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THE STUDY OF DIFFERENT AERATION RATE EFFECT DURING COMPOSTING OF RICE STRAW ASH AND FOOD WASTE IN MANAGING THE ABUNDANCE OF RICE STRAW AT PADDY FIELD

Irnis Azura ZAKARYA[1,2,3*], Siti Noor Baya KHALIB[3], Andrei Victor SANDU[1,4,5]

[1]Centre of Excellence for Geopolymer and Green Technology, Universiti Malaysia Perlis.
[2]Centre of Excellence for Biomass Utilization, Universiti Malaysia Perlis
[3]School of Environmental Engineering, Universiti Malaysia Perlis, Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis.
[4]Gheorghe Asachi Technical University of Iasi, Faculty of Material Science and Engineering, 61A D. Mangeron Blvd., 700050 Iasi, Romania
[5]Romanian Inventors Forum, 3 Sf. Petru Movila St., Bloc L11, III/3, 700089 Iasi, Romania

Abstract

The composting of rice straw ash with food waste and addition of effective microorganisms as an additive has been investigated by using the laboratory-scale of bin composter reactor at different aeration rates of 0.4, 0.6 and 0.8L/min.kg with an initial C:N ratio 30 of compost mixture. The physicochemical parameters were monitored for pH, temperature, C:N ratio and phtotoxicity in term of germination index during 30 days of composting period. The results showed the longest phase of thermophilic temperature, minimum C:N ratio and the maximum GI obtained at compost pile aerated with 0.6Lmin.kg compared to the other two aeration rate of 0.4L/min.kg and 0.8L/min.kg. In term of pH for all three treatments of compost pile, the values obtained are within a range that is acceptable for the matured compost.

***Keywords**: Composting; Aeration Rate; Rice Straw Ash; Food Waste*

Introduction

In Malaysia, ~~a~~ millions of tonnes of rice had grown each year producing ~~a~~ millions of tonnes of the crop residues, known as rice straw and makes up around 50% of the entire crop [1]. The production of paddy has increased year after year, from more than 2.5 million tons of paddy produced in 2010 to more than 2.7 million tons of paddy in 2014. Rice straw is usually managed by on-farm burning after the harvest season. There are several reasons behind the burning of these rice straw by farmers. These include: it is seen as a cheapest and easiest way to prepare the field for the next cultivation season, crop rotation do not allow sufficient time for decomposing, to prevent rice disease, to eliminate source of insects pests and rat infestation [2-4] and lack of cost-effective treatment approaches [5].

However, the soil would lose all organic material and nutrient content from the straw if it is totally removed from the paddy field [1]. The effect of on-farm rice straw burning towards the field is at least in terms of paddy productivity and the sustainability of the soil compared to the removal of straw from the paddy field. *Y. Singh and B. Singh* [6] stated that by returning the straw back into the field, it can help to builds up organic matter in the soil and the nutrient content that contained in the straw can be returned back to the soil as well.

* Corresponding author: irnis@unimap.edu.my

C. Zhou et al., [7] mentioned that the main fraction of rice straw is lignocelluloses and its degradation is essential for the operation of composting. However, lignocellulosic biomass was difficult to degrade so that the efficient composting performance was generally hard to be achieved. Because of the high content of lignocelluloses and wide C:N ratio, rice straw among certain organic materials are resistant to microbial attack [8]. Regarding to the issue of lignocelluloses, rice straw will be burned before being used to help in accelerating the composting process.

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 [9, 10]. Suitable aeration rate is important during the composting process as one of the parameters influencing the compost quality.

In previous studies, there were different aeration rates recommended such as, 0.1-0.8L/min·kg OM during the composting of agricultural wastes [11], 0.125-0.75L/min·kg OM in the composting of dairy manure with sawdust [12], 0.4-0.9L/min·kg OM in the composting of active municipal solid waste [13], 0.30-0.71L/min·kg OM during the composting of chicken manure with sawdust [14], 0.24-0.72L/min·kg OM in the composting of pig feces with corn stalks [15], 0.01-0.04L/min·kg OM in the decomposition of organic wastes and enzymatic activities during the composting process in a 100L bioreactor [16], 0.15-0.90L/min·kg OM in composting of penicillian mycelial dreg with sewage sludge, sawdust and rice straw [17], 0,0.18-0.54L/min·kg OM on greenhouse gas emissions during composting of pig feces with corn stalks [18] and 0.1-0.3L/min·kg OM in the composting of sewage sludge with corn stalks [19].

The main objectives of this study were to investigate the effect of pH, temperature, C:N ratio and germination index towards various aeration rates during composting of rice straw ash with food waste at 30 initial C:N ratio of compost mixture.

Materials and methods

Source materials

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). Food waste (FW) was collected from stalls near School of Environmental Engineering, UniMAP. Goat dung was 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 3L (marinated the mixture for 1 week before used) for 3000g 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.

