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Comparative Study between Different Chopping Rotations and Raw Materials for Composting Process

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RECYCLING of crop residues in agriculture through production of compost brings much needed organic matter to the soil. Composting was studied by using three chopping rotations 1000,1300 and 1500 rpm, three feeding rates of 0.250,0.500 and 0.750 t/h of both rice and corn residues and with application of mixture from different bacterial inocula (cellulose decomposing bacteria *cellomonas* sp., nitrogen fixing bacteria *Azotobacter chroococcum*, Phosphate dissolving bacteria *Bacillus megatherium* and *Sacchromyces cervisiae*). The performance of chopping machine during cutting rice straw and corn stalks residues in terms of particle size distribution, energy, C/N ratio, P, pH, microbial activities and maturity duration were experimentally investigated as a function of change in chopper drum speed and material feed rate. The results reveal that the farm residues chopping machines were recommended to be used for cutting the crop residues into small pieces to encourage the microbial activities. The best treatment was achieved with chopper drum speed of 1500 rpm and material feed rate of 0.250 t/h with biofertilizers application for both corn stalks and rice straw residues, which produced a compost with maturity period lower than compost without biofertilizers application, narrow C/N ratio, rich with mineral contents like P and K for corn stalks and rice straw, respectively.

Keywords: Chopping rotations, Crop residues, Maturity composting and Microbial activity.

Composting is a biological process in which organic biodegradable wastes are converted into hygienic, hums rich product (compost) for use as a soil conditioner and an organic fertilizer (Popkin,1995). This is also used to provide biological control against various plant pathogens (Hoitink and Grebus, 1994). The evaluation of compost has focused on compost maturity to determine the completion of the composting process (Tiquia, 2003); and the assessment of composting strategies to optimize the process and produce good quality end product (Ouedraogo *et al*., 2001 ; Borken *et al*., 2002 and Tiquia, 2003). Most of the criteria used in the evaluation of the composting process and compost stability (maturity) were based on physical and chemical parameters of the organic material, whose behavior reflects the metabolic activity of microorganisms involved in the composting process. These parameters include a drop in compost temperature (Flynn and Wood, 1996), organic matter and nutrient contents (Tiquia, 2003, Baddi *et al*., 2004 and Grigatti *et al.* , 2004) and C : N ratio (Kaushik and Garg, 2004). Proper management of the crop residues by utilizing microorganisms may result into availability of good quality manure as well as protection of environment from pollution (Ulusoy *et al*., 2009). The main target of chopping farm residues machines is become nowadays more important due to the consequent increase of farm residues all over the world, because of the extensive agriculture and existence of large quantities of farm residues. Rice straw is considered one of the main environmental problems in Egypt. The corn stalks seem to be less as an environmental problem but can be considered one of the main sources for insects and rats. El- Saadany (2003) concluded that the percentage of cutting efficiency increased with increasing the numbers of helical shaft revolution until it reached the maximum cutting efficiency. Jekendra and Singh (1991) reported that the energy requirement of various fodder harvesting machines differ significantly from those of net cutting. Crop acceleration, compaction and conveyance normally consume more than 50 % of total energy while energy consumed in shearing stems is normally less than 3%. Operating at speeds between 25 to 35 m/s gives an optimum cutting energy requirement for forage materials. El-Iraqi and El-Khawaga (2003) found that the maximum percentages in cutting length less than 5cm were 87.80 and 92% obtained for rice straw and corn stalks residues, respectively, at cutting speed of 10.09m/s, feeding rate of 0.771ton/h. The maximum values of power consumption of 4.90 and 4.76kW were obtained at the same feeding rate and cutting speed for cutting rice straw and corn stalks, respectively. Parr *et al*. (1992) stated that the components of rice straw are mainly cellulose and hemicelluloses encrusted by lignin, in addition to a small amount of protein, which makes it high in C:N ratio. Therefore it is resistant to microbial decomposition compared to straw from other protein-rich grains such as wheat and barley. Misra and Roy (1980) reported that composting is carried out by adding straw, animal dung and green manure crops which often mixed. The pits are filled layer by layer, each layer being 15 cm thick. Usually, the first layer is of a green manure crop or water hyacinth, the second layer is a straw mixture and the third layer is of animal dung.; a water layer of about 4 cm depth is maintained on the surface to create anaerobic conditions which help to reduce losses of nitrogen. Approximate quantities of the different residues in tons per pit are: rice straw 0.15, animal dung 1.0, green manure 0.75 and superphosphate 0.02. Three turnings are given in all, the first one month after filling the pit and, at this time, the superphosphate is added and thoroughly mixed in. Water is added as necessary. The second turning is done after another month and the third two weeks later. The material is allowed to decompose for three months and produces about eight tons of compost per pit.

