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Entela Çobani[1], Xhuana Xhika[2], Denisa Selimi[3]

MANAGEMENT PROBLEM OF OLIVE POMACE GENERATED AS A WASTE BY-PRODUCT DURING THE OLIVE OIL PRODUCTION. CASE OF THREE-PHASE OLIVE OIL MILL IN ELBASAN COUNTY, ALBANIA.

Abstract

The olive sector is one of the most important agro-industrial sectors in the world and especially for the Mediterranean region, as it is the largest producer and consumer in the world, where about 95% of global production is concentrated there, with Spain as the biggest producer. In the recent years (2000s-2010s) the cultivation of olive trees has grown in Albania, where about 100,000 farmers (one third of total farmers in Albania) are involved in olive growing and olive processing. However, the production of olive oil also generates solid and liquid wastes, which have great impacts on the environment, if not treated, including surface and groundwater contamination, air pollution and soil degradation. These wastes are generated in large quantities during a short period of time, of around 4 months (October-January) leading to serious management problems. The main wastes coming from olive processing are Olive Mill Wastewater (OMWW) and Olive Pomace (OP), which depending on the type of olive oil mill (pressing or centrifugation), take on different physicochemical characteristics but essentially all wastes are characterized by phenolic compounds, fats, high organic load and acidic pH of 4.8-5.2. In this paper, we will focus only on the solid waste, where we will calculate the amount of olive pomace produced by olive mills in Albania and Elbasan County (the third largest county producer in national level in Albania for olive oil and table olives) for olive production year of 2022, we will see the three possible scenarios of olive pomace treatment and management plans and finally we will present a case study of a three-phase olive oil mill in Elbasan County which has implemented a solid waste treatment unit for this waste by-product as a solution for the management problem of olive pomace.

Keywords

olive mills, olive pomace, olive waste by-products, phenolic compounds

[1] *Dr. Entela Çobani, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania, email: entela.cobani@fin.edu.al*

[2] *BSc. Xhuana Xhika, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania, email: xhuana.xhika@fin.edu.al*

[3] *BSc. Denisa Selimi, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, St. Muhamet Gjollesha 54, 1023, Tirana, Albania, email: denisa.selimi@fin.edu.al*

1. OLIVE OIL PRODUCTION IN ALBANIA & ELBASAN COUNTY

Like every other Mediterranean country, the olive cultivation in Albania represents an important, traditional and old agricultural activity, with an important economic, social and historical significance. The olive cropping area in Albania is situated in the western coastal region, which represents 36,2 % of the country territory and where about 60 % of the population lives. It extends from the northern border of Shkodër to Konispol to the south, by penetrating the mainland towards the east, through river valleys, creating a continuum of olive groves [2].

Olive cultivation is important for the Albanian agrifood sector as represented by the fact that about one-third of the farmers operate in the olive sector. Currently the number of olive trees is estimated at around 11 million and the olive area is estimated at about 54,000 ha. However, compared to other mediterranean countries, the olive sector in Albania is far behind in terms of the number of plants per capita (around 3.5 compared to 4-10 plant per capita in Italy, Spain and Greece), as well as in terms of yield per plant and overall product quality. Some of the problems that Albania has in the olive oil sector are very small orchards at a competitive disadvantage, the difficulty of mechanization because of steep land, lack of pruning, irrigation and phytosanitary measures and lack of basic technical skills on processing [2].

Table 1. Olive production in Albania (source: Institute of Statistics of Albania)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production (000 ton)	92	98	96	99	107.8	117.6	98.3	132	110.2	157.7

Olive cultivation for the olive oil production is highly concentrated in the counties of Fier, Berat, Vlore and Elbasan, which together cover 80% of total production. Most of the olive processors (olive oil mills) are also located in these regions [1].

