



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

- CROATIA -

September 2024



Project management



Identification of olive sector



Holistic circular business



VET curricula



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## National Report on current situation in the olive oil sector - Croatia

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## 1. Executive Summary

Olive oil production is an important agricultural activity in Croatia, especially in the coastal regions of Istria and Dalmatia. By-products and waste from the olive oil production sector in Croatia represent significant environmental challenges, but also offer opportunities for innovation and sustainability. By adopting integrated waste management strategies and investing in research and development, Croatia can improve the sustainability of its olive oil sector and contribute to the circular economy.

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

The report is part of Work Package 2 (Identification of olive sector circular needs and emerging skills and/or professions for transition of the olive oil sector to a circular economy in the 5 countries) of the CIRCOLIVE project (Developing skills for introducing circular business models and digital technologies in the olive oil sector) and represents deliverable D2.1. (National Report on the current situation in the olive oil sector - Croatia).

### 1.1. Background and Purpose

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

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

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

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

### 1.2. Key Findings

This report presents the research results of primary and secondary sources of data on the state of the circular economy in the olive sector and olive oil production in Croatia. Primary sources included field data collection on a planned sample of respondents through a survey and interviews with relevant stakeholders in the olive sector, olive oil production and education providers in Croatia. Secondary data included the analysis of available literature



related to this topic. Data was collected on the numerical indicators of olive production, the technologies used in the olive grove, the handling of residues after pruning in the olive grove, the methods and capacity of processing olives into olive oil, the quantities and handling of by-products/waste after olive processing, and the prevalent circular economy practices in the olive growing sector and oil industry in Croatia as well as potential Croatian institutions that could provide vocational education and training in the area of the circular economy. The obtained research results provide an insight into the current state of the circular economy in Croatia, and provide an overview of the opportunities, strengths, weaknesses and threats of the implementation of the circular economy in the olive sector and olive oil production.

### 1.3. Recommendations

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

## 2. Introduction

### 2.1. Overview of the Olive Sector

In Croatia, the olive is grown exclusively in the Adriatic Croatia region, where it represents the dominant agricultural culture. Traditionally, it is grown primarily for the production of virgin olive oil, while the production of table olives is mostly limited to production for personal needs. In addition to the production function, the olive plays an important role in shaping rural landscapes and maintaining ecological balance in agriculture. In the last twenty years, the areas under olive groves have gradually increased and in 2022 they amounted to 19,900 ha. With the increase of olive grove areas, the production of olive fruits also increased, and consequently the production of olive oil, which in 2022 reached the amount of 5,100 tons of oil, which is almost twice as much as was produced in 2000.

As the olive growing sector in Croatia grows, so does the amount of by-products and olive waste, which presents challenges, but also opportunities for sustainable practices. The main by-products in the olive growing and olive oil production sector are olive pomace, waste water from the oil mill, olive pits and olive leaves and branches. Management of these by-products

in Croatia is gradually developing, driven by environmental regulations and increasing awareness of sustainable practices.

## 2.2. Objectives of the Report

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

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

## 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 10 respondents, but data was collected from 18 respondents, namely 10 respondents for the olive grower's category, 7 respondents for the olive grower's and olive mills owners' category and 1 respondent for the olive mill owner category (Table 1). The questionnaires were collected online via Google forms.

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

with circular business agro-food experts/professionals). The other one for providers of education in Croatia (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 2 respondents for experts in the agri-food sector and 2 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.

Table 1. Description of the sample of respondents who participated in the online survey (N=18)

Variable	N	Percentage (%)
<b>Gender</b>		
Male	14	77.8
Female	4	22.2
<b>Age</b>		
Up to 36	6	33.3
37 - 56	4	22.2
57 and more	8	44.5
<b>Education</b>		
High school and lower	4	22.2
Bachelor degree	5	27.8
Master degree	7	38.9
PhD	2	11.1
<b>Enterprise size</b>		
Micro (< 10 employees)	12	66.7
Small (< 50 employees)	5	27.8
Medium sized (< 250 employees)	1	5.6
<b>Agriculture is in the household</b>		
The only source of income	7	38.9
Predominant source of income (>50%)	2	11.1
Additional source of income (<50%)	9	50

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 for used sources 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

Republic of Croatia is a south-eastern European country, and with its 1,777 km of Adriatic Sea coastline, it also qualifies as a Mediterranean country. The Mediterranean climate, characterized by hot summers and mild winters, supports olive cultivation along the Croatian Adriatic coast. While, the Velebit mountain range acts as a barrier, preventing this climate from extending far into Croatia's inland regions. As a result, olive groves are found only in this coastal region of Croatia, limiting the range of olive and olive oil production. Croatia is administratively divided into 21 counties. Olive cultivation is possible in seven of these counties (from the southern to the northern part of the coast): Dubrovnik-Neretva (2,700 ha), Split-Dalmatia (5,250 ha), Šibenik-Knin (2,860 ha), Zadar (3,760 ha), Lika-Senj (170 ha), Primorje-Gorski Kotar (910 ha), and Istria (4,250 ha) (CBS, 2020).

The characteristics of the olive groves vary between the southern and northern regions of the olive cultivation area. In the southern part, including Dalmatia and the islands, olive cultivation is mostly extensive or semi-intensive due to the stony soils (Sladonja et al., 2012). In contrast, the northern part (Istria) features semi-intensive or intensive olive cultivation on deep or semi-deep "Terra Rossa" soil (Oplanić, M., 2011).

In Croatia, olives are traditionally grown primarily for the production of virgin olive oil, while the production of table olives is mostly limited to a small number of plants and production for personal needs (Gugić et al., 2010). There are a large number of olive varieties in Croatia, among which 'Oblica' is the most widely cultivated olive variety, particularly in the southern regions of the Croatian Adriatic coast, including Dubrovnik-Neretva, Split-Dalmatia, Šibenik-Knin, Zadar, and Lika-Senj counties, while the autochthonous variety 'Buža' is the most widespread variety in Istria County (PAAFRD, 2023). Certain olive cultivars, such as 'Oblica' and 'Buža,' can be used for both purposes.

### 4.2. Historical Development of Olive Cultivation

Olive cultivation in Croatia has a history spanning centuries. Based on olive stones discovered near Vranjic (close to Split) and subsequent analysis, archaeologists believe that olives have been present since the 9<sup>th</sup> century BC (Zadro and Perica, 2007). The spread of olive cultivation along the eastern Adriatic coast can be attributed to the Ancient Greeks and Romans.

The thousand-year-old olive trees on the Brijuni Islands, in Kaštel Štafilić and in Lun (island of Pag) (Miljković, 2011) stand as living witnesses of the olive cultivation from ancient times, while archaeological finds such as olive mills, amphoras, and *villae rusticae* further attest to the long-standing tradition of olive growing (Sladonja et al., 2012). Throughout the history, olive growing in Croatia has experienced periods of both decline and growth, but it continues to this day.



The area of olive cultivation and the enhancement of olive production saw notable growth in the early 1980s because of the UNDP/FAO programme (Gugić et al., 2010). Today, the advancement of olive production continues to be encouraged through local and regional initiatives, as well as through funding from European Union sources.

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

The Ministry of Agriculture has provided guidelines for managing pomace and vegetative water intended for producers in the olive oil and table olive sector (Ministry of Agriculture, 2024). These guidelines reference various laws and regulations; however, some, like the *Law on Sustainable Waste Management* (NN, no. 98/2019) and *Law on Fertilizers and Soil Improvers* (NN, no. 32/2019), are outdated. It is necessary to update mentioned guidelines in order to align them with current laws, particularly the *Law on waste management* (NN, no. 84/2021) and the *Law on Fertilizer Products* (NN, no. 39/2023).

Certain laws, like the *Law on Waste Management* (NN, no. 84/2021), do not specifically address procedures for olive by-products but provide guidelines for handling bio-waste and by-products. Article 15 of this law defines by-products and outlines the process for including them in the *Register of By-Products* (<https://ogo.mzoe.hr/Ocevidnici/PopisPDF/7>).

Waste water, as a byproduct of olive oil production, must be used exclusively in accordance with the principles of good agricultural practice and adequately disposed of in accordance with the *Water Law* (NN, no. 47/2023). A water permit is required for each discharge of wastewater in Croatia, except when the entire amount of these waters is used exclusively on agricultural lands for the purpose of nourishing plants or maintaining and/or improving the physical and/or chemical properties of the soil (Ministry of Agriculture, 2024).

*The Low-Carbon Development Strategy of the Republic of Croatia until 2030 with a view to 2050* (NN, no. 63/2021) suggests potential agricultural measures such as collecting pruning residues for use as energy.

## 5. Olive Production Analysis and Olive Oil Processing

### 5.1. Cultivation Practices and Varieties

Data on the methods of olive production were collected during the primary research conducted in Croatia as part of the CIRCOLIVE project on a sample of olive growers (N=10) and olive growers and oil mill owners (N=7). The assortment is presented on the basis of data submitted by the Agency for Payments in Agriculture, Fisheries and Rural Development (PAAFRD), (PAAFRD, 2024) and processed according to the most represented varieties. Synonymy (different names for the same genotype) and homonymy (the same name for different genotypes) represent the problem of specifying the names of the cultivars that are present in the document, therefore, for example, 'Istarska bjelica', 'Istarska belica', 'Bianchera' are mentioned, which can represent the same genotype. The most represented domestic variety in Croatia is 'Oblica', which is represented by 1,957,230 trees (53.51%), while the most represented of the introduced varieties is the Italian 'Leccino' with 536,553 trees (14.67%). Among the domestic varieties, one of the most represented are 'Istarska belica' (4.83%), 'Buža' (4.33%), 'Lastovka' (3.46%) and 'Levantinka' (1.88%).

Of the 10 surveyed olive growers, the majority grow olives according to the principles of conventional agriculture, and in the sample of olive growers and oil mill owners (N=7) an equal proportion (42.9%) use the conventional and ecological cultivation method (with an eco-label) in the olive grove (Figure 1).

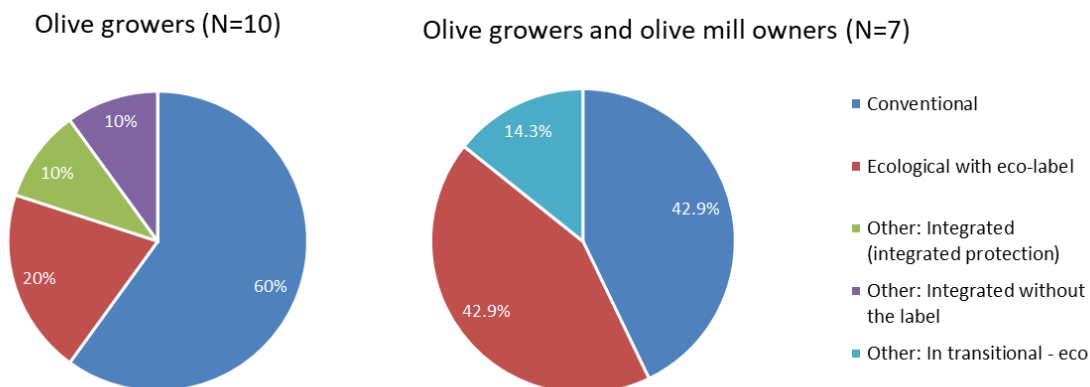


Figure 1. Technology used in the olive grove

When choosing answers for technological interventions related to the circular economy, olive growers and olive growers and owners of oil mills could choose several answers and a combination of interventions was possible (eg mulching and inert plant cover from cut grass). Of the 18 offered technological interventions related to the circular economy, 6 of them are not applied by a single olive grower. The majority of olive growers (80%) use organic fertilizers when fertilizing their olive groves, and the majority (60%) mulch the residues from pruning olive trees, thereby contributing to the circular economy. In the meantime, 40% of respondents grass-covers their olive groves, and only one surveyed olive grower maintains the vegetation cover in the olive grove by livestock nutrition. 60% of the surveyed olive groves carry out precise application of pesticides, and 50% of olive groves use integrated protection against weeds, diseases and pests. Rainwater is collected and used for irrigation by 2 respondents, and 3 respondents implement controlled irrigation and manage water rationally and sustainably in this way. Two olive growers use recycled containers and packaging in their production. Not a single olive grower uses waste or purified water for irrigation, precision irrigation, photovoltaic panels, hybrid motors and biofuels (Figure 2).

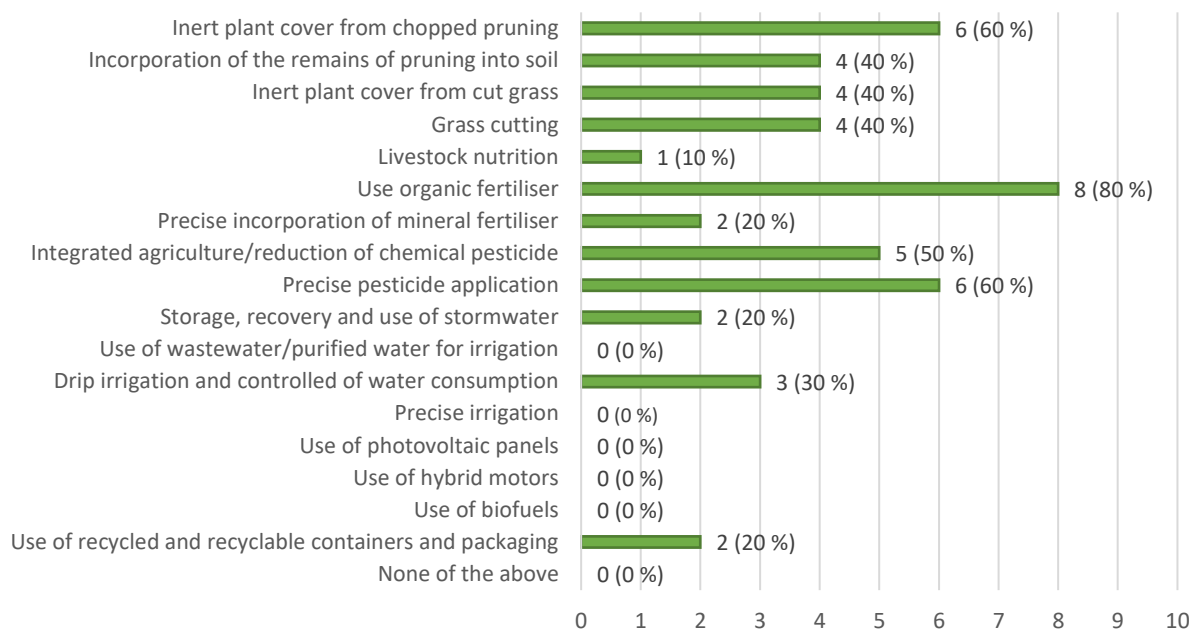


Figure 2. Technological interventions related to the circular economy applied by olive growers in the olive grove (N=10)

Four olive growers and oil mill owners mulch the residues after pruning in their olive groves, and three interviewees mulch the plowing residues. Inert plant cover from cut grass is applied by four (57.1%) respondents, and five (71.4%) maintain the grass cover by mowing. The largest number of respondents apply organic fertilization in their olive groves (85.7%), and one applies mineral fertilizers by precise introduction. Methods of integrated protection against weeds, diseases and pests are applied by two respondents, and three respondents use precise application techniques during application. One respondent applies controlled irrigation with a drip system, and collects rainwater and waste/purified water and uses it for irrigation. One olive grower and oil mill owner uses photovoltaic panels, and one uses biofuel as an energy source (Figure 3).

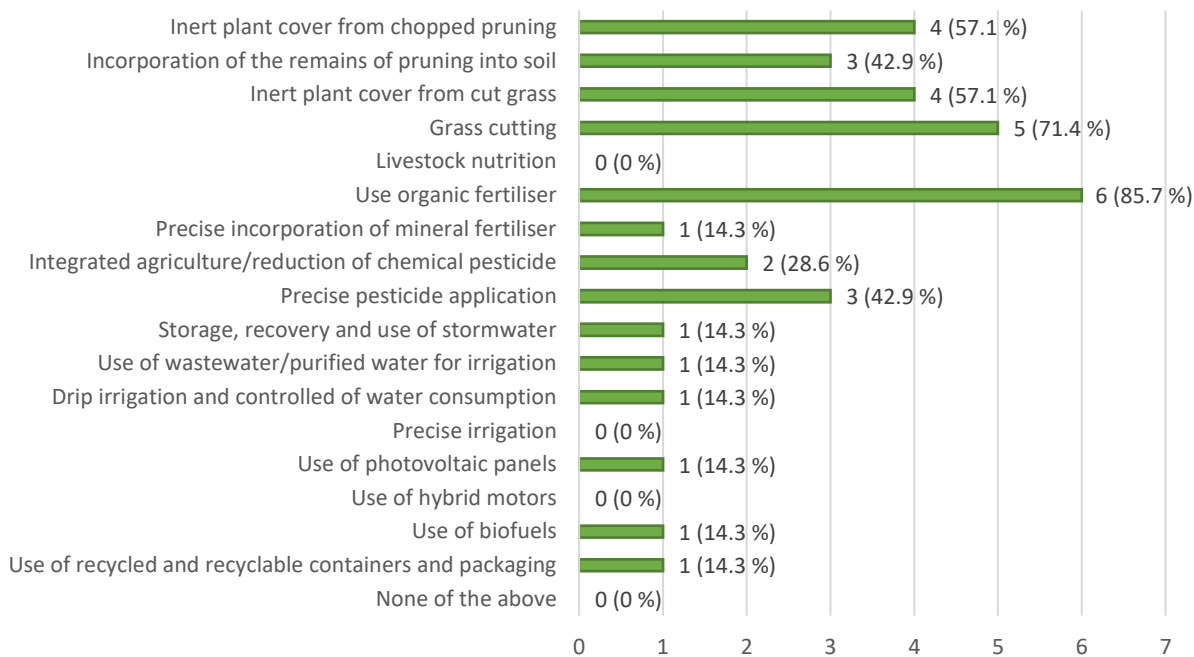


Figure 3. Technological interventions related to the circular economy applied in olive groves by olive growers and oil mill owners (N=7)

When managing the soil, most olive growers (60%) carry out a combination of soil cultivation and mulching, 30% only soil cultivation, and 10% shallow cultivation and mowing (Figure 4). The majority of olive growers and oil mill owners (57.1%) manage the soil in their olive grove by soil cultivation and mulching (Figure 4).

