THE FEASIBILITY OF OLIVE HUSK CO-COMPOSTING WITH COTTON WASTE

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ABSTRACT

Olive husks (OH), obtained from the olive oil two-phase system extraction, pose important problems for composting due to the concentration of lignocellulosic substances and the fat content. A composting pile was prepared by mixing OH with cotton waste (CW) as a bulking agent (67% OH + 33% CW, dry weight), in a static pile system with forced ventilation. The evolution of ventilation demand showed an initial delay in raising the maximum microbial activity, due to the sticky texture resulting from the high fat concentration in OH, which may imply low porosity. High fat concentration caused problems associated with compaction and oxygen entry into the composting mass. After this first phase, the evolution of the composting process was satisfactory. The thermophilic phase lasted 49 days whilst the active phase lasted 91 days. The mixture was then allowed to mature over a period of two months. During the active phase a high degradation of fat was observed (84%). However, the degradation of lignocellulosic compounds from olive stones was low. The evolution of the humification and maturity parameters (TOC/TN, HI, PHA, HAC/FAC and CEC/TOC) showed an increase in the humification degree during the active phase. These parameters, together with the basal respiration and FDA hydrolytic activity, indicated that, at the end of the active phase, the material was mature and biologically stabilised to a sufficient degree for agricultural purposes.

INTRODUCTION

The importance of the olive oil industry in Mediterranean countries is well known, as is the serious problem that the olive mills have in disposing of their by-products, such as the olive husk (OH). In the two-phase centrifugation olive oil production system, olive husks are the main byproduct generated. OH is a semi-solid waste with high moisture content, includes mainly skin, pulp and stone, and is highly contaminating and phytotoxic, due to the presence of polyphenols, salts and fats (Madejón et al., 1998). The OH has the highest organic matter (OM) content and K concentrations similar to the wastes generated in the different olive-oil extraction systems, ie. olive mill wastewater (OMW). It also has a slightly acidic pH, with the nutrient and fats levels close to those of the solid fraction of OMW (Bernal et al., 2000). Different experiments have demonstrated the feasibility of composting wastes from the olive-oil production, OMW (Tomati et al., 1995, Paredes et al., 2000), its solid fraction (García-Gomez et al., 2003) and the sludge (Paredes et al., 2002). Of the different materials used as bulking agents for co-composting olive-mill wastes, Paredes et al. (2000 and 2002) indicated that cotton waste provides adequate physical conditions, together with the amount of N to reach the necessary initial C/N ratio.

The aim of this work is to study the feasibility of composting the organic waste olive husk with cotton waste as a bulking agent. The evolution of chemical and biochemical parameters during the process was tested together with maturity degree of the final product.

MATERIALS AND METHODS

A composting mixture was prepared at the following rate (dry weight basis): olive husk (OH) 67% and cotton waste (CW) 33%. About 2500 kg of mixture were composted in trapezoidal static piles, by the on-demand removal of heat by pressure-forced aeration (feedback), as described by García-Gomez et al. (2003). Ventilation demand was measured as the time of ventilation necessary to maintain the temperature below 55 ºC. The biooxidative phase of composting lasted for 91 days, and the maturation phase two months.

The samples were analysed for organic matter (OM) content by loss on ignition at 430 ºC for 24 h, for total nitrogen (TN) and total organic carbon (TOC) by automatic microanalysis, as was the water-soluble organic carbon (HOC), and for NaOH-extractable C (EXC) and fulvic acid carbon (FAC) after precipitation of the humic acid carbon (HAC). Lignin and cellulose concentrations were determined by the American National Standards methods and the hemicellulose concentration by subtracting the cellulose concentration from the hollocellulose value, obtained by Browning's method. The fat content was determined by diethyl-ether extraction (Soxhlet system). Basal respiration and FDA hydrolysis activity were determined after pre-incubation of the fresh samples at 20 ºC for 24 h. Fresh samples were incubated at 26 ºC for 10 d. The CO_2 evolved was determined by titration with HCl the NaOH solution placed in a vial inside the incubation flask. The FDA hydrolysis was determined by the modified method of Inbar et al. (1991).

RESULTS AND DISCUSSION

The ventilation demand indicates that the maximum microbial activity was reached during the first 20 days of composting (García-Gómez et al., 2003). The evolution of the temperature and ventilation demand showed an initial delay in raising the maximum microbial activity, and in the development of high thermophilic temperatures (Fig. 1), due to the initial texture. The fats give a particular texture to the composting mass that inhibits the oxygenation (gas exchange) of the pile, whilst their hydrophobic character makes difficult the absorption of water added to the pile in order to maintain an adequate moisture content. The fat content diminished by 84 % during the bioxidative phase (Table 1), mainly during the thermophilic phase, remaining low and practically constant during maturation. These results are higher than the 70% lipid degradation found in OH composted with wheat straw (Madejón et al., 1998).

After easily degradable organic-C has been consumed, giving the greatest decrease in OM and in C/N ratio (Table 1), more resistant compounds such as cellulose, hemicellulose and lignin can be degraded, and partly transformed into humus. To avoid the concentration effect produced by the loss of weight due to OM degradation (Inbar et al., 1991), their absolute concentration must be calculated. The degradation of lignin and cellulose polymers basically occurred during the thermophilic phase, decreasing from 42.0 to 38.3 %, and from 22.4 to 21.8 %, respectively. At the end of the process, lignin was degraded by 10 % compared to the initial amount, cellulose 4 % and hemicellulose 37 %, the degradation of which occurred during the full process (final values 37.6, 21.7 and 19.2, respectively). The lower degree of lignin and cellulose degradation observed may have been due to the cellulose fraction being bound to the lignin (Lynch, 1987), making both organic matter fractions more difficult to degrade.

