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Using polyethylene sleeves with forced aeration for composting olive mill wastewater pre-absorbed by vegetative waste

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ABSTRACT

Composting in closed polyethylene sleeves with forced aeration may minimize odor emissions, vectors attraction and leachates associated with open windrows. The present study demonstrates the use of this system for composting olive mill wastewater (OMW), the undesired stream associated with the olive milling industry. A polyethylene sleeve of 1.5-m diameter and ca. 20-m long was packed with shredded municipal green waste which was pre-soaked in OMW for 72 h. Process conditions were controlled by means of a programmable logic controller (PLC) equipped with temperature and oxygen sensors. Thermophilic temperatures (>45 °C) were maintained for one month followed by temperatures in the range of 30–40 °C, ca. 20 °C above ambient temperature, for a period of 3.5 months. Oxygen levels were controlled and the system was kept aerobic. Water content gradually decreased with sufficient levels for efficient composting. The finished compost was non-phytotoxic to Cress (*Lepidium sativum* L.) in a lab bioassay. It was also found suitable as an ingredient in peat, tuff, and coir based growing media, evaluated by plant growth tests with basil and ornamental plants. The viability of this approach for disposing off OMW is much dependent on the liquid absorption capacity of the vegetative waste.

1. Introduction

Olive mill wastewater (OMW) is the liquid by-product obtained from a three-phase olive oil processing, either by traditional mechanical press, or by continuous centrifugation systems. This oil extraction process yields an oily phase (olive oil), a solid phase (olive fruit residues; pomace) and an aqueous phase, i.e., wastewater originating from fruit water and the washing water used in the process. OMW is typically acidic (pH ~ 4–5) and contains extremely high organic load with large range of physico-chemical and biological properties. For example, Azbar et al. (2004) reported a range of 40–220 g l^{-1} for chemical oxygen demand (COD) and 0.002–80 g l^{-1} for total phenols (TP); Roig et al. (2006) reported a range of 5.5–12 dS m^{-1} for electrical conductivity (EC). Besides the oil extraction process, the high variability in OMW properties was attributed to olive harvest time, irrigation level, cultivar type and fruit water content (Aviani et al., 2012). Nonetheless, these unique characteristics of OMW prevent its direct discharge into domestic wastewater treatment plants (Laor et al., 2011a; Rozzi and Malpei, 1996; Sayadi et al., 2000).

Unlike most industrial effluents, OMW does not contain synthetic contaminants or threatening levels of heavy metals. Thus, contrary to the classic "wastewater treatment" approach, numerous studies advised the recycling of OMW with the advantage of utilizing their plant nutrients value (Zipori et al., 2018). The most commonly advised recycling approach is controlled land spreading which was explored in a large number of studies (e.g. Chartzoulakis et al., 2010; Hanifi and El Hadrami, 2008; Laor et al., 2011a; Tomati et al., 1996). In this regard, the inherited potential toxicity of OMW has been widely reported, mostly in relation to plants (Aliotta et al., 2002; Barbera et al., 2014; El Hadrami et al., 2004; Saadi et al., 2007, 2013) and to some extent to microorganisms (Barbera et al., 2013; Capasso et al., 1995; Mekki et al., 2008; Kurtz et al., 2015). Yet, following land application, only short-term phytotoxic effects were observed in most cases (Piotrowska et al., 2006; Saadi et al., 2007, 2013), although Mekki et al. (2008) detected increased concentrations of phenolic compounds at a depth of 1.2 m in a sandy soil, 4 months after application and extracted a moderately phytotoxic residual phenolic fraction from the upper soil layer 1 y after application. Moreover, several authors have cautioned against potential adverse effects of OMW application on soil physical and hydraulic properties (Colucci et al., 2002; Levy et al., 2018, Mahmoud et al., 2010, 2012).

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A smaller number of studies explored co-composting of OMW with other solid wastes as an alternative recycling approach. In that case, OMW was used to obtain the initially desired moisture content of the composting mixture as well as to wet it during the thermophilic phase, while the composting mixture is essentially used as a reactor with the aim of treating the maximum amount of liquids (Aviani et al., 2010). Although more costly than land spreading (Laor et al., 2007), co-composting of OMW might be preferred to avoid potential freshwater contamination or damage to soil and crops caused by spreading phytotoxic and unstabilized wastewaters. It is also advantageous by eliminating the need of applying liquids to land during winter (the olive milling season) when the soil can be muddy. Finally, depending on co-wastes and process conditions, the resultant compost may be used as an ingredient in growing media where its economic value is greater compared to compost used as a soil amendment. Previous studies on OMW composting used different kinds of co-wastes, including sewage sludge and cotton waste (Bernal et al., 1998), wheat straw (Galli et al., 1997; Tomati et al., 1995) olive mill solid waste, livestock manure and wheat straw (Aviani et al., 2010); livestock manure, cotton gin waste, municipal sewage sludge and industrial food waste (Paredes et al., 2005, 2001, 2000); or olive mill solid waste only (Vlyssides et al., 1996). Urea was added in some of these studies to obtain the desired C:N, depending on the wastes selected.

