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Original Research Article

Using Biotechnology in Recycling Agricultural Waste for Sustainable Agriculture and Environmental Protection

F.N.Al-Barakah, S.M. A. Radwan* and R.A.Abdel-Aziz

Department of Soil Science, College of Food and Agricultural Sciences, King Saud University, P. O. Box 2460 Riyadh 11451, Saudi Arabia

Corresponding author

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A B S T R A C T

Composting is a way to transform the waste materials left over from agricultural production and processing into a useful resource. The potential of composting to turn on-farm waste material into farm resources makes it an attractive proposition. This study was conducted to assess compost production at large commercial scale using three different agricultural waste (date trees, olive trees and maize) and animal manure (sheep manure) with four rates as organic activator (5 ,10 ,20 and 40%) as well as chemical activator treatment. Turned windrow method was applied in the composting process. The piles were turned every week; then temperature was checked and values were recorded every day. Composite samples were collected regularly for testing chemical and biological parameters. The results showed a specific decrease in C/N ratio of all treatments especially in 20% and 40% organic manure treatments, combined with production of compost free from coliform group bacteria and Cadmium heavy metal. The organic manure as activator provides good quality compost product as compared to chemical activator. It could be concluded that the commercial compost product made from agriculture waste and treated with the organic manure activator is a safe alternative to chemical fertilizers and the best soil amendment that nature provides. These agricultural wastes, when fully exploited could have an important role in the production of safe and healthy food in Saudi Arabia.

Introduction

There are shortages of organic fertilizers in the arid areas including Saudi Arabia. Saudi Arabia produced annually about eleven million tons of agricultural wastes. Composting the agricultural waste is an alternative trail to alleviate the negative impact of its accumulation and/or avoid the environmental pollution.

Abou Hussein and Sawan (2010) concluded that recycling agriculture wastes is a must for environment as well as economical saving. This recycling will not only increase agricultural production but also will improve its quality. Composting is considered a biological process in which microorganisms convert organic residues into soil-like material called compost. Geisel (2001) and El-Hagga *et al.* (2004) reported windrows composting is a commonly used processing method. The microbial decomposition of organic wastes is controlled by environmental factors affecting microbial activity within the windrow piles. There are some factors affecting composting and directly influence the rate of decomposition, such as particle size, moisture content, aeration, temperature, C/N ratio and pH. Therefore, intensive management of the composting process by turning and moisture addition is likely to affect the N fertilizer value of the mature compost.

Microbial inoculation of compostable material could allow the inoculated microorganisms *(Streptomycs aurefaciens, Trichoderma viridie, T. harzianum, Bacillus subtilis, B. licheniformis)* to dominate over the indigenous microbiota and successfully develop appropriate degradation (Badr El Din *et al.*, 2000).

The important advantages of composting are the reduction of the wastes, the destruction of weed seeds and of pathogenic microorganisms (Bernal *et al.*, 2009). Additional benefits of composting as mechanism for waste management are production of valuable soil amendments, low operation costs, easy to be applied in most of developing countries, and encouragement of environmentally friendly practices such as reduction of the emission of greenhouse gases, promote the efficiency of fertilizer application (Hoornweg *et al.,* 2000).

One feature of sustainable agriculture is its lower dependence on chemical fertilizers and recycling of on-farm residues to maintain and/or improve soil fertility. Recycling of agricultural wastes is worthy for providing high quality organic fertilizers that can be used in fertilization of agricultural lands. Managing residues plays an important role in system nutrient cycling and in the dynamics of plant pathogens. The microorganisms play significant role in the recycling process due to powerful enzymatic mechanisms involved in their biological system and the challenge is to enhance the value of plant residues at the expense of the negative value through the composting process (Blaine Metting, 1993).

Microbial technologies for agriculture and waste management are receiving significant attention to meet the special need of developing countries. Therefore, this work aims at raising the fertilizing value of some agricultural wastes through the composting process using different rates of animal manure as compost activator.

