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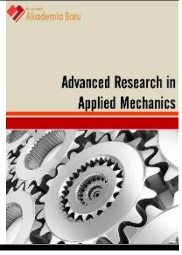

Evaluation of Stability and Maturity of Compost Quality During Composting of Rice Straw Ash with Food Waste

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ABSTRACT

The physicochemical and biological changes was examined during composting of rice straw ash with food waste in order to assess the effectiveness as stability and maturity of compost at initial C:N ratio of 25 with three different aeration rates of 0.4, 0.6, 0.8 L/min.kg. The rice straw was burned at 300°C temperature to produced rice straw ash before being used to compost with a food waste. A laboratory-scale of bin composter reactor in a cone-shape was used during the composting process. The composting mixture with aeration rates of 0.4 and 0.6L/min.kg maintained the temperature exceeding 55°C for three and more than three days to meet the requirement of pathogen destruction compared to the composting mixture with aeration rate 0.8L/min.kg. The final C:N ratio for composting mixture with aeration rates 0.4, 0.6 and 0.8L/min.kg was 13, 12 and 10. The final germination index in composting mixture with aeration rate 0.6 and 0.8L/min.kg was exceed 80%,; however, the germination index in composting mixture with aeration rate 0.4L/min.kg was never over 80%. The pH values and moisture content obtained for all composting mixture was in a range of 7-8 and 40-70%.

1. Introduction

Rice straw is considered one of the most important agricultural residues and represented as one of the major by-products from rice production process in most of the rice producing countries. It was produced after the cereal crops are harvested [26]. The amount of rice straw derived was estimated by the information of the rice production [25]. The production of paddy was increases from more than 2.5 million tonnes in year 2010 into more than 2.7 million tonnes of paddy in year 2014. This means that, the same amount of rice straw residue also was produced in that year (FOASTAT). It is a non-edible product, which often left in the paddy field after harvesting process [17].

The farmers usually burning the rice straw on-farm as a method of disposal after the harvesting season. To avoid the burning process that causing harmful towards human and soil paddy field itself, composting process is seen as a an environmental method in managing the abundance of rice straw

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at paddy field. Composting is a biological process in which organic matter (OM) can be utilize by the aerobic thermophilic and mesophilic microorganisms as substrate and mainly will be converted into mineralized products (CO_2, H_2O, NH_4^+) or stabilized OM, mostly as humic substance [3,12].

However, the main fraction of rice straw is lignocellulose which was difficult to degrade and make the efficient composting performance generally hard to be achieved or required a longer time for the decomposition process [32]. Regarding to the issue of lignocelluloses, rice straw will be burned before being used to help in accelerating the composting process, which is known as rice straw ash (RSA). Food waste was used to be composted with rice straw ash during this study because of its high moisture content. Besides that, in Malaysia, food wastes are one of the largest components of municipal solid waste produced [15]. Although considerable research has been conducted on composting of rice straw with various organic materials [18,21,23,24,32,33], but no information available on the effect of composting rice straw ash with food waste was done.

Application of stable and maturity of compost into the soil as organic amendment can improve the soil structure by increasing soil organic matter; improve the plant growth and soil fertility besides enhancing the function of soil for carbon sequestration [20]. However, if immature and unstable compost was applied into the soil, it would fix the nitrogen contain in the soil and will restrict the plant growth by competing the oxygen and toxic substances will be released [3]. To produce a successfully compost and assure the safety of compost in agriculture land application, the stability and maturity of compost product need to be achieved. Stability of compost are refers to microbial activity. Maturity is refers to the amount of degradation of phytotoxic organic substances [9].

Bernal *et al*., [3] and Nolan *et al*., [19] pointed out that the compost stability and maturity cannot be well described by a single property or parameters. Thus, the stability of compost during this study will be refers to the changes of pH, temperature, moisture content, C:N ratio and aeration rate. Meanwhile, the maturity of compost will refer to the germination test.

The main objective of this study was to evaluated the stability and maturity of compost quality during composting of rice straw ash with food waste at initial C:N ratio of 25 and three different aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg.

2. Materials and Methods

2.1 Source Materials

Food waste (FW) was collected from stalls near School of Environmental Engineering, UniMAP. Rice straw (RS) was collected from a local farmer of paddy field at Arau, Perlis. RS was shredded to 2-3cm to allow a uniform size before the burning process using a shredder machine. RS was burned in a muffle furnace at 300°C for 30 minutes to produce rice straw ash (RSA). Goat dung used as a source of nitrogen for the composting mixture of RSA and was collected from goat farm at Padang Siding, Pauh, Perlis.

