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Bio-Processing the Crop Residues with Different Amendments for Producing High Quality Compost

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Abstract: Bio processing of different plant residues (cotton stalks, rice straw, bagasse and their mixture with various amendments (farmyard manure, rock phosphate, feldspar, bentonite, vinasse, urea and elemental sulfur), and some inoculants for preparing four miscellaneous compost heaps, then its left to bioprocess for four months. The evaluation of physic- chemical, biological and some maturity indices of composted materials were practiced during the composting process.

Obtained results revealed that bulk density, water holding capacity and nutrients content (total and available forms of N, P, and K) were greatly increased with progressing the composting process, while the values of pH and EC were fluctuated among the different heaps and different stages of composting process. Moreover, the organic carbon and organic matter was declined with progressing the composting time for all investigated heaps. At maturity stage, which expressed by some indices namely dehydrogenase activity, C/N ratio, E4/E6, NH_4/ NO_3 ratio, germination index (GI) and humification indices, all refers to that all investigated heaps reached to reasonable degree of maturity, particularly the GI and humification rate (HR), where the values of GI exceeded 60% for cress and barley seeds, while its values of HR reached up to 15% for all investigated heaps.

Keywords: Crop Residues, Bio-Processing, High Quality Compost.

Introduction

The estimated amount of agricultural residues in Egypt ranges from 30 to 35 million tons. Some of the agricultural residues are used as animal fodder, and the others are issued as fuel in indoor primitive ovens that cause health problems and damage to the environment. The rest is burned in the field causing local and regional air pollution problems. The main crops which generate large amounts of residues are rice, wheat, and sugarcane.

The type and quantity of agricultural residues in Egypt vary in location and in time (harvest season) as farmers cultivate the most profitable crops given the local conditions and season. This is a significant issue when studying the nature of the agricultural residues supply quantity that varies according to in time and location, Fig. (1) Shows the amounts of different types of agricultural residues in Egypt.

Composting is one of the technologies of integrated waste management strategies used for recycling the organic materials into useful product.

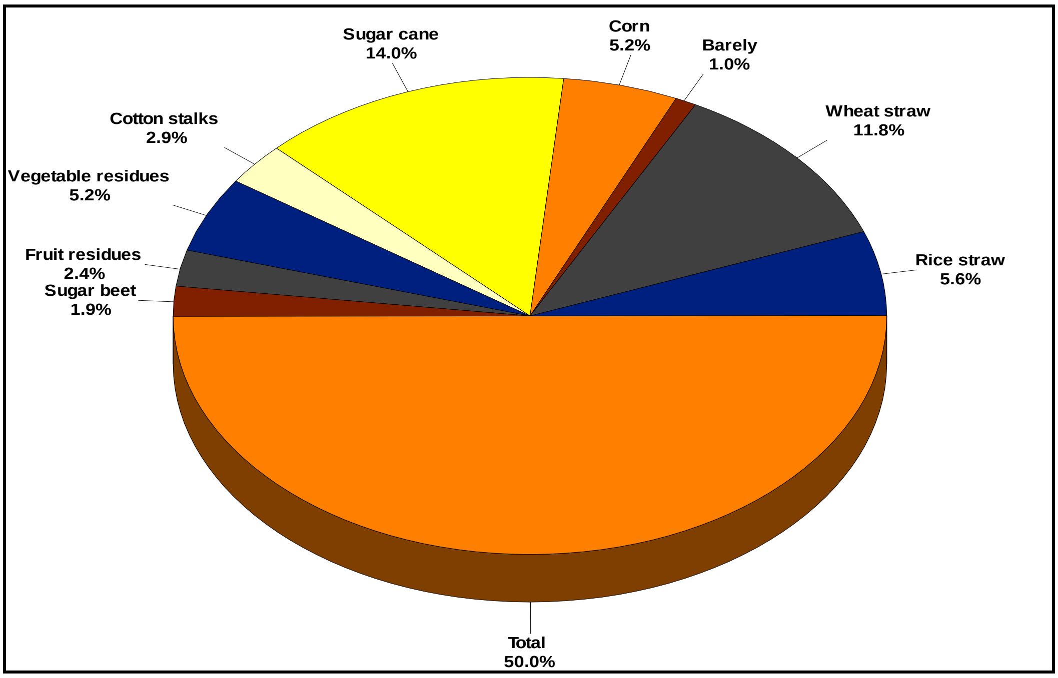

Fig. (1): Amount of agricultural residues in Egypt.

