SVU-IJAS SVU-International Journal of Agricultural Sciences
Volume 3 Issue (3) pp.: 71-84, 2021
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2021.66837.1089

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RESEARCH ARTICLE

Effect of rock phosphate and plant growth-promoting rhizobacteria on physical and chemical properties change of corn residues during composting.

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Abstract

This study aims to study the effect of adding rock phosphate and plant growth-promoting rhizobacteria (PGPR), in the physical and chemical properties of the corn residues compost during aerobic decomposition. Four composting heaps were included in this study as it follows, 1) traditional method composting heap (T1), 2) heap was supplied with rock phosphate (T2), 3) heap was supplied with rock phosphate + *Bacillus megatherum* culture (T3), and 4) heap was supplied with rock phosphate+(*Bacillus.megatherum, Azospirillum lipoferum, Azotobacter chroococcum*) mixed cultures (T4). All compost treatments showed an increase in temperature right after composting started. The heap treated with three bacterial inoculums (T4) reached the highest peak values of 62.2°C on day 12 compared to other treatments. At the end of the composting period T1 recorded the lowest value of bulk density (533 kg/m^3) compared to other treatments. The pH value declined to stabilize with the end result at 100 days being 6.9, 7.4, 7.1 and 7.0 for composting treatment T1, T2, T3 and T4, respectively. The initial C/N ratio was 61:1 for all composting treatments, and the final values of total C/N ratio after the 100 days were 15:1, 14:1, 12:1 and 10:1 for composting treatments T1, T2, T3 and T4 respectively. Compost supplied with rock phosphate and three bacterial inoculums (T4) reached has more N, P and K content compared to other composting treatments T1, T2, T3. These results indicated that adding rock phosphate and (PGPR) to corn residues during composting improve nutritional value of the resulting compost.

Keywords: Composting; Growth promoter; Rock phosphate; Corn residues.

1. Introduction

In 2012 Egypt produced about 35 million tons per year of agricultural residues about 21 million tons of agricultural wastes per year (plant and animal) are left without avail and Corn residues account for about 5.65 million tons per year (16.1%) at ratio. in Egypt, maize, sorghum, rice and cotton crops. Such crops represent the largest crops from which the most wastes about10.34 million tons, that are not taken advantage of, are resulted, moreover, by recycling these wastes, the economic return of farms can be increased and the environment can be protected from pollution (Hassan *et al.*, 2014). Incorporation of plant residues in agricultural soils is primarily a means to sustain soil organic matter content, and improve physical properties, increase nutrients' availability and enhance the biological activity (Smith *et al.*, 1993). Recycling of agricultural wastes for crop production is an acquisition, in recent years because of lack of nutrients and high cost of chemical fertilizers (Biswas, 2011).

Composting is a well-known form of organic waste stabilization, where conditions may be created which allows the natural occurrence of thermophilic temperatures, under

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Received: March 27, 2021; Accepted: June 8, 2021; Published online: June 18, 2021.

particular conditions of moisture and aeration (Rodrigues *et al.*, 1995) compost value depends on the quality of the substrate. Nevertheless, composts prepared from farm wastes have low nutrient content, particularly potassium (K) and phosphorus (P) and are considered poor suppliers of nutrients to crops. Composting is an effective and environmentally friendly method to stabilize organic wastes, inactivate pathogens, and recycle nutrients (Zhang and Sun, 2015). During the preparation of composting, animal manure should be mixed with plant residues to adjust the C: N Ratio to be around 30:1 (Preusch *et al.*, 2004).

A possible means of improving the nutrient content in compost to prepare enriched compost by addition of rock phosphate (RP), waste mica and some benefit microbes (Narayanasamy and Biswas, 1998).The use of some beneficial bacteria with P-enriched compost in an incorporated manner improves the growth and yield in chickpea (Shahzad *et al.*, 2008).Plant growth promoting rhizobacteria (PGPR) are important inoculants for integrated nutrient management which help in dissolving inorganic P by excreting organic acids and chelation to release P in soil solution (Adesemoye *et al.*, 2008). It was reported that there are several PGPR inoculants currently commercialized that promote growth either by improved nutrient acquisition, fixing atmospheric nitrogen, solubilizing insoluble phosphates, suppression of plant disease, or phytohormone production (Khan and Bano, 2016). The use of rock phosphate (RP) as an alternative for P fertilizer is gaining attention in sustainable agriculture through microbial solubilization (Reddy *et al.*, 2002) and preparation of RP-enriched compost (Achal *et al.*, 2007). The mixing of RP with organic materials such as animal feces, plant residues and inoculation with acid-producing microbes may enhance P solubility from RP because when organic materials decompose, more soluble P is released due to the action of organic acids produced by the microbes (Puente *et al.*, 2004). The incorporation of organic residues either singly or in conjunction with a cheap source of mining element as rock phosphate may help to improve soil quality and productivity (Gaind *et al.*, 2006). Rock phosphate enriched compost which was solubilized by phosphate solubilizing fungi and applied on a mung-bean crop, significantly enhanced yield and P-uptake (Shrivastava *et al.*, 2011). Therefore, this study aims to evaluate the effect of rock phosphate and plant growth-promoting rhizobacteria, follow and understand the changes in the physical and chemical properties of the corn residues compost during aerobic decomposition.

