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Co-Composting of Sewage Sludge with Food Waste Using Bin Composter

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Abstract: Optimization of sludge composting has been analysed by co-composting of sewage sludge with food waste by using a bin composter with regular aeration. Two bin composting experiments were set up to study the effect of different mixing ratios of food waste from the wet market to sewage sludge from Al Hadhbah waste water treatment plant which is located in Tripoli on some physical and chemical characteristics of the resulted compost. The selected ratios were 1:2 (A) and 1:3 (B) of food waste to sewage sludge respectively. Composting was conducted for 100 days and the sampling from the mixtures was performed each five days. Temperature (T), pH, electrical conductivity (EC), total organic carbon contents (TOC %) and total nitrogen contents (TN %) were monitored during the composting. The ratio of C/N, inorganic residual material (ash content) and nutrient changes as represented by potassium (K %) and phosphorus (P %) contents was also determined. The compost produced in this study has a favorable ratio of C/N (13.43 for compost A and 14. 32 for compost B). With significant amount of nutrients (TN %, K%, P%) The results of analysis of variance (ANOVA) revealed a significant effect of elapsed composting time (at the probability level of 0.05) on T, pH, TOC%, K% and P%. The effect of composting ratio was insignificant (at the probability level of 0.05) on T, TOC %, TN %, C/N and P%. The multiple comparison results using Tukey's test showed significance difference between the mean values of EC and K% among the composting ratio at the confidence level of 95%. Generally, the compost ratio of 1:2 was found to be the most suitable for use as organic fertilizer.

Key words: a bin composter, food waste, sewage sludge, fertilizer.

INTRODUCTION

To date, human all over the world have been generating more and more waste at a steadily increasing rate. In most parts of the world, solid wastes are disposed of either in open dumps or sanitary landfills or by incineration. Methods of treatment like incineration and sanitary landfilling are expensive. Solid waste management expresses the main matter where it does not have any organized and efficient system in managing solid wastes. This poor management has definitely brought about negative influences to the natural environment. By way of a result, the growing amount of waste has led to the exhaustion of natural resources that further provides a way to environmental risks (Kathirvale *et al*., 2003) Biodegradable wastes are certainly linked with the humiliating environment, especially as we shed light on the maddening quantity of contaminants being produced; they are leachate and methane gas. Section stores and shops have also augmented popularity as the responses to people's needs. In developing countries, the state of the wet market is unwell constructed. For example fruits and vegetable waste and food waste from restaurants

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inside wet market which are products to be thrown away on a daily basis(Omotara *et al.,* 2004) Tee (2009) stated that waste created by local residents is 16000 tonnes of domestic waste per day and the average waste per capita has escalated to 1.44 kg from 0.45 kg a day, determined by the economic status of the involved zone.

The average percentage of solid waste is 45% for food waste, 24% for plastic waste, 7% for papers, 6% for steel 3% for glass and 15% for others .(Baeyens *et al.* 1997) reported that the cost of sewage sludge treatment is high, as it has roughly 35-50% of the total operating costs of the wastewater treatment. (Chooi, 1984) stated that sewage sludge can be dried and used as compost as it covers high nutrient value. In comparison, the sludge is able to recover soil fertility and products more crops by safeguarding adequate source of nutrients which are important to the soil(Rantala *et al.,* 1999, Kuai *et al.,* 2000). Therefore, cost-effective sustainable technologies are needed by the industries to ensure the safe disposal of industrial sludge. The high moisture content, low carbon content and high nutrient value of the sludge are the reason why it is usually dried and used as a fertilizer. Currently, sewage sludge disposal has been prepared through a number of ways such as incineration, land-filling, and composting(Kim *et al.,* 2000).