The composting process is an exothermal biological oxidation of organic matter carried out by a dynamic and quick succession of populations of aerobic microorganisms [1]**.** Composting is essentially a mass of interdependent bioprocesses carried out by an array of micro and macroorganisms resulting in decomposition of organic matter. Microscopic organisms such as bacteria, Fungi, actinomycetes and protozoa are the chemical decomposers, while large organisms such as worms, mites, snails, beetles, centipede and millipedes are mainly the physical decomposers[2]**.**

Although the microbial community naturally presented in composted raw materials usually carries out the process satisfactorily, the inoculation of agricultural residues with efficient lignocelluolytic microorganisms such as *Trichoderma* , *Phanerochaete* and *Pleurotus* are capable of efficiently metabolizing cellulose and lignin in a variety of lignocellulosic materials resulting in hasting their decomposition rate[3,4]**.** Microbial activity plays a leading role on transformations occurring during humification process. When the substances constitute an important fraction of the total organic matter, what potentially makes lignocellulolytic microorganisms the most adequate to conduct the humification process[5]. In this concern, [6]demonstrated that some of that compounds released from lignocelluloses degradation as consequence of microbial activity, such as polyphenols, sugar and amino compounds seems to promote the humus formation.

In spite of the importance of composting process, it has some drawbacks, including their low levels of nutrients (1-2% N and less than 1% P) as compared to chemical fertilizers. However, such problems seemed to be solved by blending several miscellaneous of crop residues with some amendments such as natural minerals, rocks , organic fluids ,i.e.,vinasse and corn steep, and bioactivators, which any of them must be applied at relevant stages of composting process. Such amendments resulted in accelerating of the decomposition rate, correcting the nutrients deficiency and increasing the ability of produced compost for protecting plants against phyto-pathogens[7,8].

Compost maturity and stability are key factors during composting. Immature compost, when applied to soils maintains high decomposition activity, which may cause a decrease of oxygen concentration and soil Eh and, as result the creation of a strongly reducing environment at the rhizosphere level. Also, immature compost may retard plant growth due to nitrogen starvation, anaerobic conditions and phyto-toxicity of NH_4 and some organic acids [9]. Therefore, it is essential to determine the degree of maturity to avoid these risks.

The aim of this work is to evaluate the composting process of bio-enriched composts made from different plant residues and different amendments through measuring of physico –chemical and biological changes occurred in constructed heaps during different stages of composting as well as some maturity indices.

2- Materials and Methods

2.1. Composting performance:

Various crop residues and amendments were collected from different sources to prepare four miscellaneous compost heaps at different locations. The intact plant residues (rice straw, bagasse and cotton stalks) were chopped to particle size less than 25 mm. Three heaps were prepared from each plant residue and the fourth prepared from the mixture of three plant residues and olive pomace. The four heaps received the various amendments as in the following:

Heap1: 1500 kg rice straw + 150 kg farmyard manure + 75 kg rock phosphate + 75kg feldspar + 150 kg bentonite + 15 kg urea + 15 kg elemental sulfur + vinasse solution(1%).
Heap2: 1500 kg bagasse + the same additives in Heap1.
Heap3: 1500 kg cotton stalks + the same additives in heap1.
Heap4: 500kg rice straw + 500kg bagasse + 500kg cotton stalks + 100 kg olive pomace + the same additives in heap1.

The main characteristics of the plant residues and amendments were presented in Table (1).

