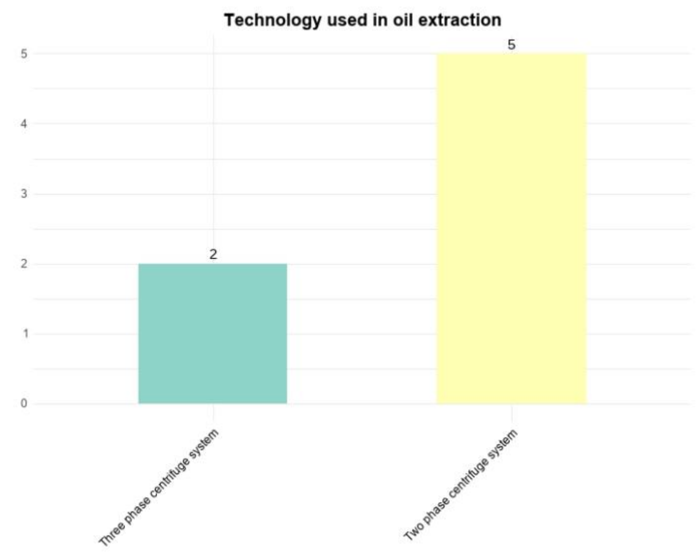


Fig. 5: Histogram representing the techniques used for oil extraction.

Only three respondents extract pits at their mills, and for four of these, pit separation occurs after oil extraction from either dry or wet pomace (Fig. 6: Olive pits extraction and Fig. 7:

Separation phase of olive pits).

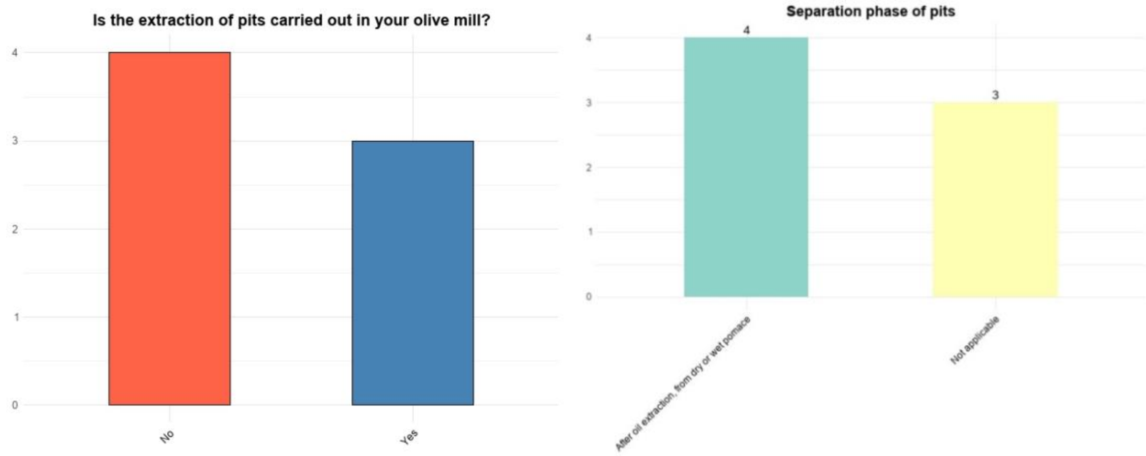


Fig. 6 and 7: Histograms representing information related to the use of olive pits: whether they are extracted in the mill or not, and what extraction technique is applied.

5.3. Cultivation area, Yield Trends and Production Statistics

According to the International Olive oil Council, olive oil production has been growing in the last decades with alternate variability from around one million tonnes in 1990–1991 up to more than 2.3 in 2015–16 (International Olive Oil Council, 2018). The largest contributor has always been Spain, reaching 767 thousand tonnes in 2022-23 followed by Italy with 328 thousand tonnes (figure 8). In particular, today Italian olive production covers approximately 1,14 million of ha, 80% of which are located in the southern zone of Italy, where in particular Puglia is responsible for around 340 000 ha followed by Calabria and Sicily. These three regions account for more than 70% of Italian olive oil production (*Seval Kurtoğlu et al., 2024*).

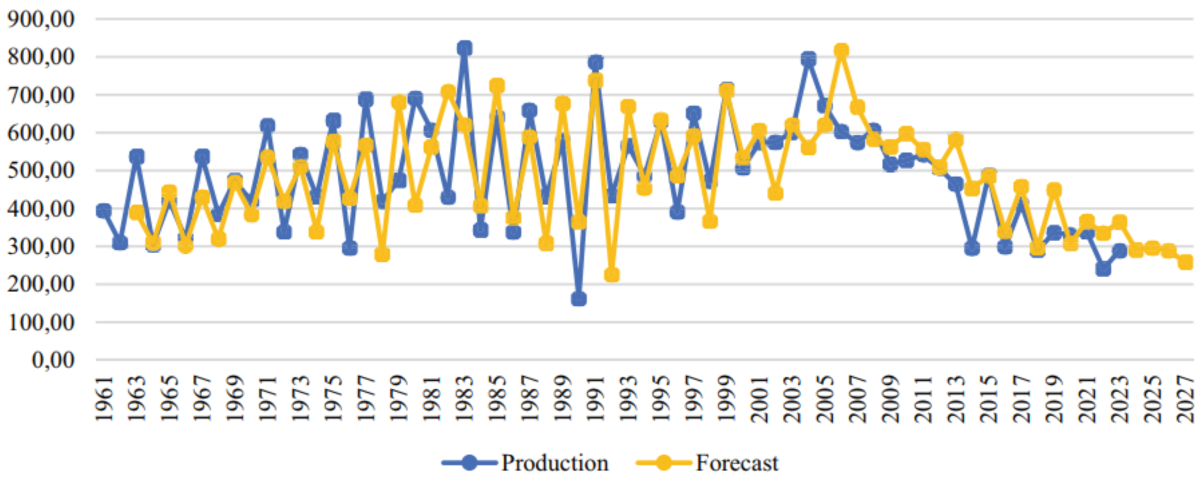


Fig. 8: olive oil production in Italy during 1961–2023 and production estimate for the period 1963–2027 (Seval Kurtoğlu et al. 2024).

Respondents report an average olive cultivation area of 5.55 hectares. Most of the olive trees fall within the 5 to 20 years age range, totalling 15,225 trees. This suggests that the producers are likely operating on a small scale, managing around 10 hectares of land. Additionally, trees older than 20 years are also commonly reported (Fig. 9): Distribution of olive trees by age of the plants).

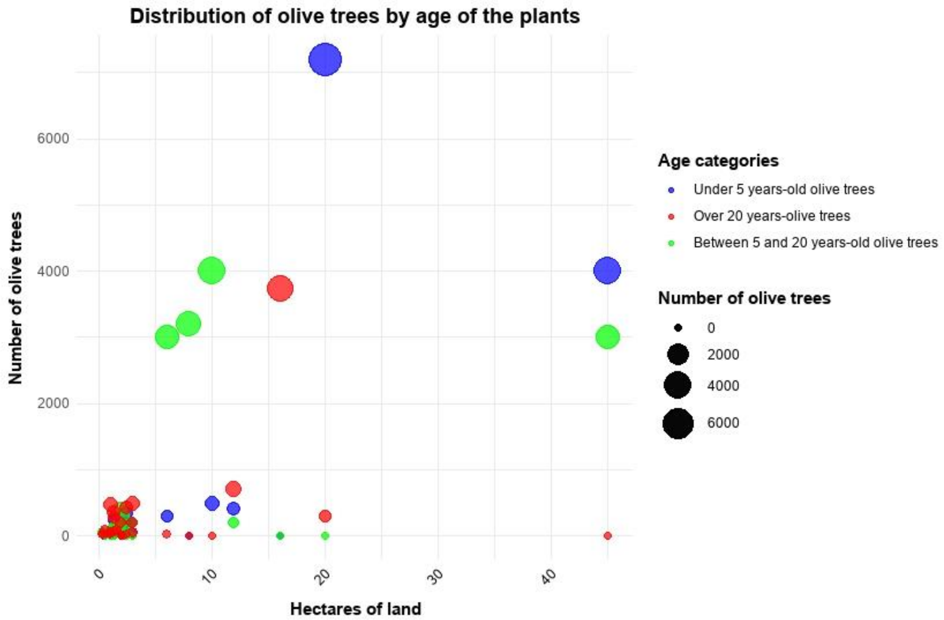


Fig. 9: Distribution graph of olive trees reported by each respondent, classified by age of the trees.

According to Fig. 10 (Distribution of olives processed per year), the highest average quantity of olives processed occurred in 2022, with a total of 740 tons, across the years 2021, 2022, and 2023.

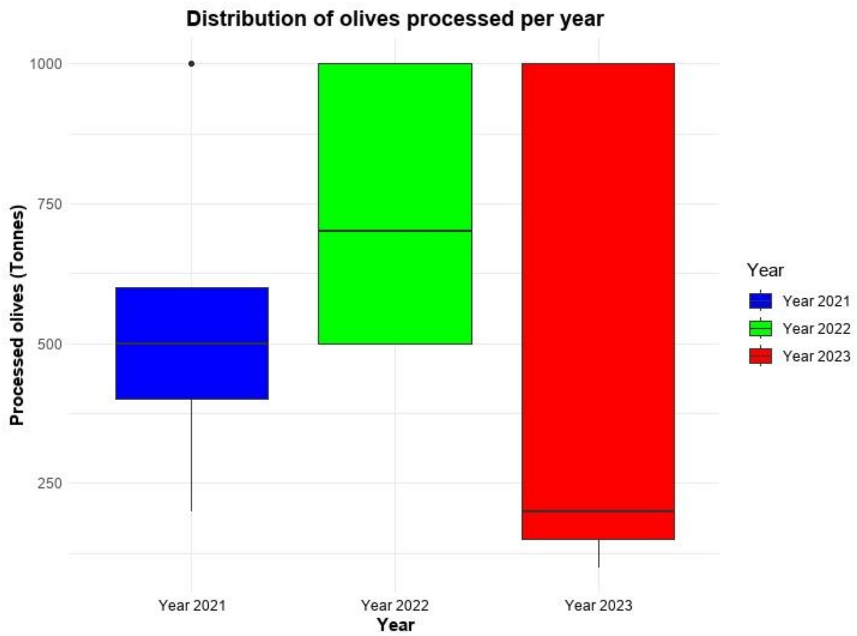


Fig. 10: Boxplot representing the distribution of olives processed in the mill in the years 2021, 2022, and 2023.

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

6.1. Olive Leaves and Branches

One of the by-products are the olive leaves, produced by the pruning and harvesting of olive trees. Normally, olive leaves get gathered with other objects such as twigs and branches. From the total pruning residues, it is estimated that the leaves constitute 25% of the dry weight (Manzanares et al., 2017). Olive oil by-products are formed mainly by wood (Ruiz et al., 2006). In Italy, from mature olive trees, depending on their structure and size, an average of between 10 and 30 kg of these wastes are produced each year. Considering Italian olive growing area and the average number of trees per hectare, annual biomass production would be 1.87 million tons (Buttol, 2018).

Respondents report an average olive cultivation area of 5.55 hectares, with most olive trees being between 5 and 20 years old, totalling 15,225 trees. Trees older than 20 years are also frequently reported (Fig. 10: Distribution of olive trees by age of the plants).

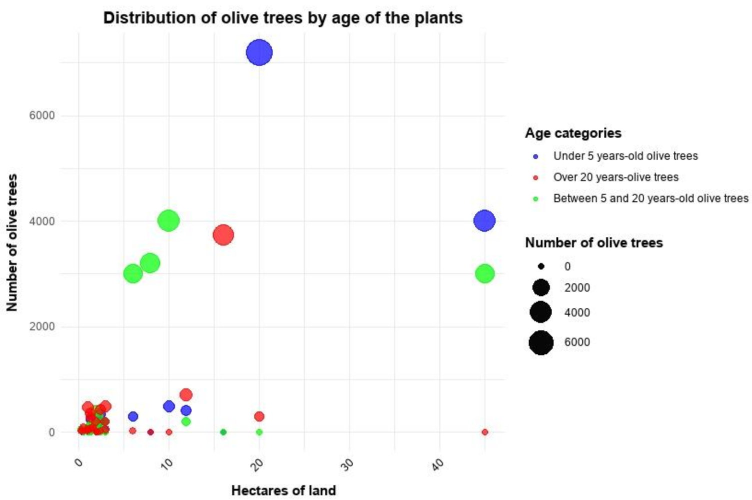


Fig. 9: Distribution graph of olive trees reported by each respondent, classified by age of the trees.

Conventional cultivation techniques are the most commonly used, followed by ecological methods that do not have eco-label certification (Fig. 1: Technology used in the olive grove).