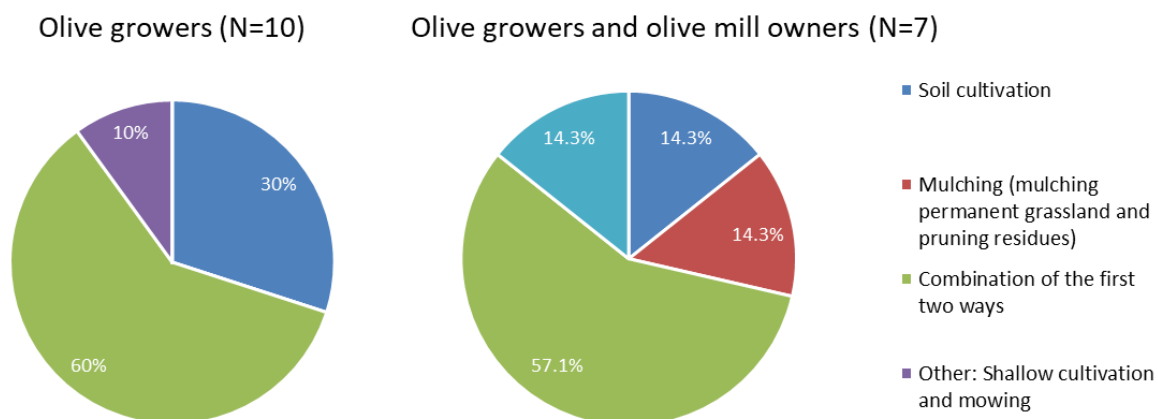


Figure 4. The method of soil management in an olive grove

During the regular pruning of olives, a by-product is created in the form of leaves and branches, and its quantities depend on the age and lushness of the olive trees, as well as on the number of prunings carried out annually in the olive grove. According to the results of research within the CIRCOLIVE project, most olive growers (90%) and olive growers and oil growers (100%) carry out winter pruning every year (Figure 5), while summer pruning is carried out by 60% of olive growers, i.e. 71.4% of respondents from the category of olive

growers and the olive mill owners (Figure 6). Only one surveyed olive grower prunes olives in winter every few years (Figure 5).

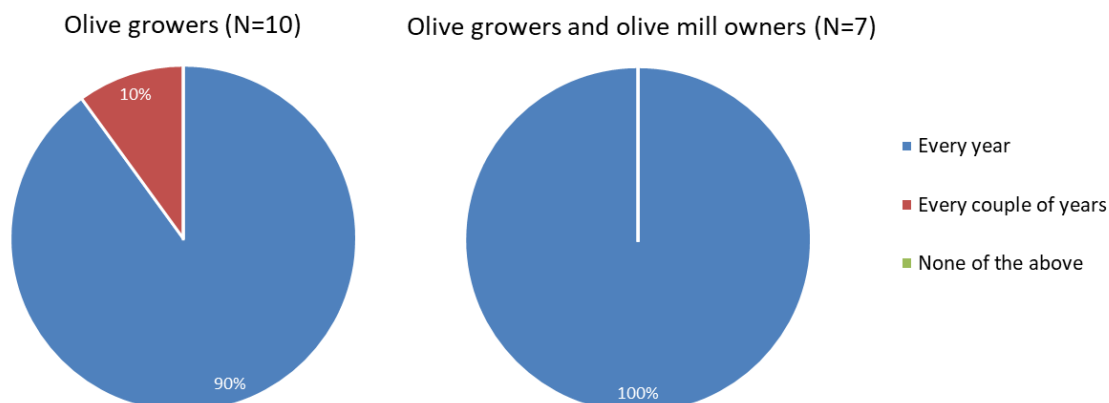


Figure 5. Frequency of winter pruning

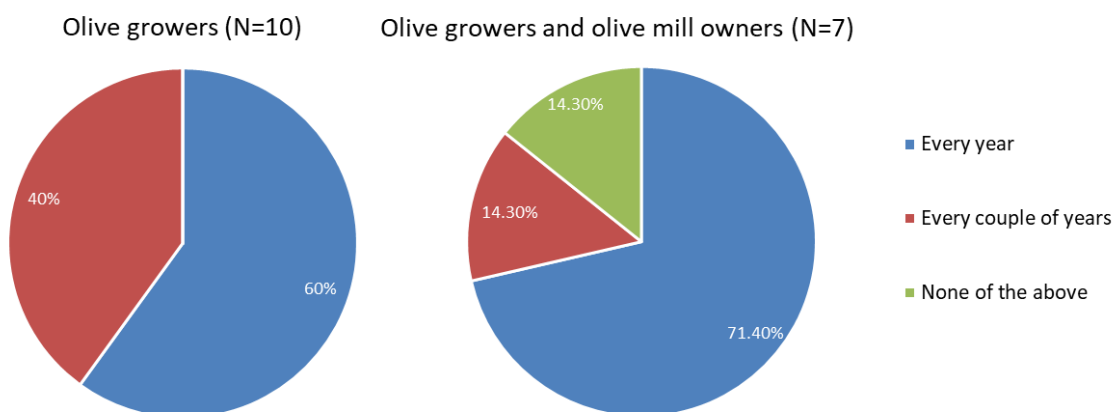


Figure 6. Frequency of summer pruning

When choosing an answer about the handling of pruning residues, olive growers could choose several answers, and their combination is possible (eg firewood and production of useful and decorative items) (Figure 7).

The largest number of olive growers mulch the residues from pruning (50%) or use them as firewood (50%). A small part of the olive growers burns the residues from pruning in a controlled manner, composts them, uses them to feed livestock and to make useful and decorative objects. Not a single olive grower uses pruning residues for the production of firewood pellets and for the needs of the pharmaceutical and food industries (Figure 7).

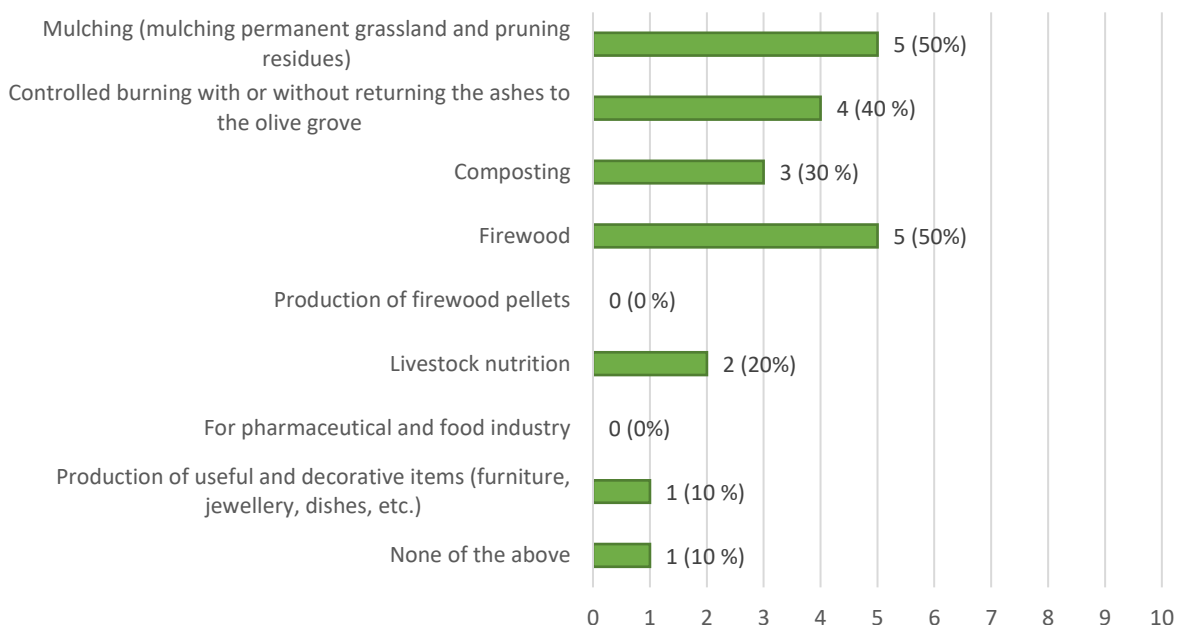


Figure 7. Method of dealing with olive pruning residues (Olive growers, N=10)

On the other hand, with respondents from the category of olive growers and olive mill owners, the situation with the use of residues from olive pruning is somewhat different. All olive growers and olive mill owners mulch the residues from pruning olive trees, and three respondents use them to produce pellets for firewood. A smaller proportion of respondents use pruning residues as firewood and for making useful and decorative items. Only one olive grower and olive mill owner composts pruning residues, one burns them in a controlled manner, while no one uses them for livestock nutrition and for the needs of the pharmaceutical and food industry (Figure 8).

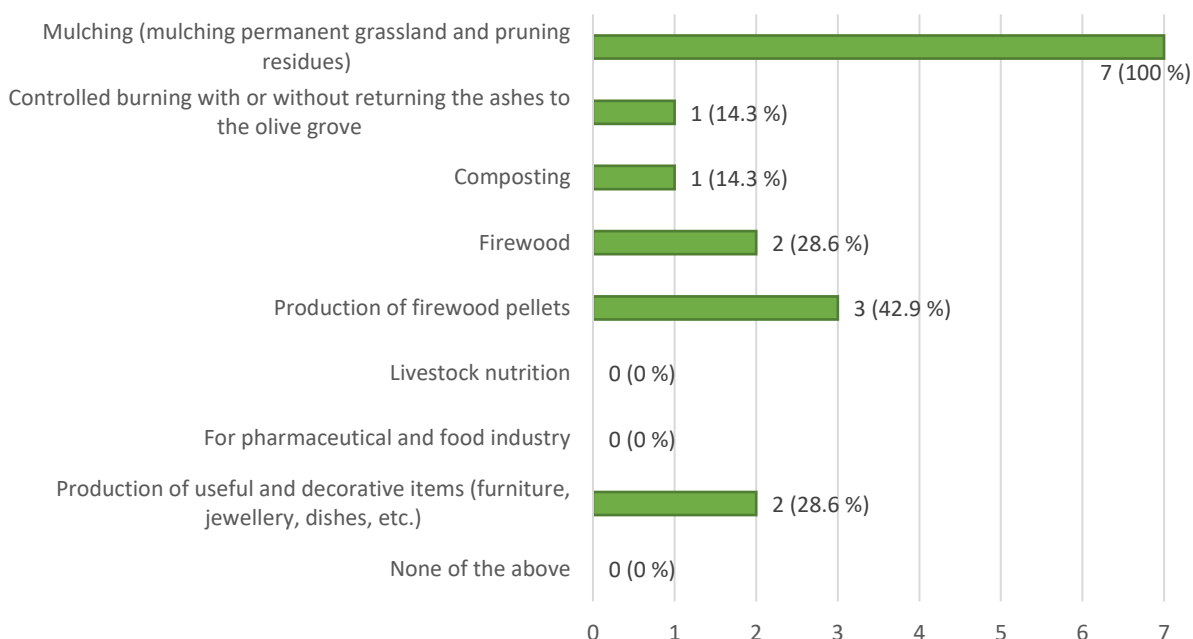


Figure 8. Method of dealing with olive pruning residues (Olive growers and olive mill owners, N=7)

## 5.2. Olive Oil Extraction Methods

A good distribution of oil mills and adequate processing capacity considering the total mass of produced olives is a prerequisite for timely and fast processing, i.e. production of high quality virgin olive oil (Koprivnjak and Červar, 2010). According to a source from 2010 (Gugić et al., 2010), there were 129 oil mills in Croatia, of which 62% had installed a continuous processing method using the centrifugal extraction process, while in the remaining oil mills the method of processing was pressing (Table 2). In the research of Koprivnjak and Červar (2010), it was determined for the period from 2007 to 2009 that there were 25 oil mills in the County of Istria with a total processing capacity of 24.4 t/hour, which is slightly more than the number and capacity for the County of Istria mentioned in the research of Gugić et al. (2010) for approximately the same period. A third source states the existence of 186 oil mills with a total daily (10 hours) processing capacity of 10 tons (Gašparec-Skočić and Milat, 2011). The official website of the Ministry of Agriculture states that there were about 160 oil mills in the Republic of Croatia in 2017, with an average processing capacity of about 1,300 kg/hour (Ministry of Agriculture, 2024). The magazine for olive growing and oil production 'Maslina' maintains a list of oil growers from season to season, and for the year 2023 a total of 182 active plants for olive processing in Croatia are listed (Maslina, 2023), and the distribution by administrative areas is shown in Table 2.

Table 2. Number and capacity of oil mills in Croatia

County	2010*					2023**	
	Number of olive mills	Total capacity per county (t/h)	Systems with pressing	Systems with centrifugation	Relative share of olive mills out of the total in Croatia (%)	Number of olive mills	Relative share of olive mills out of the total in Croatia (%)
Istria	20	17.0	0	20	15.5	31	17.0
Primorje-Gorski Kotar	9	6.0	2	7	7.0	14	7.7
Lika-Senj	1	0.3	0	1	0.8	0	0.0
Zadar	21	31.0	14	7	16.3	41	22.5
Šibenik-Knin	15	12.5	5	10	11.6	20	11.0
Split-Dalmatia	39	28.0	17	22	30.2	47	25.8
Dubrovnik-Neretva	24	18.0	11	13	18.6	29	15.9
<b>Total</b>	<b>129</b>	<b>113.8</b>	<b>49</b>	<b>80</b>	<b>100.0</b>	<b>182</b>	<b>100.0</b>

Sources: \* Gugić et al., 2010, \*\* Maslina, 2023

It can be concluded that there is a minor discrepancy between the literature data on the number of oil mills and the capacity of oil mills in Croatia, most likely due to different data collection methods. For the purposes of calculating the balance of olive processing and estimating the amount of olive processing residues produced, it will be assumed that the information from a professional magazine about the number of oil growers is the most current

due to the mutual interest of oil growers to advertise and olive growers to look for olive mills in that magazine, and that it is therefore the closest to the real values on the field. Therefore, for the number of oil growers in Croatia, the rest of the document will use the information about 182 plants for processing olives into oil.

As part of the CIRCOLIVE project, a survey collected information from a total of 8 olive mill owners, most of whom are also olive growers (7/8). Among the respondents, oil mills with a processing capacity of 500 - 2000 kg/hour (50%) were the most represented, followed by oil mills with a capacity of more than 2000 kg/hour (37.5%). These data correspond to data on the average processing capacity of oil mills in the period 2007-2009. in the Croatian region of Istria, then represented in the olive and oil industry of Croatia with an average of slightly more than 15%, which ranged between 50 - 3,500 kg/hour, with an average of 974 kg/hour (Koprivnjak and Červar, 2010). Among them, oil mills of small and medium capacity were numerically more represented, although together they represented a smaller share in the total processing capacity (Koprivnjak and Červar, 2010).

With regard to the progressive increase in production from 2007 to the present, it is assumed that the average processing capacity has also become larger, and for the purposes of calculating the balance of olive processing and estimating the amount of olive processing residues produced in Chapter 6, it will be assumed that today's average processing capacity of oil mill is closest to the data from the literature of an average of 974 kg/hour or 1 t/hour, for the sake of additional simplification of the calculation.

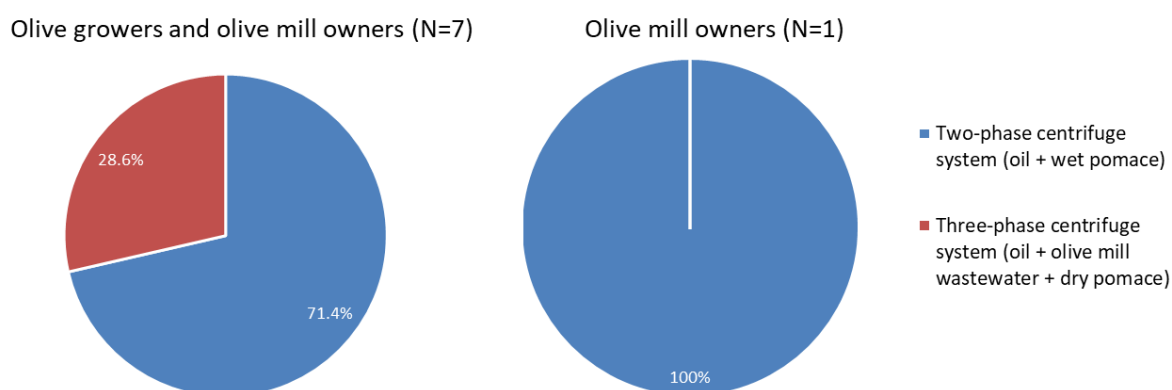


Figure 9. Division of oil mills with regard to the type of system for centrifugal separation of oil, pomace and water

It is known that the extraction of oil from ground olive fruits after mixing in Croatia is almost exclusively carried out using centrifugal systems, while the traditional pressing process is used sporadically, and considering the much lower processing capacity, the share of traditional presses in olive processing is negligibly small (Koprivnjak and Červar, 2010). Regarding the type of centrifugal separation, it can be with three outputs (oil, liquid phase and dry pulp) or with two outputs (oil and wet pulp). In the research of Koprivnjak and Červar (2010), in oil mills in Istria in the period 2007-2009. two-phase systems were predominantly represented (58.1 %), and it was observed that the share of two-phase systems in the total processing of fruits was higher every year, which agrees with the results of the survey on the CIRCOLIVE project. In the oil mills surveyed, 75% were oil mills with two exits, or the so-called two-phase centrifugal separation systems (Figure 9).

Therefore, for the purposes of calculating the balance of olive processing and estimating the amount of olive processing residues produced in Chapter 6, it will be assumed that today in Croatia, oil extraction by pressing technology is negligibly small, i.e. that two-phase systems are represented with a share of 75%, while the rest are three-phase systems for separating oil from residues.

### 5.3. Cultivation area, Yield Trends and Production Statistics

In Croatia, the olive is grown exclusively in the Adriatic Croatia region, where it represents the dominant agricultural culture. It is significant because its cultivation generates a higher added value per unit of investment than in the production of annual crops, and the resulting product is used in its entirety and directly for human consumption. In addition to the production function, its role in shaping rural landscapes and maintaining the ecological balance in agriculture is important, and as a culture that requires a significant engagement of human labor, complementary to tourist activity. In the last 20 years or so, olive growing in the area of Adriatic Croatia has experienced significant growth. During this period, the area under olive groves increased from 11,398 ha in 2000 to 19,900 ha in 2022, which represents an increase of 75% (Table 3).

