Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.3, 2015

Effect of Co-composting Fish and Banana Wastes with Organic Municipal Solid Wastes on Carbon / Nitrogen Ratio

Aya El Zein, MS[1] Hamdy Seif, PhD[2] Essam Gooda, PhD[3]

1. Department of Civil & Environmental Engineering, Beirut Arab University, Beirut, Lebanon
   E-mail: ayaalzein@hotmail.com
2. Ph.D. Environmental Science and Engineering. Prof. of Sanitary Eng. Sanitary Eng., Department of Civil & Environmental Engineering, Beirut Arab University, Beirut, Lebanon, Consultant PO 21544,
   E-mail: hamdy.seif@link.net&hamdy.seif@bau.edu.lb
3. Professor of Water Resources Engineering Civil Engineering, Department of Civil & Environmental Engineering, Beirut Arab University, Beirut, Lebanon, Alexandria, Egypt
   E-mail: essamgooda@yahoo.com & e.gooda@bau.edu.lb

Abstract

This study seeks to assess the quality of co-composted shredded Municipal Solid Wastes (MSW) with fishery wastes, banana mulch wastes and aerobically composted slaughterhouse wastes. They are most common in Southern Lebanon and are likely candidates to investigate the carbon and nitrogen amendments to the MSW. The overriding goal of this study is to make the co-composting method as practical as possible for ordinary people to reproduce it in natural field settings by using a low cost technology and a good quality fertilizer. At a low maintenance cost, three initial trials were executed in this study to optimize the composting process of these waste ingredients. The objective of the first two trials was to evaluate composting processes in two different bioreactors and using the two different mix ratios of co-composted waste material. However the third trial`s objective was to develop and validate the composting process of 4 different waste mix combinations by using commercially available plastic barrels as self-heating bioreactors. The evaluations are focused on process indices during composting and chemical indices of carbon/nitrogen (C/N) ratio of the final compost. A mathematical optimization model is presented. Components of the composting are estimated in order to satisfy C/N ratio in the range between 20 and 30. The chosen ideal weight of the composting is 25 kg. Output data of optimization model, C/N ratio as a main parameter as well as secondary parameters components of composting are tabulated. A multiple regression analysis is performed to relate the main parameter to the secondary parameters. Finally, this study suggests that specific weights for fish and banana mulch wastes can be considered suitable for efficient composting with organic fraction of MSW. If implemented successfully at individual household or larger municipality level, it will contribute to the minimization of wastes.

Keywords: C/N ratio, municipal solid wastes (MSW), Fishery wastes, Agricultural solid wastes, Compost, Saida Solid Waste Management plant (SWM).

1. Introduction

With an estimated population of 5.6 million in 2013, Lebanon generates around 2.04 million tons of municipal solid wastes (MSW) constituting 90% of total waste stream. According to Sweep-net (2014), MSW generation rate varies approximately from 0.8Kg/capita/day in rural areas (North, South, Nabatiyeh and Bekka) to around 0.95 - 1.2 Kg/capita/day in urban areas (Beirut and most of Mount Lebanon). More than sixty percent of municipal solid waste content is organic matter. For example, according to Merhebi F. (2014), the percent frequencies of MSW components are food waste (50%), paper and cardboard (15 to 17%), plastics (10 to 13%), metals (5 to 6 %), glass (3 to 4 %), textile, wood and others (10 to 12%).

The biodegradable component of solid wastes can be disposed using different methods including landfill, anaerobic digestion, gasification, pyrolysis, incineration, and composting. In Lebanon, around 51% of solid waste is landfilled, 32% is openly dumped, 9% is composted and 8% is recycled (Merhebi, F., 2014). The percent of composted waste is small. Also its quality does not meet the international requirements (El Mawla, D., 2014). Moreover, the legislative, financial, institutional and social barriers collectively impede the sustainability of successful composting facilities and the generation of good quality compost products.

Today, there is an anaerobic digester and an open area for compost maturation in the Solid Waste Management (SWM) plant of Saida city. It consists of an open space for the biological decomposition of organic matter into compost without being properly managed and controlled. The Municipality does not benefit from any economic returns of compost products.

The fishing and fruit sector across the coastal zone of Southern Lebanon produces considerable amounts of wastes which are disposed along with other MSW without making use of them. In fact, Saida is an active fishing city with limited agricultural lands (some wheat, vegetables, fruits especially citrus and banana). The fishery harvest output ranges from one to four tons of different types of fish per day. Of each ton of fish output, one third is considered as waste and sent for disposal along with other MSW of the city. As for banana sector, Banana occupies 2,790 ha of the agricultural lands in South Lebanon with an annual output of 85,600 tons for both local consumption and export to the Arab countries (Chalak, & Sabra, 2007). Banana production is increasing in South Lebanon at the expense of cultivated areas for citrus production because of its economic value. International data concur that banana sector generates a significant amount of wastes estimated to be 1.5-2 times of its generated output. Each plant produces one to five bunches of bananas. Using waste approximates of 200 t/ha/year (Sellin et al., 2013), banana waste output in South Lebanon ranges from 128, 400 to 171,200 t/ year.

The C/ N ratio of 25-30:1 is ideal for efficient composting. However, this ratio is usually given for materials on a dry weight basis. It is important when blending raw materials to create a mixture that will approximate this ideal ratio and provide the proper characteristics for aerobic composting. A higher C/ N ratio will result in a slower rate of decomposition. A lower ratio results in excess nitrogen loss and possible odors if the mix is not stirred often. Two types of material are needed for a compost pile: those high in carbon and those high in nitrogen. Microorganisms in the compost pile use carbon as an energy source and nitrogen for protein synthesis (Fares, R., Fares, E., & De-Nardo, F., 2011).

Varying the mix ratio of waste ingredients plays an important role in the decomposition process. As such, this study seeks to explore the possibility of altering mix ratios of 4 waste ingredients as a way to improve the quality of the generated MSW compost product. Specifically, this study seeks to assess the quality of co-composted shredded MSW with fishery wastes, banana plantation wastes and anaerobically composted slaughterhouse wastes. The overriding goal of this study is to test if co-composting these 4 ingredients using a low cost technology provides a viable solution for recycling the wastes of banana plantations, fishery industries and composted meat and producing a quality fertilizer for use in agricultural applications which can be done at any scale and to make the co-composting method as practical as possible for ordinary people to reproduce it in natural field settings. These four wastes ingredients are most common across the coastal zone of Southern Governorate in Lebanon making it a likely candidate to investigate as carbon and nitrogen amendments to the MSW. Since there is no universal agreement on which method is best for defining the maturity of the composted products, composting plants operators rely on the affordable technologies available in their geographical regions and countries. In this pilot study, the primary indicator of maturity to be investigated is C/N ratio along with physical characteristics such as color, odor, moisture and temperature.

Although considerable research on composting of various organic wastes has been conducted, published information on the characteristics of co-composted municipal solid wastes with fishery wastes, banana plantation wastes and anaerobically composted slaughterhouse wastes is not available.

This study has been conducted to evaluate the performance of a pilot-scale in-vessel composting of representative wastes generated in cities and towns within Saida district, South Lebanon. Three initial trials were executed in this study in an attempt to optimize the composting process of the four waste ingredients using low cost maintenance composting approach in natural field settings. The objective of first two trials was to evaluate composting processes in two different bioreactors and using two different mix ratios of co-composted waste material. The objective of the third trial was to develop and validate the composting process of 4 different waste mix combinations using commercially available plastic barrels as self-heating bioreactors.

