COMPOSTING “ALPERUJO”, THE MAIN BY-PRODUCT OF THE SPANISH OLIVE OIL INDUSTRY. EFFECTS OF BULKING AGENT AND AERATION ON THE PROCESS AND AGROCHEMICAL EVALUATION OF COMPOST

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SUMMARY: Introduction of the two-phase centrifugation system for olive oil extraction during the early nineties in Spain has led to the yearly generation of approximately four million tons of an acidic solid olive-mill by-product called “alperujo” (AL). It has high moisture, organic matter and potassium contents and a considerable proportion of fats, proteins and water-soluble carbohydrates and phenols.Composting was considered a suitable alternative for the AL disposal as some of those properties are not compatible with agricultural requirements. In order to evaluate the efficiency of the bulking agent, the AL was co-composted with either, grape stalk (GS) or olive leaf (OL), using forced ventilation assisted by mechanical turning and the composting progress monitored, GS contributing more than OL to improve the advance of the process. However, both mature composts were equally free of phytotoxicity and showed a similar composition. Also, the evaluation of the most suitable aeration technology for AL composting was carried out by using two identical piles prepared by mixing AL with fresh cow bedding (FCB) as bulking agent. Forced ventilation was employed in conjunction with mechanical turning in one of the piles, whereas only mechanical turning was used in the other pile, the process was completed in less time when forced ventilation was coupled to mechanical turning. Also, a slight delay in the evolution of pH, C/N ratio, biodegradation of fats and organic matter was observed when only turning was employed. However, the recommended method for composting AL is only turning since the composition of the end-product in this case was comparable to the composted AL using forced ventilation. Furthermore, substantial economical savings may be expected by selecting mechanical turning alone, which include capital costs for aeration equipment and the amount of water needed for irrigation. The non-phytotoxic AL-compost, rich in organic matter, potassium and organic nitrogen but poor in phosphorus and micronutrients, was compared with a cattle manure (CM) and a sewage sludge compost (SSC) for use as organic amendment on a calcareous soil. The experiment was conducted with a commercial pepper crop in a greenhouse using fertigation. The marketable yields of pepper obtained with all three organic amendments were similar, but when CM and SSC were used for soil amendment, the soil organic matter content was significantly reduced after cultivation, while it remained almost unchanged in the AL-amended plots.

1. INTRODUCTION

It is a well-known fact that the olive-mill industry has a great social and economic importance for Mediterranean countries such as Spain, Italy, Greece, Portugal, Turkey, Morocco and Tunisia. The two-phase centrifugation system was introduced in Spain to reduce the environmental impact generated by the high production of olive-mill wastewater in the three-phase system. Although the two-phase system greatly reduces wastewater generation and its contaminant load, it still produces a solid but very moist by-product called in Spanish “alperujo” (AL), whose disposal constitutes a great economic and technical problem for producers. Nowadays, AL production by the Spanish olive oil industry may exceed four million tons per year; therefore it is necessary to find appropriate solutions for its disposal.

In this sense, among the methods proposed for the disposal of the olive-mill wastes and by-products, composting is increasingly considered a suitable method for AL valorisation to obtain organic fertilisers and amendments. Therefore, AL compost can be employed as valuable products to improve soil properties, supply nutrients and reduce the use of chemical fertilisers in agricultural systems as well as control plant diseases. This fact seems clearer if we take into account that most Mediterranean soils are characterized by low organic matter contents, which are increasingly leading to soil degradation process and fertility loss.

During the last years, our team has developed different composting experiments, financed by the European Commission, in collaboration with other research groups from Italy, Greece, and Portugal. They focused on AL characterisation, bulking agent selection, evaluation of the best aeration conditions and the most appropriate monitoring parameters as well as the agricultural effectiveness of the final product obtained. The aim of this communication is to show some of the results obtained from our research by studying the effects of bulking agent and aeration system on the composting process and evaluating the agrochemical characteristics of the obtained composts.

2. EXPERIMENTAL STUDY

2.1. Characterisation of raw materials

2.1.1 Olive mill waste

The agrochemical characterisation of 20 AL samples (Alburquerque et al., 2004) showed that AL has high moisture content and slightly acidic pH values, is rich in potassium but rather poor in phosphorous, calcium and magnesium. In addition, its nitrogen content is low as also the content of the main micronutrients. AL is characterised by a high organic matter content, lignin, hemicellulose and cellulose being its main constituents and determining that AL usually presents an unbalanced and relatively high C/N ratio. It also shows important contents of fats, water-soluble carbohydrates and phenolic compounds.