Cellulose is the main polysaccharide in terrestrial ecosystems. Rice straw has a cellulose content of 37 - 49%. It represents a huge source of energy for microorganisms. The ability of bacterial and fungal communities to degrade cellulose aerobically is widespread among some soil microbial groups.

Examples of cellulose degrading bacteria are found in both filamentous (*e.g*., *Streptomyces, Micromonospora*) and non-filamentous (*e.g*., *Bacillus, Cellulomonas, Cytophaga*) genera (Lynd *et al*., 2002).

The use of bacteria, actinomycetes and fungi in the decomposition of organic matter produces good results by taking advantage of their enzymatic activities, favoring the elimination of organic waste and providing beneficial metabolic products to the soil (Tiquia *et al.* (2002a) and Singh & Sharma, (2003). The enzymatic activities of these microorganisms play an important role in the degradation of complex substrates such as lignin and cellulose (Tiquia *et al*., 2002b). The aim of the present work is cutting crop residues into pieces (rice straw and corn stalks) in order to minimize their size and volume to facilitate and rapid composting Optimizing some operating parameters (chopper rotating speed, and material feed rate) affecting the performance of crop residues chopping machine and studying the effect of biofertilization in accelerating composting process.

Material and Methods

Two experiments were carried out at a private farm in West Nubaria, the first experiment (rice straw and corn stalks) were prepared for chopping process. This experiment was performed at stationary chopper driven by Universal 650M tractor PTO (power take off) shaft. The chopping machine model A- 210 was locally manufactured by Altec Company. with outer feeding opening width of 40X40 cm and 8 blades, the blades were treated before chopping. All experiments were carried out at different combinations of chopping cylinder peripheral velocity of 33.10; 43.10; and 49.71m/s corresponding to 1000; 1300 and 1500 r.p.m respectively. Material feed rates were; 0.250; 0.500 and 0.750 t/h. All used farm residue materials were air dried. Table(1) showed some crop residues specification before chopping process.

TABLE 1. Some average of crop residues specifications before chopping process

7Kind of residues	Stem diameter (cm)	Stem length (cm)	Moisture content (%)
Rice straw	0.3-0.4	87-115	9.5
Corn stalks	2.5-3.0	189-236	17.8

After each treatment, crop residues were collected from the machine output and their lengths were classified into four categories as follows: the first group of lengths is less than 5 cm; the second is between > 5 to 10 cm; the third is between > 10 to 15 cm, and the fourth is between is over than 15 cm. according to ASAE (2001).

Estimation of the required energy was calculated according to formula of Hunt (1983):

$$Power = \left\lfloor \mathrm{F.C}\left(1/3600\right) PE.LCV.427.\xi_{thb}.\xi_{m}.1/75.1/36 \right\rfloor \text{ (kW)}$$

where: F.C= Fuel consumption, (lit/h)
P.E= Fuel density (for solar 0.85 kg/m^3)
LCV= Calorific value of fuel (11000 k.cal/kg)
ξ_{thb} .= Thermal efficiency of engine (35% for diesel engine)
ξ_m = Mechanical efficiency of the tractor engine (85%)

The energy can be determined as follows:

Energy requirement (kW. h/ton) = Required power (kW)/ Effective field capacity (ton/h).

The second experiment was carried out to identify individually plants specifications and compost periods due to residue lengths and their microbial activities, two types of compost were prepared with and without biofertilizer application to investigate effect of biofertilzers in improving compost. The treatments were classified as following (Table 2).