Materials and Methods

The present investigation was carried out at El-Jouf region, Saudi Arabia to study the bioconversion of agricultural waste into valuable product (compost) using the sheep manure as organic activator. For the preparation of compost as organic fertilizer, the turned windrow method was used (Fleming, 2001). Three agricultural wastes of palm trees, olive and maize were mechanically grinded to produce waste of particle size 2 inches then equally mixed. Sheep manure is used as organic activator with different rates. Five treatments were implemented by using mixture of agricultural wastes with four rates of sheep manure as organic activator (5, 10, 20 and 40%) as well as chemical activator treatment.

Five different treatments were composted aerobically in windrows (15 x 2.5 x 1.2 m) with aeration through turning (Suhaimi and Ong, 2001). Eighteen tons of each treatment were prepared, and mixed well mechanically. The chemical activator mixture [(20 kg ammonium sulphate (20.6%N) + 7 kg superphosphate (15.5% P_2O_5) + 2.5 kg of potassium sulphate, 48%K_2O)] was mixed well with one ton from the mixture of agricultural waste,in the first treatment. Commercial calcium carbonate at rate of 2% was added to all treatments. The different materials of each treatment in the experiment (mixture of agricultural waste, sheep manure, chemical activator and calcium carbonate) were divided into three parts. The first portion of the chopped mixture of agricultural waste was scattered over the area (37.5 m^2) followed by addition of a portion of the chemical activator or the sheep manure with the different rates, and finally a portion of commercial calcium carbonate was spreaded over it. The first layer was also inoculated with a mixture of 1×10^8 of each of *Streptomycs aurefaciens, Trichoderma viridie, T. harzianum, Bacillus subtilis* and *B. licheniformis* (1 L/ton) as a microbial activator for fasting decomposition in all treatments and then wetted. The moisture was considered satisfactory when a handful of material would wet the hand but not drip (about 60-70% WHC). The material then thoroughly tamped. The first layer was about 40 cm height was then built. The other two layers were built over the first layer in the same manner. Water was added if necessary to keep the moisture content inside the pile at 60% of the weight through the experiment. The materials in each pile were mechanically turned every week. Pile temperature was monitored daily through the center of the compost piles at different locations of depth 50 cm. The piles were left 3 months for composting. Homogenized and randomized samples were taken manually after 0, 3, 6, 9 and 12 weeks, mixed thoroughly and four replicates were examined microbiologically for total count of aerobic mesophillic bacteria, aerobic mesophillic and thermophillic cellulose-decomposing bacteria. The serial dilution plate count procedure was used to estimate the total count of aerobic mesophillic bacteria (Difco, 1966). Dobus's cellulose medium (Allen, 1982) was used for the counting of aerobic mesophillic and thermophillic cellulose- decomposing bacteria. Total coliforms were counted onto standard violet red bile (VRB) agar incubated at 37^{o}C for 24 h (ICMSF, 1983). Microbial counts were expressed as colony-forming units per gram of compost materials (cfu/g). Representative samples of surface and the central parts of the piles were also taken manually after 0, 30, 60 and 90 days, mixed thoroughly and examined physically for EC (Chen *et al.*, 1988), and chemically for OC% (AOAC, 1970), pH, OM%, C/N ratio, NH_4-N, NO_3-N and total N by Kjeldahl method (Page *et al.*, 1982), total-P, total-K, Cu, Fe, Mn, Zn, Cd, Ni and Pb (Cottenie *et al.*, 1982). At the end of the experiment, density and toxicity of the produced compost were determined.

Results and Discussion

Temperature changes

Temperature is an important factor in composting efficiency, due to its influences on the activity and diversity of microorganisms (Finstein *et al*., 1986). Changes in temperature during the composting process are shown in Table (1). The outside temperature was about 37^{o}C in the day and 27 ^{o}C in the night.

