International Biodeterioration & Biodegradation 65 (2011) 560–564

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Composting of olive leaves and pomace from a three-phase olive mill plant

Michael Michailides [a], Gerasimos Christou [a], Christos S. Akratos [a], Athanasia G. Tekerlekopoulou [a], Dimitrios V. Vayenas [a,b,*]

[a] Department of Environmental and Natural Resources Management, University of Ioannina, Seferi 2, 30100 Agrinio, Greece
[b] Institute of Chemical Engineering and High Temperature Chemical Processes, Stadiou Str., Platani, GR-26504 Patras, Greece

ARTICLE INFO

Article history:
Received 20 January 2011
Received in revised form
25 February 2011
Accepted 25 February 2011
Available online 17 March 2011

Keywords:
Compost
Three-phase olive mill waste
Germination index
Lettuce
Cress
Amendment

ABSTRACT

The composting of olive leaves and olive pomace from a three-phase olive mill was tested as a method for solid waste reuse. The process was carried out using a compost windrow and mixing olive leaves and pomace at a ratio of 1:2. Compost was retained in the windrow for 60 days during which thermophilic temperatures developed for the first 40 days. The compost was then placed into a closed area to mature for another 60 days. The final product proved to be high quality amendment with C/N 27.1 and high nutrient concentrations (N, 1.79%; P, 0.17%; K, 4.97%; Na, 2.8%). Mature compost presented the highest germination index (198%) reported to date, as the germination index in the majority of previous studies is under 80%. Furthermore, tests revealed that addition of 31.5 tons of compost per ha, could increase lettuce yield by 145%.

1. Introduction

Olive oil production is significant in Mediterranean countries as they produce over 95% of the worldwide production (Aktas et al., 2001). Olive mills process olives for the extraction of olive oil either using a discontinuous press (classical process) or a solid/liquid centrifuge (centrifugal process). Both these processes produce two waste streams: olive mill residual solids and olive mill wastewaters (OMW). OMW consist of the fruit water content and the water used to wash and process the olives. Annual OMW production is estimated at over 10^7 m^3 (Benitez et al., 1997), with a pollutant load equivalent to about 22 million people per year (Roig et al., 2006).

The most common technologies for olive oil extraction are the two- and three-phase centrifugation systems. Two-phase systems, which are more advanced than three-phase, are usually used in Spain and Italy and produce olive oil and olive humid husks (OHH) (Alfano et al., 2008). OHH is an aqueous solid by-product (56.6% water content) with high phenols content (74.5%) (Alburquerque et al., 2004). OHH is usually spread on fields causing environmental problems (Alfano et al., 2008). In Greece olive oil extraction is carried out in c.2300 small-scale, rural, agro-industrial units. These are usually three-phase systems and the by-products include olive mill residual solids and OMW. Typically, the weight composition of OMW is 83–96% water, 3.5–15% organics, and 0.5–2% mineral salts (Greco et al., 1999). Residual solids include olive leaves and olive pomace. Only the olive pomace is post-treated, usually undergoing a second oil extraction, the residuals of which are used for combustion. Lately several attempts of composting solid waste from olive oil extractions have been documented.

Composting usually refers to an aerobic stabilization of organic matter, which is then applied to agricultural cultivations to improve plant growth (Komilis and Tziouvaras, 2009). Composting processes involve transforming organic matter to humic compounds which are more stable (Alburquerque et al., 2009). Most attempts of composting olive mill by-products have used OMW from two-phase mills, adding several other agricultural by-products as bulking agents. The other by-products used include wool waste and wheat straw (Altieri and Esposito, 2010), olive leaves, wood chips and rice by-products (Komilis and Tziouvaras, 2009), sesame bark (Sellami et al., 2008), poultry manure (Hachicha et al., 2008, 2009a, 2009b), sheep litter and grape stalks (Cayuela et al., 2006, 2010), and sewage sludge (Sanchez-Arias et al., 2008). Only a few research groups have used olive leaves as bulking agents (Alfano et al., 2008). Depending on the available carbon and nitrogen of the by-products used, all the above experiments have led to final mature material with a C/N ratio ranging from 11.5 (Sellami et al., 2008) to 53.5 (Alfano et al., 2008).

* Corresponding author. Department of Environmental and Natural Resources Management, University of Ioannina, Seferi 2, 30100 Agrinio, Greece. Tel.: +30 26410 74117; fax: +30 26410 74176.
E-mail address: dvagenas@cc.uoi.gr (D.V. Vayenas).

0964-8305/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ibiod.2011.02.007

Since in Greece the majority of olive mill plants are three-phase and small-scale plants the above mentioned methods cannot be applied. The aim of the present work was to produce a high quality soil amendment using only wastes from an olive mill.

To assess compost maturity, the germination index (G.I.) is usually used. G.I. experiments were introduced by Zucconi et al. (1981) and include the quantification of seed growth when liquid compost extracts are applied (Komilis and Tziouvaras, 2009). The most commonly used seeds for these experiments are those of *Lepidium sativum* (salad cress). In the above experiments, the G.I. ranges from 45% (Alfano et al., 2008) to 87.7% (Hachicha et al., 2009a).

The present work presents preliminary results of compost processes using olive pomace and olive leaves. To monitor the process and assess compost quality, temperature, pH, electrical conductivity, moisture content, total C, total N and total P, were determined at various stages of the experiment. To evaluate the quality of the final product, G.I. experiments were performed using cress seeds (*L. sativum*) and lettuce plants (*Lactuca sativa*). The final target of this work was to develop an attractive low cost technology which could be used from small-scale olive mill plants.