Composting experiment

A cone-shape laboratory-scale of bin composter reactor used for this study was modified from several researchers on previous study [12, 21] as shown in Figure 1. The dimension of bin composter is 50 cm height and 41cm and 13cm in diameter (top and bottom, respectively) with a volume of 31.43m^3. 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 digital thermometer to record daily was located 20cm height from the bottom reactor. The reactor was equipped with a fine-masked net, 8cm from the bottom to place the composting materials. An aeration air flow tube was installed 4cm from the top 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 was 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: 3kg FW: 2kg GD: 1L EM. Three different aeration rate of 0.40, 0.60 and 0.80L/min·kg OM were used during the composting process at an initial C:N ratio of 30. Each composting process lasted 30 days. The characteristics of the raw materials are presented in Table 1.

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.

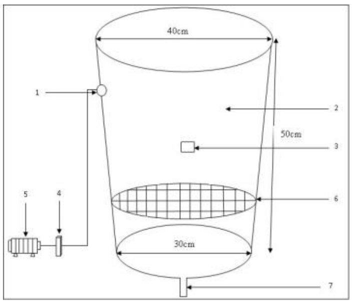

Fig. 1. Composting reactor and its components: (1) Gas sampling port; (2) Composting material; (3) Digital thermometer; (4) Gas flowmeter; (5) Air pump; (6) Fine-masked net; (7) Leachate sampling port.

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 [7]. The moisture content was determined by oven drying 5g fresh sample at 105°C for a period of 24 hours [22]. 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 [23].

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	8.0 21	-	-	-	-	-	-

Results and discussions

pH

Figure 1 shows the changes of pH values for three treatments of RSA-compost with a similar pattern. The pH values for RSA-compost treatment of 0.4L/min.kg increased from initial pH of 7.914 to maximum pH of 8.648. The pH content for RSA-compost treatment of 0.6L/min·kg increased from 7.039 to maximum pH of 8.679. Initial pH for RSA-compost 0.8L/min·kg was 7.407 and increases to maximum pH of 8.557. After that, pH values for three RSA-compost treatments decreased to 8.405, 8.419 and 8.336 on day 30 for 0.4L/min.kg, 0.6L/min·kg and 0.8L/min·kg.

The increases of pH at the beginning of the composting process was due to the production and released of ammonia during ammonification and mineralization of organic nitrogen as a result of microbial activities [24, 25]. The pH values starting to decrease at the end of the composting time and stabilized in an alkali values because of the release of carbon dioxide during the decomposition process, volatilization of ammonia and the production of organic and inorganic acids. The decomposition of organic matter and H^+ was released from microbial nitrification also causing the decreased of pH at the later stages of composting period [25, 26].

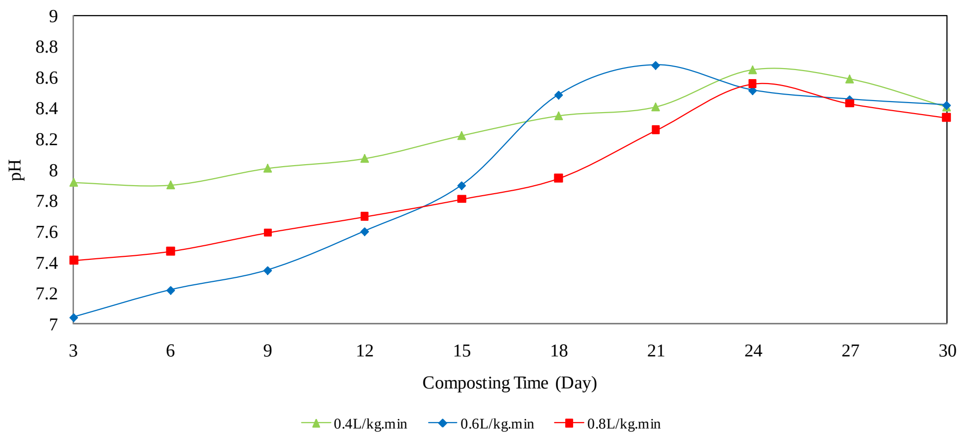

Fig. 2. pH variation versus composting time.

Temperature profile

Figure 2 shows the rapid increase in temperature for the three of RSA-compost treatments which indicating a marked microbial activity. According to *Y. Zhang and Y. He* [27], all composting mixture must exceed 55°C for at least for three consecutive days to destroy the phatogen and weed seed. RSA-compost pile aerated at a rate of 0.8L/min·kg did not meet this requirement since the highest recorded temperature was only 54°C on the 7th and 8th day. This happens because its aeration rate was excessive and caused heat loss [14, 15]. Meanwhile the highest temperature in the pile aerated with 0.4L/ min·kg and 0.6L/min·kg was 56 and 60°C appearing on the 10th and 9th day.