Besides that, the prepared liquid effective microorganisms (EM) will be poured into the mixture of compost as a source of microorganism to help in accelerating the decomposition process [20]. EM also functions to reduce the odour emission during the process. EM will be prepared according to the recipe obtained from Solid Waste Corporation (SWCorp), Perlis. One piece of *tempe* will mix with 250g granulated brown sugar and 3liter (fermented the mixture for 1 week before used) for 3kg of waste. The ratio of liquid EM (liter) to compost mixture (kilogram) is 1:1. RS, RSA, FW and GD was characterized for pH, moisture content, C:N ratio, total carbon and nutrient content (nitrogen, phosphorus, potassium) meanwhile the liquid EM was characterize for only pH. The characteristics of the raw materials are presented in Table 1.

Table 1
Characteristics of the Raw Composting Materials

Materials	pH	Moisture content (%)	Total Carbon (%)	Total Nitrogen (%)	C:N	Phosphorus (%)	Potassium (%)
Rice straw ash (300°C)	7.886	7.40	41.66	2.00	20.83	0.08	0.34
Food waste	7.556	81.92	40.00	2.50	16.00	-	-
Goat dung	7.997	11.55	18.22	1.01	18.04	-	-
Effective microorganisms	8.021	-	-	-	-	-	-

2.2 Composting Experiment

A laboratory-scale of bin composter reactor used for this study was modified from other research [1,18] as shown in Fig.1. The reactor is a cone-shape. The dimension of bin composter is 50 cm height and 40cm and 30cm in diameter (top and bottom, respectively). The reactor had a removable lid to be opened each times when the temperature inside the reactor was dropped for sample collection and also for mixing and turning process. A hole was made on the lid of bin composter for gas measurement and air outlet. A rubber stoppers was used as a sealer to the hole during the composting process.

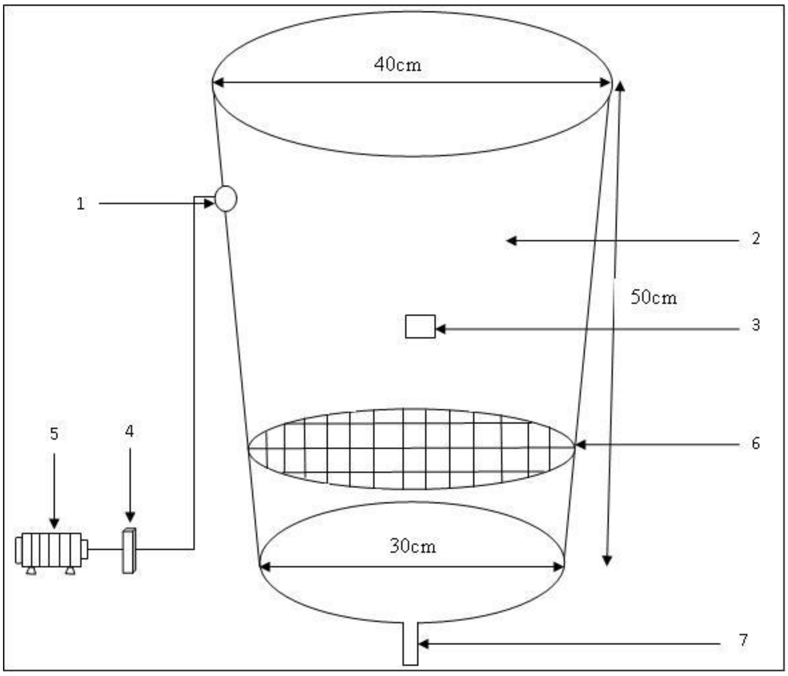

Fig. 1. Composting Reactor and its Component: (1) Gas Sampling Port; (2) Composting Material; (3) Digital Thermometer; (4) Gas Flowmeter; (5) Air Pump; (6) Fine-Masked Net; (7) Leachate Sampling Port

The reactor was equipped with a fine-masked net, 8 cm from the bottom to place the composting materials. An aeration air flow tube was installed 40 cm from the bottom of the reactor to maintain an aerobic condition during the composting process. The air was supply by using an air pump at a controlled rate. A hole also made at the center of the bottom reactor for leachate collection.

The mixture of rice straw ash and food waste with goat dung and EM as organic accelerator are manually mixed in a ratio of 1kg RSA: 2.4kg FW: 2kg GD: 1L EM. Three different aeration rate of 0.40, 0.60 and 0.80L/(min.kg) OM was used during the composting process at an initial C:N ratio of 25. Each composting process lasted 30 days.

