

**Review Article**

**OLIVE POMACE: FROM AN OLIVE MILL WASTE TO A RESOURCE, AN OVERVIEW OF THE NEW TREATMENTS**

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Received: 31 Jul 2018 Revised and Accepted: 01 Nov 2018

**ABSTRACT**

In this article, an overview of treatment alternatives of olive pomace that is olive oil mill waste are covered. Olive pomace characteristics, the new treatments for improving the extraction of olive oil are mentioned. Attention is drawn to present-day applications of olive pomace. The search concerning the improving of the nutritional value of olive pomace is referred, focusing, on biological treatment with microorganisms in liquid and solid-state fermentation.

**Keywords:** Olive pomace, Biotreatment, Valorisation

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DOI: <http://dx.doi.org/10.22159/jcr.2018v5i5.28840>

**INTRODUCTION**

Olive oil farming is a significant feature of land use in Mediterranean regions [1], covering over five million hectares in the EU Member States [2]. Most of the world's production of olive oil, 2918000 tons in 2017 (International Olive Council, 2017) [3], is based in the countries of southern Europe, the Near East and North Africa, where olive (*Olea europaea* L.) cultivation is a centuries-old tradition, especially for oil extraction [4]. However, many other countries such as Argentina, Australia, and South Africa are becoming emergent producers since they are promoting intensive olive tree cultivation [5].

Olive pomace, also called, olive cake or olive husk is the solid residue obtained after olive oil extraction. It is one of the most abundant agro-industrial by-products in the Mediterranean area [6]. According to the International Olive Council reports, 2017, world olive production in 2018 is expected to come in at around 6000000 tons. The olive pomace consists of the lignocellulosic matrix (cellulose, hemicelluloses and lignin) with phenolic compounds, uronic acids, and oily residues [7, 8]. The amount and physicochemical properties of these residues (olive pomace) produced will depend on the method used for the extraction. Indeed, there are two ways of extracting the oil: traditional pressing, used for many centuries with only minor modifications and centrifugation (two and three-phase system) one, that the olive oil industry has taken over in the last decades [5].

The management of these huge quantities of residues involves a problem for these industries due to their high phytotoxicity [5] and their potential as pollutants in some cases and to the costs associated to the treatments needed for their proper removal [7, 9, 10].

This study provides a summary of updated information on research works that propose different valorisation methods based on scientific studies, laying special emphasis on olive pomace.

**Search criteria**

In this review, articles were included from Google Scholar, Mendeley, Research gate, PubMed databases, and Science Direct, using several keywords for search: olive pomace/cake, olive oil, extraction system of olive oil. The articles were selected for reviewing using as a filter from the most recent to the oldest.

**Olive oil extraction systems and waste products**

The extraction of olive oil involves different processes such as washing the olives, grinding, mixing and the extraction itself, which

is the basic step of the whole process. The quantity and physico-chemical properties of the waste produced will depend on the method used for the extraction [11, 12]. Discontinuous (press) and continuous processes are the main methods used in the production of olive oil. According to the separation method used in continuous operation, two technologies are recognized: two and three-phase centrifugation processes [11, 12]. Even though traditional pressing is a relatively obsolete technology, it is still in use by some olive oil producers in the world. In the traditional press process, olives are washed, crushed and kneaded. The resulting paste is then pressed to drain the oil. After extraction, a solid fraction, called olive pomace, is obtained as a by-product with an emulsion containing the olive oil which is separated by decantation of the remaining wastewater of the oil mill (fig. 1). It is also a three-phase system as it generates three fractions at the end of the process: a solid (olive pomace) and two liquids (oil and wastewater) [12, 13].

On the other hand, the three-phase continuous centrifugation system, which is the predominant process in modern oil mills at the Mediterranean level, generates three phases: oil, wastewater, olive pomace. The extraction of olive oil is done in successive phases, unlike the discontinuous process. The olives are washed, crushed, mixed with hot water and kneaded to form the olive paste which is then diluted. The liquid and solid phases are separated by centrifugation giving the olive pomace and must (an emulsion). The must then undergoes centrifugation to separate the oil from the wastewater (fig. 1). Despite the advantages of this system over pressing (complete automation, better oil quality, reduced surface area), it also has drawbacks (higher water and energy consumption, higher wastewater production and installations more expensive) [4, 12, 14].

For the two-phase centrifugation system, the olives undergo the same steps as those of the previous three-phase system. However, this method of extracting olive oil works with a new two-phase centrifugal decanter (oil and olive pomace) which does not require water for the separation of oily phases and solids containing olive pomace and wastewater. This system was launched on the market with the labeling of "ecological", due to the reduction of water consumption, and "two phases" because it produced two fractions: a liquid (olive oil) and a solid called wet olive cake (fig. 1) [12–14].

