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ORIGINAL PAPER

Waste management in the olive oil industry in the Mediterranean region by composting

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Abstract Consumer-friendly markets fuel the massive food processing industry, which in turn generates vast volumes of waste. Processing of olive oil in the Mediterranean regions are major contributors of pollution in that area. This paper investigates management of wastes generated during processing of olive oil, focusing on olive husks and their disposal. The most effective method of disposal of olive husk waste is composting. Composting is an aerobic process in which microorganisms, under optimum conditions, biodegrade organic content present in the olive waste. Mechanical aeration conducted at optimum temperature during the process of composting is preferred as it produces compost that has reduced levels of phenols and lipids. The resulting compost is used as soil additive in olive plantations.

Keywords Food processing · Olive oil wastes · Waste management · Olive husks · Composting

Introduction

Foodwaste, though less harmful to the environment than industrial and other forms of wastes, is often neglected as far as its treatment and management are concerned (Tsai et al. 2006). Much attention is being paid to the environment and its protection, and appropriate consideration and efforts are being made in order to prevent or reduce environmental pollution (Kroyer 1995). Recently, the food industry has been getting a lot of attention due to the widespread manufacture and supply of fresh and processed foods to consumers. Wastes from all these industries have similar characteristics; the presence of organic materials like proteins, carbohydrates, suspended solids, high BOD and COD, high nitrogen content and high oil and grease content (Kroyer 1995).

The Mediterranean region is world renowned for its olive plantations and processing of olive oils (Caputo et al. 2002). Olive oil processing is typically characterised by large amounts of wastes, especially in the 3–4 months of intensive olive oil production. These industries produce up to 30 million tons of waste by-products per year (Caputo et al. 2002). In the case of management of olive oil wastes, composting has been known to be an effective solution to the olive waste disposal problem (Arvanitoyannis and Kassaveti 2006).

Composting is an aerobic decomposition process in which thermophilic bacteria under controlled conditions convert the organic matter into a stable soil-like product (Thassitou and Arvanitoyannis 2002).

This paper discusses composting as the most efficient means of solving the waste crisis faced by olive oil industries in the Mediterranean region. It covers the process of extraction of olive oil, and concentrates on waste management of olive husks generated during the two-phase extraction process.

Solid waste management

Due to its exorbitant volumes generated, solid waste is of great concern. The figures for waste generation are unreliable and are usually based on estimates (Thassitou and

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Arvanitoyannis 2002). Industrial and agricultural wastes are accountable for contamination of soil and water (Thassitou and Arvanitoyannis 2002). The processing of olive oil results in the production of both solid and liquid wastes; olive husks being the major solid waste generated from the pressing of the olive fruits, and olive mill wastewater being the liquid waste generated (Caputo et al. 2002).

Treatment methods should take into consideration the high moisture content and predominantly organic content of food wastes (Tsai et al. 2006). Odour produced by microbial decomposition of the waste is a common problem in the treatment of food wastes (Tsai et al. 2006). Landfilling of solid wastes leads to leaching and contamination of surface and ground waters (Tsai et al. 2006). Landfills are isolated waste storage spaces and not an ideal solution to solving food waste disposal problems, as they are Fehr et al. 2002). Scarcity of land for landfilling, increasing costs and environmental concerns such as leaching has made landfills an unpopular choice (Fehr et al. 2002). Thus innovative waste management systems of composting, biodegradation and bioremediation may be more viable when compared to conventional methods like incineration, pyrolysis and landfilling (Thassitou and Arvanitoyannis 2002).

Bioremediation: the solution

Bioremediation is the process of transforming the contaminated environment with the help of microorganisms or enzymes, to a non-toxic endpoint. Bioremediation is widely accepted all over as a treatment solution that is least harmful to the environment. In the process of bioremediation, the microorganisms, either genetically modified or naturally occurring, break down or decompose contaminants in the environment (Thassitou and Arvanitoyannis 2002).

