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Biodegradation of olive husk mixed with other agricultural wastes

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ABSTRACT

In this study, the evolution of the most important parameters (temperature, pH, electrical conductivity, total organic carbon, total nitrogen, and C/N ratio) describing the composting process of olive oil husk with other organic wastes was investigated. Four windrows for obtaining two mixed wastes composts (MWCs) and two green wastes composts (GWCs) were prepared.

All the raw materials used showed appropriate physical and chemical properties for composting process. The total organic carbon values of the final composts were suitable for agricultural purpose and in particular two of them (one MWC and one GWC) showed an increase of 47.6% and 40.3% in respect to the minimum levels established by the Italian legislation. After the biodegradation the C/N ratio could be considered satisfying for ready-to-use compost in three of the four windrows. The Ni and Pb concentrations did not overcome the Italian law limits in all windrows, while the Zn content was higher than the limit value only in two windrows (one of both MWC and GWC composts).

The findings highlighted that among the four composting processes, the best general results were found for one of the two GWCs produced.

1. Introduction

The importance of olive oil mill industry in Mediterranean countries is well known, as well as the serious problems that olive mill factories have in disposing their by-products (Garcia-Gomez et al., 2003). The Apulia region is one of the largest olive oil producers in Italy, with 37% of the overall product (D'Amico et al., 2005), and as a consequence of olive wastes.

The evolution from the traditional press mill to the modern two phases continuous extraction system has led to an inconvenient change in residues produced. In particular, the last process produces a semisolid husk including both vegetal liquids and solid residues from the olives, contrary to the traditional techniques in which the solid and liquid residues are separated and can be more easily managed.

The olive oil mill wastes (OMWs) are characterized by high organic load and a substantial quantity of plant nutrients (N, P, K, Ca, Mg and Fe) that could increase both soil fertility and crops production (Zenjari and Nejmeddine, 2001; Tejada and Gonzales, 2003; Montemurro et al., 2004, 2006), so that the recycling or the valorization of such wastes can be environmentally and economically beneficial.

The olive oil husk (OLH) obtained from modern extraction is rich in easily degradable organic matter, polyphenolics, unextracted oil and organic acids and, therefore, cannot be safely land-applied on a regular basis (Canet et al., 2008). Composting has shown to be a suitable method to recycle OLH because it needs low technical and economical requirements. However, the OMWs, mainly olive mill wastewater and OLH, need to be mixed with ligno-cellulosic materials, due to their sticky texture, to obtain adequate physical conditions of the starting mixtures (Garcia-Gomez et al., 2003). Since physical and chemical properties of OLH are rather unsuitable for direct biodegradation, in Mediterranean areas many complementary residues such as animal manures, olive leaves, cereal straw, pruning wastes or horticultural residues are usually utilized in composting processes.

Furthermore, the potentially harmful organic substances in the OMWs are degraded during the biodegradation process (Tejada and Gonzales, 2004), allowing the safe use of the obtained compost in agricultural fields. Therefore, composting could be an interesting alternative in recycling large amounts of a wide range of the residues produced in Mediterranean areas, resulting in an organic fertilizer suitable to be applied in their own fields, saving fertilization costs and improving their typically poor and erosion endangered soils (Canet et al., 2008).

Several studies have been performed on the composting of olive husk (Bernal et al., 1998; Paredes et al., 2000; Baeta-Hall et al., 2005; Alfano et al., 2008), but there is still a lack of information on biodegradation of this material mixed with agricultural Mediterranean wastes.

On this matter, the objective of this research was to study the evolution of parameters describing the composting of olive husk,

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in association with other agricultural wastes, for obtaining mixed and green wastes composts.

2. Methods

2.1. Composting procedure

Two fresh OLH were collected from two different two-phase centrifugation olive oil milling factories: the former was obtained from the Oil Mill Cooperative in Palo del Colle (OLH_P) and the latter from the Di Battista Oil Mill in Lucera (OLH_L), both in Apulia region (Southern Italy). Four windrows of OLH mixed with different organic residues were made. The specified proportions (on fresh weight basis) are reported in Table 1. The windrows were prepared and processed simultaneously from the summer of 2004 for obtaining two mixed wastes composts (MWCs) and two green wastes composts (GWCs), as defined by the Italian legislation (Decree n. 217, 29/04/06).