2. Materials and Methods

2.1. Raw materials

2.1.1. Plant residues

The corn crop (*Zea mays* L.) its stalks and leaves were collected from some farms in Qena Governorate. The corn residues were air dried and chopped into small pieces (2-3 cm length) by the waste mincer.

2.1.2. Cattle dung

Cattle dung was obtained from the Animal Production Farm at the Faculty of Agriculture, South Valley University, it was added at rate 250 kg/t corn residues as a source of degrading microorganisms. Some Characteristics of raw materials are presented (Table 1).

Table 1. Characteristics of corn residues and cattle manure.

	Waste type	
Characters	Corn residues	Cattle manure
pH (1-10)	5.4	8.7
Ec (1-10) ds/m	4	4.5
Moisture content (%)	6.81	84.4
Organic matter (%)	95	71
Organic C (%)	55	41.18
C/N Ratio	105	32
Ash (%)	5	29
Total N (%)	0.52	1.27
Total P (%)	0.002	0.47
Total K (%)	0.2	0.88
Bulk density kg/m^3	210	433

2.2. *Rock Phosphate*

Rock Phosphate (RP) obtained from El-Sebaiya site mines (25°10′30″N 32°40′43″E) Aswan Governorate, Egypt. The ground (RP) crushed and sieved to pass through a (270 mesh) contained 31.8 % P_2O_5, it was added at a rate of 145 kg/ t corn residues.

2.3. Plant growth promoting rhizobacteria (PGPR)

Three strains of PGPR: *Azospirillum lipoferum*, *Azotobacter chroococcum* and *Bacillus megatherum* were used to inoculate some treatments of compost heaps. *A. chrococcum* and *A.lipoferum* strains were obtained from Biofertilizer Unit, Faculty of Agriculture, South Valley University, Qena, Egypt. *B. megatherum* strain was obtained from the Microbial Resource Centre, Faculty of Agriculture, Ain Shams University.

2.4. Chemical activator

A chemical activator mixture was added at a rate 30 kg ammonium sulphate, 20.5% + 15 Kg superphosphate 15.5 % + 15 Kg Calcium carbonate/t corn residues.

2.5. Composting treatments

Compost was prepared in the four heaps which have a size of 1 m width, 2 m long and 1.25 m height under the study were constructed four treatments as the following:

T1-Compost 1: Whereas, traditional method composting was used as a control (corn residues + fresh cattle dung + chemical activator)

T2-Compost 2: Corn residues+ cattle dung + chemical activator+ rock phosphate at 2% P .

T3-Compost 3: Corn residues+ cattle dung + chemical activator+ rock phosphate at 2% P + *B. megatherum* culture.

T4-Compost 4: Corn residues + cattle dung + chemical activator+ rock phosphate at 2% P + (*B.megatherum, A.lipoferum, A. chroococcum*) mixed cultures.

2.6. Preparing of PGPR inoculants

Bacterial strains (*A.lipoferum, A. chroococcum and B.megatherum*) were separately grown in three fermentors each containing 10 liters of molasses medium (50 ml molasses + 5 g peptone/1000 ml distilled water), at 28-30 ºC for 5 days. The counted numbers of viable cells in cultures at the time of use for compost inoculation were 1.7 x 10^8, 2.3 x 10^8 and 1.1 x 10^8 for *A. lipoferum, A. chroococcum* and *B. megatherum*, respectively. The inoculants were added at rate 10 litters/t residues. The compost heaps were inoculated with bacterial inoculants at the curing phase when the temperature had steadied around 40 °C (30 days of composting period). In the mixed treatment (T4), equal volumes of the three cultures were mixed before adding to the compost heap (Hamid *et al.,* 2020).

