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Design and Fabrication of In-Vessel Composting Machine for Food Waste

Shaifatulna'im Shamsuddin[1], Mohd Asyraf Md Junos[2]

[1#]Mathematics, Science and Computer Department, Kuching Polytechnic, Locked Bag 3094, KM 22, Matang Road, 93050 Kuching, Sarawak, Malaysia

[2#]Petrochemical Engineering Department, Kuching Polytechnic, Locked Bag 3094, KM 22, Matang Road, 93050 Kuching, Sarawak, Malaysia

[1] *shaitulnaim@poliku.edu.my*

[2] *asyraf@poliku.edu.my*

Abstract

In Malaysia disposal food waste at landfill sites is the largest source for emission of greenhouse gasses (GHG). In line with the government's National Strategic Plan reducing GHG by diverting food waste from entering landfill, Blueprint POLYGreen Polytechnic Malaysia was launched on 1st April 2015 .Food waste contributes the largest domestic waste in polytechnics. Hence, in order to manage food waste which an average of 100L/ week and towards the implementation of food waste composting before or by year 2019, Polytechnic Kuching Sarawak is committed to conduct a pilot project using in-vessel composting method. In this project, small scale food waste composter machine with a maximum load of 6 kg of food waste is designed and fabricated. Meanwhile, the optimum composting condition in the vessel is maintained by Peripheral Interface Controller (PIC). The performance of in – vessel composting machine food waste machine is evaluated by loading a 2 kg of food waste consist of vegetable scrap, fish processing and onion as bulking material into the composter and compost cycle for 30 days. C/N ratio, pH value, moisture content and N-P-K ratio obtained shows final compost were matured and produce complete fertilizer. These results will be an input and will be helpful for better understanding about in-vessel food waste composting and will have important implications in developing appropriate treatment of food waste using in-vessel composting in Polytechnic Kuching Sarawak.

Keywords *— food waste, in-vessel composting , CN ratio, quality of compost.*

1. Introduction

In 2005 municipal solid waste generated was 7.34 millions tons and predicted to increase to 10.9 millions tons in 2020 , *(Alias 2010).* Food waste content is about 60 % of the municipal solid waste, thus the estimate amount of food waste generated in 2005 is 4.404 million tons and estimated to increase to 6.54 million tons in 2020 *(Azlina et al 2012).* Food waste in Malaysia is not segregate at source nor separated from other solid waste at landfill sites before disposal. At present there are 289 landfills in Malaysia and only 7 out of total landfill are sanitary landfill *(Syed Ali ,2009)*.The high amount of food waste generated is the main cause to most of the issue related to landfills such as foul odour, toxic leacheate, emission of greenhouse gases and vermin infestation *(Lee, et al. 2007).* Composting has emerge as an attractive option for treating food waste due less environment pollution and beneficial use of the final product . One of the potential recycling method of food waste in Malaysia is in-vessel composting (**Table 1**) *(Azlina et al 2012)*. This is because these technologies as by the products are relatively safe, can be used as soil amendment *(Kim and Kim, 2010)*. Besides, recycling the abundant of food waste can producing revenue from sale of biogas , animal feeds and agricultural compost *(Azlina et al 2012).*

Table 1 : Potential recycling method of food waste in Malaysia is in-vessel composting *(Azlina et al 2012)*

Food waste recycling option	Description	Examples of countries applying recycling options
Anaerobic digestion/Co-digestion	Food waste is collected and fermented to produce methane gas which is collected as renewable energy *(Knipe, 2005)*	Germany, Great Britain
Composting	Home composting(food waste digesters) or in vessel composting facility whereby the product can be used as fertilizers or soil amendment (*Knipe, 2005* and *Kim and Kim 2010*)	Great Britain , Korea
Dry or wet feed	Facility that processes and converts food waste into safe animal feeds (*Kim and Kim , 2010*)	Korea

Currently, there are 30 polytechnics across Malaysia with an average of 5000 to 6500 residents per polytechnic at one time. Based on this, food waste contributes the largest domestic waste in polytechnics. Hence, in order to manage food waste which an average of 100L/week, frequent trips of waste collection are needed and as a result, increase the cost of waste management to the polytechnic. So to overcome this problem and to reduce the use of space in landfill, polytechnic has decided to implement in-vessel food waste composting. Each polytechnic will be installed with food waste composter which can hold a capacity of 200 kg and can produce as much as 60 kg compost and 7 days retention time. Therefore, this project is a pilot project to the Polytechnic Kuching Sarawak to support the POLYGreen programme towards the implementation of food waste composting before or by year 2019.