Table 3. Areas of olive groves; harvest and fruit yield; number of trees; production of olive oil and table olives and the average yield of oil in Croatia in the period 2010-2022

	Year							
	2000 <sup>1</sup>	2009 <sup>1</sup>	2010	2018	2019	2020	2021	2022
<b>Area harvested (ha)<sup>2</sup></b>	11,398	15,304	17,096	18,700	18,610	20,280	19,940	19,900
<b>Fruit production (t)<sup>2</sup></b>	16,215	32,592	38,001	28,420	33,220	33,230	23,870	40,130
<b>Fruit yield (t/ha)<sup>2</sup></b>	1.4	2.13	2.22	1.52	1.79	1.64	1.20	2.02
<b>Number of olive trees<sup>3</sup></b>	n.d.*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3,657,548
<b>Production of olive oil (t)<sup>4,5</sup></b>	2,579	4,917	5,000 <sup>4</sup>	3,400 <sup>5</sup>	4,100 <sup>5</sup>	3,700 <sup>5</sup>	2,900 <sup>5</sup>	5,100 <sup>5</sup>
<b>Production of table olives (t)<sup>6,7</sup></b>	n.d.	n.d.	1,500 <sup>6</sup>	600 <sup>7</sup>	600 <sup>7</sup>	600 <sup>7</sup>	500 <sup>7</sup>	600 <sup>7</sup>
<b>Average oil efficiency (%)</b>	15.9	15.1	13.2	12.0	12.3	11.1	12.1	12.7

Sources: Gugić (2010)<sup>1</sup>; FAOStat (2023)<sup>2</sup>; PAAFRD (2023)<sup>3</sup>; IOC (2023)

<https://www.internationaloliveoil.org/wp-content/uploads/2023/12/HO-W901-13-12-2023-P.pdf><sup>4</sup>

IOC (2023) <https://www.internationaloliveoil.org/wp-content/uploads/2023/12/HO-CE901-13-12-2023-P.pdf><sup>5</sup>

IOC (2023) <https://www.internationaloliveoil.org/wp-content/uploads/2023/12/OT-W901-13-12-2023-P.pdf><sup>6</sup>

IOC (2023) <https://www.internationaloliveoil.org/wp-content/uploads/2023/12/OT-CE-901-13-12-2023-P.pdf><sup>7</sup>

\* n.d. - no data



Based on the conducted primary research on a sample of olive growers (N=10) in Croatia, it was established that they cultivate an average of 10.6 ha of olive groves. The analysis of the size structure of the plantations shows that 50% of the surveyed olive growers cultivate an area of 5 or less hectares of olive groves, while more than 10 ha of olive groves are cultivated by 20% of olive growers. In a sample of 7 olive growers, who in addition to plantations also own an oil mill, it was determined that they cultivate significantly larger areas of olive groves than the respondents who are only olive growers - an average of 21.7 ha. Among this group, only 14% cultivate 5 or less hectares of olive groves, while 43% of respondents produce on an area of more than 10 hectares.

The increase in the area under olive groves had an effect on the higher production of olive fruits as well as on the increase in the production of olive oil. The production of olive fruits in 2022 amounted to 40,130 tons, which, compared to the year 2000, is an increase of about 147%. It can be seen that the increase in the area under olive trees does not result in a proportional increase in the olive production. Thus, the yield of olives fluctuates from 1.20 tons/ha, which was recorded in 2021, to 2.13 t/ha in 2009. Such deviations in the yield of olive fruits are, to the greatest extent, a consequence of the action of natural conditions in a particular production year.

The highest production of olive oil was achieved in 2022, when 5,100 t of oil was produced, which is almost twice as much as was produced in 2000. The average olive oil production yield in the period from 2000 to 2022 ranged from 11.1% to 15.9% (Table 3).

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

Olive cultivation is an important agricultural activity in Croatia, especially in the coastal regions of Istria and Dalmatia. As the production grows, so does the generation of by-products and waste materials, presenting both challenges and opportunities for sustainable practices. The main by-products of olive oil production are olive pomace, waste water (vegetable water) from the oil mill, pits (if separated from the pomace), and olive leaves and branches (Delgado et al., 2022). The management of these by-products in Croatia is developing, driven by environmental regulations and increasing awareness of sustainable practices. For example, the use of olive pomace for energy production through combustion or biogas production is increasingly widespread in the world (Christoforou and Fokaides, 2016). In addition, advances in wastewater treatment technologies, such as anaerobic digestion and membrane filtration, offer potential solutions to reduce its environmental impact while harnessing valuable substances such as polyphenols and irrigation water (Mehta et al., 2021). Despite these advances, challenges remain. The small and fragmented nature of olive oil production in Croatia makes it difficult to implement centralized solutions for waste management (Alfano et al., 2009). Furthermore, the economic viability of converting by-products into commercially viable products depends on the development of appropriate technologies and market demand (De Corato et al., 2018). In conclusion, by-products and waste materials from the olive oil production sector in Croatia represent significant environmental challenges, but also offer opportunities for innovation and sustainability (Klisović et al., 2021). By adopting integrated waste management strategies and investing in research and development, Croatia can improve the sustainability of its olive oil industry and contribute to the circular economy.

When talking about the production of residues from olive production in Croatia, several factors that influence it should be taken into account. The first is the significant growth of the olive sector in the last 20 years or so, in which the area under olive trees has almost doubled (Table 3), and the number of built and modernly equipped oil mills has also increased many times (Table 2). In parallel with the increase in the volume of olive production, continuous investments in the education of olive growers and the modernization of production technology, which resulted in the fact that today oils from Croatia win the most prestigious awards at world olive oil competitions. However, olive production in Croatia is also characterized by large annual fluctuations in fruit yields and olive oil produced, which is also evident from Table 3. It can therefore be concluded that, as a result of the development of this sector, there is an increasingly pronounced need for efficient management of increasing amounts of olive production residues, primarily residues from pruning and processing of olive fruits.

### 6.1. Olive Leaves and Branches

Olive leaves and branches, as a residue of olive production, are created during the regular pruning of olive trees, and the rest of olive leaves are also accumulated during the extraction of leaves from olive fruits before processing olives into oil (Novoselić et al., 2021). Olive leaves, due to their rich content of phenolic substances, become an interesting raw material for the food, pharmaceutical and cosmetic industries (Markhali et al., 2020, Romero-Marquez et al., 2023).

The amount of available olive leaves and branches during pruning depends on the number and age of the olive trees. According to data from the register of olive groves obtained by PAAFRD for 2022 there are 3,657,548 olive trees in Croatia (PAAFRD, 2023). On the basis of the conducted primary research on a sample of olive groves (N=10), with regard to the age of the respondents' plantations, it was determined that trees aged 5-20 years predominate with a share of 57%, trees older than 20 years have a share of 35%, while 8 % of trees are younger than 5 years. The amount of pruning residues depends on the age and luxuriance of the trees, and it is estimated that the amount of pruning residues in one year is about 42.3 kg/tree in trees in full bearing (Moreno-García et al., 2018).

Based on the conducted primary research on a sample of olive growers (N=10), the majority of them apply interventions of mulching pruning residues and incorporation of pruning residues into soil. From the above, it can be concluded that olive growers use the by-products of pruning, branches and leaves, as organic material which they shred by mulching and return into the soil, enriching it with organic matter (Figure 2). Furthermore, olive growers often use the option of controlled burning of the pruning residues and returning them to the olive grove, composting the pruning residues, and using the wood removed from the olive grove as firewood (Figure 7).

Olive growers and olive mill owners most often use interventions of mulching pruning residues and their incorporation into soil (Figure 3), which agrees with the results of respondents from the category of olive growers. Only a small part of them decide to use the wood as firewood or to produce firewood pellets (Figure 8). Therefore, it can be concluded that there are almost no pruning residues as a potential by-product after the agrotechnical pruning measure.

When it comes to pruning and the amount of green and woody mass removed, it depends on whether it is winter or summer pruning, and their frequency. According to the results of the research as part of the CIRCOLIVE project, it was determined by surveying olive growers that 90% of them do winter pruning every year, while all olive growers and olive mill owners do winter pruning every year (Figure 5). The survey results showed that 60% of olive growers and 70% of olive growers and olive mill owners perform summer pruning every year (Figure 6).

According to the presented results on the frequency of winter and summer pruning on a sample of olive growers and olive growers and olive mill owners it can be concluded that most of them prune every year, and this leads to a greater creation of green and woody mass, which, according to the previously stated methods of use, is mulched and incorporated back into soil by the majority of respondents and thereby enriching the soil with organic matter.

Furthermore, during the interviews conducted on the CIRCOLIVE project, ways of using the residues after pruning were determined. A stakeholder in the business with by-products/waste from olive sector stated that he processes olive branches and that he gets about 70 kg of pellets from 100 kg of branches (Interview with by-products/waste from olive sector stakeholder). A stakeholder in the olive growing and oil production stated that he owns a mulching machine in which he processes the branches and mixes them with pomace compost and returns them to the olive grove (Interview with olive growing and oil production stakeholder).

According to the estimate presented in Table 4, based on the product of the number of olive trees and the normative amount of pruning residues, the result is 154,714.28 tons of pruning residues on an annual level in Croatia. The stated number should be taken with reservation because the number of trees in Croatia includes young trees that are not yet fully productive, and therefore the amount of pruning residues after pruning is significantly lower in kg compared to the norm used for the calculation of 42,3 kg/tree which corresponds to a tree in full bearing (Moreno-García et al., 2018).

Table 4: Calculation of potential total amounts of pruning residues after pruning olive trees according to the number of trees in Croatia in 2022

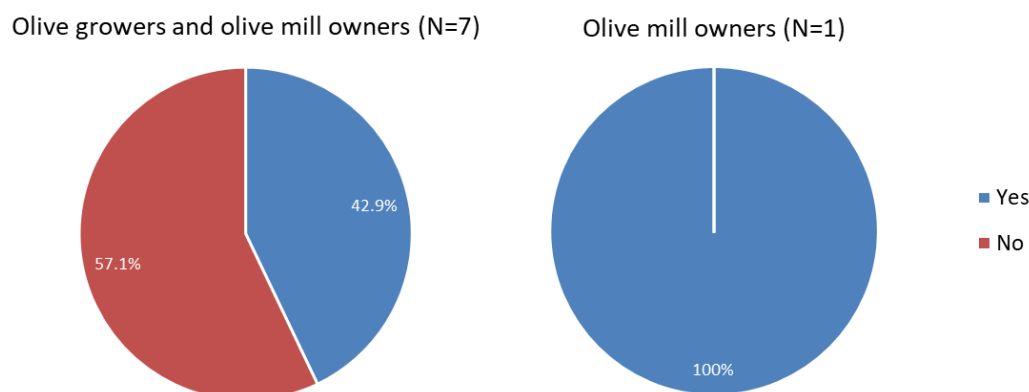
Calculation of the potential amount of pruning residues in a year in Croatia	
<b>Number of olive trees in Croatia (2022):</b> <b>3,657,548</b>	Source: PAAFRD, 2023
<b>Normative of pruning residues in kg/tree:</b> <b>42.3 kg</b>	Source: Moreno-García et al., 2018
<b>Calculation: 3,657,548 x 42.3 kg = 154,714,280 kg = 154,714.28 tons of pruning residues</b>	

In conclusion, according to the results presented in this subsection, pruning residues do not represent a significant challenge as a by-product in the olive sector in Croatia. Primarily for the reason that, after pruning, most olive growers shred the pruning residues by mulching, and usually incorporate them back into the olive grove and thus enrich the soil with organic matter. Part of the pruning residues that are not disposed of by returning to the soil can be chopped and pelletized and in this way create a new product intended for the market.

## 6.2. Olive Pits

Olive pits, which are a by-product of the production of olive oil, have the potential for wide application in various sectors, including the energy sector, agriculture and industry. In Croatia, interest in using this waste is growing in order to increase the sustainability of the olive industry and reduce the impact on the environment. One of the most significant applications of olive pits is their use as biofuel (Sanchez et al., 2015). In Croatia, there are examples of using olive pits for heating residential buildings or in industrial plants, which reduces the need for fossil fuels and contributes to the reduction of greenhouse gas emissions (Medic, 2015). In agriculture, olive pits can be used as a natural material to improve soil structure (Brunetti et al., 2005). Crushed seeds can be applied as organic mulching material, which helps conserve soil moisture, reduce erosion and prevent weed growth. This approach is particularly useful in arid coastal areas, where water conservation is critical. Olive pits, as a valuable source of bioactive phenolic compounds, oleic acid, plant proteins and dietary fiber, also have potential for use in cosmetic and pharmaceutical purposes (Galitsopoulou et al., 2022).

According to the data obtained through surveys on a sample of olive growers and olive mill owners, the following data were obtained on the method of handling the pit during processing in Croatia. As many as 50% of the respondents have a system for extracting the ground parts of the pits of the olive fruits from the rest of the fruit processing after extracting the oil (Figure 10).



Picture 10: Separating the pit from the olive fruit in the olive mill

In the tested sample, the separation of pits during processing is done in the phase after the extraction of oil from dry or wet pomace (Figure 11).

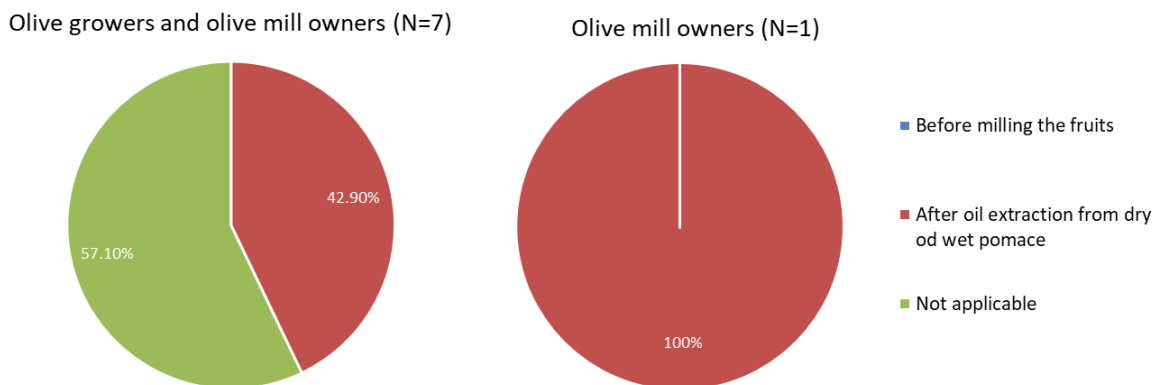


Figure 11. Stages of separating the pit from the olive fruit in the olive mill

Below are the results of the qualitative research, i.e. the interviews conducted with stakeholders in the olive growing and oil production. A stakeholder in the olive growing and oil production uses olive pits on agricultural land as mulch. During the interview, he stated that 10-12% of the total weight of the olive fruit is made up of the olive pit, which can vary from year to year (Interview with olive growing and oil production stakeholder).

Since there is no official data in Croatia on the amount of pits as a residue of olive processing, these data can only be obtained by calculation. With the assumption of an annual harvest of 40,130 tons of olive fruit and a share of 10% of pit weight in the weight of olive fruit, it can be calculated that approximately 4,013 tons of stones could be separated in Croatia on an annual basis (Table 5).

Table 5: Calculation of potential total quantities of olive pits according to the olive harvest in Croatia in 2022

Calculation of the potential amount of olive pits according to the olive harvest in Croatia	
<b>Olive harvest in Croatia (2022):</b> <b>40,130 tons</b>	Source: FAOStat, 2023
<b>Normative percentage of pit in olive fruit:</b> <b>10 %</b>	Source: Interview with olive growing and oil production stakeholder
<b>Calculation, with a pit share of approximately 10%: 40,130 t urod maslina = 4,013 tons of pit per year</b>	

According to the results in Table 5, it can be concluded that on an annual level, the amount of olive pits that can potentially remain as a by-product after olive processing in Croatia is not large. However, from the survey data of about 50% of oil growers who extract pits from olive pomace, it can be concluded that the amount of pits currently obtained in Croatia is twice as small as the possible total amount. Since some olive mills already remove the pit during processing and use it for heating or as an organic material for mulching, it can be concluded that the olive pit is optimally used in Croatia. Using olive pits for heating residential buildings or industrial plants reduces the need for fossil fuels and thus contributes to the reduction of greenhouse gas emissions, and in agriculture, to improve the structure of the soil by using the pits as a natural material that helps preserve moisture in the soil, reduce erosion and prevent the growth of weeds.

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

Considering the technology of separating the oil from the rest of the ground olive fruits and the organization of production, several different types of residues can be named, which can be considered as by-products or waste depending on their further usage. The composition of the residues from the olive mill will depend to the greatest extent on the initial average composition of the olive fruits and on the amount of added water in terms of dilution and, of course, on the extraction technology.

The process of extracting virgin olive oil from olive fruits produces, in addition to oil, the remains of virgin olive oil production, which can be categorized in different ways depending on the purpose. In terms of processing and utilization for agronomic purposes as a soil improver after oil extraction, the following types of by-products remain, which are quantitatively the most significant and therefore the biggest problem for disposal, i.e. a challenge for processing and utilization:

- two-phase olive pomace (wet pomace)
- three-phase olive pomace (dry pomace)
- liquid residue of three-phase olive processing (waste water from olive processing).

Above are the theoretical residues after processing olives in olive mills. In reality, these processing residues may contain wastewater from washing the processing line, tanks, work surfaces and floors, and with it detergent residues and environmental contamination (soil, pebbles, leaves and twigs), but also potentially dangerous substances such as residues of mineral oils used for machine lubrication, pesticide residues and heavy metals originating from fruits or from the environment. In practice, although uncommon, it can happen that different types of residues from the processing of olive fruits are mixed with each other or with other types of waste.

From the theoretical data on the mass balance of substances for the olive processing process using a two-phase or three-phase system for extracting oil from residues (Table 6) (Peri and Proietti, 2014), it is possible to calculate the potential total amount of residues after olive processing from the total amount of fruit and the share of two-phase and three-phase oil mills in Croatia.