Three periods were distinguished: a phase of latency which correlates to microbial population adapted in the compost conditions, a phase of sudden rise in temperature up to 64 ^{o}C and a phase of cooling in which the temperature decreased progressively and returned to its starting values. At the beginning, the temperature was between 34 - 36 ^{o}C and increased to 40–42 ^{o}C (the end mesophilic stage) after 4 days (data not shown). After 7 days, temperature was raised to 52-56 ^{o}C with little variations till the third week. The maximum values 62-64 ^{o}C were found after 3 and 4 weeks. Then the temperature gradually decreased and reached to 34-38 ^{o}C by the end of composting (3 months). The high temperature inside the piles is necessary to destroy pathogens. However, temperature should not exceed 65^{o}C, as this would kill almost all microorganisms and cause the process to cease. The rising of temperature during composting is mainly due to the activity of microorganisms in the degradation of agricultural wastes. The results were in agreement with the findings of El-Meniawy (2003); Abdel-Aziz & Al-Barakah (2005) and Eida (2007). The obtained results revealed that a negative correlation was found between temperatures and composting time, this was due to decreasing in temperature by the end of composting. Generally, the increase in temperature may be also attributed to the suitability of composting conditions (C/N ratio, moisture content, aeration, particle size) for microbial and enzymatic activities. On the other hand, the decrease in temperature was attributed to the decrease in microbial and enzymatic activities. This was supported by the results of Noguerira *et al*.(1999). The aeration is important in composting process for providing the oxygen needed to support aerobic microorganisms, controlling the temperature and for removing water vapor, CO_2 and other gases (Haug, 1986). The overall goal of the aeration is to maintain compost temperature in the range 50-55 ^{o}C to obtain efficient thermophillic decomposition of organic wastes (Mckinley and Vestal, 1984). Thus, precise temperature control is necessary to provide pathogenic reduction, while maintaining a healthy comity of composting microbes (Mckinley *et al*., 1985). The maturity stage was started when the temperature decreased to normal air daily temperature and remain constant with turning of the piles (Harada *et al*., 1981). Therefore, this parameter is considered as a good indicator for the end of the biodegradation phase in which the compost achieves maturity (Jimenez and Garcia, 1989).

Microbiological changes

Data in Table 2 showed that total bacterial counts was increased gradually and reached its maximum after 6 weeks from initial, then decreased until the end of the composting period (120 days). These results indicated the importance of mesophilic bacteria at the beginning of composting as they attack readily decomposable constituents of organic wastes. These data are in accordance with those obtained by Khalil *et al.* (2001) who demonstrated that bacteria flourished because of their ability to grow rapidly on soluble protein and other readily available substrates and because they are the more tolerate to high temperature. They added also that mesophilic microorganisms are responsible for the initial decomposition of organic materials and the generation of heat responsible for the increase in compost temperature. The sharp decreases in microbial population at the maturity

Table.1 Mean of temperature variations during composting process

Treatments	**Time (weeks)**								
	0	1	2	3	4	6	8	10	12
	Temperature (^{o}C)								
Agricultural wastes+ CA	35	52	57	62	63	54	48	41	34
Agricultural wastes+ 5% SM	36	53	58	62	64	55	47	42	36
Agricultural wastes+ 10% SM	35	54	56	63	64	56	46	45	38
Agricultural wastes+ 20% SM	34	56	58	65	63	53	49	43	36
Agricultural wastes+ 40% SM	35	55	58	64	63	55	48	44	37

CA: Chemical Activator SM: Sheep Manure

Table.2 Microbiological changes during composting of agricultural wastes treated with different rates of sheep manure (Counts / g dry material).

