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Composting of agricultural residues with olive mill waste and rock phosphate to reduce environmental pollution and enhance phosphorous release

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ABSTRACT

Olive mill waste (OMW) is one of agricultural residues (AGRs) that has serious environmental hazards emanating mainly from its phytotoxic phenolic components. This study investigated the feasibility of producing compost with reduced phenolic content and increased available phosphorus. Other composting effects on compost constituents were also evaluated. Four piles were constructed using AGRs as basic constituents, 4% of RP was added to each pile. Different rates of OMW [4.2, 2.9, 2.2 and 0 % (v/v)] were added to the compost piles. Turned windrow method was applied in the composting process. Compost samples were collected from each pile at 0, 45 and 90 days then composite sample of each was analyzed to determine the total phenolic content (TPC), available phosphorus (AP) and other compost parameters. The results obtained demonstrate that the percent reduction of TPC was affected by pile size since 57.97 and 50.56% in piles (1 and 2) versus 29.52 and 23.01 in piles (3 and 4) of TPC was dissipated at 45 days, these values were slightly changed in piles 1 (57.85%) and 2 (51.87%) while, great changes were recorded in piles 3 (43.07%) and 4 (48.4%) after 90 days of composting time. Also, AP release was significantly affected by composting time since it increased from 14.41, 32.49, 35.63 and 32.46 ppm at 45 days to 45.85, 52.4, 58.95 and 46.64 ppm at 90 days in piles 1, 2, 3 and 4, respectively. The other characteristics of the end product of all piles were within the range of standard compost with C/N ratio ranging from 14.44 to 17.11, pH around neutral and with acceptable organic matter and NPK content. The final product of all piles was free from pathogenic nematodes and weed seeds. It can be said that co-composting of OMW with RP-enriched AGRs can lead to a significant reduction of TPC and release of AP from RP; and the end product can be safely used for soil amendment/fertilizer.

INTRODUCTION

Agricultural residues (AGRs) are generated in large quantities but unfortunately, they are underutilized as sources of renewable biomass in agriculture. The amount of AGRs in Egypt is estimated to be around 117 million tons yearly [39 million tons crop residues (34%) and 78 million tons animal excreta and poultry droppings (66%)] (El-Shimi, 2016). This represents a national resource of significant economic value. Small portion of AGRs are used as roofing material, animal feed, fuel and packing material, while the rest is disposed of by burning in the field. Although burning AGRs in the field is considered a

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cheap and easy way of disposal of excess residues, this practice results in air pollution and increases soil erosion. Sometimes, it causes respiratory problems and increases the fog occurrences even in far-away cities (Lalchandani, 2012). Direct incorporation of AGRs might improve soil health and solve the problem of air pollution (Sidhu and Beri, 1989; Beri et al., 1992, 1995) but unfortunately, it is not practical due to the short period available between crop harvesting and sowing of the next crop. Besides, it involves additional cost of labor, irrigation and extra tillage (Sidhu et al., 1998). It decreases the subsequent crop yields due to production of microbial phytotoxins and allelochemicals (Rao and Mikkelsen, 1977) and immobilizes the available nitrogen (Kimber, 1973). Incorporation of AGRs under anaerobic condition increases the CH_4 emission from fields (Conrad, 2002; Chidthaisong et al., 1996). This gas is one of the main gases that cause global warming.

Composting is one of environmentally safe methods of recycling AGRs. It provides a valuable source of plant nutrients especially N, P, K and organic substrates and therefore improves physical, chemical and biological properties of a soil. Thus, composting of AGRs can lead to an increase in agricultural productivity, improve soil biodiversity, and reduce ecological risks and contribute to a better environment.

Over the last three decades, the olive cultivated land in Egypt has expanded dramatically, since it increased from 3700 ha in 1980 to 65303 ha in 2009, approximately nineteen-fold. The olive oil industry generates large amounts of olive mill waste (OMW) that are harmful to the environment. The problems arise from OMW are for its high organic load and its chemical composition, which makes it resistant to degradation. Unfortunately, OMW also contains phytotoxic components (phenolic compounds) that inhibit microbial growth (Capasso et al., 1995; Ramos-Cormenzana et al., 1996), and adversely affect the germination and vegetative growth of plants (Linares et al., 2003). Because olive oil phenols are amphiphilic, only a fraction of the phenolics enters the oil phase, and a large proportion (>98%) is lost with the waste stream during processing (Rodis et al., 2002). It is estimated that the toxic load of OMW in terms of phenolic compounds is up to a thousand times larger than that of domestic sewage (Niaounakis and Halvadakis, 2004). Due to their instability, OMW phenols tend to polymerise during storage into condensed high-molecular-weight polymers that are particularly difficult to degrade (Ayed et al., 2005; Crognale et al., 2006). For these reasons, the uncontrolled disposal of OMW has traditionally become a great problem in Mediterranean countries because of their polluting effects on soil and water (Sierra et al., 2001; Piotrowska et al., 2006).