TABLE 2. Classified treatments of chopping residues

Treatment	Rice (ton/h)	Corn(ton/h)
1000 RPM	R1 with 0.250 t/h	C1 with 0.250 t/h
	R4 with 0.500 t/h	C4 with 0.500 t/h
	R7 with 0.750 t/h	C7 with 0.750 t/h
1300 RPM	R2 with 0.250 t/h	C2 with 0.250 t/h
	R5 with 0.500 t/h	C5 with 0.500 t/h
	R8 with 0.750 t/h	C8 with 0.750 t/h
1500 RPM	R3 with 0.250 t/h	C3 with 0.250 t/h
	R6 with 0.500 t/h	C6 with 0.500 t/h
	R9 with 0.750 t/h	C9 with 0.750 t/h

During compost preparation, cellulose decomposing bacteria were added to speed organic wastes decomposition where biofertilizers mixture containing N-fixer (*Azotobacter chroococcum*) , P. solubilizers (*Bacillus megatherium*) and yeast (*Sacchromyces cervisiae*) which were added, one liter of biofertilizers mixture beside 1 liter of molasses is added to 98 liter of water to obtain 100 liters of ready to use biofertilizers mixture functioning as accelerator reduces the composting period as well as increases the nutritional value of compost.Nitrogen content was determined by micro-Kjeldahl method (Jackson, 1967). Phosphorus and potassium were determined according to Cottenie *et al.* (1982). Phosphorus was photometrically determined using Vanadate method and measured by spectrophotometer, while potassium was extracted by 1N ammonium acetate and pH 8.5 measured by flam photometer.

Compost samples were analyzed for total counts of microorganisms according to Nautiyal (1999). For counting phosphate dissolving bacteria Bunt and Rovira medium was used as described by Abd El- Hafez (1966). For counting azotobacters, nitrogen deficient medium was used as described by Abd El-Malek and Ishac (1968) and aerobic cellulose decomposer on CMC agar medium was done according to Someya (1980).

Results and Discussion

Effect of chopping machine rotation and feeding rate on the percentages of cutting lengths

The percentages of cutting lengths were highly affected by the different chopping machine rotating speed, and feeding rates. Concerning chopper rotating speed on the percentage of cutting lengths, Tables 3 and 4 showed the effect of increasing chopper rotating speed and feeding rate for both rice straw and corn stalks. For rice straw, the obtained data showed that increasing rotating speed from 1000 to 1500 rpm, with all constant feed rate increased the percentage of cutting length (<5cm), (>5- 10cm) and (>10-15cm) from 0.00 to 64.37%, while decreased (>15cm) from 62.78 to 23.71% for all treatments. On other hand, increasing the feeding rate from 0.250 to 0.750 ton/h showed different resulted data, but in general, the feeding rate of 0.250 ton/h achieved more residue length percentage as compared with the other feeding rates specially with rotation speed of 1500 rpm. Relating to corn stalks, data showed that increasing rotating speed from 1000 to 1500 rpm, with all constant feed rate increased the percentage of cutting length (<5cm), (>5- 10cm) and (>10-15cm) from 15.00 to 54.72%, while decreased (>15cm) from 12.90 to 0.00% for all treatments. Data collected from corn stalks experiment showed that, the feeding rate of 0.250 ton/h achieved more residue length percentage as compared with the other feeding rates specially with rotation speed of 1500 rpm. The previous data were similar to Lotfy (2003).

TABLE 3. Effect of chopping machine rotation and feeding rate on the percentages of cutting lengths of rice straw

Feeding Rate ton/h	Chopping rotations and treatments											
	1000 RPM				1300 RPM				1500 RPM			
	Residue length,(%)											
	5cm≤	>5-10cm	>10-15cm	>15cm	5cm≤	>5-10cm	>10-15cm	>15cm	5cm≤	>5-10cm	>10-15cm	>15cm
0.250	R1				R2				R3			
	0.00	2.18	34.95	62.87	2.12	16.82	30.01	51.05	5.20	7.46	52.13	35.21
0.500	R4				R5				R6			
	0.00	0.86	49.08	50.06	0.22	9.52	42.21	48.05	4.26	28.97	43.06	23.71
0.750	R7				R8				R9			
	0.00	0.00	64.37	35.63	0.00	5.87	54.20	39.93	2.72	17.90	33.06	46.32

TABLE 4. Effect of chopping machine rotation and feeding rate on the percentages of cutting lengths of corn stalks