2.7. Heap formation

Corn residues (2 – 3 cm length) were thoroughly mixed for homogenization purpose, and four heaps were prepared. A heap of the corn residues of 1.5 m long, 1.0 m width and 1.0 m height were made for the composting process. In all heaps the moisture content was adjusted to reach about 60 % of their water holding capacity. The composting process could continue for 100 days, including the maturation period. The heaps were turned for aeration every 7 days of composting time. Eventually, the heap was covered with banana leaves to prevent the fast drying of the residues.

2.8. Compost analysis

Samples were collected from 3 points of the composting heap every 10 days and were kept in a deep freezer at 4 ºC in a refrigerator for analyses. The phsico-chemical properties of collected samples during the composting process were determined as follows:

Temperature of the composting heap was measured daily using the thermometer stainless steel at different points of an area at a depth of 60 cm according to (Juárez *et al.,* 2015). pH value was measured in a suspension compost/distilled water ratio 1:5 (w/v) using glass electrode Jenway 3510 pH Meter (Smith *et al.,* 2002). The electrical conductivity was determined in an extract compost/distilled water ratio 1:10 (w/v) using 4510 conductivity meter (JENWAY, UK) (Sánchez-Monedero *et al.,* 2001). Moisture content was determined by forced-air ovens at 105˚C for 24 hr. (Lazcano *et al.,* 2008). Organic matter was determined by weight loss on ignition at 550˚C for 4h (Møller *et al.,* 2000). Bulk density was determined according to (Huerta-Pujol et al., 2010). Total nitrogen was measured using Kjeldahl digestion method (Jackson, 1973), the ratio between nitrogen to carbon content of the compost samples was calculated according to the following procedure: C: N ratio = %Carbon Content ÷ %Nitrogen Content. Acid solution of the digested compost sample was used for determination of total phosphorus and potassium (Page *et al.,* 1982).

3. Results and Discussion

3.1. Changes in Physical and chemical properties during composting process

Temperature

Changes in temperature of four different composting treatments are shown in

(Fig 1). In general, all treatments show an increase in temperature right after composting started. All heaps rapidly arrived at the thermophilic phase on day 2 (more than 52°C). After first turning (at day 7), the temperatures increased again and during heap turning, some temperature may lose. The occurrence of losses of heap temperature during mixing composting material in every week was also reported by (Qian *et al.*, 2014). The heap treated with three bacterial inoculums (T4) reached the highest peak values of 62.2°C on day 12 compared to composting treatments T1, T2 and T3, for which it was 54.5, 58.5 and 58.6 °C, respectively. This increase in temperature in the treatment T4 compared to other treatments may be due to an increase in microbial activity, which increased the rate of organic matter decomposition (Hanajima *et al.*, 2006). Figure 1 shows that the temperature gradually decreased afterwards and finally stabilized near the ambient temperature at 55-60 days for all composting treatments. This result is in accordance with those of other investigators (Liu *et al.*, 2011 and Kutsanedzie *et al.*, 2012).

3.1.1. Changes in compost Bulk Density (BD)

The data shown in Fig. 2 Show the amount of change in compost bulk density during the compost. There is an inverse relationship between the compost bulk density and the compost period due to the decomposition of the organic components and the loss of substrates during the compost, as reported by (Larney *et al.*, 2000). The data shows, at the end of the composting period T1 recorded the lowest value (533 kg/m^3) compared to other treatments. This result may be due to additional RP for making the mixtures at initial time before composting for treatments T2, T3 and T4. Higher rates of bulk density indicate an increase in mass and a reduction of porosity and air capacity. In contrast, very little bulk density can imply extreme substrate aeration indirectly and a droplet in the available water portion (Nappi and Barberis, 1992). Raviv *et al.* (1987) mentioned that as the composting process length, the general particle size shifted from larger to smaller particles.

3.1.2. Changes in pH

Data in Fig. 3. Showed that on the 10th day of composting the pH of compost arrived at its peak value which is clearly related to temperature, also maybe caused to encourage NH_3 production during composting (Spencer and Van Heyst, 2013). The pH value declined to stabilize with the end result at 100 days being 6.9, 7.4, 7.1 and 7.0 for composting treatment T1, T2, T3 and T4, respectively. This indicates a good quality compost and within the suggested range of 6–8.5, as has been reported by (Fogarty and Tuovinen, 1991). The decrease in pH during the first period of composting is expected because of the acids formed during the metabolism of readily available carbohydrates (Gautam *et al.*, 2010). The pH rises above neutral because the acids are consumed by microorganisms and ammonium is produced from protein degradation.