Improving solubility of rock phosphate (RP) is critical for phosphorus (P) management in cropping. Compost is one of methods of increase P availability in RP (Van Straaten, 2002). Composting manure and/or biological waste with RP has been shown to enhance the dissolution of the RP (Mishra and Bangar, 1986; Singh and Amberger, 1991) and is practiced widely as a low-input technology to improve the fertilizer value of manure (Mahimairaja et al., 1995).

The hypothesis for the present study therefore was that, co-composting OMW and RP with basic AGRs would reduce the total phenol content of OMW as well as enhance phosphate releasing from RP.

MATERIALS AND METHODS

Compost constituents

Olive mill waste

Fresh OMW used in this study was obtained from an olive oil production plant in RassSudr, South Sinai Governorate, Egypt, which uses a three phase decanter system, for the extraction of olive oil.

Rock phosphate (RP)

RP was purchased from Abotartour Company, New Valley, Egypt. According to the company, it contained total P, 13.4% (30.8%P_2O_5), water soluble P, 0.037 ppm.

Agriculture residues

Agriculture residues used in this compost were Rice straw, sheep manure, weeds and casuarinas remnants. They were collected from Abokalam farm, South Sinai governorate shortly before using in the compost.

Compost preparation

Four compost piles were constructed. The piles 1 and 2 were approximately 4 m^3 in size while the piles 3 and 4 were approximately 2 m^3 in size. All piles contained basic components of sheep manure (50%), rice straw (47%) and casuarinas remnants (3%). Rock phosphate was added at 4% (v/v) to each pile. Olive mill waste was added in different rates (v/v) as 4.2, 2.9, 2.2 and 0% to compost piles 1, 2, 3 and 4, respectively. Few amounts of calcium sulfate and NPK fertilizers were added to all piles to accelerate the composting process. Water was added to keep moisture content at (50–60%) throughout the composting period. To improve the aeration, the compost piles were turned and well mixed periodically. Samples of 3 kg each were taken from each pile at 0, 45 and 90 days for chemical analyses.

Chemical analyses

Chemical analyses were conducted for evaluating pH (1-10 soil-water w/w) electric conductivity (EC) (1-10 soil-water w/w), organic matter (OM), organic carbon (OC), the total NPK content (TN, TP, TK), NO_3-N, NH_4-N, AP, TPC and ash. These analyses were conducted at intervals of 0, 45 and 90 days of composting process as previously described by El Sebai et al. (2015).

Chemicals and reagents

The solvents were purchased from Merck (Darmstadt, Germany). The Folin–Ciocalteau phenol reagent was purchased from Sigma Chemical Co (Sigma–Aldrich Company Ltd, Great Britain).

Total phenol content determination

The total phenol content of OMWs was determined colourimetrically at 725 nm using the Folin–Ciocalteau reagent according to a modification of the Gutfinger (1981) method. The methanolic solution of olive mill waste extract (0.1–0.3 ml), 20 ml of de-ionized water and 0.625 ml of the Folin–Ciocalteau reagent were added in a 25 ml volumetric flask. After 3 min, 2.5 ml of saturated solution of Na_2CO_3 (35%) were added. The content was mixed and diluted to volume with deionized water. After 1 h, the absorbance of the sample was measured at 725 nm against a blank using a double-beam ultraviolet–visible spectrophotometer Hitachi U-3210 (Hitachi, Ltd., Tokyo, Japan). Gallic acid served as a standard for preparing the calibration curve, and ranged from 60 to 140 g/25ml of assay solution.

Statistical analysis

The effect of different olive mill waste level and time after treatment on reduction of TPC and AP were analysed using Statistix 9 (Statistix analysis Software) (Thomas and Maurice 2008); which were performed with General Linear Model's procedure (factorial analysis) with olive mill waste level treatments as the fixed effect; interactions between treatments and sampling dates were also studied. This procedure computes the analysis of variance for reduction of TPC and releasing of AP during the whole experiment time. The F test assumes that the within-group variances are the same for all groups. The null hypothesis of these tests is that different olive mill waste level and time are equal. A large F test and corresponding small p-value (say, smaller than 0.05) is evidence that there are differences, by using Tukey test to compare means of treatments.

