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Kitchen Waste Disposal and Management Practices in Urban Region of Bangladesh through Barrel Composting System

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Abstract

The present paper is based on a study that was performed to assess the kitchen waste management through barrel composting system in order to produce organic fertilizer, and to investigate the physicochemical properties (pH and moisture content) including nutrient contents (OC, N, P, K and S) and heavy metal concentration (Pb, Cd and Cr) of the produced organic fertilizer during the period from July 2016 to June 2017 in the urban area of Tangail region. Kitchen wastes were collected twice in a week for 6 months from 2 halls of Mawlana Bhashani Science and Technology University (MBSTU) and 2 wards of Tangail municipality and divided into 2 phases. About 5.8 kg organic fertilizer was produced from 178.52 kg kitchen waste, which was highly enriched with nutrients. The pH of the composts was increased and moisture contents (67 to 71% in 1st phase and 36 to 44% in 2nd phase) were decreased with duration and waste dried up period. Finally, moisture content ranged from 23 to 31%. The produced organic fertilizer contained organic carbon (24.42 to 27.68%), total nitrogen (2.035 to 2.533%), C/N ratio (10.07 to 12), phosphorus (0.735 to 0.872%), potassium (2.83 to 3.89%) and sulphur (0.578 to 0.68%). The Pb concentration exceeded in green barrel, whereas it was negligible in black barrel. The Cd and Cr concentrations in both types of barrels were within permissible level.

Keywords
Kitchen waste; Barrel compositing; Organic fertilizer; Heavy metals

Introduction

Kitchen waste is one kind of solid waste which is produced from the kitchen during the time of preparing and processing of food that makes a large portion (50-60%) of the total solid waste generated in Bangladesh (Rahman and Ali, 2000). These organic substances are bulky to handle and contribute to numerous liquid and gaseous emissions that deteriorate dumpsite environments. The waste generation rate was 0.41 kg/capita/day in urban area of Bangladesh, while waste collection efficiency varied from 37 to 77% with an average of 55% (Rahman and Ali, 2000). Huge amount of uncollected wastes, a high proportion of which are organic, creates nuisance and pollutes the local environment rapidly that needs appropriate treatment (Bahauddin and Uddin, 2012). Composting is a method of organic solid waste treatment and barrel composting is one of the affordable, easiest and cheapest process by which compost is produced that can reduce the weight and volume of waste, and can produce an inoffensive and useful product (Islam *et al*., 2011). The process of composting can take as little as 3-6 months. Ideally, compost is matured for 3-4 months before use. This finished product is high in carbon and nitrogen and is used in landscaping, horticulture and agriculture as a soil conditioner and fertilizer (Sambali and Mehrotra, 2009). Besides, it is the eco-friendly process that can enhance the biodiversity and environment (Rahman and Ali, 2000). Finally composting can be a profitable business and provide income and employment opportunities for the poor (Rahman and Ali, 2000). The uses of compost fertilizers are gaining popularity day by day amongst farmers in Bangladesh (BBS, 2012) and recently its demand is gradually increasing, and its circle is extended to peri urban and urban areas (Dilkara *et al*., 2016). The vermicompost application showed higher result for growth and yield indices and nutrient content when compared with conventional aerobic compost used for vegetables production (Islam *et al*., 2016). Vermicompost is enriched with beneficial microbes to increase the organic fertilizer value and reduce the dose of application. The vermicompost increases nitrogen and phosphorous availability by enhancing biological nitrogen fixation and phosphorous solubilization (Padmavathiamma, Li and Kumari, 2008). In conventional aerobic composting, biological aerobic transformation takes place whereas different organic product can be added to the soil without detrimental effects of crop growth (Baca, Fornasier and Nobil, 1992). Composts provide all nutrients in readily available forms and also enhance uptake of nutrients by plants. The compost plays a major role in improving growth and yield of different field crops production (Sreenivas, Muralidhar and Rao, 2000).