Feeding Rate ton/h	Chopping rotations and treatments											
	1000 RPM				1300 RPM				1500 RPM			
	Residue length cm,(%)											
	≤5	>5-10	>10-15	>15	≤5	>5-10	>10-15	>15	≤5	>5-10	>10-15	>15
0.250	C1				C2				C3			
	22.30	49.11	28.59	0.00	38.55	34.57	22.08	4.80	54.72	26.14	15.00	4.14
0.500	C4				C5				C6			
	21.47	50.52	28.01	0.00	31.21	38.38	26.74	3.67	47.31	21.10	18.69	12.90
0.750	C7				C8				C9			
	20.32	51.92	27.76	0.00	26.03	43.70	29.31	0.96	42.80	29.54	21.60	6.06

Effect of chopping machine rotation and feeding rate on energy requirements

Data in Fig. 1 showed a remarkable increase in energy requirements as the chopper rotating speed increased for the used residues for any feed rate. Concerning rice straw, obtained data showed that increasing rotating speed from 1000 to 1500 rpm, and different feeding rates from of 0.250 to 0.750 ton/h, increased energy requirements from 31.54 to 70.07 kW. h/ton. The same attitude was revealed to corn stalks where data showed that increasing rotating speed from 1000 to 1500 rpm for all feeding rate, increased the energy requirements from 47.31 to 203.32 kW. h/ton . The increasing of energy requirements by increase chopper rotating speed was attributed to more of the cutting blades knocking number per unit time. On the other hand, the increasing of energy requirements by increasing residues feeding rate was attributed to the excessive quantity of the used material on the cutting blades, which increases the load on the machine parts that tends to increase power, then energy requirements (Yore *et al*., 2005).

Effect of chopping machine rotation and biofertilizers application on C/N ratio, P and K of the matured compost

C/N ratio, phosphorus and potassium contents of the obtained compost from corn and rice straw under the different chopping rotating speed, feeding rates and biofertilizers application used to accelerate composting process and enrich compost with nutritive materials were significantly recorded (Fig. 2-4). Highest mineral contents were recorded with R3 and C3 with biofertilizers application compared with the other treatments.

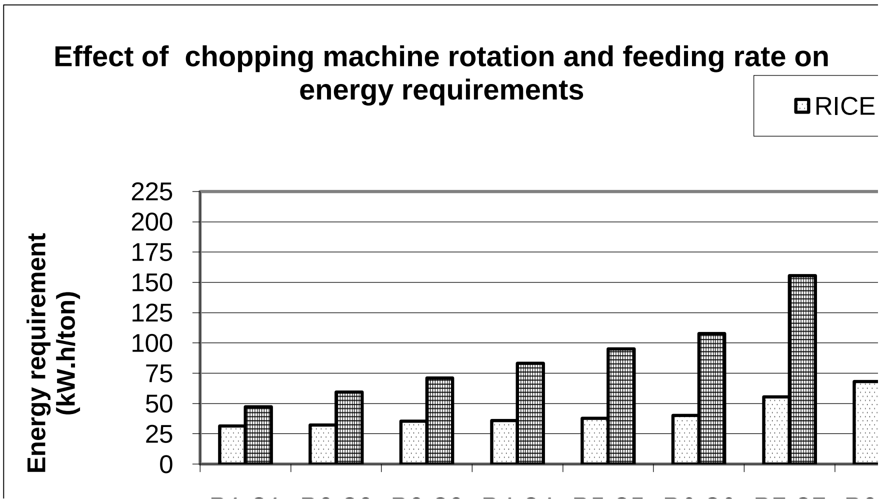


Fig. 1. Effect of chopping machine rotation and feeding rate on energy requirements of rice straw and corn stalks