Taking the data on the amount of olive fruits produced in Croatia in 2022 (40,130 tons) and the assumption of 75% representation of two-phase processing systems in Croatia, and applying the mass balance from Table 6, the potential total amounts of residues from the processing of olives into virgin olive oil were calculated (Table 7).

Table 6. Mass balance for the olive processing process (Peri and Proietti, 2014)

Materials entering and leaving the olive processing process	Two-phase system	Three-phase system (modern)	Three-phase system (first generation)
<b>Input (% of input amount of fruit)</b>			
Input amount of olive fruit	100	100	100
Water from washing olive fruits	10	10	10
Added water to the oil/pomace-water centrifugal separator	0	30	75
Added water to oil/water centrifugal separator	5	5	5
<b>TOTAL in processing</b>	<b>115</b>	<b>145</b>	<b>190</b>
<b>TOTAL ADDED WATER</b>	<b>15</b>	<b>45</b>	<b>90</b>
<b>Output (% of input amount of fruit)</b>			
Oil	13	13	13
Pomace	87	62	62
Water	15	70	115
<b>TOTAL after processing</b>	<b>115</b>	<b>145</b>	<b>190</b>

It was assumed that in the olive mills with a two-phase processing system, three quarters of the total harvest was processed in 2022, which amounted to about 30 thousand tons of olive fruit, with the potential of producing almost 4 thousand tons of virgin olive oil, while olive mills with a three-phase system processed about 10 thousand tons of fruit and produced a thousand tons of virgin olive oil.

Table 7. Potential total quantities of olive processing residues in the production of virgin olive oil in Croatia, based on the 2022 harvest (40,130 tons of fruit)

Materials entering and leaving the olive processing process	Two-phase system (2-F)		Three-phase system (3-F, modern)	
<b>Input</b>				
	<i>% of input amount of fruit</i>	<b>75% 2-F (kg)</b>	<i>% of input amount of fruit</i>	<b>25% 3-F (kg)</b>
Input amount of olive fruit	100	30,098	100	10,033
Water from washing olive fruits	10	3,010	10	1,003
Added water to the oil/pomace-water centrifugal separator	0	0	30	3,010
Added water to oil/water centrifugal separator	5	1,505	5	502
<b>TOTAL in processing</b>	<b>115</b>	<b>34,612</b>	<b>145</b>	<b>14,547</b>
<b>TOTAL ADDED WATER</b>	<b>15</b>	<b>4,515</b>	<b>45</b>	<b>4,514.63</b>
<b>Output</b>				
Oil	13	3,913	13	1,304
Pomace	87	26,185	62	6,220
Water	15	4,515	70	7,023
<b>TOTAL after processing</b>	<b>115</b>	<b>34,612</b>	<b>145</b>	<b>14,547</b>

According to the calculation shown in Table 7, in 2022, in olive mills with a two-phase system, a total of about 26 thousand tons of wet olive pomace and 4.5 thousand tons of waste water from the oil mill were obtained. Olive mills with a three-phase system, assuming that they are mostly relatively modern olive mills with less need for water addition than first generation three-phase systems, in 2022 about 6.22 thousand tons of dry pomace and about 7 thousand tons of waste water from the olive mills were obtained.

Olive pomace, although often considered waste, contains valuable ingredients such as residual oil, phenolic compounds and dietary fiber (Difonzo et al., 2021). Traditional disposal of pomace in landfills raises concerns because of the high organic load and the potential leachate contamination. According to the results of the survey in Croatia, olive pomace is used in several ways.

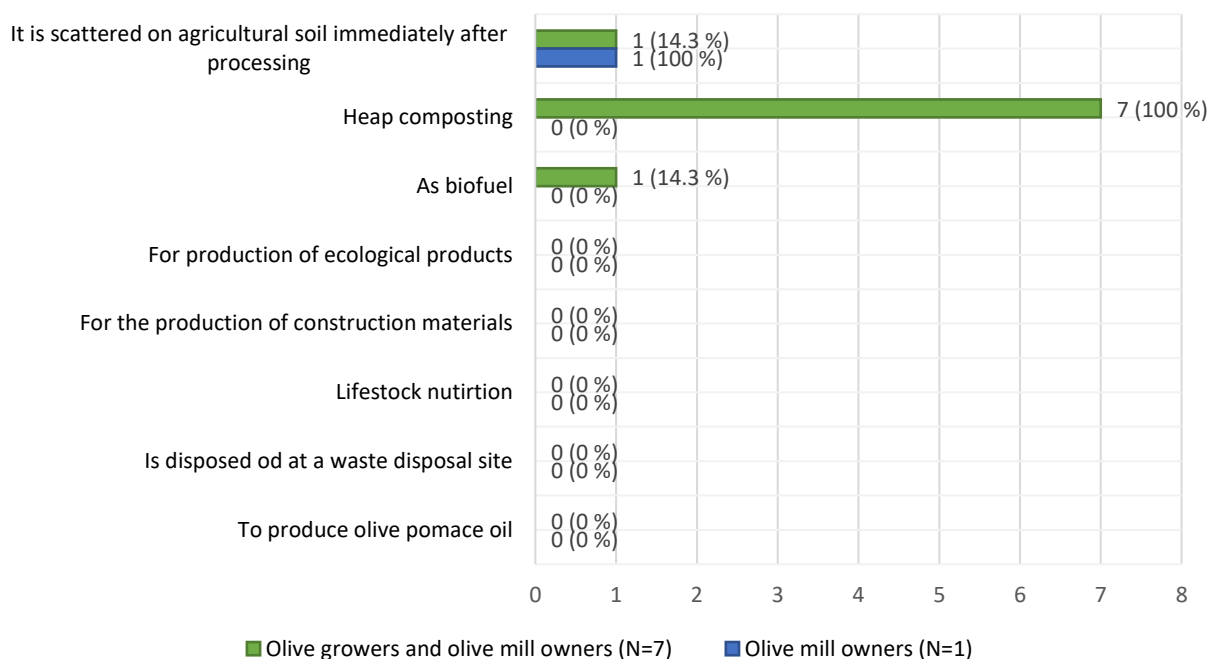


Figure 12. The way of using or disposing of wet or dry pomace

According to the results of the survey shown in Figure 12, all surveyed olive growers and olive mill owners compost wet or dry pomace in piles, and only one of them scatters part of the pomace on agricultural land immediately after processing or uses the pomace as biofuel. The majority of olive growers and olive mill owners (85.7%) compost pomace for more than 12 months, and 14.3% of respondents compost up to 12 months. According to the results in Figure 12, the olive mill owner who participated in the research scatters pomace on agricultural land immediately after processing.

Below are the results of qualitative research, that is, translated interviews with a stakeholder in the business with by-products/waste from olive sector and a stakeholder in the olive growing and oil production. Information obtained from the stakeholders in the business with by-products/waste, was on how they produce energy products (pellets) from olive pomace from two-phase processing and residues after pruning olive trees. The planned annual production is from 3 to 5 thousand tons of pellets, and he obtains 40 to 50% of the product from the total amount of input raw material. The obtained products are pomace pellets and olive pruning pellets. As for the production technology of olive pomace products, the



aforementioned stakeholder uses double drying, mechanical and thermal. During mechanical drying, the percentage of moisture in pomace decreases from 70% to 30%. The capacity of the plant for the production of pellets from olive pomace is currently 1,000 tons per year (Interview with by-products/waste from olive sector stakeholder).

A stakeholder in the olive growing and oil production uses part of the pomace on its own agricultural land. After 12 to 15 months, he mixes the composted pomace with manure from organic production from other farmers and uses it as such on a third of the land area every year. Part of the obtained pomace is further sent for processing into energy products (pellets) from olive pomace (Interview with olive growing and oil production stakeholder).

After the research and assessment of the potential total quantities of pomace in Croatia, it can be concluded that the quantities of wet pomace originating from the two-phase system of olive oil production are quite large. Due to the high proportion of water in the two-phase pomace, organic matter and nutritious macro and micro elements, the residues of olive oil production are most often used as soil improvers, especially in poor soils, but after adequate processing or composting. Composting is also the most widespread method of disposal and use of pomace in Croatia, which solves the largest amount of residue. In addition, a smaller part of the resulting pomace is disposed of and used in the production of pellets that are used as an energy source.

#### 6.4. Waste Water

Waste water from the olive mill is another significant by-product, consisting of water used in the processing process mixed with vegetative water with dissolved organic substances originating from the olive fruits. Wastewater is rich in phenols, organic acids and fats, which makes it a high pollutant if not treated appropriately (Ahmad et al., 2020). On average, waste water contains about 5% organic substances, 1.3% oil, 1.5% sugar, 1.1% higher alcohols, 0.6% polyphenols, 0.3% pectin and impurities, and 0.3% nitrogen compounds (Žužić, 2008). The practice of discharging wastewater into natural waterways or its direct application to land can lead to soil and water pollution, affecting local ecosystems (Akhtar et al., 2021). In many European countries, it is forbidden to discharge olive mill waste water into the environment, and there are legal regulations for the proper disposal and use of these waste water obtained from the production of olive oil. Among wastewater treatment methods that can be used are concentration by evaporation or membrane filtration (reverse osmosis and ultrafiltration) (Di Giovacchino, 2013).

According to the results in Figure 13, respondents from the category of olive growers and olive mill owners alike choose the options Purification and reuse (irrigation) (57.1%) and Purification and release into the environment (57.1%) as ways of using wastewater from the olive mill, and one olive mill owner pre-treats the waste water from the olive mill, and sends it to the public drainage system for further processing.

During the qualitative research, i.e. interviews conducted with a stakeholder in the sector of olive growing and oil production, the respondent states that in his plant for the production of olive oil, there is not much generation of waste water because they use a fat and oil separator, during which water is separated from oil and the water is further used for irrigation (Interview with olive growing and oil production stakeholder).

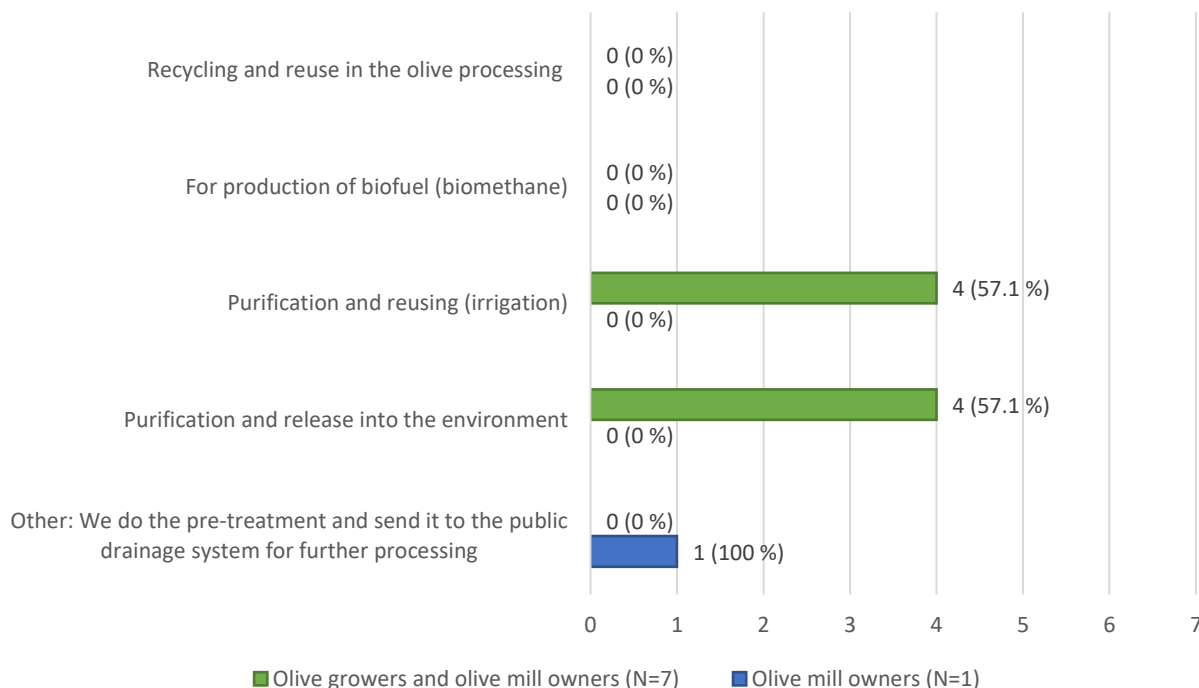


Figure 13: Disposal of waste water from the olive mill

Waste water, as a by-product of olive oil production, must be used exclusively in accordance with the principles of good agricultural practice and adequately disposed of in accordance with the Croatian *Water Law* (NN, No. 47/2023). A water permit is required for every discharge of wastewater in Croatia, except when the entire amount of that water is used exclusively on agricultural land for the purpose of nourishing plants or maintaining and/or improving the physical and/or chemical properties of the soil (Ministry of Agriculture, 2024). Since more than 75% of oil mills in Croatia use a two-phase olive processing system in which less waste water is generated compared to other methods of olive processing, the majority of waste water originates from three-phase systems and the water used for washing processing facilities. According to the results of survey research and interviews, all waste water from the olive mill is disposed of in adequate ways, most often by purifying it and reusing it for irrigation or releasing it into the environment.

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

The production of preserved table olives has not been developed in Croatia (Gugić et al., 2010), and therefore the residues of table olive production do not represent significant quantities in the relatively small production of the Republic of Croatia.

Lampante olive oil is an oil of impaired quality that is not intended for consumption and should be refined. Since there are no technical-technological possibilities for refining olive oil in Croatia (Gugić et al., 2010), olive oil of the lampante category can be counted among the remains of olive production. Official data on the quantities of this category of olive oil have not been found in Croatia, however, considering the relatively small production in Croatia, which meets approximately 50% of the needs of the Croatian market, it could be assumed that

almost all produced and imported oil is consumed and that quantities of olive oil of the lampante category in terms of olive production residues are negligible.

## 7. Sustainability and Environmental Impact

One of the primary aspects of sustainability in olive growing is the adoption of ecological farming practices. Organic olive farming avoids the use of synthetic fertilizers and pesticides, which can lead to soil degradation, water pollution and loss of biodiversity (Pleguezuelo et al., 2018). In Croatia, an increasing number of olive growers are switching to organic farming, stimulated by environmental awareness and the growing demand for organic products on the market (Perpar and Udovč, 2019). Organic farming practices also promote soil health through the use of natural composts and crop rotation, which helps maintain soil fertility and structure.

Water management is another key element of sustainable olive growing. Olive trees are naturally drought tolerant, but climate change has brought erratic rainfall patterns, making more efficient use of water even more important. Drip systems, which deliver water directly to the roots of the trees, are increasingly being used in Croatian olive groves. This method minimizes water wastage and ensures that the trees receive the optimal amount of moisture, reducing the overall water footprint of olive growing.

Preservation of biodiversity is also an integral part of sustainable olive growing (Marino et al., 2019). Traditional olive groves in Croatia, often interspersed with wild plants and animals, support rich biodiversity. Olive growers are encouraged to preserve these traditional practices, which help maintain ecological balance and increase the resistance of olive trees to pests and diseases. Furthermore, integrating cover crops, such as legumes, into olive groves can improve soil health, prevent erosion, and provide habitats for beneficial insects.

In the production process, sustainability efforts are focused on energy efficiency, waste management and reduction of greenhouse gas emissions (Gkissakis et al., 2020). Many olive mills in Croatia invest in energy-efficient technologies, such as modern presses and centrifuges, which reduce energy consumption during oil extraction. The use of renewable energy sources, such as solar panels, is also becoming increasingly popular to power olive mills, further reducing the sector's carbon footprint.

Waste management is a significant challenge in olive oil production, but it also provides opportunities for sustainable practices. Olive pomace and vegetable water, the main by-products, can be reused instead of being disposed of as waste (Valta et al., 2015). In Croatia, innovative methods such as composting olive pomace for use as a soil improver or its use in biogas production are being researched. In addition, advanced plant water treatment technologies, including anaerobic digestion and phytoremediation, could help reduce its environmental impact and enable recovery of valuable resources (Agrahari and Kumar, 2024).

### 7.1 Sustainable Practices in Olive Farming and Olive Oil Producing

Some of the sustainable practices in olive growing according to Michalopoulos et al. (2020) are: scattering chopped pruning residues on the soil surface in the olive grove; composting of organic material in smaller quantities (leaves from local olive mills, wastewater from the

three-phase olive mill system and pruning residues) and incorporating it back to the soil of olive groves; application of a specific pruning strategy (summer and winter pruning) on an annual basis; enrichment of the natural vegetation of olive groves with cover crops; avoiding tillage and weed control by mowing.

According to the results of the primary research carried out on a sample of olive growers, olive growers and olive mill owners, as well as olive mill owners shown below, it was determined that certain sustainable practices in olive growing and oil production are carried out in Croatia.

According to the results of the primary research conducted on a sample of olive growers (Figure 1), it was determined that conventional technology in olive groves is the most common among 60% of the surveyed olive growers, while there are 20% of olive growers with organic production who also possess an eco label. In the sample of olive growers and olive mill owners, conventional technology and ecological technology with an eco label are equally represented (Figure 1). As for the method of soil management in olive groves, the majority of surveyed olive growers as well as respondents from the category of olive growers and olive mill owners use a combination of tillage and mulching as a method of soil management in olive groves (Figure 4).

Half of the respondents from categories olive growers and olive mill owners and olive mill owners remove the pit (Figure 10), which reduces the amount of residues after processing the olives because they are still adequately utilized. After extracting the pit, olive growers and olive mill owners usually use it as an energy source in its original form, and as an organic fertilizer. All olive growers and olive mill owners compost olive pomace, and for most of them composting lasts longer than 12 months. The olive mill owner who separates the pits plans to sell it on the market, but does not compost the olive pomace (Figure 14).