Environmental impacts of Agro-based industries

Rise in populations worldwide have led to an increase in agricultural productivity and an equal increase in contribution to environmental degradation by the increased use of pesticides and fertilizers, heavy metal accumulation in soil, and most importantly the contamination of ground and surface waters by agricultural run-off (Kroyer 1995). In recent times, agricultural policies have been adapted to boost agricultural productivity (Kroyer 1995). Kroyer (1995) suggests that more should be done to change these policies and regulatory standards and encourage research in these areas to safeguard the environment. Research into solving the waste issues of agro-based industries would help these industries use their raw materials efficiently, thereby reducing the generation of wastes and by-products to protect the environment while achieving quality standards in food production (Kroyer 1995). Various economical, technical and organisational hurdles make practicing environmentally sustainable treatment of olive wastes a challenge (Caputo et al. 2002).

Olive oil processing industries

Statistics indicate that Spain is the highest producer of olive oil in the world, producing over 1.1 million tonnes of oil in 2007 (International Olive Council 2007). The olive oil industry is of special concern in the region due to the considerable amounts of olive oil produced and the scale of issues when it comes to waste reduction and treatment of olive wastes (Caputo et al. 2002). The disposal and treatment of olive mill wastes has become a serious environmental issue in the Mediterranean region, as they are being generated in large quantities within a limited period of time, causing soil and water pollution (Arvanitoyannis and Kassaveti 2006) (Tables 1, 2).

Extraction of olive oil

The unrestricted discharge of olive mill wastewater and the environmental concerns attached to it, led to the development of two-phase method for olive oil extraction in Spain, which restricts unlimited water usage and hence reduces

Table 1 Production of olive oil production trend from the years 2000 to 2007 (in 1,000 tonnes)

Region	2000–2001 (1,000 tonnes)	2001–2002 (1,000 tonnes)	2002–2003 (1,000 tonnes)	2003–2004 (1,000 tonnes)	2004–2005 (1,000 tonnes)	2005–2006 (1,000 tonnes)	2006–2007 (1,000 tonnes)
Spain	973.7	1411.4	861.1	1412.0	989.8	826.9	1108.7
France	3.2	3.6	4.7	4.6	4.7	4.4	3.4
Greece	430.0	358.3	435.0	308.0	435.0	370.0	370.0
Italy	509.0	656.7	879.0	685.0	879.0	603.0	603.0
Portugal	24.6	33.7	41.2	29.1	41.2	48.0	48.0
Total	1940.5	2463.7	1942.7	2448.0	2357.2	1928.6	2141.7

Source: Olive Oils (2007). International Olive Council, http://www.internationaloliveoil.org/downloads/production2_ang.PDF [viewed on 21/10/08]

Table 2 Worldwide statistics of olive oil production

Worldwide olive oil production	460 million gallons
Worldwide olive oil consumption	486 million gallons
Average annual world olive oil consumption over the last 30 years	1,465,000 metric tons
Spain's share	30%–190 million trees
Italy's share	24%
Largest producers worldwide	Spain, Italy, Greece, Portugal, Tunisia, Turkey, Syria

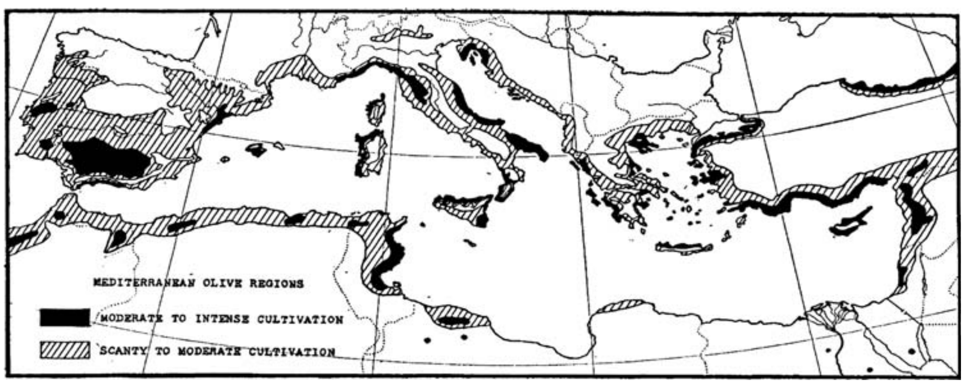
Source: The Olive Oil Source (2008) n.d. http://www.oliveoilsource.com/statistics.htm [viewed on 21/10/08].

the level of aqueous effluents considerably (Borja et al. 2006). As indicated in Fig. 1, the succeeding process in the extraction of olive oil is washing with water (Borja et al. 2006; GEA n.d.; Alburquerque et al. 2004). The olives are thoroughly washed and cleaned to remove leaves and impurities before being sent to the mills where the oil is extracted and wet cakes are formed as residue (Borja et al. 2006; Alburquerque et al. 2004). In the mills, the cleaned olives are then pressed with screens of sizes 6–7 mm to produce a mashed product (GEA n.d.). This product is centrifuged in the two-phase decanter at a temperature of 30–35°C at which point the oil content is released from the fruits (Borja et al. 2006; GEA n.d.; Alburquerque et al. 2004) (Figs. 2, 3, 4).