Table (1). Physico - chemical of the used plant residues and amendments

Parameters	Raw material and amendments								
	Rice straw	**Cotton stalk**	**Sugar cane Bagasse**	**Olive Pomace**	**Farmyard manure**	**Vinasse**	**Rock phosphate**	**feldspar**	**Bentonite**
WHC%	71.22	44.28	72.34	78.2	316.4	-	-	-	-
Bulk density (Kg/m^3)	181	238	155	520	0.68	1.21	-	-	-
pH	7.05	5.83	5.60	6.62	9.38	4.67	7.70	7.8	8.10
EC(dS/m)	7.47	2.85	0.92	1.99	5.8	19.43	3.10	0.52	6.21
Organic-C%	50.39	55.53	56.98	55.88	22.05	22.82	0.45	0.39	0.15
Organic matter %	86.68	95.51	98.01	96.11	37.93	39.25	0.77	0.67	0.26
Total – N%	0.67	0.71	0.81	1.21	1.20	1.22	0.036	N.D	0.028
Total – P%	0.09	0.40	0.23	0.34	0.70	0.21	9.96	0.35	0.38
Total – K%	1.24	1.42	0.64	1.80	1.90	5.32	0.38	7.72	1.34
C/Nratio	75.21	78.21	70.35	46.18	18.22	18.77	12.50	-	5.36
$N- NO^-_3$ (ppm)	29.12	97.68	48.53	58.2	1566.0	-	-	-	-
$N – NH^+_4$ (ppm)	48.53	351.87	242.67	27.3	481.0	-	-	-	-
Total soluble – N (ppm)	77.65	449.55	291.20	85.5	2047.0	225.5	-	-	-
Total – Fe (ppm)	860.9	397.7	17.6	321.0	169.5	1686.8	4800.0	1397.0	5932.0
Total – Mn (ppm)	87.5	18.8	11.3	7.1	42.5	23.5	360.0	64.6	1500.0
Total – Zn (ppm)	22.0	19.4	21.5	11.7	27.9	9.4	82.0	22.7	73.0
Total – Cu (ppm)	4.9	6.9	2.8	3.1	4.2	-	11.5	36.40	47.0

Composting process was executed on the concrete floor by arranging the plant residues with farmyard manure and bentonite in successive layers to make trapezoidal heaps at dimensions of 3x4x1.8m for width, length and height, respectively. After construction of heaps, they inoculated with lignocellulytic inoculant composed of *Trichoderma harzianum* and *Trichoderma viridi* cultured on commercial liquid media at rate of 1L/ ton composted materials, then the heaps re-inoculated after 30 days of composting with the same rate.

- After establishing the heaps, they received mixture solution composed of 1% vinasse and 1% urea.
- After 30 days of composting process (2^{nd} turning), rock phosphate, feldspar and elemental sulfur in highly fineness grade form were thoroughly incorporated with the composted materials, then the shower of 1% vinasse solution was well spread on the heaps.

- The heaps were turned every 15 days using a front end loader. The moisture content was adjusted to about 50-60% along the composting period.
- Temperature was fluctuated from 55 to 65°C in all heaps (within the core region at depth of 60-70Cm and its adjacent zones) during active stage of composting (60 days), then its decrease to range from 35 to 45 °C during the last one month (maturity stage).
- After three months of composting process, the four heaps re- constructed at dimensions of 2.5x3.5x1.5 m for width, length and height, respectively, then they inoculated with 2 liter from a mixture of rhizobateria inoculant, which contains *Bacillus polymyxa, Serratia mercescens and Pseudomonas fluorescen*. Afterwards, 1% vinasse solution was broadcasted on the heaps. The four heaps left to cure for 30 days.

2.2. Compost sampling:

After elapsing the composting process (four months), three symmetrical locations were selected along each heap, i.e., at the top, the middle and the bottom to collect representative samples. At each location, a hole was made and three samples were taken and combined to form composite sample. Triplicate composite samples from each heap were collected periodically at day 30,60,90 and 120 and stored at 4°C immediately prior to analysis the physicochemical and microbiological traits as well as maturity indices.