Other AL characteristics, as its poor physical structure due to the combination of high moisture content and small particle size, as also its limited consistency as solid material, make it scarcely porous and easily compactable. These properties make necessary the addition of appropriate bulking agents to reach a successful composting.

2.1.2 Supplemental organic wastes (bulking agents)

The bulking agents used in the composting experiments were grape stalk (GS), olive leaf (OL) and fresh cow bedding (FCB), the latter including abundant cereal straw. They were selected not only taking into account their physico-chemical characteristics, but also their availability and cost. GS and OL had acid pH values, high organic matter and lignin contents and relatively low cellulose content. By the contrary, FCB had bigger pH and nutrient content, lower lignin content and C/N ratio and good water-retainer characteristics. All them showed lower water content than AL.

2.2. Composting performance

Trapezoidal piles with approximate dimensions 1.5 m high and a 2×3 m base were composted in a pilot plant. Composting experiments (Table 1) were based on the Rutgers strategy which employs on-demand ventilation through temperature feedback control (Finstein et al., 1985) combined with mechanical turning for piles 1-2 and 4, while pile 3 was only managed by mechanical turning. During the process, moisture content was maintained within the interval 40-55%.

Table 1. Composition and management of the composting mixtures (AL: alperujo, GS: grape stalk, OL: olive leaf and FCB: fresh cow bedding).

Mixtures	Composition (%)		Weight (kg)	Turnings	Forced ventilation (*)
	Fresh basis	Dry basis			
Pile 1	94.6 AL1 + 5 GS + 0.4 urea	(87/12/1)	2600	3	yes (55 °C)
Pile 2	94.6 AL1 + 5 OL + 0.4 urea	(87/12/1)	2600	3	yes (55 °C)
Piles 3 and 4	90 AL2 + 9 FCB + 1 AL compost	(87/11/2)	4000	14	3 (no) 4 (yes, 55 °C)

*Ceiling temperature for continuous air blowing.

2.3. Greenhouse culture

AL compost (ALC) was evaluated for the commercial production of pepper (Capsicum annuum cv "Orlando") under fertigation and greenhouse conditions. In this study, ALC was compared with a cattle manure (CM) and a sewage sludge compost (SSC), currently used for horticultural production in Southern Spain.

Complete details of the composting performance and the analytical methods employed can be consulted in Alburquerque et al. (2006b) and Cegarra et al. (2006), while the greenhouse experience could be checked in Alburquerque et al. (2006a).

3. RESULTS AND DISCUSSION

Our composting experiments revealed the importance of bulking agent addition for AL composting performance and its great impact on substrate aeration conditions. In piles 1 and 2, the forced ventilation was unable to activate the process during the first month of composting, as showed the scarce temperature increase (Figure 1). After the first turning, temperatures increased in both piles as a response to substrate aeration improvement, mixing and homogenisation, but the temperature increase was more rapid and important in pile 1, indicating that GS acted as a better bulking agent than OL.

