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Salma Hachicha, Mohamed Chtourou, Khaled Medhioub, Emna Ammar

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Research article

Compost of poultry manure and olive mill wastes as an alternative fertilizer

Salma HACHICHA, Mohamed CHTOUROU, Khaled MEDHIOUB, Emna AMMAR*

UR Étude et Gestion des Environnements Urbains et Côtiers, LARSEN, École Nationale d'Ingénieurs de Sfax, BP W, 3038 Sfax, Tunisia

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Abstract – We studied a compost made of poultry manure, olive mill wastes and mineral-rich wastewater, as an alternative fertiliser. The composts were of high quality, characterized by high levels of nutrients, a relatively low C/N ratio of 15–17 and a fertilizing value similar to that of conventional cattle manure, however without phytotoxicity. Field experiments showed an increase in potato production of 31.5–35.5 t/ha, compared to 30.5 t/ha using cattle manure. The use of olive mill wastewater did not have any negative impact on soil pH, electrical conductivity and phenols. The compost made of poultry manure and olive mill by products appears therefore as a promising ecological alternative to classical fertilizers.

poultry manure / olive mill cake / olive mill wastewater / composting / agronomic valorisation of by-products / agro-food industries

1. INTRODUCTION

The intensification of agro-food activities such as the industrialization of poultry meat and the extraction of olive oil generates a huge quantity of organic by-products, which are causing serious environmental problems to solve. Indeed, on the one hand, poultry meat has become the main source of proteins in many developing countries like Tunisia. The industrialization of this activity is generating huge amounts of poultry manure. For meat chicken, the average animal produces 2 kg in 7 or 8 weeks, while the yearly output of a layer or genitor is estimated to 65 kg (Bouzouaia and Rannen, 2003). This by-product of this agro-industry is well known for its negative impact on the environment. It has some anaesthetic effects and a high concentration of ammonia which when released in the atmosphere spreads a very bad smell (Georgakakis, 2000).

On the other hand, the extraction of olive oil, a very important product to populations around the Mediterranean Sea, causes another threat to the environment. Indeed, despite the benefits of olive oil as a source of fat in many Mediterranean diets and a main activity in the economic development of many southern Mediterranean countries, its extraction releases huge amounts of solid/liquid waste matter regardless of the processes used. A semi-solid residue known as olive mill cake has a typical moisture of 40% and a liquid-phase commonly known as olive mill waste. This black effluent contains a proportion of fine solid matter including remaining particles of crushed olive stones, flesh and skins, sugars, nitrogen-containing compounds, volatile acid, polyalcohol, pectin, fats, salts and polyphenols. The volume of olive mill wastewater may vary from 50 to 150 L for 100 kg of the processed olives depending on the processing system (Sierra et al., 2001; Parades et al., 2001; Chtourou et al., 2004).

In Tunisia, the first by-product of the agro industry amounts to approximately 650 000 tons of poultry manure every year while the second rejects 500 000 tons of olive mill wastewater yearly (Bessadok, 2001; GIPA, 2004). Both pollutants represent serious environmental problems that need to be handled urgently. Several works have suggested using poultry manure as a fertilizer to improve crop production in organic farming. However, excessive manure applications are plant toxic due to high salt content and accumulation in plants of trace metal, which may pose a health risk and lead to ground and surface water pollution (Nicholson et al., 1996; Wong et al., 1999). Moreover, the addition of bulking agent during cattle and pig manure composting was demonstrated to have a positive effect on enzyme activities and the choice of bulking agent strongly affected the potential capacity and properties for mineralization of organic phosphorus in manure composts (Vuorinen, 2000).

Olive mill wastewater was also suggested as a soil fertilizer (Tomati et al., 1996; Ammar and Ben Rouina, 1999; Houot, 2000; Zenjari and Nejmeddine, 2001). Nevertheless, recent results revealed that this solution has some drawbacks such as infiltration of phenolic compounds and inhibition of microflora (Shabou et al., 2005). Hence, composting was proposed as a better solution for both pollutants but separately. However, to our knowledge, there is scarce information on composting poultry manure by using olive mill wastewater.