2. Material and Methods

2.1 Location/ Site of Experimental Trials

All composting trials were performed in the waste water treatment facility (MSWF) in Saida city (which has been operational since 2013), as shown in Figure 6.

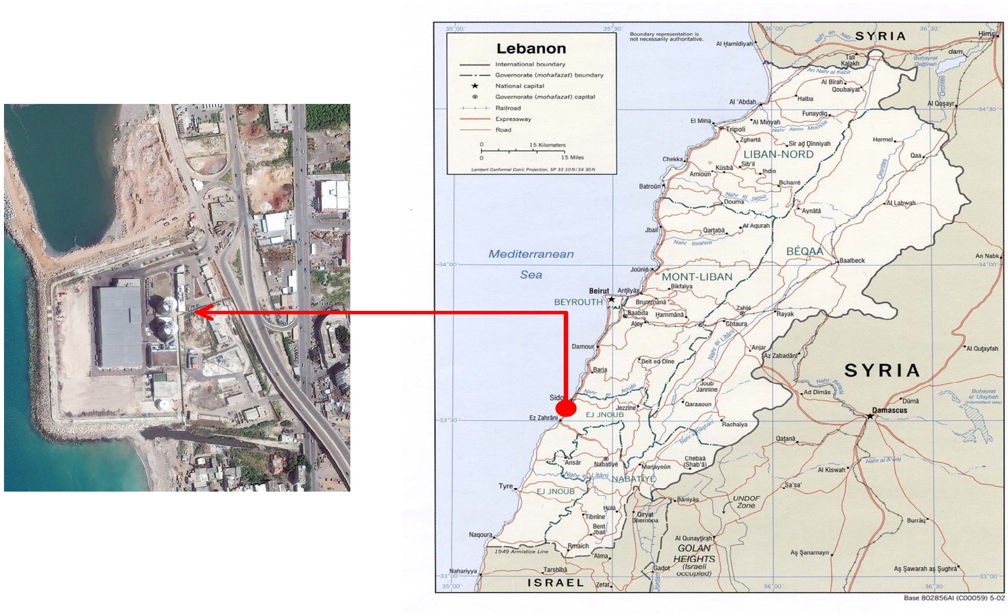


Figure 6: Site of the experiments

This waste water treatment facility (MSWF) is on the sea side (south-west of Saida city) very close to an industrial area and Siniak river. The experiments were executed in the north-east side of the facility dedicated for waste water treatment adjacent to the site where municipal solid wastes are being treated (Figure 6). This site was chosen for the ease of transport of the raw waste material and because it has a small laboratory for moisture content testing.

2.2 Description of Aerobic Bioreactor

In the design of the aerobic reactors for preliminary testing trials, two options were initially investigated: The use of fixed non rotating barrel and the use of mechanically rotating barrel with an internal shredder. The use of a rotating horizontal barrel with an internal shredded part was tested only in the first two trials (in which the first trial failed due to insufficient particle size of banana wastes). The horizontal rotating barrel was fixed on an iron stand. It has horizontal shaped openings at the upper edge of the barrel. This design is intended to mix, aerate and rotate the composted material. It is designed to rotate 10 times per minute every half an hour (followed by a half an hour rest phase), as shown in figure 2. Air is supplied through aeration blades (i.e. serve as actively aerated bioreactor). However, recurrent motor failures and maintenance interruptions did not encourage its use in subsequent trials so fixed barrels were used for their practicality and simplicity.

Serving barrel as bioreactor is a standard plastic [possibly of high density polyethylene material (HDPE)] cylindrical barrel with an approximate diameter of 48 cm, height of 90 cm, 163 liter capacity and weights 5 kilograms. The top and bottom of the purchased barrel are circular, flat, and equal in diameter. Its estimated surface area to volume ratio is 0.11, as shown in figure 2.

a) Before modifying b) After modifying c) During composting

Figure 7: The mechanical barrel.

To allow air movement, the drainage of excess moisture and to ensure aerobic digestion inside the barrel, around 24 holes of 1 cm diameter were randomly made on the sides of the barrel.

When the waste filled almost two thirds of the barrel depth, the top of it was covered with a black colored perforated nylon liner (to minimize heat loss and maintain temperature) and was covered with a perforated nylon liner/cover with 1 cm diameter holes throughout the active decomposition stages (22-24 days). From a practical point of view, the selected barrel type has multiple advantages: a) it provides insulation to aid heating of compost material b) it can be fully enclosed and requires little maintenance c) it can be easily moved around the facility d) By controlling moisture and aeration hot and rainy days, it enables the easy mixing and turning of the compost materials and minimizes odor problems.

The barrel can compared to a self-heating reactor, defined as a reactor relying solely on microbial heat production to obtain process temperatures, and having no temperature control besides some external insulation e.g. nylon cover (Mason, I.G., & Milke, M.W., 2005).

2.3 Waste Types and Preparation

The first three experimental trials involve an aerobic composting of a mix of four waste materials or substrates: fishery house wastes, municipal solid waste, banana plantations wastes and composted meat.

The composted meat was obtained from Beirut Slaughterhouse facility located in Karantina region which had undergone an anaerobic digestion process. Shredded banana plantation wastes (stems/trunks and leaves) was secured by a local supplier who deals with the local fermenting facility in “Al Abbaseya” village , South Lebanon and managed by the association for the development of rural capacities. The mixed municipal solid waste was obtained from the Municipal Solid Waste Factory (MSWF) in Saida. It was used as raw material in the composting trials. Fish wastes were obtained from Saida Fishery Syndicate. At the waste water treatment facility, all wastes were separately screened, sorted and manually mixed together as per the specified waste combinations for each experimental trial. (Figure 8), The water addition was made based on subjective judgment. When the compost material was a moist paste that remained intact when holding in hand palm, water is not needed. If the compost material was not intact, water was needed.

Figure 8: The experimental site during the preparation

2.4 Composting Process

Waste mix ratios were adapted following Carbon / Nitrogen C/N formula developed by Tom Richard, Department of Agricultural and Biological Engineering, Cornell University.

Where:

$$R = \frac{Q_1(C_1 \times (100 - M_1) + Q_2(C_2 \times (100 - M_2) + Q_3(C_3 \times (100 - M_3) + \cdots \ldots Q_n(C_n \times (100 - M_n)}{Q_1(N_1 \times (100 - M_1) + Q_2(N_2 \times (100 - M_2) + Q_3(N_3 \times (100 - M_3) + \cdots \ldots Q_n(N_n \times (100 - M_n)}$$

R = C/N ratio of compost mixture
Q_n = mass of material n ("as is", or "wet weight")
C_n = carbon (%) of material n
N_n = nitrogen (%) of material n
M_n = moisture content (%) of material n
For dried chemical sample tests, the equation will be:

$$R = \frac{W_F C_F + W_B C_B + W_S C_S + W_M C_M}{W_F N_F + W_B N_B + W_S N_S + W_M N_M} \quad \text{Eq.1}$$

Where:

R= C/N ratio.

W_F, W_B, W_S, W_M = weights of fish, Banana, Slaughterhouse, organic MSW wastes respectively.

C_F, C_B, C_S, C_M = Total Carbon of fish, Banana, Slaughterhouse, organic MSW wastes respectively.

N_F, N_B, N_S, N_M = Total Nitrogen of fish, Banana, Slaughterhouse, organic MSW wastes respectively.