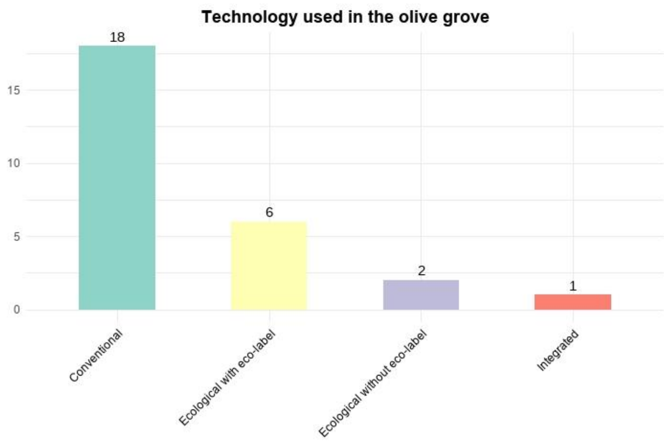


Fig. 1: Histogram representing the technologies used by olive producers for olive cultivation.

Among the circular economy practices reported, 'grass cutting' is the most prevalent, followed by the use of organic fertilizer, 'inert plant cover from cut grass', and incorporating pruning residues into the soil (Fig. 2: Interventions related to circular economy applied in olive grove).

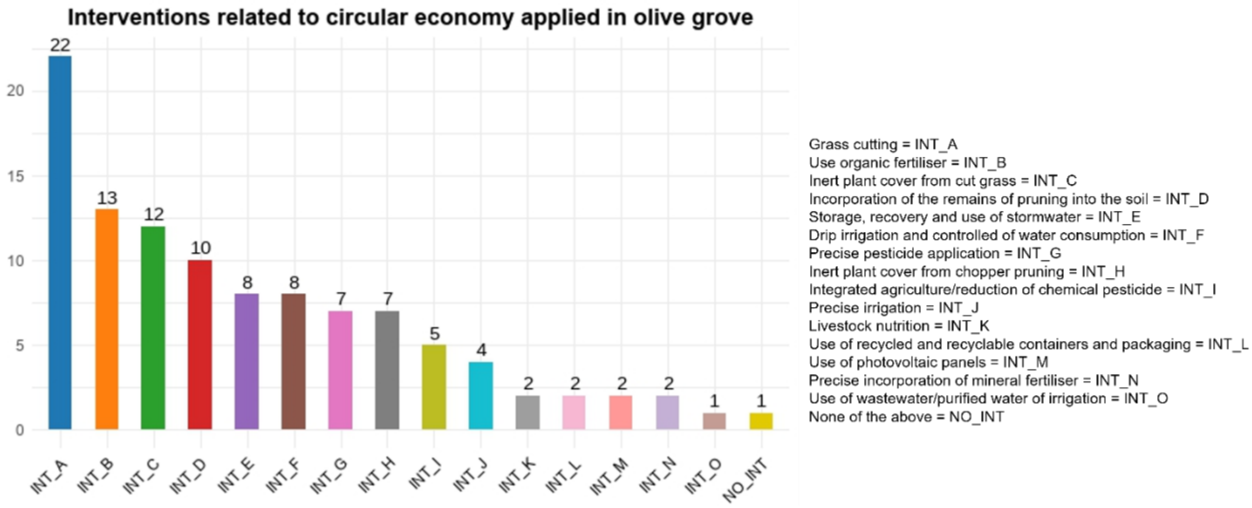


Fig. 2: Histogram representing the circular economy interventions applied by respondents to olive cultivation.

Mulching, which includes permanent mulching, grassland use, and pruning residues, is the most widely practiced soil management technique (Fig. 3: Soil management).

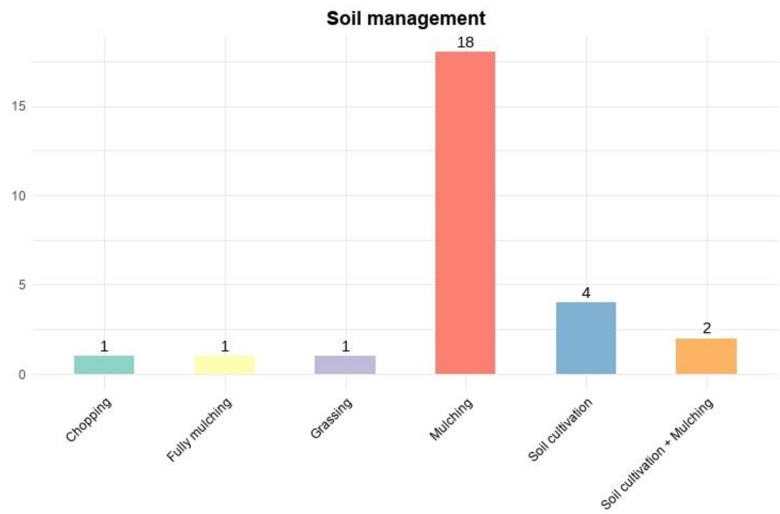


Fig. 3: Histogram representing the soil management interventions applied by respondents.

Additionally, the majority of respondents report that the most common pruning frequency for olive groves is annual, covering both summer and winter seasons (Fig. 4: Frequency of winter and summer pruning).

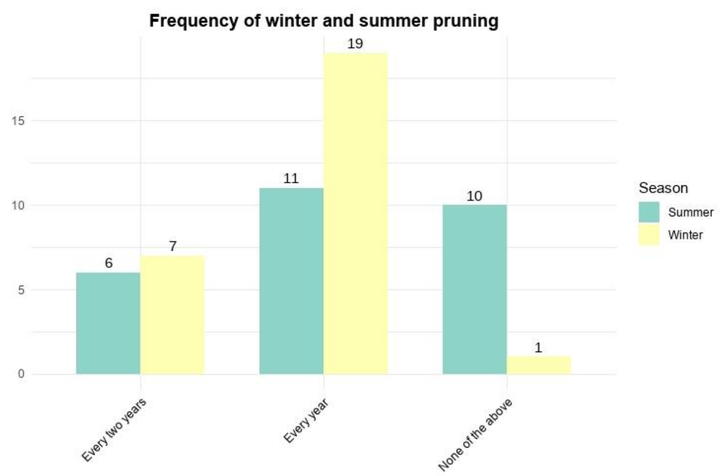


Fig. 4: Histogram representing the frequency of summer and winter pruning applied to the olive trees of

the respondents.

For managing pruning residues, the most common procedures are mulching (15 responses) and producing pellets for firewood (13 responses), with controlled burning being less common (9 responses) (Fig. 11: Procedures used for pruning residues management).

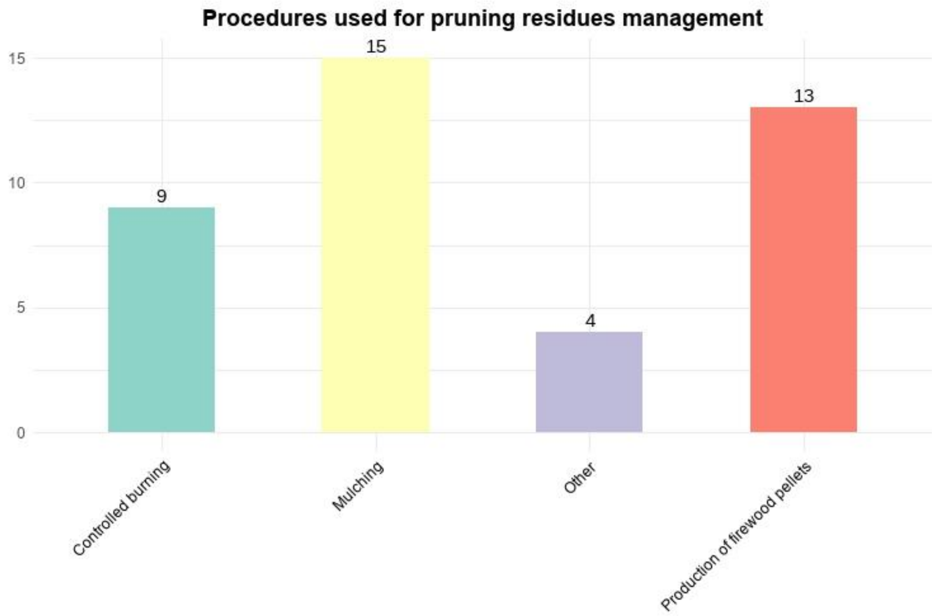


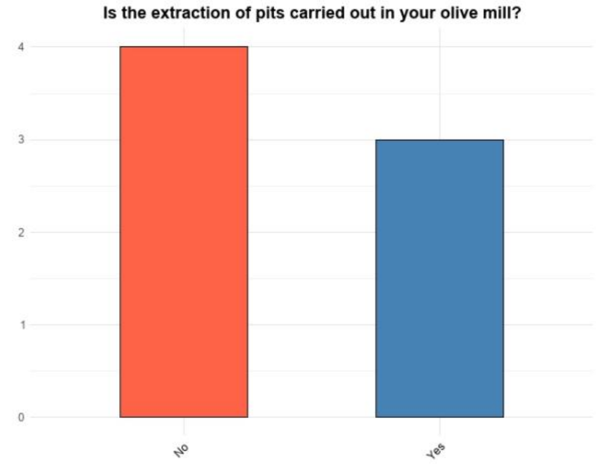
Fig. 11: Histogram representing the management methods applied to olive pruning residues.

The data collected from the interviews revealed that all respondents use pruning residues, such as leaves and branches, for composting. Additionally, one of the growers use part of the leaves for animal feed, the thinner branches for pellet production, while the thicker ones are sold to furnaces. Notably, one of the interviewees attempted to produce a liqueur from olive leaves. However, due to low market demand, the production was subsequently discontinued.

6.2. Olive Pits

Biomass has an important place among the energy resources that are considered renewable. A major opportunity within the olive oil production industry is the exploitation of certain by-products obtained during the processing of olives for oil, such as pomace and olive pits, which can be used as biofuels (Omer, 2008). In Italy with the passing of the Prime Ministerial Decree of 8th October 2004 pits from olive pomace were included in the category of biomass fuels as vegetable matter produced exclusively from the mechanical processing of agricultural products (ISTAT, 2009).

Among the respondents, only three separate the pits at their mill. For four respondents, the separation of pits takes place after oil extraction, from either dry or wet pomace (Fig. 6: Olive pits extraction and Fig. 7: Separation phase of olive pits).



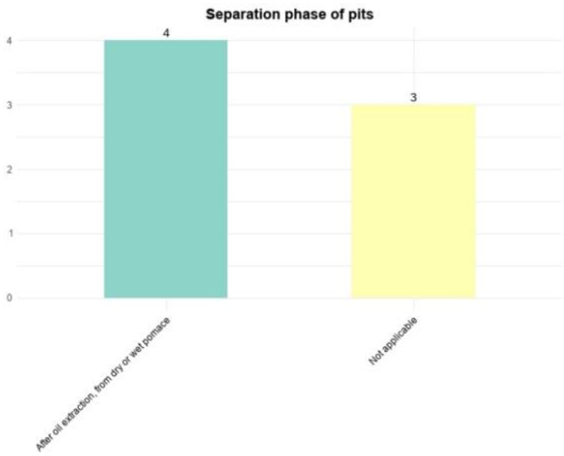


Fig. 6 and 7: Histograms representing information related to the use of olive pits: whether they are extracted in the mill or not, and what extraction technique is applied.

The data collected from the interviews revealed that all olive pits extracted from the pomace are used as fuel for energy production. This is either separated within the olive mill's ecosystem, where the energy generated is used for heating the facilities and washing water, or, in most cases, it is separated from the pomace by third-party companies and used as fuel to produce energy. One of the interviewees mentioned that within the olive mill ecosystem, the pomace is not completely deprived of pits, as the pomace processors to whom it is sold prefer it this way. Only a portion is pitted. This indicates that olive pits are considered a valuable resource, which various actors in the olive oil supply chain do not intend to forgo.

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

On the average, for each ton of olive oil produced, 2.33 tons of olive pomace are obtained (Intini et al., 2014). Thus, considering Italian olive oil production, 328,000 t in 23/24, about 764,000 t of pomace are produced. The most important Italian legislation on the subject is the previous Prime Ministerial Decree of 8th March 2002 (DPCM, 2002), in which virgin pomace was considered as a vegetable fuel that may be freely used, while exhausted pomace, which has undergone a chemical process, was categorized as no dangerous waste and was therefore subject to constraints. Subsequently, with the passing of the legislative Decree no 152 of 3rd April 2006 (D. Lgs 152/2006). and the Prime Ministerial Decree of 8th October 2004 (DPCM, 2004). the earlier Prime Ministerial Decree of 8th March 2002 was modified and exhausted pomace was categorized as a fuel.

Out of the seven olive mill operators, five use a two-phase centrifugal extraction system (producing oil and wet pomace), while two employ a three-phase centrifugal system (yielding oil, olive mill wastewater, and dry pomace) (Fig. 5: Technology used in oil extraction). Regarding the utilization of waste products, five respondents reported using pomace as biofuel (Fig. 12: Utilization of pomace).