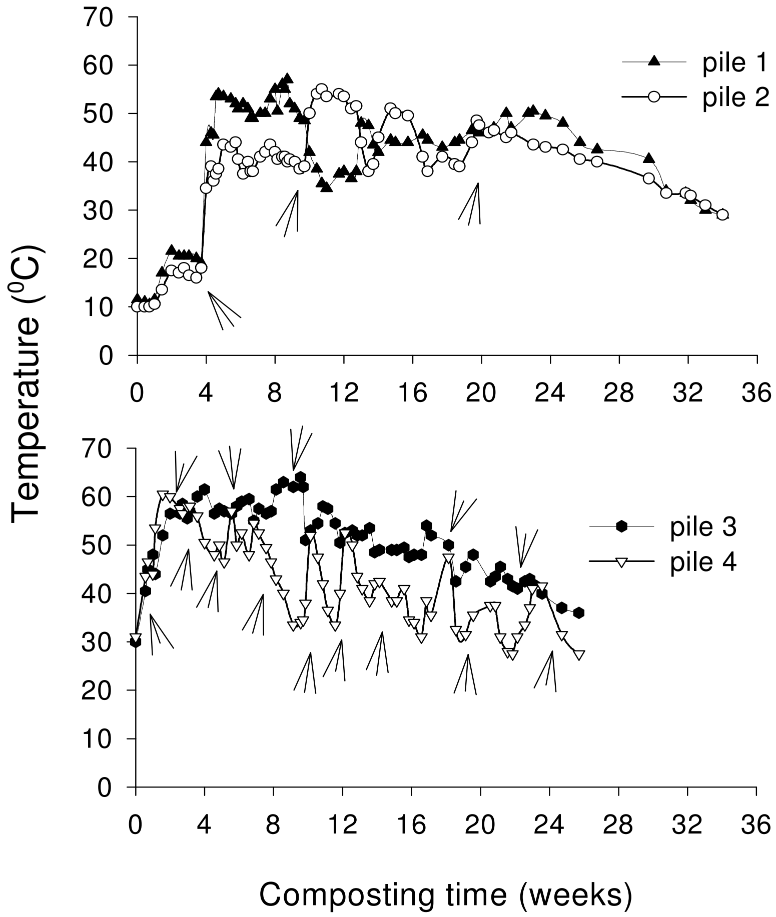

Figure 1. Temperature profile during the bio-oxidative phase of composting (arrows indicate turnings)

On the contrary, piles 3 and 4 showed a rapid and much earlier increase in temperature during the initial phase of the process, this fact suggesting a clear improvement of the physical structure of the substrate due to the addition of the FCB as bulking agent. FCB also provided available nutrients, an easily degradable organic matter and an important inoculum effect due to the microbial populations living into the fresh manure. All these factors in conjunction with the frequent turnings (pile 3) or by both forced ventilation and turnings (pile 4), favoured a rapid activation of the composting process in these piles. In addition, forced ventilation provoked that pile 4 showed lower maximum temperatures (Figure 1) due to its cooling effect, favouring a more diverse microbial activity, and also exerted a positive effect of oxygen conditions, enhancing both facts the composting performance. However, forced ventilation provoked a higher water evaporation in pile 4 and, hence, a greater water consumption compared to pile 3.

3.1 pH

Substrate pH values were greatly influenced by aeration conditions, coinciding scarce pH increase periods with low process progress. Thus, pH maintained acid values during the first month of the process in piles 1 and 2 (Figure 2), coinciding with the deficient aeration conditions and the scarce temperature increases (Figure 1). After the first turning (pile 1) and after the second (pile 2), pH increased until alkaline values. As shown temperature tendency, the pH rose rapidly in pile 4, while pH increase was slower in pile 3 due to its worse aeration conditions (only turned) compared to pile 4.