The Mawlana Bhashani Science and Technology University (MBSTU), Bangladesh has five halls occupied by 1000 students and staff, and the Tangail municipality has a total population of 128,785 where the municipality consists of 21,115 households with a density of population 3650/km^2 (Tangail Municipality, 2006). Every day a large amount of wastes produced from the kitchen of these halls and municipal areas. The waste is thrown here and there, producing bad odor, spreading flies, rodents vector diseases. Islam *et al*. (2011) conducted a study on MBSTU campus and found that the kitchen waste management through barrel composting system can provide a solution dealing with the most significant component of waste. It reduced the weight and volume of waste and produced inoffensive and useful product which was also enough for existing university gardening. This compost can be used by farmers in place of expensive and energy-intensive artificial fertilizers. So it is necessary to establish a model of waste management system in MBSTU campus and the Tangail municipality area by converting kitchen waste into organic fertilizer and compost in a continuous process to build awareness among the urban people regarding the sustainable use and management of kitchen waste within the university and the community. The main objective of this study is to identify the best management practice of kitchen waste through barrel composting system to reduce the volume of kitchen wastes and to convert it into the organic fertilizer through composting which is used for vegetable and flower gardening in the study area.

Materials and Methods

The study was conducted in two student halls of Mawlana Bhashani Science and Technology University namely Bangabandhu Sheikh Mujibur Rahman Hall (St-1) and Shaheed Janani Jahanara Imam Hall (St-2); (Figure 1) and two wards of Tangail municipality namely Akurtakur Para (St-3) and Thana Para (St-4) (Figure 1). The reference period of the study is one year from July 2016 to June 2017.

Sample collection: A green barrel (GB), which is considered as standard and a black barrel (BB), which is to determine the changes with respect to green barrel, were placed at each station. The barrels placed were named as GB-1 and BB-1 in St-1, GB-2 and BB-2 in St-2, GB-3 and BB-3 in St-3, and GB-4 and BB-4 in St-4. The residues of different vegetables and spices such as onion, garlic, ginger and piper were collected from kitchen twice a week in the afternoon on regular basis for a period of 6 months. The wastes were weighed with balance and then dumped into the barrels for composting.