Treatments	Time in weeks				
	0	3	6	9	12
	Total bacterial counts (Counts ×10^7 CFU/g)				
Agricultural wastes+ CA	15	74	165	132	23
Agricultural wastes+ 5% SM	37	86	181	156	48
Agricultural wastes+ 10% SM	49	110	192	162	77
Agricultural wastes+ 20% SM	65	115	196	180	96
Agricultural wastes+ 40% SM	86	119	210	186	104
	Mesophillic aerobic cellulose decomposer (Counts ×10^4 CFU/g)				
Agricultural wastes+ CA	139	32	98	63	54
Agricultural wastes+ 5% SM	158	60	117	86	75
Agricultural wastes+ 10% SM	160	66	128	97	82
Agricultural wastes+ 20% SM	168	77	136	121	84
Agricultural wastes+ 40% SM	176	90	138	133	96
	Thermophillic aerobic cellulose decomposer (Counts ×10^5 CFU/g)				
Agricultural wastes+ CA	26	81	102	69	41
Agricultural wastes+ 5% SM	38	85	113	78	54
Agricultural wastes+ 10% SM	41	92	123	86	55
Agricultural wastes+ 20% SM	59	100	123	91	66
Agricultural wastes+ 40% SM	63	106	129	91	78
	Total coliform (Counts ×10 CFU/g)				
Agricultural wastes+ CA	67	31	2	-	-
Agricultural wastes+ 5% SM	119	43	5	-	-
Agricultural wastes+ 10% SM	122	43	6	-	-
Agricultural wastes+ 20% SM	142	48	6	-	-
Agricultural wastes+ 40% SM	159	57	8	-	-

CA: Chemical Activator SM: Sheep Manure

stage could be deduced to the diminution of moisture and depletion of organic matter at the later stage of composting process. Data also clearly showed that total bacterial counts were increased as the rate of sheep manure increased. The treatment of agricultural waste + 40% sheep manure gave the highest bacterial counts, while the treatment of agricultural waste + 5% sheep manure recorded the least one. These results were in harmony with those of Abo-Sedera, (1995) and Radwan & Awad (2002).

Data in Table 2 show sharp decrease in counts of mesophilic aerobic cellulose decomposing bacteria at the third week of composting followed by increases till the end of the composting process. These results indicated the importance of mesophilic aerobic cellulose decomposing bacteria at the beginning of composting as they attack cellulytic decomposable constituents of organic wastes. The decreasing in mesophilic aerobic cellulose decomposing bacteria after 3 weeks was due to the high temperature (62 – 64 ^{o}C) recorded at that time. These results were in harmony with those of El-Meniawy (2003) and Eida (2007).

Counts of thermophilic aerobic cellulose decomposing bacteria in the composted materials showed a marked increase after 21 days of composting and reached its maximum counts at the 6th week (Table, 2). This was mainly due to the high temperature of the pile during this period of composting. Thermophilic aerobic cellulose decomposing bacteria, thereafter, decreased with the fall of temperature until the end of the composting period. This decline in numbers could deduced to the postulates mentioned by Ryckeboer *et al.* (2003) that during the curing and maturity phase the cellulose may become inaccessible to enzymatic attack because of low water content or association with protective substrates such as lignin. These results also indicated that changes in temperature of the composted piles govern the types and development of microorganisms concerned in the decomposition process (Abdel-Aziz & Al-Barakah, 2005 and Eida, 2007). In general, aerobic cellulose decomposing bacteria were increased as the rate of sheep manure increased and rend of total bacterial counts.

Results showed that total coli form counts were higher in all sheep manure treatments as compared to chemical activator treatment (Table 2). Data clearly showed that total coli form counts were gradually decreased during the first 6 weeks and completely disappeared at the ninth week in all treatments. This could be attributed to the achievement of maximum compost temperature 62 -64 ^{o}C at the third week. This high temperature is sufficient to kill pathogens and parasite inside the composting pile. These results are in line with those of Lasaridi *et al*. (2006) and Sadik *et al*.(2012). These results clearly proved that the produced compost is free from pathogens and parasites.