Compost maturity can be assessed by either measuring the activity of the microbial biomass, or by the evaluation of the organic matter humification degree (Iglesias-Jimenez and Pérez-García, 1992). The presence of fats interfered in the quantification of the EXC, FAC and HAC fractions, because the fats are co-extracted by saponification in EXC and are co-precipitated in HAC at pH 2. For this reason, these fractions were quantified after extracting the fats. The parameters related to the degree of humification of OM used as indices of maturity are: humic to fulvic acid ratio (HAC/FAC), which indicates the polymerization index, percentage of humic acids (PAH), as HAC/EXC x 100, humification index, as (HAC/TOC) x 100, HOC/Org-N ratio and CEC/TOC ratio (Roig et al. 1988; Iglesias-Jiménez and Pérez-García, 1992; Bernal et al., 1998). The progressive increases observed in HI, PAH and HAC/FAC during composting (Table 1) imply an increase in the OM humification level and its transformation into more complex and polymerised structures corresponding to humic type substances (García-Gómez, et al., 2003), and therefore a higher stabilisation degree of the OM, reaching PAH values close to 60 %. As composting progresses, the oxidation of OM leads to the appearance of new functional groups, meaning that the CEC increases with the degree of humification. In this experiment, the CEC/TOC ratio clearly increased during the composting process, reaching by the end of the process higher values than the limit proposed as an indicator of maturity in manures (1.7 and 1.9 $mmol_c\ g^{-1}$; Roig et al., 1988; Iglesias-Jiménez and Pérez-Jimenez, 1992). The HOC/Org-N ratio decreased during composting (Table 1), especially during the thermophilic phase, being stable during the maturation phase, as indicated by the Hue and Liu (1995).

***Table 1**. Characteristics of the organic matter at different composting times.*

Composting time (days)	OM (%)	TOC/TN	Fat (%)	HOC/ Org-N	HI	PHA	HAC/FAC	CEC/TOC ($mmol_c\ g^{-1}$)
0	85.13	25.81	8.62	3.27	7.45	40.39	0.68	1.33
49	83.98	18.56	3.62	2.20	8.68	50.06	1.00	1.53
91	82.23	20.53	1.00	1.12	11.56	68.48	2.17	1.99
174	82.48	19.07	1.34	1.79	11.62	69.04	2.23	2.63

OM: organic matter; TOC: total organic carbon; TN: total nitrogen, Org-N: organic nitrogen.

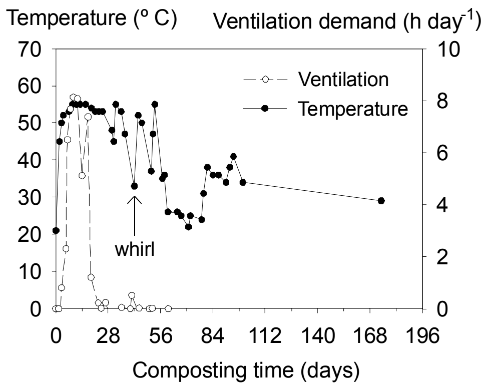

***Figure 1**. Evolution of temperature and ventilation demand during composting.*

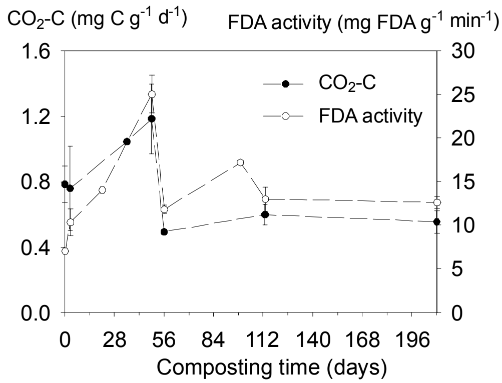

***Figure 2.** Evolution of the basal respiration and FDA activity.*

The measurement of basal respiration rate ($C\text{-}CO_2$ evolved) indicates the total metabolic activity of all microbiological processes that occur during OM degradation (Haynes, 1999). Measurement of fluorescein diacetate (FDA) hydrolysis has been used frequently to evaluate the total enzymatic activity of the microbial population present in soil and in organic substrates, however it has seldom been used in composting (García-Gomez et al., 2003). FDA activity increased quickly during the thermophilic phase (Fig. 2) in agreement with ventilation demand evolution (Fig. 1). Basal respiration and FDA activity followed the same pattern as temperature, decreasing at the end of the thermophilic phase, which indicates a decrease in the organic substrates degradable by the microflora. The FDA activity decreased slowly after the thermophilic phase due to establishment of the new mesophilic microflora. The values of basal respiration after maturation were very close to those found by Hue and Liu (1995) (0.06-0.63 mg C-CO_2 g^{-1} d^{-1}) in mature composts of different origin, which indicates the microbial stability reached after the composting process.

Therefore, the OH can be composted with CW as bulking agent, giving a stabilised and humified product. As a general conclusion, it can be said that the two-phase olive oil extraction system can become an environmentally friendly technology by integrating a composting system for transformation of the wastes into stabilised compost.

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