The air pump run continuously, but it turned off about 15 minutes for sample collection and also for mixing and turning process once every three days. About 50 gram of sample was withdrawn after each turning once every three days until the end. The sample was divided into two parts. One part was immediately analyzed for pH, total carbon and phytotoxicity evaluation. The other part was air dried to a constant weight at 60°C for 2 days for chemical analysis and then ground the sample to pass through 1-2mm sieve and stored in a dessicator.

2.3 Compost Analysis

The temperature of the compost pile was measured by a digital thermometer recorded daily. About 1g of sample was placed into 10ml de-ionized water, stirred up and then left the mixture to settle before measured the value of pH by using a pH meter electrode [32]. The moisture content was determined by oven drying 5g fresh sample at 105°C for a period of 24 hours (ASTDM, 2003). The carbon to nitrogen ratio was obtained by dividing the value of total carbon to the value of total nitrogen. The seed germination technique was used to evaluate the phytotoxicity of compost extracts [34].

3. Results and Discussions

3.1 pH

The changes of pH in composting of rice straw ash and food waste at different aeration rates are shown in Fig.1. The pH values for composting mixtures at aeration rates 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg increases in the early stages before slightly dropped at the later stages. The increases of pH in composting mixtures was due to the release of ammonia from ammonification and mineralization of organic nitrogen during the initial phase of composting [29]. At the later stages, the pH decreased was caused by the decomposition of organic matter, volatilization of ammonical nitrogen and the production of organic and inorganic acids [5]. The values of pH in all composting mixtures was in a range of 7-9 in which, acceptable for mature compost.

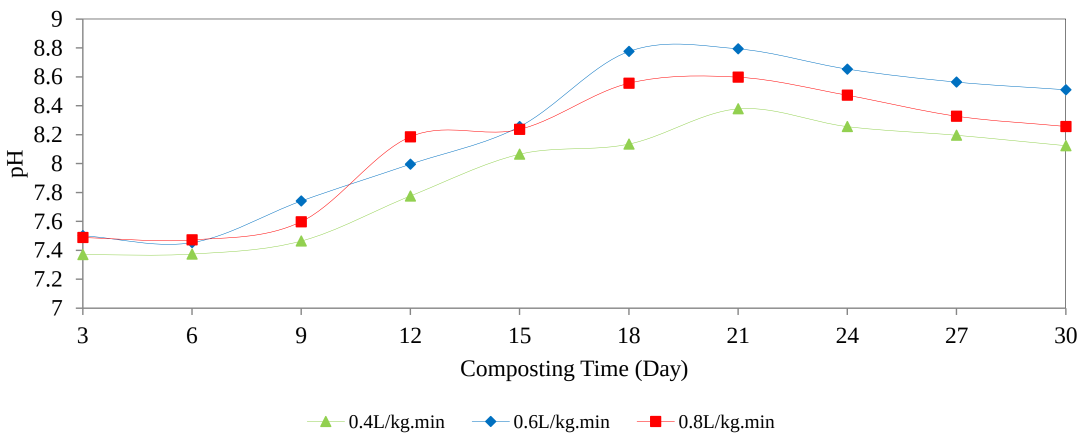

Fig. 2. pH Variation over Composting Time

3.2 Temperature Profile

Fig.2. shows the changes of temperature during the composting mixture with aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg. Temperature affected the physicochemical characteristic, not only biological rates and the population dynamics of microbes [2,13]. It is a very important parameters to monitor the composting process in making the compost enough mature. There are three phases of temperature need to be achieve during the composting process which; meshophilic, thermophilic and curing phase.

According to Zhang and He [31], all composting mixture must exceed 55°C for at least for three consecutive days to destroy the phatogen and weed seed. The temperature in three composting mixture increases rapidly to reach a maximum temperature of 56°C for aeration rate 0.4L/min.kg, 57°C for aeration rate 0.6L/min.kg and 54°C for aeration rate 0.8L/min.kg. The composting mixture with aeration rates of 0.6L/min.kg had a longest thermophilic phase for 10 days with maintained the temperature exceeding 55°C for 5 days. Composting mixture with aeration rate of 0.4L/min.kg had a thermophilic phase for 8 days and maintained the temperature exceeding 55°C for 5 days. It ensured the maximum pathogen reduction and the stabilization of organic matter for composting mixture with aeration rates of 0.4L/min.kg and 0.6K/min.kg. Although the composting mixture with aeration rate of 0.8L/min.kg had a thermophilic phase for 8 days, but it not meet the requirement for pathogen destruction because it not reach the temperature more than 55°C. The composting mixture entered the curing phase after the easily degradable compounds were depleted and then, the temperature slowly dropped to ambient temperature [11].

