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INVESTIGATION OF OPTIMUM INITIAL MOISTURE CONTENT OF CO-COMPOSTING PROCESS IN KHULNA CITY OF BANGLADESH

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ABSTRACT

Composting is the biological degradation of highly concentrated biodegradable organic wastes in the presence of oxygen (aerobic decomposition) to carbon dioxide and water, whereby the biologically generated waste heat is sufficient to raise the temperature of the composting mass in the thermophilic range (50°C to 65°C). In this study, temperature variation and Volatile Solids reduction of the composting process in different initial moisture content were investigated. Also determine the optimum initial moisture content in co-composting process. Organic solid waste was prepared according to waste proportion vegetable wastes: food wastes: waste paper: sawdust as 40:35:10:15. Organic solid wastes (OSW) and faecal sludge (FS) was mixed ratio 90:10 (OSW: FS). Total seven initial moisture content of organic solid wastes and faecal sludge were taken such as 20%, 30%, 40%, 50%, 60%, 70% and 80%. To investigate the effect of initial moisture content on volatile solids (VS) degradation and temperature parameters for total 14 reactors were used. Composting tests were performed in 30 days duration every initial moisture content. Temperatures at composting mass were continuously monitored. Maximum temperature of composting process was 55°C to 65°C which raised within 7 days in the moisture range between 50% and 70%. The area under the temperature curve in °C.h was highest in the initial moisture range between 50 and 70%. It should be noted that a higher value of the area under the temperature curve indicates higher heat production and thereby higher VS degradation. For detemination of optimum moisture content, the area under the temperature curve in °C.h and %VS reduction was highest in the initial moisture content range between 55% and 70%. VS reduction sharply decreased at an initial moisture content below 30 to 40%.

Keywords: *Organic solid waste (OSW), Temperature, Co-composting, Moisture content and volatile solids reduction*

1. INTRODUCTION

Khulna is the country's third largest city in Bangladesh and has been known as an industrial city with a port. The whole city area is only 2.5 meters above the mean sea level. Khulna has a history of about one hundred years. Composting is the best option for solid waste management. However, composting offers a cost-effective sustainable solution for the biodegradable organic wastes. This is a very effective process for recovering waste materials and for minimizing environmental emission by stabilizing the organic wastes in the shortest period of time. In practice, the main biological process applied for solid wastes is composting (Haug, 1993). Although this biological decomposition can take place under aerobic or anaerobic conditions, composting is mainly considered as anaerobic process. Anaerobic composting has higher odor potential because of the nature of many intermediate metabolites (Haug 1993), whereas aerobic composting minimizes the potential of nuisance odors (Metcalf & Eddy,1979). The decomposition rate in anaerobic composting is also very slow.The use of organic solid waste has a long history mainly in areas of the world. The biodegradable portion could be managed either by recycling and recovering through biological treatment, or disposal to landfills. Solutions for effective and sustainable Faecal Sludge Management (FSM) presents a significant global need. FSM is a relatively new topic, however, it is developing rapidly and gaining acknowledgement. FSM can be managed together with composting process and the find process is usually named as Co-composting.

Co-composting is a resource recovery technique resulting in production of soil conditioner from the combined organic solid waste and Faecal Sludge. Co-composting is the term used to indicate the composting of two different materials together. In this case Faecal Sludge (FS) and organic solid waste (OSW), both are composted together. Other organic materials, which can be used or subjected to Co-composting, comprise animal manure, sawdust, wood chips, bark, slaughter, sludges and solid residues from food and beverage industries. Cocomposting of Faecal Sludge and organic solid waste is advantageous as these two materials complement each other. Faecal sludge is relatively high in nitrogen content on the other hand organic solid waste is high in Carbon content. Both materials can be converted into a useful product by doing Co-composting. High temperatures attained in the composting process are effective in inactivating excreted pathogens contained in the FS and will convert both wastes into a hygienically safe soil conditioner-cum-fertilizer. The key factors affecting the biological decomposition processes are carbon to nitrogen ratio, moisture content, oxygen supply, aeration, particle size, pH, temperature, turning frequency, microorganisms and invertebrates, control of pathogens, degree of decomposition and nitrogen conservation (Strauss et al, 2003 and Diaz et al., 2002) consequential products of biological metabolism are compost, carbon dioxide, water and heat (Bari and Koenig, 2001). A general rule of thumb for pathogen the high temperature during the composting of various materials is effective for the pasteurization of pathogenic microorganisms in the materials, for the promotion of water evaporation from the composting solid materials, and for the acceleration of the rate of degradation of organic matter in the composting materials. Microbial activity and the physical structure in the composting process can be affected by moisture content; also it has a central influence on the biodegradation of organic materials (Zhang et al., 2013). A moisture content of 50 to 70 percent of total weight is considered ideal (Daniel, 2014). To a moisture content below 40%, microbial activity decreases and to greater than 65% water expels air most of the interstices between the particles of biomass, which hinders the diffusion of oxygen and can lead to conditions microaerophilic or anaerobic (Scoton et al., 2013). By filling voids between waste particles and increasing the potential of compaction, the high moisture content reduces the free air space and lessens the oxygen accessible to microorganism leading to anaerobic conditions (Zhang et al., 2013). Most compostable materials have a lower- than- ideal water content, the composting process may be slower than desired if water is not added (Daniel, 2014). High or very high moisture content, more than 80%, does not compromise the nutrient content of the compost (Vázquez and Soto, 2017).