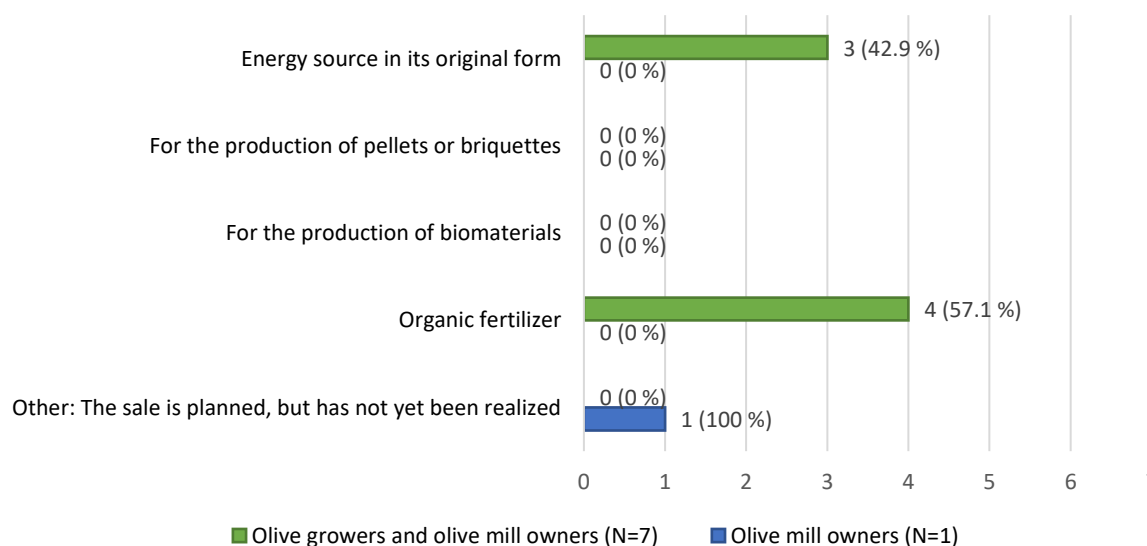


Figure 14. The way of using olive pits

Olive growers and olive mill owners apply two ways of reusing waste water from the oil mill, namely purification and reusage (irrigation) and purification and release into the environment.

The olive mill owner releases waste water from the olive mill into the public drainage system with prior pre-treatment (Figure 13).

In conclusion, sustainable practices in olive growing and olive oil production are key to minimizing the environmental impact of the olive industry in Croatia. By adopting ecological agriculture, efficient water use, energy-efficient technologies and effective waste management strategies, Croatia can ensure that olive oil production remains environmentally responsible and economically viable for future generations.

## 8. State of Circular Business Practices in the Olive Sector

The increase in the volume of olive production in Croatia is accompanied by an increase in the amount of organic residues from that production, primarily residues from olive pruning and processing. However, although some forms of sustainable management in the olive sector are applied in Croatia, the increased amount of organic residues from olive growing requires a wider application of innovative practices in the management of this biomass based on the principles of the circular economy.

### 8.1. Trends and Preferences

The remains of organic mass from olive production can be valorized in the context of the circular economy, which, in the green transition strategy, is one of the key topics of the common agricultural policy of the European Union. When it comes to disposing of pruning residues in olive growing, the most common way of disposing of them was to remove them from the plantations and burn them, with the resulting ash, which contains valuable minerals and nutrients, usually not being returned to the plantations. However, recently, the shredding of these residues in the plantation itself has been increasingly applied, which is a consequence of the increasingly better equipment of farms with heavy mulchers, as well as state subsidies that encourage weeding and mulching of inter-row areas in perennial plantations. As a rule, olive pomace, which is left behind after the processing of the fruit, is deposited in piles where it remains for about 10-12 months. After such extensive composting (without adding other organic materials and mixing), the obtained mass is spread over the olive groves as an organic fertilizer. Also, an increasing number of olive mills are installing equipment for extracting pits from pomace, which is then used as a very valuable, energy-rich fuel.

According to the data obtained in the survey conducted for the purposes of the CIRCOLIVE project, olive pruning residues are most often disposed of by mulching (65%), followed by the use of firewood (41%). Burning of pruning residues is used by 29% of respondents, and composting by 24% of them. In rarer cases, the pelleting of pruning residues and the production of decorative objects are used (18% frequency each), while these residues are used for feeding livestock by 12% of respondents (Figures 7 and 8).

Among olive growers, the most common motives for mulching pruning residues are: Availability of technologies, knowledge and experience (for 50% of respondents) and Lower costs and/or higher income (for 40% of respondents) (Figure 15). The most common motives for using pruning residues for firewood are: Lower costs and/or higher income (for 30% of respondents) and Awareness of sustainability (for 20% of respondents). Lower costs and /or higher income (30%) and Available technology, knowledge and experience (20% of

respondents) are most often cited as motives for controlled burning of pruning residues. The main motive for composting pruning residues is Awareness of sustainability (40% of respondents).

Respondents who, in addition to olive groves, also own olive mills pointed out that their main motive for mulching is Awareness of sustainability (for 86% of respondents), followed by Lower costs and Available technology, knowledge and experience, which was stated by 71% of them (Figure 16). In general, Awareness of sustainability stands out as the most expressed motive in most of the mentioned ways of dealing with pruning residues among this group of respondents.

Olive growers and olive mill owners, similarly to olive growers, see the advantage of pellets in their high energy value (Figure 17 and 18). The majority of olive growers and olive growers and olive mill owners agree that composting pruning residues reduces organic waste in landfills, and they also perceive the obtained compost as a quality organic fertilizer (Figure 19 and 20).

Olive growers, in regards to pomace composting, state that the compost obtained in this way is a high-value organic fertilizer and it improves the structure of the soil (Figure 23). Olive growers and olive mill owners agree with the statements about the benefits of composting: composting is the best way to use olive pomace, that the resulting compost is a high-value organic fertilizer, compost improves the structure and biological activity of the soil (Figure 24).

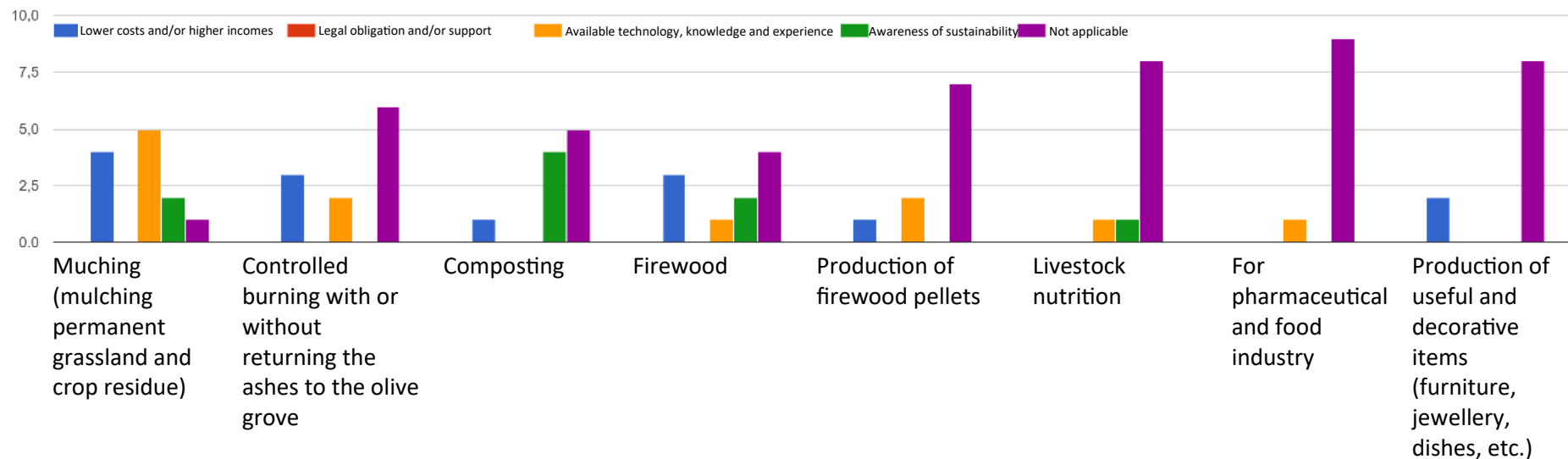


Figure 15. Motives for the application of certain ways of dealing with pruning residues (Olive growers, N=10)

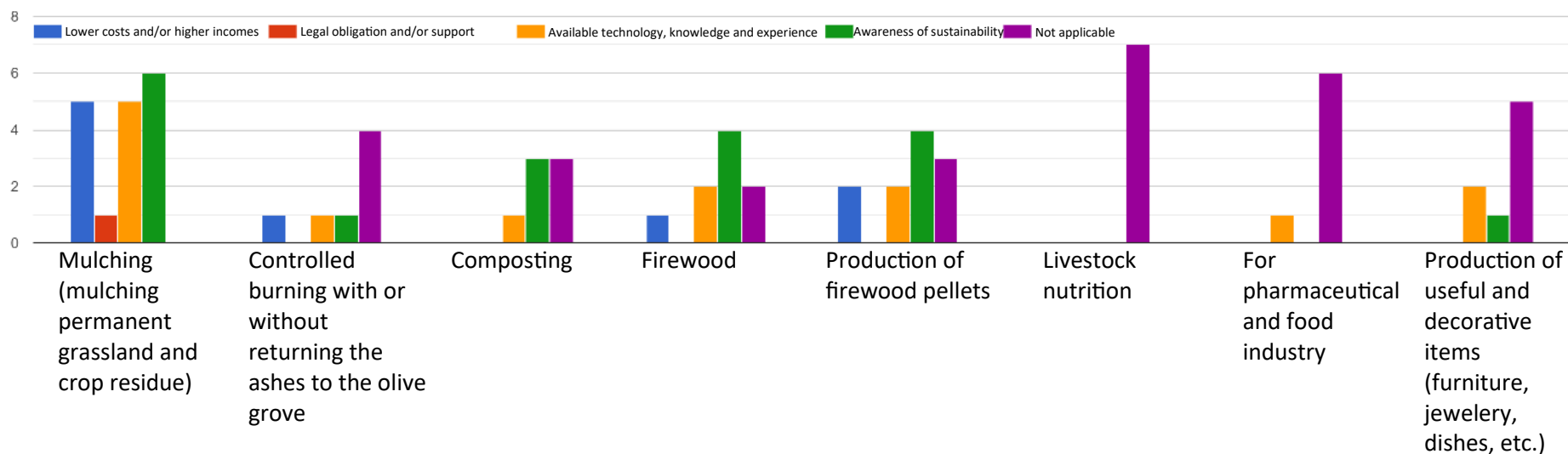


Figure 16. Motives for the application of certain ways of dealing with pruning residues (Olive growers and olive mill owners, N=7)

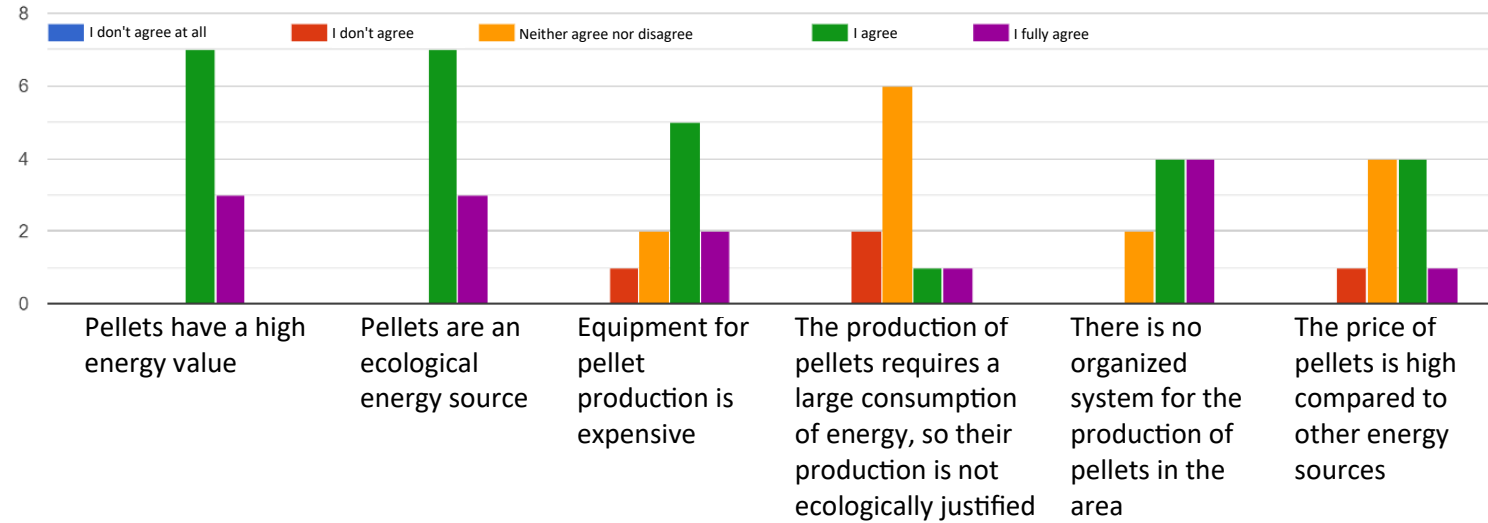


Figure 17. Advantages and disadvantages of producing firewood pellets from pruning residues (Olive growers, N=10)

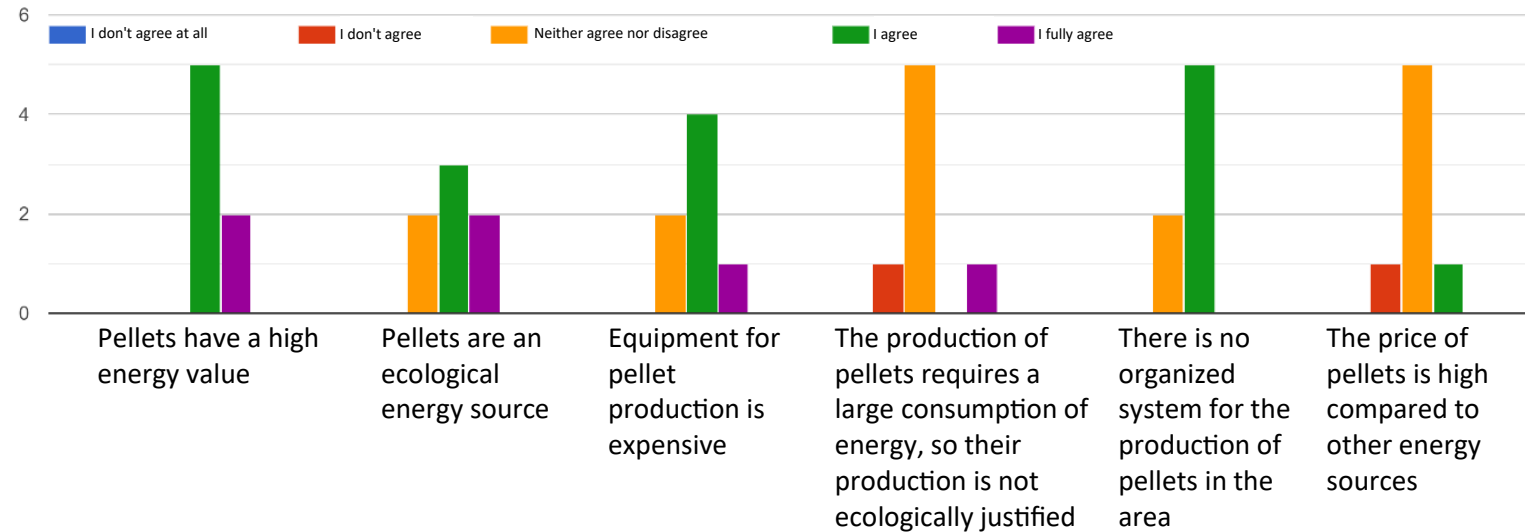


Figure 18. Advantages and disadvantages of producing firewood pellets from pruning residues (Olive growers and olive mill owners, N=7)

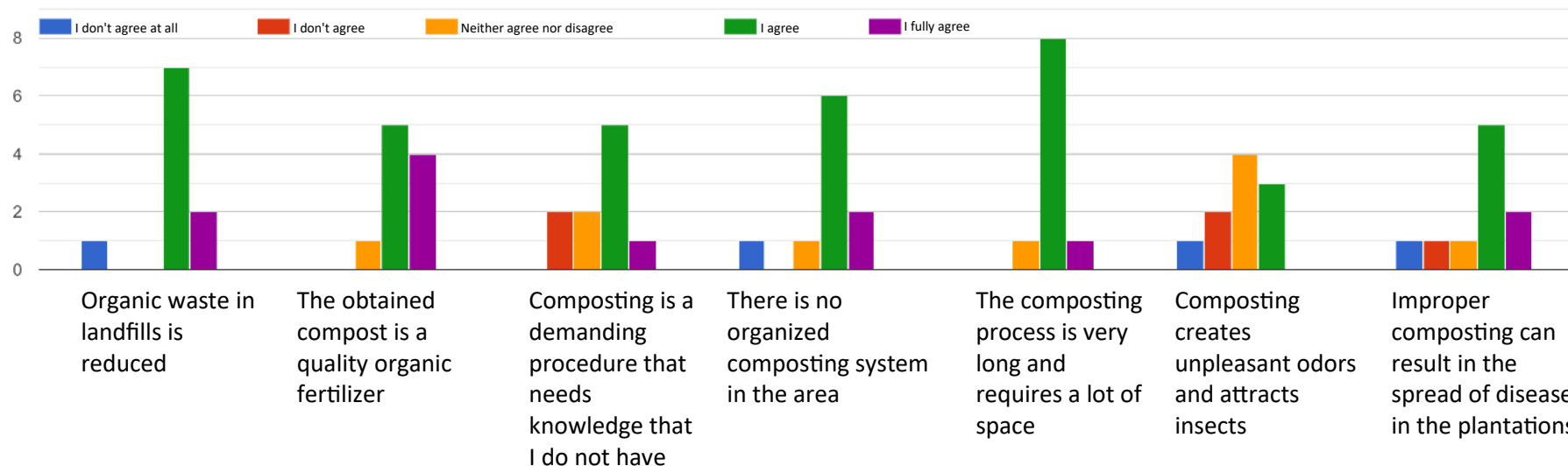


Figure 19. Advantages and disadvantages of composting pruning residues (Olive growers, N=10)

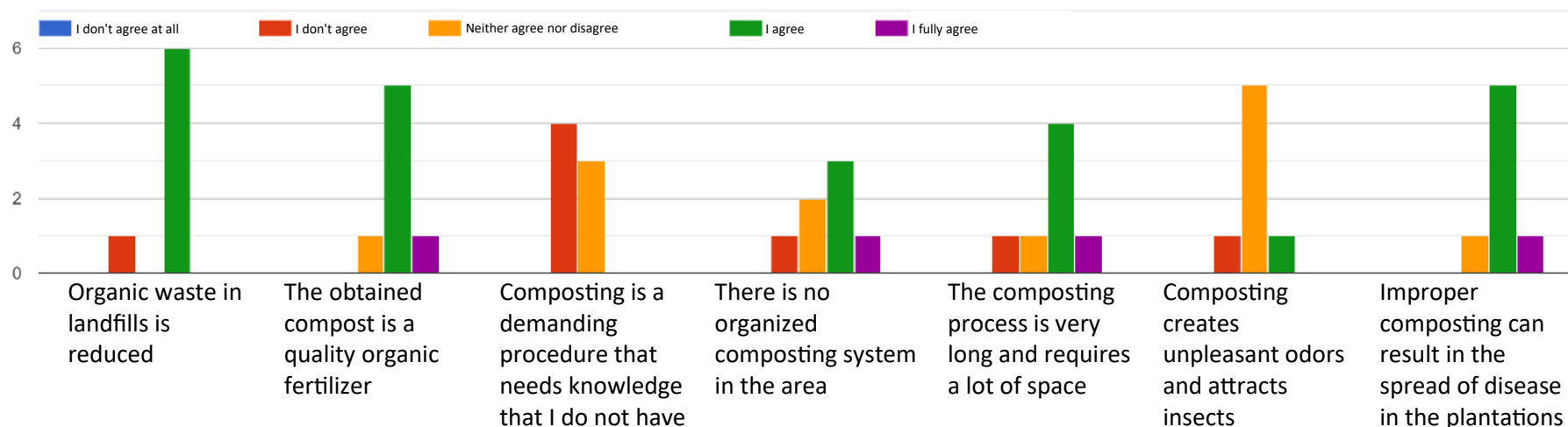


Figure 20. Advantages and disadvantages of composting pruning residues (Olive growers and olive mill owners, N=7)

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

Olive pomace that is disposed of inadequately in the environment becomes a potential source of soil and groundwater pollution because it contains phenolic compounds, residues of unextracted olive oil and organic acids. Also, olive pomace is the source of unpleasant odors attributed to volatile fatty acids. Therefore, efforts are being made to find solutions for its recovery, which, in addition to eliminating environmental hazards, would also achieve its sustainable use. The prerequisite for using olive pomace as an organic fertilizer is the appropriate nutrient content and chemical, physical, physiological and mechanical properties according to the *Law on Fertilizer Products* (NN, No. 39/2023) as well as the content of heavy metals in accordance with the *Regulation on the Protection of Agricultural Land from Pollution* (NN, No. 71/2019).