There is a lot of interest towards understanding in-vessel composting method. Hence, in this project, small scale food waste composter machine with a maximum load < 10L or <10 kg of food waste is designed and fabricated. Two main objectives of this study are to design and fabricate economic in - vessel composting for food waste machine and to evaluate the performance of in - vessel composter for food wastes treatment. The evaluations including the quality of the final compost which is C/N ratio, pH value, N P K and moisture content are studied. As, the performance of in – vessel composting machine food waste machine is not known. Therefore, the quality at final compost will be an input and will be helpful for better understanding about in-vessel food waste composting. The results obtain of this study will have important implications in developing appropriate treatment of food waste using in-vessel composting in Polytechnic Kuching Sarawak

2. Methodology

2.1 Materials and Components

The In-Vessel Composting Machine for food waste project involved designing, fabricating, and programming and testing. The design stage includes identification of product, providing a sketching, brainstorming for the best possible design and material, conducting the fabrication of the composter and testing refer are illustrated in **Figure 1** Designing Stages In Fabricating IVC**, Figure 2** Flow Charts In Fabricating IVC and **Table 2** List of Component.

Figure 1 – Designing Stages In Fabricating IVC

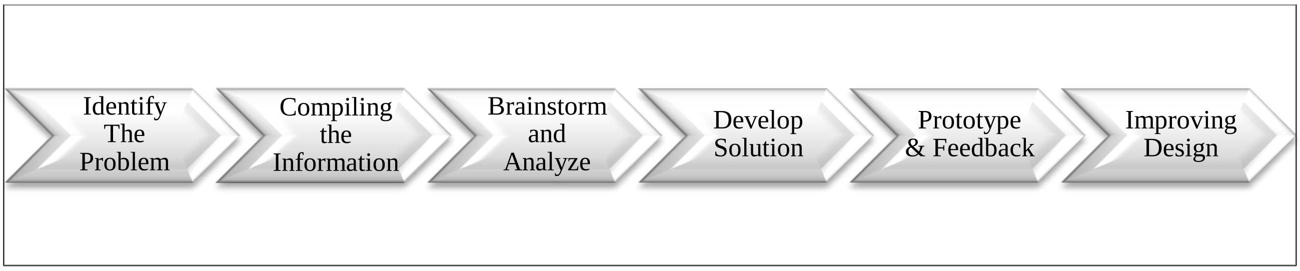

Figure 2 – Flow Charts In Fabricating IVC

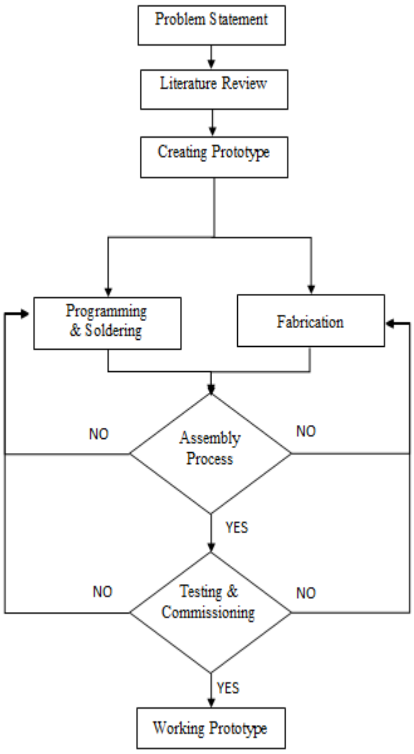

Table 2 – List of Components In Vessel Composter

No	Part	Material	Details
1.	Casing	Aluminium Sheet	Reliable & easy to bend
2.	Frame	Aluminium Tube	Lightweight
4.	Flip plate	Steel rod, steel plate	Must be thick enough for welding
5.	Stirrer	Steel rod	Need to bend
6.	Heater	Steel Heating Element	Need to bend
7.	Fan for Air Inlet / Outlet with cover	Thin PC Fan	With specific fan speed as calculated.
8.	Power Supply Unit	Same spec used on PC	400W, Compact design
9.	Controller Box	PVC / ABS / Plastic	To protect the micro controller
10.	Trap Box for Activated Carbon	Wiring Mesh	Absorb the inconvenient smell.
11.	Holder for Motor	Aluminium plate	Affix motor for Flipper and Stirrer,
12.	Collection Chamber	Plastic	Container for finished product