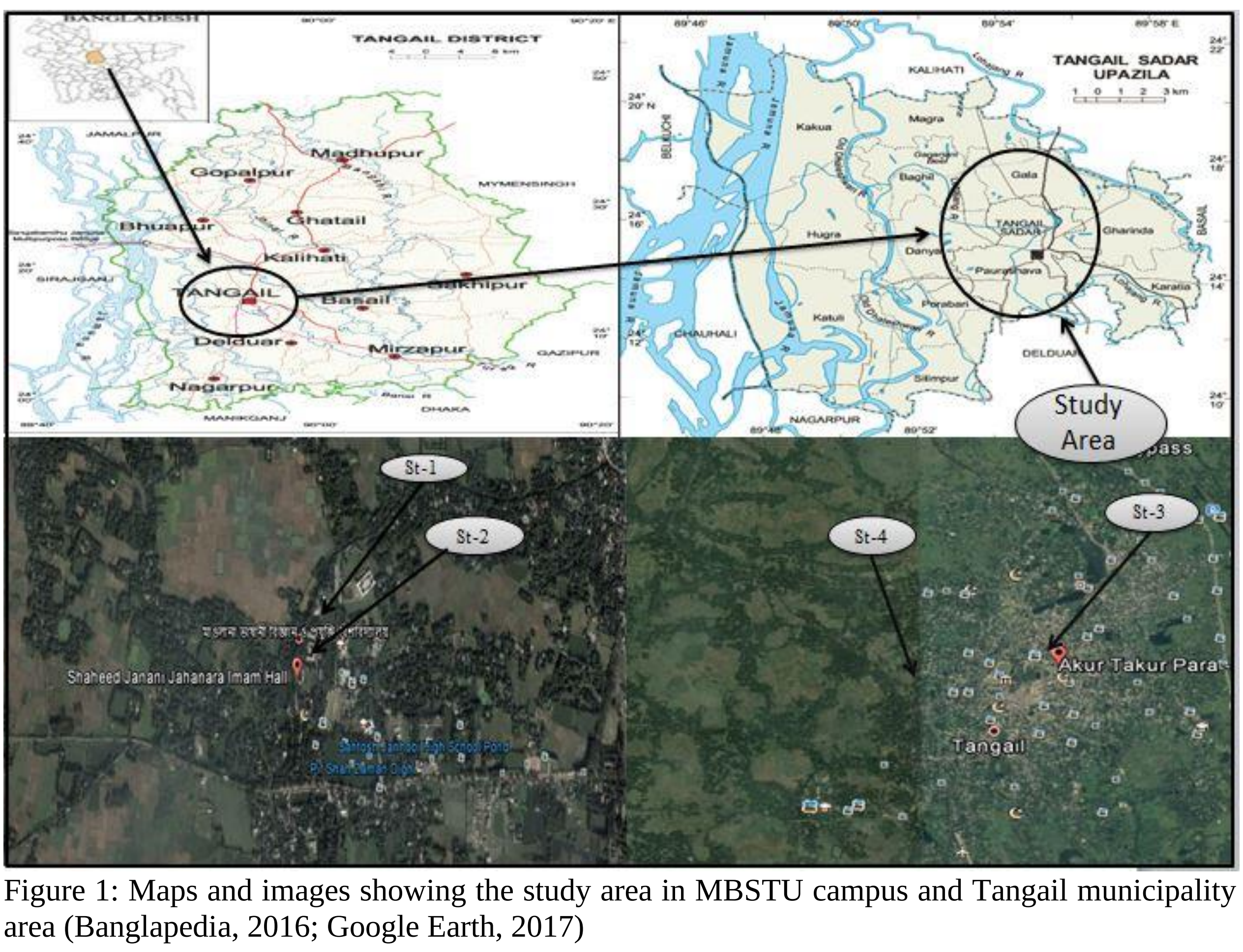

Figure 1: Maps and images showing the study area in MBSTU campus and Tangail municipality area (Banglapedia, 2016; Google Earth, 2017)

Conversion procedure: The conversion of compost from kitchen waste was carried out by Barrel Composting System that takes limited space and is easy to handle. The process was continued for a period of 6 months where first 3 months were considered as 1st phase and later 3 months considered as 2nd phase. The temperature was measured for 4 times a day (morning, noon, afternoon and night) when the barrels were fully packed with wastes. After 7 days of dumping (when the volume of waste was significantly reduced), wastes were dumped into black barrel for 4 days to compare the change of characteristics of compost. A 100 ml water was added into black barrel and was stirred for 3-5 minutes. Three months later, at least 3 samples were collected from each type of barrels and brought to the laboratory to measure the temperature, pH and moisture content. In the same way, after 6 months, at least 3 samples were taken from the barrels to measure its temperature, pH and moisture content assuring that the compost is made. Then the samples were oven dried for 24 hours and weight was taken by electric balance. At next step, the samples were examined in the laboratory to measure the quality of organic fertilizer.

Sample analysis: Temperature and pH of the waste were measured by using thermometer and digital pH meter. The moisture content was estimated by the following equation: Moisture content (%) = [{(wet weight-dry weight)/ wet weight} x 100]. The organic carbon was estimated by Walkley and Black's wet oxidation method, total nitrogen by Kjeldhal's method, phosphorus by vanado-molydo-phosphoric acid method, potassium by flame photometry method and Di-acid (HNO_3-$HClO_4$) digestion was used for the estimation of sulphur in compost samples (Goyal, Dhull and Kapoor, 2005; Sundberg and Smars, 2004). The presence of Pb, Cd and Cr in produced organic fertilizer was measured by Atomic Absorption Spectrophotometer (Model: AA-7000).

Results and Discussion

Produced organic fertilizers

A total of 5.80 kg organic fertilizer was produced from 178.52 kg kitchen wastes, where 3.064 kg was produced in green barrel and 2.736 kg in black barrel. This waste is highly enriched with nutrients. In both types of barrels, the highest amount of organic fertilizer was produced at St-1. On the other hand, lowest amount of waste was produced at St-2 (Figure 2). At St-3 and St-4, more or less same amount of kitchen wastes was disposed, and almost same amount of organic fertilizer was produced. The produced organic fertilizers were enough for existing university gardening, organic farming and other purposes.