Olive growers pointed out the Lack of technology and knowledge as the most pronounced obstacle for the application of certain methods of dealing with pruning residues, followed by High initial investments and costs, and Legal restrictions or insufficient support (Figure 21).

Respondents who, in addition to olive groves, also own an olive mill, believe that the main obstacles to dealing with pruning residues are High initial investments and costs, Lack of social and environmental awareness, and Lack of technology and knowledge (Figure 22). In general, this group of respondents believes that the mentioned obstacles are less pronounced than they are experienced by olive growers.

The majority of respondents consider the high price of pellet production equipment and the lack of an organized system for pellet production in the area to be a disadvantage in pellet production (Figures 17 and 18).

As disadvantages of composting pruning residues, olive growers identified composting as a demanding process that requires knowledge, furthermore, there is no organized system for composting in the field, the composting process is long and requires a large space, and inappropriate composting can result in the spread of diseases in plantations (Figure 19).

As disadvantages of olive pomace composting, the majority of respondents state that the pomace decomposes slowly, that composting takes at least 12 months, and that the legal regulations for the use of olive pomace compost in agriculture are complex (Figures 23 and 24).

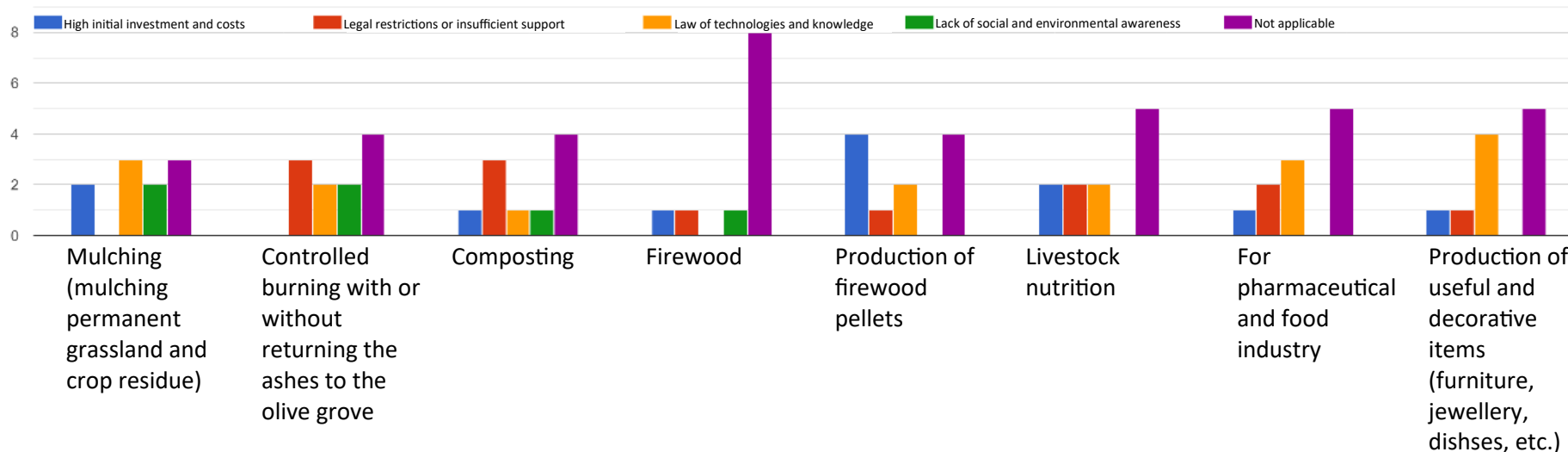


Figure 21. Obstacles to the application of certain ways of dealing with pruning residues (Olive growers, N=10)

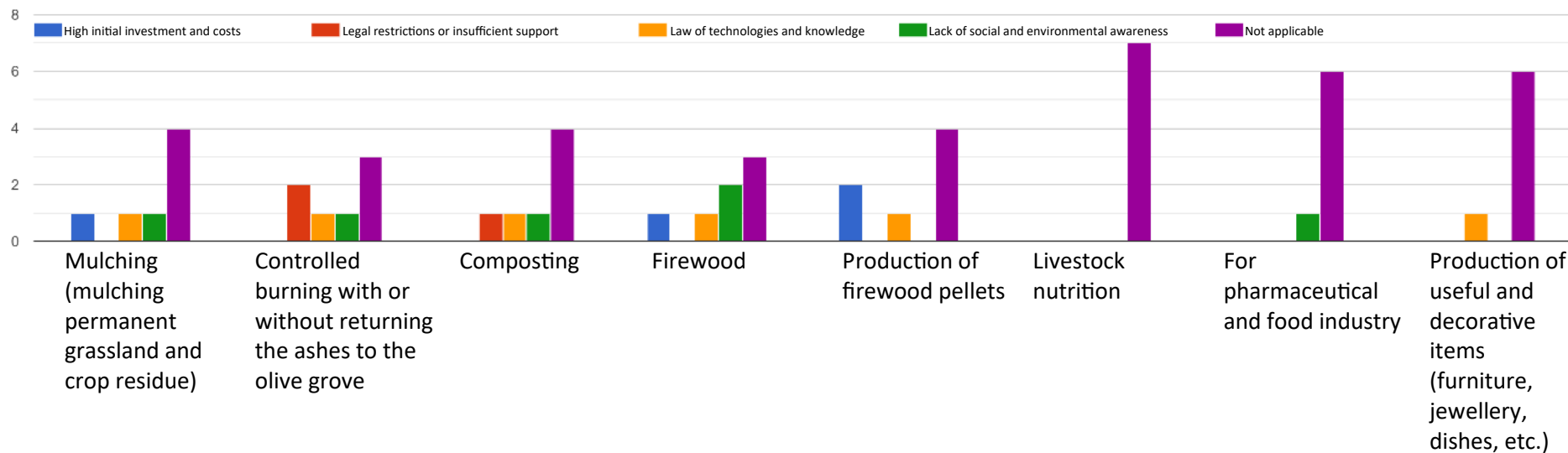


Figure 22. Obstacles to the application of certain ways of dealing with pruning residues (Olive growers and olive mill owners, N=7)

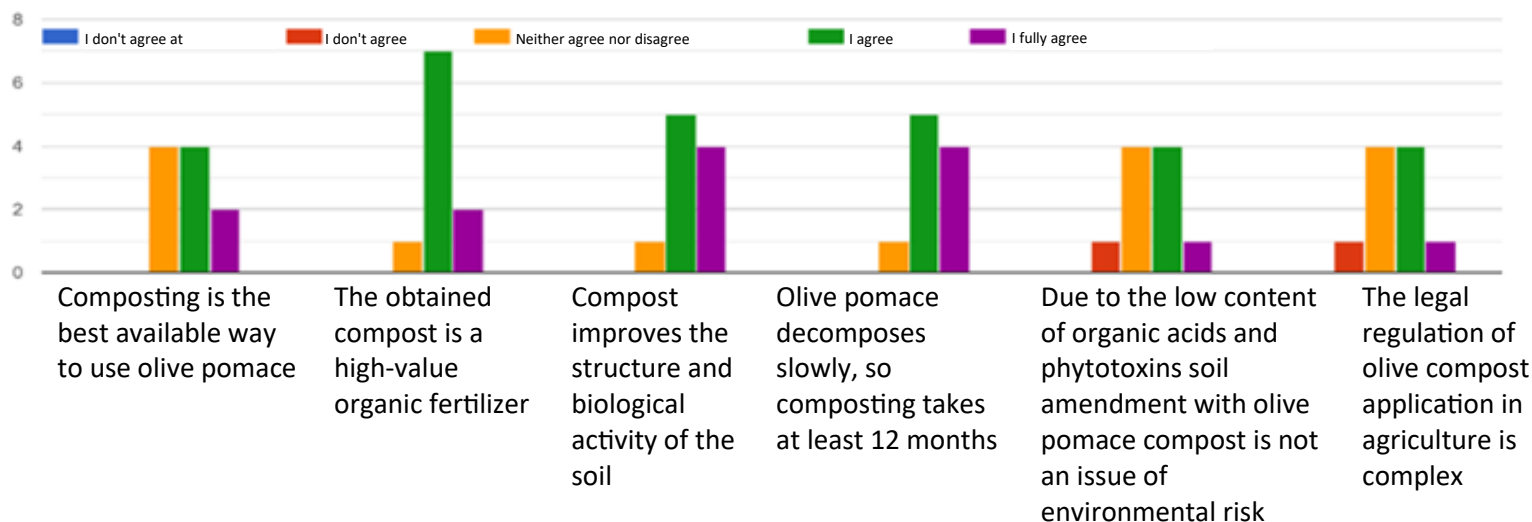


Figure 23. Advantages and disadvantages of composting olive pomace (Olive growers, N=10)

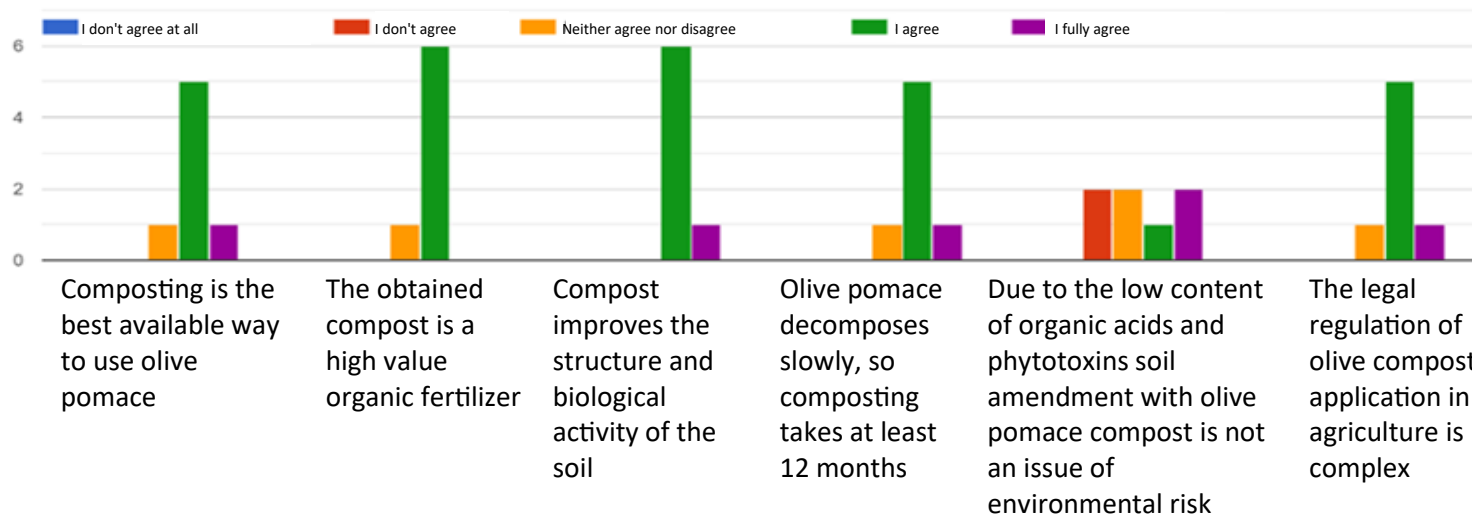


Figure 24: Advantages and disadvantages of composting olive pomace (Olive growers and olive mill owners, N=7)

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

An example of the good practice of applying the circular economy in olive growing is the biowaste management model implemented by the utility company Ponikve in the city of Krk. The model is based on the collection of all pomace that remains after processing olives in all olive mills on the island of Krk, as well as branches and other pruning residues. They are mixed with green and bio waste from the household and everything is composted together. In this way, in 2022, 780 tons of olive pomace, 1,582 tons of green waste and 4,510 tons of bio-waste were processed. About 5,000 tons of compost were produced, which, after analysis, were partly distributed free of charge to all users of the utility company's service, and partly sold (<http://www.ponikve.hr/>).

Extraction of olive pits during their processing is carried out by several olive mills in Croatia, which was also confirmed by this research. The pits are separated from the pomace of olives, after processing the fruits into olive oil. Olive pits are a very valuable fuel that can be used for heating buildings, since their energy value is about 30% higher than wood pellets. At the same time, the price of 1 ton of olive pits is 270-300 euros, which is 50% cheaper than the price of wood pellets (<https://baustela.hr/odrziva-gradnja/grijanje-na-kostice-od-masline-duplo-jeftinije-from-pellets-and-more-and-more-popular/>).

During the primary research in Croatia, it was determined that the selected survey respondents also apply certain sustainable practices in the olive growing sector. Pruning residues are mostly disposed of by mulching or used for firewood, composting and pelletizing of pruning residues is carried out. Wastewater is mostly treated and reused for irrigation. From interviews conducted with a stakeholder in the business with olive by-products/waste, it was established that the stakeholder produces pellets from pomace and pellets from olive pruning. On an annual level, 3 to 5 thousand tons of pellets are produced, which is the largest possible production with the current capacity of the plant, and states that certain legal and financial restrictions prevent the expansion of this plant in order to be able to process all available pomace in the area of its plant.

## 9. Technological Advancements

### 9.1. Innovations in Production and Processing

In Mediterranean basin, large quantities of olive-processing residues are generated each year during the olive mill's operation activities. Treatment and disposal of solid olive mill waste, i.e. olive pomace and liquid, i.e. olive mill wastewater represents one of the main problems faced by industries involved in the production of olive oil. Raw olive mill waste is potentially phytotoxic due to the presence of polyphenols, lipids and organic acids, making its disposal a major environmental problems in the Mediterranean countries. On the other hand, it also contains high content of organic matter and plant nutrients that could be recovered as fertilizers to sustain yield production. Further, both olive pomace and olive mill wastewater are also a valuable source of value added raw chemicals (e.g. hydroxytyrosol, vitamin E, fatty acids, various antioxidants, etc) that can be further used in pharmaceutical or chemical industry. Additionally, the recovery of biomass-derived by-products, such as olive leaves, has significant potential to become an alternative for natural additives in food production.

Therefore, Table 8 summarizes projects and some of the scientific publications in the field of valorization of olive by-products studied by Croatian scientific community.