The choice of the extraction system determines a variation of the performance in the case of the super-intensive farming method [15]. Indeed, the 2-phase system can only be used for industrial

production, where by-products (mainly olive oil and heat energy) is of considerable economic value [16]. The renewed attention to this system for its qualitative advantage superior to the 3-phase system

does not justify the switch to the 2-phase system whose residue management requires colossal technical means and obeys precise economic objectives [16].

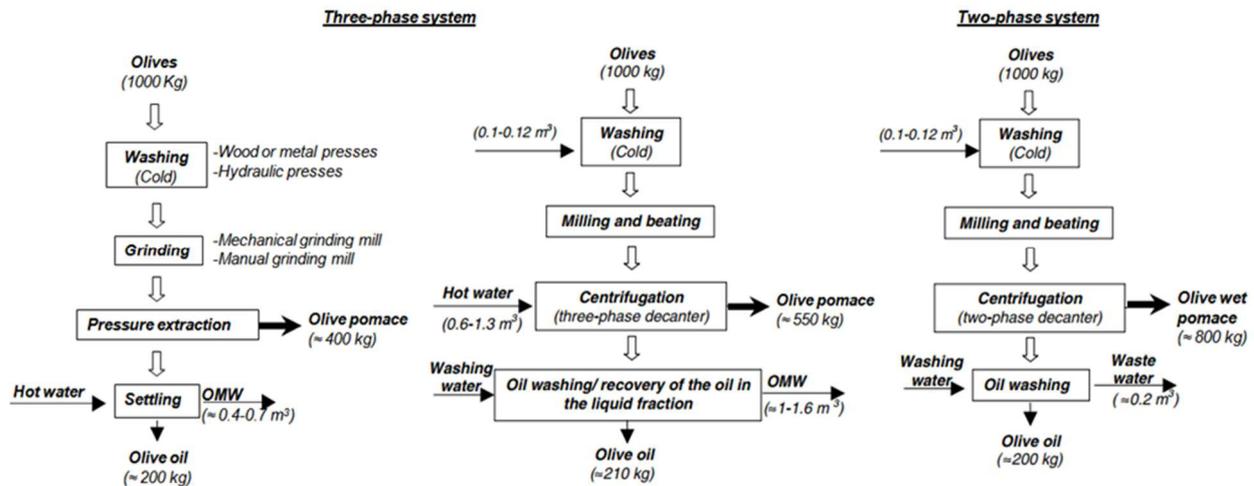


Fig. 1: Comparison between the three different extraction systems for olive oil [4, 11]

### New treatments for improving the extraction of olive oil

In addition to the conventional extraction method mentioned above, other methods can be applied in the processing of olive oil to improve its extraction. Indeed, several recent studies have been conducted in this sense:

- The treatment by "megasonic waves" of the pulp before the mixing allows to increase the extraction rate of the olive oil without the alteration of its characteristics [17–19].
- The substitution of the mixing process by microwave heating then by megasonic treatment of the dough [20].
- The warm water pretreatment of olives improves the extraction of olive oil [21].
- The addition of formulations containing a number of hydrolytic enzymes, particularly pectinases, xylanases, and cellulases, during the mixing, increases the oil extraction yields [22].
- The addition of Calcium Carbonate at the beginning of the mixing phase would significantly increase the extraction yield of the olive oil [23, 24].
- It is possible to extract oil from uncrushed olives (without any size reduction) using solvent using pressure and high temperature [25]. This process can replace the kneading step of the conventional extraction process. According to Al-Otoom *et al.* [25], not crushing the olive fruit will reduce the energy consumption and operating cost of the oil extraction process and will also increase the yield of olive oil extraction.
- Replacing the traditional mechanical crusher by partial de-stoner machine [26].

### Solid by-product (Olive pomace and wet pomace)

Olive pomace is the solid brown residue resulting from the process of producing olive oil. It consists of the crushed hull, the skin and the pulp of the olive; It still contains a certain amount of oil and a large amount of water depending on the variety of olives, and especially the extraction process used [27–29].

On average, 1000 kg of olives produces 200 kg of oil, whatever the extraction system used, it also produces the quantities in residues which varies according to the extraction system used (fig. 1):

- 400 kg of olive pomace (35% humidity) and 600 kg of wastewater (vegetable water) using the traditional system [4, 5, 30].
- 550 kg of olive pomace (50% water content) and 1000-1200 kg of oil mill wastewater using the continuous three-phase system [21, 26].
- 800 kg of olive pomace (60% humidity), using the continuous two-phase system [4, 5].