In wet and dry season, the moisture content always decrease after composting in most of the composting process. The volatile solid was always decreases after composting process (Alamin et at., 2017). In wet and dry season's maximum temperature of passively aeration inside reactors were almost same (Alamin et at., 2017). A comparison of the areas under the temperature curves for different composting layers and their respective self-heating tests confirm the biological degradation results obtained by the multilayer analysis (Bari & Koenig., 2000). The total initial mass of Biodegradable volatile solids (BVS) for different pilot-scale tests was estimated from the sum of the volatile solids degraded in the first stage, second stage and a further self-heating test (LAGA., 1985; Koenig & Bari., 1998) after the second stage. Turning also reduces particle size (Bari, 1999) and increases biodegradation rates (Tiquia et al., 1997; Hamelers., 1993). Using a linear relationship between outlet air temperature and mean internal temperature of the composting mass the extent of degradation in the composting mass was predicted on the basis of outlet air temperature alone (Bari et. at., 2000). Finstein & Miller (1985) noted that, for any given processing duration, the higher the rate the more stable and easily handled the residue and this facilitates storage, transport, and final disposal with a minimal cost. The aim of this study was (i) to investigate temperatura variation and volatile solids degradation of the Co-composting process in different initial moisture content and (ii) to determine the optimum moisture content in co-composting process.

2. MATERIALS AND METHODS

2.1 Source, type and preparation of wastes

In forced aeration composting process, total seven initial moisture content such as 20%, 30%, 40%, 50%, 60%, 70% and 80% of organic solid wastes and faecal sludge. Two reactors were taken for every initial moisture content. Total seven initial moisture content was selected and taken 14 reactors. Suitable organic solid wastes were collected from a student's hall of KUET and solid waste management plant. Sawdust was collected from a local sawmills and waste paper from offices. Sawdust was used as a bulking agent in the composting process. The faecal sludge was collected from a septic tank. Organic solid waste was prepared according to waste proportion vegetable wastes: food wastes: waste paper: sawdust as 40:35:10:15. Organic solid waste (OSW) and faecal sludge (FS) ratio are 85:15. In the Co-composting process was done using a series of reactors. All the wastes were mixed uniformly. Collected different waste was mixed at the roof of the Civil Engineering Department in KUET are shown Figure 1. Water was added to prepare different initial moisture content of dry mixed waste and to put into the reactor.

Figure 1: Collected different waste mixing at roof of Civil Engineering Department in KUET

2.2 Bench scale Reactor

Bench-scale tests were conducted using vacuum flasks of 1L volume (Shimizu Brand, Japan) as a bench-scale reactor. About 400 g of waste mixtures is necessary to fill each of the reactors. The waste inside the reactor was compacted loosely to provide proper porosity for composting process. The opening of the flasks were closed by pieces of cork and the thermometers were inserted into the flask for taking reading time to time until the temperature reached the ambient temperature. Before and after experiments the selected physical tests like total solids, moisture content and volatile solids were performed. The temperature reading was collected for these reactors for 28 days. It was also observed in the variation of temperature during the process. Then total solids, moisture content and volatile solids were determined and variation in different moisture content calculated.

2.3 Experimental program

The study was concluded by means of different initial moisture content of the bench scale reactor in accord with the specifically designed experimental program as described in Table 1.Then composting tests were done using a series of reactors, according to a planned experimented program. Total 14 reactors are used for experiment.