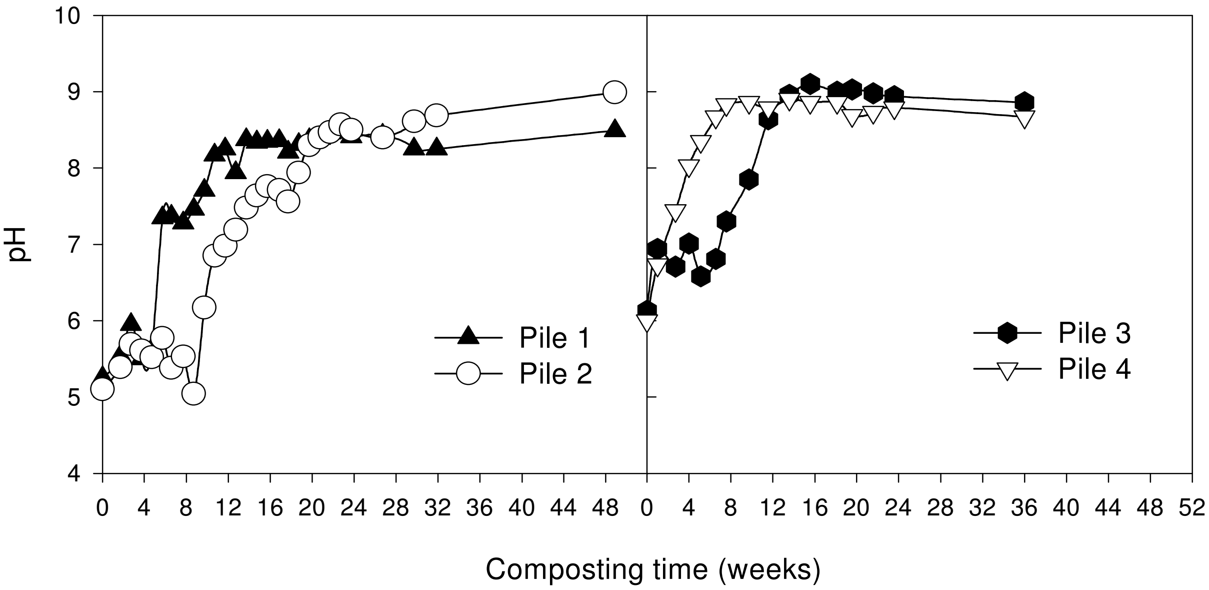

Figure 2. Evolution of pH during composting process

3.2 Total organic matter degradation

The better aeration conditions in piles 1 and 4 compared to piles 2 and 3, respectively, provoked that organic matter losses showed clear differences during our experiments (Figure 3). The most important losses were detected during the thermophilic phase, reaching a final value of 50% (pile 1), 34% (pile 2), 54% (pile 3) and 61% (pile 4). Low organic matter degradation periods always coincided with acid pH and low temperature values, all them related to deficient aeration conditions.

It is important to note that the lignocellulosic nature of the AL determined a low degradation rate in all the experiments, provoking that the composting time was much longer in AL than in other composting substrates such as municipal solid wastes and sewage sludges. This is a typical behaviour of AL composting and other lignocellulosic materials (Eiland et al., 2001; Baeta el al., 2005; Cayuela et al., 2006; Manios et al., 2006).

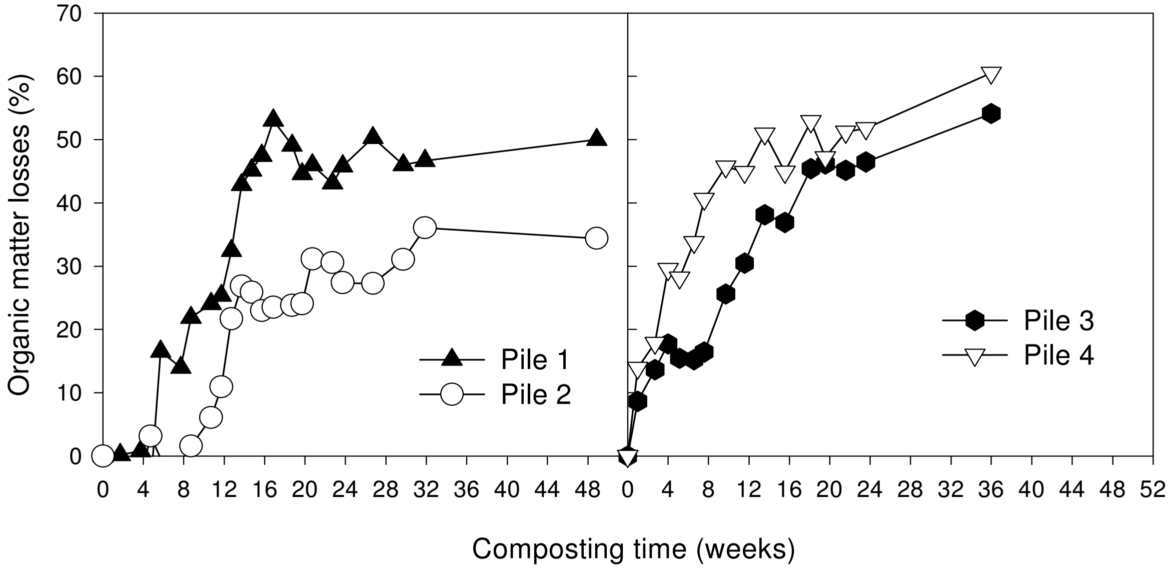

Figure 3. Organic matter losses during the composting process

3.3 Nitrogen and C/N ratio

In all the piles a clear predominance of the organic forms of nitrogen was observed during the composting process with no production of nitrates. It seems that AL composting conditions (long thermophilic periods, high values of pH and C/N ratio and low degradation rate) can favour the nitrogen immobilisation and its loss as ammonia. There was an increase in the total nitrogen concentration as a result of the organic matter mineralization which reduced the weight of the piles and decreased the C/N ratio in all them.