2.3. Analytical Methods:

- Physico-Chemical properties were determined according to[10,11].
- E4/E6 ratio (Extinction coefficient) was measured on the alkaline extract (0.1N NaOH) and then followed by spectrometric determination at 460 and 660nm, respectively[10].
- Seed germination index (GI) and root length were assayed to evaluate maturity of compost according to[12].
- Dhydrogenase activity (DHA) was assayed according to[13].

Humification indices:

The total humic extract (THE) ,humic (HA) and fulvic acids (FA) were measured according to [14], while the humification indices were calculated according to[11].

2.4. Statistical analysis:

All data were statistically analyzed according to[15].

3- Results and Discussion

3.1. Changes in Physico-chemical properties during composting process.

3.1.1. Some physical properties:

Changes in some physical properties of different compost heaps during the composting process are presented in Table (1). The values of bulk density and water holding capacity (WHC) increased greatly with the progressing of the composting process and reached their maximum at the end of the process (120 days). However, there was clear variation in values of the two studied parameters between the different heaps under investigation. The values of bulk density rose from 0.24, 0.29, 0.21 and 0.23 kg/m^3 after 30 days of decomposition to 0.41, 0.60,30 and 0.39kg/m^3 after 120 days of decomposition in respective to the heaps of cotton stalk, rice straw, bagasse and their mixture. The corresponding water holding capacity percentages also raised from 96.57, 89.90, 95.20 and 94.80 after 30 days of decomposition to 223.30, 141.5, 152.60 and167.50 after 120 days of decomposition. These results reflected the effect of the nature of raw material irrespective of the presence of different amendments and shredding process, where were the same for all raw materials used. On the other hand, the gradual increases occurred in bulk density and WHC might be attributed to the breakdown of lignocellulose, the recalcitrant fraction of plant residues structure resulting in reducing the volume of raw materials and consequently increasing the capacity of water retention. These results are in accordance with those obtained by[16,17,18].

3.1.2. pH and EC:

Table (3) shows the changes occurred in pH and EC of different heaps during the different periods of composting process. The values of pH exerted little reduction excluding the heap of cotton stalk; which exhibited gradual increasing with progressing the composting process (pH values were raised from 7.42 to 7.95). However, the pH values of the heaps of rice straw and bagasse were slightly near acidic pH values along the compost process, while the pH values of mixture heap were fluctuated around neutral value. The pH values at 120 days of decompositions were 6.79, 6.41 and 7.12 for rice straw, bagasse and mixture heaps, respectively. This behavior of pH might be due to the variation of the decomposition nature for each plant residue. As general the slight decrease in pH was due to the decomposition of organic materials leading to produce organic acids [19]**.** Additionally, the rising pH values might be elucidated by the ammonification and mineralization of organic nitrogen through microbial activity[19,20,21].

Table (2): Changes occurred in water holding capacity and bulk density during composting process

Heap / Period (day)	Cotton Stalk	Rice straw	Bagasse	Mixture
Water holding capacity (WHC%)				
30	96.57	89.90	95.20	94.80
60	150.28	121.00	122.00	138.0
90	203.00	136.40	148.00	161.5
120	223.30	141.50	152.6	167.5
Bulk density (BD kg/m^3)				
30	0.24	0.29	0.21	0.23
60	0.28	0.42	0.25	0.29
90	0.31	0.58	0.28	0.37
120	0.41	0.60	0.30	0.39
LSD at 0.05	WHC	BD		
Heap (H)	22.98	0.002		
Period (P)	22.98	0.002		
HXP	45.96	HXP		