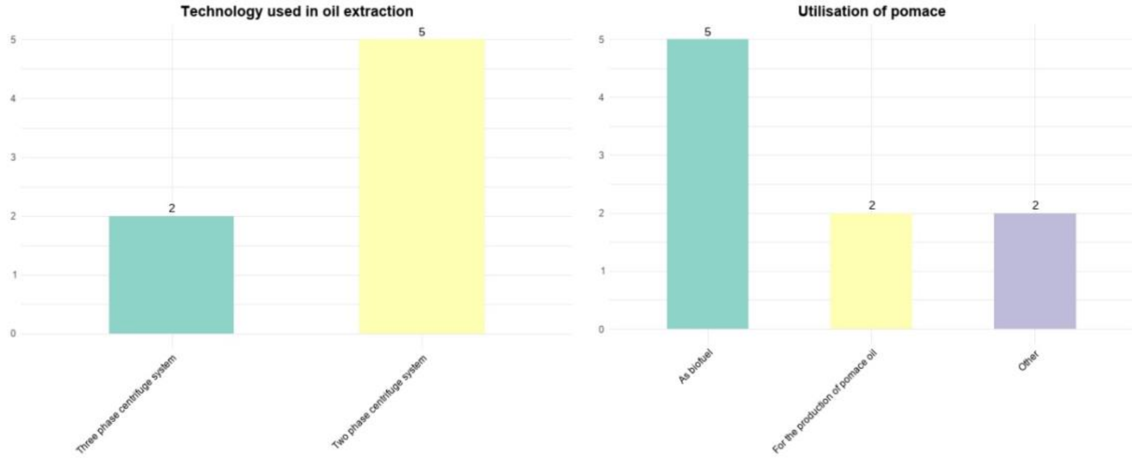


Fig. 5 and 12: Histograms representing technology used in oil extraction and reasons for utilization of pomace

From the data collected from the interviews, it emerged that 2 respondents use or rely on mills with two-and-a-half-phase and 3 respondents on mills with three-phase systems. The pomace produced is either sold or given away for free to pomace processing plants.

6.4. Waste Water

From 5 kg of olives 1 kg of extra virgin olive oil can be produced on average and the remaining 4 kg consist of olive mill wastewaters with specific characteristics according to the type of olive (Consolación Sánchez-Sánchez et al., 2020). Considering 2023/24 olive oil production in Italy, the estimated total production of wastewaters for that year would be 1,31 million of tons.

The Legislative Decree n° 152 of 1999, transposition of the European Directives 91/271/CEE and 91/676/CEE, regulates the waters safeguard from pollution. The article 38 of this act makes reference to the Italian Law n°574 of 1996 with regards to agronomic use of sewage sludge and other wastes. With Law n°574, the agronomic use of these by-products is allowed on the ground of their composition and the characteristics of soils. Such use has to be authorised each time by the competent public authority on the ground of simple documentation but subordinate to limitations, verifications and possible sanctions in order to avoid any fraudulent activity that can pollute water sources. This law allowed the direct application of the olive mill wastewaters without previous treatment (Kapellakis et al., 2007).

Regarding the use of waste products in olive production, four respondents utilize purified vegetation water, which is subsequently released into the environment (Fig. 13: Utilization of wastewater).

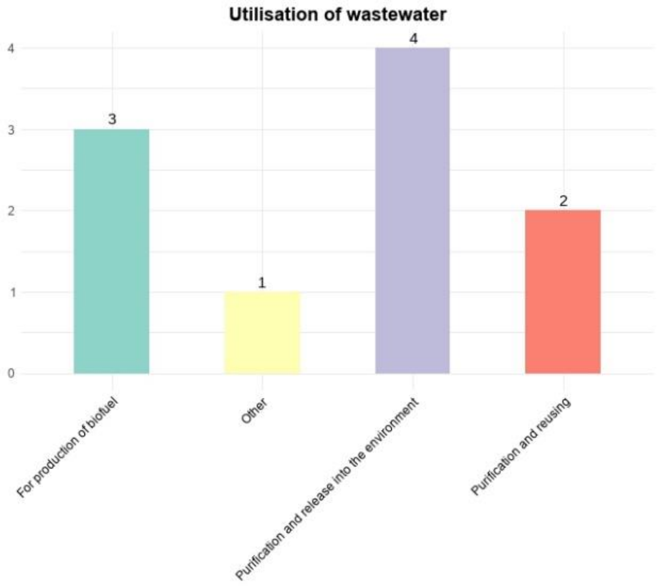


Fig. 13: Histogram representing reasons for utilization of wastewater.

Those who have access to a 3-phase decanter (3 of the respondents) use the wastewater for agronomic purposes after purification. For those who have access to a 2.5-phase decanter (2 of the respondents), the wet pomace, which is rich in wastewater, is sent to biogas plants for energy production.

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

Based on the interviews conducted, no other types of by-products were identified or valorized.

7. Sustainability and Environmental Impact

7.1. Sustainable Practices in Olive Farming and Olive Oil Producing

Regarding the Italian olive oil sector, the extreme fragmentation of the production structure, the different farming systems, the vast national olive germplasm, and the prominent economic, cultural (from gastronomy to medicine, from art to mythology and history), social and environmental value of olive, make it difficult to generically define a univocal model of sustainability (ISMEA, 2020). The identification of the high number of variables that must be taken into consideration in the sustainability assessment/ self-assessment process for both the agricultural and the processing phases represents a crucial point for a correct definition of actions and policy. In Italy the drafting of a "total" sustainability technical guide as it was intended as an operational support for the enhancement and promotion of a sustainable olive oil supply (Lombardo et al., 2022).

The predominant technology utilized in olive cultivation is conventional methods, with ecological techniques that do not possess eco-label certification being the next most common (Fig. 1: Technology used in the olive grove).

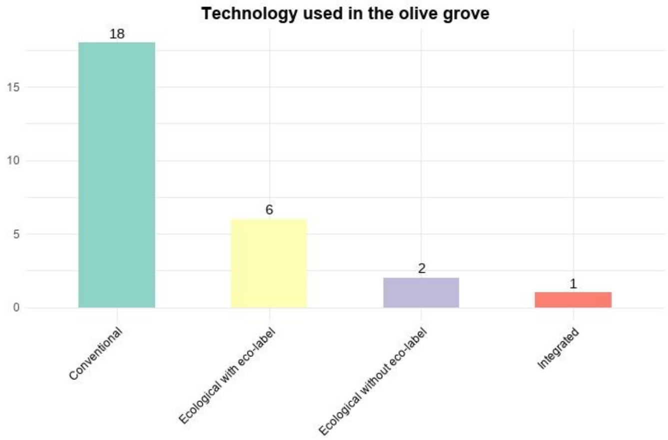


Fig. 1: Histogram representing the technologies used by olive producers for olive cultivation.

Among the circular economy practices reported by respondents, "grass cutting" emerges as the most frequently applied method. This is followed by the use of organic fertilizers, "inert plant cover from cut grass" and the incorporation of pruning residues into the soil (Fig. 2: Interventions related to circular economy applied in olive grove).

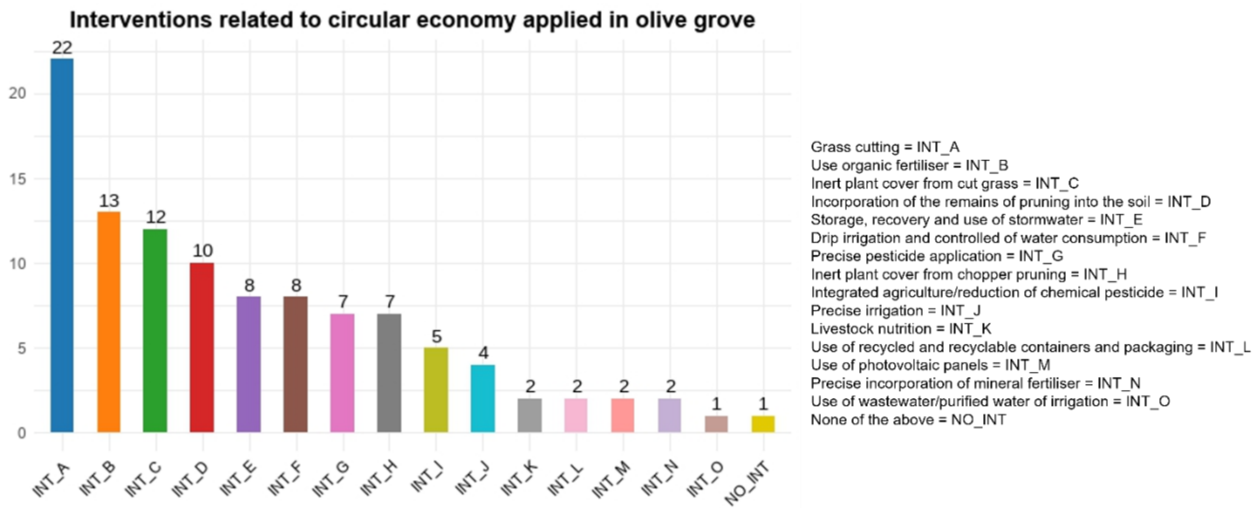


Fig. 2: Histogram representing the circular economy interventions applied by respondents to olive cultivation.

From the interviews, it emerged that the respondents use the pits derived from the pomace for energy production, in their facilities, for example, to heat washing water or sold to other industries. Additionally, pruning residues are primarily used as fertilizer through mulching. Some of the respondents use purified wastewaters for field irrigation.

8. State of Circular Business Practices in the Olive Sector

8.1. Trends and Preferences

More than 500,000 Italians have a job related to circular economy, such data confirms the importance of this approach within the supply chain, including the olive sector (Ncube et al., 2022).

Olive pomace, in olive oil production, consists in the most abundant solid by-product (64% of the mass), nowadays it is mainly used to extract pomace oil and the cake residue is destined to energy production (Ncube et al., 2022). In addition, solid residues, olive cakes, are also widely used as feedstock, being one of the fields in which it is possible to create new value from biomass (Raimondo et al., 2021). Wet pomace is also used as fertilizer by being spread on farmlands (within the limit of 80 tons per ha and after a maximum of a month after production). However, such practice must be compliant with the geological, pedological and hydrologic conditions of the site (Stempfle et al., 2022).

Although the majority of respondents do not employ practices related to the use of pruning residues, those who do primarily cite sustainability awareness as the main reason for mulching. Additional motivations include cost-effectiveness and increased revenue from composting, as well as the production of pellets and firewood. Similar patterns are observed with respect to the challenges associated with using pruning residues (Fig. 14: Motivations for utilization of pruning residues).

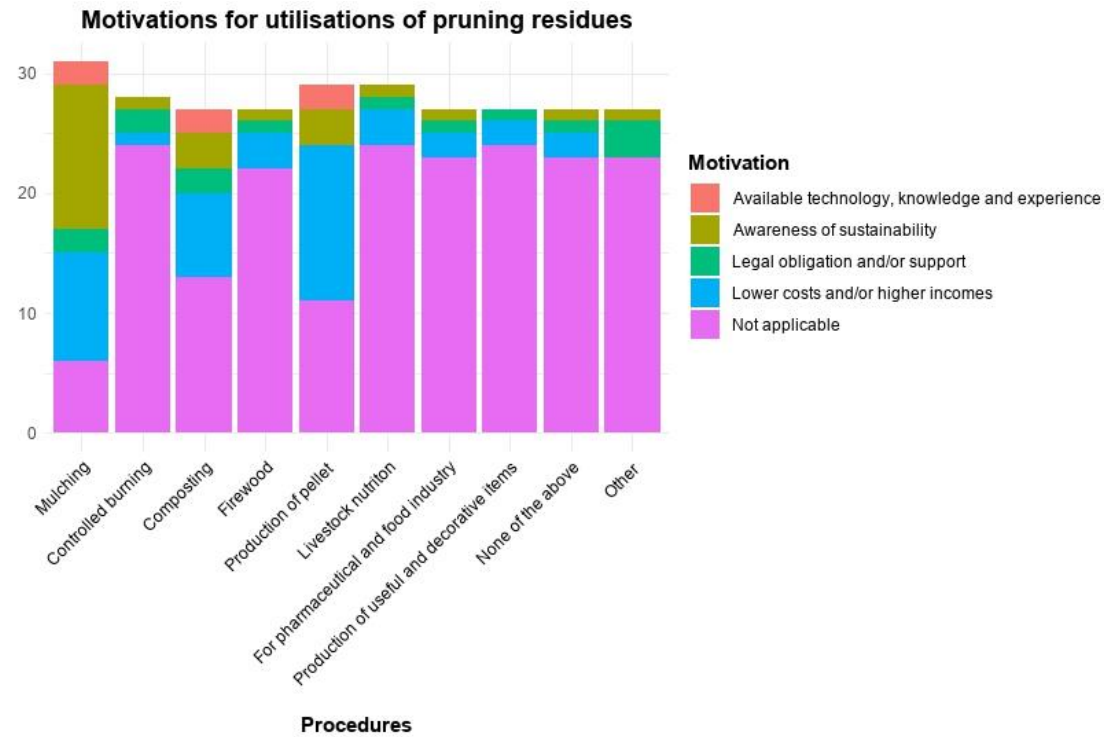


Fig. 14: Stacked bar chart representing the reasons for using pruning residues.

Key obstacles to mulching include a lack of technology or expertise and the substantial initial investments required. For composting, significant barriers include not only technological or knowledge gaps but also legal restrictions and inadequate support for implementation (Fig. 15: Obstacles for utilization of pruning residues).