Choosing: R=C/N=25 and $W_F+W_B+W_S+W_M=25$ Kg since

$0 < W_F < 25$ $0 < W_B < 25$ $0 < W_S < 25$ $0 < W_M < 25$

T_C and T_N and C/N were carried out on dried samples for each waste ingredient and by substituting the results, by using trial and error and common sense. The four types of wastes with certain different weights were chosen for mixture experiments.

Mixed waste was placed in the barrel, because of concerns that composting material might not heat up significantly (not large enough to be self-insulating) if the waste ingredients were added over time or gradually. The modified barrels were filled to almost 2/3 height of mixed waste mixture. The compost material was left for at least (22-24) days for decomposition in the barrel. Then, the decomposing organic wastes were piled up in open ground space and layered with black nylons cover on the ground for maturing for 4 days. (Figure 9).

Water was added throughout the whole experimental period depending on the temperature daily recordings and the testing done at the laboratory for the moisture content. The compost material in all barrels was manually turned over 2-3 times during the first active stage of decomposition period (22-24) days. After every turn, temperature recordings were taken at two depths (25 cm and 50 cm of top compost surface) using Alla Brand handheld digital thermometer (-50°C to +200°C). Active stage of composting process ranged between (22-24) days. The total compost production duration was 154 days for trial two and 91 days for trial three.

The monitoring of the pile is very important in order to ensure the optimum pile decomposition. The monitored factors are: pile temperature, moisture and odor (Fares et al.). Measurements of Nitrogen and Carbon in compost were carried out on the dried sample. The C/ N ratio was calculated as the quotient of Cover N.

The change in temperature, moisture content were monitored during composting while the change of waste volume, pH, C/N, TC, TOC, TN of the experiments were tested before and after composting.

Figure 9: The mature compost for trial test two

2.5 Description of experimental trial

The first experimental trial was carried out in April, 2014. This first trial involved two waste mix combinations of the four types of wastes (banana, fish, slaughterhouse and municipal solid waste): (B,F ,S ,M ,1.1.1.1) and (B,F,S,M 4.1.1.1) using a mechanically rotating barrel. Both experiments failed because of mechanical problems in the rotating barrel which hindered significantly the composting process. Available temperature recordings were low. No samples were taken from the two mix waste experiments of this trial.

The second experiment trial started in April 29th, 2014. It involves two steps. Step one pertains to the active stage of decomposition (total of 35 days i.e. step one ended in June 2nd, 2014). Step two pertains to the curing /maturation stage (after 154 days i.e. step two ended in November 6th, 2014).

Trial two involved two waste mix combinations of the four types of wastes (banana to other waste mix ratio: (B.F.S.M 1.1.1.1) and (B.F.S.M 4.1.1.1) using two types of composting techniques (rotating versus fixed barrels). Three experiments were executed:

One experiment with banana to other waste mix ratio (B.F.S.M 4.1.1.1) (or 10; 2.5; 2.5; 2.5) kg each so that total weight of wastes used was 17.5 Kg was carried out in a mechanical rotating barrel.

Second experiment with same banana to other waste mix ratio (B.F.S.M 4.1.1.1) was carried out in the fixed (non-rotating) cylindrical shape barrel.

Third experiment with banana to other waste mix ratio (B.F.S.M 1.1.1.1) or (2.5; 2.5; 2.5, 2.5) Kg so that total weight of wastes used 10 Kg was carried out in a fixed (non-rotating) cylindrical shape barrel as composting vessel. Higher temperature recordings (degree Celsius) were noted in the fixed barrel compared to mechanical barrel. One composite sample was taken from each step (after 35 days and 154 days of composting) for C/ N ratio determination.

The third experimental trial started in August 15th, 2014. It involved three steps (3.1, 3.2 and 3.3) corresponding to 27 days, 45 days and 91 days of maturation.

Trial two involved four waste mix combinations of the four types of wastes (mix ratio: B.F.S.M 9,1,5,10; B.F.S.M 12,1,10,2; B.F.S.M 18,3,2,2; B.F.S.M 15,2,4,4) using one type of composting technique (fixed barrels). Composite samples from the barrels were taken at 27 days, 45 days and 91 days of maturation for C/N ratio determination.

2.6 Sampling and Analytical Methods

Sampling was done after the end of the active stage of decomposition at different dates as specified for each trial (35 days and 154 days in Trial two; 27, 45 and 91 days in Trial three). Samples from mature compost material were taken in right to left manner from top, center and bottom. Collected samples were mixed together in a bucket; then, a composite sample of around 500 grams was taken out using grain shovel, placed in a zig-zag bag and shipped directly to the Environment Core Laboratory at the American University of Beirut. The laboratory testing at the Environment Core Laboratory was done according to internationally approved methods. The pH was determined using APHA 4500-H method; moisture content was determined by gravimeter (weight loss after drying at 105ºC).The total nitrogen and total carbon were determined using Thermo-Finnegan Flash EA 1112 Elemental Analyzer, and the practical range of determination for nitrogen is 0.03% to 46% and for carbon it is 0.04% to 72%.

3. Results and Discussion

As mentioned before, the trial one failed and the experimental work was completed through trial two and trial three.

3.1 Physical characteristics of the Compost

One of the main objectives of composting is the reduction of its volume. The total volume was calculated and compared by measuring the height of the compost on each barrel at the first and last days of the experiments (Table 1). The reduction of organic solid wastes led to the reduction of the entire volume of organic solid waste. After the composting was completed, the volume of the organic waste was reduced by more than 50% of its initial volume.

Table 1: The variation of the height for each barrel before and after composting

	H before Cm	H after Cm	% volume decrease
B1	61	30	50.8%
B2	65	27	58.4%
B3	64	25	60.9%
B4	70	35	50%

Where H before and H after are the heights of the compost before and after composting in the barrel.

The compost product in trial (2) and trial (3) studies were generally had uniform dark brown to black appearance with little or non-recognizable pieces/components of used waste such as banana leaves. .The compost smells soil-like and did not emit any unpleasant odor. In trial three, the color of the decomposed material varied in the barrels from light to dark brown-reddish color with visible aggregates suggesting instability.

3.2 Trial two

3.2.1 Carbon / Nitrogen Ratio

Table 2: TC, TN and C/N characteristics of samples of Trial two by days of composting.

samples No.		Sample label	Date		Days of composting	Weight (kg)				Bacteriological analysis			chemical analysis				C/N ratio	
						Banana	Fish	Slaughter house	MSW	fecal coliform	E.coli	Salmonella species	pH	T.C%	T.O.C%	T.N%	Theoretical Initial	After composting
second trial step (1)	Mechanical Turning B1	275	Start Ends	29\4\2014 2\6\2014	35	4	1	1	1	$37*10^5$ cfu in 1 g	present in 1g	not recovered in 25g (NH017384)	6.94	17.3	13.1	1.24	18.97 -- 22.64	13.95
	Barrel 2	276	Start Ends	29\4\2014 2\6\2014	35	4	1	1	1	$33*10^5$ cfu in 1 g	present in 1g	not recovered in 25g (NH017385)	7.8	11.9	9.12	0.9	18.97 -- 22.64	13.22
	Barrel 3	277	Start Ends	29\4\2014 2\6\2014	35	1	1	1	1	$93*10^5$ cfu in 1 g	present in 1g	not recovered in 25g (NH017386)	7.77	11	7.85	0.97	13.8 - -16.5	11.34
second trial step (2)	Barrel 2	522	Start Ends	29\4\2014 2\6\2014	154	4	1	1	1	<10 cfu in 1 g	Absent in 1 g			27	27.1	2.41	18.97 -- 22.64	11.2
	Barrel 3	522	Start Ends	29\4\2014 2\6\2014	154	1	1	1	1	<10 cfu in 1 g	Absent in 1 g			21.5	20.6	1.66	13.8 - -16.5	12.95