Concerning the EC values, they exhibited different trends due to the different tested heaps through the composting periods from 30 to 120 days. For instance, due to cotton stock heap the EC values fluctuated between 3.50 (90 days) and 4.28 (120 days), while for bagasse heap it fluctuated between 6.32 (120 days) and 7.37 (30 days). However, any of rice straw, bagasse and the mixture heaps exhibited decreases in salinity degree during the process of decomposition from 30, 60, 90 and up to 120 days. Only for the cotton stalk heap the differentiation of EC degrees in response to the decomposition time was slight effective and/or recognized. The rising of EC values during the composting process might be attributed to the degradation and mineralization of organic substances and release of soluble salts[21,22,17]**.**

Table (3): Changes occurred in pH and electrical conductivity during composting process

Heap / period (day)	Cotton Stalk	Rice straw	Bagasse	Mixture
pH				
30	7.42	7.11	6.84	6.93
60	7.58	6.83	6.38	7.06
90	7.62	6.57	6.32	6.92
120	7.95	6.79	6.41	7.12
EC (dS m^{-1})				
30	3.54	6.48	7.37	4.88
60	3.61	4.30	5.46	5.12
90	3.50	5.46	6.61	5.32
120	4.28	5.53	6.32	5.30
LSD at 0.05	pH	EC		
Heap(H)	0.172	0.429		
Period(I)	0.172	0.429		
HX1	0.345	0.858		

Table (3): Changes occurred in pH and electrical conductivity during composting process

3.1.3. Organic carbon and organic matter (Volatile solids):

Results in Table (4) exerted that organic carbon declined with progressing the composting time for all investigated heaps. Organic carbon reduced greatly in rice straw heap, where the loss of carbon reached to 50.37% followed by cotton stalk (45.04%), while the bagasse and mixture were exhibited the less carbon losing (41.52 and 39.71%,respectively).These results may be elucidated by the variation in biochemical composition of the used raw materials (Cellulose, hemicellulose and lignin, Table 1). In addition, the greatest reduction in organic carbon was occurred during the biooxidative interval, where the biochemical constituents exposed to thermophilic, biological and chemical decomposition resulting in strong degradation of organic materials. The reduction of carbon had being caused due to the degradation of organic materials and the carbon lost mainly as carbon dioxide during the composting process. Similar trend were obtained by [23,24,22].

Table (4): Changes occurred in organic carbon and organic matter during the composting process

Heap / period (dry)	Cotton Stalk	Rice straw	Bagasse	Mixture
Organic carbon (%)				
30	41.51	47.90	50.27	45.2
60	32.41	36.00	39.47	35.92
90	28.65	28.13	33.47	31.20
120	22.85	23.60	29.40	27.25
Carbon lossing%	45.04	50.73	41.52	39.71
Organic matter (%)				
30	71.39	82.37	86.46	77.74
60	55.75	61.91	68.18	61.78
90	49.27	48.38	57.56	53.66
120	39.30	40.59	50.56	48.50
L.S.D at 0.05	Organic .C	Organic matter		
Heap(H)	2.901	2.623		
Period(I)	2.901	2.623		
HX1	5.801	5.246		

Organic matter, which represented the volatile solids content decreased with progressing the composting time as result of losing the organic carbon through microbial oxidation. The loose of volatile solid varied among the tested raw materials particularly bagasse and cotton stalk (from 89.46 to 50.56 % and from 71.39 to 39.30 %, respectively), which exerted more resistance to decomposition than rice straw. This may be due to their recalcitrant constituents. In this context, [19]revealed that the high content of recalcitrant decomposable compounds, such as cellulose and lignin in leaves and sawdust may account for the relative low degree of volatile solid loss after 63 days of composting**.**

3.1.4. Nutrients content (fertilizer value):

Table (5) shows the nutrients content of compost heaps during different stages of composting process. Results revealed that the essential elements (N, P and K) that represented the fertilizer value of compost increased in the produced composts. Values of total – N content increased gradually with progressing the composting time in all investigated heaps. At the beginning of the composting process the total- N contents were 0.92, 0.64, 1.06 and 0.91% in the heaps of cotton stalk, rice straw, bagasse and their mixture, respectively. Their corresponding, values were 1.44, 1.42, 1.49 and 1.37%, respectively, at the end of process (120 days). These findings may be due mainly to the net loss of dry mass as the loss of organic carbon in terms of carbon dioxide as well as the water loss by evaporation during the mineralization of organic matter leading to increase the total – N by concentration effect[19,24,22]. Also, the values of total phosphorus and potassium contents were behaved like wise the total – N content.