3.1.3. Changes in the electrical conductivity (EC)

The impacts of 100 days of composting on the EC of heaps are shown in fig. 4. EC described the contents of soluble salt through the composting, the first values of

Figure 1. Changes in temperature during composting process.

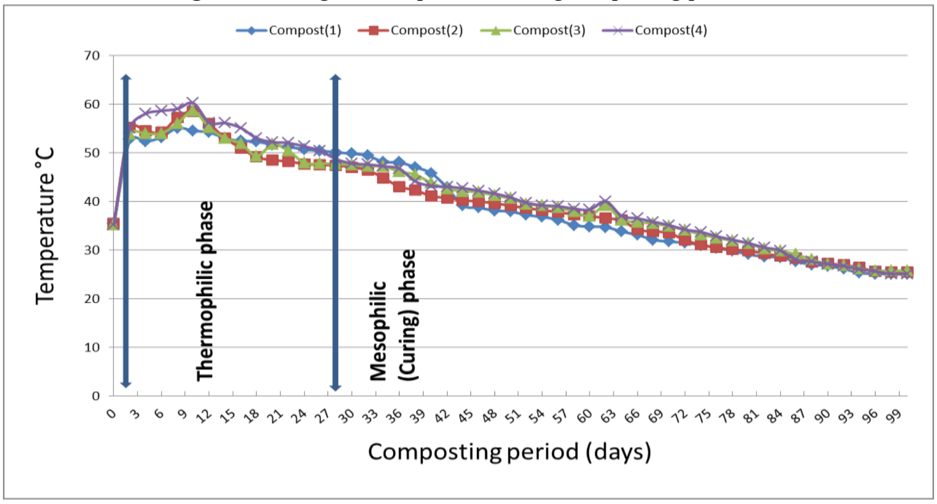


Figure 2. Changes in (BD) of compost heaps during composting.

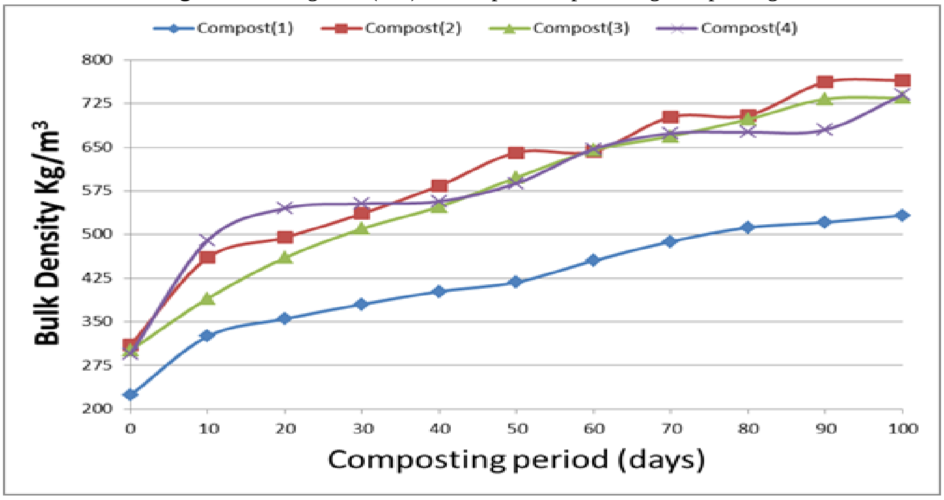


Figure 3. Changes in pH of compost heaps during composting.