This work describes the evolution of the composting parameters of mixtures of poultry manure, an industrial agro food

* Corresponding author: ammarenis@yahoo.fr

waste and exhausted olive mill cake, a by-product from soap factory, used as bulking agent and olive mill wastewater as a humidifier. Two aerated windrows were investigated. Potato of the variety *Spunta* was cultivated in soils amended with the prepared composts. The impact of the by-products used during all the process was assessed by the determination of soil physico-chemical properties.

2. MATERIALS AND METHODS

In this work, compost was achieved by mixing poultry manure and exhausted olive mill cake from soap factory as bulking agent and olive mill wastewater as a humidifier. Windrows including defined proportions of poultry manure and exhausted olive mill cake were well mixed and aerated by mechanical turning to keep the moisture range of 45 to 60%. During the biological process, physico chemical properties were checked and when stabilised, the agronomic properties of both obtained composts were tested on potato crop in vivo: *Spunta species* (Fig. 1). The impact of intrinsic properties of olive mill wastewater used during composting was assessed by soil physico-chemical determination.

2.1. Raw materials

Two raw materials were used in the composting process.

The first raw material poultry manure was collected from an industrialized farm in the area of Sfax, Tunisia. It was characterized by high pH, a high total organic carbon (20% d.w.), an ash content of 60% of d.w. and a low C/N ratio. The second, exhausted olive mill cake, obtained from a soap factory in the same area, had a low pH, high C/N ratio and relatively low minerals (Tab. I). These raw materials were mixed in two windrows (WI and WII) of 8000 kg each, having the following composition:

- Windrow I: 75% Poultry manure + 25% Exhausted olive mill cake;
- Windrow II: 25% Poultry manure + 75% Exhausted olive mill cake.

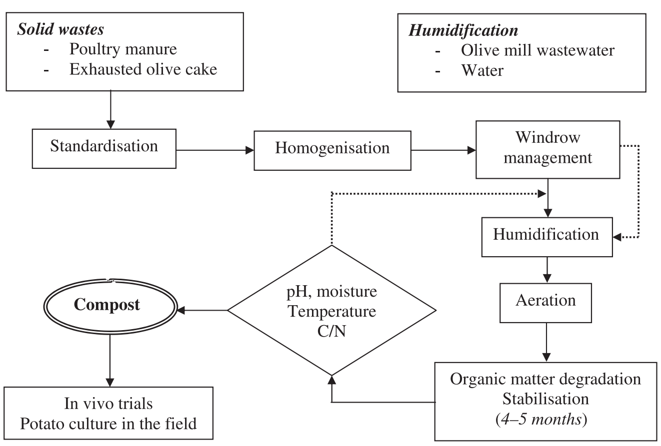

Figure 1. Experimental design and process controle. C: carbon content; N: total nitrogen content.

Table I. Physico-chemical characteristics of poultry manure and exhausted olive cake used for composting. PM: Poultry manure; EOC: Exhausted olive mill cake; OMW: Olive mill wastewater; TOC: Total organic carbon; TKN: Total kjeldahl nitrogen; d.w.: Dry weight.

Parameters	pH	Moisture (%)	TOC (% d.w.)	TKN (% d.w.)	C/N
PM	9.45	45.50	20.17	1.72	11.73
EOC	5.85	19.65	42.00	1.05	39.14
OMW	5.29	90.00	42.97	0.60	71.20

Both windrows were humidified with olive mill wastewater which had an acidic pH (≈ 5.3), high chemical oxygen demand expressing the carbon content (COD: 178 g/L) and low dry matter content (10%), its C/N ration was 71 and it contained relatively important concentrations of phosphorus and potassium, respectively 3.10 and 1.23% expressed on dry matter basis. The olive mill wastewater had also high contents in phosphorous (259.72 ppm), potassium (91.70 ppm), magnesium (298.5 ppm) and sodium (280.4 ppm); the rate of nitrogen over phosphorous was equal to 2.3.

2.2. Composting process

During the composting process, moisture was maintained around 50% (w/w). Both windrows were turned once every 3 to 4 days during the first two months and once a month for the remaining period of composting. Temperatures were measured on a daily basis at different positions in the core of the windrow and the average of all the measurements was recorded.