Concerning the soluble forms of nitrogen, obtained results exerted that concentration of N- NH+4 increased initially until 60 day of the process (thermophilic phase) as indicative of high ammonification rate at this phase as well as the mineralization of organic –N compounds. Afterwards, the values decreased as consequence of composting process progressed[19,22]. However, the N-NH4 values were still high at the end of the process and it had highly exceeded the maximum limit of 400 mg kg -1[25]. High content of N- NH4 in last stage of composting may be attributed to inoculation of the compost heaps with cellulolytic fungi and plant growth promoting *rhizobacteria*, which led to accelerate the mineralization process and biological nitrogen fixation at latter stages of the process [26,27,22]. The levels of nitrate increased gradually during the initial stages of decomposition (thermophilic stage), then it reached the peak at the end of the process. These results reflect that nitrate formation decreased during raising the temperature and dominance of ammonification conditions. In this concern, [28,19]showed that nitrification hardly occurred under thermophilic condition since high temperature (greater than 40°C) and excessive amount of ammonia inhibited the activity and growth of nitrifying bacteria.

Concerning the availability of phosphorus and potassium (Table 5) data inferred that the levels of both available P and K increased gradually with progressing the composting time in the four heaps under investigation. Results revealed that the supplementation of the tested heaps with mineral amendments and inoculation with lingocellulotytic fungi and rhizobacteria led to increase significantly the availability of P and K reaching to their high appreciable values at the end of the process. These high values were 361.5 and 715.8 ppm in the cotton stalks heap, 311.0 and 613.5 ppm (rice straw heap), 316.5 and 825.4 ppm in the (bagasse heap) and 302.8 and 714.5 ppm (the mixture heap) for P and K, respectively. The results are indicative of the key role of composted organic materials (humified materials), which efficiently affecting the dissolution of P and K from the applied mineral amendments such as rock phosphate and feldspar during the composting process [29,30,22]. [31] demonstrated that humic substances particularly fulvic acid adsorb a significant amounts of Ca and release H+ ions, which help in rock phosphate solubilization. Also humic substances produced during composting time may check the re- precipitation of solubilized P and Ca by complexity of both ions and creating a sink in the system for further dissolution of rock phosphate.

Table (5): Changes occurred in nutrients content (Fertilizer value) of different compost heaps with progressing the composting time

Heap	period	Total-N (%)	Total-P%	Total-K%	Available P(ppm)	Available K (ppm)	$N-NH_4$ (ppm)	$N-NO_3$ (ppm)
Cotton stalk	30	0.92	0.52	1.42	225.5	316.0	451.4	161.9
	60	1.04	0.57	1.63	246.0	465.2	582.4	223.8
	90	1.40	0.58	1.92	248.3	575.3	540.2	313.5
	120	1.44	0.60	2.18	361.5	715.8	465.1	391.7
Rice straw	30	0.64	0.29	1.14	171.0	316.5	196.7	96.4
	60	0.94	0.36	1.38	193.7	489.5	251.0	132.3
	90	1.33	0.40	1.59	238.0	561.9	336.8	221.4
	120	1.42	0.46	1.60	311.0	613.5	441.0	371.0
Bagasse	30	1.06	0.42	1.37	218.6	532.8	563.4	298.6
	60	1.13	0.54	1.61	255.2	617.3	614.7	379.7
	90	1.47	0.58	1.79	318.1	782.3	490.2	398.8
	120	1.49	0.61	1.81	316.5	825.4	506.0	431.9
Mixture	30	0.91	0.41	1.43	221.8	408.0	588.4	286.4
	60	1.19	0.48	1.59	247.6	497.9	637.3	328.0
	90	1.32	0.60	1.62	271.5	671.3	581.3	379.0
	120	1.37	0.60	1.72	302.8	714.5	570.0	425.5
LSD at 0.05								
Heap(H)		0.074	0.026	0.026	27.93	29.40	51.89	28.73
Period(I)		0.074	0.026	0.026	27.93	29.40	51.89	28.73
HXI		0.149	0.053	0.053	55.87	58.80	103.8	57.46