3.4 Fats, water soluble phenols and germination index

As shown Figures 4, 5 and 6, fats and water soluble phenols decreased during the process coinciding with increases in the germination index (GI). The GI increase indicated a clear detoxification of the composting substrates which slowed down during the periods of deficient aeration conditions, as did the fat degradation process. As composting advanced, GI increased from irrelevant initial values to final values bigger than 50%. The GI delay detected in piles with the most deficient aeration conditions (piles 1 and 3) coincided with the delay in the evolution of other parameters, such as temperature (Figure 1), pH (Figure 2) and organic matter and fat losses (Figures 3 and 4). Therefore, the above parameters could be considered as good indicators of the evolution of the AL composting process.

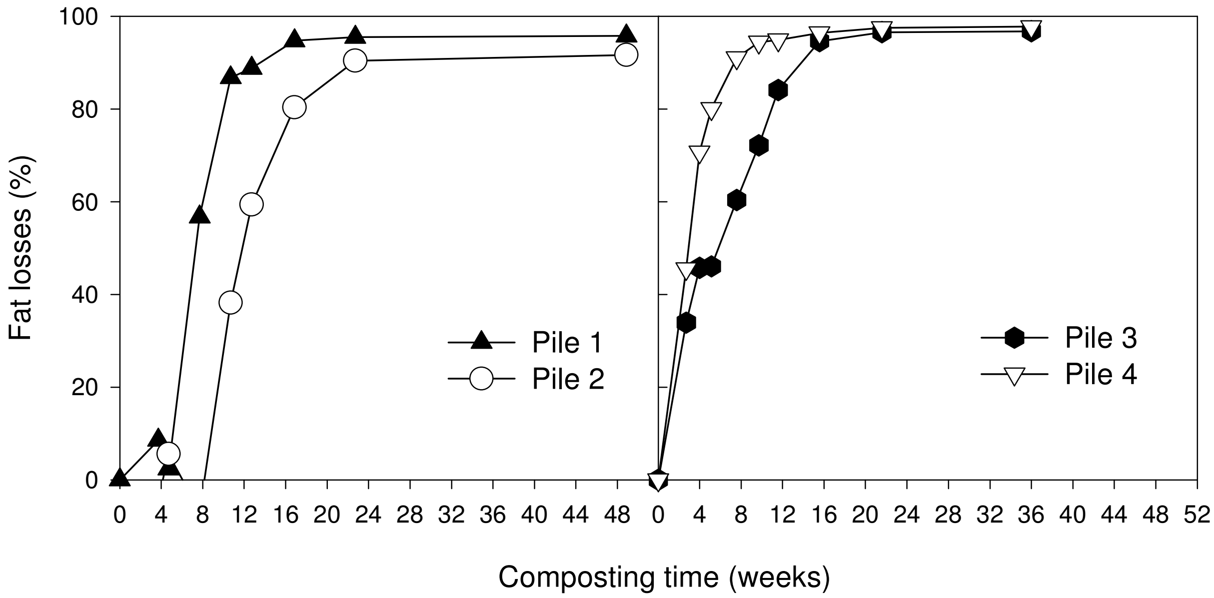

Figure 4. Fat losses during the composting process

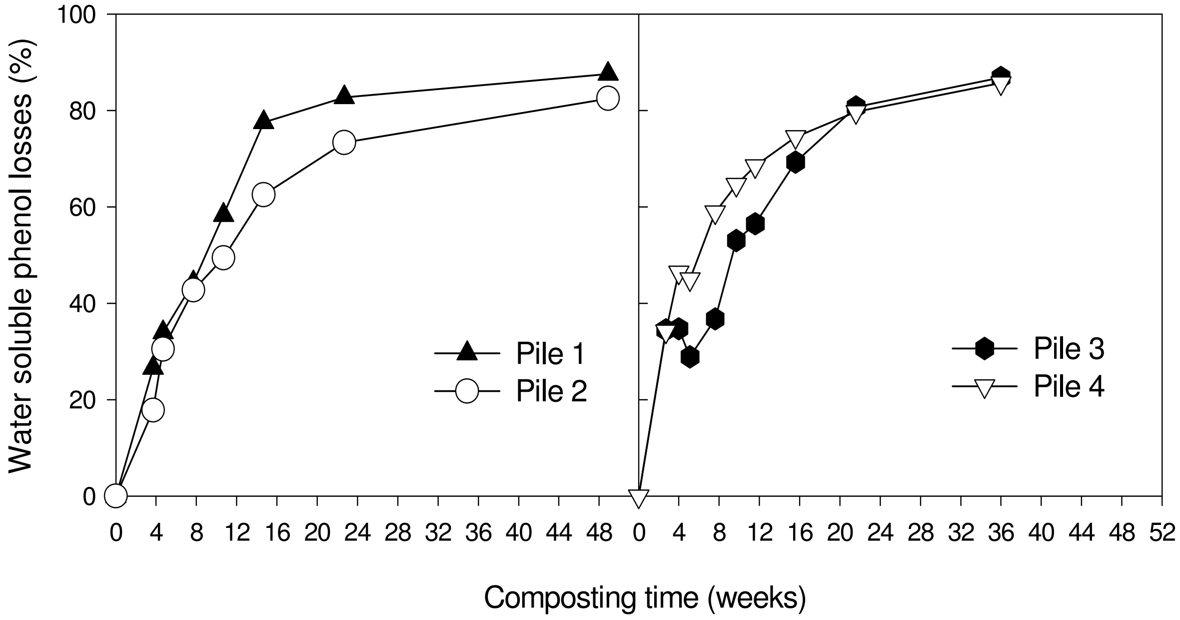

Figure 5. Water soluble phenol losses during the composting process

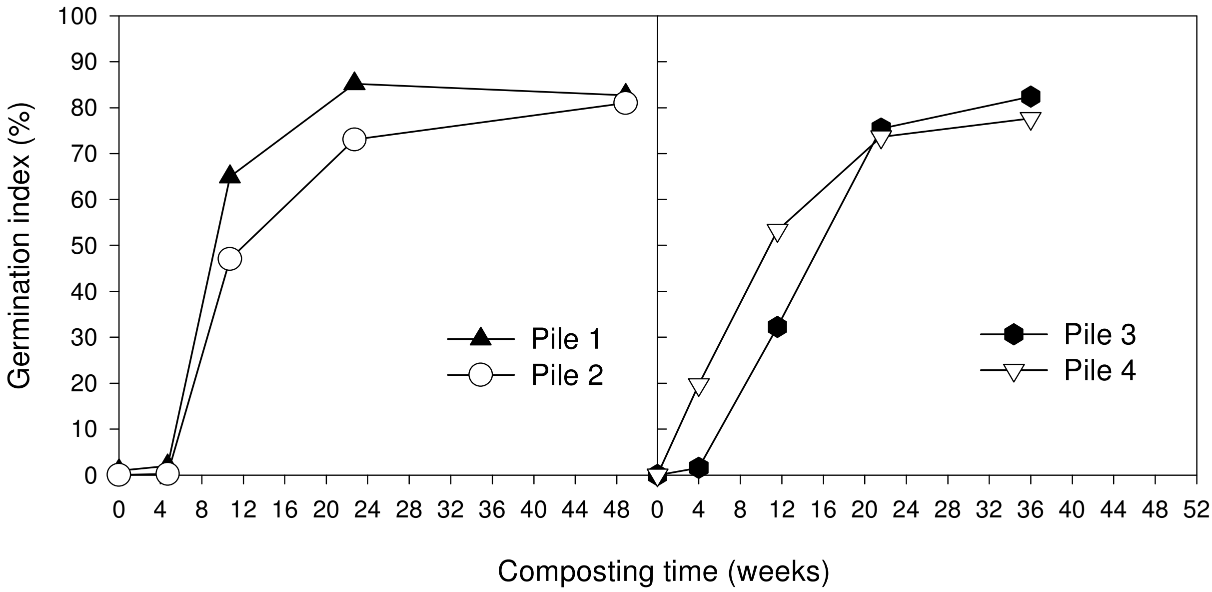

Figure 6. Evolution of the germination index (GI) during the composting process

3.5 Compost characteristics

The composting process produced similar non-phytotoxic end-products, which had alkaline pH values and were very rich in organic matter (Table 2), nearly half being composed of lignin (fraction poorly biodegradable and an important precursor of humic substances). During the process, fats, water-soluble carbohydrates and phenols were intensely degraded, all these compounds showing low contents in the mature composts.