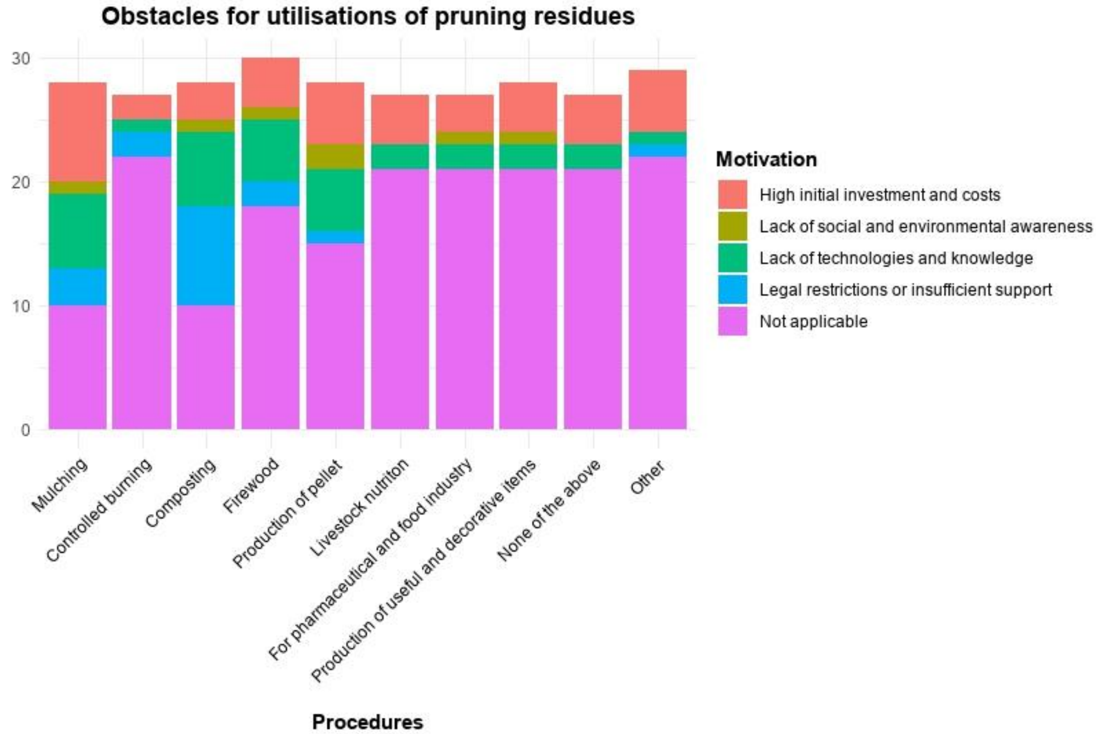
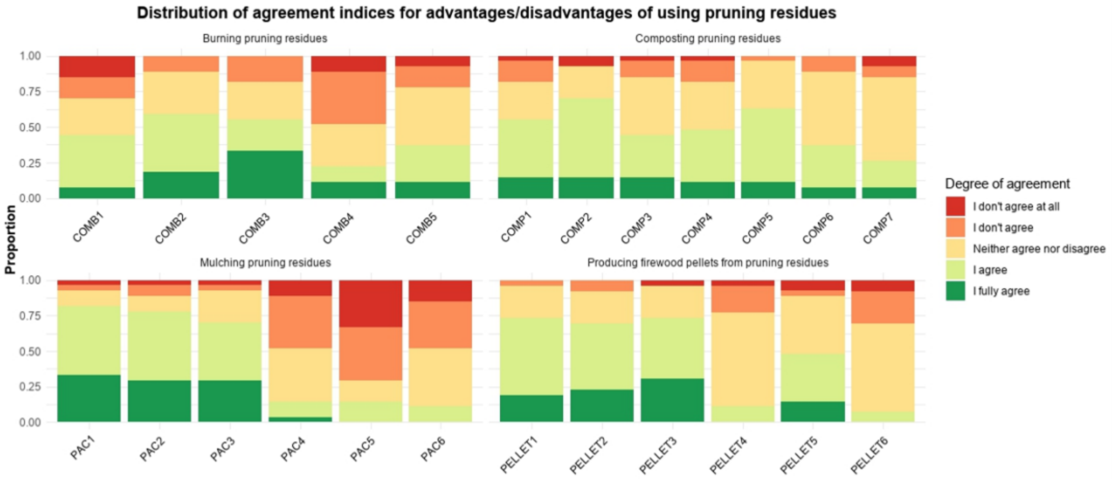


Fig. 16: Stacked bar chart representing the barriers for using pruning residues.

Fig. 16 (Distribution of agreement indices for advantages/disadvantages of using pruning residues) presents responses on a 1-5 Likert scale for four indices assessing the pros and cons of various uses of pruning residues: burning (COMB1-5), composting (COMP1-7), mulching (PAC1-6), and pellet production (PELLET1-6). The graph illustrates the proportion of responses for each item, with different colours representing various levels of agreement as outlined in the legend. For the burning index (COMB), respondents generally show strong agreement with the statements, except for item COMB4, which suggests that burning pruning residues is ineffective due to the loss of valuable organic material. Respondents were more likely to disagree with this statement. A similar trend is observed in the mulching index (PAC), where items 4, 5, and 6, which address soil health post-mulching, received greater disagreement. Regarding the pellet production index (PELLET), overall agreement is relatively high, although items 4 and 6 - concerning costs and energy consumption - show a more neutral stance among respondents, indicating neither strong agreement nor disagreement. Lastly, the composting index (COMP) generally reflects strong agreement for most items, except for items 6 and 7, which deal with odours from composting and soil health post-composting. For these items, respondents exhibit a neutral position, neither agreeing nor disagreeing.



"The plant residues burning is in accordance with the principles of good agriculture practice" = COMB1
"Useful because pests and disease are controlled" = COMB2
"Extracting the branch from the plantation requires a lot of work" = COMB3
"It is not useful because valuable organic material is lost" = COMB4
"It is harmful to the air and the local ecosystem" = COMB5

"The most cost-effective way of using pruning residues" = PAC1
"A positive effect on the structure and content of organic material in the soil" = PAC2
"Useful because it prevents the growth of weeds and erosion and conserves moisture in the soil" = PAC3
"Disease development and pest attack are encouraged" = PAC4
"Increases the danger of fire outbreaks" = PAC5
"Negative impact on soil pH value" = PAC6

"Organic waste in landfills is reduced" = COMP1
"The obtained compost is a quality organic fertilizer" = COMP2
"Composting is a demanding procedure that needs knowledge that I do not have" = COMP3
"There is no organized composting system in the area" = COMP4
"The composting process is very long and requires a lot of space" = COMP5
"Composting creates unpleasant odours and attracts insects" = COMP6
"Improper composting can result in the spread of disease in the plantations" = COMP7

"Pellets have a high energy value" = PELLET1
"Pellets are an ecological energy source" = PELLET2
"Equipment for pellets production is expensive" = PELLET3
"The production of pellets requires a large consumption of energy, so their production is not ecologically justified" = PELLET4
"There is no organized system for the production of pellets in the area" = PELLET5
"The price of pellets is high compared to other energy sources" = PELLET6

Fig. 16: Stacked bar charts representing the distribution of agreement indices for advantages/disadvantages of using pruning residues

The overall distribution of agreement levels regarding the recycling and reuse of pomace and vegetation water, as assessed by the SANS (6 items), VEG (6 items), and BIO (4 items) indices, generally indicates a tendency towards disagreement among respondents. Notable exceptions are VEG2, which states that "Reducing fresh water consumption contributes to ecological sustainability and reduces the negative impact of olive processing on the environment," and BIO1, which asserts that "Pomace is a high-quality renewable energy source." Respondents demonstrate strong agreement with these statements (Fig. 17: Distribution of agreement indices for advantages/disadvantages of recycling olive pomace and wastewater).

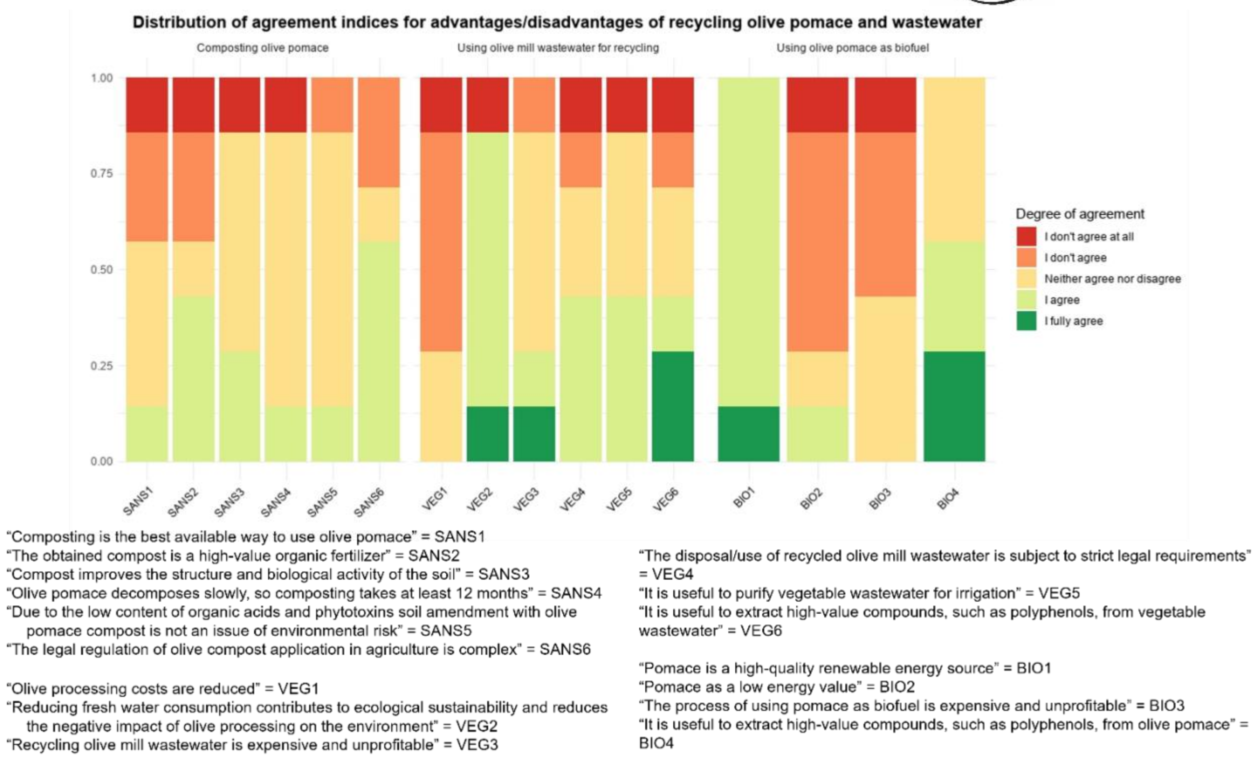


Fig. 17: Stacked bar charts representing the distribution of agreement indices for advantages/disadvantages of recycling olive pomace and wastewater.

Regarding the use of waste products in olive production, four respondents report utilizing purified vegetation water, which is subsequently released into the environment. The primary use of extracted pits is as an energy source (Fig. 18: Purpose of olive pits use).

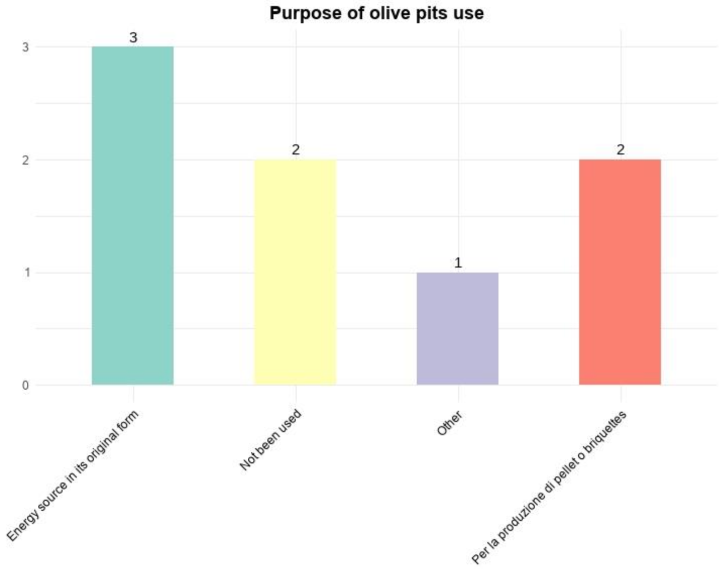


Fig. 18: Histogram representing purpose of olive pits used.

In terms of agreement with statements about using pits as an energy source, items 1, 2, and 5 received the highest levels of agreement, whereas items 3 and 4 garnered the highest levels of disagreement among respondents (Fig. 19: Using olive pits as an energy source).