Physicochemical parameters of organic fertilizer

Temperature

The broad range of optimum temperatures for composting process is from 45ºC to 65ºC (Sundberg and Smars, 2004). The range of temperature for optimal composting is between 52ºC and 60ºC, whereas lower temperatures might be more suitable for composting (Zein, Seif and Gooda, 2015). During the period of dumping, the atmospheric temperature was within the range from 26.4ºC to 28.6°C that indicated shiny weather. In the 1st phase of the composting process, the temperature was ranged from 24.7ºC to 37.2°C in green barrel (GB); it was 24.3ºC to 39.1°C in black barrel (BB). The temperature of both the types of barrels was similar and showed mesophilic (<40°C) nature (Table 1). The highest temperature was measured in BB-3 (37.25°C) and lowest in GB-4

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(35.02°C). The temperature was raised sharply at noon from the morning with highest at afternoon and decreased at night. The rise in temperature in the composting barrel was mainly due to the exothermic reactions associated with the respiratory metabolism of the microorganisms involved in the composting process. It confirmed the study of Sundberg and Smars (2004) and Tchobanglous (1977). In the 2nd phase of the composting processes, the highest temperature was measured in BB-3 (31.3°C) and lowest in GB-1 (30.5°C) with a range from 29.1 to 32.1°C indicating rapid decomposition and production of the organic fertilizer. In both the phases, the temperature of black barrel was higher than the green barrel, which could be due to the addition of extra water in the black barrel. In home container composting system, the temperature never reached above 30°C (Sambali and Mehrotra, 2009) which was observed in the entire study period.

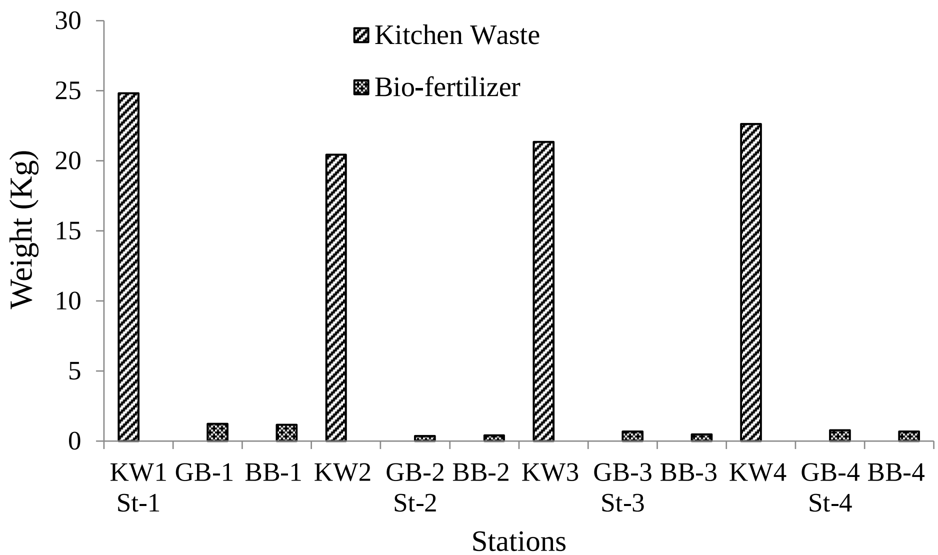

Figure 2: Amount of kitchen wastes used to produce organic fertilizers

Table 1: The temperature, pH and moisture content of kitchen waste composting process

Sampling		Temperature (°C)		pH		Moisture (%)	
Stations	Barrels	1st phase	2nd phase	1st phase	2nd phase	1st phase	2nd phase
St-1	GB-1	35.59±2.81	30.5±1.45	6.89±1.18	9.34±0.10	67±0.12	37±0.12
	BB-1	37.07±2.44	31.1±1.62	7.05±1.02	8.81±0.19	70±0.10	44±0.11
St-2	GB-2	35.58±2.38	30.9±1.56	6.76±0.68	8.21±0.10	69±0.10	40±0.13
	BB-2	36.86±1.87	31.1±1.76	7.04±0.89	8.27±0.26	71±0.12	39±0.16
St-3	GB-3	35.26±1.96	30.8±1.81	6.92±0.81	8.36±0.12	67±0.10	36±0.13
	BB-3	37.25±2.30	31.3±1.70	7.05±0.77	8.13±0.25	69±0.10	42±0.12
St-4	GB-4	35.02±1.93	30.9±1.55	6.92±0.84	8.54±0.12	67±0.10	41±0.11
	BB-4	37.17±2.49	31.2±2.03	7.16±1.06	8.39±0.55	70±0.10	43±0.11

pH

The pH of organic material ranged from 5.5 to 8.5 which is a good indicator for decomposition (Li and Zhang, 2000). The highest and lowest pH in GB was 9.37 and 6.13, respectively, both at S-1; while in BB, the highest and lowest pH was 9.3 (at S-4) and 6.13 (at S-1), respectively (Table 1). In first month, pH was lower than next two months indicating that organic acids were formed