3.2. Maturity evaluation:

3.2.1. Dehydrogenas activity (DHA-ase):

The evaluation of dehydrogenase activity during the different stages of composting process was done as a real expression of microbial activity, where it involved in the respiratory chains of all organisms and it refers to groups of most endocellular enzymes, which catalyze the oxidation of organic matter[32]. As seen in Table (6) the values of DHA-ase were high through the initial phases of composting process particularly active stage (biooxidative stage) at 60 days of composting, then they dramatically depressed at the latter stages of the process.

Table (6): Development of some maturity aspects of compost heaps with progressing composting time

Heap	period	DHA (mg/tpf/100g)	C/N ratio	E4/E6	NH_4/NO_3	GI- grass	GI-barley
Cotton stalk	30	415.8	45.11	2.16	2.78	46.4	51.3
	60	429.6	31.16	2.43	2.60	61.5	75.0
	90	195.4	20.89	2.38	1.72	83.8	85.9
	120	86.5	15.86	2.32	1.18	92.8	112.2
Rice straw	30	447.9	74.84	3.15	2.04	35.3	43.5
	60	481.2	38.29	2.24	1.89	52.0	61.2
	90	193.8	21.15	2.75	1.52	68.4	74.5
	120	89.8	16.61	2.54	1.18	79.5	89.7
Bagasse	30	412.6	47.42	2.91	1.88	36.2	48.7
	60	430.0	35.32	2.17	1.61	58.1	78.5
	90	181.9	22.76	1.98	1.22	65.0	89.6
	120	91.7	19.73	1.97	1.17	85.0	111.6
Mixture	30	417.0	49.67	2.89	2.05	41.80	51.70
	60	438.5	30.18	2.52	1.94	50.00	72.40
	90	179.8	23.63	2.23	1.53	56.87	75.2
	120	90.4	19.89	2.12	1.33	79.80	98.60
LSD at 0.05							
Heap (H)		16.35	5.259	0.234	0.28	3.326	4.661
Period(I)		16.35	5.259	0.234	0.287	3.326	4.661
HXI		32.69	10.52	0.468	0.574	6.653	9.322

Additionally, the heap of rice straw exhibited the most microbial activity rather than another heaps. These results clearly noted that there is a strong relationship between high microbial activity and degradation of organic matter at active stage of composting. These findings are in accordance with those of [33,24,22] who showed that DHA-ase activity decreased with composting time for different organic feedstock then remained stable after 2-3 months.

3.3.2. C/N ratio:

The C/N ratio decreased gradually with progressing the composting time, then it reached to reasonable ratios of 16.20, 16.38, 19.73 and 20.58 for heaps of cotton stalk, rice straw, bagasse and their mixture, respectively) at the end of the composting process. These final values considered in acceptable levels for compost maturity according to [33] who suggested a C/N ratio between 15 and 20 is ideal for ready use compost without any restrictions.

3.2.3. E4/ E6 ratio:

The ratio of optical densities of alkaline extract (humic Substance) at 460 and 660 nm, E4/E6 as indicative of the degree of condensation of aromatic nucleus of humus, which it refers to maturity of compost [34]**.** The ratios of E4/E6 due to the investigated four heaps exerted nearly similar behavior in which they decreased slowly during the composting process. These results may be referring to produce more poly-condensed humic acid particularly the heap of bagasse.