Elbasan is the third most important region in terms of olive production, especially the olives for olive oil production.This area has 19,598 lands spread over 9,763.216 ha, where about 2,370.999 olive trees are planted, where the typical variety for the Elbasan area is “Mixani i Elbasanit”. The area with the highest productivity in the Elbasan region is the Dumrea area with Belsh City as its center. This region is because it has some advantages:

1. Large land areas, around 0.35-0.4 ha per capita, among the highest in Albania.
2. Dumrea is rich in water, with abourt 85 karst lakes.
3. There are many immigrants or seasonal workers in Greece, who have brought their knowledge here, creating their own businesses in the field of olive cultivation.

All these factors combined have led to a large increase in olive plantations, olive mill factories and olive oil, as well as an increase in the generation of olive wastes and by-products [1].

1.1. OLIVE OIL MILLS

There are currently three different types of olive mill factories: traditional factory, two-phase system factory and three-phase system factory.The first type of factory is based on the pressing

process, while the other two are based on the centrifugation process for olive oil exctraction. Pressing process for olive oil exctraction has existed since the ancient times, and it still exists today but as an outdated method, which continues to be preferred by some countries such as Greece.

The three-phase system factory was first created in the 70s, which today has a fairly wide use in our country. The products at the end of the centrifugation process in factories with a three-phase system are: olive pomace or olive husk (with moisture 40-45%), olive mill wastewater and olive oil. A very important disadvantage of the three-phase system is the increase in the amount of wastewater generated, due to the increased water consumption at the centrifugation process [3].

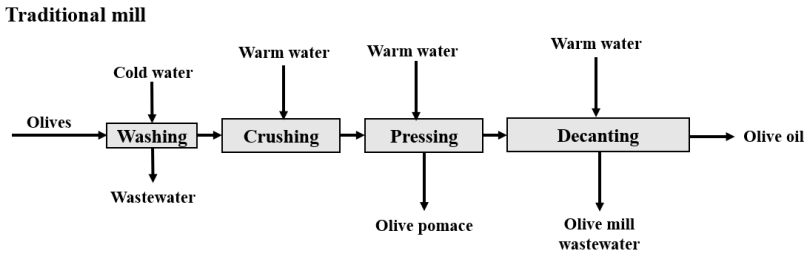


Figure 1. Scheme of traditional factory [3].

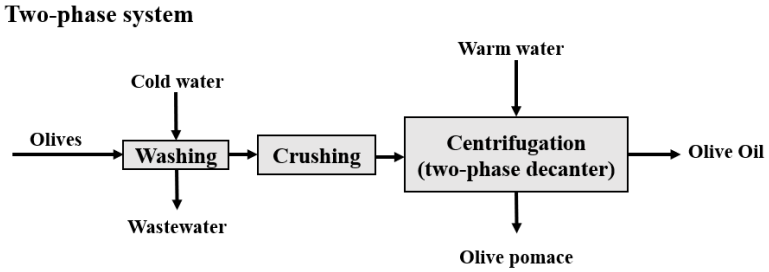


Figure 2. Two-phase system [3].

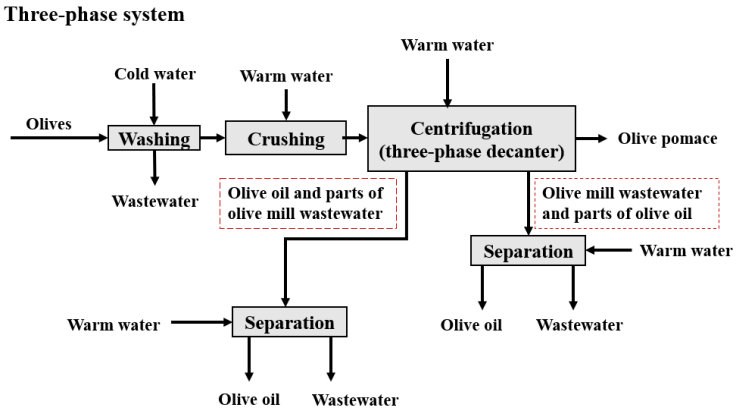


Figure 3. Three-phase system [3].