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having bad odour. After completion of 1st phase composting process, the pH was increased because of more decomposition of organic matter (Fang and Wong, 1999). The microorganisms of compost operate best under the pH ranged from 5.5 to 8.0 (CWMI, 1996). The pH of green and black barrel waste was within the range of 5.5 to 8 that indicated microbial operation for decomposition was carried out. The pH of green barrel waste ranged from 8.03 to 9.47 in 2nd phase composting process. The highest and lowest pH in GB was 9.47 (at S-1) and 8.03 (at S-2), respectively. In BB, the highest and lowest pH was 9.3 (at S-4) and 7.73 (at S-4), respectively. When the composting proceeds, the organic acids get neutralized. Mature compost generally has a pH between 6 and 8 (CWMI, 1996). The pH of matured compost ranged from 7.73 to 9.18 in both barrels. The result showed that the pH in both barrels was almost similar and alkaline in nature indicating that the compost was matured, and organic fertilizer is produced.

Moisture content (%)

The moisture content is the water which is essential for metabolic processes (Sharma, 2003). At >65% moisture content, anaerobic condition develops causing bad odours as well as the depletion of the aerobic bacteria (Goyal, Dhull and Kapoor, 2005). At <40% moisture content, bacterial activity for decomposition is reduced (Rahman, 2004). In 1st phase of composting process, the moisture content in both types of barrels was higher than 65% in most cases. Thus, decomposition rate was slow with some bad odour. The average moisture content in GB and BB was 68.5% and 71%, respectively (Table 1). After completion of 1st phase of composting process, the kitchen waste was gradually dried up by solar radiation and then moisture content was decreased gradually. The reduction in moisture content was observed at all stations in 2nd phase of composting process with an average of 38.5% in GB and 42% in BB. The average moisture in both green and black barrels was below 50% which was lower than the study of Islam *et al.* (2011). Comparing with GB, the moisture content in BB was almost nearest to the standard while a little higher amount due to adding of water and stirring. The mature compost was almost dry in physical appearance.

Nutrient content of organic fertilizer

Organic carbon (OC)

The content of organic carbon in composted fertilizer was ranged from 24.73 to 26.05% in GB, whereas the highest and lowest organic carbon content was 26.05% at St-2 and 24.73% at St-3, respectively (Table 2). In BB, the highest and lowest organic carbon content was 27.68% at St-2 and 24.42% at St-1, respectively (Table 2). The result of the study showed that the contents of organic carbon in both GB and BB at all the stations were more or less within the standard (10 to 25%) set by NACC (2015). So, it can be said that the organic fertilizer is rich in organic carbon. It is suitable for different purposes like organic farming, agriculture, gardening, and harvesting of crops.

Total nitrogen (TN)

The content of total nitrogen in organic fertilizer ranged from 2.103 to 2.533% in GB and 2.035 to 2.441% in BB which was within the standard level (0.5 to 4.0%) of NACC (2015). The ratio of the carbon to nitrogen (% of dry weight) is a key indicator of the suitability of composts as a growth medium. For good compost, ideal C/N ratio is 12 to 18 (Cal Recycle, 2006). The C:N ratio in GB was 12, 12, 10.92 and 10.07; and in BB 12, 12, 11.84 and 11.24 at St-1, St-2, St-3 and St-4, respectively indicating good quality of organic fertilizer (Table 2).

Table 2: Nutrient content of organic fertilizers produced from both green and black barrels