Physicochemical changes

Dry matter content

Dry matter content of the different treatments decreased gradually during the whole period of composting (Table, 3). Total loss of dry matter content amounted to be 45.0, 46.0, 46.6, 46.8 and 47.4 % from the initial amount of treatments No. 1, 2, 3, 4, and 5, respectively. These results are in line with those of Wallace (2003) and Eida (2007). The present results clearly indicate the rapid degradation of agricultural waste treated

Table.3 Physicochemical changes during composting of agricultural wastes treated with different rates of sheep manure as organic activator

Treatments	Time in days			
	0	30	60	90
Dry Matter (Kg)				
Agricultural wastes+ CA	18213	12545	10691	10017
Agricultural wastes+ 5% SM	18456	12313	10692	9966
Agricultural wastes+ 10% SM	18397	12057	10855	9827
Agricultural wastes+ 20% SM	18397	11938	11018	9789
Agricultural wastes+ 40% SM	18425	11676	10896	9685
pH				
Agricultural wastes+ CA	8.68	7.84	7.68	7.52
Agricultural wastes+ 5% SM	8.50	7.62	7.46	7.32
Agricultural wastes+ 10% SM	8.41	7.51	7.43	7.31
Agricultural wastes+ 20% SM	8.33	7.49	7.32	7.15
Agricultural wastes+ 40% SM	8.18	7.36	7.28	7.11
EC (dSm^{-1})				
Agricultural wastes+ CA	2.13	2.62	2.91	3.48
Agricultural wastes+ 5% SM	2.35	2.74	3.05	3.59
Agricultural wastes+ 10% SM	2.50	2.94	3.15	3.61
Agricultural wastes+ 20% SM	2.63	2.88	3.21	3.86
Agricultural wastes+ 40% SM	3.06	3.20	3.60	4.20
Organic matter (%)				
Agricultural wastes+ CA	92.45	65.72	56.41	51.77
Agricultural wastes+ 5% SM	90.84	64.95	55.16	49.04
Agricultural wastes+ 10% SM	88.56	63.53	54.25	47.37
Agricultural wastes+ 20% SM	84.72	60.84	51.72	45.49
Agricultural wastes+ 40% SM	77.04	59.14	47.82	41.60
Organic Carbon (%)				
Agricultural wastes+ CA	53.63	38.12	32.72	30.03
Agricultural wastes+ 5% SM	52.48	37.67	31.99	28.45
Agricultural wastes+ 10% SM	51.37	36.85	31.46	27.47
Agricultural wastes+ 20% SM	49.14	35.29	30.00	26.39
Agricultural wastes+ 40% SM	44.68	34.30	27.73	24.13

CA: Chemical Activator SM: Sheep Manure

Table.4 Changes in N-forms and C/N ratio during composting of agricultural waste treated with different rates of sheep manure as organic activator

Treatments	Time (weeks)			
	0	30	60	90
	Total N (%)			
Agricultural wastes+ CA	1.06	1.34	1.43	1.48
Agricultural wastes+ 5% SM	0.85	1.35	1.46	1.55
Agricultural wastes+ 10% SM	0.90	1.42	1.53	1.69
Agricultural wastes+ 20% SM	1.08	1.55	1.64	1.79
Agricultural wastes+ 40% SM	1.20	1.68	1.76	1.84
	NH_4 (ppm)			
Agricultural wastes+ CA	524	337	284	212
Agricultural wastes+ 5% SM	362	225	173	136
Agricultural wastes+ 10% SM	447	262	196	147
Agricultural wastes+ 20% SM	492	281	232	158
Agricultural wastes+ 40% SM	499	293	206	162
	NO_3 (ppm)			
Agricultural wastes+ CA	62	337	389	422
Agricultural wastes+ 5% SM	64	364	396	447
Agricultural wastes+ 10% SM	70	392	415	465
Agricultural wastes+ 20% SM	76	402	427	483
Agricultural wastes+ 40% SM	80	419	484	510
	Organic N (%)			
Agricultural wastes+ CA	1.00	1.27	1.36	1.42
Agricultural wastes+ 5% SM	0.81	1.29	1.40	1.49
Agricultural wastes+ 10% SM	0.85	1.35	1.47	1.63
Agricultural wastes+ 20% SM	1.02	1.48	1.57	1.73
Agricultural wastes+ 40% SM	1.14	1.61	1.69	1.77
	C/N ratio			
Agricultural wastes+ CA	53.63	30.02	24.06	21.15
Agricultural wastes+ 5% SM	64.79	29.20	22.85	19.09
Agricultural wastes+ 10% SM	60.44	27.29	21.40	16.85
Agricultural wastes+ 20% SM	48.18	23.84	19.11	15.25
Agricultural wastes+ 40% SM	39.19	21.30	16.41	13.63