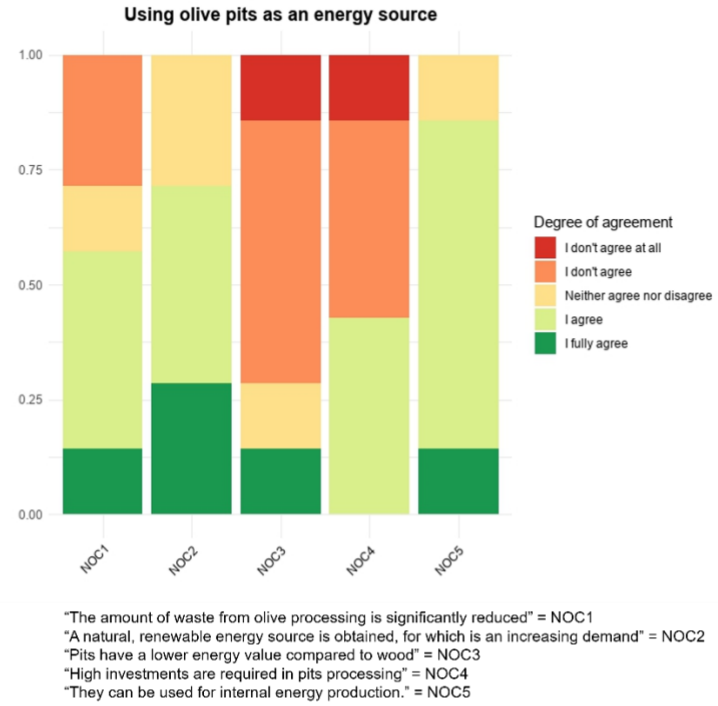


Fig. 19: Stacked bar chart representing reasons for using olive pits as an energy source

From the interviews, it emerged that the motivations and relevant factors for managing by-products/waste from olive oil processing or those obtained in the field are primarily social and economic. All respondents showed a strong interest in sustainability, often linked to cultural factors and family traditions in managing their activities. Additionally, the economic factor is significant, as in many cases, the generated by-products are sold to third-party companies, thus generating a profit, or they are donated, saving on storage and disposal costs. One interviewee reported that proper management of by-products from olive oil production allowed him to shift from a management cost of 2.5 euros per quintal of milled olives to a profit of 3 euros for the same quantity of milled olives.

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

Italy is one of the key players in the olive oil market, as witnessed by the income produced by this sector that is proved to be one of the pillars of the Italian economy (STATISTA, 2021). Nevertheless, in recent years, the Italian olive oil sector underwent a loss of competitiveness, due to the recent phytosanitary problems as well as to the scarce technological improvement and unproper process management in the mill plants (Irene et al., 2018). Whereas the agronomic issues are going to be solved, the lack of technological innovation still needs to be addressed, being the high costs of machinery, the lack of infrastructures, the problems in waste disposal, and the small/medium industrial capacity are the most severe limiting factors (Perone et al., 2022).

Although the majority of respondents do not employ practices related to the use of pruning residues, those who do primarily cite sustainability awareness as the main reason for mulching. Additional motivations include cost-effectiveness and increased revenue from composting, as well as the production of pellets and firewood. Despite these motivations, significant technological gaps and challenges hinder the effective implementation of circular practices.

Technological Obstacles:

- **Mulching:** key obstacles to mulching include a lack of technology or expertise. Respondents identified technological deficiencies as a major barrier, suggesting that the available methods and equipment for mulching are not sufficiently advanced or accessible.
- **Composting:** for composting, significant barriers include not only technological or knowledge gaps but also legal restrictions and inadequate support for implementation. These technological challenges, combined with regulatory constraints, impact the efficiency and feasibility of composting practices.
- **Pellet production:** in pellet production, overall agreement is relatively high. However, concerns related to costs and energy consumption reflect a more neutral stance among respondents, indicating that the technological solutions for pellet production are not fully optimized or well-supported.
- **Burning:** regarding burning, respondents generally show strong agreement with the effectiveness of burning practices, except for the concern that burning leads to the loss of valuable organic material. This suggests that the technologies and practices for burning might not be fully developed or effective in retaining organic value.

The overall distribution of agreement levels concerning the recycling and reuse of pomace and vegetation water reveals a tendency toward disagreement among respondents. Notable exceptions include the statement that "Reducing fresh water consumption contributes to ecological sustainability and reduces the negative impact of olive processing on the environment," with which respondents strongly agree. Similarly, respondents view pomace as a high-quality renewable energy source. Finally, the use of waste products in olive production shows that only a few respondents utilize purified vegetation water, which is then released into the environment. The primary use of extracted pits is as an energy source. Agreement levels with statements about using pits as an energy source vary, with some statements receiving high levels of agreement while others see significant disagreement, highlighting ongoing technological gaps and the need for improved practices.

From the interviews, it emerged that, from a technological perspective, the primary concern for respondents is the limited access to technology. Examining the most cited practice of by-product valorization, namely the recovery of phenolic compounds from leaves and vegetation water, the main limitation for the actors in the olive-oil sector is the lack of opportunity to install extraction plants within their companies. Respondents expressed concern about the lack of adequate space in agricultural enterprises/olive mills for constructing such plants and the absence of skilled personnel capable of operating such equipment.

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

According to Eurostat data (Eurostat, 2017), the circular economy in Italy proves to have a greater weight than in other European countries. More than five hundred thousand Italians have a job linked to the circular economy approach. It is therefore important to investigate individual case studies of particular economic and environmental interest, such as the olive oil one, to increase productivity and decrease the impact of the product on the environment and the whole supply chain.

Although many respondents do not currently employ practices related to the use of pruning residues, those who do identify key best practices and motivations for implementing circular approaches. The main reason cited for mulching is a strong awareness of sustainability. Additional motivations include cost-effectiveness, increased revenue from composting, and the production of pellets and firewood. These practices highlight effective strategies for incorporating circular principles into olive oil production.

Best Practices:

- **Mulching:** effective mulching practices are driven by a clear focus on sustainability. Best practices include utilizing available technology and expertise to enhance the effectiveness of mulching. Successful implementation often involves adapting methods to local conditions and ensuring that the technology used is accessible and efficient.
- **Composting:** best practices in composting involve overcoming technological and knowledge gaps by investing in appropriate technology and seeking regulatory support. Successful composting practices include adhering to guidelines that address both the technological and legal aspects, ensuring that composting is both feasible and environmentally beneficial.
- **Pellet production:** pellet production is recognized as a valuable circular practice, with best practices involving optimizing cost and energy efficiency. Effective pellet production practices focus on improving the technology used and managing the production process to balance cost and energy consumption, thereby maximizing the benefits of this approach.
- **Burning:** although burning of pruning residues is generally seen as effective, best practices involve addressing concerns about the loss of valuable organic material. Implementing advanced burning technologies and practices that minimize material loss can enhance the effectiveness of this method.

The overall distribution of agreement regarding the recycling and reuse of pomace and vegetation water reflects positive practices, with notable exceptions being the strong agreement on reducing fresh water consumption for ecological sustainability and recognizing pomace as a high-quality renewable energy source. Finally, the use of waste products in olive production highlights best practices, such as the utilization of purified vegetation water and the energy use of extracted pits. High agreement with statements about using pits as an energy source, combined with effective management of this resource, underscores successful practices in integrating waste products into the production process.

The practices for implementing the circular economy in the olive oil sector, as suggested by the interviewed participants, were discussed in paragraph 6 titled "BY-PRODUCTS AND WASTE PRODUCTION IN THE OLIVE SECTOR."

9. Technological Advancements

9.1. Innovations in Production and Processing

The olive oil production is one of the most important sectors of Italian food economy, but it can be thought to provide systemic technological innovation with selective and costly improvements (Martino et al., 2017). Besides these difficulties, techniques such as high-pressure ultrasonic extraction and microwave-assisted extraction are being integrated into production processes. These innovations not only increase oil yield but also may improve the sensory and nutritional qualities of the final product, while reducing processing time and energy consumption (Roselli et al., 2019; Turkan Mutlu Keceli, 2023). Moreover, the adoption of advanced analytical methods allows for rapid and precise quality assessment of olive oils. These methods facilitate quality control and contribute to the overall improvement of product standards in the market (Turkan Mutlu Keceli, 2023).

Olive oil by-products can be used in different ways for resource recovery, improving the sustainability of oil production. Pruning residue consists of branches, which could be used as biomass for fuel production (Intini et al., 2014), and leaves, which could be useful for phenolic compound extraction (Cerri et al., 2024) or animal feeding. For example, Mattioli et al. (2018) used selenium-fortified olive leaves as a dietary source of Se for rabbits, demonstrating an increase of bioactive compounds content in meats. Olive mill wastewaters and pomace are also a great source of polyphenols, that can possess antioxidant and antimicrobial activity (Pannucci et al., 2019; Ricelli et al., 2020). Russo et al. (2022) proved an antibacterial activity of phenols extracted from wastewaters (Fig. 20) against clinically relevant Gram-positive and Gram-negative human pathogens but also against phytopathogens like *Pseudomonas syringae* pv. *Tomato*. Given their bioactivity, these compounds can be used as functional ingredients for the production of fortified and enriched foods, like cereal-based foods (Cedola et al., 2020).

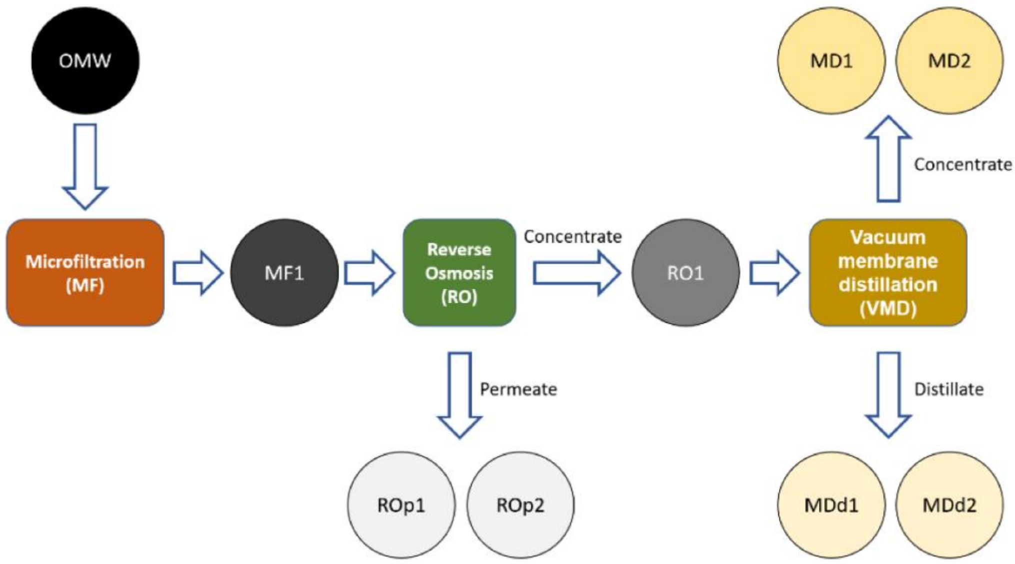


Fig. 20: Schematic representation of olive mill wastewaters purification process

9.2. Future Technological Trends in the Sector

Olive oil production in Italy boasts a thousand-year-old tradition and represents one of the most interesting fields of Italian agriculture. Nowadays the olive oil extraction is carried out with technological industrial processes (continuous or discontinuous), even though the quality and the quantity of the obtained oil are still to be optimized, producing a significant economic loss for the oil sector. A possibility for trying to solve the problem could be the exploitation of biotechnology in the olive oil industry, considering also eco-sustainability and lower environmental impact of the enzymes used (Chiacchierini et al., 2007).

10. Market Analysis

10.1. Market Forces

In recent years, olive oil consumption is spreading to non-traditional areas of the world, from northern European countries to the American continent and almost everywhere where there are wealthy consumers willing to pay for a more expensive substitute of other vegetable oils. both traditional and new markets have changed and are still changing rapidly (Carbone et al., 2014). In this changing market, the production area remains a major factor for market segmentation and acts as an effective quality clue (Fotopoulos and Krystallis, 2001; van der Lans, 2001). The relevant clues related to the geographical roots of olive oil are diverse: (i) the country of origin may be reported on the label, according to different national rules (in Italy, it is mandatory); (ii) the macro-area (in Italy, there are substantial differences in volumes, quality, and reputation among Southern, Central, and Northern macro-areas even if information on this does not appear in the label) (Aprile et al., 2012); (iii) the region, that in some case is well renowned and highly reputed (i.e., Tuscany whose olive oil is worldwide famous) (Carbone et al., 2014).