RESULTS AND DISCUSSION

Changes in chemical composition of compost preparations throughout composting process

Table 1 shows the changes in chemical composition of the suggested compost preparations (piles) at 0, 45 and 90 days of composting process. In all piles some chemical characteristics such as ash, AP and TP were increased, others such as OM, OC, C/N ratio and TPC were decreased and the rest (pH, EC, TN, TK, NH4-N and NO3-N) varied in their change among different piles.

At the start of composting process, properties of compostable materials were around the acceptable values for an optimal composting process, where a carbon to nitrogen ratio of the composting materials was ranged from 19.9 to 24.9. Also, the other parameters such as organic matter and the content of macronutrients were within the acceptable range.

At 45 days, of composting process, expected decrease in organic matter, organic carbon and C:N ratio were found. AP recorded 14.41, 32.49, 35.63 and 32.46 ppm in Piles 1, 2, 3 and 4, respectively. The TPC recorded a significant decrease in all piles from 408.8, 349.9, 280.5 and 199 at zero time to 171.8, 173, 197.7 and 153.2 at 45 days of composting in piles 1, 2, 3 and 4, respectively. At the end of composting process (90 days), the AP recorded continuous increase in all piles. It was 14.41, 32.49, 35.63 and 32.46 ppm at 45 days and became 45.85, 52.4, 58.95 and 46.64 ppm, after 90 days of composting in Piles 1, 2, 3 and 4, respectively.

Other compost properties were changed as expected after any active composting process. The final C:N ratio recorded 17.11, 14.44, 15.95 and 16.98 for piles 1, 2, 3 and 4, respectively. Similar C:N ratio was reported by Sellami et al. (2008) who studied the effects of co-composting of olive cake with different organic residues. The C:N ratio considers one of the main characters that often used as an a reliable parameter not only to follow the development of the composting process but also it can be used as indicator for composting maturity (Khalil et al., 2001). pH around neutral, a notable decrease of organic matter was realized. The main macronutrients (NPK) content in all compost piles achieved the upper level for high quality compost. Marked reduction of volume size (about 50%) was observed after 90 days from the beginning of composting process (data not shown). This is as expected because composting reduces both the volume and mass of the raw materials while transforming them into valuable soil conditioners (Rynk, 1992). The experimental results show that the final product of all treatments was free from pathogenic nematodes and weed seeds (data not shown).

The potential of composting the agricultural residues to turn it into a value added product for soil amendment makes it an attractive proposition. The present findings

Table 1. Chemical properties of the compostable materials at 0, 45 and 90 days of composting process.

Characters	Pile 1			Pile 2			Pile 3			Pile 4		
	0	45	90	0	45	90	0	45	90	0	45	90
PH	ND	7.52	7.29	ND	7.73	7.52	ND	7.51	7.56	ND	7.68	7.85
EC (ds/m)	ND	4.1	4.11	ND	5.13	3.85	ND	6.42	2.89	ND	4.41	2.47
TN (%)	1.23	0.90	0.85	0.85	0.9	1.15	1.51	0.95	0.95	1.06	1.05	0.95
$N\text{-}NH_4$ (ppm)	ND	112	193	ND	67	53	ND	53	59	ND	53	48
$N\text{-}NO_3$ (ppm)	ND	33	28	ND	26	-	ND	40	89	ND	20	33
OM (%)	45.89	30.9	25.88	36.5	32.3	28.64	51.84	31.62	24.87	38.67	32.29	27.81
OC (%)	26.61	17.92	14.54	21.17	18.73	16.61	30.06	18.34	14.43	22.43	18.73	16.13
C:N Ratio	20.01	19.48	17.11	24.91	20.81	14.44	19.91	19.31	15.95	21.16	17.84	16.98
Ash (%)	54.11	69.1	74.12	63.5	67.7	71.36	48.16	68.38	75.13	61.33	67.71	72.19
TP (%)	0.84	2.29	3.93	0.94	2.0	3.21	0.52	2.48	2.59	0.7	2.12	2.65
TK (%)	1.4	0.76	0.97	0.65	0.73	0.88	1.24	0.88	0.58	0.77	0.8	0.74
AP (ppm)	ND	14.41	45.85	ND	32.49	52.4	ND	35.63	58.95	ND	32.46	46.64
TPC (ppm)	408.8	171.8	172.3	349.9	173.0	168.4	280.5	197.7	159.7	199.0	153.2	103.4

are in consistent with the previous data that obtained by other researchers (Abdel-Aziz et al., 2012; El Sebai et al., 2015). Composting is widely accepted as an alternative for converting AGRs to eco-friendly fertilizers. Manures and composts are not only low in cost as compared with chemical fertilizers, but also their produce is healthier and carries extra benefit. However, most of the organic materials and their manures are deficient in macro-nutrients content, therefore, a large quantity is required to be applied to satisfy crops nutritional demand.