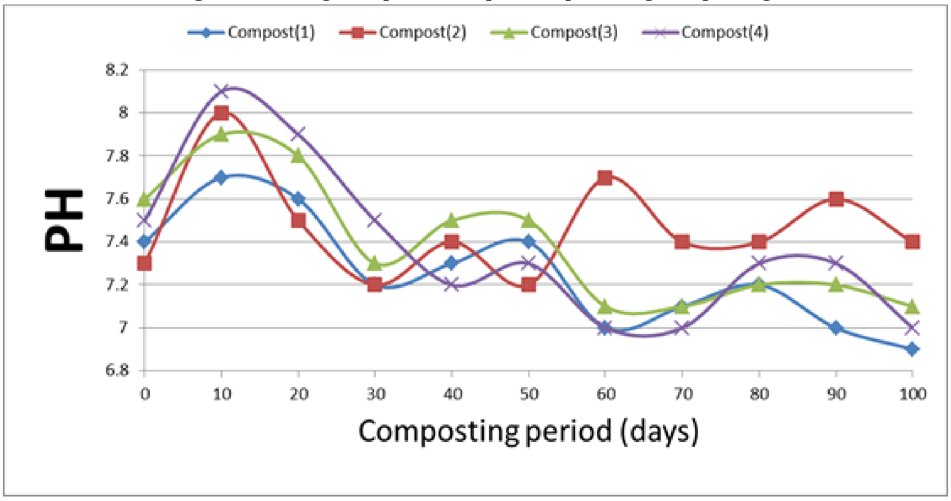


Figure 4. Changes in EC of compost heaps during composting

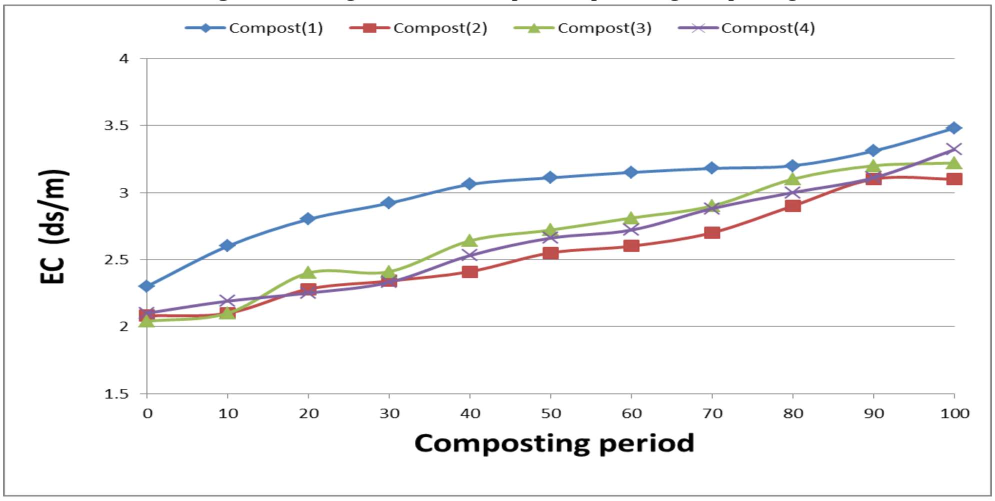


Figure 5. Changes in (TOC) of composting treatments with time.

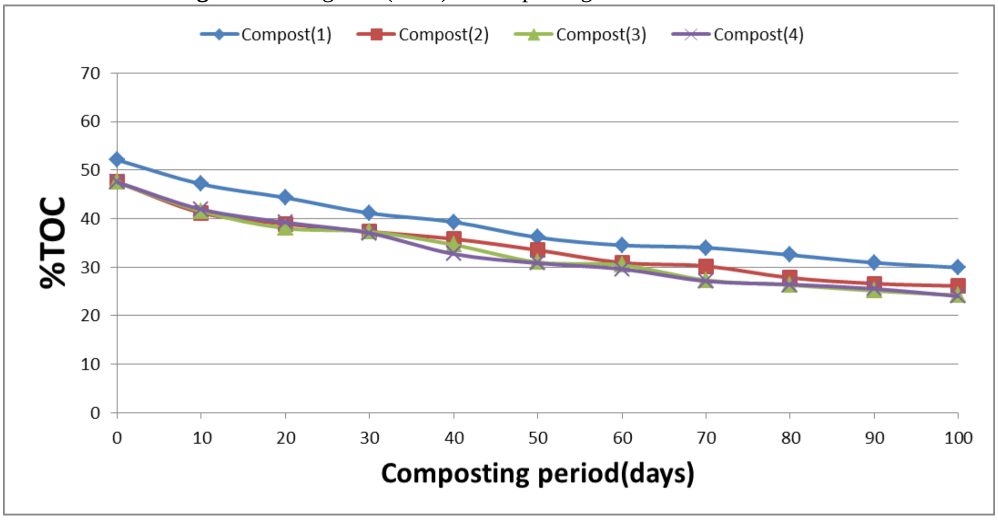
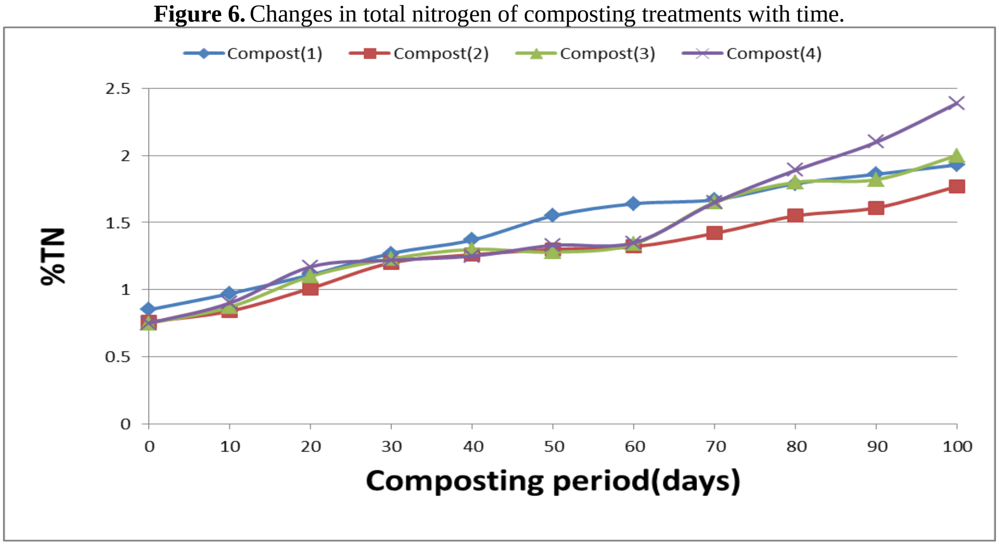