In the early 90s, several companies promoted new types of centrifuges that could separate olive oil and olive pomace from the source without the need to add water. This type of centrifuge is used in factories with a two-phase system, which is characterized as ecological due a reduced water consumption and is called two-phase system since two products are produced: olive oil and olive pomace with a moisture content of 55-70%.

In Europe, Spain has completely replaced three-phase systems with two-phase systems, while there are many countries like Albania, where the three-phase system prevails. The main disadvantage of two-phase systems is the increased moisture content of the solid product, which makes it difficult to manage it, transport it and treat it.

Table 2. Inputs and Outputs [3].

	Inputs		**Outputs**	
Traditional pressing	Olives Water for olive washing Energy	1000 kg 0.1-0.12 m^3 40-63kWh	Olive oil Olive pomace Olive mill wastewater	~200 kg ~400 kg 0.4-0.6 m^3
Three-phase process	Olives Water for olive washing Water for centrifugation Energy	1000 kg 0.1-0.12 m^3 0.5-1 m^3 90-117 kWh	Olive oil Olive pomace Olive mill wastewater	~200 kg ~500-600 kg 1-1.2 m^3
Two-phase process	Olives Water for olive washing Energy	1000 kg 0.1-0.12 m^3 <90-117 kWh	Olive oil Olive pomace Olive mill wastewater	~200 kg ~800-950 kg 0.085-0.11 m^3

1.2. CHARACTERISTICS OF OLIVE POMACE

At the end of the olive oil processing, factories produce solid waste from two sources. The first source is the olive leaves and stems that come from the olive washing at the beginning of processing, and the second source is the pits that come after the pressing and centrifugation process. A determining parameter for the mass and volume of olive pomace is the moisture content of the olive fruit, the higher the moisture content, the greater the volume of waste produced.

Another factor that affects the volume of olive pomace generated is the system the olive mill factory uses. The solid waste produced often contains a high % of moisture and oxygenated compounds such as phenols, consequently these affect the reduction of the calorific value of the olive pomace. Other compounds found in olive pomace that have polluting potential are amounts of Cl (HCl, furan or dioxin), as well as the potential to lower the pH of soils by turning them acidic and increasing soil salinity and making soil hydrophobic, as inflitration decreases [3].

As mentioned earlier, different olive oil production methods produce residues with different compositions. The table below shows the physical and chemical parameters of solid waste from

olive factories with three different production methods. Based on the table, it is found that factories that use the two-phase production system produce solid waste with the highest percentage of moisture, compared to other olive oil production methods.

Table 3. Characteristics of olive pomace for three different olive mills [3].

Characteristics	Pressing	Three-phase	Two-phase
Moisture (%)	27,2 ± 1,048	50,23 ± 1,935	56,80 ± 2,188
Fats-Oils (%)	8,72 ± 3,254	3,89 ± 1,449	4,65 ± 1,736
Proteins (%)	4,77 ± 0,024	3,43 ± 0,017	2,87 ± 0,014
Saccharides (%)	1,38 ± 0,016	0,99 ± 0,012	0,83 ± 0,010
Celulose (%)	24,1 ± 0,283	17,37 ± 0,203	14,54 ± 0,170
Ash content (%)	2,36 ± 0,143	1,70 ± 0,105	1,42 ± 0,088
N-organic (%)	0,71 ± 0,010	0,51 ± 0,007	0,43 ± 0,006
P (%)	0,07 ± 0,005	0,05 ± 0,004	0,04 ± 0,003
Phenolic compounds (%)	1,14 ± 0,06	0,326 ± 0,035	2,43 ± 0,15
K (%)	0,54 ± 0,045	0,39 ± 0,033	0,32 ± 0,027
Ca (%)	0,61 ± 0,059	0,44 ± 0,043	0,37 ± 0,036
TOC (%) – Total Organic Carbon	42,9 ± 3,424	29,03 ± 2,317	25,37 ±2,025
C/N	60,7 ± 5,352	57,17 ± 5,033	59,68 ± 5,254
C/P	588,7 ± 51,25	552,9 ± 48,20	577,2 ± 50,31