### Characteristics and nutritional value of olive pomace

The chemical composition of olive pomace varies within very wide limits. It depends on the intrinsic factors of the fruit (variety, stage of maturation), the process of extraction of the oil and the depletion of the solvent [27]. The raw olive pomace contains the crushed hull, skin, pulp, water (~ 25%) and residual oil (4.5-9%) [32], with cis-oleic acid as the most abundant fatty acid [33]. Olive pomace contains small amounts of organic nitrogen (crude protein) and a high proportion of fiber [5]. On average, the olive pomace contains 10% hemicellulose, 15% cellulose and 27% lignin. These parameters make it possible to classify this product in a highly lignified and walled substrate of very low digestibility. The digestibility of hemicellulose (50-60%) is almost double that of cellulose (26-43%) [32]. The high fiber content renders olive oil easily digestible for ruminants [6,34]. The cellulose content in olive pomace varies between 14% and 26%, but this important amount of energy source is blocked in the lignocellulosic complex and remains inaccessible to the microorganisms of the ruminant [35]. The lignin content is particularly high. Olive pomace contains phenolic compounds among the factors that inhibit the growth of microorganisms. They come from the olive whose phenolic compounds represent 0.3% to 5%, but also from the degradation of lignin as a function of the treatment carried out [36].

The chemical composition, given by several authors, is summarized in table 1. The olive pomace has a slightly acidic pH, a high concentration of organic matter (mainly fibers) and particularly rich in potassium. Polyphenols are the other interesting compounds found in olive pomace. Unlike other organic residues proposed for agricultural purposes, the concentration of heavy metals in olive pomace is almost non-existent (concentration below 1 mg/kg for Lead, Cadmium, Chromium, and Mercury).

Table 1: Physico-chemical characteristics of olive pomace from different extraction systems

| Parameters                           | Traditional system | Continuous system |            | References   |
|--------------------------------------|--------------------|-------------------|------------|--------------|
|                                      |                    | 3 phases          | 2 phases   |              |
| Size (mm): diameter (D), languor (L) | D6.1, L22.5        | D6.1, L22.5       | D6.1, L21  | [37]         |
| Density (kg/m <sup>3</sup> )         | 622.5              | 622.5             | 653-780    | [37,38]      |
| Conductivity (mS/cm)                 | 0.5                | 0.5               | 2.6-3.42   | [4,39]       |
| Durability (%)                       | 97.5               | 97.5              | 91.41-92.6 | [37,38,40]   |
| heating value (MJ/kg)                | 19.6               | 19.6              | 20.4       | [37,38]      |
| pH                                   | 5,29               | 6.6               | 5.1-5.32   | [4,39,41]    |
| Moisture (%)                         | 27.9               | 44.1-51.2         | 78.7-64    | [14,41]      |
| Ashes (%)                            | 3.55               | 2.4               | 4.3-6.74   | [4,37-39]    |
| Organic matter (g/kg)                | -                  | -                 | 932.6      | [4,39]       |
| lignin (g/kg)                        | 194.7              | -                 | 426.3      |              |
| Hemicellulose (g/kg)                 | 168.4              | -                 | 350.8      |              |
| Cellulose (g/kg)                     | 114.9              | -                 | 193.6      |              |
| Fat (g/kg)                           | 60-87.2            | 40-46             | 121        | [4,14,42]    |
| Protein (g/kg)                       | 65.1               | -                 | 71.5       | [4]          |
| Organic carbon (g/kg)                | 429                | 490±2             | 514-524.3  | [4,14,38,41] |
| Soluble phenols (g/kg)               | 11.46              | 4.5±0.4           | 31.7       | [4,38,41]    |
| Nitrogen (g/kg)                      | -                  | 10.4±2.0          | 16.2-19.8  |              |
| Phosphorus (g/kg)                    | -                  | 1.2±0.2           | 0.7-1.2    |              |
| Sulfur (g/kg)                        | -                  | 0.013             | 0.011      | [37]         |
| Hydrogen (g/kg)                      | -                  | -                 | 6.56       |              |
| Arsenic (mg/kg)                      | -                  | <0.1              | <0.1       |              |
| Cadmium (mg/kg)                      | -                  | <0.05             | <0.05      |              |
| Mercury (mg/kg)                      | -                  | <0.05             | <0.05      |              |
| Nickel (mg/kg)                       | -                  | 1.6               | 2.5        |              |
| Lead (mg/kg)                         | -                  | 0.2               | 2.2        |              |
| Chromium (mg/kg)                     | -                  | 1.2               | 0.7        |              |
| Copper (mg/kg)                       | -                  | 14.0-14.2         | 17-21.3    | [4,37,41,43] |
| Zinc (mg/kg)                         | -                  | 9.9-10            | 8-21       |              |
| Sodium (mg/kg)                       | 92.1               | 103.8             | 214.3-800  | [3,12,32]    |
| Calcium (mg/kg)                      | 17148.4            | 3218.7            | 1693-4500  |              |
| Magnesium (mg/kg)                    | 1189.7             | 511.1             | 808-17 00  |              |
| Potassium (mg/kg)                    | 11366.2            | 16020.2           | 28433.9    |              |
| Iron (mg/kg)                         | 54.0               | 87.4              | 302.3-614  |              |