The first method, incineration is inept as its moisture content is high, there is need to handle unsafe gas emission appropriately. Land-filling method is found to be very expensive because it is not easy to get unfilled grounds suitable for the purpose and also, once a landfill is opened; there will be a set of stringent rules and regulations that need to be followed (Hackett *et al.,* 1999). Land-filling process also produces unpleasant smell and some by-products. The by-products of these gases have a great propensity to pollute the water surface and similarly the ground(Yun *et al.,* 2000). Composting is a method of solid waste organization whereby the organic component of the solid waste stream is physically decomposed under measured conditions to a state in which it can be handled, kept and or applied to the land without adversely affecting the environment(Xiao *et al.,* 2009). Co-composting of sludge with solid food waste was expected to be one choice for waste use and might offer several environmental and economic welfares. Mixing of two types of materials can provide better moisture content and more stable nutrients for the microorganisms to carry out the composting process(Singh *et al.,* 2010, Yeoh *et al.,* 2011) reported that the co-composting is one of the important bio-waste treatments in the palm oil manufacturing for reaching sustainable process and zero waste.Nonetheless, improper conditions of composting may result in several problems such as gas release, bad odor, low quality product production postponement and high handling cost. The wide uses of microorganisms in composting processes are similarly enclosed under clarifications of many investigators. The maturation process of compost can be quicker by supporting the microorganisms to get finial product. However, the microorganisms have desirable effects on the biological characteristics of the organic material.. This study focused on the investigation of the co-composting process of sewage sludge from waste water treatment plant which was mixed with food waste from the wet market in Tripoli Libya. Two different ratios of mixing 1:2 and 1:3 were adopted for this study. The aims were to determine the physicochemical changes of co-composting of food waste to sewage sludge and to determine the best mixing ratio of food waste to sewage sludge by using bin composters.

MATERIALS AND METHODS

Co-composting was used to produce compost from food waste and sewage sludge. Food waste samples were collected from the wet market and sewage sludge samples were collected from Al hadhbah waste water treatment plant in Tripoli Libya. Both samples were mixed and homogenized manually at different ratio of 1:2 and 1:3 (i.e., waste: sludge) by weight, respectively. The composter has measurements of 90 cm in height and 60 cm in diameter and was painted in black to absorb the sun ray. A mixture of sewage sludge and food wastes was prepared and poured from the top of

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the composter. Two kgs of recycled compost were added to the mixture to further facilitate the composting process. A flow of air was created in the composter that aids the aeration. The final product of the compost was collected from the bottom of the composter using an opening designed at the bottom of the composter. This was achieved through constructing a number of uniformly distributed holes each had a diameter of 2 cm and located at the lower side of the bin.

Compost Analysis

Sampling was performed by taking 100 gms of compost from the bin composter at different places(Brinton *et al.,* 2012). The temperatures were measured by means of thermometer at the core of the reactor at the beginning of each experiment and every 5days for 100 days. Many samples of the compost were taken to determine pH, Total nitrogen, Potassium (K%) and Phosphorus (P%), Total Organic Carbon (TOC%), and Electrical Conductivity(EC). The pH values of the compost were determined using a method defined by (Carnes and Lossin 1970). Total nitrogen was determined using Kjeldahl method. Potassium (K%) and phosphorus (P%) were measured by inductively coupled plasma mass spectrometry. Total organic carbon TOC% was determined by heating the dried sample at 550 ˚C for 4 hours. The organic matter was converted to carbon content using a factor of 54 % (Navarro *et al.,* 1990). Wet density was estimated by filling 500 mL of distilled water in a beaker with the material(Schulze 1962). C/N ratio was analyzed using CHNS-O Analyzer which is an elemental analyzer dedicated to the simultaneous determination of the percentage (%) of carbon, pH, nitrogen, Electrical conductivity values of the compost were determined using a method defined by(Rayment and Higginson 1992). All the measurements which conducted on the samples were performed at the beginning of each experiment and every 5 days for 100 days from June 2016 to September 2016.

Statistical Analysis

Analysis of variance without replication (ANOVA) was performed to statistically assess the effects of the elapsed composting time and the mixing ratio on some physical and chemical properties of the compost using a 95% confidence level. For more convenient purposes, it was suggested to use the intervals of 10 days rather than 5 days for the elapsed composting time factor. Tukey's test was used to determine differences among the composting ratio using a 95% confidence level, as well. All statistical analyses were performed using MINITAB statistical package software (Inc 2003).

RESULTS AND DISCUSSION

Physicochemical analyses were conducted on raw materials of food waste and sewage sludge before mixing which is shown in Table 1. The parameters of initial food waste and sewage sludge as depicted in Table (1) are responsible for compost maturity. The values of these parameters are within their optimum range as mentioned by (Anwar *et al.,* 2015). Results of co-composting of food waste to sewage sludge with mixing ratio of 1:2 and 1:3 are shown in Table 2.