Table 1. An experimental program of Co-composting process

weight proportion Organic Solid Waste : Faecal Sludge	Percentage of Initial Moisture Content	Number of reactors
85 : 15	20%	2
	30%	2
	40%	2
	50%	2
	60%	2
	70%	2
	80%	2

3. RESULTS AND DISCUSSION

3.1Temperature variation in forced composting process

When moisture content 20% temperature was almost same to ambient temperature. Maximum temperature of composting process was 65ºC which raised within 7 days in the moisture content 60%. Moisture content 50% reactor maximum temperature was raised 58ºC within 6 days. After 18 days all reactors temperatures were the same which is very close to ambient temperature. when the initial moisture content of the reactor increased the temperature was increased until moisture content 70% but when moisture content increased 70% temperature of the reactor was not increased. It can be concluded that Maximum tempearture increased initial moisture content 55% to 70%. The initial moisture content below 30% of mixed waste do not to work for the composting process. Temperature variation in different moisture content of co-composting process was presented in Figure 2.

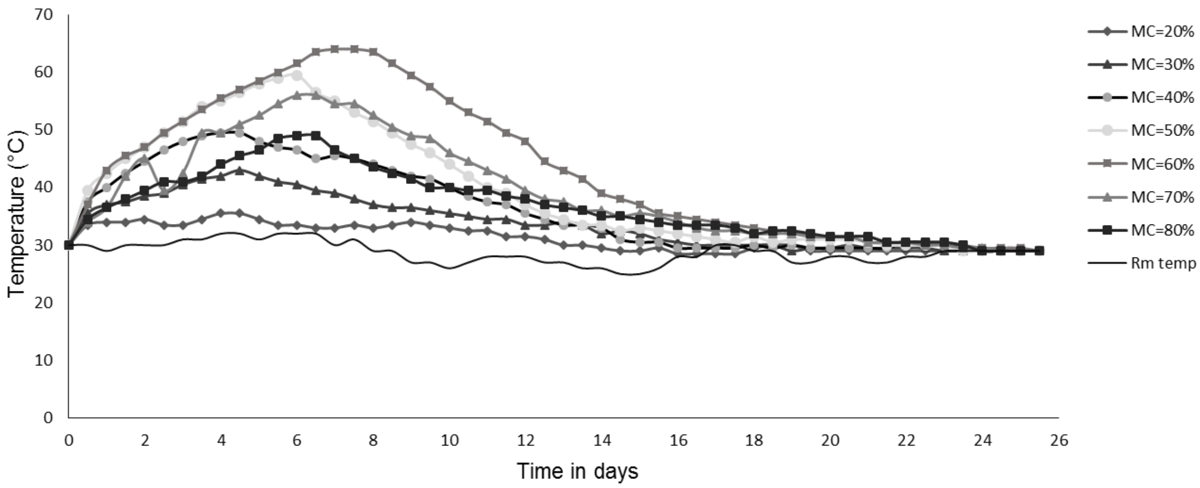

Figure 2: Temperature variation in different moisture content of Co-composting process

3.2 Mass balances for different initial moisture content

The change in total mass (TM), moisture content (MC) and volatile solids (VS)during bench scale Co-composting tests of different initial moisture content was present in Table 2. The moisture content (MC) reported on a wet basis and volatile solids (VS) on a dry basis. Different initial moisture content of the waste mixtures are taken such as 20%, 30%, 40%, 50%, 60%, 70% and 80%. In initial MC 20%, 30%, 40%, 50%, 60%, 70% and 80% forced aerated Co-composting process, the average percent reduction of total mass were 17.1%, 18.4%, 17.3% and 11.9% respectively. In third stage percent reduction of total mass, moisture content volatile solids and fixed solids were 6.5%, 11% 11.4%,14%, 15.5%, 18%, 21% and 15.7% respectively. In the average percent reduction of volatile solids of different initial moisture were 6.5%, 11%, 14.4%, 16.2%, 19.7%, 17.3% and 12% respectively. When moisture content 50% to 70% average total mass and volatile solids reduction were reached maximum. Maximum volatile solids reduction varied 16 % to 20% of moisture content 50% to 70%. When initial moisture content are increased to 80% then average total mass and volatile solids reduction were decreased. Initial moisture content 20% to 40% of waste mixture total mass reduction are sharply decreased.