Parameters	Sampling stations	Green barrel		Black barrel		Standard (NACC, 2015)
		Average	Range	Average	Range	
Organic Carbon (%)	St-1	25.23	24.73 to 26.05	24.42	24.42 to 27.68	10-25
	St-2	26.05		27.68		
	St-3	24.73		25.37		
	St-4	25.51		27.43		
	Mean	25.38		26.23		
Total Nitrogen (%)	St-1	2.103	2.103 to 2.533	2.035	2.035 to 2.441	0.5-4
	St-2	2.171		2.307		
	St-3	2.263		2.142		
	St-4	2.533		2.441		
	Mean	2.27		2.23		
Phosphorous (%)	St-1	0.842	0.842 to 0.874	0.79	0.735 to 0.79	0.5-1.5
	St-2	0.869		0.763		
	St-3	0.874		0.758		
	St-4	0.847		0.735		
	Mean	0.86		0.76		
Potassium (%)	St-1	3.89	3.287 to 3.89	3.326	2.834 to 3.326	1-3
	St-2	3.722		2.834		
	St-3	3.526		3.156		
	St-4	3.287		2.954		
	Mean	3.60		3.07		
Sulphur (%)	St-1	0.603	0.603 to 0.68	0.59	0.578 to 0.67	0.1-0.5
	St-2	0.68		0.668		
	St-3	0.657		0.582		
	St-4	0.639		0.578		
	Mean	0.65		0.61		

Phosphorus (P)

The phosphorus contents in both GB and BB at all the stations were within the standard level (0.5 to 4.0%) of NACC (2015). The highest phosphorus content 0.874% was measured in GB-3 and 0.79% in BB-1 that showed the content of P was higher in GB than BB (Table 2).

Potassium (K)

The potassium content was calculated in produced organic fertilizer and it was ranged from 3.287 to 3.890 % in GB with an average of 3.606%, and 2.834 to 3.326% in BB with an average of 3.062%. The highest content was measured in GB-1 and BB-1 (Table 2). Comparing with standard level (0.1 to 3.0%) set by NACC (2015), it can be concluded that the potassium content in organic fertilizer was higher in all barrels except BB-2.

Sulphur (S)

The sulphur contents measured in organic fertilizer ranged from 0.603 to 0.681% in GB with an average 0.645% and 0.578 to 0.668% with an average 0.601% in BB (Table 2) which was higher than standard level (0.1 to 0.5%) set by NACC (2015). The highest sulphur content was measured in GB-2 and BB-2 and is suitable for organic farming, gardening and harvesting.

Heavy metals in organic fertilizer

Lead (Pb)

The concentration of Pb in organic fertilizer ranges from 30.58 to 39.71 ppm in GB and 22.574 to 28.048 ppm in BB. The highest Pb content was measured in GB-2 and BB-1 with lowest in GB-4 and BB-2 (Figure 3). According to NACC (2015), the permissible level of lead in organic fertilizer is 30 ppm. The concentrations of Pb were high in GB at all stations because of different vegetables having absorbed the heavy metal. In green barrel, there was not any moderation to prepare the organic fertilizer in barrel composting. The concentration of lead exceeded in green barrel in all the four stations. Station St-2 showed the highest concentration that is alarming for student's health. In black barrel, the concentration was below the acceptable level. So, the moderated barrel should be used for composting process.

Cadmium (Cd)

The Cd concentration in organic fertilizer ranged from 1.57 to 2.95 ppm in GB with highest and lowest Cd content was at St-2 and St-1, respectively. In BB, the Cd content ranged from 1.52 to 2.28 ppm while highest at St-1 and lowest at St-2, respectively (Figure 4). The Cd concentration in both GB and BB at all the stations is within the standard level.

Chromium (Cr)

The Cr concentration of organic fertilizer (Figure 5) was highest in GB-4 (24.71 ppm) and BB-1 (21.99 ppm) whereas it was lowest in GB-2 (20.49 ppm) and BB-2 (20.37 ppm). At the same time, all the Cr concentrations at all stations were within the standard of 50 ppm (NACC, 2015).