Table 8. Projects and scientific articles in the field of valorization of olive by-products in Croatia

PROJECTS		
Project name	Period	Web site
Valorisation of olive mill waste material by microbial multispecies biocatalytic aggregates – VALOLIVEWASTE	2022 – 2025	<a href="https://biocolloid.ijs.si/projects/arrs-j4-4561/">https://biocolloid.ijs.si/projects/arrs-j4-4561/</a>
Reduction of greenhouse gas emissions through urban and agricultural waste utilization in plant production- REDGREENPLANT	2022 – 2025	<a href="http://redgreenplant.iptpo.hr/">http://redgreenplant.iptpo.hr/</a>
High voltage discharges for green solvent extraction of bioactive compounds from Mediterranean herbs – GREENCOLTEX	2017 – 2021	<a href="http://greenvoltex.pbf.hr/">http://greenvoltex.pbf.hr/</a>
Valorization of olive waste in sustainable food innovation – NutriOliWa	2015 – 2019	<a href="https://croris.hr/projekti/projekt/116">https://croris.hr/projekti/projekt/116</a>
Reference	Article name	DOI/URL
Černe et al., 2023	Effect of olive-processing technology on the utilization of olive mill pomace as a soil amendment	<a href="https://doi.org/10.1002/jeq2.20464">https://doi.org/10.1002/jeq2.20464</a>
Filipović et al., 2020	Modeling water flow and phosphorus sorption in a soil amended with sewage sludge and olive pomace as compost or biochar	<a href="https://doi.org/10.3390/agronomy10081163">https://doi.org/10.3390/agronomy10081163</a>
Kučić Grgić et al., 2020	The influence of olive pomace on the environment	<a href="https://doi.org/10.15255/KUI.2019.020">https://doi.org/10.15255/KUI.2019.020</a>
Lončarić et al., 2021	Various techniques for phenolic removal from olive mill wastewater	<a href="https://doi.org/10.17508/CJFST.2021.13.2.15">https://doi.org/10.17508/CJFST.2021.13.2.15</a>
Kučić Grgić et al., 2017	Treatment of Olive Mill Waste	<a href="https://doi.org/10.15255/KUI.2017.045">https://doi.org/10.15255/KUI.2017.045</a>

Gugić et al., 2010	Status overview and prospects of olive growing in Croatia	<a href="https://hrcak.srce.hr/69062">https://hrcak.srce.hr/69062</a>
Mitar et al., 2019	Extraction and Stability of Olive Pomace Polyphenols in Natural Deep Eutectic Solvents	<a href="https://hrcak.srce.hr/225426">https://hrcak.srce.hr/225426</a>
Repajić et al., 2018	Stability of olive leaf drink upon storage at different temperatures	<a href="https://doi.org/10.31727/gzb.41.5.8">https://doi.org/10.31727/gzb.41.5.8</a>
Novoselić et al., 2023	Compositional Changes during Storage of Industrially Produced Olive Oils Co-Milled with Olive Leaves	<a href="https://doi.org/10.3390/foods13010073">https://doi.org/10.3390/foods13010073</a>
Novoselić et al., 2021	The Use of Olive Leaves in Buža Olive Cultivar Oil Production: Exploring the Impact on Oil Yield and Chemical Composition. Agriculture	<a href="https://doi.org/10.3390/agriculture11100917">https://doi.org/10.3390/agriculture11100917</a>

## 9.2. Future Technological Trends in the Sector

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

### 1) Composting

- a) *the use of microbial inoculants to improve composting of olive pomace (VALOLIVEWASTE)*
- b) *soil amendment with olive pomace compost (REDCREENPLANT; Černe et al., 2023; Filipović et al., 2020; Kučić Grgić, et al., 2020; Kučić Grgić et al., 2017; Režić, 2013; Kosor, 2008; Černe and Oplanić, 2021)*

**2) Biochar production** - *biochar production aiming to produce organic amendment safe for agricultural use (REDCREENPLANT, Filipović et al., 2020)*

**3) Anaerobic stabilization** - *anaerobic stabilisation aiming to produce biogas (Kučić Grgić et al., 2020; Klanac, 2022; Režić, 2013)*

**4) Heating** - *a renewable resource for heating (M.O.R.E.; Kosor, 2008; Palvčić, 2023)*

### 5) Utilization of olive pomace-derived bioactive compounds

- a) *microbial biotransformation aiming to produce added value raw chemical that can be used in polymer, food and pharmaceutical industries (VALOLIVEWASTE)*
- b) *further use in pharmaceutical and polymer industries (Kučić Grgić et al., 2020; Spaić, 2016; Albahari, 2022; Mitar et al., 2019)*

### 6) Utilisation of olive leaves

- a) *used as a resource of natural additives for olive oil quality improvement*
- b) *extraction of polyphenols to assess their antimicrobial activity (Novoselić et al., 2023; Novoselić et al., 2021; Han, 2020)*

**7) Utilization as animal feed** - *used as a resource for animal feed (Kosor, 2008).*

Based on the studies summarized, it can be concluded that in view of valorisation of olive mill waste, whether solid or liquid composting, anaerobic stabilisation, biochar production, and heating can be a promising valorisation approaches. The studies also revealed that elevated levels of phenolic substances in both olive pomace and olive mill wastewater indicates for their potential use as added value raw chemicals in polymer, pharmaceutical or chemical industries. Also, olive leaves can be used as a resource for natural additives in olive oil quality improvement. However further research is needed to implement new valorisation technologies to the industrial-scale application.

## 10. Market Analysis

Market analysis is the process of determining the viability of a new product/service on the market in order to better position it on the market. Market analysis determines the state of the market, opportunities, threats, opportunities and weaknesses that should be taken into account when placing a new product/service on the market. In the following sub-chapters, an analysis of the market of by-products and waste from olives in the olive growing sector in Croatia was carried out.

### 10.1. Market Forces

The market for by-products and waste from olives in the olive growing sector in Croatia is not sufficiently developed. Therefore, any innovative product made from olive by-products and waste is welcome. A search of secondary databases found some information on the types of products obtained from by-products/waste from olives produced and available in Croatia.

The given data in Table 9 show innovative products produced from olive by-products/waste such as pomace, pits transformed into new products of various uses such as cosmetics, organic fertilizers, firewood. It should be pointed out that newly created products represent a valuable potential for the market, especially because modern consumers are more and more environmentally oriented and focused on sustainable products. Such products generate efficient and sustainable utilization of by-products from the olive growing sector while creating new products.

Below is an overview of the market potential of by-products from the olive growing sector according to the results obtained from a survey conducted on a sample of olive growers (N=10), olive growers and olive mill owners (N=7), and olive mill owners (N=1).

Table 9: Presentation of some products produced from by-products/waste from olives produced in Croatia

Product	Packaging	Price	Purpose	Manufacturer	Source
<b>Olive pomace pellets</b>	Bag 15 kg	6,70 euros	Fertilizer	ŠULOG d.o.o., Krapinska 12 10298 Donja Bistra, Hrvatska	<a href="https://www.agroklub.com/poljoprivredni-oglasnik/oglas/peleti-od-komine-masline-15-kg-nova-inovativna-tehnologija/56097/">https://www.agroklub.com/poljoprivredni-oglasnik/oglas/peleti-od-komine-masline-15-kg-nova-inovativna-tehnologija/56097/</a>
<b>Olive pits</b>	1t	270 – 300 euros	Heating	Uljara Baioco d.o.o. Ulica Michele della Vedova 55 52216 Galižana, Croatia	<a href="https://baustela.hr/odrziva-gradnja/grijanje-na-kostice-od-masline-duplojeftinije-od-peleta-i-sve-popularnije/">https://baustela.hr/odrziva-gradnja/grijanje-na-kostice-od-masline-duplojeftinije-od-peleta-i-sve-popularnije/</a>
<b>Olive pomace</b>	1t	5,58 euros (promotional price)	Fertilizer	Ponikve eko otok Krk, Vršanska ul. 14, 51500, Krk	<a href="https://otok-krk.org/krk/ponikve-eko-otok-krk-eko-maslinarski-kompost-komina-masline">https://otok-krk.org/krk/ponikve-eko-otok-krk-eko-maslinarski-kompost-komina-masline</a>
<b>Scrub for face and hands from olive pits and lavender</b>	Tub 75 ml	6,50 euros	Cosmetics	Sapunoteka, Tromilja 9, Lozovac 22221	<a href="https://sapunoteka.com/products/piling-za-lice-i-ruke-kostice-masline-lavanda">https://sapunoteka.com/products/piling-za-lice-i-ruke-kostice-masline-lavanda</a>
<b>Olive pomace cosmetics</b>	Various products (lotions, creams, peels...)	-	Cosmetics	HELIOS GEA d.o.o. Rovinjska 43, Bale 52211	<a href="https://www.helios-gea.com/">https://www.helios-gea.com/</a>
<b>Olive body scrub (ground olive pit)</b>	Cream, 150 ml	7,50 euros	Cosmetics	Biofarm, Ventilatorska 14, Lučko, 10250	<a href="https://www.biofarm.hr/product/piling-za-tijelo-maslina-150ml/">https://www.biofarm.hr/product/piling-za-tijelo-maslina-150ml/</a>
<b>Olive pomace cheese</b>	Quarter of cheese, 650 g	25,22 euros	Food	Gligora delikatese d.o.o. Figurica 22/A, 23251 Kolan, otok Pag, Hrvatska	<a href="https://webshop.gligora.com/proizvod/sir-zigljen-iz-maslinove-komine?variant=0.65">https://webshop.gligora.com/proizvod/sir-zigljen-iz-maslinove-komine?variant=0.65</a>
<b>Olive leaf extract</b>	Liquid form in a bottle 500 ml	19,91 euroa	Food supplement	Gross, OPG, Smoljanci 2a, Svetvinčenat 52342, Hrvatska	<a href="https://bioterra.hr/shop/cijena/ekstrakt-lista-masline">https://bioterra.hr/shop/cijena/ekstrakt-lista-masline</a>

According to the obtained results, the motives for applying mulching of pruning residues are: available technology, knowledge and experience, lower costs, and awareness of sustainability. From a market point of view, this way of using pruning residues does not generate a new product based on pruning residues, but mulching pruning residues enriches the soil with

organic matter, and in this way olive growers directly encourage the circular economy and reduce the need to introduce organic matter in olive groves (Figures 15 and 16).

Respondents perceive pellets obtained from pruning residues as a highly valuable energy source, which is a market force due to which pellets can be better positioned on the market. As disadvantages for the production of pellets, olive growers emphasize the high cost of equipment for the production of pellets, the higher price of pellets compared to other energy sources, and the absence of an organized system in the area for the production of pellets (Figures 17 and 18).

Respondents agree that composting pruning residues reduces organic waste and that the resulting compost is a high-quality organic fertilizer, while they highlight the lack of an organized composting system in the surrounding area, the length and space required for composting, and state that improper composting can lead to the spread of diseases in plantations (Figure 19 and 20).

According to the research results obtained within the framework of the CIRCOLIVE project, the market potential of olive pomace is to obtain a high-value organic fertilizer. This is a suitable way of disposing of olive pomace, because the organic fertilizer obtained in this way improves the soil structure. As shortcomings in the production of this type of fertilizer, the interviewees cite the long duration of composting and the complex legal regulations in the application of the compost obtained in this way in agriculture (Figures 23 and 24).

## 10.2. SWOT Analysis

SWOT analysis is the most frequently used tool for creating a business strategy. The analysis was made in the form of a SWOT matrix, where internal factors (area of own influence) - strengths and weaknesses and external factors (which we cannot influence) - opportunities and threats are considered.

In Table 10, the SWOT analysis was created according to available secondary sources of data such as: *Law on Waste Management* (NN, No. 84/2021), *Law on Fertilizer Products* (NN, No. 39/2023), and the *Regulation on the Protection of Agricultural Land from Pollution* (NN, No. 71/2019) and according to primary data collected through interviews and a questionnaire as part of research within the CIRCOLIVE project. The main advantages and opportunities in the business with olive by-products/waste are the new products that are obtained, such as pellets from pruning residues, organic fertilizer from pomace and pruning residues. Furthermore, by-products for production are available nearby, given that olive growing is one of the leading agricultural sectors in the Adriatic part of Croatia. The olive by-product/waste market is not particularly developed yet, and there are no significant competitors in Croatia, which is an excellent opportunity for start-ups. The possibility of obtaining financial resources from EU funds can also help in this undertaking. On the other hand, the underdevelopment of this market brings with it certain weaknesses and threats, such as foreignness of the market potential and strategies for placing new products on the market. Another significant difficulty is the incompleteness of the production technology itself, the processing of by-products from olive waste, which often after implementation in the plant can show certain technical weaknesses in performance (Interview with by-products/waste from olive sector stakeholder). Legislation as such is not fully regulated in the sector of by-products/waste from

olives, and as a result there is ambiguity in the handling of certain residues and by-products from olives (Interview with by-products/waste from olive sector stakeholder; Interview with olive growing and oil production stakeholder). Although olive growing is one of the leading agricultural sectors in the Adriatic part of Croatia, if a larger number of olive waste processing plants were to be established, the problem of insufficient quantities of by-products would arise. Insufficient financial support for innovative projects, as well as the problem of assistance in the construction of basic infrastructure/facilities for the processing of olive by-products/waste, were also identified as potential weaknesses and obstacles (Interview with olive by-products/waste from olive sector stakeholder). Also, during interviews with educational program providers, no courses/educations exclusively focused on the circular economy in the olive growing sector were identified, and this is really necessary in order to involve potential new stakeholders in the business with olive by-products/waste..

Table 10. SWOT analysis of marketing by-products/waste from the olive growing sector in Croatia

Strengths	Weaknesses
<ul style="list-style-type: none"> <li>• Inovative and new products</li> <li>• The possibility to launch a start-up in the area of circular economy</li> <li>• Co-financing from EU funds for starting a business related to by-products/waste</li> </ul>	<ul style="list-style-type: none"> <li>• Unexplored market potential</li> <li>• Unfamiliarity of production technology</li> <li>• Unregulated legislation in handling by-products/waste</li> <li>• Unequal interpretation of olive by-products/waste by different ministries, which lead to ambiguity in handling</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>• Proximity to the EU market</li> <li>• Market breadth (energy market, fertilizer market, cosmetics and pharmaceutical market, food industry...)</li> <li>• Absence of significant competitors on the market</li> <li>• Proximity to available raw olive materials (by-products/waste)</li> </ul>	<ul style="list-style-type: none"> <li>• Competition in neighboring Mediterranean countries</li> <li>• More advanced technologies in competing countries</li> <li>• Insufficiently large amount of olive by-products/waste considering the total production for entering the foreign market</li> <li>• Insufficient financial support from decision-makers (politicians) regarding innovative ways of reuse</li> <li>• Absence of educational programs exclusively focusing on the circular economy in the olive growing sector</li> </ul>

### 10.3. Regulatory Challenges and Barriers

The olive by-product/waste market is still in its initial phase in Croatia, and is not fully regulated. Doing business in such an environment can be challenging because the business conditions are not defined. From interviews conducted with stakeholders from the olive growing sector, the biggest challenges in dealing with by-products and waste from the olive growing sector are the undefined legislation, different interpretations of the law by individual ministries, certain restrictions on placing such products on the market, which is why the produced by-products are often reused on the olive grove, most often in the form of organic fertilizer (Interview with olive growing and oil production stakeholder). Furthermore, with business entities that exclusively deal with the processing of by-products from the olive

growing sector, many problems arise in the technological process of processing by-products, primarily due to the specific properties of the raw material. For example, due to the higher content of oil in pomace or the greater elasticity of olive wood compared to other woods, the technology available on the market often does not follow the specified specificities of the raw material (Interview with by-products/waste from olive sector stakeholder). Also, according to the results of the conducted survey, it can be identified that there are certain legislative problems in the classification of olive pomace and its disposal in order to produce organic fertilizer and put it on the market.

According to the researched situation from the available secondary literature and primary research, it is concluded that there are significant challenges and obstacles in the market of olive by-products/waste in Croatia. The recommendation for the more successful development of this market is to first establish uniform legislation and terminology in the sector of olive by-products/waste. After that, it is necessary to offer a set of subsidies for projects aimed at the utilization and valorization of olive by-products/waste that would motivate stakeholders to improve the circular economy in the olive growing sector in Croatia.

## 11. Vocational Training (VET)

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

During the primary research conducted in Croatia as part of the CIRCOLIVE project on a sample of olive growers (N=10), olive growers and olive mill owners (N=7), and olive mill owners (N=1), it was determined that there is no training exclusively specialized in the area of by-product and waste utilization from the olive growing sector. However, certain training programs have been established that contain parts of education aimed at using by-products and waste from the olive growing sector.

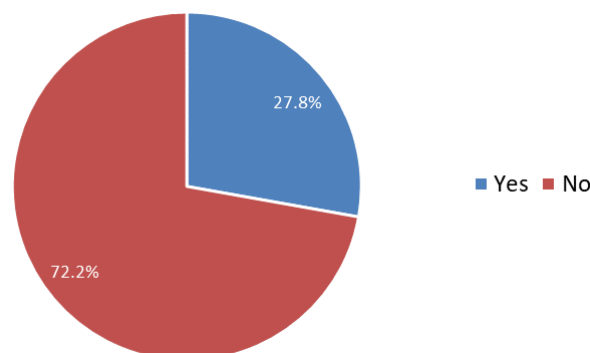


Figure 25. Data on completed courses, training and education in the circular economy (N=18)

The results of the survey showed that only 27.8% of respondents completed some form of course, training or education that had smaller parts of education related to the circular economy in olive growing (Figure 25). They stated that they completed the course for olive growers at the Diopter Open University, which included a lecture on the subject, listened to individual lectures on the subject as part of the program of Mediterranean agriculture at the

University of Applied Sciences of Rijeka, and the training provided by the Agency for Payments in Agriculture, Fisheries and Rural Development.

During the interview, a stakeholder in the olive growing and oil production sector stated that during his high school agricultural education and schooling at the Faculty of Agriculture in Zagreb, as part of some courses and subjects, he gained knowledge about the circular economy (Interview with olive growing and oil production stakeholder).

The stakeholder in the business with by-products and waste from olives had no previous education and training in the area of the circular economy (Interview with by-products/waste from olive sector stakeholder).

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

Stakeholders in education, when asked whether, according to their knowledge, there is a formal or informal form of education in the sense of circular business in the olive growing sector, they stated that they are only familiar with institutions that teach this concept as part of already existing courses and programs (Interview with education stakeholder).

According to the results of the surveys, only a small number of respondents (27.7%) had some contact with educations aimed at raising awareness and educating in the area of the use of by-products and waste from the olive growing sector (Slika 25). These trainings were only a small part of the wider trainings for olive growers conducted at the Diopter Open University, as well as the program of Mediterranean agriculture at the University of Applied Sciences of Rijeka and the lectures of the Agency for Payments in Agriculture, Fisheries and Rural Development. The educations lasted 3 to 4 months at the Open Universities, or 36 months to 5 years if it was conducted at the University of Applied Sciences of Rijeka as part of the Mediterranean Agriculture studies, but only a small part of the education was dedicated to the circular economy in the olive sector.

A stakeholder in education stated during an interview that students of the University of Zadar, specifically in the course 'Olive growing and oil production', go through 30 hours of lectures, 15 hours of seminars and 15 hours of practical classes where circular economy issues are included as a teaching unit (Interview with education stakeholder).