The management of pruning residues in the olive oil sector is influenced by various market forces. Most respondents do not use procedures related to pruning residues, but those who do cite sustainability awareness as the primary motivation for mulching. They also highlight the economic benefits associated with composting, such as low costs and increased revenue from the production of pellets and firewood. However, significant challenges emerge: key obstacles to mulching include a lack of technology or knowledge and the high initial investments required. For composting, in addition to these gaps, legal restrictions and inadequate support for implementation are notable barriers. (Fig. 14 and Fig. 15: Motivations/Obstacles for utilization of pruning residues)

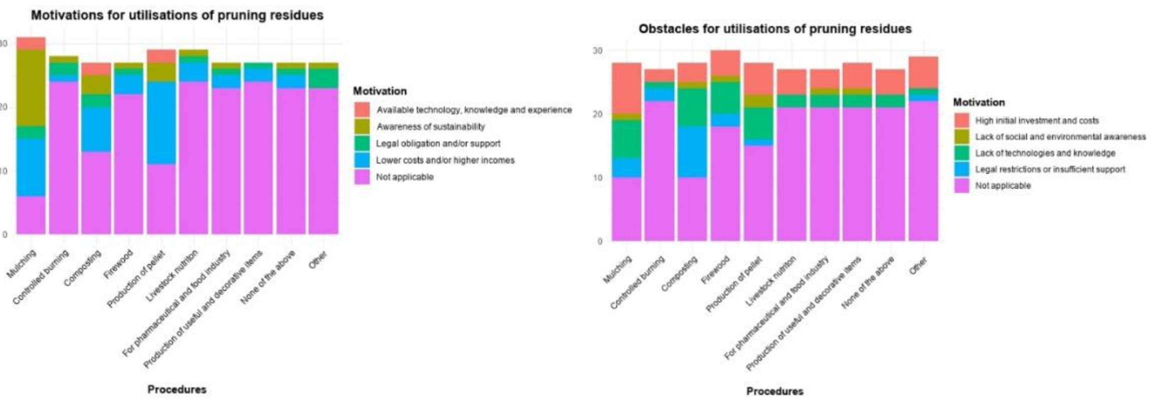
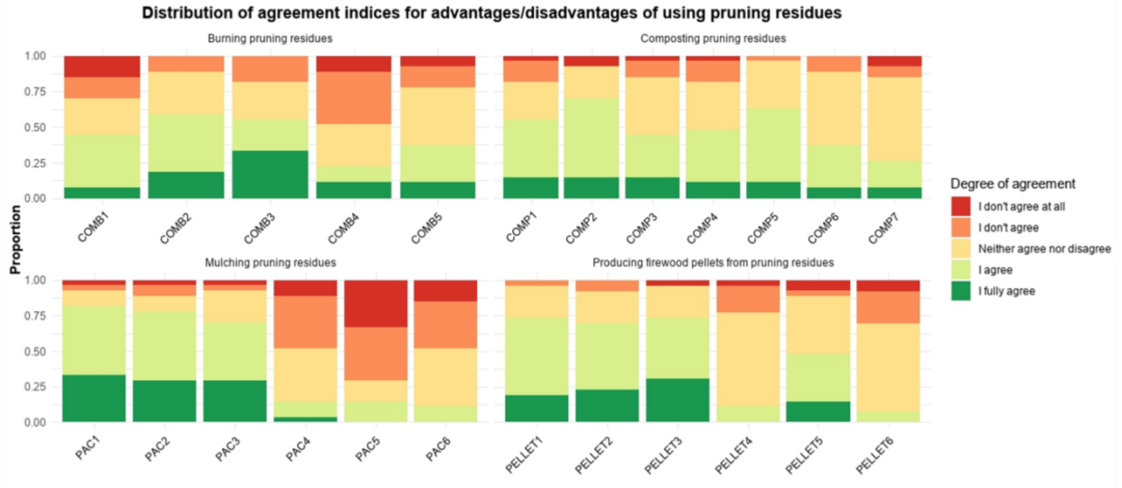


Fig. 14 and 15: Stacked bar chart representing the reasons and barriers for using pruning residues.

Regarding pellet production (PELLET index), overall agreement is relatively high, although items 4 and 6 - concerning costs and energy consumption - reflect a neutral stance among respondents, indicating neither strong agreement nor disagreement (Fig. 16: Distribution of agreement indices for advantages/disadvantages of using pruning residues).



"The plant residues burning is in accordance with the principles of good agriculture practice" = COMB1
"Useful because pests and disease are controlled" = COMB2
"Extracting the branch from the plantation requires a lot of work" = COMB3
"It is not useful because valuable organic material is lost" = COMB4
"It is harmful to the air and the local ecosystem" = COMB5

"Organic waste in landfills is reduced" = COMP1
"The obtained compost is a quality organic fertilizer" = COMP2
"Composting is a demanding procedure that needs knowledge that I do not have" = COMP3
"There is no organized composting system in the area" = COMP4
"The composting process is very long and requires a lot of space" = COMP5
"Composting creates unpleasant odours and attracts insects" = COMP6
"Improper composting can result in the spread of disease in the plantations" = COMP7

"The most cost-effective way of using pruning residues" = PAC1
"A positive effect on the structure and content of organic material in the soil" = PAC2
"Useful because it prevents the growth of weeds and erosion and conserves moisture in the soil" = PAC3
"Disease development and pest attack are encouraged" = PAC4
"Increases the danger of fire outbreaks" = PAC5
"Negative impact on soil pH value" = PAC6

"Pellets have a high energy value" = PELLET1
"Pellets are an ecological energy source" = PELLET2
"Equipment for pellets production is expensive" = PELLET3
"The production of pellets requires a large consumption of energy, so their production is not ecologically justified" = PELLET4
"There is no organized system for the production of pellets in the area" = PELLET5
"The price of pellets is high compared to other energy sources" = PELLET6

Fig. 16: Stacked bar charts representing the distribution of agreement indices for advantages/disadvantages of using pruning residues

Five respondents reported using pomace as biofuel (Fig. 12: Utilization of pomace).

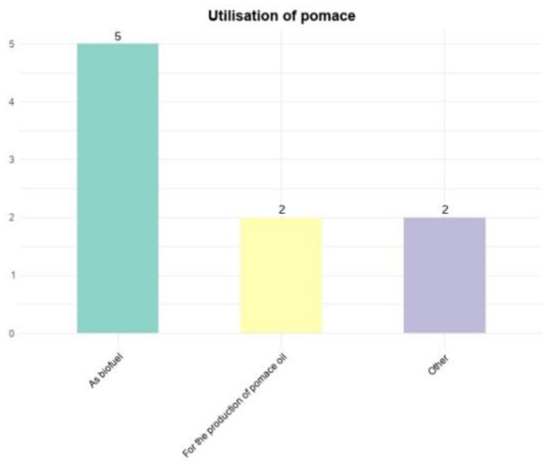


Fig. 12: Histogram representing reasons for utilization of pomace.

However, the general trend in agreement with statements about recycling and reusing pomace and vegetation water, as assessed by the SANS (6 items), VEG (6 items), and BIO (4 items) indices, tends toward disagreement. Exceptions include VEG2, which states that "Reducing fresh water consumption contributes to ecological sustainability and reduces the negative impact of olive processing on the environment," and BIO1, which claims that "Pomace is a high-quality renewable energy source." Respondents show almost complete and full agreement with these statements, respectively (Fig. 17: Distribution of agreement indices for advantages/disadvantages of recycling olive pomace and wastewater).

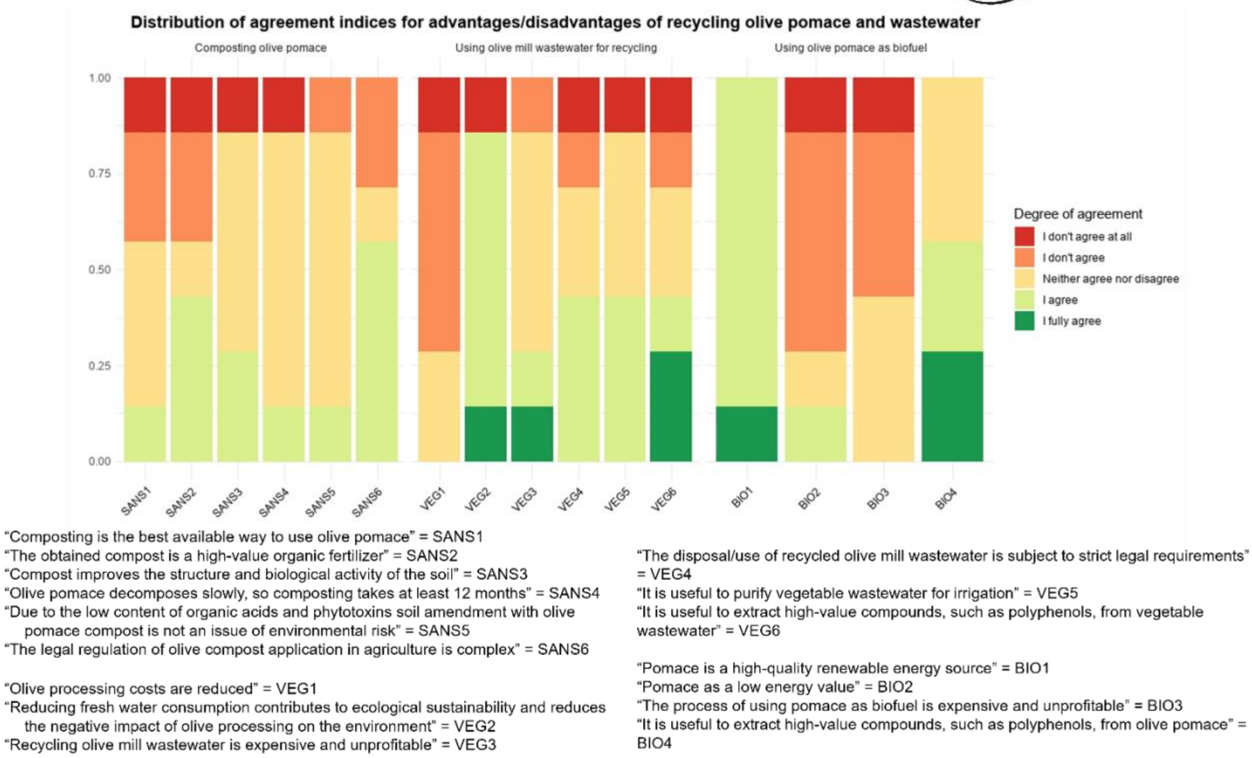


Fig. 17: Stacked bar charts representing the distribution of agreement indices for advantages/disadvantages of recycling olive pomace and wastewater.

Regarding the use of pits as an energy source, items 1, 2, and 5 receive the highest levels of agreement, while items 3 and 4 show the highest levels of disagreement among respondents (Fig. 19: Using olive pits as an energy source).

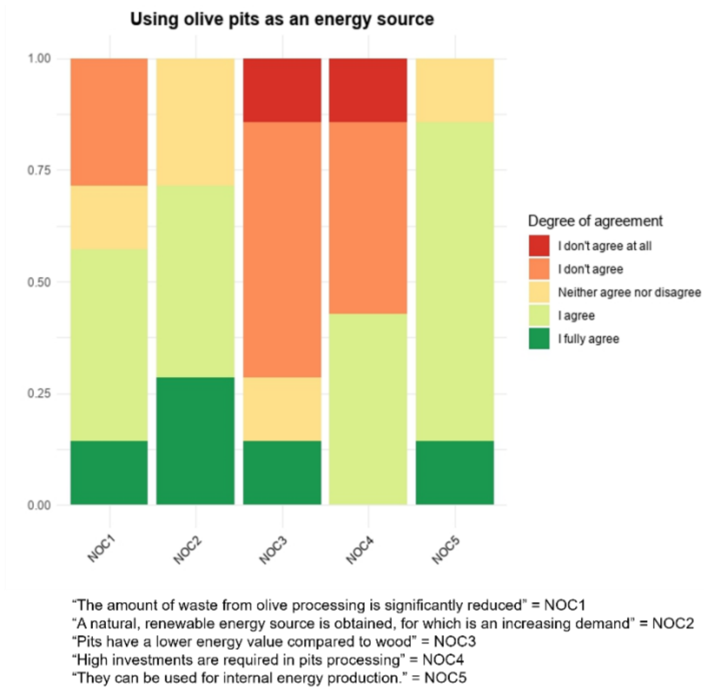
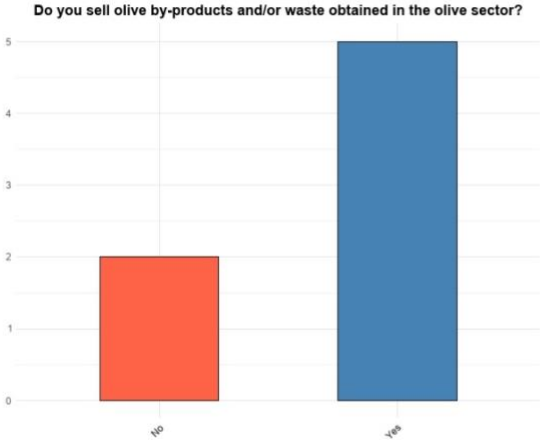


Fig. 19: Stacked bar chart representing reasons for using olive pits as an energy source

Additionally, five respondents reported selling by-products of olive production. Statements related to the positioning and sales of these by-products, such as pomace and olive pits, generally receive positive levels of agreement (Fig. 21: Sale of olive by-products and Fig. 22: Placement and sale of mentioned sold products).