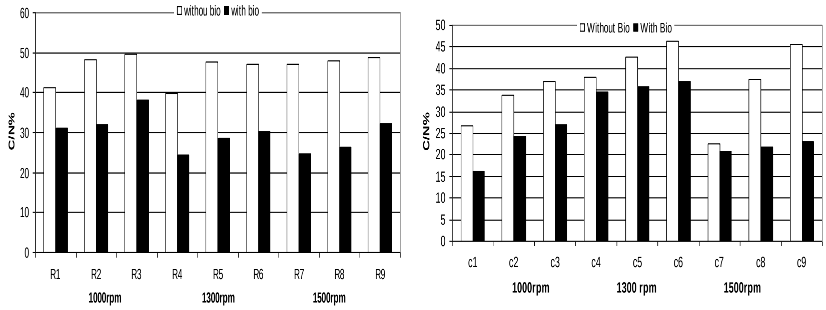
From the obtained results it was clear that chopping machine rotation 1500rpm with feeding rate 0.250 ton/h and biofertilizers application recorded the highest mineral contents of compost followed by the other studied treatments. The lowest mineral contents of compost recorded with 1000 rpm and 0.750 ton/h without biofertilizers application of both corn stalks and rice straw. Each gram of obtained compost contains millions of beneficial microorganisms that synergistically work to break down organic matter, enrich compost with mineral nutrients and eliminate pathogens. Of the microorganisms present, 80 to 90% are bacteria, including actinomycetes and aerobic bacteria. They have an important and effective role in the compost pile, through consuming, digesting and recycling plant residues. These bacteria are also versatile, extracting carbon and nitrogen from virtually any organic substance as a source of energy. They use this energy to create protein and reproduce. Also, microbial activities generate heat, increasing the temperature of the compost pile, which further speeds the decomposition process (Casandra Maier, 2004).

Also, N values might have increased due to the nitrogen-fixing bacterial activity that commonly occurs at the end of composting. The increased amount of N at the end of composting is due to this stored source of N (Bishop and Godfrey, 1983).

The phosphorus (P) content increased with biofertilizers treatment, compared to the treatment without biofertilization, this result is in accordance with the other reports (Sommer, 2001, Iyengar & Bhave, 2005 and Tai & He 2007).

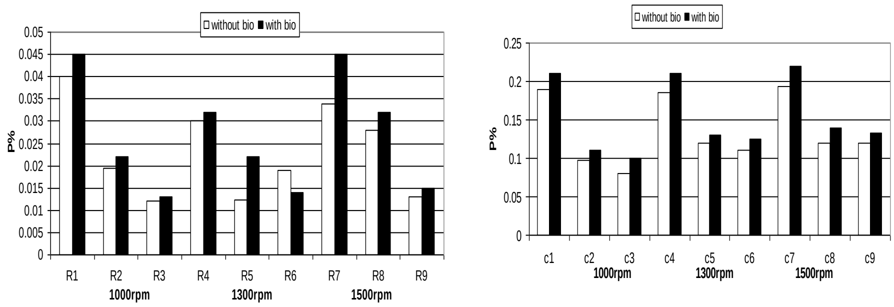
K is known as the element that is easily leached out. However, in this study the K value increased in biofertilization treatments. The use of rice straw as a medium that can absorb moisture and maintain its structural integrity and porosity, might avoid the loss of K in compost (Iyengar and Bhave, 2005). K plays an important role in plant growth where its function is to increase the elongation of the root, control ion balance, improve protein synthesis, encourage enzyme reaction, and improve the photosynthesis process and food development (Sabiani *et al*., 2004).

The initial carbon to nitrogen (C/N) ratio is one of the most important factors influencing compost quality Rui Guo *et al*. (2012). C/N ratio of corn stalk and rice straw before composting is 57.1 and 41.8, respectively. Composting process lowered this wide C/N ratio to 26.37, 22.45, respectively. For compost treatment R3 and \C3 which indicates the important role of composting and microbial activity in accelerating composting process and reach maturity of compost.



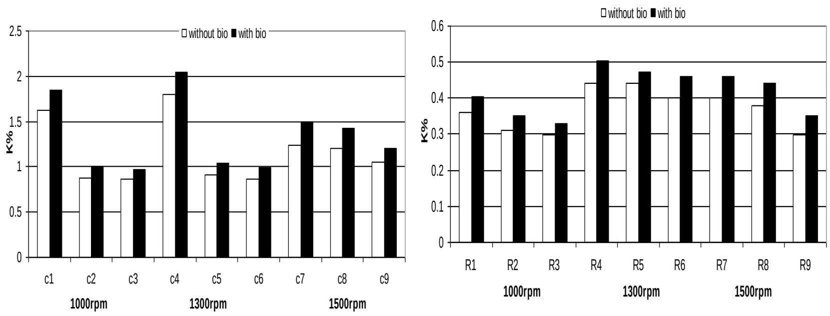
(Rice straw) (Corn stalk)