Table (1). Parameters of initial food waste and sewage sludge.

Parameters	Food Waste	Sewage Sludge
pH	8.75	6.32
Nitrogen%	1.35	1.07
C/N	31.97	13.48
Potassium%	1.13	0.75
Moisture%	63.52	68.97
Phosphorus%	0.53	1.05
TOC%	33.27	32.42

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Table (2). Physical and chemical parameters of initial material mixture of food waste to sewage sludge with mixing ratio 1:2 and 1:3.

Parameters	Initial material mixture of food waste to Sewage Sludge	
	Ratio1:2Bin composter A	Ratio1:3 Bin composter B
Color	Black	Black
Odor	Smells like soil	Smells like soil
Size distribution	Friable, fine and uniform	Friable, fine and uniform
Phosphorus%	1.13	0.98
Potassium%	0.38	0.58
pH	7.84	8.32
Nitrogen%	2.40	1.50

Temperature

The initial temperatures of bin composters were 23 and 26.5 0C for A and B, respectively as shown in figure 1. Temperatures of both composters increased significantly (at the probability level of 0.05) and sharply to around 43 and 42 °C, from day 2 until day 20 of the treatment. The rapid rise in temperature might be due to bacterial decomposition activity in the compost. The thermophilic phase in the present stage was continued until day 25 of the treatment before the temperature of bin composter declined gradually after it got the maturity phase on day 40 of the treatment when the curing stage was started. The comparisons between the mean values of temperature among the compost ratio as determined by Tukey's test (at the confidence level of 95%) indicated no significant difference. The final temperature of bin composters reduced gradually to reach 18 and 20 °C for composter A and B, respectively. These were observed at the end of the composting process which shown a good degree of stability (Satisha and Devarajan 2007).

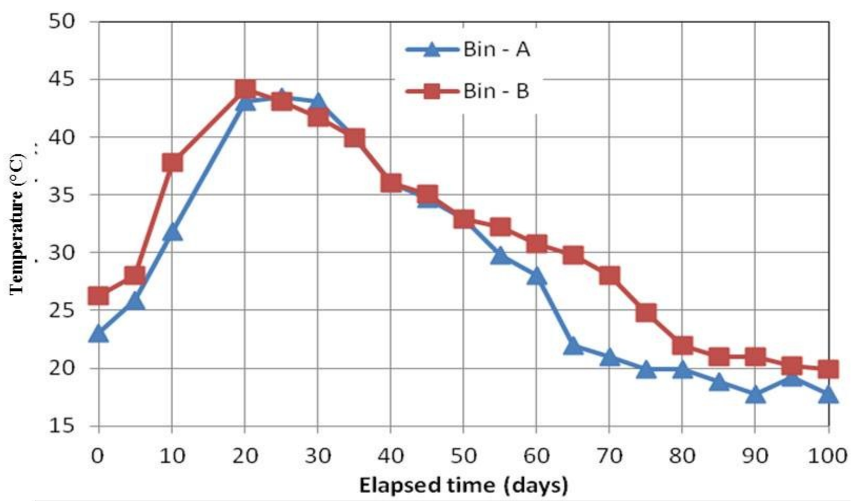

Figure (1). Temperatures profile of composting using bin composters A and B.

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pH

In Figure 2, it is shown that the initial pH of the compost were 8.46 and 8.32 for composters A and B, respectively, then augmented sharply to maximum values of about 8.87 for composter A and 8.53 for composter B in the first month of composting. The results of ANOVA indicated that the effects of the elapsed composting time and the composting ratio were significant at the probability level of 0.05. Growth of pH value at the beginning of the composting process might be due to the protein mineralization which led to the increase in ammonia produced by the biochemical reactions of nitrogen-containing materials and varying of amino acids and peptide to the ammonia (Crawford, 1983; (Liao *et al.,* 1997, Paredes *et al.,* 2002). According to Tukey's test, the comparisons among the compost ratio revealed no significant difference between the mean values of pH at the confidence level of 95%. The final values of pH were reduced to 7.01 and 7.36 for composters A and B respectively, as depicted in figure 4. These values agreed with the study of (Sundberg *et al.,* 2004). They stated that for fully developed composting, the pH frequently ranged from 7 to 9.