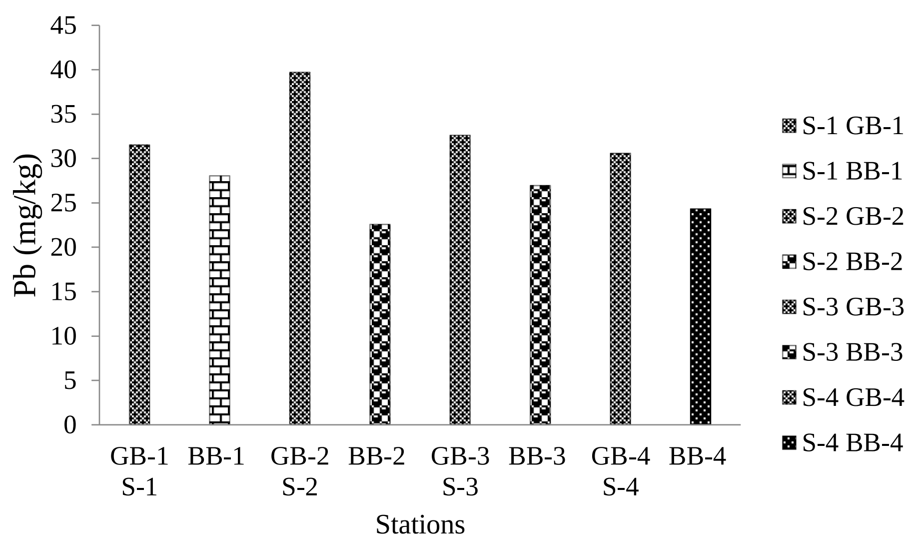

Figure 3: The Pb concentration of organic fertilizer at both GB and BB in four sampling stations

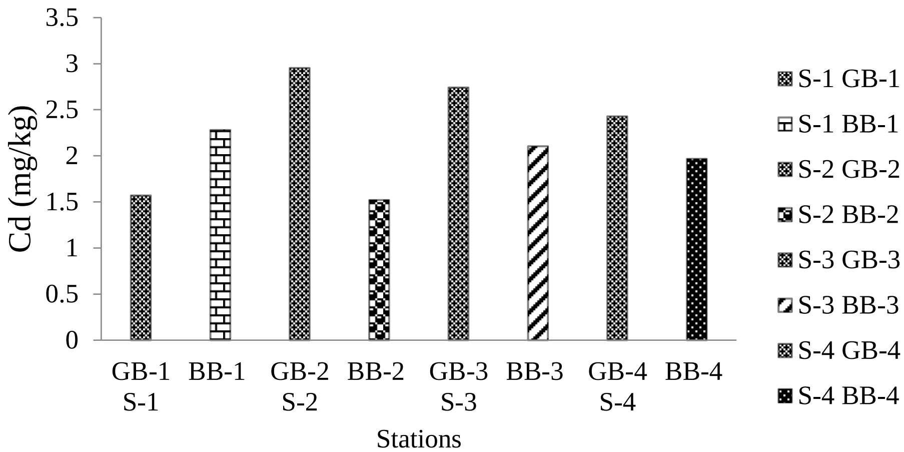

Figure 4: The Cd concentration of organic fertilizer at both GB and BB in four sampling stations

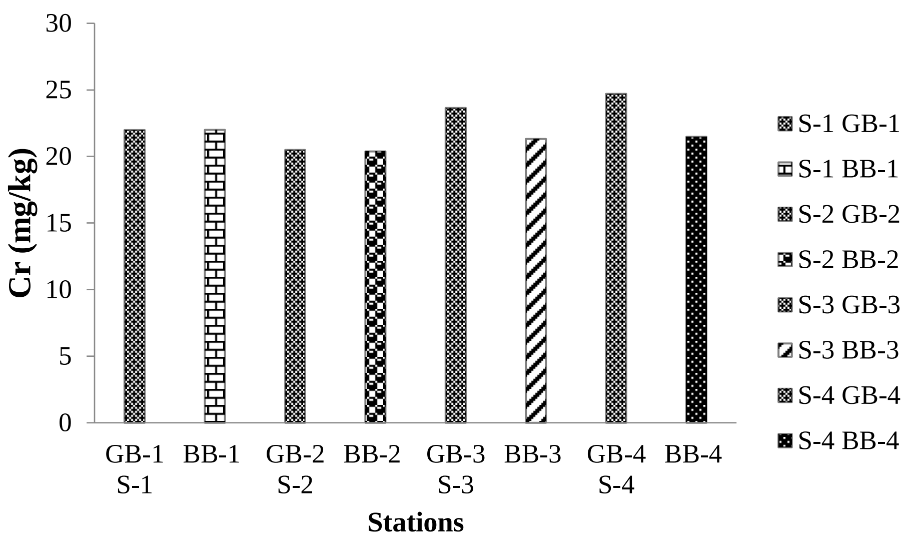

Figure 5: The Cr concentration in organic fertilizer produced from kitchen waste

Pearson correlations among parameters of organic fertilizer in green and black barrels

In GB, pH showed positive correlation with OC, K and Pb but negative correlation with moisture, TN, P, S, Cd and Cr. Moisture showed positive correlation with OC, TN, S, Pb, Cd and Cr but showed negative correlation with P and K (Table 3). The OC showed positive correlation with K, S, Pb and Cd but negative correlation with TN, P and Cr. The TN showed significant negative correlation with K ($r= -.967$, $p<0.05$), and the S showed significant positive correlation with Cd ($r= +.981$, $p<0.05$). The Pb showed positive correlation with Cd but negative correlation with Cr. The Cd showed negative correlation with Cr.