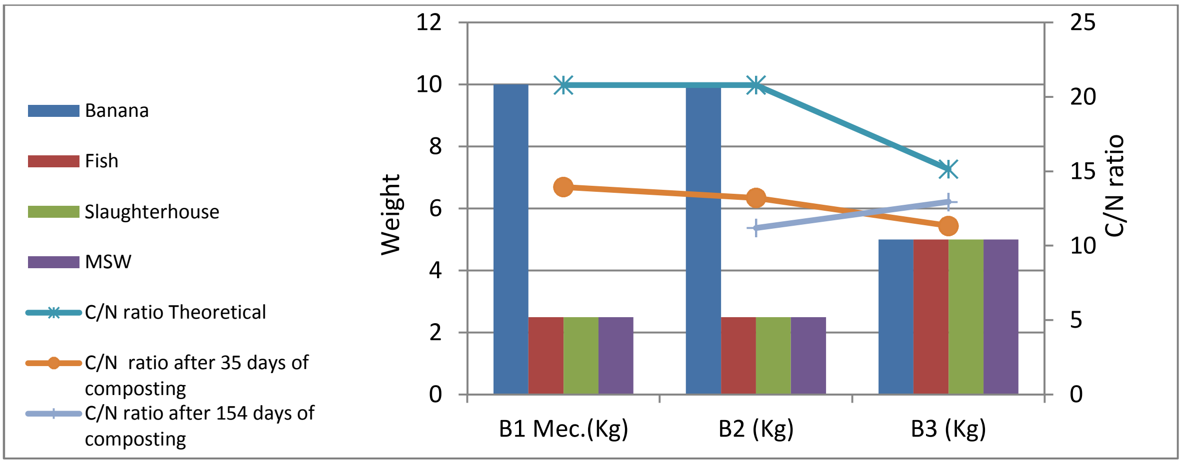
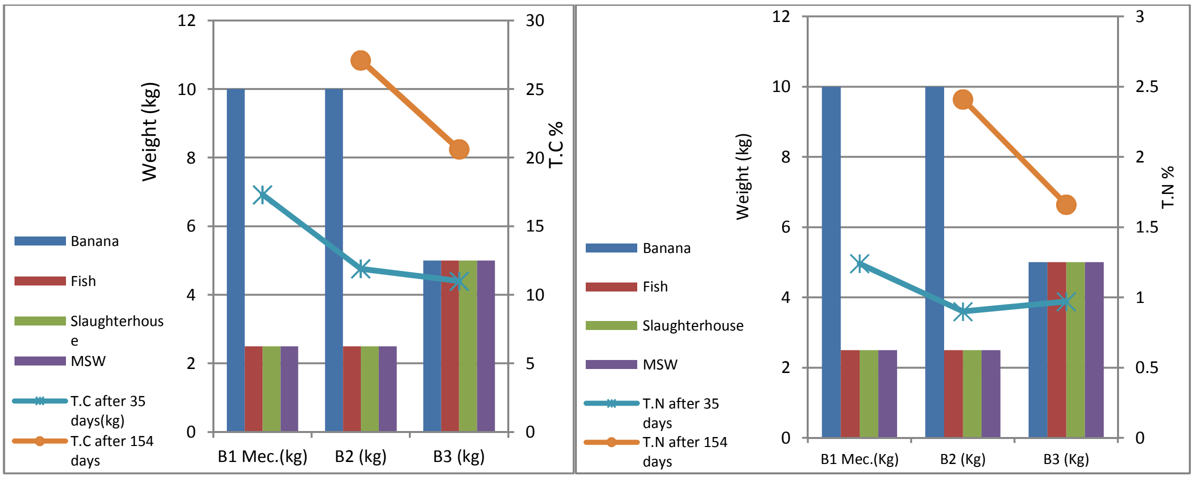


Figure 10: The variation of C/N ratios before and after composting for different Barrels (trial two).

After 35 days of composting, the C/N ratio of the compost in the mechanical barrel decreased by 26.5%, the compost in B2 decreased by 30%, and in B3, the C/N ratio decreased by 18%. However, after 154 days of composting, the C/N ratios were 40.4% in B2 and 6.1% in B3. The results of C/N ratios after (35and 154) days of composting between barrels showed that the C/N ratio decreased by14.5% in B2, whereas it increased by 12.4% in B3. It is possible that the initial C/N ratio in B3 was low enough to slow down the carbon degradation much more than nitrogen degradation. However in B2, the initial C/N ratio and composting conditions slowed down the carbon degradation and nitrogen transformations process. (

Figure 10)

3.2.2 Total Carbon, Total Nitrogen



a) Total Carbon b) Total Nitrogen

Figure 11: TC and TN after 35,154 days of composting in each barrel.

Total Carbon and Total Nitrogen increased decomposition gradually during the period from (35 to 154) days by (56%, 48.8%) and (62.6 %, 41.5%)in B2,B3 respectively. The higher TC and TN suggest that maturation had not yet been achieved and that the degradation processes were possibly interrupted due to more than one factor.

After applying the two different techniques for 35 days (mechanical barrel and fixed barrel) on the samples that had the same mixture (B,F,S,M 4,1,1,1)., the results showed that the samples from the mechanical barrel B1 (17.3%,1.24%,13.95%) had relatively higher TC, TN and slightly higher C/N ratio than samples taken from fixed barrel B2 (11.9%, 0.9%, 13.22%) respectively. On the other hand, the samples taken from the barrels on which the same technique was used, with different waste ratio (B,F,S,M 1,1,1,1) , (B,F,S,M 4,1,1,1) the results showed that fixed B3 (11%,0.97%,11.34%) had relatively comparable TC and TN but slightly lower C/N ratio to the sample from B2 (11.9%, 0.9%, 13.22%) respectively.

The max Total Carbon utilization by microbial activity was highest in B2 (27.1%) after 154 days of composting. (Figure 11).