Before the final product is obtained, the oil from the decanter is polished (Alburquerque et al. 2004). The olive oil thus formed is of high quality (Borja et al. 2006).

Another method of extracting olive oil is by the three-phase method. However, this method does not produce olive oil of as good a quality as that of the two-phase method (Borja et al. 2006; Alburquerque et al. 2004). The three-phase method separates the olive oil, vegetation water, which along with the process water leads to a lot of olive mill wastewater, and the olive husk (Cayuela et al. 2007). Thus, to reduce water consumption and the quantity of wastewater generated, the two-phase system was adopted in Spain, which consumes very little water and leaves solid residues (olive husks) with high moisture content (Cayuela et al. 2007; Baeta-Hall et al. 2004). The olive husk thus generated can be either combusted for energy production or used in composting (Baeta-Hall et al. 2004; Cayuela et al. 2007).

Fig. 1 Olive oil production in European countries. Source: Whittemore (n.d.)



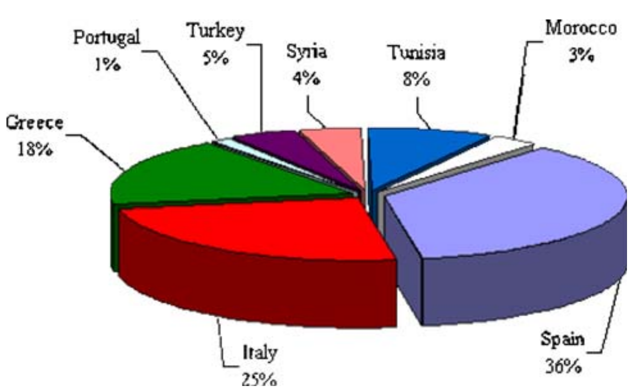


Fig. 2 Main olive oil producing countries (2005). Source: UNCTAD (2008)

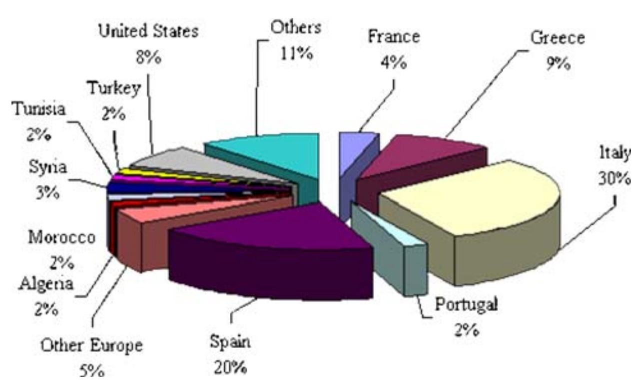


Fig. 3 Main olive oil consuming countries (2005). Source: UNCTAD (2008)

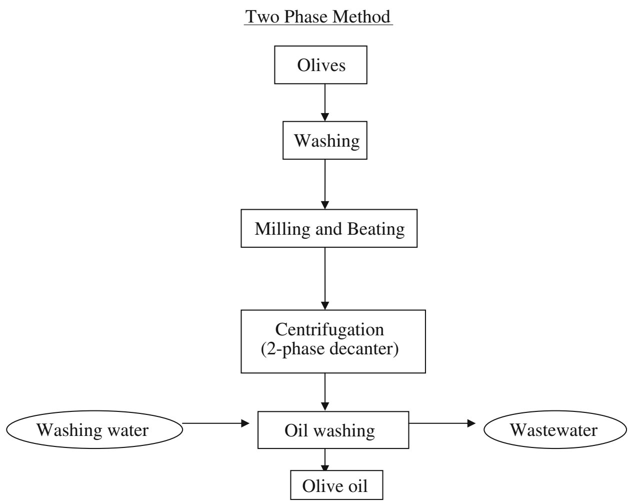


Fig. 4 Flowchart explaining the two-phase process of olive oil extraction. Source: Alburquerque et al. (2004)