Figure 6. Changes in total nitrogen of composting treatments with time.



EC for all compost heaps being 2.3, 2.08, 2.04 and 2.1 ds m^{-1} for composting treatment T1, T2, T3 and T4, respectively. The compost heaps showed regular increases in EC through the composting period. The composting materials conductivity rates at end of composting period were 3.48, 3.1, 3.22 and 3.32 ds m^{-1} for treatments T1, T2, T3 and T4, respectively. The increase in the electrical conductivity of all compost heaps due to the mineralization of organic matter, which increased concentration of soluble salts (Chan *et al.,* 2016). On the other hand, addition of RP decreased the EC to low degrees in the composts with an increase in RP amendment level compared to C1 (Lu et al., 2014).

3.1.4. Changes in Total organic carbon (TOC)

The TOC concentration (Figure 5) declined slightly for all treatments, similar results were found by (El-Din and Abo-Sedera, 2001; Estafanous, 2003 and Seoudi, 2013). The initial values of TOC were 42.61%, 45.05 %, 49.05% and 49.47% for composting T1, T2, T3 and T4, respectively. After compost maturity the TOC reached 29.9%, 26.1%, 24.2% and 24% for treatments T1, T2, T3 and T4, respectively this indicates that the rate of carbon loss was higher in T2 compared T1 that can be attributed to addition of RP into the composting mass. Also, the rate of carbon loss was higher in both T3 and T4 inoculated treatments with (*B.megatherum*) and (*A. lipoferum* + *A. chroococcum* + *B.megatherum*) respectively compared with T1 and T2. According to Tumuhairwe et al. (2009) large TOC losses suggest pronounced microbial activity in the former. Diaz *et al.* (2020) reported that during composting, C is a source of energy for microorganisms to build up cells.

3.1.5. Changes in total nitrogen (TN)

Data in Fig. 6 showed changes ensued in total nitrogen percentage during different times of the composting process. Data shows that the percentage of TN regularly increased during the composting process. The increase in nitrogen percentage in different heaps may be caused to a concentration impact caused by active decomposable of the facilely degradation carbonaceous substrates, Resulting a decrease in the mass of the compost heaps (Pramanik *et al.*, 2007 and Zhong *et al.*, 2018). In general, during the first 60 days of composting the TN concentration shows a slight increase in treatment T1 compared with other treatments. Whereas the increase ratio was 48.17 %, 42.42%, 44% and 44.4 % for treatments T1, T2, T3 and T4, respectively. This decrease in TN in treatments T2, T3 and T4 may be due to the addition of Rock Phosphate containing a lesser amount of N (Biswas *et al.*, 2009). On the other hand, the reason might be the intense NH_3 emission due to rock phosphate alkalinity (Wu *et al.*, 2017). After an initial heat up period of 60 days, enrichment of compost by *B.megatherum* (T3) and *A. lipoferum* + *A. chroococcum* + *B.megatherum* (T4) run to increases in nitrogen content like compared to the T2 treatment. Whereas, the inoculation with (*B.megatherum*) alone leads to an increase of 11.5% over T2. This increase can be attributed to carbon losses during the process of composting. The main increase in nitrogen content was shown in the treatment T4 that inoculated with (*A. lipoferum* + *A. chroococcum* + *B.megatherum*) which showed an increase of 25.94% in nitrogen over the T2. The found results may be defended by non-symbiotic nitrogen fixing activities affected by *A. chroococcum* and *A.lipoferum* (Li *et al.*, 2020 and Seoudi, 2013). Madusari *et al.* (2020) showed that the nitrogen content in compost with the addition of *Azotobacter* is slightly higher than compost without the addition of *Azotobacte*r.