3.3 Trial Three Experiments

3.3.1 Carbon / Nitrogen Ratio

	Samples No.	Job number	Date	Composting days	Weight (kg)				Chemical analysis					C/N intial	Moisture content %
					Banana	Fish	Slaughter House	MSW	pH	T.C%	T.O.C%	T.N%	C/N		
Third trial step (1)	**B1**	***483***	start 15\8\2014 ends 11/9/2014	**27**	**9**	**1**	**5**	**10**		**23.5**	**25.3**	**1.87**	**12.5**	**22.6-24.15**	**46.3**
	B2	***483***	start 15\8\2014 ends 11/9/2014	**27**	**12**	**1**	**10**	**2**		**22.7**	**18.6**	**1.92**	**11.8**	**21.50-22.87**	**52.2**
	B3	***483***	start 15\8\2014 ends 11/9/2014	**27**	**18**	**3**	**2**	**2**		**25.5**	**25.8**	**2.2**	**11.5**	**21.50-25.0**	**50.6**
	B4	***483***	start 15\8\2014 ends 11/9/2014	**27**	**15**	**2**	**4**	**4**		**25.1**	**25.7**	**2**	**12.5**	**21.96-24.79**	**47.1**
Third trial step (2)	**B1**	***522***	start 15/8/2014 ends 29/9/2014	**45**	**9**	**1**	**5**	**10**		**21.2**	**22.3**	**1.96**	**10.8**	**22.6-24.15**	**36.2**
	B3	***522***	start 15/8/2014 ends 29/9/2014	**45**	**18**	**3**	**2**	**2**		**25.3**	**22.8**	**2.24**	**11.2**	**21.50-25.0**	**38.3**
Third trial step (3)	**B1**	***616***	start 15/8/2014 ends 14/11/2014	**91**	**9**	**1**	**5**	**10**	**8.63**	**22.6**	**16.8**	**1.67**	**13.5**	**22.6-24.15**	**37.7**
	B2	***616***	start 15/8/2014 ends 14/11/2014	**91**	**12**	**1**	**10**	**2**	**8.8**	**20.23**	**16.5**	**1.94**	**10.4**	**21.50-22.87**	**36.9**
	B3	***616***	start 15/8/2014 ends 14/11/2014	**91**	**18**	**3**	**2**	**2**	**8.32**	**24.4**	**21.4**	**1.83**	**13.3**	**21.50-25.0**	**39.9**
	B4	***616***	start 15/8/2014 ends 14/11/2014	**91**	**15**	**2**	**4**	**4**	**8.27**	**24.3**	**22.3**	**1.69**	**14.3**	**21.96-24.79**	**48.3**

Table 3: TC, TN and C/N characteristics of samples of Trial three after certain days of composting.

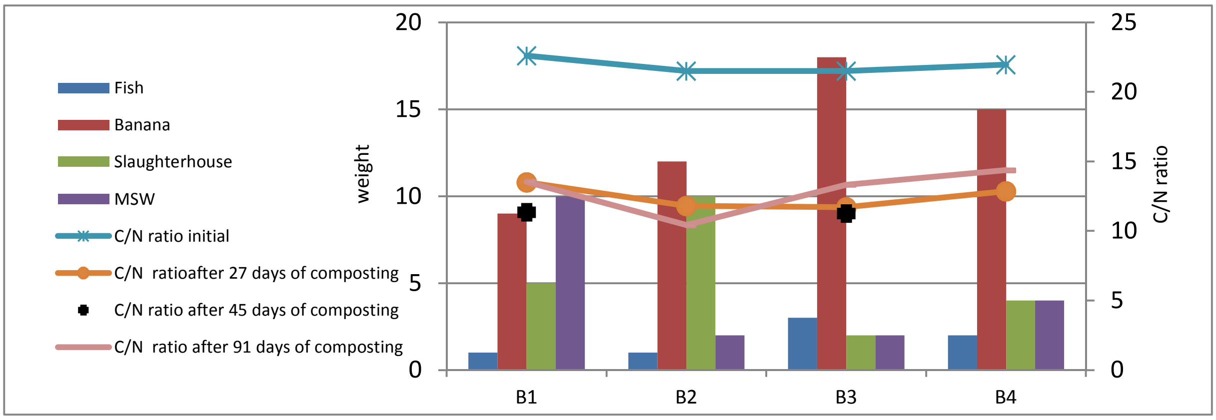


Figure 12: The variation of C/N ratio of each barrel at different times of composting (trial three).

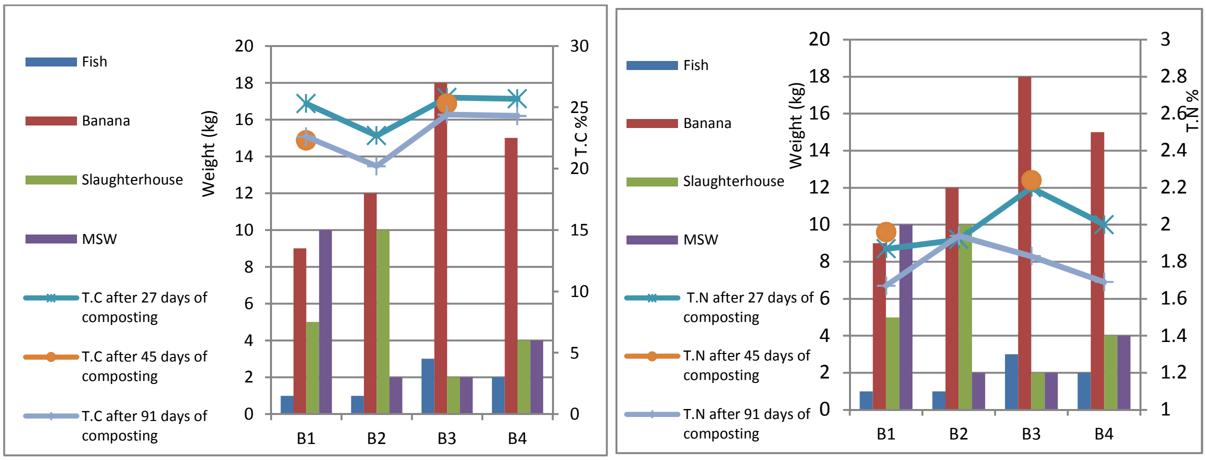
The C/N ratio of trial three decreased from around 25% at the beginning of the experiment, while it decreased below 20% at the end of the composting process. After 27 days , the C/N ratios of B1,B2,B3and B4 were (12.567,11.823,11.591,12.55) and (13.53,10.42,13.33 ,14.37) after 91days respectively, as shown in

, these trends prove that by using the windrow composting method, starting with around 25 % of C/N ratio, good maturity can be expected from the mixture of fish, Banana mulch wastes with organic MSW.

After 27 days of decomposition, the percent change (reduction) in C/N ratio was highest 46% in B3 (B,F,S,M 18,3,2,2), followed by 45% in B2 (B,F,S,M 12,1,10,2), 44.4% in B1 (B,F,S,M 9,1,5,10) and 42.8% in B4 (B,F,S,M 15,2,4,4).

After 91 days, the decrease in C/N ratio was 51.5% in B2 (B,F,S,M 12,1,10,2), 40.1% in B1 (B,F,S,M 9,1,5,10), 38% in B3 (B,F,S,M 18,3,2,2) and 34.5% in B4 (B,F,S,M 15,2,4,4). (Figure 12)

3.3.2 Total Carbon and Total Nitrogen (Trial Three)



a) Total Carbon b) Total Nitrogen

Figure 13: The variation of TC and TN for each barrel at different time of composting (trial three).

The percent change (reduction) in TC during the period (from 27 to 91 days) showed the highest reduction in B2 (10.88%) followed by (10.67%) reduction in B1, (5.44%) reduction in B4, and (5.42%) reduction in B1.

The percent change (reduction) in TN during the period (from 27 to 91 days) showed the highest reduction in B3 (16.8%) followed by (15.5%) reduction in B4, (10.7%) reduction in B2, and (1%) reduction in B1.