Management of wastes produced during the processing of olive oil

Generally, 30% of the raw materials used in food industries become wastes rather than by-products (Schaub and Leonard 1996). In the olive oil industries, the characteristics of waste generated during olive oil production, such as moisture and oil content depends on the process used for oil extraction (Arvanitoyannis and Kassaveti 2006). The olive husk waste contains considerable amounts of polyphenols and lipids that are generated during the process of olive oil extraction (Caputo et al. 2002). The biological method of composting is the most preferred treatment of these wastes (Arvanitoyannis and Kassaveti 2006).

Composting

A part of the organic matter is aerobically degraded in the composting process by micro organisms to carbon dioxide and water, while the remaining fraction results in the formation of bio-fertilizers by the process of humification (Vlyssides et al. 1996; Tomati et al. 1996; Paredes et al. 2000; Bertoldi and Shnappinger 2001; Baeta-Hall et al. 2004). The compost formed from the aerobic process is a good fertilizer and can enhance plant growth and increase the water holding capacity of the soil (Arvanitoyannis and Kassaveti 2006). Of the aerobic composting technologies in Spain, the windrow turned pile or the aerated static pile methods are most commonly used (Baeta-Hall et al. 2004). The technologies vary in the mixing of the material, the method of air supplied, and the time and temperature required for composting (Baeta-Hall et al. 2004). However, the method of composting employed depends on the end product and the environmental protection criteria required (Tiquia et al. 2002; Savage 1996, Baeta-Hall et al. 2004).

The processing of olive oil results in the production of both solid and liquid wastes; olive husks being the major solid waste generated from the pressing of the olive fruits, and olive mill wastewater being the liquid waste generated (Caputo et al. 2002).

A typical composting process requires optimum temperature and moisture conditions to allow for the growth and functioning of microorganisms (Arvanitoyannis and Kassaveti 2006). According to Arvanitoyannis and Kassaveti (2006), the moisture content should be between 50 and 65%. Sufficient aeration and porosity between particles to allow for the air to flow through is also important (Arvanitoyannis and Kassaveti 2006). During the process of composting, bulking agents are added to maintain optimum moisture and aeration levels (Caputo et al. 2002).

Composting of olive husks

The olive husks are mixed with a small proportion of grape stalks and the mixture is churned once every two weeks by mechanical aeration (Baeta-Hall et al. 2004). The grape stalks are used as bulking agents as they are easily available and cost effective. They decrease the moisture content and provide more means for aeration in the mixture (Baeta-Hall et al. 2004). According to Baeta-Hall et al. (2004), temperature plays a vital role in the composting process; and is linked with microbial activity, the C:N ratio and the pH. The temperature of the compost piles is measured daily at a depth of 20 cm from the top of the pile and at other random points in the pile. Mechanical turning aids in a gradual increase in temperature, which leads to an enhanced thermophilic phase (Baeta-Hall et al. 2004).

The C:N ratio of 25–35 is the most favourable for composting (Tomati et al. 1996; Barrington et al. 2002, Charest and Beauchamp 2002; Baeta-Hall et al. 2004 and Arvanitoyannis and Kassaveti 2006). If the C:N ratio is high, then the composting process will begin slowly and continue for a longer time (Baeta-Hall et al. 2004). The process of composting takes, over a period of 6 months to reach maturation stage (Baeta-Hall et al. 2004). At times it is essential to optimize the microbial growth for industrial use, as the decomposition process is very slow (Thassitou and Arvanitoyannis 2002). Raw olive husks are primarily covered with mesophilic bacteria and their population seems to increase at the end of the composting process (Baeta-Hall et al. 2004). Mesophilic bacteria initiate decomposition of the waste at temperature between 30 and 45°C, resulting in exothermic reactions thereby facilitating the growth of thermophilic bacteria at 50–60°C (Thassitou and Arvanitoyannis 2002). If left uncontrolled, the thermophilic bacteria may further increase the temperature to about 70°C leading to lower activity (Thassitou and Arvanitoyannis, 2002). Thus oxygen concentrations, pH, moisture content, carbon to nitrogen (C:N) ratio and particle size must be optimized in order to achieve maximum efficiency (Thassitou and Arvanitoyannis 2002).