3.2.4. NH_4/NO_3 ratio:

This ratio represented the reverse trend between NH_4 and NO_3 during the composting process, where it decreased during the decomposition stages, particularly at latter stage for all the investigated heaps. These results are indicative of causing the nitrification process at the end of composting process (curing stage) and this is hardly occurred under thermoplilic conditions[28,19]. Therefore, the composts produced from these heaps may be considered mature compost.

3.2.5. Germination index (GI):

Germination index (GI) contains the measurement of relative seed germination and relative root elongation of cress and barley seeds. Germination index is the most sensitive parameter used to evaluate the toxicity and degree of maturity of compost[12]**.** Results in Table (6) indicate that the values of GI varied according to the type of heap compost raw material and the period of decomposition as well as the type of germinated seeds. The GI values of both tested plants increased with progressing the composting time and reached the peak at the latter stage of the process (120 days), where it exceeded 50%, the acceptable value of GI, which suggested by[12]**.** These findings emphasized the maturity of the produced composts from the four heaps and may be applied to soil without causing phytotoxicity. The obtained results are in agreement with those of [19,17] who reported that the low percentages of GI at the early composting stages may be attributed to release of high concentration of ammonia and low molecular weight organic acids, which might be remediated as the composting process proceeded. Additionally, [35] exerted that phytotoxicity or poor plant response can result from several factors such as oxygen demand and accumulation of toxic compound namely alcohol, methane, low molecular weight organic acids, ammonia and toxic nitrogen compounds, the immobilization of nitrogen with high C\N ratios and the presence of heavy metals and mineral salts.

3.3. Humification indices:

Different alkali extractable fractions of the organic matter such as total extractable carbon and humic and fulvic acids as well as the ratio between them as the best indicators of compost maturity [36]. Humification indices are tabulated in Table (7). The ratio of CHA/CFA increased with proceeding the composting time as indicative of development of humification process with progressing the composting time particularly at the maturation stage. These results are in accordance with [5] who exhibited that as the decomposition proceeds, the fulvic acid fraction either decreases or remains unchanged, while humic acids are produced. Furthermore, the humification index values decreased while, the values of humification rate increased for all studied heaps.

These results emphasized the increasing humification at the latter stages, where occurred the transformation of organic materials to humic like substances [37]**.** In this context, [5] revealed that the degree of humification and compost maturity can be evaluated by means of the humification index.

Table (7): Humification indices of the produced composts during the different stages of composting process

Heap	Period(day)	Cotton stalk	Rice straw	bagasse	mixture	L.S.D.
CHA/CFA ratio						
	30	1.21	1.10	1.03	1.60	
H	60	1.71	1.59	1.58	1.59	0.123
P	90	2.25	2.04	1.75	1.71	0.123
HXP	120	2.30	2.11	1.76	1.90	0.247
Humification index (HI %)						
	30	3.40	3.47	3.41	2.70	
H	60	3.07	2.09	2.21	1.76	0.190
P	90	1.62	1.63	1.77	1.44	0.190
HXP	120	1.45	1.42	1.44	1.17	0.380
Humification rate (HR %)						
	30	3.00	3.00	3.00	4.00	
H	60	9.00	7.00	6.00	9.00	0.396
P	90	13.00	13.00	10.00	14.00	0.396
HXP	120	20.00	19.00	15.00	19.00	0.792
LSD at 0.05	CHA/CFA	HI	HR			
Heap(H)	0.123	0.190	0.396			
Period(P)	0.123	0.190	0.396			
HXP	0.247	0.380	0.792			

Conclusion

In conclusion, evaluation of different compost type at the end of composting process after (120 days) indicated that, generally, Bagasse compost was superior in OM %, OC%, total N , NO_3-N, TP% and available - K parameters as compared to other compost type under studied. Moreover, Cotton compost was superior in water holding capacity (WHC %), total K%, and available P along with decreased in EC value as compared to other compost type.. Accordingly, it can be used to improve the chemical properties of the soil and crops productivity.

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