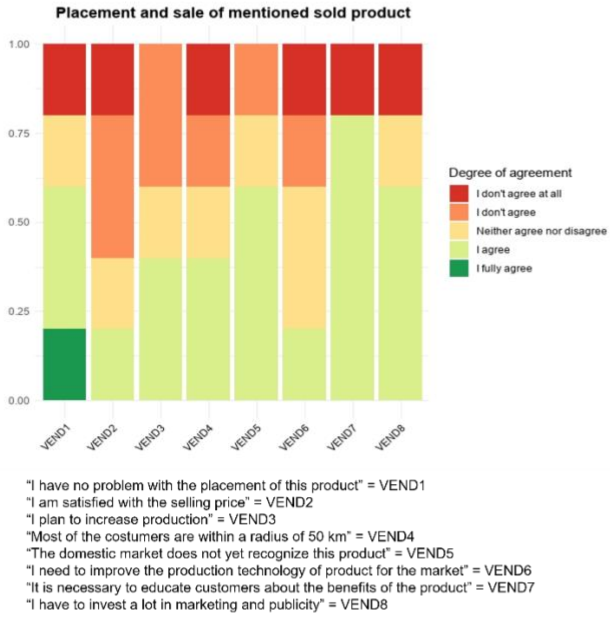


Fig. 21 and 22: Histogram representing if the respondents sale their olive by-products and stacked bar chart representing reasons for placement and sale of mentioned sold products.

Regarding marketing practices, three of the respondents stated that they sell the pomace to oil mills. These are traditional oil mills that have collaborated with olive growers and millers for generations, so there has been no competition over the purchase price of the produced pomace. One respondent reported giving away the pomace for free, but only after removing the olive pits, which are then sold separately. The last respondent mentioned giving away the pomace with olive pits to third-party companies. Those who donate the pomace for free save on management costs that would otherwise be incurred if it remained at the mill. All respondents indicated that pruning residues are reused in the field and are not sold.

10.2. SWOT Analysis

SWOT-analysis using SWOT diagrams or matrices are a key part of any planning activity of an organization. SWOT is an abbreviation of strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal factors, and opportunities and threats are external. SWOT-chart (scheme) allows analysing an innovative project, taking into account every factor on which the development of the organization depends. The information field of SWOT-analysis can be formally represented in the following form:

where S is the set of information related to the field of strengths, W is the set of information relating to the field of the weaknesses, O is the set of information related to the opportunity field. To implement the SWOT-analysis there are different approaches, the most preferable are the "assessment-importance" method and the "portfolio analysis" method (Kudriavtceva, 2019).

Strengths:

1. **High Agreement** on pellet production (PELLET): there is generally strong agreement on the benefits of pellet production. However, the neutral stance on items 4 and 6, related to costs and energy consumption, suggests a mixed perception of its

economic and energy efficiency.

2. **Strong Agreement** on pomace as renewable energy (BIO1): respondents demonstrate almost complete agreement with the statement that "Pomace is a high-quality renewable energy source," indicating strong recognition of its value as a renewable resource.
3. **Agreement** on reducing fresh water consumption (VEG2): there is a notable agreement with VEG2, which asserts that "Reducing fresh water consumption contributes to ecological sustainability and reduces the negative impact of olive processing on the environment," highlighting a clear understanding of environmental benefits.

Weaknesses:

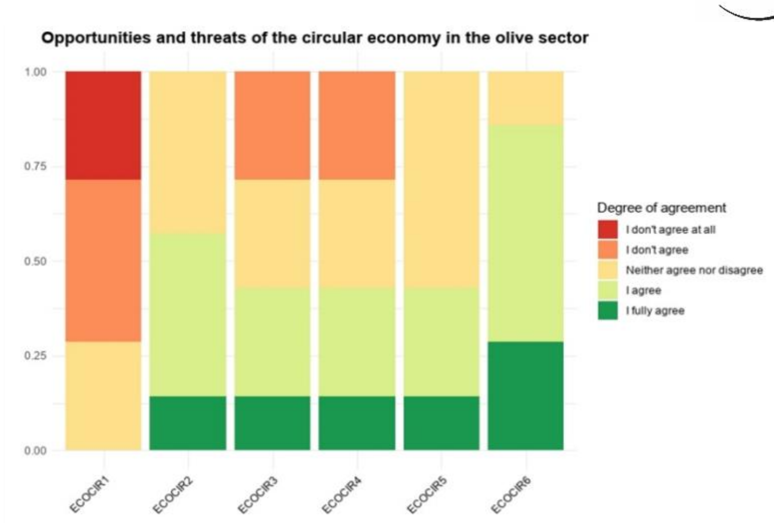
1. **Neutral Response** to composting issues (COMP): items 6 and 7 of the composting indexes (COMP), which address odours from composting and soil health post-composting, receive neutral responses. This indicates concerns or uncertainties about the effectiveness and impact of composting practices.
2. **Disagreement** on recycling and reuse (SANS, VEG, BIO): the overall trend in responses towards the recycling and reuse of pomace and vegetation water leans towards disagreement. This reflects a general lack of support or confidence in current recycling and reuse practices.

Opportunities:

1. **Improvement** in pellet production efficiency: the neutral stance on costs and energy consumption suggests an opportunity to enhance pellet production processes, potentially making them more economically viable and energy-efficient.
2. **Enhanced** composting practices: addressing concerns related to odours and soil health could present an opportunity to improve composting methods, thereby increasing their acceptance and effectiveness in residue management.
3. **Promotion** of circular economy measures: although public subsidies for circular economy measures received complete disagreement (ECOCIR1), other related items show higher levels of agreement. This discrepancy presents an opportunity to advocate for better subsidy structures or alternative incentives to promote circular economy practices.

Threats:

1. **Resistance** to recycling and reuse: the general disagreement regarding the recycling and reuse of pomace and vegetation water highlights a potential threat to the adoption of sustainable practices. Overcoming this resistance will be crucial for advancing these practices in the sector.
2. **Lack of support** for circular economy incentives: the complete disagreement with the statement that public subsidies stimulate circular economy measures (ECOCIR1) poses a threat to the implementation of circular economy initiatives, potentially hindering progress in this area.



"Public subsidies stimulate olive growers to apply circular economy measures" = ECOCIR1
"The processing of olive by-products and waste requires large capital and labour investment" = ECOCIR2
"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" = ECOCIR3
"There is no organized olive by-products and waste processing system in the area" = ECOCIR4
"The legislative framework limits the development of circular economy in olive sector" = ECOCIR5
"It is necessary to raise awareness about the benefits of implementing circular economy in olive sector" = ECOCIR6

Fig. 23: Stacked bar chart representing opportunities and threats of the circular economy in the olive sector

The interviews provided useful data for conducting the SWOT analysis. Regarding the strengths in the management and valorization of by-products, companies highlighted the economic return, both in terms of increased revenue and reduced expenses (e.g., internal energy production), and the moral aspect behind the reuse of by-products. As for the weaknesses, respondents focused on the lack of highly qualified personnel, the absence of dedicated areas for by-product valorization, and the lack of funds to invest in the implementation of circular practices in by-product management. Regarding opportunities, respondents referred to potential external companies interested in purchasing agro-food sector by-products to generate energy or extract bioactive compounds. Finally, the most cited threat is the significant climate instability and severe drought, which are severely challenging Italian agricultural companies.

10.3. Regulatory Challenges and Barriers

Regarding the Italian olive-oil sector, the extreme fragmentation of the production structure, the different farming systems, the vast national olive germplasm and the prominent economic, cultural (from gastronomy to medicine, from art to mythology and history), social and environmental value of olive, make it difficult to generically define a univocal model of sustainability (ISMEA 2020).

1. Challenges in pruning residues management: despite the environmental benefits associated with utilizing pruning residues, most respondents do not implement related procedures. For those who do, sustainability awareness drives practices like mulching. They also cite benefits such as low costs and increased revenue from composting, as well as pellet and firewood production. However, significant regulatory challenges and barriers persist.

Key obstacles to effective mulching include:

- **Lack of technology or knowledge:** there is insufficient technological support and expertise available, which hinders the adoption of effective mulching practices.
- **Significant initial costs:** high upfront costs for implementing residue management

technologies pose a substantial barrier.

- **Legal restrictions:** regulatory constraints affect the implementation of composting practices. For instance, legal requirements surrounding composting processes and waste management can be stringent and complex, limiting practical application.
- **Insufficient support:** there is inadequate regulatory and institutional support for overcoming these barriers, making it difficult for practitioners to navigate compliance and operational requirements.

2. Issues with burning residues: in the context of burning residues (COMB index), respondents generally agree with most statements. However, item COMB4, which argues that burning pruning residues results in the loss of valuable organic material, faces considerable disagreement. This highlights a regulatory challenge: while burning might be a commonly used practice, it does not align with best practices for preserving organic matter, which can be a regulatory concern.

3. Composting regulations: the composting index (COMP) typically garners strong agreement on its benefits, although items 6 and 7 - addressing odours from composting and soil health post-composting - receive a neutral stance from respondents.

This neutrality reflects potential regulatory challenges related to composting, including:

- **Regulatory compliance for odour control:** regulations may mandate specific measures for controlling odours, impacting how composting operations are managed.
- **Soil health standards:** compliance with regulations concerning soil health after composting can be a barrier, as practitioners must ensure that composting practices meet regulatory standards.

4. Pellet production and energy consumption: regarding pellet production (PELLET index), while overall agreement is relatively high, items 4 and 6 concerning costs and energy consumption receive neutral responses.

This neutrality may indicate regulatory barriers related to:

- **Cost regulations:** regulatory requirements regarding the cost-effectiveness of pellet production can impact its feasibility.
- **Energy efficiency standards:** compliance with energy efficiency regulations for pellet production can affect the overall viability and adoption of this technology.

5. Recycling and reuse of by-products: responses regarding the recycling and reuse of pomace and vegetation water (SANS, VEG, BIO indices) generally show disagreement.

This reflects potential regulatory barriers such as:

- **Recycling regulations:** regulatory frameworks for the recycling and reuse of agricultural by-products may be restrictive or unclear, limiting the adoption of these practices.
- **Environmental compliance:** regulations regarding the environmental impact of reusing by-products can be stringent, affecting the practical implementation of these measures.

6. Circular economy measures: the statement ECOCIR1 - "Public subsidies stimulate olive growers to apply circular economy measures" - receives complete disagreement, suggesting a regulatory barrier in the form of inadequate financial incentives. While other related items show higher agreement, this discrepancy highlights the need for more effective regulatory support and incentives to promote circular economy practices in the olive oil sector.

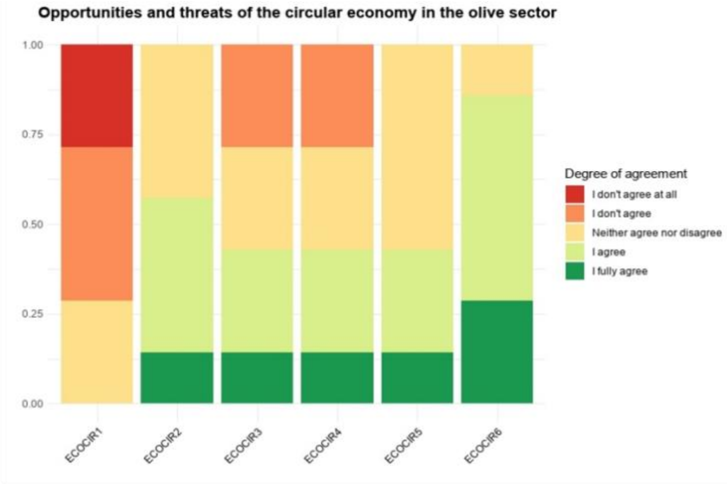


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Fig. 23: Stacked bar chart representing opportunities and threats of the circular economy in the olive sector

The only reference to legislative barriers that limit the valorization of by-products pertains to the management of wastewaters. Specifically, one if the interviewers referred to Legislative Decree No. 152 of April 3, 2006 (known as the "Testo Unico Ambientale") and its directives regarding the storage and use of wastewater (D. Lgs 152/2006).

11. Vocational Training (VET)

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

Focusing on the olive oil sector, the training available in Italy is limited. On the academic side, there is the 'Course in Agronomy and Olive Cultivation' at the University of Bologna, which focuses on specific agronomic practices for olive cultivation. In addition, the University of Florence offers a 'Master in Olive Growing and Olive Oil', which covers technical, management, and marketing aspects of the olive sector.

Outside the academic sphere, there are also a number of Masters and courses in the South of Italy: Treccani Academy's 'Master EVOO Business Management', which focuses on the development of the extra virgin olive oil business between innovation, sustainability, and financing, the EvooSchool's courses for tasters, and finally, the ITS course 'Higher Technician in Agricultural Production and Transformation with specialization in the Olive Oil Sector' in Rome.

Finally, there are two other ITS courses in Puglia and Calabria on management and processing in the olive sector: "Higher Technician in Olive Oil Supply Chain Management" and "Higher Technician in Production and Processing in the Olive Oil Supply Chain".

Only 1 respondent declared to have a bachelor's degree in "Scienze delle Produzioni e del

Marketing Agroalimentare” obtained at the University of Foggia.

From the interviews with VET organizations, it is evident that, despite the extensive range of training available in the agri-food sector in our country, there is a notable gap in courses that integrate the technical skills of the olive oil sector with the principles of the circular economy. In fact, courses specifically focused on the olive oil sector are quite rare.

While there is a growing interest in the circular economy, only a few institutions currently offer specialized courses for the olive oil industry. However, the recognition of the importance of these skills indicates a significant potential for the future development of such courses.

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

The agri-food industry is a key sector for the Italian economy, characterized by a wide range of products, from wine to olive oil, from livestock to cheese and charcuterie. Training in this sector is essential to ensure product quality, environmental sustainability, a circular economy for the reuse of by-products and waste materials, and competitiveness on the global market. In addition to specific university courses in the agri-food sector offered by various universities, it is possible to find a wide range of funded and non-funded courses throughout the territory.