After the thermophilic phase, the compost material reaches room temperature, which is its maturation stage (Tiquia et al. 2002; Baeta-Hall et al. 2004). For the compost generated from the olive oil waste to reach maturation stage, mechanical aeration is the most efficient method (Baeta-Hall et al. 2004). Mechanical aeration is widely preferred in the olive oil industries, as this method helps in increasing the temperature and achieving increased efficiency during humification (Baeta-Hall et al. 2004). This method is more energy-effective and needs less technical expertise (Baeta-Hall et al. 2004).

The phenolic and lipid content which are important constituents of olive husks reduce drastically at the end of the composting process (Baeta-Hall et al. 2004).

The organic matter is reduced to more than 50% at the final stage of composting (Baeta-Hall et al. 2004). The stability of the compost depends on the degree of humification, and there is an approximate reduction in phytoxicity at the end of compost maturation (Baeta-Hall et al. 2004).

For composting to work as a waste treatment solution, it requires a partnership between the waste producers (industries) and the waste managers (composting facilities) (Fehr et al. 2002). Composting can be successful only when adequate raw material is available periodically. It is vital that the compost produced from biodegradable waste has economic value, without which the waste management system would not be a viable one. The biological process of composting should go hand in hand with the presence of adequate raw materials and economic value added to the compost. By efficient working of the collection, storage, and transportation systems of foodwaste, and efficient production of compost, there will be a constant recycling of nutrients thereby causing less harm to the environment. Efficient management of foodwaste through composting can bridge the gap between the waste producers and waste managers (Fehr et al. 2002).

New developments in olive waste solutions in the Mediterranean regions

Energy recovery and the integrated waste disposal system

The olive husks generated during the process have a considerably high calorific value.

Recently, energy recovery from olive husks is being implemented in order to make it an environmentally sustainable industry (Caputo et al. 2002; Arvanitoyannis and Kassaveti 2006). The olive husks are typically characterised by low sulphur and nitrogen content and a fairly high heating value (Caputo et al. 2002).

Thermal combustion of olive oil wastes in order to recover energy and produce electricity is environmentally sustainable when compared to non-thermal disposal, as it reduces the mass of the overall waste, reduces release of pollutants and the recovered energy can be used to power olive oil mills (Caputo et al. 2002).

The integral waste disposal system is another development in reducing the impact of olive oil wastes in the Mediterranean regions. In this method, the olive mill wastewater and the olive husks are treated together. The wastewater is treated and then used to irrigate olive plantations and the husks are converted to cakes and used for extraction of olive oil and eventually used as fodder (Azbar et al. 2004).

Conclusion

Generally, the management of foodwaste and food processing waste is neglected when compared to other types of wastes. With the increase in global populations, agricultural production has also increased. Agricultural practices have moved from the traditional to industry-oriented. This had led to increased pollution levels in the environment. The large volumes of food and food wastes produced in today's consumer-friendly market stresses the fact that the treatment and disposal of wastes should be carried out in an eco-friendly manner.

The processing of olive oil is largely concentrated in the Mediterranean regions, with Spain being the highest producer of olive oil, around 138 million gallons. The processing of olive oil generates vast quantities of both solid and liquid wastes. Olive husks are the most predominant solid waste generated from these industries. They are rich in phenols and lipids, which are harmful to the environment; and have been known to cause phytotoxicity and pollute surface and ground waters in the Mediterranean regions.

Composting has been proved to be an efficient method in treating the olive husks, which is a major percentage of the waste generated in the olive oil industry. Mechanical aeration is the method most preferred by industries. It is cost effective and requires minimum technical expertise. Mechanical aeration helps hasten the composting process by increasing the temperature of the waste to be composted. This helps the microbial reactions and improves the quality of compost formed.

Composting reduces the phenolic and lipid content in them. In the past, landfilling has been used as a means to dispose olive husks. This led to the leaching of phenols and lipids into the environment and caused phytotoxicity.

Some of the new developments in waste management of olive oil processing in food waste industry include the recovery of energy and integrated treatment of olive mill wastewater and olive husks. Since the olive husks have a high heat capacity they can be combusted to recover energy to generate electricity.

Integrated waste management is a system in which the treated wastewater from the olive mills is circulated back and used to irrigate olive plantations. The compost produced from the olive husks can be used as fertilizer in these plantations, thereby evolving into a closed system.

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