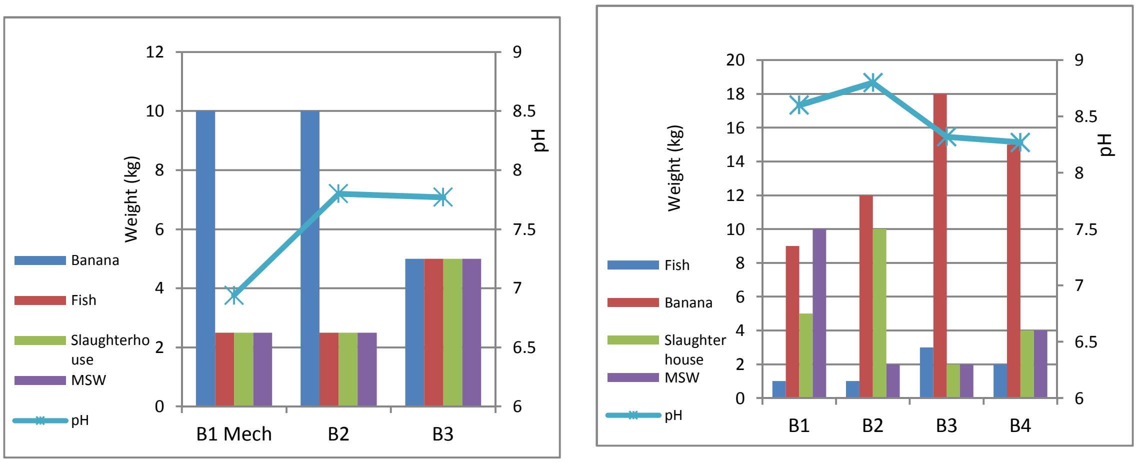
The percent change in TC, TN and C/N ratios between the samples from four fixed barrels are consistent in the sense that we observe a decrease in total carbon, increase in total nitrogen and decrease in C/N ratio over more days of decomposition.

These findings indicate that interplay of different factors (waste mix, initial CN content, moisture content and physical properties of waste ingredients specifically bulking agent used banana) affects the final TN, TC and CN ratios. (Figure 8).

3.3.3 Acidity, pH Changes

Ideally, the pH should be in the range of 6-8 to allow the highest rates of decomposition. If the pH is outside this range, microbial activity will be compromised and decomposition will be slowed or even stopped (Fourti, O., Jedidi, N., & Hassen, A.M., 2011). In trial 2, all the results of the pH are in the range rate of decomposition, but even in the mechanical barrel the pH had the lowest value equal to 6.94 as shown in

Figure 14.



a) Trial Two

b) Trial Three

Figure 14: The Different of pH tests for each barrel after (35) and (92) days of composting for trial two and trial three respectively.

4. Mathematical Optimization Model

The aim of optimization model is to understand the effects of weights for four types of wastes, mixed for composting, on C/N ratios. These wastes are fish, banana, slaughterhouse and municipal solid wastes. The mathematical model consists of two mass- balance equations with four unknowns as well as four constraints depending on special boundary conditions set by the designer. The four unknown weights, WF, WB, WS, & WM are to be estimated according to method adapted by Tom Richard (Ahn, H.K., Sauer, T.J., Richard, T.L., Glanville, T.D., 2009) which has four types and four different weights of wastes.

Main equations; (2) and (3) are given below:

$$C/N = \frac{C_F W_F + C_B W_B + C_S W_S + C_M W_M}{N_F W_F + N_B W_B + N_S W_S + N_M W_M} \qquad \text{Eq.2}$$

$$W_F + W_B + W_S + W_M = 25\ kg \qquad \text{Eq.3}$$

According to experimental results, values of C_F, C_B, C_S, C_M and N_F, N_B, N_S, N_M, are substituted in Eq. (2). Also, according to literature studies, values C/N should be in the range of 20 to 30. This means that Eq. (2) can be written as:

$$C/N = \frac{11.1 \times W_F + 39.4 \times W_B + 16.5 \times W_S + 31 \times W_M}{2.3 \times W_F + 1.21 \times W_B + 1.18 \times W_S + 1.23 \times W_M} = 20,21,22, \ldots \ldots \ldots .30 \qquad \text{Eq.4}$$

Four boundary conditions (5) & (6) & (7) & (8) must be satisfied, as given below:

$$0 < W_F < 25\ Kg \qquad \text{Eq.5}$$

$$0 < W_B < 25\ Kg \qquad \text{Eq.6}$$

$$0 < W_S < 25\ Kg \qquad \text{Eq.7}$$

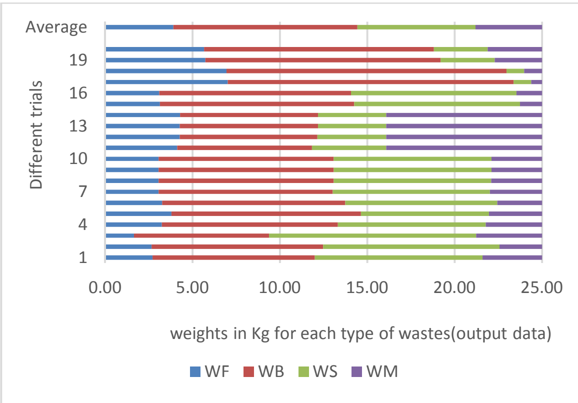
$0 < W_M < 25$ Kg Eq.8

A set of 220 runs was performed. Output of mathematical optimization model shows values of W_F, W_B, W_S, and W_M for each C/N ratio in the range of 20 to 30. Samples of data are presented in Table 4Other output data are given in Appendix (A).

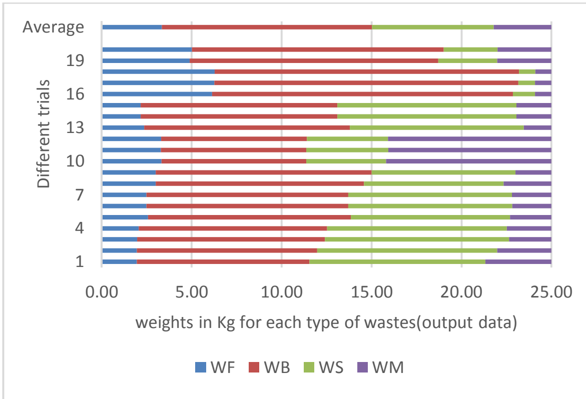
Table 4: Samples of data: (a)

Table 4 (a)									
W_F	2.72	2.66	1.65	3.26	3.79	3.26	3.06	3.06	3.06
W_B	9.29	9.81	7.73	10.07	10.85	10.47	9.97	10.02	10.03
W_S	9.59	10.10	11.85	8.45	7.32	8.70	8.99	9.01	9.02
W_M	3.41	2.43	3.78	3.22	3.04	2.56	2.98	2.91	2.89
C/N	20	20	20	20	20	20	20	20	20
Table 4 (b)									
W_F	1.95	1.96	1.97	2.06	2.58	2.49	2.49	3.00	3.01
W_B	9.61	10.02	10.43	10.47	11.26	11.21	11.20	11.59	12.00
W_S	9.77	10.01	10.24	9.99	8.86	9.12	9.10	7.76	8.00
W_M	3.67	3.01	2.36	2.48	2.30	2.18	2.20	2.66	2.00
C/N	21	21	21	21	21	21	21	21	21

Charts are presented to show all output data. Sample of these charts are shown in Figure 15



a) C/N ratio = 20



b) C/N ratio = 21

Figure 15: Samples of output data

4.1 Multiple Regression Analysis

All output data resulted from mathematical optimization model are tabulated. There are around 220 runs are performed. Samples of these data are presented in Table 4. Data of C/N are considered as main parameter Y where data of W_F, W_B, W_S, and W_M are considered as secondary parameters, X_1, X_2, X_3, and X_4. To relate Y to values of X_1, X_2, X_3, X_4, a multiple regression analysis is done.