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In this study, the temperature probe is assembled to control temperature of compost is in the optimum range 55^0C to 65^0C. This is because most of the studies reported that the optimum temperature range for effective decomposition was at 50^0C to 70 ^{0}C. In thermophilic temperature, the dominant micro-organisms might attack rapidly soluble readily degradable compounds, high content of available nutrients and relatively small size of organic fraction particles. It is also reported that composting above 55^0C could kill pathogen and sanitize the compost. Temperature of the composting must be below 75^0C because higher temperature cause denaturation of enzymes in microbial cells. (*Mohd Ali Hassan et al 2010*)

Turning and mixing is important to allow uniform moisture distribution and to aerate and agitated the material. Turning frequency depends on the rate of the composting. If the temperature is above 70^0C, Fan will be switch ON to dissipate heat. A blower is used to forced or to draw air through the pile (*Mohd Ali Hassan et al 2010*) . In this study a 2 unit of fan is assemble to provide positive and negative aeration in the composter. One is for draws air into the composting chamber. And the other is for draws out air from the composting chamber for dissipate heat function. In this study PIC microcontrollers are programmed to be timers and control aeration , mixing process, moisture control in the composting chamber and transferring process from upper chamber of composting to lower chamber for curing process.

2.2 Method

Preparation Amount of Substrate Compositions

The main composting substrates were vegetables scraps from spinach and fish processing waste. The root of spinach and ¾ of its stem were chopped into maximum length of 2cm. The unused parts of mackerels were removed and ground using a kitchen blender. The onion (*Allium cepa L)* peels were obtain from grocery shop. All the compostable material were mixed manually in a basin before loading into the vessel of the composter**.** The compost cycle was for 30 days

Onion peels were chosen as onion peels is easily available bulking agent, can act as a moisture adjuster due to low moisture content and high cellulose content, which can be a good source of carbon. The characteristic of waste and bulking agent in terms of percentage of moisture, carbon and nitrogen content, and the values of the carbon to nitrogen (CN) ratio have been measured in an earlier study (*Norazlina Abdullah 2010)* . The optimized mixture formulation for kitchen waste composting was referred from *Norazlina Abdullah (2013),* following the fixed CN ratio of 30 and MC of 60%. **Table 3** shows the amount of substrate compositions. All substrates were weighed using a weighing scale, then mixed manually in a basin before loading into the composter. Compost cycle was for 30 days and the composters were placed in the laboratory at 25 $\pm$ 5 ^{o} C.

Table 3 - Amount of Substrate Compositions Used In The Experiment. *(Norazlina Abdullah 2013)*

Substrate	Amount (g)
Load size	2kg
Vegetable scraps	880g
Fish processing waste	395g
Onion peels	725g

2.3 Compost Maturity test

In this study, after 30 days of kitchen waste composting the CN ratio, moisture content, pH value, and N-P-K content of final compost were determined. The final compost quality testing are conducted at Sarawak Plantation Chemistry Lab for two batch. Which is sampel for batch **27 Jun - 27 July 2015** and **28 July - 27 August 2015.** The ideal moisture content for composting will depend on the water holding capacity of the materials being composted. Composting proceeds best at a moisture content of 50–60% by weight. The moisture content tended to decrease due to the high temperature level and aeration during composting process in the thermophilic phase in the IVC machine.

pH is a measure of soil acidity or soil alkalinity. A number express pH on a scale from 0 to 14. A neutral reading is 7. Any reading below 7 represent an acid soil and the lower the number the more acidic the soil. Any number above 7 indicates an alkaline condition and alkalinity increases as the number on the scale increases. Optimum pH will vary from plant to plant, but a pH between 5.0 to 7.0 is generally accepted as the best range for most plants. The pH of the soil governs what nutrient are available to plants. if the soil pH is above or below the recommended range (5.0-7.0) nutrient may be not be soluble (absorbable by plants)or they may be so soluble that they become Phytotoxic . Therefore a plant can show sign of nutrient deficiencies or toxicity even when the correct amount of fertilizer is applied to the plant.