If we take the educational offer of the Emilia Romagna region as an example, in 2022-2023, 17 courses in the agri-food sector were approved, covering topics related to product quality, valorization and promotion of excellence, traceability, and sustainable agriculture.

Of these:

- 5 courses of 300/500 hours, Higher Education
- 8 courses of 800 hours, IFTS courses
- 4 courses of 2000 hours, ITS courses

Only 1 respondent declared to have a bachelor's degree in “Scienze delle Produzioni e del Marketing Agroalimentare” obtained at the University of Foggia.

The interviews revealed that only a portion of the respondents had received any form of training in circular economy. The courses were provided either by their regional authorities or by companies where the respondents had previously worked. Additionally, one respondent indicated that, as a director, he had no training in circular economy, although some of his collaborators did.

Most institutions prefer a combined approach that includes theory, practice, and company visits. This method is considered the most effective in providing comprehensive and practical training.

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

Combining face-to-face classes with online learning provides students with greater flexibility and accessibility. This blended approach is complemented by the integration of agronomic, economic, and technological skills into training programs, which is considered a best practice for preparing participants to tackle the challenges of the circular economy. Furthermore, skills are frequently validated through practical assessments, projects, and company visits, enabling students to demonstrate their abilities in real-world contexts.

Only 1 respondent declared to have a bachelor's degree in “Scienze delle Produzioni e del Marketing Agroalimentare” obtained at the University of Foggia.

None of the interviewees expressed opinions regarding "Practices Identified Regarding the Education Programs on Circular Business Practices in the Olive Sector."

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

Regions and autonomous provinces are responsible for VET programs and most apprenticeship-type programs. The social partners contribute to the definition and development of active employment policies relevant to VET and lifelong learning. They design and implement programs tailored to local needs and economic structures. This fragmented approach could also apply to agri-food industries.

While there are currently limited specific courses available, universities and vocational training institutions are recognized as key potential providers for such programs in the future.

12. Conclusion

12.1. Summary of Key Insights

The Italian olive sector holds significant economic and cultural importance, contributing substantially to global olive oil production and employing hundreds of thousands of people. Primarily concentrated in southern regions such as Puglia, Calabria, and Sicily, olive cultivation represents not only an economic asset but also an ecological and landscape heritage. However, the sector faces critical challenges in terms of sustainability and competitiveness in the international market. Referring to the 2022/2023 olive oil campaign, Italy is the third European producer and the fourth world producer of extra virgin olive oil. The sector is characterized by a fragmented structure, mainly comprising small family-run farms situated in hilly and mountainous areas. This fragmentation poses challenges for competitiveness and technological innovation, while simultaneously ensuring a wide variety of olive oils, with over 800 different cultivars.

Climatic and geographical conditions significantly influence production. The southern regions benefit from favorable climates, but water scarcity and rising temperatures due to climate change are compelling many producers to reconsider traditional cultivation techniques, seeking innovative solutions for managing natural resources.

The olive oil production process has notable environmental impacts, particularly concerning waste management. The sector generates substantial by-products, such as olive pomace, pits, and vegetation water, which can become a source of pollution if not properly managed.

However, with the adoption of circular practices, these by-products can be transformed into valuable resources. Additionally, field residues such as pruning waste are often repurposed as fertilizer, utilized in practices like mulching, or sold/given away to third-party companies. Olive pomace, made up of water, pulp residues, and pit fragments, is the most abundant by-product. Traditionally viewed as waste, many companies now recognize its potential as biomass for energy production or as raw material for the extraction of olive pomace oil. Likewise, olive pits can be utilized as a renewable fuel due to their high calorific value and low ash content, rendering them a valuable resource for energy production.
On the other hand, vegetation water poses a significant challenge because it is highly polluting due to its high content of phenolic compounds. Recent studies indicate that, if treated properly, it can be used for irrigation or for extracting bioactive substances with antioxidant and antimicrobial properties. This presents new opportunities for valorization, enhancing the sustainability of the olive sector. The management of by-products is another crucial aspect of the sector. The adoption of circular practices is becoming increasingly common, with pomace and pits utilized for energy production or other purposes. Some companies are experimenting with using purified vegetation water for agronomic applications, thereby alleviating environmental pollution. Nevertheless, the sector is still in the early stages of transitioning to a circular economy model, with many companies facing challenges related to costs, technologies, and the complexity of regulations.

From a technological standpoint, the sector continues to face significant barriers. Most Italian olive mills are small, processing less than 1,000 tons of olives annually, which limits their capacity to invest in new technologies. Many facilities operate with outdated equipment and lack the resources necessary to adopt advanced technologies, such as two-phase decanters, which reduce the production of vegetation water.
Technological innovation has begun to play a vital role in the olive sector, especially in improving production efficiency and reducing environmental impact. Innovative techniques such as ultrasound or microwave extraction are being adopted in some companies to increase oil yield and improve the sensory and nutritional qualities of the product while reducing processing times. However, these technologies require significant investments that many small businesses cannot afford.

The Italian olive sector, with its millennia-old tradition, strives to balance the preservation of traditional practices with the adoption of new technologies and sustainable business models. The challenge lies in maintaining the quality and diversity of Italian olive oil while reducing the environmental impact of production. To facilitate the transition to more sustainable practices, education and professional training are essential. However, only a few courses specifically address the olive sector, and even fewer integrate principles of the circular economy. While some universities and higher technical institutes are beginning to include sustainability and by-product management in their curricula, the training landscape remains fragmented and not always accessible to all industry operators. It is vital that vocational training programs include not only technical skills in olive cultivation and processing but also knowledge of by-product management and the adoption of circular technologies. By equipping producers and olive mill operators with the necessary tools to adapt to a rapidly changing economic and regulatory environment, the industry can move towards more sustainable practices.

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

The implementation of circular practices in the Italian olive sector is crucial to ensuring long-term sustainability and competitiveness. However, this transition requires significant investments in innovative technologies, regulatory simplifications, and a cultural shift among producers. Many Italian olive mills, especially small and medium-sized ones, lack access to modern technologies, such as equipment for extracting bioactive compounds from leaves and vegetation water, which could transform by-products into valuable resources. Government support, through subsidies and low-interest financing, is essential to encourage the adoption of these technologies, thereby reducing environmental impact and increasing the sector's profitability.

In addition to technological investments, the sector needs a simplification of the regulatory framework. Currently, laws governing by-product management, such as those related to olive pomace and vegetation water, are often complex and vary across regions, creating uncertainty for producers. It is essential to unify the regulations, making them more accessible and flexible, to incentivize the agronomic use of waste and the adoption of more sustainable practices. A clear and coherent regulatory framework would allow companies to fully capitalize on the economic benefits of circularity.

Training plays a crucial role in this transition. Sector operators must be adequately trained on the opportunities offered by circular practices and the available technologies. Vocational education and training (VET) providers should expand their offerings to include specific courses on the circular economy, by-product management, and innovative technologies for olive oil production. Collaboration between universities, research centers, and businesses is essential to ensure that the necessary knowledge and skills are disseminated throughout the sector.

Finally, the creation of economic incentives, such as subsidies and tax breaks, is critical to facilitating the adoption of circular practices. Companies that invest in sustainable technologies or develop circular business models should be rewarded, lowering investment costs and promoting the transition to a more sustainable and competitive economy. Only through an integrated strategy involving all stakeholders in the supply chain can the Italian olive sector successfully address the challenges of the future.

12.3. Policy Implications and Recommendations

The policy implications for promoting the adoption of circular practices in the Italian olive sector are profound and require a coordinated effort from institutions, businesses, and training service providers. A crucial aspect is the need for policies that incentivize technological innovation, particularly for small and medium-sized enterprises (SMEs) in the sector. Institutions must promote the dissemination of technologies that reduce waste and enhance the value of by-products, through targeted funding and tax incentives. Policies supporting access to facilities for extracting bioactive compounds, such as polyphenols, can create new economic opportunities and improve the sector's international competitiveness.

Another key element is the simplification of the regulatory framework. Current regulations for managing agricultural waste, including olive pomace and vegetation water, are often complex and fragmented at the regional level. It is essential that national policies harmonize these regulations, facilitating the adoption of circular practices through clear standards and precise guidelines for sustainable by-product management. This would reduce regulatory uncertainty, which currently discourages investments in green technologies.

Educational policies must also be a priority. To encourage widespread adoption of circular practices, institutions must collaborate with vocational education and training (VET) providers to develop programs that integrate skills in circular economy, technological innovation, and sustainable resource management. Policies that incentivize continuous education in the olive sector, and that support specific courses on these topics, can help bridge skills gaps and spread best practices.

Finally, strengthening the connections between research, the private sector, and public policy is essential. Political institutions must facilitate cooperation between universities, research centers, and olive companies to stimulate innovation and accelerate the transition towards a more sustainable economy. By creating knowledge-sharing platforms and offering economic incentives, public policies can play a crucial role in supporting the transformation of the sector towards greater circularity. Only through a joint commitment can a sustainable future for the olive sector be ensured.

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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.

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.

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.

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.

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.

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

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	

	Yes-No
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	High initial investment and costs							
	Legal restrictions or insufficient support							

implementation	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	1	2	3	4	5

plantation requires a lot of work					
It is not useful because valuable organic material is lost	1	2	3	4	5
It is harmful to the air and the local ecosystem	1	2	3	4	5

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

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

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

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Pellets have a high energy value	1	2	3	4	5
Pellets are an ecological energy source	1	2	3	4	5
Equipment for pellets production is	1	2	3	4	5

expensive					
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 within a radius of 50 km	1	2	3	4	5
The domestic market does not yet recognize this product	1	2	3	4	5

I need to improve the production technology of product for the market	1	2	3	4	5
It is necessary to educate customers about the benefits of the product	1	2	3	4	5
I have to invest a lot in marketing and publicity	1	2	3	4	5

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

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Public subsidies stimulate olive growers to apply circular economy measures	1	2	3	4	5
The processing of olive by-products and waste requires large capital and labor investments	1	2	3	4	5
Olive by-products and waste from the olive sector pose a threat to the environment if they are not processed according to the principles of the circular economy	1	2	3	4	5
There is no organized olive by-products and waste processing system in the area	1	2	3	4	5
The legislative framework limits the development of circular economy in olive sector	1	2	3	4	5
It is necessary to raise awareness about the benefits of implementing circular economy in olive sector	1	2	3	4	5

Questions for both groups: Socio-economic characteristics of respondents

29) Respondent's gender
   a) Male
   b) Female
   c) I don't want to answer

30) Respondent's age ____________ year

31) Enterprise location

    Country ________________

    Region _________________

32) Respondent's education
   a) High school and lower
   b) Bachelor degree
   c) Master degree
   d) PhD

33) Education in the field of agriculture

    Yes - No

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

   Yes - No

35) If YES, enter the following information about education:
   a. Education name ____________________________________
   b. Organization in charge (Vocational Education and Training (VET) provider). _______________________________________
   c. Duration

      ____

   d. Method of implementation

      Online

      In presence

Hybrid mode

e. Obtained title

____

36) Enterprise size:

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

37) Agriculture is for my household

a) The only source of income

b) Predominant source of income (> 50%)

a) Additional source of income (< 50%)

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

Yes - No

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

a) Online

b) In presence

c) Hybrid mode

40) Dear responded,

Thank you for your time and contribution to Circolive project

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

Yes – No

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

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

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

Date:

Location:

Enterprise name:

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

Enterprise size:

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

Type of enterprise (possible multiple choice):

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

Interviewees' business role:

1. Executive
2. Manager
3. Operations and production

Interviewees' years:

Interviewees' educational level:

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

2. Describe the olive processing technology
- Describe the olive by-products and waste processing technology also if you know future technology trends if you know

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

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

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

5. Did you have any barriers or gaps when starting the olive by-products/waste business?
- Social (lack of environmental – social awareness, culture -tradition, deficiencies in collaborative economy networks)
- Economic (high initial investment, higher costs, lower profitability)
- Political-legal-institutional (regulatory limitations, lack of institutional supports and insecurity regarding incentives and aid)
- Innovation and technology (obsolescence, little development – access to technologies, lack of technical knowledge)

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

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

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

Strengths (Strengths describe what an organization excels at and what separates it from the competition)

Weaknesses (Weaknesses stop an organization from performing at its optimum level)

Opportunities (Opportunities refer to favorable external factors that could give an organization a competitive advantage)

Threats (Threats refer to factors that have the potential to harm an organization)

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

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

If yes, who is the provider of this education, duration of education, way of conducting the education (In presence, online, hybrid mode)

If no, do you plan participating in an educational program on the circular economy in the olive sector?

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

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

14.2.3. ANNEX 3: Structured interview with VET providers

ANNEX 3: Structured interview with VET providers

Date:

Location:

VET name:

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

Type of VET:

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

Interviewees' role:

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

Interviewees' years:

Interviewees' educational level:

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

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

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

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

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

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

6. What are the identified best practices in your country regarding the education programs in the context of circular business practices?

- offered trainings, training methods, recognition paths/qualification validation methods

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

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

9. If yes, which ones?

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

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