Fig. 2. Effect of chopping machine rotation, feeding rates and biofertilizers application on C/N ratio, of the matured compost for rice straw and corn stalk



(Rice straw) (Corn stalk)

Fig. 3. Effect of chopping machine rotation feeding rates and biofertilizers application on P%, of the matured compost for rice straw and corn stalk



(Rice straw) (Corn stalk)

Fig. 4. Effect of chopping machine rotation feeding rates and biofertilizers application on K%, of the matured compost for rice straw and corn stalk

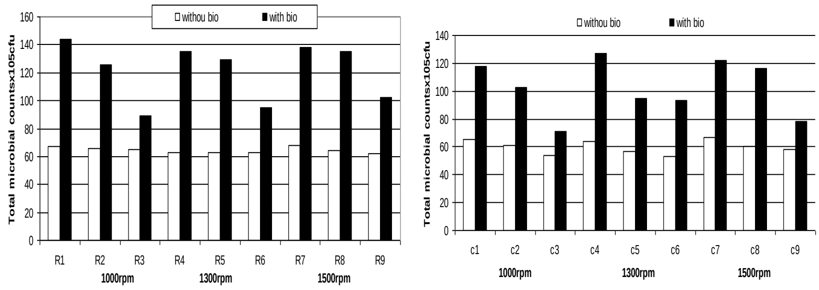
Microorganisms may also immobilize soil nutrients, particularly in soils with residues which have a wide C: N ratio. So, organic residues should be composed to narrow the C: N ratio during humification before being applied to soil as crop amendments. Enriched plant residues with mineral fertilizers results in a product similar in every respect to that obtained from farmyard manure. Sound management of organic residues plays a crucial role in bio-organic farming (Saber, 2001).

As the bacteria in the compost pile consume and digest organic matter, they excrete and free up important minerals and nutrients, including nitrogen, potassium, carbon, ammonia, magnesium, phosphorus and micronutrients. Once the mature compost is added to soil, the plants can absorb these nutrients. Adding compost to nutrient-poor soil may make it able to support plants (Casandra Maier, 2004).

It was observed from Fig. 5-7 that the cellulose decomposing bacteria, *Azotobacter* and yeast presented in higher densities especially with biofertilized compost. Microbiological analysis, however, indicated pronounced differences in the counts of tested microorganisms in both biofertilized or non-biofertilized composts under the different chopping speed and feeding rates. The treatment of corn stalks and rice straw with cellulose decomposer, *B. megatherium* , *Az. chroococcum* and *S. cervisiae* gave the most desirable characteristics of the final product with respect to the narrow C/N ratio, high nitrogen content and high denisties of *Azotobacter.*

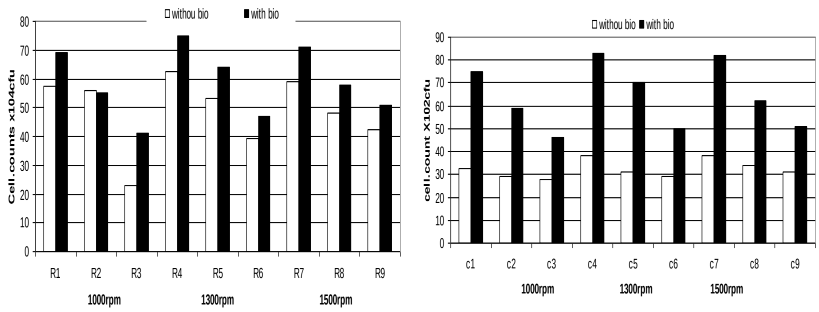
Feng *et al*. (2011) observed that ligninolytic enzymes increased the degradation ratio of lignin and hemicellulose, and indicated that the presence of ligninolytic enzymes could improve lignocellulose waste composting and enhance the activity of microorganisms. *A. chroococcum* to fix nitrogen and considerably reduced the predecomposition time of wastes (McMahon *et al*., 2009). The promoting effect due to application of *A. chroococcum* not only due to the nitrogen fixation but also to the production of plant growth promoting substances, production of amino acids, organic acids, vitamins and antimicrobial substances as well, which increase soil fertility, microbial community and plant growth (Russell, 1989). On the other hand, Estefanous, (2003), Tiquia, (2005) and Abd El-Gawad (2008) reported that enrichment of compost materials with *A. chroococcum* and phosphate solubilizers increased the nitrogen and humus content and decreased the C/N ratio of the produced compost.