CA: Chemical Activator SM: Sheep Manure

with sheep manure as organic activator if compared to agricultural wastes treated with chemical activator. This may be due to the increase of microorganism's activity in biodegradation of agricultural waste in the presence of sheep manure as organic activator if compared to chemical activator treatment. It seems that the highest rate of decomposition took place at high temperature and the rate was decreased during the subsequent low temperature period.

pH

It is well known that the pH adjustment is important for healthy plant growth. In the present study, pH values of raw materials of the different treatments at initial time of composting were slightly alkaline, 8.68, 8.50, 8.41, 8.37 and 8.18 for the treatments No. 1, 2, 3, 4, and 5, respectively (Table, 3). During composting, pH values decreased gradually due to the formation of organic acids during the metabolism of relatively readily available carbohydrates, consumption of ammonia by microorganisms and as a result of volatilization of free ammonia to the air. Finally, the pH tended to stabilize due to humus formation with its buffering capacity at the fermentation of composting activity as also mentioned by Khalil *et al.* (2001) and Abdel-Aziz & Al-Barakah (2005).

Salinity level (EC)

It was observed that EC of agricultural waste treated with sheep manure as organic activator was higher than that of chemical activator treatment at the initial time of composting (Table, 3). Moldes *et al.* (2007) demonstrated that the components contributing most to salinity are Na^+, K^+, Cl^-, ammonia, nitrate and sulfate. They also added that lower levels of pH indicate a lack of available salts, while high levels indicate a large amount of soluble salts that may inhibit biological activity or may be unsuitable for soil application if large quantities of the compost are used. Although the gradual increase in the EC during the composting process of different treatments, they did not exceed over the recommended limits. The increment in EC values may be attributed to loss of biomass through the biotransformation of organic materials and also to release of some contents as mineral elements. Similar results indicated an increase in EC during composting process (Abd El- Maksoud *et al.*, 2002 and Abdelhamid *et al.*, 2004). Recently, Lasaridi *et al*. (2006) proposed that value of 4.0 ds/m for EC is a level considered tolerable by plants whereas values from 6 to 12 ds/m indicating toxicity due to salts for most plants up to the Greek standers.

Organic carbon and organic matter content

Changes in the figures of organic carbon (OC) and matter (OM) contents during composting of different treatments found to be in line with those recorded for the dry matter content (Table, 3). The most active period of decomposition was noticed at the high temperature periods. This indicates the important role of the thermophilic organisms in the decomposition process (Abo- Sedera, 1995 and El-Meniawy, 2003). The organic carbon and matter contents were decreased during the composting process. The decreases of OC and OM were expected owing to the evolution and volatilization of CO_2 throughout the biodegradation of OM by aerobic heterotrophic microorganisms. The loss in organic matter content during the decomposition

Table.5 Changes in total macro-nutrient (%), micro-nutrients and heavy metal (μg g^{-1}) during composting of agricultural waste mixed with different rates of sheep manure as organic activator.