2.3. Physico-chemical and microbiological analyses

2.3.1. Physico-chemical determinations

Samples were taken at turning and consisted of a homogenous mixture of 3 sub samples taken at 3 different depths of the windrow. The following compost properties were analysed: water content was determined by drying at 105 °C for 24 h. The pH and electrical conductivity were determined in a solution made by 20 g of the sample in 100 mL of distillated water. Ignition of dry matter at 550 °C in a muffle furnace for 4 h provided the total organic matter determination.

Total organic carbon (TOC) was determined by dichromate oxidation. Total nitrogen was determined by Kjeldahl method. Extractible NO_3-N in composts was determined by shaking a sample of 2.5 g (as a dry substance) in 50 mL of water for 2 h. The concentration of NO_3-N was analysed by ionic chromatography. Macro and micro elements were first extracted by heating 2.0 g of compost with HNO_3 and HCl, then the filtrate was analysed by atomic absorption spectrophotometry. The analyses for the characterization of raw materials were performed on five samples and the mean of the results was reported with the statistical analysis expressing the incertitude using ANOVAR software.

2.3.2. Microbiological analyses

A microbiological analysis was held at the end of the biological process to ensure of the hygienic aspect of the prepared composts. A compost sample of 10 g was suspended in 90 mL of a sterile peptone water solution and stirred at 150 rpm for 10 min at 28 °C. The suspension was used for microbial count by cell enumeration assessed by the determination of the number of colony forming units (cfu), according to ISO 7218 (1985). Serial decimal dilutions of each suspension (10^{-1} to 10^{-5}) were plated in triplicate on different agar media: Plate Count Agar (PCA, Pronadisa, Madrid, Spain), for the total aerobic mesophilic and thermophilic flora incubated respectively at 30 °C and 55 °C for 72 h, brilliant green bile broth (Bio-Rad, Marnes-la-Coquette, France) using most probable number technique for coliform flora (ISO 4831, 1987), trypticase sulphite with neomycin and polymixine agar (TSN, Bio-Rad, Marnes-la-Coquette, France) for anaerobic sulfito-reducing flora (NF XPV 08-061) and oxytetracycline glucose agar (OGA, Pronadisa, Madrid, Spain) for yeasts and fungi enumeration (NF V08-059, 1995).

2.4. Assessment of compost phytoxicity

For the evaluation of the compost toxicity, a semi-early variety of *Spunta* (*Solanum tuberosum L.*) was used in different plots of 500 m^2 each, fertilized with the prepared composts applied at a rate of 30 tons/hectare. Four plots were amended respectively with compost I (P_{PM}), compost II (P_{EOC}), a mix of 75% compost I and 25% of cattle manure ($P_{mix\ I}$), another mix with 75% compost II with 25% of cattle manure ($P_{mix\ II}$) and a control plot was fertilized with only conventional cattle manure (P_C). Then, potatoes were planted in these plots. The assessment of the composts agronomic effects were based first on the plant growth measurements (in height) throughout the growing season established according to the mean of one hundred plants, and second on the determination of the potato production harvested at the end of the crop cycle.

2.5. Effects of compost watered with olive mill wastewater on soil characteristics

The impact of olive mill wastewater used during composting on soil properties was assessed by physico-chemical analysis of soil sampled at three depths: 0.15; 0.30 and 0.50 m. pH, electrical conductivity and phenol concentration were determined just after harvesting potatoes.

3. RESULTS AND DISCUSSION

3.1. Characterization of composting parameters

3.1.1. Temperature evolution

The temperature increased significantly over time in the two windrows. After around 10 days, the temperature rose to above 45 °C and remained approximately at 50 °C for 10 days. Then, it increased to reach 60 and 63 °C respectively in windrow I and II. Finally, it dropped after 40 days and stabilized at above 40 °C. This stabilization occurred around at least 100 days of composting (Fig. 2).