In particular, the OLH_P was mixed with pruning wastes (PWs) and, to increase the initial N concentration of the composting mixture, with sheep manure (SM) or urea (U) in windrows P1 (MWC) and P2 (GWC), respectively. The OLH_L was blended in windrows L1 (MWC) and L2 (GWC) with cattle manure (CM) and ammonium sulphate (AS), respectively, supplemented with wheat straw (WS), sawdust (SD) and lettuce residues (LRs) in different proportions. The purpose of using ligno-cellulosic wastes in these mixtures was to obtain a bulking agent for compensating the low porosity of husk. Mixtures were composted in trapezoidal piles (1.5 m high with a base of 2–3 m), and the composting process was conducted over 116 days, both in Palo and Lucera. The bio-oxidative phase was considered finished when the temperature was stable, close to the external value, and reheating did not occur. The windrows were stirred mechanically for aeration by a turning machine when the internal temperature, measured by thermocouple probe (CHEMIE, Bari, Italy) with a digital thermometer (Delta Ohm HD 9215), reached or exceeded 60 °C. The temperature was recorded weekly at three depths: 1/3, 2/3 and 3/3 from the top of the each composting pile. The average value was used to represent the temperature profile during biodegradation. Besides, the moisture content in piles was determined by gravimetrical method and was maintained at the same level (over 40%) by manual irrigation throughout the composting period. The initial main characteristics (mean of three values) of the raw materials are reported in Table 2. The OLH_P was stored before it was used, so the moisture content was lower than in the OLH_L.

2.2. Sampling and analytical determinations

Analytical determinations were made on raw materials and on the samples taken during the whole biodegradation. The results are expressed on dry weight basis.

Three samples from each pile were collected every 10–15 days and were immediately stored at 4 °C till analysis. The windrows were also sampled at the end of the maturation phase to follow the evolution of some chemical characteristics of the composted materials. The samples were taken by mixing six sub-samples from six sites of each windrow, spanning the whole.

Electrical conductivity and pH were measured in 1:10 (w/v) water soluble extraction at 24 ± 1 °C. The conductivimeter used was a CRISON 524 and the pH-meter used was a CRISON microTT 2050. The moisture content was determined by drying a sample at 105 °C until the constant weight was reached. The total organic carbon (TOC) was measured by dichromate oxidation and the total nitrogen (N) by the Kjeldahl method. Total P, Zn, Cu, Pb and Ni were determined by Inductively Coupled Plasma-Optical Emission spectrometry (ICP-OES) after digestion in HNO_3 65% in a pressurized microwave.

3. Results and discussion

All the matrices used (Table 2) showed suitable physical and chemical properties for composting process, because they had enough amount of TOC and total N. Furthermore, the heavy metals content of these raw materials were similar to those reported by other authors (Sharma et al., 1997; Paredes et al., 2005).

In Table 3, the chemical–physical properties of the initial windrows (t0) and of stabilized products after biodegradation (tf) are reported.

The temperature is a consequence of the microbial activity during biodegradation process. Depending on the feedstock and its physical state, the temperature usually rises within the first few days of composting from the environmental level to 60–70 °C. It remains at this level with minor fluctuations for several days and then gradually decreases to a constant state near the external value (Epstein, 1997).

The temperature profiles of each windrow of this study are shown in Fig. 1. The results confirmed the different phases described above, occurring sequentially in time, even if the behavior was variable according to the composted mixtures.

Table 1
Composition of the raw materials of the different windrows (kg).

Raw materials	Windrows			
	L1	L2	P1	P2
Olive oil husk of Palo del Colle (OLH_P)			800	800
Pruning wastes (PWs)			400	400
Sheep manure (SM)			280	
Urea (U)				50
Olive oil husk of Lucera (OLH_L)	700	350		
Cattle manure (CM)	200			
Ammonium sulphate (AS)		50		
Wheat straw (WS)	100	80		
Sawdust (SD)	30	80		
Lettuce residues (LRs)	400	100		

Table 2
Chemical characteristics of the raw materials (means of three values calculated on the dry weight basis).

Parameters	OLH_P	PWs	SM	U	OLH_L	CM	AS	WS	SD	LRs
Moisture (%)	25.8	59.7	59.8	–	55.7	47.0	–	12.0	15.4	89.0
TOC (g kg^{-1})	410	453	212	200	414	222	–	350	404	401
Total N (g kg^{-1})	13.6	14.8	23.5	460	14.3	15.1	210	7.01	3.00	36
Total P (g kg^{-1})	7.0	7.0	13.0	–	9.0	10.0	–	7.5	0.06	0.3
C/N	30.1	30.6	9.02	0.43	28.9	14.7	–	50.0	135	11.1
Zn (mg kg^{-1})	19.3	21.7	135	–	19.7	66.0	–	13.5	11.7	76.3
Cu (mg kg^{-1})	28.3	22.3	39.3	–	28.3	31.3	–	13.8	3.4	14.5
Ni (mg kg^{-1})	50.0	118	69.3	–	55.3	83.0	–	45.3	48.0	21.0
Pb (mg kg^{-1})	<1	<1	<1	–	<1	<1	–	<1	<1	<1