Table 2: Change in total mass, moisture content and volatile solids of forced aeration process in different moisture content

Initial MC	Reactor No	Total mass initial (gm)	Total mass final (gm)	Reduction %	MC initial (gm)	MC final (gm)	Reduction %	VS initial (gm)	VS final (gm)	Reduction %
20%	R-1	318	295	7.2	64	58	8.9	220	204	7.2
	R-2	335	315	6.0	67	62	8.0	231	218	5.9
30%	R-3	385	343	10.9	116	99	14.6	232	208	10.5
	R-4	370	326	11.9	111	94	14.9	223	198	11.3
40%	R-5	423	354	16.3	169	133	21.4	214	184	14.0
	R-6	420	366	12.9	168	151	10.0	213	181	14.8
50%	R-7	560	475	15.2	280	233	16.8	231	193	16.5
	R-8	559	470	15.9	280	229	18.2	230	193	16.0
60%	R-9	720	586	18.6	432	347	19.8	241	194	19.5
	R-10	705	575	18.4	423	343	18.9	236	189	20.0
70%	R-11	634	494	22.1	444	331	25.5	163	134	17.5
	R-12	694	550	20.7	486	371	23.6	178	147	17.2
80%	R-13	742	627	15.5	594	493	16.9	127	111	13.0
	R-14	735	623	15.2	588	488	17.0	126	112	11.4

3.3 Relationship between Moisture Conteent VS Degradation

Total seven initial moisture content from 20% to 80% of organic solid wastes and faecal sludge were selected to test using conduct under run 14 reactors to investigate the effect of initial moisture content on VS degradation and on temperature parameters. The %VS reduction was highest in the moisture range between 50 and 70%. VS reduction sharply decreased at an initial moisture content below 30 to 40%. Maximum volatile solids reduction percentage 19.72% of initial moisture content 60%. Relationship between % VS reduction and initial % moisture content in bench-scale test is illustrated in Figure 3.

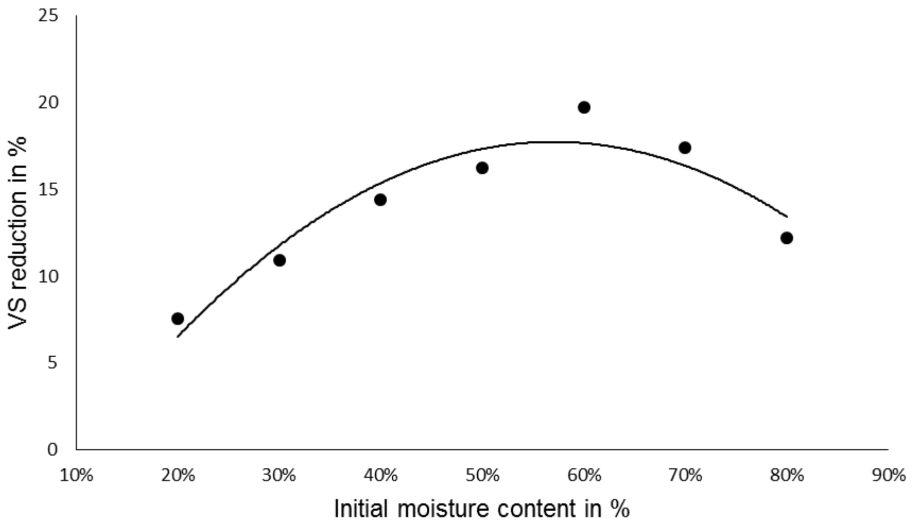

Figure 3**:** Relationship between % VS reduction and initial % moisture content in bench-scale test.

3.4 Relationship between Moisture Content and Temperature

Maximum temperature of composting was 55°C to 65°C which raised within 7 days in the moisture range between 50% and 70%. The area under the temperature curve in °C.h was highest in the initial moisture range between 55 and 70%. °C.h mean that °C is temperature and h is time of co-compost process in hour. Temperaure (°C) with co-composting period (h) is area under temperature (°C.h). It should be noted that a higher value of the area under the temperature curve indicates higher heat production and thereby higher VS degradation. The relationship between the area under the temperature curve and the initial moisture content in bench-scale tests using 14 reactors is illustrated in Figure 4.