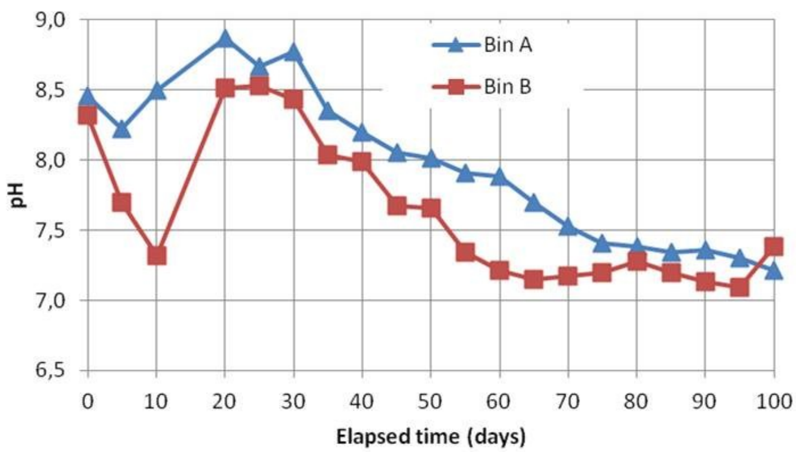

Figure (2). pH profile of composting using bin composters A and B.

Electrical Conductivity (EC)

Electrical conductivity is the ability of a material to transmit an electrical current and electrical conductivity is expressed in the units of dS/m. The initial concentrations of EC were 1.48 dS/m and 1.53 dS/m for composter A and B, respectively. These values augmented with the final concentration of 1.89 dS/m for composter A and 1.53 dS/m for composter B. It can be observed from figure 3 that composter A presented a significant increase (according to Tukey's test at the confidence level of 95%) over composter B. This is a significant application of compost in agriculture since high soil salinity may prevent plant development and growth. The data obtained in this study were in the range of another study by (Helić *et al.,* 2011) on composting of municipal solid waste with different additives and values of electrical conductivity with mixture composting of municipal solid waste, poultry manure and sawdust. They found that EC were 1.50 dS/m and 2.62 dS/m for both reactors, respectively.

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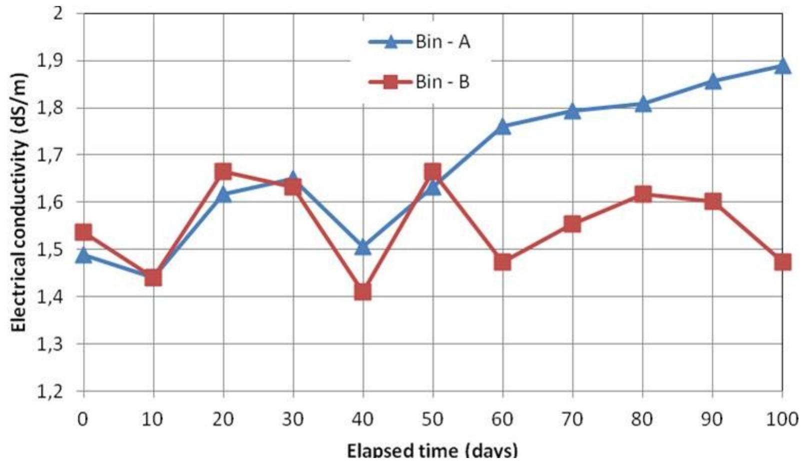

Figure (3). Electrical conductivity profiles of composting using bin composters A and B.

Total Organic Carbon

Unlike the composting ratio, the results of ANOVA showed a significant effect of the elapsed composting time on TOC%. The results also revealed that TOC % decreased in a similar way in both composters A and B. The initial values of TOC% for composters A and B were 46.23 and 48.04% respectively, and dropped quite dramatically to 40.21 and 37.08% at the end of composting as depicted in figure 4. Such decreasing in TOC% during composting time was also noted in many similar studies (Sampedro *et al.,* 2007, Haque and Gholami 2012). However, according to Tukey's test, the comparisons among the compost ratio revealed no significant difference between the mean values of TOC % at the confidence level of 95%.

