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# A review of olive mill solid wastes to energy utilization techniques

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ABSTRACT

In recent years, the utilization of olive industry by-products for energy purposes has gained significant research interest and many studies have been conducted focused on the exploitation of olive mill solid waste (OMSW) derived from the discontinuous or continuous processing of olive fruits. In this review study, the primary characteristics of OMSW and the techniques used to define their thermal performance are described. The theoretical background of the main waste-to-energy conversion pathways of solid olive mill wastes, as well as the basic pre-treatment techniques for upgrading solid fuels, are presented. The study aims to present the main findings and major conclusions of previously published works undertaken in the last two decades focused on the characterization of olive mill solid wastes and the utilization of different types of solid olive mill residues for energy purposes. The study also aims to highlight the research challenges in this field.



**Contents**



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## 1. Introduction

The olive (*Olea europea*) is an evergreen tree traditionally cultivated for the production of oil and table olives. More than 97% of global olive production is concentrated in the Mediterranean basin, with Spain being the main world producer (7,870,000 tonnes) followed by Italy, Greece, Turkey, Morocco and Tunisia. On a global scale, the olive production in 2013 exceeded 20,000,000 tonnes (FAO, 2015).

The production of olive oil is characterized by significant amounts of residues, both solids and liquids, and their management is a challenge issue for the olive mill operators from both economic and environmental perspectives.

The solid residues derived from the olive oil industry constitute a promising biomass resource because their thermochemical characteristics provide the opportunity for their potential utilization for energy purposes, offering at the same time a solution to the management problems.

The produced amount of solid and liquid residues differs according to the technology applied for the extraction of olive oil. Two basic oil extraction technologies are applied, namely the traditional pressing and the centrifugation method. Traditional pressing was applied for many centuries. However, in the last decades three-phase and two-phase centrifugation processes have been applied by the majority of olive mills (Roig et al., 2006). Regarding two and three-phase centrifugation, the produced oil yield is similar for the two processes, but there is a significant difference in the produced amount and the composition of solid and liquid residue fractions (Arvanitoyiannis and Kassaveti, 2008) (Fig. 1).

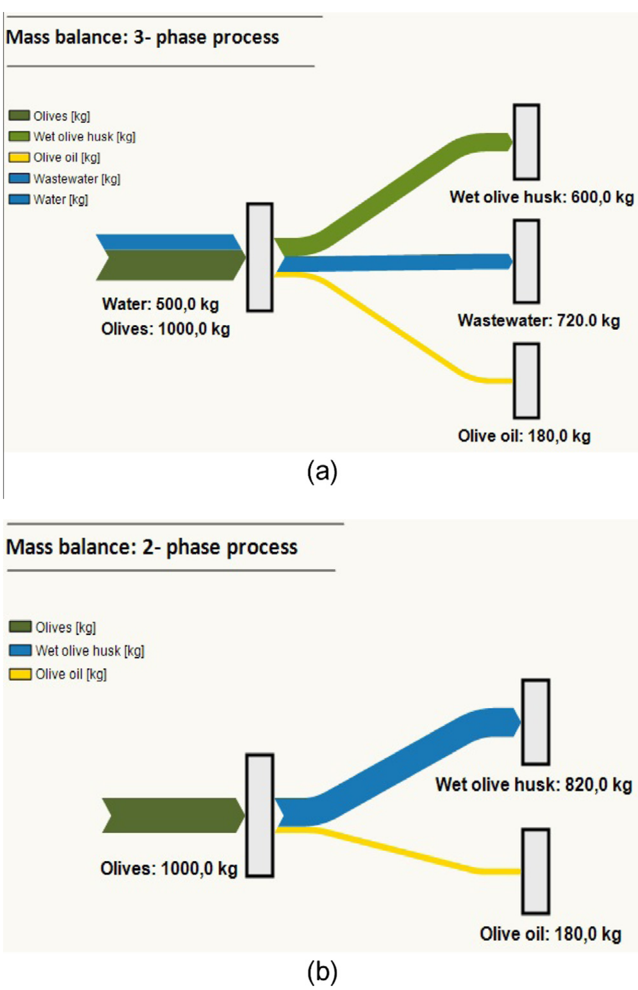


**Fig. 1.** Mass balance of three-phase (a) and two-phase (b) centrifugation oil extraction method (Alburquerque et al., 2004; Vlyssides et al., 2004).

The three-phase centrifugation system generates three fractions at the end of the process: a solid residue fraction called olive husk or olive pomace (Three-Phase Olive Mill Waste – 3POMW), and the oil and wastewater liquid fractions. On the other hand, the two-phase system produces two fractions at the end: the oil fraction, and a solid/water mixture (Two-Phase Olive Mill Waste – 2POMW) residue which is suitable for subsequent extraction and drying (Niaounakis and Halvadakis, 2006).

Several studies have been conducted during the last two decades that examined the thermochemical characteristics and performance of solid olive wastes. Various methods and technologies have been investigated, and the potential exploitation of solid olive wastes for energy purposes was evaluated (Caputo et al., 2003; Ramachandran et al., 2007; Arvanitoyiannis and Kassaveti, 2008; Abu Tayeh et al., 2014; Kinab and Khouri, 2015).

This study aims to highlight the recent research findings in the field of solid olive mill waste utilization for energy purposes though a review of studies conducted in the last two decades. Different types of solid residues such as olive pomace or olive kernels (also called olive stones) derived from both two and three-phase centrifugation were used in several studies for the production of clean energy. The main technologies applied, the main objectives and the results obtained are extensively discussed.

## 2. Theoretical background

### 2.1. Characterization of solid olive mill wastes-applied methods and techniques

The investigation of the physicochemical characteristics of the processed feedstock and the understanding of the phenomena taking place during the thermal processing of solid olive wastes, as well as of the parameters affecting the final product, are of fundamental importance for optimizing the utilization processes and maximizing their energy efficiency. The physicochemical characterization of solid olive wastes is an important task for understanding, predicting and evaluating the thermal performance and use of solid olive wastes as an energy source (Garcia et al., 2014).

#### 2.1.1. Chemical composition and energy value

The moisture contents of the solid olive mill residue fractions vary according to the applied olive oil extraction technology. The fraction 2POMW is a thick sludge that is a mixture of stone and pulp of the olive fruit, as well as olive mill wastewater. Its moisture content is in the range of 55–70%, which is significantly higher when compared with the olive cake derived from traditional press systems (20–25%) and the 3POMW fraction (40–45%) (Christoforou et al., 2014).

The chemical composition of olive mill wastes depends on various parameters such as the olive fruit varieties and cultivation conditions. Furthermore, the chemical composition of the solid olive residues is affected by the extraction method, and thus the solid residues derived from the two and three-phase centrifugation process are significantly different. Cellulose, hemicellulose and lignin are the main components, followed by fat and protein. Mineral analysis results indicated that the major elements in 2POMW and 3POMW are potassium, followed by calcium and sodium (Rodríguez et al., 2008; Fokaides and Polycarpou, 2013; Dermeche et al., 2013).

The energy content of the processed feedstock is of great importance for the viability of a potential thermochemical utilization plant. Solid olive wastes have been indicated as containing a considerable amount of energy (LHV = 15.58–19.81 MJ/kg), which