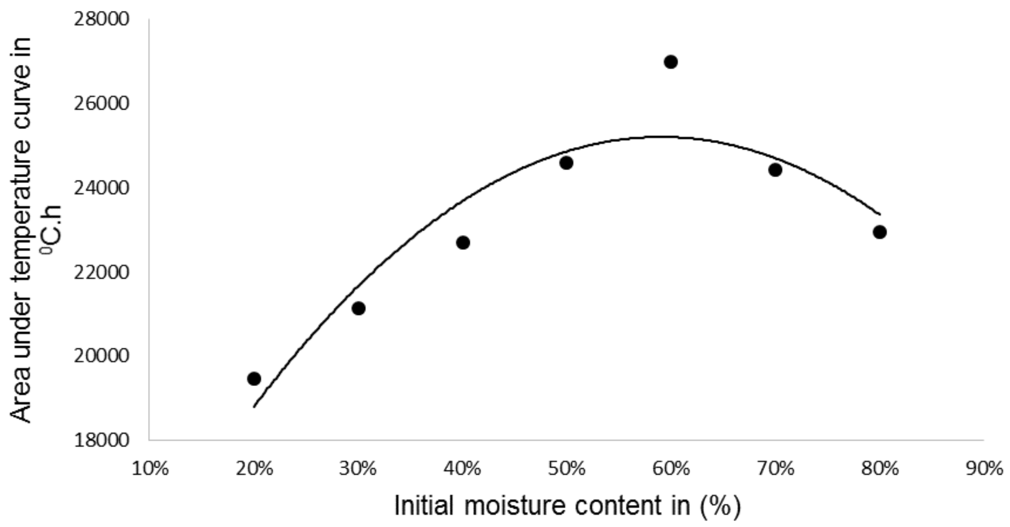

Figure 4: Relationship between the area under temperature curve and initial % moisture content in bench-scale test

3.5 Relationship between Volatile solids reduction (%) and Arean under temperature

An attempt have been made so far to establish the relationships among the area under the temperature curves and VS reduction (%) according to Bari(1999) using data of more than 14 reactors which were applied for similar type waste mixture different moisture content of compost. For forced aeration composting process, the correlation between $A_{total-ambient}$ (area under net temperature increase curve) in °C.h and volatile solids reduction (%) is presented Figure 5. The correlation co-efficient was R^2 = 0.9446 which followed a linear relation. In forced aeration Co-composting process can be determined more exactly volatile solids degradation from the correlation between area under temperature curve and VS reduction (%) with different moisture content.

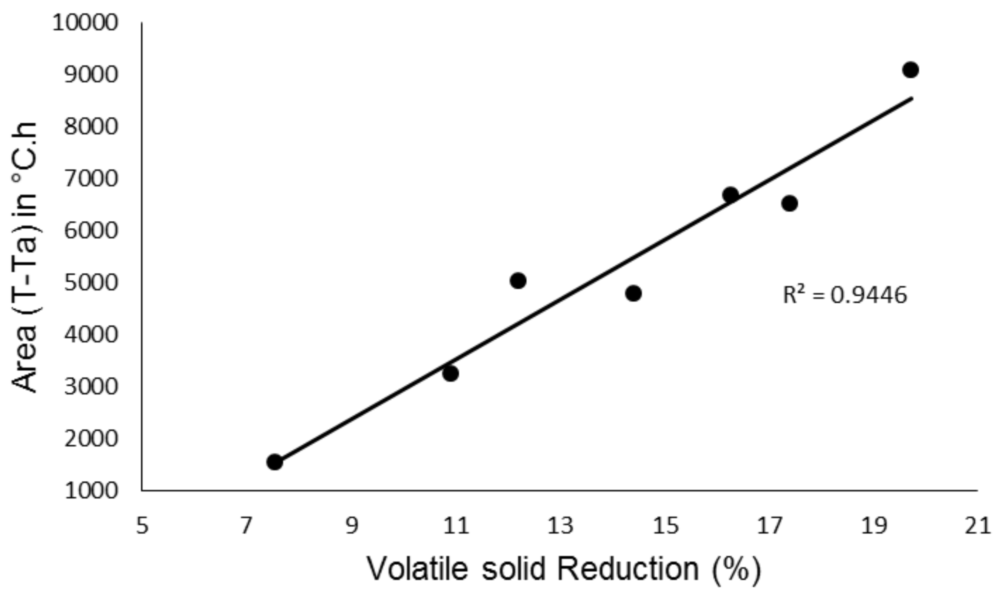

Figure 5: Correlation between $A_{total-ambient}$ (area under temperature curve after completion) in °C.h and Volatile solids reduction (%) in co-composting process.

4. CONCLUSIONS

Based On The Result Of This Study The Following Conclusions Are Drawn:

- Maximum temperature of composting was 55ºC to 65ºC which raised within 7 days in the moisture range between 55% and 70%.
- In the volatile solids reduction sharply decreased at an initial moisture content below 30 to 40%. Maximum volatile solids reduction percentage 19.72% of initial moisture content 60%. The %VS reduction was highest in the moisture range between 55 and 70%. Volatile solids reduction sharply decreased at an initial moisture content below 30 to 40%.
- In forced aeration co-composting process can be determined more exactly volatile solids degradation from the correlation between area under temperature curve and VS reduction (%) with different moisture content.
- The area under the temperature curve in ºC.h and %VS reduction is found to highest in the initial moisture content range between 55 to 70%. It should be noted that a higher value of the area under the temperature curve indicates higher heat production and thereby higher VS degradation.

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