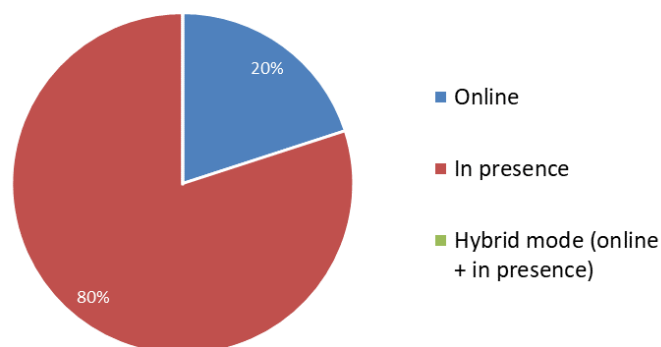


Figure 26. Method of implementation of courses, training and education in circular olive growing and/or agriculture (N=5)

According to the results of a survey of olive growers and olive mill owners about the completed educations in circular olive growing and/or agriculture, the respondents stated that the educations were mostly conducted in presence (80%), and only a small part of the education was conducted online (20%) (Figure 26).

Respondents who, as part of their education, also had lectures on the circular economy in olive growing, after completing the aforementioned education, mostly obtained the title 'olive grower' after completing a course at the Open University or the title 'Bachelor of Mediterranean Agriculture'.

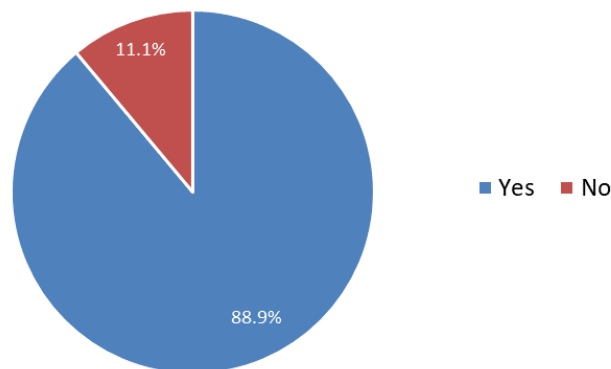


Figure 27. Expressed interest in attending a course on the valorization of olive by-products and waste (N=18)

According to the results of the primary research, about 89% of respondents are interested in attending a course that would be exclusively dedicated to education in the area of the circular economy in the olive sector, that is, the valorization of by-products and waste from olives (Figure 27).

A stakeholder in the business with by-products and waste from olives stated during the interview that he is interested in attending education in the field of circular economy (Interview with by-products/waste from olive sector stakeholder). However, a stakeholder in the olive growing and oil growing sector is interested in participating in education as an external associate or lecturer (Interview with olive growing and oil production stakeholder) because he has a lot of experience in that area and believes that he could thus contribute to the development of the circular economy in Croatia.

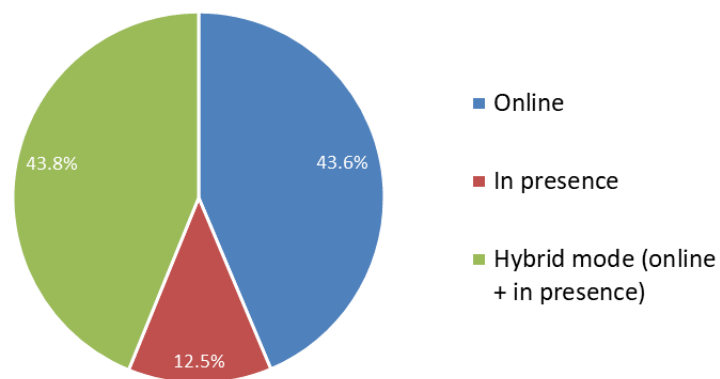


Figure 28. Preferred form of delivery of the course on the valorization of olive by-products and waste (N=16)

According to the results of the primary research conducted in Croatia, respondents indicated the online method (43.8% of respondents) and the hybrid method (online and in presence) (43.8% of respondents) as the most suitable method for conducting a course on the circular economy in the olive sector, while only 12.5% of respondents indicated that the most suitable method would be education exclusively in presence (Figure 28).

Both stakeholders in education agreed during the interview that the best technique and method of educating experts in circular business would be a combination of theoretical and practical parts and educational visits to olive groves and olive mills where this type of circular economy is already implemented (Interview with education stakeholder).

A stakeholder in the olive growing and oil production sector believes that the most appropriate method of conducting education would be in presence (Interview with olive growing and oil production stakeholder), while a stakeholder in the business with by-products and olive waste is ready to attend any of the mentioned forms of education (Interview with by-products/waste from olive sector stakeholder).

As topics from the area of circular economy in the olive growing sector that they would like to hear on the courses, the interviewees mentioned the following topics: Use of olive production residues for the production of pellets; Utilization of residues after pruning olives; Composting and production of pellets from olive pomace; Composting pomace and pruning residue; Valorization of by-products from olive mills; Composting of olive residues and composting of olive pomace; Use of by-products from olive processing; The possibility of using by-products and waste from olive processing; Processing of wet pomace and methods of its use and separation and use of olive pits; Technologies for the production of new products from olive by-products and waste; Utilization of pomace and waste water.

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

In Croatia, the existence of educational programs that exclusively deal with the circular economy in the olive growing sector has not been established, but certain forms of education

have been found that have certain parts dedicated to this topic, such as the training programs for olive growing jobs within the seven public open universities (POU). At two universities within the framework of professional undergraduate studies and at three universities within the framework of undergraduate and graduate studies, there are courses that can deal with topics from the circular economy in the olive sector, and there is potential for the establishment of new study programs that would have courses dedicated to the sustainable management of residues from olive production and circular economy.

Stakeholders in education during the interview pointed out that they believe that Universities of biotechnical sciences, Polytechnics, Public and Private public universities are an example of the best practice in Croatia in terms of education. They emphasize the advantage of community colleges as an institution that can additionally devote itself to participants who have previous knowledge and provide them with practical experience of working in olive growing (Interview with education stakeholder).

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

Potential institutions that could provide a training course on circular business in olive growing are listed in Table 11.

During the interviews conducted with stakeholders in education, as potential institutions that could provide a training course on circular business in olive growing, the respondents highlighted the University of Zadar and University of Applied Sciences of Rijeka, where they are employed, various institutions for training adults and the Croatian Employment Service which offers vouchers for the acquisition of micro-qualifications and partial qualifications from various sectors, partially co-financed by the Croatian Employment Service and EU Funds. Currently, there is training for the ecological production of medicinal plants, so in the future there would be the possibility of developing education on the topic of circular business in the olive growing sector. Stakeholders in education emphasize that the specific knowledge of the teaching staff who would carry out the aforementioned training is needed, so the choice of the institution to implement the program depends on that (Interview with education stakeholder).

Table 11. Potential institutions that could provide education on circular business in olive growing

Name of faculty/university	Study programme name	Course name
Faculty of Food and Biotechnology, University of Zagreb	Undergraduate study Food Technology	Olive processing
Faculty of Agriculture, University of Zagreb	Graduate study Horticulture – Fruit growing	Olive growing
Faculty of Food Technology Osijek, Josip Juraj Strossmayer University of Osijek	Graduate study Food Engineering	Oil and fat technology
University of Split	Undergraduate study Mediterranean Agriculture	Olive growing
University of Split	Graduate study Mediterranean Agronomy	Olive processing technology
University of Split	Graduate study Mediterranean Agronomy	Elaigraphy i elaiotechnique
University of Zadar	Graduate study Mediterranean Agriculture	Olive growing technology and olive oil production
Name of university	Study programme name	Course name
University of Applied Sciences “Marko Marulić” of Knin	Professional undergraduate study Karst Agriculture – Plant production	Olive growing
University of Applied Sciences of Rijeka – Department of Agriculture Poreč	Professional undergraduate study Mediterranean Agriculture	Olive growing
Name of public open universities	Programme name	
Libar	Olive grower	
Učilište Izvor Znanja, Vodice	Training programme ‘Olive growers’	
Učilište FINIS	Training programme for olive growers	
POU-UPA "Vodnjan-Dignano"	Training programme for olive growers	
POU Božić	Training programme for olive growers	
Diopler	Training programme for olive growers	
Učilište Cibalae	Training programme for olive growers	

## 12. Conclusion

### 12.1. Summary of Key Insights

Olive oil production is an important agricultural activity in Croatia. As this industry grows, so does the generation of by-products and waste, which presents challenges but also opportunities for sustainable practices. The main by-products of olive oil production are olive pomace, waste water from the olive mill, pits and olive leaves and branches. The production of preserved table olives has not been developed in Croatia, and therefore the remains of this production do not represent significant quantities.

During the research as part of the CIRCOLIVE project, it was determined that the conventional method of olive production is the most represented in Croatia, while ecological and integrated

methods are represented with a smaller share. Regarding the pruning residues from the winter and summer pruning of olive trees, which is carried out every year, according to the research results, it can be concluded that they do not represent a significant challenge as a by-product in the olive growing sector in Croatia, because most olive growers use the pruning residues by subjecting them to mulching, composting or pelletizing. Half of the respondents in Croatia separate the pit from the olive pomace and use it for heating or as an organic material that enriches the soil, so it can be concluded that part of the olive pits is used in a suitable way in Croatia.

In Croatia, olives are largely processed using a two-phase system for extracting the oil from the residues. The mentioned method of processing produces smaller amounts of waste water, which is adequately disposed of, purified and reused, mostly for irrigation, i.e. it is discharged into the environment or the public drainage system. The high proportion of water, organic matter and nutritious macro and micro elements are the reason why olive pomace can be used as a soil improver, but only after adequate processing. According to the results of the survey, all surveyed olive growers and olive mill owners compost wet or dry pomace in piles for more than 12 months, and only part of the pomace is scattered on agricultural land immediately after processing. Furthermore, part of the olive pomace from the two-phase processing is used for the production of pellets that are used as energy sources.

In general, the respondents' awareness of sustainability and the availability of technologies, knowledge and experience stand out as the most expressed motive when dealing with olive by-products/waste. Respondents who do not implement certain sustainable practices in olive growing state the lack of technology and knowledge, high initial investments and legal restrictions as the most common reason.

Although the olive by-product/waste market is not yet particularly developed in Croatia, research has established the existence of certain products from olive by-products/waste, such as pomace or pits, transformed into new products with different uses, such as cosmetics, organic fertilizers, firewood, which represent a valuable potential for the market. Such products generate efficient and sustainable exploitation of by-products from the olive growing sector while creating new products.

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

By-product management in Croatia is slowly developing, driven by environmental regulations and increasing awareness of sustainable practices. Despite the development of the use of residues from the olive sector, challenges remain related to the small and fragmented nature of olive oil production in Croatia, which makes it difficult to implement centralized solutions for waste management.

## 12.2. Recommendations for the Implementation of Circular Practices in the Olive Sector

One of the primary aspects of sustainability in olive growing is the adoption of ecological agricultural practices, which avoid the use of synthetic fertilizers and pesticides that lead to soil degradation, water pollution and loss of biodiversity, and therefore this form of agricultural practice should continue to be encouraged in Croatia.

The increase in the volume of olive production in Croatia is accompanied by an increase in the amount of organic residues from that production, primarily residues from olive pruning and processing. Residues after pruning can be shredded in the plantation itself using a mulcher. This way of using pruning residues enriches the soil with organic matter, and in this way olive growers directly encourage the circular economy and reduce the need to introduce organic matter in olive groves. However, the residues after olive pruning can be composted and further used as organic fertilizer, but also pelletized and used as a high-value energy source.

In the olive oil production process, sustainability efforts should also be focused on energy efficiency, waste management and reduction of greenhouse gas emissions. Many olive mills in Croatia invest in energy-efficient technologies, such as modern centrifuges, which reduce energy consumption during oil extraction. It is also recommended to use renewable energy sources, such as solar panels, to power olive mills, which further reduces the sector's carbon footprint. Management of waste and by-products from olive processing is a significant challenge in olive oil production, but also provides opportunities for sustainable practices.

Olive pomace and vegetable water, the main by-products, should be reused instead of being disposed of as waste. Olive pomace, which remains after the processing of the fruits, needs to be composted and can then be spread over the olive groves as an organic fertilizer. Also, olive pomace can be mixed with green and bio waste from the household and composted together. Composting pomace and pruning residues reduces organic waste, but the biggest drawback of this method of disposal in Croatia is the lack of an organized composting system in the area, as well as the length of time and space required for composting. This is a suitable way of disposing of olive pomace, because the organic fertilizer obtained in this way improves the soil structure.

There are other more innovative methods of using pomace, such as the use in biogas production, which has not yet taken off in Croatia. Although some forms of sustainable management are applied in Croatia in the olive growing sector, the increased volume of organic residues from olive growing requires a wider application of innovative practices in the management of this biomass based on the principles of the circular economy. Water management is another key element of sustainable olive growing. Therefore, the reuse of purified water from olive mills for irrigation of olive groves should be encouraged as one of the practices in sustainable olive growing. Also, an increasing number of olive mills are installing equipment for extracting pits from pomace, which is then used as a very valuable, energy-rich fuel. After extracting the stone, it is mostly used in Croatia as an energy source in its original form, and as an organic fertilizer, which are both suitable ways of reuse.

Since the existence of vocational education and training on the topic of the circular economy has not been established in Croatia, it is recommended to create independent programs that

would provide adequate education to interested stakeholders and provide them with the necessary knowledge and skills to implement circular business models in olive growing.

### 12.3. Policy Implications and Recommendations

The management of olive by-products and waste in Croatia is developing, driven by environmental regulations and increasing awareness of sustainable practices. The remains of organic mass from olive production can be valorized in the context of the circular economy, which, in the green transition strategy, is one of the key topics of the common agricultural policy of the European Union.

The main advantages and opportunities in dealing with by-products/waste from olives are the new products that are obtained and the proximity of the available raw material, which is concentrated in the area of Adriatic Croatia. Since the olive by-product/waste market is not yet particularly developed, there are no significant competitors in Croatia, which is an excellent opportunity for start-ups that opens up the possibility of obtaining financial resources from EU funds.

However, according to the researched situation from the available secondary literature and primary research, there are significant challenges and obstacles in the market of olive by-products/waste in Croatia. Since this market in Croatia is only in its initial phase of development, it is not fully regulated, which brings with it certain weaknesses such as lack of knowledge of market potential and strategies for placing new products on the market. The biggest challenges in dealing with by-products and waste from the olive sector are the undefined legislation, as a result of which there is ambiguity in the handling of certain olive residues and by-products, which is why the produced by-products are most often reused on farms in the form of organic fertilizer. Furthermore, a significant difficulty is the lack of knowledge of suitable technology for the processing of by-products and waste from olives, primarily due to the specific properties of the raw material and the lack of sufficient knowledge in this area. Insufficient financial support for innovative projects and the lack of assistance in the construction of basic infrastructure/facilities for the processing of olive by-products/waste were also identified as potential weaknesses and obstacles. In addition, no educations exclusively focused on the circular economy in the olive growing sector have been identified, which is extremely necessary in order to involve potential new stakeholders in the business with olive by-products/waste.

The recommendation for the more successful development of this market is primarily to establish uniform legislation and terminology in the sector of olive by-products/waste. After that, it is necessary to offer subsidies for innovative projects aimed at the utilization and valorization of olive by-products/waste that would motivate stakeholders to improve the circular economy in the olive growing sector in Croatia. In addition, the existence of adequate professional education and training on the subject of the circular economy would provide the necessary knowledge and skills to implement circular business models in olive growing in Croatia. By adopting integrated waste management strategies and investing in research and development, Croatia could improve the sustainability of olive oil production and contribute to the circular economy in the olive sector.

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## 14. Appendices

### 14.1. Glossary of Terms

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## 14.2. Survey Questionnaires and Interviews

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

#### ANNEX 1: ONLINE SURVEY TARGETING MSMEs IN THE OLIVE SECTOR

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

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

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

The answers to this survey will help us in developing of skills for introducing circular business models and digital technologies in olive oil sector.

In this survey definition of **Circular Economy** presents methods and possibilities of using olive by - products and waste in olive sector.

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

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

- questions for olive producers

- questions for olive producers

1. Volume and characteristics of olive production on the enterprise

- Total area under olive groves \_\_\_\_\_ ha
- Total number of olive trees by age
  - o Olive groves until 5 years \_\_\_\_\_ trees

- Olive groves between 5 to 20 years \_\_\_\_\_ trees
- Olive groves older than 20 years \_\_\_\_\_ trees

2. Technology used in your olive grove (one answer)

- a) Conventional
- b) Ecological with eco-label
- c) Other

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

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

4. Type of soil management in your olive grove

- a) Soil cultivation
- b) Mulching (mulching permanent grassland and pruning residues)
- c) Combination of the first two ways
- d) Other:

5. Intensity of winter pruning in your olive grove
- a) Every year
  - b) Every couple of years
  - c) None
6. Intensity of summer pruning in your olive grove
- a) Every years
  - b) Every couple of years
  - c) None
7. Select the procedure with olive pruning residues in your olive grove (multiple answers is possible)

Procedure

- |   |
|---|
| a) Mulching (mulching permanent grassland and pruning residues)                   |
| 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	High initial investment and costs
for	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 plantation requires a lot of work	1	2	3	4	5
It is not useful because valuable organic material is lost	1	2	3	4	5
It is harmful to the air and the local ecosystem	1	2	3	4	5

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

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

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

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



Equipment for pellets production is expensive	1	2	3	4	5
The production of pellets requires a large consumption of energy, so their production is not ecologically justified	1	2	3	4	5
There is no organized system for the production of pellets in the area	1	2	3	4	5
The price of pellets is high compared to other energy sources	1	2	3	4	5

- questions for olive mill owners

13. Installed olive mill capacity: \_\_\_\_\_ kg/hour

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

2021 year - \_\_\_\_\_ olive fruit tons

2022 year - \_\_\_\_\_ olive fruit tons

2023 year - \_\_\_\_\_ olive fruit tons

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

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

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

Other \_\_\_\_\_

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

Yes - No

17. In witch phase are pits being separated?

a) Before milling the fruits

b) After oil extraction, from dry or wet pomace

c) Not applicable

Other \_\_\_\_\_

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

a) It is scattered on agricultural soil immediately after processing

b) Heap composting

c) As biofuel

d) For production of ecological products.

e) For the production of construction materials.

f) Livestock nutrition

g) Is disposed of at a waste disposal site

Other (specify): \_\_\_\_\_

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

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

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

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

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

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

- Recycling and reuse in the olive processing
- For production of biofuel (biomethane)
- Purification and reusing (irrigation)
- 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	I don't agree	Neither agree	I agree	I fully agree
---------	---------------	---------------	---------	---------------

	agree at all		nor disagree		
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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