Due do the high organic load, phenolic compounds, oil content, acidic pH the olive pomace has great impacts in the environment if not managed or treated such as: harmful emissions if it is burned, soil contamination, increasing soil salinity, decreases soil infiltration etc.

1.2.1. The olive pomace generated in Albania and in Elbasan County for 2022 olive crop year.

Based on table 4 (olives in tons for oil production) and 5 (olive pomace produced by the type of factory), we will calculate the amount of olive pomace produced for the three-phase and two-phase factory in Albania and Elbasan County for the year 2022.

Table 4.Olives used for oil production in crop year 2022.

Agricultural production in tons of olives used for oil production (2022)	
In Albania	**In Elbasan County**
157,700 ton	25,564 ton

Table 5. Olive pomace generated for two and three-phase process [3].

Type of centrifugation	Olive pomace generated from 1000 kg of olives
Two-phase process	950 kg/ton
Three-phase process	600 kg/ton

Olive pomace produced in Albania in 2022:

1. Two-phase process:

$[OP]_{produced}$ = mass $_{olives}$ x OP $_{two\text{-}phase}$ =157,700 ton x 950 kg/ton =149,815 ton

2. Three-phase process:

$[OP]_{produced}$ = mass $_{olives}$ x OP $_{three\text{-}phase}$ =157,700 ton x 600 kg/ton =94,620 ton

Olive pomace produced in Elbasan County in 2022:

1. Two-phase process:

$[OP]_{produced}$ = mass $_{olives}$ x OP $_{two\text{-}phase}$ =25,564 ton x 950 kg/ton =24,285.8 ton

2. Three-phase process:

$[OP]_{produced}$ = mass $_{olives}$ x OP $_{three\text{-}phase}$ =25,564 ton x 600 kg/ton =15,338.4 ton

1.2.2. Three possible scenarios of olive pomace treatment and management plans

The treatment techniques for olive pomace include two methods: *biological methods* and *thermal methods*. Biological methods include anaerobic digestion and composting. Anaerobic digestion uses microorganisms which, in absence of oxygen, break down complex compounds into simpler compounds. At the same time, this process is accompanied by the methanization process, which produces the gases that make up biogas. After biogas production, it can be used in boilers for heating systems in households or olive mills boiler, but it can be also used to produce electricity that covers the expenses of the olive mill. Composting is another method that it can be used for the olive pomace treatment, when the final product is effectively composted into a valuable organic fertilizer and soil conditioner, and it can be applied in soils that are degraded or nutrient-deficient [3],[5].

In the thermal methods there are a lot of techniques, including: pyrolysis, incineration, gasification etc. All these methods use temperature to treat olive pomace, but depending on the needs, requirements, costs they are applied in different cases. For example, in Greece there are some plants called olive pomace treatment plants, that use temperature and hexane for olive pomace oil extraction and olive husk producing. Due to extremely high costs, treatment of olive pomace is neglected and is often deposited in the environment without any criteria, causing a lot of environmental problems and that is the main reason we need to manage and treat it properly.

For the olive pomace management and treatment there are three possible scenarios that can be applied in: *individual level, common level,* or *central level*. The individual level means that every olive mill factory needs to implement a special unit for olive pomace treatment, but taking into consideration, that most of the factories are with three-phase system, which means that besides the

solid waste they have to manage and treat the olive mill wastewater, they usually deal only with the wastewater and the olive pomace is deposited in the ground around the mill area without any criteria or treatment. This happens because the amount of solid and liquid wastes for an olive season produced by the mill is exceptionally large, which is associated with high costs for treatment units. In other words, is exceedingly difficult for a mill factory to properly treat its wastes, because even if it has a treatment unit, this unit will have a low-cost technique but not necessarily effective [4].