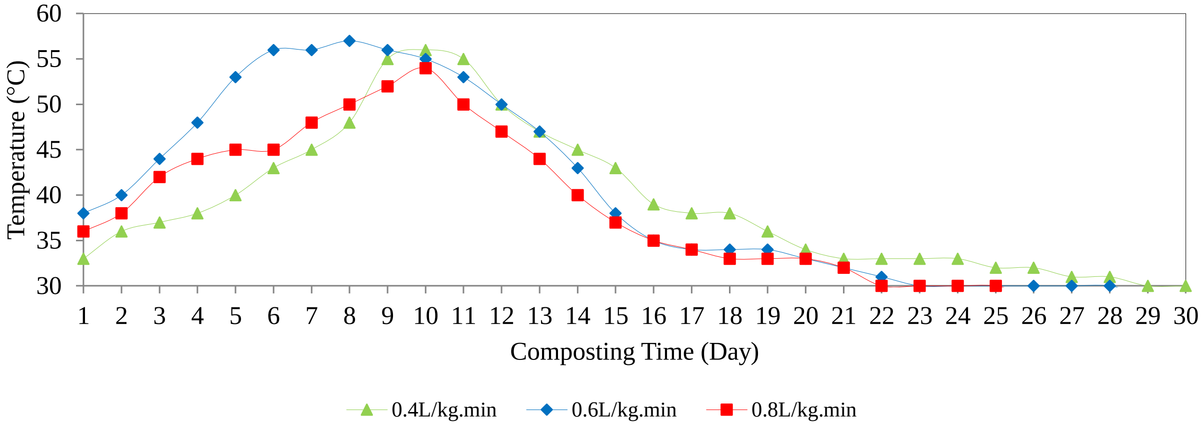

Fig. 3. Temperature Variation over Composting Process

3.3 Moisture Content

Fig. 3 shown the changes values of moisture content that increasing at the early stage of composting process before decreased at the later stage for all composting mixture with aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg. Actually, the different aeration rates used not directly affected the value of moisture content obtained. It is because, the moisture content is important as a medium in transporting the dissolved nutrients that are required for the physiological and metabolic activities of microorganisms [16]. However, the value of moisture content must be between in a range of 40-60% to form a mature compost [10,27]. All the composting mixture of aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg obtained a values of moisture content in that range and the compost had mature after 30 days of the composting process.

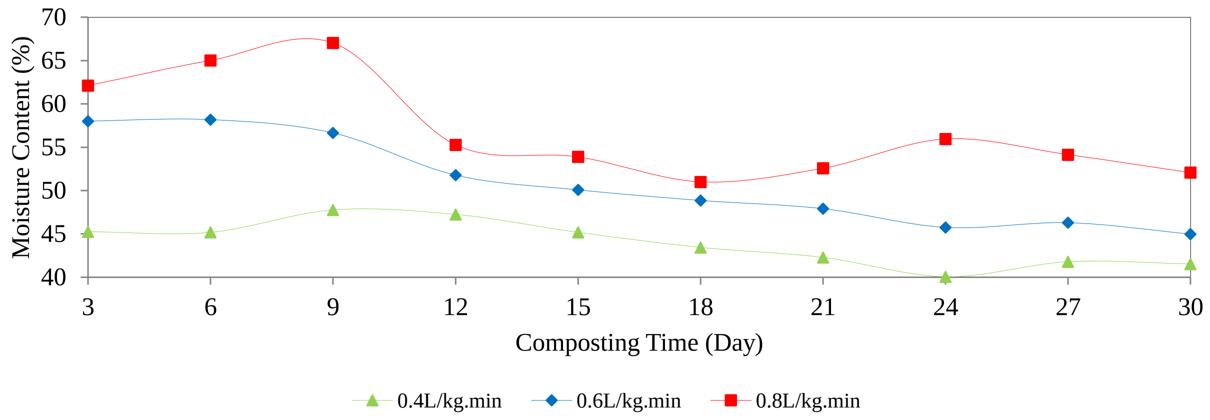

Fig. 3. Moisture content Variation over Composting Time

3.4 Germination Index

The changes of germination index in composting of rice straw ash and food waste at different aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg are shown in Fig.4. According to Gariglio *et al.*, [8] and Brewer and Sullivan [4], germination test is a sensitive indicator of maturity and often conducting to evaluate the phytotoxicity of compost produced. If the GI value obtain more than 80%, it can be considered that the compost has reach the level of maturity and practically the compost was free from phytotoxins substances and mature [28,30].