This evolution of temperature revealed a usual thermal effect accompanying organic matter biodegradation as was explained

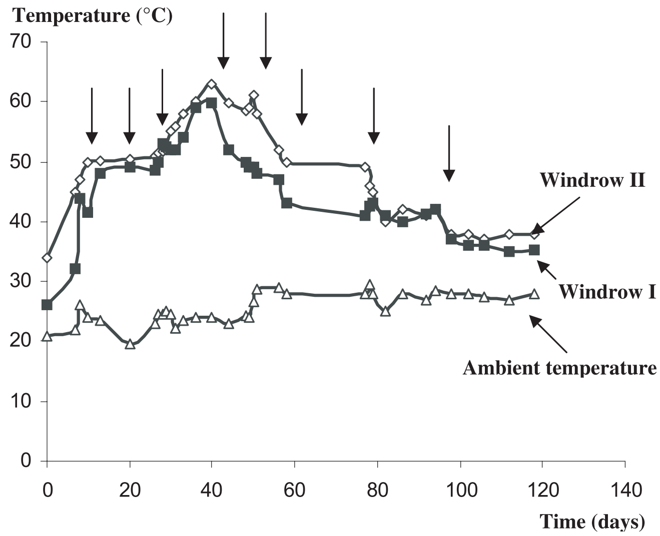

Figure 2. Temperature evolution during composting mixtures of poultry manure and exhausted olive cake. Windrow I: 75% poultry manure and 25% exhausted olive cake; windrow II: 25% poultry manure and 75% exhausted olive cake. Turnings are indicated by the arrows.

by Mustin (1987). A short mesophilic phase was followed by a relatively long thermophilic phase indicating the quick establishment of microbial activities in the composting windrows. The microorganisms consumed the soluble organic matter and ambient nutrients and then underwent aerobic degradation to generate heat, biomass and carbon dioxides. The short-term drop in temperature was due to the cooling effect caused by the mechanical turning of the piles used for the aeration.

The addition of olive mill wastewater while turning the windrows provided the composting medium with organic matter, which enhanced temperature increase. The windrows entered the cooling phase on about day 40 with a sharp drop in temperature. There was no significant difference in the maximum temperature and the length of thermophilic phase between windrows I and II. This is in line with findings related to co-composting pig manure with leaves (Huang et al., 2001).

3.1.2. Organic matter degradation

Poultry manure and exhausted olive mill cake showed a high organic matter content. But since exhausted olive mill cake is deficient in nitrogen, poultry manure supplemented very well olive mill wastewater by adding the needed nitrogen and minerals. Table II shows changes in the chemical composition of the windrows (I and II) during composting. About 15% of organic matter content in the respective windrow I and windrow II were lost with the composting time. The important initial rate of poultry manure in windrow I included easily decomposable compounds (organic carbon and nitrogen), which should account for a relatively higher degree of organic matter loss in windrow I as was shown in previous works (Eklind and Kirchmann, 2000).

Table II. Changes in the chemical composition of the windrows prepared during composting mixtures of poultry manure and exhausted olive cake (Windrow I: 75% poultry manure and 25% exhausted olive cake; windrow II: 25% poultry manure and 75% exhausted olive cake). OM: Organic matter; TOC: Total organic carbon.

Parameters	Composting time (days)					
	0	9	44	54	87	125
Windrow I						
pH	9.23	8.29	9.26	8.95	9.40	8.96
OM (%)	61.70	60.60	58.10	56.70	55.00	53.4
TOC (%)	29.00	25.75	28.42	26.20	24.115	21.30
Total nitrogen (%)	1.34	1.22	1.25	1.29	1.37	1.40
Windrow II						
pH	7.59	7.68	8.54	8.34	8.64	8.25
OM (%)	64.85	64.10	63.50	61.70	60.90	58.5
TOC (%)	36.70	37.01	31.38	27.44	25.26	23.43
Total nitrogen (%)	1.35	1.31	1.19	1.19	1.11	1.39

The kinetic model of organic matter biodegradation was slightly different in the two experimented windrows. It is expressed as:

Organic matter (%) = –0.070 t + 61.769 in windrow I; $R^2 = 0.94$

Organic matter (%) = –0.048 t + 64.679 in windrow II; $R^2 = 0.99$.

The mathematical models varied according to the windrow composition, the availability of nutrients and particle size of the components related to the nature of organic matter being composted. Windrow I seemed to be more easily biodegraded, compared to windrow II.