-: Results not available

### The applications of olive pomace

The data from the literature describe the many possibilities of valorisation of olive pomace, namely:

- Extraction of the residual oil by solvent: the first stage of recovery of the crude olive cake. This technique allows the recovery of at least 6% of oil often called "olive oil" [44].
- Its use as a fertilizer [45].
- The production of aromatic compounds of interest in the agri-food, cosmetic and even pharmaceutical fields; in fact, the fermentation of olives in solid medium by thermophilic and filamentous fungi produces a variety of compounds [13]. While the anaerobic fermentation of cow manure with olive pomace produces methane (57-65% of the biogas produced). This methane is used as a source of energy for water heating (direct) and electricity production for domestic use (indirect) [46].
- Treatment of wastewater and vegetable water: The biosorption of heavy metals and phenols by olive cake is an alternative to conventional methods that are very expensive and inefficient [47].
- Obtaining a lightweight building material with good insulation characteristics: The olive pomace can be used as a pore forming additive in the manufacture of clay bricks [28].
- The extraction of bioactive peptides [48].
- The olive pomace can be fermented to produce probiotic biomass [32].
- Olive pomace is used as orchard fuel replacement for providing additional reductions in greenhouse gas emissions [49].
- Used for gasification process, as alternative to combustion[50].

- Recommended as a remedy for the treatment of diabetes [51].
- Olive pomace could be applied not only as a physical oil sorbent but also for bioaugmentation as a biological source for hydrocarbon-based bacteria [52].
- Finally, this by-product of the olive industry can be used as feed for livestock. Sifted spent olive pomace (without stones) is easy to preserve and has better nutritional value. They constitute food reserves available during times of scarcity [53].

### Improving the nutritional value of olive pomace

Several methods have been proposed for treating olive pomace for improving its characteristics. These methods can be grouped in four categories:

1. *Chemical treatments*: Pyrolysis [7], and the older treatments such as, soda treatment [54], silage with alkalis [55], ammonia treatment [56].
2. *Physical and physicochemical treatments*: Treatment with high pressure and high temperature [57], flocculation [5, 58], adsorption [59], separation processes [60], ozonation [61], gasification [62], ultrasounds treatment [39] and torrefaction [63].
3. *Biotechnological transformations*: Biological treatment with microorganisms in liquid and solid-state fermentation [6, 36, 39, 64-70].
4. *Coupled physicochemical and biological treatments*: Ultrasounds pretreatment with fermentation [39].

### Liquid and solid state fermentation

Olive pomace has been proposed as livestock feed [6]. However, due to its high proportion of low digestible fibers and its low

concentration of proteins, especially lysine, it is recommended using protein supplements [6, 70, 71]. It is also possible to improve its nutritional properties through fermentation. This process, performed by microorganisms, has been successfully exploited for the production of animal feeds, fuel, and enzymes.

There are several reports describing the production of various enzymes using olive pomace as a substrate in liquid and solid-state fermentation, or as a supplement to the production medium. Olive pomace are ideally suited nutrient support in fermentation rendering carbon source and reported to be a good substrate for enzyme production (cellulases, xylanases, laccase etc) using microorganisms including bacteria and fungi species [70, 72, 73]. These enzymes are used in nature for their growth [34].

Several studies reported amelioration in the composition of olive pomace, regarding the fiber, protein, sugar and lipid composition after biotreatment of olive pomace with fungi and actinobacteria species. Indeed, several authors have demonstrated a reduction in the percentage of fiber after biotreatment of olive pomace with fungi in liquid and solid-state fermentation [6, 64–66, 69, 74]. On the other hand, Brozzoli *et al.* (2010) [36] reported an increase in crude protein levels for olive pomace treated with *Pleurotus pulmonarius*. In our recent study [70], we have found that the treatment of olive pomace by *Streptomyces* sp. S1M3I in a submerged culture resulted in an increase in crude protein and sugar content, and a reduction in total lipid and fiber content.

## CONCLUSION

The evaluation of innovations in the olive sector is an interesting feature. New extraction processes and perspectives of valorisation of the residues, adopted by farms and olive oil industries, play a very important role for the future development of the sector in the next future. Especially in Mediterranean countries, where olive oil chain is a pillar of agro-food business.

Indeed, in this paper, an overview of the new treatments for improving the extraction of olive oil and applications of olive pomace were mentioned. In order to give a response to the need of innovation and in order to help farms and olive oil industries to increase their competitiveness.

## AUTHORS CONTRIBUTIONS

All the authors have equally contributed

## CONFLICTS OF INTERESTS

All authors have none to declare

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