The GI values was increased for all composting mixture with increase the composting time resulting that all the toxic materials like volatile fatty acids mainly acetic acid and ammonia was decomposed completely [6]. At the end of the composting process, the GI values for composting mixture with aeration rates of 0.6L/min.kg and 0.8L/min.kg were over 80% suggesting that the compost produce was free from toxic substance and enough mature. Composting mixture of aeration rate 0.4L/min.kg only reach 75.56% of GI value on days 30, which was never over 80%. It showed that composting mixture with aeration rates of 0.4L/min.kg was slightly contain toxic materials due to the incomplete decomposition of volatile fatty acids and ammonia.

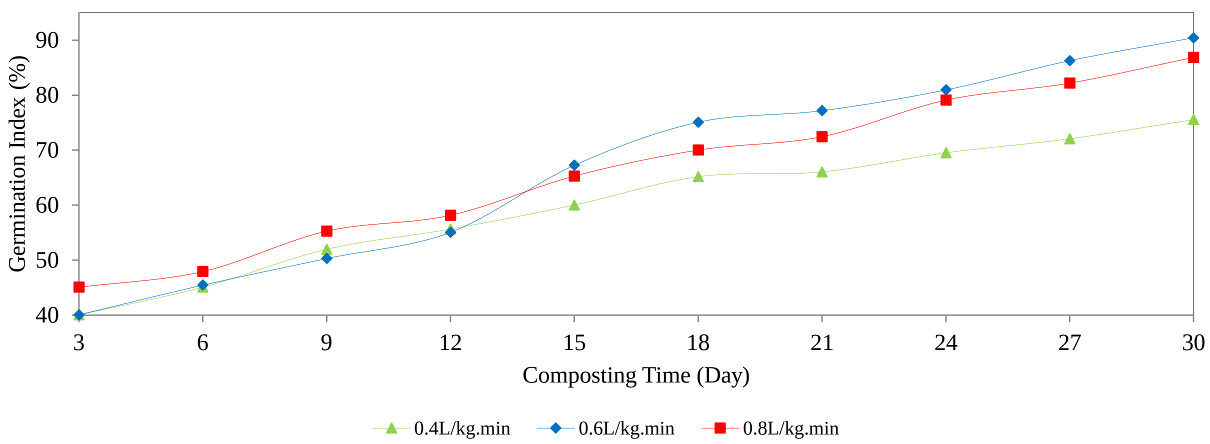

Fig. 4. Germination Index over Composting Time

3. 5 C:N Ratio

The C:N ratio was important to be used to assess the compost maturity during the decomposition process [30]. Table 2. shown the result of composting mixture with different aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg and end C:N ratio on day 30 of the composting process. The end C:N ratio for all composting mixture were decreased to 13 for aeration rate 0.4L/min.kg, 12 for 0.6L/min.kg and 10 for 0.8L/min.kg, was due to the mineralization of organic matter [22]. During the composting process, the C:N ratio appeared stable in maturation stage. According to Bernal *et al.*, [3], when C:N ratio decreased below 15, the compost had satisfied an acceptable standard of maturation. Thus, all the composting mixture with aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg can be defined as mature and can be used without restriction.

Table 2
The results of end C:N ratio for the composting mixtures

Aeration rate (L/kg.min)	Initial C:N ratio	End C:N ratio
0.6	25	13
0.6	25	12
0.6	25	10

3. Conclusion

The stability and maturity of compost quality during composting of rice straw ash with food waste have been investigated at initial C:N ratio of 25 and three different aeration rates of 0.4L/min.kg, 0.6L/min.kg and 0.8L/min.kg. The pH and moisture content values obtained for all three composting mixture obtained in a range that acceptable for mature compost. The composting mixture with aeration rate of 0.4L/min.kg and 0.6L/min.kg maintained the temperature exceeding 55°C for 3 days and 5 days during the composting but the composting mixture with aeration rate 0.8L/min.kg only reach the thermophilic phase but the temperature not exceeding 55°C for pathogen destruction. The final GI value in composting mixture of 0.6L/min.kg was 90.43% and 86.86% for composting mixture with aeration rate 0.8L/min.kg. However, the composting mixture with aeration rate of 0.4L/min.kg was never ever over 80%, which only recorded the GI value of 75.56%. The final C:N ratio for all composting mixtures also obtained in a range that acceptable for mature compost. Therefore, the stability and maturity in composting mixture with aeration rate of 0.6L/min.kg was superior to those in composting mixtures of aeration rates of 0.4L/min.kg and 0.8L/min.kg in term of temperature and germination index.

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