In spite of differences in kinetic evolution, at the end of composting process, the loss percentage of organic matter was almost equal to 13% in both experimented windrows. However, the total organic carbon losses were equal to 26% and 36%, respectively in windrows I and II. These differences would be related to their own specific compositions.

3.1.3. C/N patterns

The evolution of C/N ratio in each windrow showed a progressive decline in function of time (Fig. 3). It could be noted that C/N pattern in windrow I characterized by 75% poultry manure was lower than that in windrow II. The difference in behaviour was reduced from the 50th day of composting. Indeed, poultry manure of a high nitrogen content lead to a loss of this element in the form of ammoniacal nitrogen and consequently a slow reduction in C/N ratio occurred (Fig. 3). It could be noted that total nitrogen content of windrow I increased slightly after around 50 days of composting. It increased from 1.2% to 1.4%. This may be due to the loss of dry mass in terms of carbon dioxide and loss of water by evaporation during the mineralization of organic matter (Mustin, 1987; Fang et al., 1999; Huang et al., 2001). Nitrogen fixing bacteria may also contribute to the increase in total nitrogen in the later stage of composting (Mustin, 1987).

The changes in concentrations of total nitrogen followed a typical trend for the nutrient during aerobic composting (Tab. II). In the first 9 days of composting, nitrogen content of

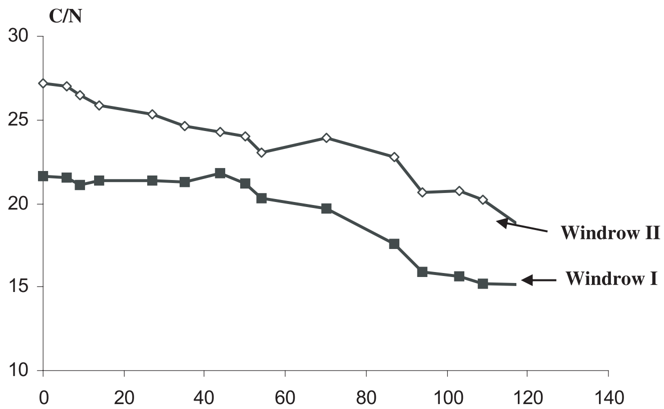

Figure 3. C/N ratio decrease during composting of mixtures of poultry manure and exhausted olive cake. Windrow I: 75% poultry manure and 25% exhausted olive cake; windrow II: 25% poultry manure and 75% exhausted olive cake.

the two windrows decreased due to ammonification as well as mineralization of organic nitrogen compounds; ammonia contents of the composting may have decreased through volatilisation loss and microbial immobilization. The absence of a decrease in ammonia nitrogen indicated that composting and maturation processes were achieved. Indeed, as Mustin (1987) and Huang et al. (2001) observed, compost with a maximum ammonia content inferior to 400 mg/kg can be considered as mature compost.

In line with Huang et al. (2001), it was found that nitrate content of the two windrows remained at a low level (< 35 mg/kg). This showed that little nitrification occurred under thermophilic conditions, which inhibited the activity and growth of nitrifying bacteria. Furthermore, at low concentrations, no significant difference of nitrate content was noted between the two windrows throughout the composting process.

3.2. Effect of compost sprayed with olive mill waste water

3.2.1. pH variation

The pH progress of the two windrows differed slightly (Tab. II). Although three phases could be noted during composting in windrow I, and because of the predominance of poultry manure in its initial composition, the pH variations were more intensive. Indeed, the pH initially exceeding 9, dropped during the first nine days. The intensive microbial activity and organic matter degradation led to the formation of carbon dioxide and organic acids. Then pH increased with bacterial hydrolysis of proteins. Ammonia, as a consequence of organic nitrogen ammonification, was produced. The solubilization of the ammonia led to the formation of ammonium and an increase in the pH values in the composting mixtures where the initial values rose from 8.2 to 9.3 and from 7.7 to 8.5 respectively in windrows I and II. At the same time, the temperature inside the windrows started to rise improving thermophilic microbial activity (Fig. 2).

However, in windrow II which had only 25% of poultry manure in its initial composition, ammonium formation was weak due to the slow rate of organic matter degradation (Fig. 3). But after the thermophilic stage, the pH dropped in the two windrows with a lesser degree in windrow II. This would be related to a relatively high proportion of exhausted olive mill cake rich in carbon and with low N content.