3.1.6. Changes in C/N ratio

One of the often-used parameters to assess the rate of de-composition in the composting process is the C/N ratio since it can reflect the maturity of the composted materials. Figure (7) shows the decrease in C/N values in all treatments due to the mineralization of organic matter. The initial C/N ratio was 61:1 for all composting treatments, and the final values of total C/N ratio after the 100 days were 15:1, 14:1, 12:1 and 10:1 for composting treatments T1, T2, T3 and T4, respectively. The treatment T4 recorded the lowest value of C/N ratio (10:1), and this may be attributed to higher carbon loss with microbial activity and increase in total nitrogen. A C/N ratio of less than 20 is considered as mature and can be used without any restriction. Although a C/N ratio of 10 to 20 normally indicates as being in the range of the mature level, the higher ratio cannot be concluded, as the compost is not mature enough (Chen *et al.,* 2011 and Iqbal *et al.,* 2015).

3.1.7. *Changes in available phosphorus (P)*

The data in the fig.8. Show that the available phosphorus increased significantly in all treatments during composting irrespective of the treatments, in general the results showed that the enriched compost with rock phosphate (RP) treatments T2, T3 and T4 contains a much greater amount of available phosphorus compared to treatment T1. This may be due to the melting of RP during composting, which led to the release of H_2PO_4 and Ca^{+2} necessary for plant growth (Mahimairaja et al., 1994). Also, hydrogen (H^+) ions emitted from organic acids during composting could be responsible for improving RP dissolution Likewise, available phosphorus release from RP can be increased through the production of weak carbonic acid, as carbon dioxide is released during the composting process (Alloush, 2003). Also, the results show inoculation with bacteria in treatments T3 and T4 significant increase in phosphorus availability compared with uninoculated treatments (T1 and T2). At the end of the composting period the treatments increased after Inoculation of bacteria at a ratio 33.1%, 47.4 %, 52.7 % and 54.6% for heaps T1, T2, T3 and T4, respectively. (Babana and Antoun, 2006) indicated that RP-enriched fertilizers inoculated with PSM had significantly larger quantities of P than those without inoculation, which may be a result of solubilization of P by PSM due to production of organic acids, namely citric, acetic, tartaric, oxalic, gluconic, lactic and a-ketogluconic acids.

3.1.8. Changes in Total Potassium (TK)

Figure 9, A gradual increase of TK in all treatments in a semi-constant pattern until the end of this increase could be due to the release of potassium from organic materials. The amount of increase in TK was in the range of 62.7-75.9% during the composting period. In general, the TK increase in prepared compost was in the order: T1>T4>T3>T2. The increase in T1 (not enriched with RP and without inoculation bacteria) can be attributed to the microbial decomposition of the organic matter and the decrease in the dry mass of the waste mixture and the mineralization processes (Gusain *et al.,* 2018).

Figure 7. Changes in C/N ratio of compost heaps during composting.