Each fertilizer contains different nutrient.Prominent featured will be the N-P-K ratio. The percentage the product contains by volume of nitrogen , (chemical symbol N) , volume of phosphorus (chemical symbol P) and volume of potassium (chemical symbol K). A 16-16-16 formulation fetilizer for example contains 16% nitrogen, 16% phosphorus and 16% potassium. All fertilizers contains at least one of these component. If anything is missing, the ratio will show a zero for that nutrient (a 12-0-0 contains nitrogen and but no phosphorus or potassium for instance)

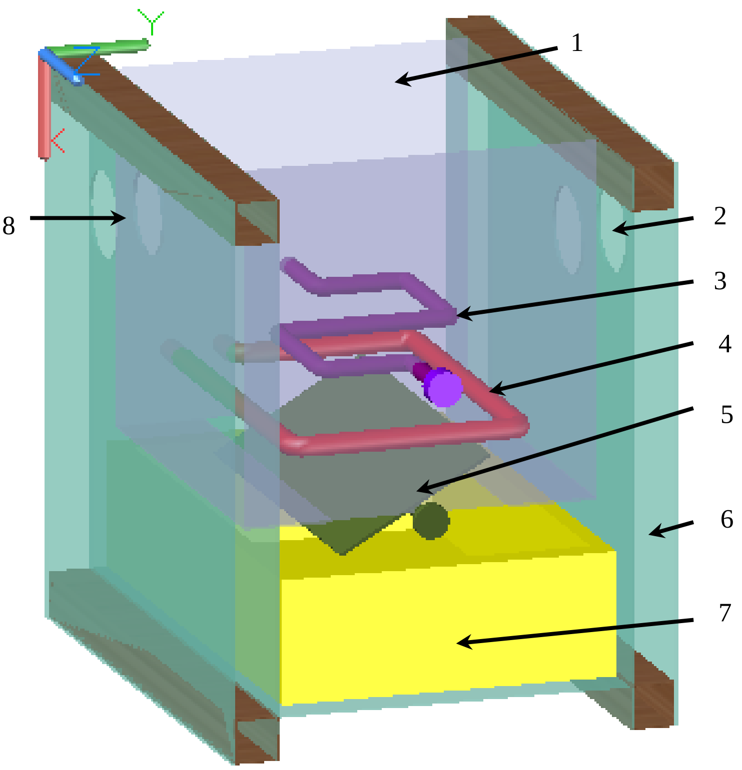
A fertilizer containing all three major nutrients is called complete fertilizer a product that supplies only one or two of them is an incomplete fertilizer, Using a complete fertilizer for every garden purpose seems sensible but in fact it isn't always the best choice. If the soil contains sufficient phosphorus and potassium and is deficient only in nitrogen you can save money by using incomplete fertilizer that provides nitrogen alone. (aluminium sulfate for example). In some instance complete fertilizers can even harm a plant.

Table 4 - Qualities CN Ratio And pH Of Compost For On Farm Use

Criteria	Optimum Quality
C:N ratio	15 – 20 : 1
Neutral pH	6-8
Moisture Content	35 – 60

3. Result and discussion

A. CAD Diagram of In Vessel Composter



No	Part
1.	Composting Chamber
2.	Fan for Air Inlet / Outlet with cover
3.	Heater
4.	Stirrer
5.	Flip plate
6.	Casing Frame
7.	Collection Chamber
8.	Trap Box for Activated Carbon

B. Compost Maturity test

Table 5 – Result of Final Compost Compared To Optimum Range *(Norazlina Abdullah 2013)*

Parameter	LOAD SIZE OF 2 KG			Optimum Range
	Sample A 27 Jun - 27 July 2015	Sample B 28 July - 27 August 2015	Sample C (Norazlina 2013)	
pH	7.6	7.6	-	5.5 - 8

Moisture (% as received)	48.9	46.9	-	35 - 60
N (% Oven Dry)	1.55	1.60	-	Do not have specific value, differ according to the type of applications needed.
P (% Oven Dry)	0.583	0.605	-	
K (% Oven Dry)	1.04	1.11	-	
C / N Ratio	9.29	9.69	9.22	10-15