After 100 days of composting, the decrease in pH was likely caused by the volatilisation loss of ammonia and the increase in H^+ from the nitrification process as was shown by Huang et al. (2001). Also, the microbial decomposition of organic matter and the production of organic and inorganic acids would be responsible for the pH decrease as found in previous work (Mustin, 1987). It should be noticed that in spite of the acidic pH of olive mill wastewater used during humidification, this effluent did not have any negative impact on the composting mixture pH.

3.2.2. Soluble phenolic compounds

The main problem generated by the spread of olive mill wastewater on soils was attributed to their phenolic content (Shabou et al., 2005). As it is well known, such phenolic compounds are recalcitrant and may contaminate soils and groundwater. However, despite their continuous use for the humidification of the windrows during all the process, the determination of soluble phenols contents in the windrows at initial time and after composting showed an important decrease of phenols in the two windrows I and II. This was respectively of 37% and 46%, expressed on a dry matter basis while the initial values were respectively 0.43% and 0.52% (d.w.).

This may be due to the intensive microbial activity. Indeed, previous works isolate bacteria, yeast and fungi and demonstrate their ability to use phenolic compounds of olive mill wastewater (Chtourou et al., 2004). The relatively low concentration of phenolic compounds remaining in the compost would be degraded by telluric flora when the fertilizer is incorporated in the soil for amendment.

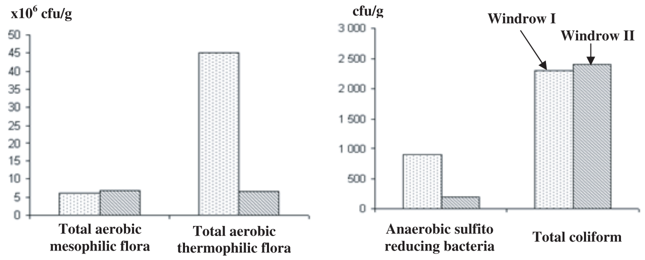

Figure 4. Microbial content of the mature composted windrows (cfu/g). Windrow I: 75% poultry manure and 25% exhausted olive cake; windrow II: 25% poultry manure and 75% exhausted olive cake.

3.2.3. Microbial flora of composts

Microbiological analysis of the mature composts showed equal concentrations of total mesophilic flora, fecal coliforms, anaerobic sulfito-reducing bacteria and yeast, and moulds. However, thermophilic flora was more important in windrow I. Pathogenic bacteria such as S*taphylococcus* and *Salmonella* were absent in the two windrows (Fig. 4). The number and types of microbial pathogens initially present in the wastes varied with animal species, geographic location of the form, and the physico-chemical composition of the manure (Bicùdo and Goyal, 2003).

Many pathogenic bacteria to humans carried via animals in poultry are found at high concentration in the manure. *Salmonella* are facultative anaerobic bacteria, which can proliferate in places with little or no oxygen, such as in manure. They can survive under adverse environmental conditions, especially pH range of 4 to 8 and temperature varying from 8 to 45 °C (Leclerc et al., 1989). However, in this study, it seems that the composting conditions can be favourable for hygienization. Indeed, the high pH value, the temperature exceeding 45 °C and the long composting time can eradicate this bacterium.

E coli, one bacterium species of faecal coliform, is part of the normal flora of the intestinal tract of humans and animals. This microorganism can grow in adverse environments characterized by low pH and low temperatures. It can survive for long periods in soil and water. Besides, faecal coliforms may occur even after a long period of hygienization due to a cross contamination after compost preparation. Nevertheless, it was demonstrated that all microbial flora are inactivated within 24 h when the temperature reaches 50 °C during an aerobic thermophilic stabilization (Bicùdo and Goyal, 2003). Moreover, the effect of olive mill wastewater on soil microbial communities and especially the suppressiveness against the plant pathogen *Rhizoctonia solani* and possibly after root pathogenic fungi was demonstrated (Kotsou et al., 2004).