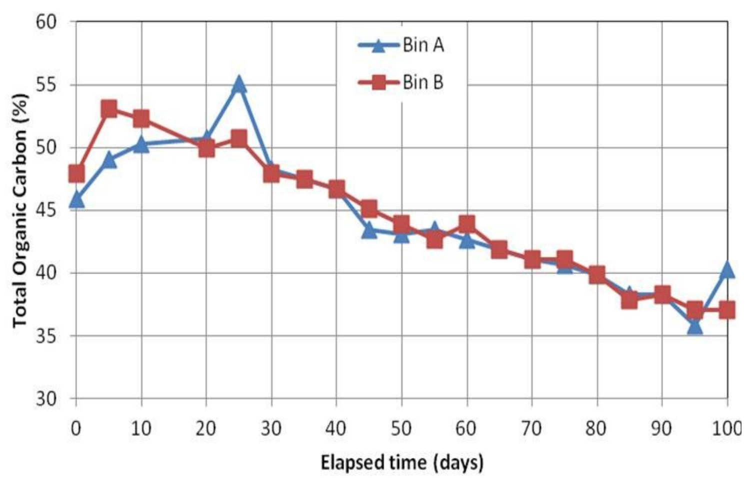

Figure (4). TOC profile of composting using Bin Composters A and B.

Total nitrogen

Total nitrogen content in both composters A and B increased from initial values of 0.89 and 0.86%, respectively. Composter B experienced a series of insignificantly statistical ups and downs (at the probability 0.05 level) in nitrogen concentration during thermophilic stage as shown in figure 5. Moreover, the results of Tukey's test indicated that the comparisons

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among the compost ratio revealed no significant difference between the mean values of total nitrogen at the confidence level of 95%. The final values of total nitrogen observed were 1.187 and 1.30% for composter A and B, respectively. However, (Nutongkaew *et al.,* 2011) reported a similar trend in increasing of the total nitrogen during the composting process.

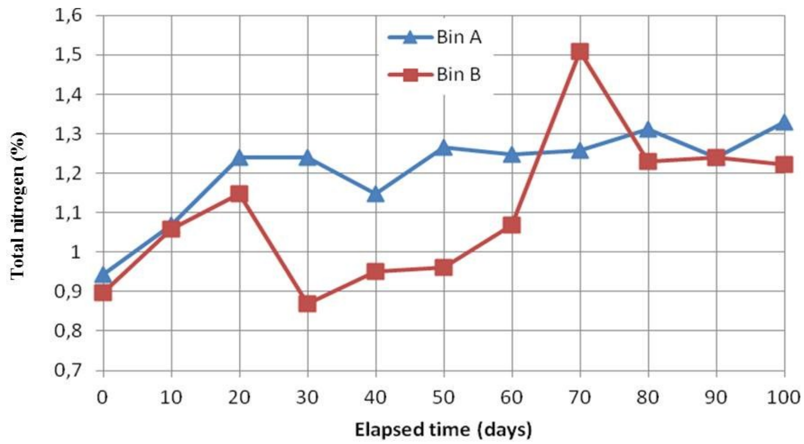

Figure (5). Changes in TN profile of composting using Bin Composters A and B.

C/N ratio

C/N ratio decreased gradually in the first two weeks of composting treatment for both composters A and B. Such typical reductions in C/N ratio were statistically significant according to the analysis of variance (ANOVA), at the probability levels 0.05 during the composting process i.e., the elapsed composting time. According to Tukey's test, the comparisons among the compost ratio revealed no significant difference between the mean values of C/N ratio at the confidence level of 95%. However, the final values for both composters were 13.43 and 14.32%, respectively, after maturation as depicted in figure 6. Such final values of C/N are favorable for composting industries.(Van Heerden *et al.,* 2002) stated that the C/N ratio less than 20 could be considered as a suit maturation level of compost. However, this enhances net mineralization of nitrogen in the soil for plant use if used as fertilizer.