Figure 4. Olive pomace dumped in soil (source: oikologicarodiaka.wordpress.com)

The central level refers to a big treatment unit that collects all the wastes produced by factories in a region, a county etc. The main benefit of large treatment plants is the use of advanced technologies such as anaerobic digestion (biogas production) for electricity or a big olive pomace drying center, associated with olive mill wastewater treatment or not. The central treatment of olive wastes is an expensive and voluminous solution, in addition to the fact that olive oil factories only operate 4 months a year, so the costs of construction, waste transportation, maintenance, and operation are very high [4]. The third plan (the most effective) concerns small plant units, where groups of olive processing factories are located in close proximity to each other and can transport and collect easily their waste for treatment. To avoid transportation costs, it is recommended that the treatment unit be located within the territory of their factories or near them.

1.3. CASE OF OLIVE MILL FACTORY LOCATED IN ELBASAN COUNTY, ALBANIA

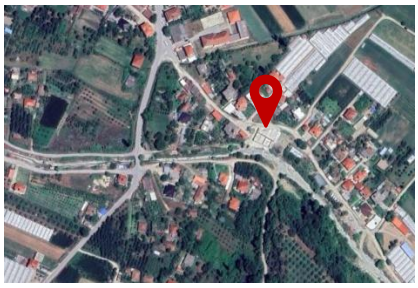


Figure 6. Satellite image of the olive oil mill (photo withdraw from Google Earth).



Figure 7. Olive pomace dryer

As a case study is taken an olive oil processing factory, built in 2021, in the village of Selita, approximately 33 km from the city of Elbasan and 18 km from the city of Cerrik. The coordinates of the mill are X= 40.886314 and Y= 19.979095. The mill has a three-phase centrifugation process, with three products at the end. In 2023, this mill saw the need to implement a unit for the treatment of olive pomace due to the large amount produced and the lack of storage space. Therefore, it installed a pomace dryer with a drying capacity of three tons/hour, thus solving the pomace management problem. Now this dried pomace is used for the factory boiler and sold for residential heating systems, thus compensating the excessive cost of installation.

CONCLUSIONS AND RECOMMENDATIONS

Although the olive sector is a very important agro-industrial sector in Albania, it is associated with a large amount of OP produced. According to physicochemical properties of OP, it was observed that it contains substances with a polluting potential such as phenols and polyphenols. Through the calculations we saw that for the crop year 2022 if all olive mill factories had two-phase systems, the amount of OP generated in Albania and Elbasan County was: 149,815 ton and 24,285.8 ton. The high costs of treatment,lack of knowgledge, negligence of various operators have caused OP in most cases to be thrown into the ground without being treated and without any criteria. Knowing the negative effects that olive pomace has on the environment, it is necessary to treat it, but starting from the high costs of installing treatment units, we analyzed three possible management scenarios and concluded that the best scenario is the cooperation of two to three factories to treat their waste jointly. In this way, costs can be shared between factories and a satisfactory treatment technique is chosen, depending on the factories' requirements. In the case of Albania, as a country where the economy relies on agriculture and toursim, the biological method of composting will be recommended, which is considered on of the low-cost methods.

Another problem that is often encountered in Albania is the drying of olive pomace in the open air, on unprotected ground and then using it in factory biomass boilers or for heating systems in households. In other European countries such as Greece, Italy and Spain, this is prohibited because olive pomace still contains olive pomace oil, which is then burned and causes air pollution. This is due to the lack of normatives acts for the management and treatment of olive waste. To avoid ths problem it is recommended that the olive pomace used in heating systems of mill boilers to be dryed in olive pomace dryer as the example of the mill that we took as a case study in Elbasan County.

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