3.3. Compost specifications

The end products were characterized and their fertilizing potential value was assessed (Tab. III). The comparison of the main physico-chemical parameters of the prepared composts (windrows I and II) with the conventional cattle manure shows

Table III. Physico-chemical specifications of stabilized composts and cattle manure. Compost I is the mature product of windrow I (75% poultry manure and 25% exhausted olive cake); compost II is the mature product of windrow II (25% poultry manure and 75% exhausted olive cake); OM: Organic matter; TOC: Total organic carbon, N.D.: Not determined.

Properties	Compost I	Compost II	Cattle manure
pH	8.96 ± 0.08	8.63 ± 0.11	8.87 ± 0.13
EC (mS/cm)	6.31 ± 0.04	5.46 ± 0.11	2.05 ± 0.07
C/N	15.12 ± 0.21	16.85 ± 0.38	16.90 ± 0.10
Ash (%)	46.60 ± 0.36	43.50 ± 1.21	30.44 ± 0.71
OM (%)	53.40 ± 0.36	56.50 ± 1.21	69.56 ± 0.71
TOC (%)	21.30 ± 0.94	23.43 ± 0.28	33.80 ± 0.25
Total N (%)	1.403 ± 0.042	1.390 ± 0.046	1.998 ± 0.063
NH_4-N (%)	0.10 ± 0.01	0.08 ± 0.01	N.D.
NO_3-N (ppm)	35.000 ± 0.985	24.470 ± 0.807	N.D.
Phosphorus (g/kg)	10.180 ± 0.987	5.256 ± 0.588	4.600 ± 0.538
Potassium (g/kg)	27.205 ± 0.945	22.093 ± 0.423	10.376 ± 0.376
Calcium (g/kg)	63.663 ± 0.119	39.000 ± 0.050	16.400 ± 0.250
Magnesium (g/kg)	5.248 ± 0.007	4.367 ± 0.015	3.800 ± 0.044
Porosity (%)	34.80 ± 0.226	35.20 ± 0.333	N.D.

globally interesting fertilizing values, yielded by the composts. According to French standards (NF U 44-051, 1981), specifying and defining organic conditioners, the prepared composts could be specified as vegetal composts since their total nitrogen expressed in percentage on a dry matter basis did not exceed 3%, and their organic matter content over organic nitrogen was inferior to 55.

The composition of minerals in each compost confirmed the beneficial effect of this organic fertilizer (Tab. III). Potassium content was high in this compost because of original provenance from poultry manure then the use of olive mill wastewater provided mineral and especially potassium and phosphor. Calcium concentration was very important in compost I, where poultry manure was predominant.

3.4. Effects on soil fertilizing value

3.4.1. Agronomic performances

The assessment of compost efficiency was performed on potato sown in the field. The potato stem growth in fields amended with each compost separately or with a combination of one compost with cattle manure did not exhibit any phototoxic effect. In Figure 5, the compost appeared to have a clear effect on growth than cattle manure. Nevertheless, the mixture of the latter with compost showed an improvement of stem growth compared to cattle manure used alone.

Moreover, the potato yield confirmed this positive effect of the different amendments used including the compost. Yet, the best yield resulted from compost I made of 75% poultry manure and 25% exhausted olive mill cake, used as the unique soil conditioner (Fig. 6). Berndt et al. (1996) reported the beneficial effect of spreading olive mill wastewater on agricultural soils. This application was demonstrated to provide an amount of fertilizer assessed at around 30 Tons/ha, without any soil polluting risk or phytotoxicity. The inequity of olive mill wastewater was hence confirmed (Ben Rouina et al., 1999; Zenjari and Nejmeddine, 2001). Tomato et al. (1996) confirmed this finding by their experiments performed on both the crop-test and plant soil system progress in a field supplied with compost of olive mill wastewater at a rate equivalent to a manuring on the basis of organic matter. The tests were conducted on maize, horticultural plants and rye grass.