The following results summarized the effect of composting on the TPC resulted mainly from OMW as well as the AP released from RP.

Effect of composting on total phenol content

The results in Figure 1 illustrate TPC throughout the composting process in compost piles differ in size and OMW rate. According to pile size, in pile 1 and 2 (4 m^3) the TCP at the starting of composting process was 408 and 349.9 ppm, respectively. While piles 3 and 4 (2 m^3) the TPC was only 280.5 and 199 ppm, respectively. For the effect of OMW rate, pile 1 received 4.2% OMW and pile 2 received 2.9% the TPC of them was 408.8 and 349.5 ppm, respectively. In pile 3 and pile 4 the OMW rate was 2.2 and 0% and the resulted TPC was 280.5 and 199 ppm, this means that 199 ppm of TPC resulted from components other than OMW. For the effect of composting time, in piles 1 and 2 significant change ($p<0.05$) was observed between 0 and 45 days since the values of TPC were 408 and 349.9 ppm and became 171.8 and 173 ppm with a reduction in percent reached to 57.97 and 50.56% for piles 1 and 2, respectively. While almost no significant change ($p<0.05$) was detected between 45 and 90 days of composting time since the values of TPC were 171.8 and 173 ppm and became 172.3 and 168.4 ppm, with a reduction in percent reached to 57.85 and 51.87% for piles 1and 2, respectively. While in piles 3 and 4 the TPC was significantly affected ($p<0.05$) by composting time since it varied from 197.7 and 153.2 ppm with a reduction percent (29.52 and 23.01%) at 45 days and from to 159.7 to 103.4 ppm with a reduction percent (43.07 and 48.04%) at 90 days in piles 3 and 4 respectively. This means that small piles need more time of composting to give similar results.

The high pollution potential of OMW is due to its content of phenolic compounds. Since, the phenolic content of this waste gives its phytotoxic and antimicrobial effects and then it becomes resistance to biodegradation. Our results supported the hypothesis that co-composting of OMW with other organic wastes such as agricultural residues is one of the approaches that can be used for biological treatment of OMW. Several authors' stated that in order to equilibrate the nutrient imbalance of OMWs, the preferred approach in the majority of cases has been the application of co-composting with other residues, such as those derived from cattle and poultry farming (Paredes et al., 2001; Hachicha et al., 2009), arable farming (Alburquerque et al., 2007; Paredes et al., 2002), various agricultural wastes (Mahmoud et al., 2012) or industry (Sánchez-Arias et al., 2008). In another experimental composting process of OMW plus barley straw, Zenjari et al. (2006) found that degradation of the phenols reached 95% after the maturation phase and the toxicity disappeared after only 2 months of composting. Composting of Two Phase Olive Mill Waste is a valid process from technical and economical viewpoints, as demonstrated by its

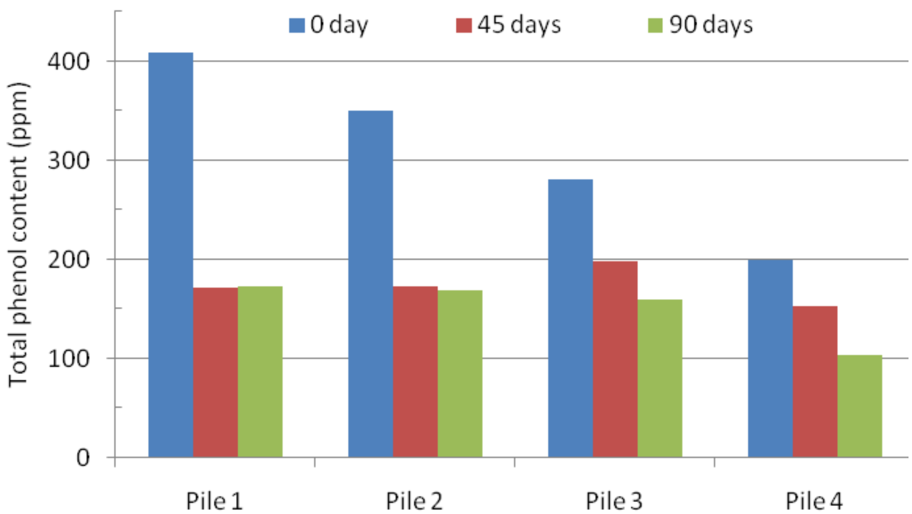

Figure 1. Total phenol content after 45 and 90 days in compost piles differ in size and rate of olive mill waste.