2. Materials and methods

2.1. Composting process

The focused olive mill is a three-phase plant located near Amfilochia city in Aitoloakarnania Prefecture (Western Greece). The materials used for compost were olive leaves and olive pomace, which were mixed in proportions of 1:2, respectively. Raw materials were placed into a covered rectangular windrow of 8 m in length, 1 m in width and 0.5 m in depth. Compost remained in the windrow for 60 days. During this first period the pile was turned approximately every week or when compost temperature decreased. The turning mechanism consisted of a parallel steel frame onto which was mounted a rotating cylinder with three endless screws (augers) set in opposite directions forming two "V"s. Tap water was added to the windrow when necessary in order to keep moisture levels high (above 50%). After this 60-day period the compost was removed from the windrow to mature. During the maturation period (60 days) the compost was piled in a covered area.

2.2. Physicochemical analyses

During the composting period compost temperature was monitored daily along the windrow at depths of 0.25 m using a temperature probe. Samples from the compost windrow were taken once every 15 days and were analyzed in the laboratory to determine several parameters. A portion of the sample was used to measure moisture content, and volatile solids (VS), by drying the sample at 105 °C for 24 h and heating at 600 °C for 4 h, respectively (FCQAO, 1996). The remaining sample was air dried and used to determine total nitrogen concentrations according to the Kjeldahl method (Bremner and Mulvaney, 1982). Total phosphorus (TP) was determined according to Murphy and Riley (1962). Absorbance was measured using a Boeco S-20 spectrophotometer. Static respiration activity was measured using manometric respirometers as described by Komilis and Tziouvaras (2009). Meteorological data (including air temperature) were collected from a meteorological station of the National Observatory of Athens located in Kompoti (near the olive mill plant).

2.3. Phytotoxicity tests

Phytotoxicity was measured by the germination index (G.I.) using the *L. sativum* test (Zucconi et al., 1981). In this test phytotoxicity is determined by comparing the root development of seeds growing in the examined compost and in untreated soil (control sample). During the test 10 g of compost samples were crushed into fine powder and mixed with 100 ml distilled water. The solution was steered for 2 h then mixed with distilled water to create five solutions of different compost proportions 0% (control), 25%, 50%, 75%, 100%. 5 ml of each compost solution was then added to a set of three petri dishes each containing 25 *L. sativum* seeds. For each solution 3 replicates were performed. Petri dishes were incubated for 48 h at 26 °C. After incubation the length of each root was measured and G.I. was calculated.

Another phytotoxicity test was performed using lettuce plants (*L. sativa*). In this test mature compost was added to the surface of four pots where 10-day old lettuce plants had been planted. The weights of the compost added to each pot were 100, 200, 300 and 400 g. These masses correspond to 31.8, 63.7, 95.6, 127.4 kg/ha, respectively. Three replicates were used for each pot. The lettuce plants were placed in a greenhouse, and each pot was irrigated with 1 L water per day. After 20 days each plant was removed from its pot and its leaves and roots were weighed. For each compost weight 3 replicates were performed.

3. Results and discussion

3.1. Temperature evolution

The composting process lasted 120 days (60 days in the windrow and 60 days for maturation) which is one of the shortest composting times tested for this kind of material. As shown in

Table 1
Compost characteristics and germination index (G.I.) comparison between the present and other studies.

Reference Alphabetical or chronological order	Compost materials	Process period (days)	Dry matter (%)	pH	EC (mS/cm)	Organic Matter (%)	Organic carbon (%)	Nitrogen (%)	TP (%)	C/N	G.I. (%)
Alfano et al., 2008	Olive humid husks and olive leaves	90	n.a.	5.4	2.4	72.0	n.a.	0.78	0.45	–	45
Cayuela et al., 2010	Olive mill waste, sheep litter and grape stalks	279	n.a.	9.5	7.31	n.a.	n.a.	n.a.	4.7	15.5	74.2
Altieri and Esposito, 2010	Olive mill waste, wool waste and wheat straw	90	50	7.4	19.5	n.a.	37.9	3.5	0.17		88.4
Komilis and Tziouvaras, 2009	Olive pulp, olive leaves, wood chips and rice by-products	548	85	9	0.5	79	36.5	1.7	n.a.	22.0	62
Sellami et al., 2008	Exhausted olive cake and sesame bark	200	78.8	8.4	4.97	40.7	n.a.	3.51	0.65	11.5	n.a.
Hachicha et al., 2009a	Olive mill sludge and poultry manure	210	n.a.	8.3	9.2	26.2	18.5	1.19	0.06	16.2	87.7
Hachicha et al., 2008	Olive mill sludge and poultry manure	120	n.a.	7.6	4660	n.a.	23.1	1.4	0.53	16.5	n.a.
Hachicha et al., 2009b	Olive mill sludge and poultry manure	260	n.a.	8.9	5.4	30.1	20.3	1.7	0.07	11.9	n.a.
Cayuela et al., 2006	Olive mill waste, sheep litter and grape stalks	280	n.a.	9.3	31.0	34.9	n.a.	1.4	0.03	15.0	72.4
Sanchez-Arias et al., 2008	Sewage sludge and olive mill solid wastes	175	n.a.	n.a.	n.a.	n.a.	n.a.	3.3	0.26	n.a.	n.a.
Alburquerque et al., 2009	Olive pulp and agricultural by-products	300	n.a.	n.a.	n.a.	n.a.	60.5	18.3	n.a.	n.a.	n.a.
Present study	Olive pomace and leaves	120	45	7.6	1.21	83.7	48.5	1.8	0.17	27.1	195