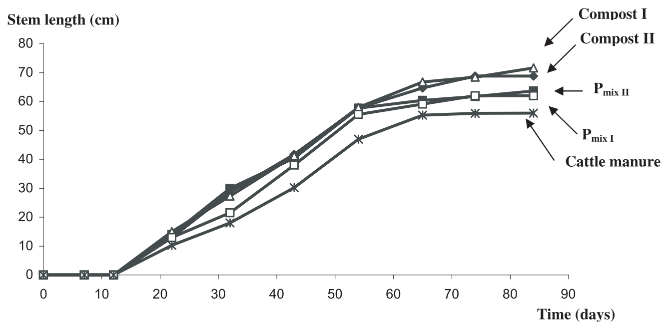

Figure 5. Stem length during potato growth in soils amended with mixtures of poultry manure and exhausted olive cake. Compost I: 75% poultry manure and 25% exhausted olive cake, and Compost II: 25% poultry manure and 75% exhausted olive cake; $P_{mix\ I}$: 75% compost I with 25% cattle manure; $P_{mix\ II}$: 75% compost II with 25% cattle manure.

3.4.2. Impact on the soil physico-chemical properties

Among the most expected risks threatening soil fertility and resulting from olive mill wastewater use, pH and EC modifications are the most important ones (Zenjari and Nejmeddine, 2001). However, the use of this compost proved to be free of such risks. Indeed, as shown in Table IV, the use of these composts seemed to have no impact in terms of pH and EC when compared to cattle manure through different soil depths.

Table IV. Physico-chemical parameters of different soil layers after amendment. EC: Electrical conductivity.

Parameters	Soil			Soil + compost I			Soil + compost II			Soil + cattle manure		
	0–15	15–30	30–50	0–15	15–30	30–50	0–15	15–30	30–50	0–15	15–30	30–50
pH	8.80	8.87	9.04	8.54	8.59	8.56	8.63	8.67	8.56	8.47	8.48	8.50
EC (mS/cm)	0.26	0.25	0.20	0.35	0.31	0.29	0.34	0.28	0.27	0.40	0.35	0.30
Phenols (%)	0.10	0.11	0.10	0.42	0.43	0.38	0.37	0.38	0.32	0.39	0.40	0.36

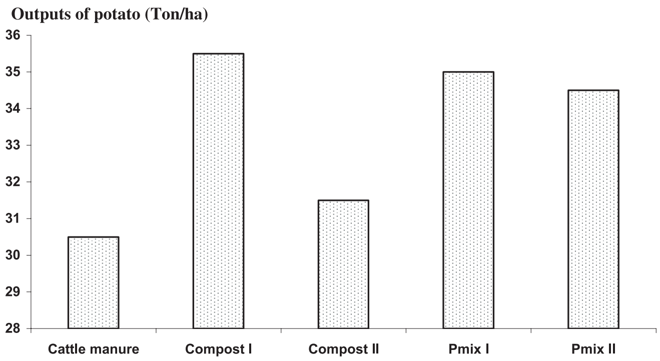

Figure 6. Outputs of potato (Tons/ha) in soils amended with different kinds of fertilizer. Compost I: 75% poultry manure and 25% exhausted olive cake; Compost II: 25% poultry manure and 75% exhausted olive cake; $P_{mix\ I}$: 75% compost I with 25% cattle manure ; $P_{mix\ II}$: 75% compost II with 25% cattle manure.

4. CONCLUSION

The composting of poultry manure mixed with olive oil wastes was demonstrated to be an efficient way to provide fertilizer. Organic matter underwent an intensive biodegradation with an important thermophilic phase within 120 days. Microbiological analyses showed that the two composts were hygienized and compost I, having a higher rate of poultry manure, was characterized by its high concentration of thermophilic microorganisms, and its high activity during the composting process. This fact was confirmed by the kinetic parameters of organic matter biodegradation. The results showed that the humidification with olive mill wastewater improved the quality of the compost. The continuous use of olive mill wastewater did not have any negative impact on the process. The harmful phenolic compounds were widely decomposed during composting and the concentration of the minor remaining part would be degraded while applying the organic conditioner into the soil. The prepared composts were similar to an organic conditioner of vegetal compost. In terms of fertilizing value, the use of such composts including poultry manure and exhausted olive mill cake humidified with olive mill wastewater did not have any negative impact on soil phenols, pH and EC at different depths. The analyzed parameters were almost the same as those of the cattle manure. As a consequence, composting would be an efficient and suitable solution for polluting by-products from agro-industries such as aviculture and oleiculture sectors.

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