The increase of biological activities caused by organic manure might be due to the available carbon sources on which microorganisms live besides conserving soil moisture and maintaining favorable soil temperature (Lou and Sun, 1994).



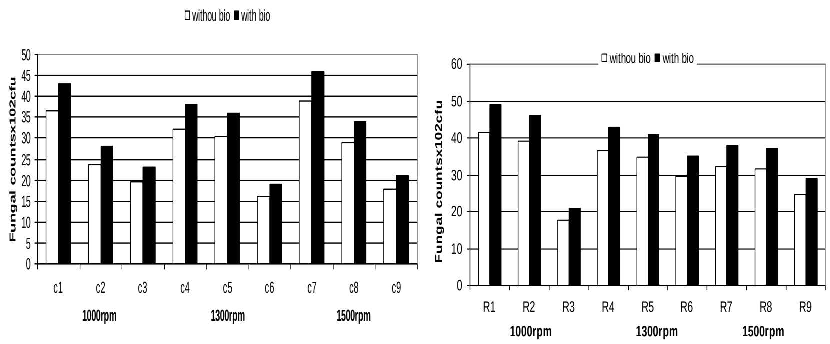
(Rice straw) (Corn stalk)

Fig. 5. Effect of chopping machine rotation feeding rates and biofertilizers application on total microbial counts, of the matured compost for rice straw and corn stalk



(Rice straw) (Corn stalk)

Fig. 6. Effect of chopping machine rotation feeding rates and biofertilizers application on total microbial counts, of the matured compost for rice straw and corn stalk



(Rice straw) (Corn stalk)

Fig 7. Effect of chopping machine rotation feeding rates and biofertilizers application on Fungi counts, of the matured compost for rice straw and corn stalk

Effect of chopping machine rotation, feeding rate and biofertilization on the period of compost maturation

The period for maturity of compost was highly affected by different chopping machine rotating speed, feeding rate and biofertilization. Figures 8 and 9 showed the effect of chopper rotating speed, feeding rate and biofertilization of both rice straw and corn stalks on compost maturation. For corn stalks, the obtained data showed that the rotating speed of 1500 rpm, with 0.250 ton/h feed rate of corn residue achieved the shortest maturity period by 50 and 70 days with biofertilization and without biofertilization, respectively. On the other hand, increasing the feeding rate to 0.750 ton/h with rotation speed of 1000 rpm of the treatment (C7), showed different resulted data, where the maturity period was 80 and 90 days with biofertilization and without biofertilization, respectively. Generally, the feeding rate of 0.250 ton/h achieved short maturity periods as compared with the other feeding rates. Relating to rice straw, data showed that increasing rotating speed from 1000 to 1500 rpm, with all studied feed rates led to decrease maturity periods. The obtained data of treatment (R3) showed that rotating speed of 1500 rpm, with 0.250 ton/h feed rate achieved the shortest maturity period by 50 and 65 days with and without biofertilization, respectively. On other hand, increasing the feeding rate to 0.750 ton/h with rotation speed of 1000 rpm (C7), the maturity period was 75 and 85 days with and without biofertilization, respectively. Generally, the feeding rate of 0.250 ton/h achieved the shortest maturity periods as compared with the other feeding rates. The previous data were similar to Lotfy (2003).

The use of cellulose decomposer, *B. megatherium* , *Az. chroococcum* and *S. cervisiae* in composting accelerated markedly decomposition process, 90 days composting is enough to produce a stable and mature compost suitable for use as fertilizer. The fertilizer obtained by composting corn stalks or rice straw inoculated with microorganisms is the highest quality compost.