In BB, moisture showed significant positive correlation (Table 4) with Cr ($r= .991$, $p<0.01$) while OC showed significant negative correlation with P ($r= -.764$, $p<0.05$), K ($r = -.983$, $p<0.05$), and Pb ($r= -.972$, $p<0.05$). The K showed significant positive correlation with Pb ($r= +.988$, $p<0.05$).

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The Pb showed significant positive correlation with Cd (r= +.952, p<0.05) whereas Cd showed a significant positive correlation with Cr (r= +.961, p<0.05).

Table 3: Pearson correlation coefficient (r-values) among physicochemical parameters, nutrients and heavy metals of organic fertilizer in green barrel (GB)

Parameters	pH	Moisture	OC	TN	P	K	S	Pb	Cd	Cr
pH	1									
Moisture	-.204	1								
OC	.260	.808	1							
TN	-.791	.576	-.008	1						
P	-.442	-.238	-.079	-.158	1					
K	.920	-.458	.106	-.967*	-.084	1				
S	-.489	.304	.394	.102	.851	-.273	1			
Pb	.195	.243	.678	-.445	.597	.359	.759	1		
Cd	-.649	.297	.276	.259	.847	-.439	.981*	.618	1	
Cr	-.712	.032	-.562	.820	-.223	-.815	-.263	-.821	-.071	1

*Correlation is significant at 0.05 levels

Table 4: Pearson correlation coefficient (r-values) among physicochemical parameters, nutrients and heavy metals of organic fertilizer in black barrel (BB)

Parameters	pH	Moisture	OC	TN	P	K	S	Pb	Cd	Cr
pH	1									
Moisture	.631	1								
OC	-.509	-.658	1							
TN	.386	.159	.532	1						
P	.945	.526	-.674	.088	1					
K	.593	.783	-.983*	-.386	.704	1				
S	-.210	-.890	.522	.014	-.104	-.631	1			
Pb	.479	.789	-.972*	-.446	.587	.988*	-.707	1		
Cd	.523	.934	-.861	-.200	.531	.931	-.867	.952*	1	
Cr	.674	.991**	-.747	.073	.607	.855	-.853	.853	.961*	1

*Correlation is significant at 0.05 levels, ** Correlation is significant at the 0.01 levels (2-tailed).

Conclusions

Kitchen waste management through barrel composting system can provide a solution dealing with the most significant component of wastes. It reduces the weight and volume of waste and produces inoffensive and useful organic fertilizer which is enriched with nutrient. After completion of composting process, total 5.8 kg of organic fertilizers was produced from 178.52 kg of kitchen wastes. The temperature, pH and moisture contents of matured compost were within the optimal level indicating good quality of organic fertilizer. The content of OC, N, P and K was within the

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standard level whereas the S content slightly exceeded the standard. The C: N ratio ranged from 10.07 to 12 indicating that the organic fertilizer is sound in quality. The Cd and Cr concentrations in both GB and BB in four stations were within the permissible level, although high Pb concentration was measured in GB. So, the organic fertilizer of GB can be used only for gardening purposes. The organic fertilizer produced in BB i.e. moderated, can be used for all purposes such as commercial and agricultural production. High quality compost i.e. organic fertilizer was produced from the kitchen waste because it was collected directly from the source point of waste generation. Produced organic fertilizer through barrel composting system is energy efficient, inoffensive and nutrient rich. It helps to manage kitchen waste of the Mawlana Bhashani Science and Technology University campus and the Tangail municipality area effectively. Now it's the time to disseminate the knowledge of kitchen waste management through barrel composting system in other university campuses and municipality areas to make their environment clean, green, healthy and friendly.

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