The general form of regression model is given as:

$Y = a + bX_1 + cX_2 + d\,X_3 + eX_4$
Eq.9

Regression analysis is done to determine the coefficients a, b, c, d, e. Results show that two models are available.

Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.3, 2015

Table 5 summarizes results of model (1) while Table 6 summarizes results of model (2).

Table 5: Optimal values of model (1) parameters and 95% confidence range.

Summary output

Regression Statistics	
Multiple R	0.999
R Square	0.999
Adjusted R Square	0.994
Standard Error	0.123
Observations	220

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	2196.716	549.179	48158.9	0
Residual	216	3.284	0.0152		
Total	220	2200			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	25.241	0.084	300.078	4.58E-285	25.075	25.407	25.075	25.407
X Variable 1	-1.385	0.007	-195.811	3.6E-245	-1.399	-1.371	-1.399	-1.371
X Variable 2	0.274	0.004	76.237	4.02E-158	0.267	0.282	0.267	0.282
X Variable 3	-0.425	0.005	-84.965	5.8E-168	-0.434	-0.415	-0.434	-0.415
X Variable 4	0	0	65535	#NUM!	0	0	0	0

Table 6: Optimal values of model (2) parameters and 95% confidence range.

Summary output

Regression Statistics	
Multiple R	0.99999
R Square	0.99998
Adjusted R Square	0.99535
Standard Error	0.12331
Observations	220

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	139696.716	34924.179	2296943	0
Residual	216	3.284	0.015		
Total	220	139700			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	-0.375	0.006	-67.239	8.1E-147	-0.386	-0.364	-0.386	-0.364
X Variable 2	1.284	0.001	1530.608	0	1.282	1.286	1.282	1.286
X Variable 3	0.585	0.002	248.156	2.7E-267	0.580	0.590	0.580	0.590
X Variable 4	1.010	0.003	300.078	4.6E-285	1.003	1.016	1.003	1.016

Table 7: shows the Comparison of coefficients due to mathematical regression models (1) and (2)

Coefficients	Model (1)	Model (2)
A	25.241	0
B	-1.385	-0.375
C	0.275	1.284
D	-0.425	0.585
E	0	1.01

Comparison between both models of multiple regression analysis is shown in

Table 7. The results showed that model (1) or Equation (10) has large constant value (high intercept) with respect to other constants and zero value of constant e which means that WM has no contribution to C/N while model (2) has a zero constant value (zero intercept) (equation (11)).

None of the coefficients has zero value. This means that each weight of the composting has its contribution to C/N. The results of model (2) can not only highly represent the data but also allow the four weights to make a separate contribution to C/N. It is also more logical and more reliable and provide a suitable condition for composting process.

$$C/N = 25.24 - 1.38W_F + 0.27W_B - 0.42W_S \qquad \text{Eq.10}$$

$$C/N = -0.37W_F + 1.28W_B + 0.58W_S + 1.01W_M \qquad \text{Eq.11}$$

By substituting the average values (weights) of W_F, W_B, W_S, and W_M for each C/N ratio starting from 20 to 30 from the previous mathematical optimization model and the weights used for each type of waste in trial three, there is a negligible difference between the values of C/N ratios, as shown in **Error! Reference source not found.**.

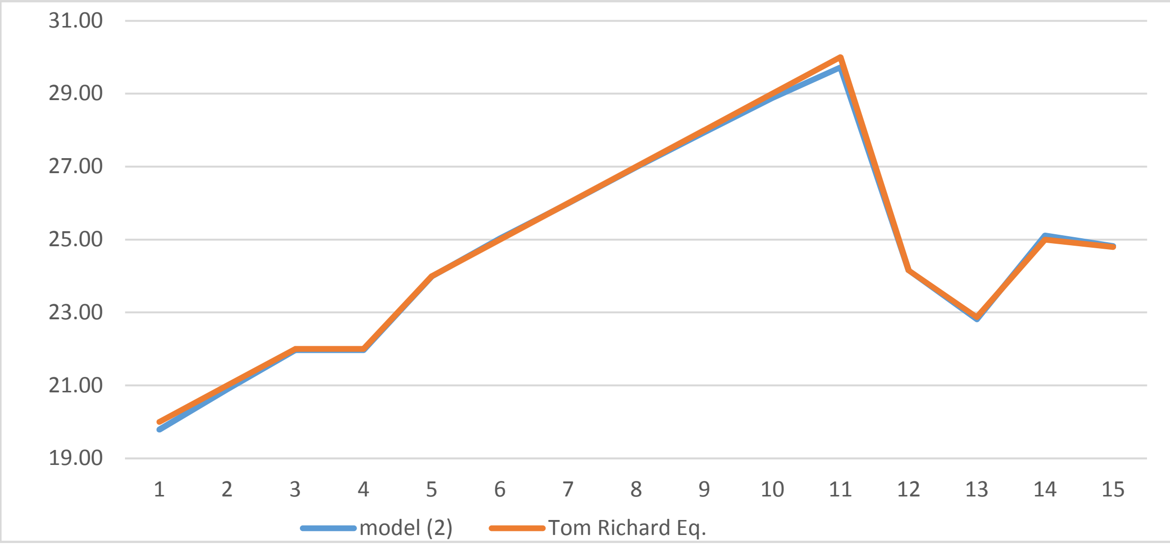


Figure 16: the different values of C/N ratios by using equations of model (2) and Tom Richard equation eq. (2).

Anova analysis for the different values of C/N ratios by using equations of model (2) and Tom Richard equation eq. (2) the results was as shown in

Table 8.

Table 8: Anova analysis results

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
19.793	14	350.262	25.019	7.133
19.9999998	14	350.825	25.059	7.325

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.011	1	0.011	0.002	0.969	4.225
Within Groups	187.962	26	7.229			
Total	**187.973**	**27**				

Conclusion and Recommendations

The study focuses on composting of banana and fish wastes with organic MSW wastes. The composting is an environmental friendly method that produces fairly hygienic products that deliver fertilizer efficacy between humid soil and organic fertilizer, making it an appropriate method for South Lebanon (Saida city). This study seeks to assess the quality of co-composted shredded MSW with fishery wastes, banana mulch wastes and an aerobically composted slaughterhouse wastes. Through this study, the following can be concluded:

1) Specific weights for fish and banana mulch wastes can be considered suitable for efficient composting with organic fraction of municipal solid wastes.
2) Moreover, evidence shows that composted materials based on fish wastes can provide useful soil-conditioning with good maturity and can be used for agricultural applications.

3) These trends prove that by using the windrow composting method, good maturity can be expected from mixing fish, banana mulch wastes with organic MSW. Rodent infestation and offensive odors were not noted in any of the compost trials.
4) The composting volume in the different barrels after shrinkage is about one half of its original volume.
5) The C/N ratio decreased from 25 % at the beginning, to below 20% at the end of the process.
6) All the results of the pH are in the range rate of decomposition; however, in the mechanical barrel, the pH goes to the lowest value equal to 6.94.
7) A mathematical optimization model is presented. Components of the composting are estimated in order to satisfy C/N ratio in the range between 20 and 30.The chosen ideal (suitable) weight of the composting is 25 kg. A total of 220 runs are performed. Output data of optimization model, C/N ratio as a main parameter as well as secondary parameters components of composting, are presented in tables and graphs to show that Banana weight contribution is the most effective component affecting C/N ratio.
8) A multiple regression analysis is performed to relate C/N as a main parameter to the component of different weights as secondary parameters. Two mathematical models are executed. The second one proves to not only highly represent the whole data but also give a chance for each weight of the composting to contribute to the main parameter C/N.
9) In trial two the percent change in TC, TN and C/N ratios in-between samples from fixed barrels, shows that both Total Carbon and Total Nitrogen have increased with the passing of time.
10) The higher TC and TN suggests that maturation is not yet achieved after 35 days and that the degradation processes have been possibly interrupted by more than one factor. (Trial two).