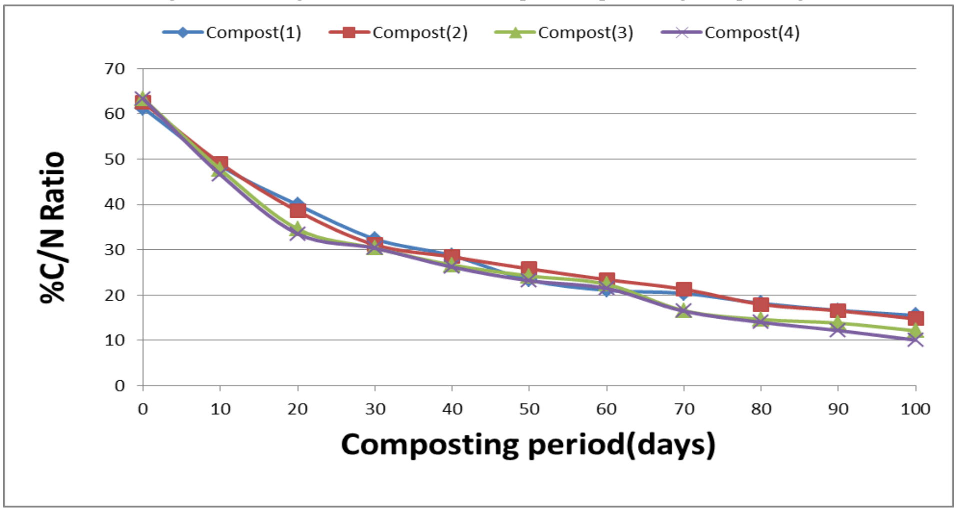


Figure 8. Changes in available (P) of compost heaps during composting.

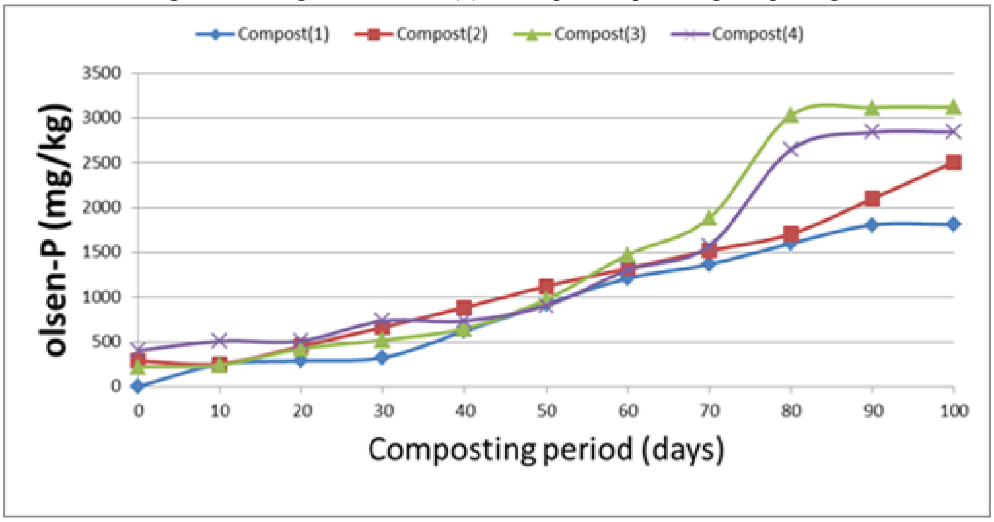
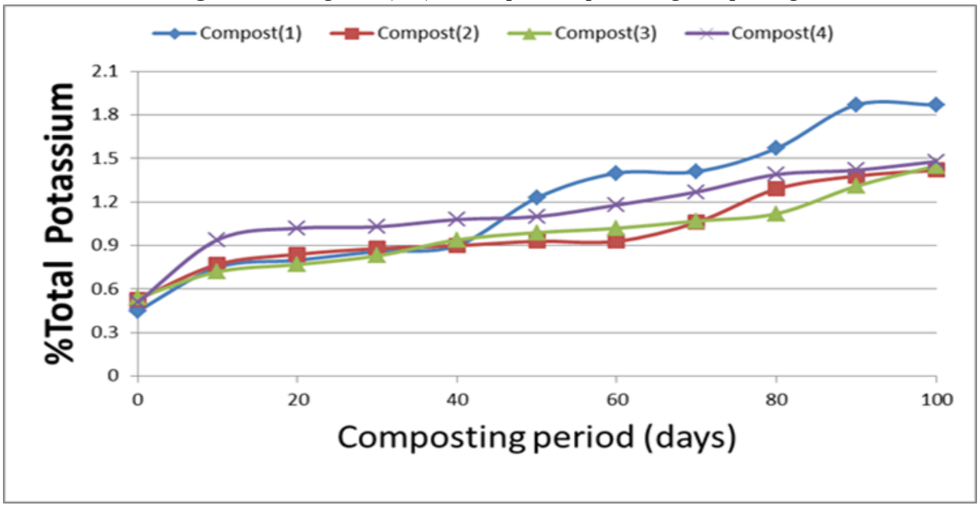


Figure 9. Changes in (TK) of compost heap s during composting.



4. Conclusion

In conclusion, the present study recommended that the composting of corn residues could be considered an option of waste management that is cheap, environmentally friendly and furthermore produces high value compost use as alternative chemical fertilizers. Also, adding rock phosphate and plant growth-promoting rhizobacteria to corn residues during composting improve nutritional value of the resulting compost.

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