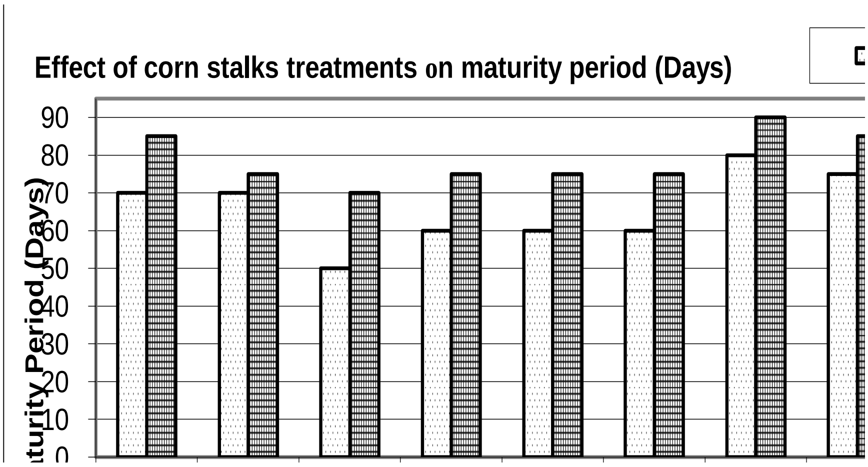


Fig. 8. Effect of corn stalks treatments on maturity period

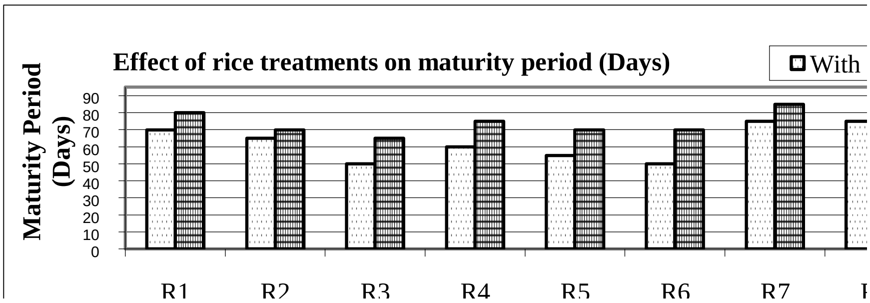


Fig. 9. Effect of Rice treatments on maturity period

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دراسة مقارنة بين سرعات التقطيع المختلفة ومواد الكمبوست على خواص الكمبوست

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تحتاج التربة وبشكل خاص في الاراضى المستصلحة حديثا إلى عملية التسميد وذلك لإعدادها وزيادة محتواها من العناصر الغذائية اللازمة لنمو النباتات وفى هذا البحث تم دراسة عمل الكمبوست باستخدام ثلاث سرعات دورانية لالة تقطيع المخلفات وهى 1000و 1300و1500 لفة/دقيقة وثلاث معدلات تلقيم الماكينة وهى 250و500و750 طن/ساعة لكل من مخلفات قش الارز وعيدان الذرة مع استخدام مخلوط من عزلات ميكروبية مختلفة وهى محللات السيليلوز السيلوموناس ومثبتات النيتروجين ازوتوباكتر كروكوكم ومذيبات الفوسفات باسيلس ميجاثيريم .

وتم اختبار اداء الة التقطيع بسرعاتها الدورانية المختلفة ومعدلات التلقيم المختلفة لمخلفات قش الارز وعيدان الذرة من خلال تقدير توزيع وحجم الجزيئات ، الطاقة المستهلكة، نسبة الكربون للهيدروجين، الحموضة، النشاط الميكروبى، فترة النضج. وقد اظهرت النتائج :

التوصية باستخدام الالات التقطيع لفرم المخلفات الحقلية الى اجزاء صغيرة لتشجيع النشاط الميكروبى وسجلت المعاملة بسرعة تقطيع للاله 1500لفة/دقيقة ومعدل تلقيم 250طن/ساعة مع استخدام التسميد الحيوى بالنسبة لمخلفات قش الارز و عيدان الذرة والتى انتجت كمبوست بفترة نضج اقل من الكمبوست الغير معامل بالتسميد الحيوى حيث حققت هذة المعاملة فترة نضج من 50 الى 70 يوم لنضج مخلفات الذرة و 50 و 65 يوم لمخلفات الارز باستخدام التسميد الحيوى وبدون على التوالى ، اقل فى نسبة الكربون للنيتروجين ، غنى بالمحتوى المعدنى للعناصر الغذائية مثل الفوسفور والبوتاسيوم لعيدان الذرة وقش الارز على التوالى.