Practically, if liquid wastes are to be composted in windrows, it is recommended to slowly pour the liquid into a trench made down the center of the windrow with periodic dams to slow the movement of the liquid, so it can be absorbed by the carbonaceous materials. The windrow can then be covered with more bulking material and left to work passively or turned as soon as liquids are absorbed, if location and feedstock allow (Bonhotal and Harrison, 2007). As with other liquid wastes, composting of OMW raises concerns related to the maximum amount of liquids that can be treated per volume of solid wastes, as well as increased risk of leachates. Odor emissions are also a concern as is always the case with new composting sites (Eitzer, 1995; Homans and Fischer, 1992) and especially if this practice is to be applied nearby the mill that might be located in the vicinity of a populated area. Moreover, excess liquids may create anaerobic conditions which in turn may emit more odor and slow degradation rates.

The EURO Bagging or Ag-Bag technology is a relatively cheap enclosed system in which the desired material is pushed into a plastic (polyethylene) sleeve while a perforated aeration pipe is laid on the bottom of the bag. This technology may be adopted in order to minimize odor emissions, vectors attraction, and leachates associated with open windrows. Advantages include simplicity in construction and operation. Moreover, because of the minimal infrastructure needs, this technology may not require building permit. A number of studies reported successful composting of green waste, biosolids and paper processing waste (Roberts et al., 2007), biosolids and shredded municipal green waste (Avidov et al., 2017), timber products, poultry manure and green waste (McMahon et al., 2008), biosolids and green wastes (Farrel, 2002) or catering waste with green waste and shredded paper (Farrell and Jones, 2010). Yet, so far this technology has not been widely used and seems to be practical mainly in certain niches, like relatively small operations and in cases where the area needed to operate the sleeves is not a constrain. Composting of OMW with the aim of maximizing the amount of composted liquids per amount of co-solid waste may be facilitated in such sleeves. In that case, the bulking material has to be pre-soaked in the wastewater and then the saturated material is packed into the sleeve. No periodic addition of liquids is possible during composting, but no leaching is expected and potential odors can be treated at the exit (e.g. by means of a biofilter).

The aims of the present study were (i) To assess whether composting of OMW pre-absorbed by green waste can proceed well without additional chemical or manure based nitrogen source; (ii) To assess the appropriateness of the resulting compost as a peat substitute in growing media for greenhouse and nurseries; (iii) To consider waste management aspects related to the feasibility of this technology as a substantial route for OMW disposal.

2. Materials and methods

2.1. Experimental setup

Fresh 15 m^3 of OMW were received on December 2014 from the three-phase olive mill in Tamra at the Lower Galilee, northern Israel (Selected properties are listed in Table 1). The OMW were placed in plastic 1-m^3 intermediate bulk containers and readily shipped to Sharonim Recycling Enterprises Ltd., located in the Sharon plain, central Israel. There, about 10 tons of shredded municipal green waste ($\leq$30 mm) were soaked in the wastewater for 72 h inside a 38 m^3 container (Fig. 1a and b). After soaking, the material was drained for 24 h and then readily shipped to Newe Ya'ar Research Center (Jezre'el Valley, northern Israel) for the composting experiment. Based on a lab-scale absorption test (Section 2.4), the potential absorption of the green waste was 1.34 kg OMW kg^{-1} dry waste. This potential absorption was fully achieved during the large-scale operation. Since the initial moisture content of the green waste was 45% (wet base), these initial waters were essentially mixed with the excess OMW in the container. For actual application, the driest possible material would be sought to increase the amount of OMW taken up by the green waste for composting.

The composting experiment was conducted in Newe Ya'ar between December 7, 2014 and June 3, 2015 using the setup described in Avidov et al. (2017). Briefly, a polyethylene sleeve of 1.5 m diameter and ca. 20 m long was packed with the composting mixture, green waste pre-absorbed by OMW, using a composting machine (Euro Bagging CM 1.5 CCS) while a perforated pipe, 2.5 in. diameter, was laid at the bottom of the sleeve during packing (Fig. 1c). Aeration was controlled by means of a programmable logic controller (PLC; Vision 570, Unitronics, Israel), using a blower (U/HC 201, Induvac, Zoetermeer, Netherlands), six temperature sensors (PT-100; Madid Ltd, Haifa, Israel) and two oxygen sensors (SO-110, Apogee Instruments, Inc., Logan, UT, USA). The PT-100 sensors were constructed in two 1.2 m long stainless steel rods, each containing three sensors at 35, 75, and 115 cm from top. One PT-100 rod and one oxygen sensor were placed in each half of the sleeve. Notably, heat conduction along the rod could result in ca. 3 °C underestimation of temperature vertical gradients (Avidov et al., 2017). After three initial days without ventilation, during which temperatures remained in the range of 35–45 °C,

Table 1
Selected properties of the OMW used in this study.

Property*	Value
pH	**4.67 (4.62, 4.72)**
Chemical oxygen demand, COD (mg l^{-1})	**114,178 (112,519, 115,837)**
Biological oxygen demand, BOD (mg l^{-1})	**35,000 (32,500, 37,500)**
Total suspended solids, TSS (mg l^{-1})	**32,753 (32,740, 32,765)**
Volatile suspended solids, VSS (mg l^{-1})	**31,715 (31,430, 32,000)**
Oil residues (mg l^{-1})	**11,656 (11,568, 11,744)**
Total phenols, TP (mg l^{-1})	**3410 (105.7)**

* Average values are in bold and each value of duplicate measurements are in parenthesis. For TP only: the standard deviation of triplicate measurements is in parenthesis.