Treatments	Macro-nutrients			Micro-nutrients				Heavy metals		
	N	P	K	Fe	Mn	Zn	Cu	Pb	Ni	Cd
	Initial									
Agricultural wastes+ CA	1.06	0.512	0.452	3800	36	54	19	9	12	0
Agricultural wastes+ 5% SM	0.85	0.459	0.344	4344	42	24	17	3	2	0
Agricultural wastes+ 10% SM	0.90	0.508	0.368	4998	47	27	20	3	2	0
Agricultural wastes+ 20% SM	1.08	0.607	0.416	5466	54	32	22	3	4	0
Agricultural wastes+ 40% SM	1.20	0.805	0.512	5748	74	49	27	4	4	0
	30 Days									
Agricultural wastes+ CA	1.34	0.562	0.532	5122	61	67	23	11	14	0
Agricultural wastes+ 5% SM	1.35	0.513	0.387	6097	83	29	23	4	3	0
Agricultural wastes+ 10% SM	1.42	0.544	0.432	6235	89	33	26	4	3	0
Agricultural wastes+ 20% SM	1.55	0.694	0.498	7116	98	38	28	4	5	0
Agricultural wastes+ 40% SM	1.68	0.911	0.629	7604	104	55	32	5	4	0
	60 Days									
Agricultural wastes+ CA	1.43	0.566	0.561	6213	69	82	24	12	15	0
Agricultural wastes+ 5% SM	1.46	0.524	0.409	6834	96	31	24	5	4	0
Agricultural wastes+ 10% SM	1.53	0.556	0.467	7212	94	34	27	5	4	0
Agricultural wastes+ 20% SM	1.64	0.709	0.525	7810	112	40	28	5	6	0
Agricultural wastes+ 40% SM	1.76	0.955	0.661	8264	127	56	33	6	5	0
	90 Days									
Agricultural wastes+ CA	1.48	0.573	0.583	6425	75	88	25	12	15	0
Agricultural wastes+ 5% SM	1.55	0.532	0.424	7156	101	32	24	5	4	0
Agricultural wastes+ 10% SM	1.69	0.569	0.482	7936	109	35	28	5	4	0
Agricultural wastes+ 20% SM	1.79	0.715	0.547	8130	122	42	30	5	6	0
Agricultural wastes+ 40% SM	1.84	0.978	0.682	8994	137	57	35	6	5	0

CA: Chemical Activator SM: Sheep Manure

period amounted to be 44.0, 45.8, 46.51, 46.3 and 46.0 % of the initial amount of treatments No. 1, 2, 3, 4, and 5, respectively. This indicates that the rate of decomposition was high in treatments mixed with sheep manure as organic activator in comparison to chemical activator treatment. This could be due to the high content of easily decomposable substances in the treatments mixed with different rates of sheep manure than that of chemical activator treatment. Moldes *et al.* (2007) mentioned that, there is no absolute level of OM that is ideal in term of compost quality, but rather the qualities must be viewed in relation to the age of compost, its N content and its intended use.

Available, organic and total nitrogen

As the result of decomposition process, NH_4-N was decreased, while, NO_3, and the percentage of total & organic nitrogen were increased in all treatments (Table, 4). Composted materials contain significant amounts of N in organic form that, whilst not easily available to plants, are also less leachable (Eida, 2007). The increase in total nitrogen percent may be due to the higher oxidation of non- nitrogenous organic materials and partially to the N_2-fixation by non-symbiotic nitrogen fixers as indexed by the increase in organic nitrogen. This indicates that the immobilization of nitrogen taken place during composting and conserved the nitrogen from loss.