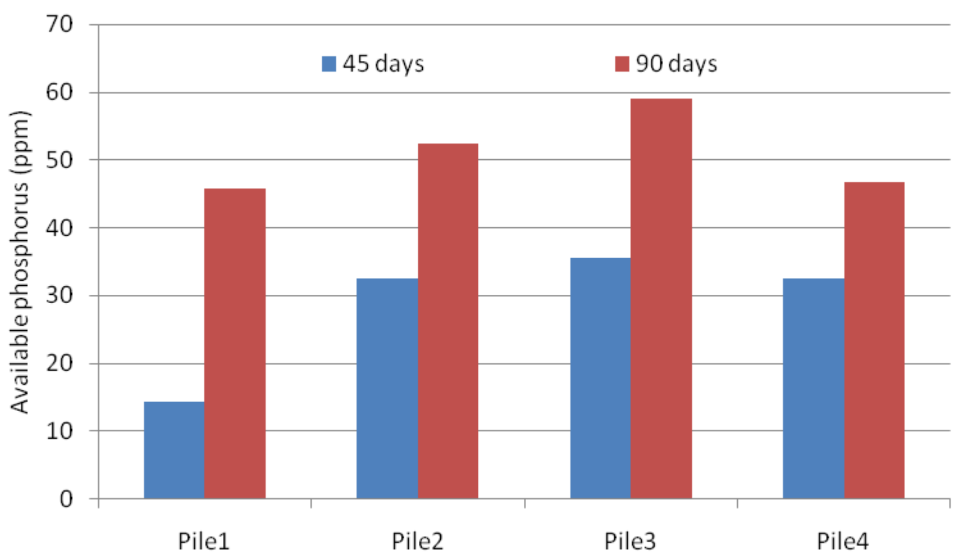

Figure 2. Available phosphorus release from compost piles containing rock phosphate at 45 and 90 days of composting periods in piles differ in size and rate of olive mill waste.

application at industrial scale (Kobek, 2004).

Effect of composting on available phosphorus release

Data in Figure 2 show that available phosphorus release from rock phosphate enriched compost piles increased with composting time. It increased from 14.41, 32.49, 35.63 and 32.46 ppm to 45.85, 52.46, 58.95 and 46.64 ppm in piles 1, 2, 3 and 4, respectively, throughout the period of composting from 45 to 90 days. No significant correlation ($p<0.05$) was detected between AP release and either pile size or OMW rate.

Increasing P availability is considered as a vital process to enhance soil fertility and then its productivity, especially under Egyptian soil conditions since; a huge portion of soluble phosphorus is converted to inaccessible form because of soil alkalinity (pH up to 8.5). Improvement of phosphorus release from rock phosphate through co-composting of RP with agricultural residues is recognized as an eco-friendly and environmental tool.

The results obtained showed a significant increase ($p<0.05$) in release of AP from RP-enriched AGRs compost are in accordance with the results of Khan and Sharif (2012) who suggested that composting of poultry litter with rock phosphate has the potential to enhance available P content of the compost.Other authors revealed that composting manure and/or biological waste with RP has been shown to enhance the dissolution of the RP (Mishra and Bangar, 1986; Singh and Amberger, 1991) and is practiced widely as a low-input technology to improve the fertilizer value of manure (Mahimairaja et al., 1995). Composting of agricultural wastes with rock phosphate is known to increase the solubility of rock phosphate (Bangar et al., 1985; Van der Berghe, 1996; Iyamuremye and Dick 1996; Biswas and Narayanasamy, 2002). However, the dissolution of rock phosphate through composting varies with its characteristics and the kind of waste (Mahimairaja et al., 1995).

Conclusion

Olive mill waste is a significant source of environmental pollution because of its high content of organic load and also because of its high content of phytotoxic and antimicrobial phenolic substances, which resist biological degradation. This study aimed to transform this noise by-product to a value added product through co-composting it with RP enriched agricultural residues. On the light of our results it could be concluded the positive effect of co-composting of olive mill waste with rock phosphate enriched compost. Since, more than 57% of TPC was reduced. As well as, a clear increase of AP was obtained since the end product contains in average 51 $mgkg^{-1}$ of AP. Moreover the quality of end product was within compost standard parameters and it can be safely used as organic fertilizers.

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