They were rich in potassium and had acceptable nitrogen contents, the latter mainly in organic form and, thus, presumably not directly available for plant nutrition whereas the content of the other macro and micronutrients was rather low. In addition, their contents in potentially toxic harmful heavy metals and sodium were irrelevant in comparison with urban waste compost (Pascual et al., 1997).

3.6 Greenhouse experiment

Organic treatments affected significantly neither marketable pepper yield nor their commercial quality, being similar between ALC, SSC and CM. In addition, there was no evidence of negative effects on plant growth of ALC treatment. Although leaf nutrient content were quite similar among treatments because of the use of fertigation, organic amendments increased nitrogen, potassium and copper leaf contents.

A clear effect of ALC treatment was on soil organic matter content, which maintained at the same level after cultivating, decreasing in the rest of treatments (control, SSC and MC). This fact reflected the high resistance to edaphic degradation of the organic matter provided by ALC according to its lignocellulosic nature.

Table 2. Main properties of the AL composts

Parameters	Pile 1	Pile 2	Pile 3	Pile 4
pH[1]	8.49	8.99	8.86	8.67
Organic matter (g kg^{-1})	896	912	816	793
Lignin (g kg^{-1})	430	399	406	387
Total N (g kg^{-1})	22.7	23.1	26.3	26.1
NH_4^+-N (mg kg^{-1})	178	185	114	119
NO_3^--N (mg kg^{-1})	61	101	32	31
P (g kg^{-1})	1.6	1.5	1.9	1.9
K (g kg^{-1})	37.0	36.2	42.7	42.5
Ca (g kg^{-1})	11.3	9.4	24.0	29.7
Mg (g kg^{-1})	2.3	1.9	5.1	5.7
Na (g kg^{-1})	1.4	1.0	4.1	4.1
Fe (mg kg^{-1})	624	525	1365	1468
Cu (mg kg^{-1})	24	33	34	36
Mn (mg kg^{-1})	38	44	86	98
Zn (mg kg^{-1})	40	50	125	138
Pb (mg kg^{-1})	9	5	17	20
Cr (mg kg^{-1})	nd	nd	12	12
Ni (mg kg^{-1})	4	5	8	10
Cd (mg kg^{-1})	nd	nd	nd	nd

[1] water extract 1:10.

nd: not detected.

4. CONCLUSIONS

The key factor for AL composting optimisation is to reach accurate oxygen conditions in the substrate by improving its physical structure with the addition of bulking agents. Adequate bulking agents provide air space and structural support which permit a proper gas exchange and prevent excessive substrate compaction, mineral and organic nutrients (available nitrogen and carbon sources) and microbial inoculum depending on their characteristics and origin, all leading to a clear improvement of the AL composting process. In our experiments, FCB behaved as the best bulking agent and OL as the worst.

In addition, our composting experiments also underlined the importance of mechanical turning application as an effective operating strategy in forced ventilated piles in order to allow a better distribution of the air in the substrates and encourage the process by restoring the air-flow channels or pores, homogenising and re-inoculating the composting substrate.

Composting AL involved relatively low level of organic matter degradation, an increase in pH and clear decreases in the C/N ratio, fats, and water-soluble organic compounds. The resulting composts obtained, which were free of phytotoxicity, had high potassium and organic nitrogen contents but those of phosphorus and micronutrients were low.

In an industrial scale development, the recommended method for composting AL is mechanical turning without forced ventilation since the composition of the end-product in this case was comparable to the composted AL using forced ventilation. Furthermore, production costs would be much lower without the ventilators and tubing involved and there would also be a substantial saving in the amount of water needed for irrigating forced air piles.

To sum up, AL together with other olive-mill wastes and by-products can be considered an important source of organic substrate for composting processes with the advantages of high organic matter content, large quantities produced, and the absence of industrial chemical contaminants. Therefore, the obtained composts from AL could be utilised widely in horticulture and organic agriculture, as an organic substrate or in olive cultivation itself, with important economical advantages.

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