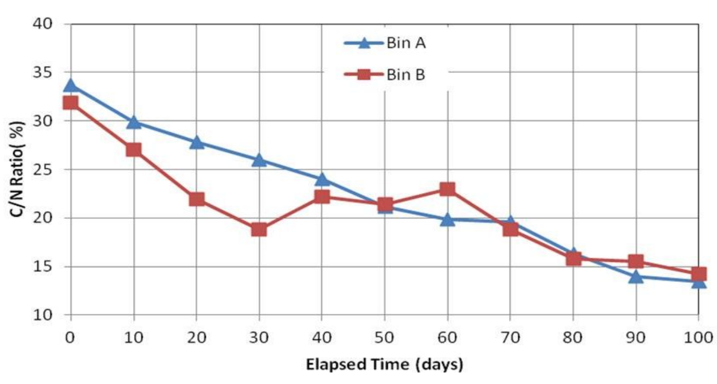

Figure (6). Changes in C/N ratio profile of composting using Bin Composters A and B.

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Nutrient Changes

Unlike P%, the analysis of variance (ANOVA) indicated that the effects of composting ratio on K% were significant at the probability levels of 0.05. On the other hand, it was found that the effects of elapsed composting time on both K% and P% were significant at the probability level of 0.05. Figure 7 shows that the content of K% in composter A increased from 1.5% to 2.97%. The content of P% also increased in composter A from 0.1% to 1.27%. Similarly, in the composter B the content of K% increased from 0.53 to 1.72% and from 0.48 to 1.08% in terms of P%. According to Tukey's test (at the confidence level of 95%), the comparisons between the mean values of K% were found to be in significant difference among the composting ratio. Unlike the mean values of K%, the mean values of P% had relatively no differences among the composting ratio. The increase of K% and P % at the end of composting could be attributed to a decrease in organic matter (Haug 1993). On the other hand, (Fei-Baffoe *et. al.*, 2015) attributed the increase of macro elements such as K% and P% to the organic matter decomposition which is leading to the net loss of dry mass, which in turn, might have concentrated the phosphorus and potassium in the compost.

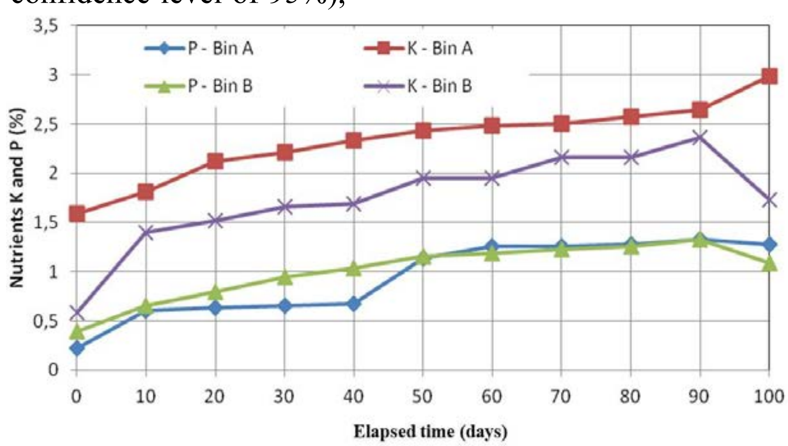

Figure (7). Changes of nutrients profile of composting using bin composters A and B

Ash Content

This test is a measure of the inorganic residual material gone after burning the oven-dried compost sample at 500 ± 50°C. The quantity of ash was depending on the kind of feedstocks composted. Initial ash content of composters A and B were 26.79 and 28.21% respectively. The final values obtained in this study of both composters were 11.32 and 12.23% for A and B respectively as depicted in figure 8. The results of analysis of variance (ANOVA) revealed that unlike composting ratio, the effects of elapsed composting time on ash content were significant at the probability level of 0.05. Similar results were reported by (Helić *et al.,* 2011, Razali *et al.,* 2012).

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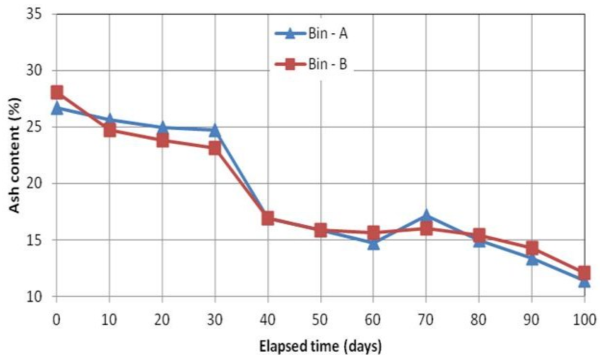

Figure (8). Ash content profile of composting using bin composters A and B.