RSA-compost aerated at 0.6L/min·kg recorded the longest thermophilic phase for thirteen days, which sustained the temperature above 55°C for six days, while ten days of the thermophilic phase recorded for pile aerated at 0.4L/min·kg and sustained the temperature above 55°C for three days. The temperature increase rapidly in these two treatments was due to the microbial proliferation [17]. In addition, these two treatments also reached the thermophilic phase within the first three days because of the mesophilic microbes and the metabolism of the psychrophilic during early stage of composting process [15]. The temperature inside compost pile then decreased to reach ambient temperature when the organic matter becomes more stabilized and the organic matter decomposition rate slowed down [14].

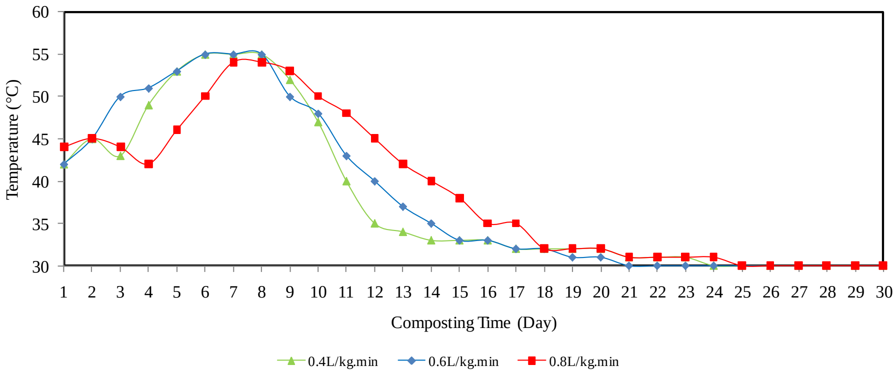

Fig. 3. Temperature variation versus composting time.

Germination Index

Germination test is often conducting to evaluate the phytotoxicity of compost produced towards plant growth [28-30]. Figure 3 shows the changes of germination index (GI) of three treatments of RSA-compost which was increases during the composting process. The increasing GI with composting time proved that the phytotoxicity compound in compost pile was gradually eliminated. GI value was more than 80% for pile aerated with 0.6L/min·kg and 0.8L/min·kg which was 96.6 and 81.7% at the end of the composting process, meanwhile 70.8% of GI value recorded for pile aerated with 0.4L/min·kg. This shown that RSA-compost treatment for 0.4L/min·kg contained slightly high phytotoxicity compound compared to RSA-compost treatments for 0.6L/min·kg and 0.8L/min·kg. This is because, 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 [31-33].

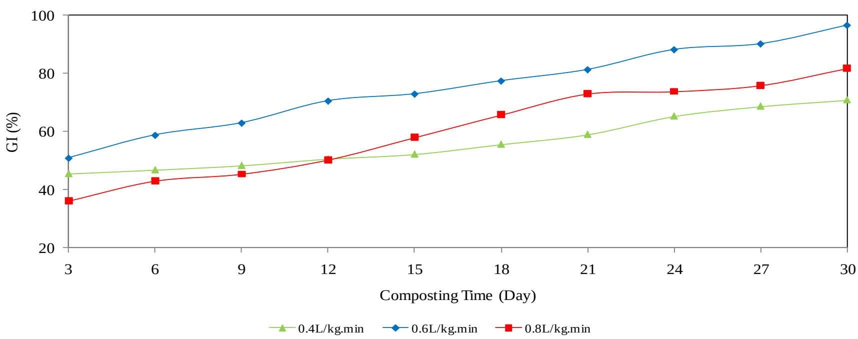

Fig. 4. Germination index variation versus composting time.

C:N ratio

Table 2 shown the result for end C:N ratio for all three treatments of RSA-compost. The C:N ratio was important to be used to assess the compost maturity during the decomposition process [34]. Compared to an initial C:N ratio of 30, the values for all three treatments of RSA-compost decreased at the end of the composting process. Compost pile aerated with 0.4L/min·kg recorded the value of 17 on 30th day of composting period, 16 and 12 values of CN ratio for pile aerated with 0.6L/min·kg and 0.8L/min·kg. During the composting process, the C:N ratio appeared stable in maturation stage.

D. Elango et al. [36] mentioned that, the value of end C:N ratio should be from 10 to 20 for compost to be decomposed completely. However, *M.P. Bernal et al.* [9] stated that when C:N ratio decreased below 15, the compost had satisfied an acceptable standard of maturation. Based on these two authors, the compost obtained for all three treatments of compost pile was matured and can be used without any restriction.

Table 2. The results of end C:N ratio for all three treatments of RSA-compost

Aeration rate (L/kg·min)	Initial C:N ratio	End C:N ratio
0.4	30	17
0.6	30	16
0.8	30	12

Conclusion

The composting of rice straw ash with food waste and indigenous microorganisms as additive showed the composting results that a compost pile aerated with 0.6L/min·kg is recommended, mainly depending on the fact that under this aeration rate, the minimum C:N ratio, maximum GI obtained and the longest phase of thermophilic stage of temperature recorded compared to the other two aeration rate of 0.4L/min·kg and 0.8l/min·kg. The pH values obtained for all three treatments of RSA-compost were in a acceptable range for matured compost.

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