CN ratio is an accurate indication of compost maturity. The carbon provides the primary energy source for microbial population growth. CN ratio starts ideally at 30 but can be higher. As carbon is broken down through composting, the CN ratio drops. Depending on the nature of the starting materials, a final ratio of 15 to 20 generally indicates a finished product.*(Umass Amherst 2014)*. In this study at after 30 days the C/N ratio is 9.29 and 9.69. It is well known that a C/N ratio below 20 is indicative of proper compost maturity. The ideal moisture content for composting will depend on the water holding capacity of the materials being composted. Composting proceeds best at a moisture content of 50–60% by weight. The moisture content tended to decrease due to the high temperature level and aeration during composting process in the thermophilic phase in the IVC machine. In this study the initial moisture content was reduced to reach 48.9% and 46.9% of weight at final compost.

It is important to measure pH of compost because pH value is indication of decomposition process. Compost microorganisms operate best under neutral to acidic conditions, with pH's in the range of 5.5 to 8. During the initial stages of decomposition, organic acids are formed. The acidic conditions are favourable for growth of fungi and breakdown of lignin and cellulose. As composting proceeds, the organic acids become neutralized, and mature compost generally has a pH between 6 and 8. The pH of finished compost should be near neutral (7.0). Values below 6 and above 8 may indicate a problem with the starting materials, the composting process, or both. In this study at the end of 30 days pH for both of the final compost is 7.6.

Besides, in this study, food waste has been used as an organic matter to produce compost. Thus this compost are also known as organic fertilizers. Important characteristic about organic fertilizers is organic fertilizer release their nutrients slowly rather than dissolving in water, organic fertilizer broken down by bacteria in the soil, providing nutrients as they decompose. Generally, the N-P-K ratio of compost varies from 1.5 - 0.5 - 1 to 3.5-1-2. In this study the N-P-K of final compost is within that range which is 1.55 - 0.583 - 1.04 and 1.6 - 0.605 - 1.11. For the quality of final compost in this study containing all three major nutrients therefore the final compost are also known as complete fertilizer.

4. Conclusion

In this study, there are a lot of aspects were considered before the fabrication, during the manufacturing process and after the testing of In –Vessel Food Waste Composter takes place. Prior to the fabrication, physical characteristic of food waste composter and specification of IVC were identified. Next, other parameter which need to put into consideration including maximum capacity, size, temperature, retention time, turning frequency, force aeration and curing area. Hence, once the details specifications are recognized, the appropriate fabrication process are selected. Simultaneously, the programming of the PIC has to be developed. Post manufacturing involving the data analysing process.

PIC systems monitor the temperature of the compost by controlling the heating element. The temperature probe will sense the heat in order to ensure the temperature are keep within the limit of 50^0C to 65^0C. Wet condition resulting a lower temperature than the limit, thus trigger the heating element to heat up. The heating process stops once the probe detect the temperature of the chamber at 66^0C. IVC also have mixing features which working automatically. A programmable motorized

Stirrer will do the mixing process by turning 1 minute per cycles for every 48 hour. The composter is turned automatically to prevent shortage of oxygen pore required for aerobic composting.

A pair of fan serves the function of force aeration. It is located at the right and left side for inlet and outlet purpose and supplying positive flows. The fans are functioning intermittently. Aeration is crucial as it is needed to supply oxygen to the compost and to dissipate excessive heat. Therefore, the fans are programmed to spinout the hot air once the temperature probe sense the temperature at 66^0C. The selected fans are carefully set up to suit the specific volume of air removal and air intake. The inlet fan and outlet fan are working simultaneously at certain rpm for a specific pre-set time. This IVC is using a single batch system. This mean, after food waste are loaded into the chamber, it will undergo the whole composting process, until then, no more waste to stack up on top the first batch. The retention time of IVC is 30 days, hence, after 30 days, the compost are flipped down into to the curing chamber for curing process. This transferring process is done by a motorized Flipper which precisely set to remove the compost at the composting chamber to the curing chamber after the pre-set period. However, manual override is provided. Performance of IVC for food waste treatment was evaluated in this study. Specific conclusions that can be drawn from this study include the following;

i. The design of food waste composter has a sufficient size, operates in order to prevent rapid dissipation of heat and moisture and yet is small enough to allow good air circulation.
ii. The final compost produced in this study was satisfactory for agricultural application.

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