Table (3). Physicochemical properties of the final compost at two stages

	pH	C/N	K%	P%	N%	T^0C
Bin composter A	7.01	13.43	2.97	1.27	1.20	43
Bin composter B	7.36	14.32	1.72	1.08	1.30	42

CONCLUSION

Co-composting of food waste to sewage sludge can be used as another way of converting these materials into a beneficial product using a cheap and easy system, which is the bin composter. Improved biodegradation was achieved by mixing food waste to sewage sludge. In addition, the temperature achieved in composting met the sanitary requirement for pathogen killing. The compost produced in this study has a C/N ratio of 13.43 and 14.32 with significant amounts of phosphorus, potassium and nitrogen. It is noteworthy that the final product of compost had high nutrient content especially P and K. Thus, the compost can be applied safely to the soil as a conditioner to enhance its chemical quality.

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التسميد المشترك من حماة الصرف الصحي مع النفايات الغذائية باستخدام مستوعب التسميد (الكمبوست)

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المستخلص : أجرت الدراسة التحليل الأمثل لسماد الحمأة المصنع من الحمأة مع النفايات الغذائية باستخدام مستوعب الكمبوست مع التهوية العادية. نفذت تجربة الدراسة باستخدام معاملتين ناتجتين من الخلط المتجانس لسماد الحمأة المتحصل عليها من محطة معالجة مياه الصرف الصحي بمحطة الهضبة بطرابلس مع فضلات الطعام من السوق الرطب في طرابلس ليبيا وبنسب مختلفة من 1: 2 والتي تمثل المعاملة (A) و ,بنسبة1: 3 التي تمثل المعاملة (B). أُخذت عينات من الخليط كل خمسة أيام خلال كامل فترة تحضير الكمبوست. وتم تقدير كل من درجة الحرارة ودرجة التفاعل و التوصيل الكهربي و محتوى الكربون العضوي (%) و محتوى النيتروجين الكلي (%) ونسبة الكربون إلى النيتروجين والرماد المتبقي (%) والتغيرات التي حدثت في نسبة الفسفور(%) والبوتاسيوم (%) في عينات الكمبوست. وأظهرت النتائج المتحصل عليها أن الكمبوست النهائي احتوى قيماً مرغوبة من نسبة الكربون إلى النيتروجين (13.43 للمعاملة A و 14.32 للمعاملة B) مع قيم مرتفعة من محتوى النيتروجين الكلي (%) والبوتاسيوم (%) والفسفور (%). كما بينت نتائج تحليل التباين أن هناك تأثيرا معنوياً لزمن التحضير عند مستوى معنوية 0.05 وذلك على كل من درجة الحرارة و درجة التفاعل و محتوى الكربون العضوي (%) ونسبة الكربون إلى النيتروجين و البوتاسيوم (%) والفسفور (%). وفيما يتعلق بنسبة الخلط فكان تأثيرها غير معنوي عند مستوى معنوية 0.05 على كل من درجة الحرارة ومحتوى الكربون العضوي (%) و محتوى النيتروجين الكلي (%) ونسبة الكربون إلى النيتروجين والفسفور(%). وقد أظهرت نتائج المقارنة المتعددة باستخدام اختبار توكاي (Tukey's test) عند مستوى ثقة 95%، أن هناك اختلافات معنوية بين متوسطات كل من درجة التوصيل الكهربي و كذلك بين متوسطات محتوى البوتاسيوم (%) بين معاملات نسب الخلط المختلفة. وعموماً، فإنه بالإمكان اللجوء إلى استخدام نسبة الخلط 2:1 المكونة من فضلات الطعام: حمأة المجاري للحصول على منتج سمادي أكثر احتواء على العناصر الغذائية الأساسية لنمو النبات موازنة مع نسبة 3:1.

الكلمات المفتاحية: مفاعل التسميد، نفايات غذائية، حمأة الصرف الصحي، السماد.

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