C/N ratio

The C/N ratio is one of the main creteria that describe the composting process. It is often used as an index of composting maturity, despite many pitfalls associated with this approach, but it seems to be a reliable parameter for following the development of the composting process (Khalil *et al.*, 2001). Changes in the ratio of organic carbon to nitrogen during composting of agricultural wastes treated with different rates of sheep manure are recorded in Table, 4. The C/N ratios were first 53.6, 64.8, 60.4, 48.2 and 39.2 for treatments No. 1, 2, 3, 4 and 5, respectively. As the result of the changes in the amount of nitrogen and the loss of organic carbon during composting process, a progressive narrowing in the C/N ratios of the composted materials was observed reaching to 21.2, 19.1, 16.9, 15.3 and 13.6, in respective order for treatments No. 1, 2, 3, 4 and 5. The changes in C/N ratio could be taken as evidence of the degradation rate of the organic materials and the maturity of compost. These results are in line with those of Abdelhamid *et al*. (2004) who stated that C/N value of around or below 20 could be considered satisfactory. Khalil *et al.* (2001) demonstrated that the C/N ratio of mature compost should ideally be about 10 but this is hardly ever achievable due to the presence of recalcitrant organic compounds, or materials which resist decomposition due to their physical or chemical properties. Some authors reported that a C/N ratio below 20 is an indicative of acceptable maturity. However, Moldes *et al.* (2007) stated that compost might be considered mature when C/N ratio is approximately 17 or less, unless lignocellulytic materials remain.

Macronutrients

Definitely, the macronutrients N, P and K are the most consumed elements by plants at the all stages of growth. The quantity and form of N, in particular, present in manure or compost is important in shaping the quality of the material and for its agronomic use and are increasingly more often defined in compost specification (Lasaridi *et al*., 2006 and Moldes *et al.*, 2007). The concentrations of NPK were increased during the composting process in all treatments (Table, 5). Data clearly showed that the concentrations of NPK in organic manure treatments were higher than that of chemical activator treatment at initial and end of composting process. Generally, the increase in total NPK during composting may have been due to the net loss of dry mass as loss of organic C as CO_2. Moreover, total N can also be increased by the activities of associative N-fixing bacteria at the end of composting process (Abdelhamid *et al.*, 2004). These results are in similar with those obtained by different authors (Abd El-Maksoud *et al.*, 2001, 2002; Kaviraj & Sharma, 2003 and Eida, 2007).

Micronutrients

It was seen that the Fe content was higher than the other elements in all treatments (Table, 5). Conversely, the other three elements, Mn, Zn and Cu recorded moderate increases until the maturity stage. Thus composting can concentrate micronutrients (Zorpas *et al.*, 2002). Micronutrients in organic manure treatments were higher than that of chemical activator one at initial and end of composting.

Heavy metals

The initial content of heavy metals in chemical activator treatment was higher than the organic activator ones, consequently were all the values recorded at the different stages of composting process. In general, slight increase were recorded in the total content of Ni and Pb throughway the processing of compost with a little differences between the initial value and the maturity one. However, Cd was not detected in all treatments either at initial or during the composting process. Maximum permissible international values are set for heavy metals (Cd, Cr, Hg, Ni and Pb) although the limits vary widely (Hogg *et al.*, 2002).

Its worth to mention that, evaluation of compost produced from agricultural waste proved to be the product was environmentally safe in completely for agronomic purpose and human health. Since the heavy metal content of produced compost were several times lower than regulation limits prescribed by the US EAP for Exceptional Quality compost and Spanish legislation for fertilization including compost according to Lasaridi *et al.* (2006) and Moldes *et al.* (2007). Generally, the international regulations limits were ranged between mean values of 10-39, 25- 200 and 45-500 mg kg^{-1} for Cd, Ni and Pb, respectively. Whereas the values for same metals in the final product of compost were ranged between, 6 – 12, 5 – 15 and 0 mg kg^{-1} for Ni, Pb and Cd, in respective order.

It can be concluded that improper handling of agricultural waste results in several environmental risks such as pollution of soil, water and air. Therefore, it could be recommended that windrows composting is the more convenient and faster practice for composting of agricultural waste and could be replicated more than once a year for consumption a total agricultural waste to mitigate the environmental pollution.

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