Saida area shows the advantages of windrow composting, including low facility investment, high environmental-friendliness, easy operation and low failure rate. Thus, it is particularly suitable for Saida (South of Lebanon).

References

Ahn, H.K., Sauer, T.J., Richard, T.L., Glanville, T.D., (2009). Determination of thermal properties of composting bulking materials. *Bioresource Technology* 100(17), Elsevier, 3974–3981.

Chalak, L., & Sabra, N. (2007). Lebanon: Second report on the state of plant genetic resources for food and agriculture. [Online] Available: http://www.fao.org/docrep/013/i1500e/Lebanon.pdf

El Mawla, D. (2014). Solid waste management program -Municipal Waste Sorting & Composting Facility Inspection Report (Qabrikha; Kerbit Selem; Ain Bael).OMSAR.

Fares, R., Fares, E., & De-Nardo, F. (2011). Composting from A to Z. [Online] Available: http://www.moe.gov.lb/getattachment/742387fc-d9cd-4256-9753-587333c5f59a/%D8%A7%D9%84%D8%AA%D8%B3%D8%A8%D9%8A%D8%AE-%D9%85%D9%86-%D8%A7%D9%84%D8%A7%D9%84%D9%81-%D8%A7%D9%84%D9%89-%D8%A7%D9%84%D9%8A%D8%A7%D8%A1.aspx

Fourti, O., Jedidi, N., & Hassen, A.M. (2011). Comparison of methods for evaluating stability and maturity of co-composting of municipal solid wastes and sewage sludge in semi-arid pedo-climatic condition. *Natural Science, 3 (2),* 124-135.

Mason, I.G., & Milke, M.W. (2005). Physical modelling of the composting environment: *A review. Part 1: Reactor systems. Waste Management Journal*, 25, 481–500. [Online] Available: http://www.sciencedirect.com/science/article/pii/S0956053X05000462#

Merhebi, F. (2014). Lebanon Environmental Assessment of the Syrian Conflict & Priority Interventions. [Online] Available: http://www.moe.gov.lb/getattachment/6c5fbe66-e28d-4fca-a0ce-3ce92add3f83/Lebanon-Environmental-Assessment-of-the-Syrian-Con.aspx

Sellin, N., Oliveria, B.G., Marangoni, C., Souza, O., Oliveria, A.P.N., & Oliveria, T.M.N. (2013). Use of banana culture waste to briquettes. *Chemical Engineering Transactions,* 32, pp.349-354. Doi : 10.3303/CET1332059

Sweep-Net. (2014). Country report on the solid waste management in Lebanon. [Online] Available: http://www.sweepnet.org/sites/default/files/LEBANON%20RA%20ANG%20WEB.pdf

Appendix A

W_F	1.22	1.20	1.23	1.22	1.72	2.04	0.22	0.71	0.70
W_B	9.91	9.90	10.32	10.29	10.70	10.98	8.75	9.12	9.10
W_S	9.95	10.00	10.18	10.20	8.83	7.99	12.41	11.07	11.10
W_M	3.93	3.90	3.27	3.29	3.75	3.99	3.62	4.10	4.10
C/N	22	22	22	22	22	22	22	22	22

W_F	0.52	0.52	0.53	0.55	0.56	1.51	1.50	2.50	2.51
W_B	10.20	10.19	10.61	11.03	10.97	11.79	11.80	13.39	13.40
W_S	10.12	10.09	10.35	10.57	10.49	7.88	7.90	5.63	5.60
W_M	4.17	4.19	3.51	2.85	2.98	3.83	3.80	3.48	3.50
C/N	23	23	23	23	23	23	23	23	23

W_F	1.36	1.30	1.31	1.50	0.05	0.14	2.27	2.08	1.11
W_B	13.13	12.88	12.90	14.21	11.39	11.65	14.48	13.97	8.96
W_S	6.87	6.93	6.90	7.12	10.23	10.09	4.69	4.98	4.97
W_M	3.63	3.90	3.90	2.17	3.33	3.12	3.56	3.97	9.96
C/N	24	24	24	24	24	24	24	24	24

W_F	1.09	0.63	0.64	3.19	3.09	3.29	1.57	1.58	0.44
W_B	13.94	13.15	13.19	18.92	18.26	18.29	14.77	15.17	9.23
W_S	6.00	7.09	7.09	1.95	1.85	1.17	4.86	5.10	5.14
W_M	3.97	4.13	4.09	0.93	1.80	2.24	3.80	3.14	10.19
C/N	25	25	25	25	25	25	25	25	25

W_F	0.45	1.46	2.02	1.46	1.46	2.66	2.63	0.73	0.91
W_B	14.23	16.11	17.99	17.81	17.82	19.33	19.15	14.52	15.04
W_S	6.14	3.76	2.99	4.88	4.91	1.58	1.59	5.31	5.02
W_M	4.19	3.67	1.99	0.84	0.81	1.43	1.63	4.44	4.03
C/N	26	26	26	26	26	26	26	26	26

W_F	1.62	1.64	1.36	0.82	0.82	1.99	1.81	1.81	0.72
W_B	17.75	17.78	18.26	18.07	17.99	19.60	19.08	19.08	16.11
W_S	1.84	1.79	3.16	5.05	5.00	1.75	2.05	2.05	4.07
W_M	3.79	3.78	2.22	1.06	1.19	1.66	2.06	2.06	4.10
C/N	27	27	27	27	27	27	27	27	27

W_F	0.98	1.34	1.35	1.96	1.97	1.48	1.50	1.96	0.11
W_B	18.01	19.86	19.88	21.61	21.61	20.21	20.30	21.61	16.36
W_S	2.00	1.91	1.89	0.75	0.71	1.63	1.60	0.75	4.22
W_M	4.01	1.88	1.88	0.67	0.71	1.68	1.60	0.67	4.31
C/N	28	28	28	28	28	28	28	28	28

W_F	0.37	0.72	0.70	1.16	1.15	0.90	1.33	1.34	1.72
W_B	18.25	20.11	20.04	21.34	20.94	21.04	21.87	21.88	23.01
W_S	2.16	2.07	2.13	1.21	0.96	2.03	0.92	0.89	0.19
W_M	4.21	2.09	2.14	1.29	1.95	1.03	0.89	0.89	0.08
C/N	29	29	29	29	29	29	29	29	29

W_F	0.72	0.13	0.10	0.54	0.55	0.30	0.72	0.71	0.79
W_B	22.11	20.35	20.24	21.58	21.18	21.28	22.11	22.09	22.32
W_S	1.07	2.22	2.25	1.42	1.11	2.18	1.07	1.10	0.95
W_M	1.09	2.30	2.40	1.46	2.15	1.24	1.09	1.10	0.94
C/N	30	30	30	30	30	30	30	30	30

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar