The Effect of Low Initial C:N Ratio during Composting of Rice Straw Ash with Food Waste in Evaluating the Compost Quality

S N B Khalib, I A Zakarya and T N T Izhar
Centre of Excellence for Biomass Utilization, Universiti Malaysia Perlis
School of Environmental Engineering, Universiti Malaysia Perlis, Kompleks Pusat Pengajian Jejawi 3, 02600 Arau, Perlis
Centre of Excellence Geopolymer and Green Technology, Universiti Malaysia Perlis
Email: irnis@unimap.edu.my

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 low initial C:N ratio of 20 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 0.6L/min.kg maintained the temperature exceeding 55°C for three days to meet the requirement of pathogen destruction compared to the composting mixture with aeration rate 0.4L/min.kg and 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 11. The pH values and moisture content obtained for all composting mixture was in a range of 7 -8 and 40-70%. However, the final germination index in all composting mixture was never over 80%.

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 [1]. The amount of rice straw derived was estimated by the information of the rice production [2]. 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 [3]. It is a non-edible product, which often left in the paddy field after harvesting process [4].

The farmers usually burn the rice straw on-field as a method of disposal after the harvest season. To avoid the burning process that causing harmful towards human and soil paddy field itself, composting process is seen as an environmental method in managing the abundance of rice straw 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 (CO₂, H₂O, NH₄⁺) or stabilized OM, mostly as humic substance [5,6].

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 [7]. 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 [8]. Although considerable research has been conducted on composting of rice straw with various organic materials [7,9,10,11,12,13], 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 [14]. 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 [5]. To produce a successfully compost and assure the safety of compost in agriculture land application, the stability of compost product needs to be achieved. Stability of compost are referring to the amount of degradation of phytotoxic organic substances [15].

Bernal et al., (2009) [5] and Nolan et al., (2011) [16] 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.

The main objective of this study was to evaluate the compost quality during composting of rice straw ash with food waste at low initial C:N ratio of 20 at three different aeration rates of 0.4L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg respectively.

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) was poured into the mixture of compost as a source of microorganism to help in accelerating the decomposition process. EM also functions to reduce the odour emission during the process. EM was prepared according to the recipe obtained from Solid Waste Corporation (SWCorp), Perlis. One piece of ‘tempe’ was 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 characterized for only pH. The characteristics of the raw materials are presented in Table 1.

| 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 microorganism          | 8.021| -                    | -                | -                  | -    | -              | -             |
2.2. Compost experiment

A laboratory-scale of bin composter reactor used for this study was modified from other research [9,17] 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 time 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.

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 20. 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 grams 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.

![Composting reactor and its component](image)

**Figure 1.** Composting reactor and its component: (1) air sampling port; (2) composting material; (3) digital thermometer; (4) air flowmeter; (5) air pump; (6) fine-masked net; (7) leachate sampling port.

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 [7]. The moisture content was determined by oven drying 5g fresh sample at 105°C for a period of 24 hours [18]. 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 [19].

3. Results and Discussions

3.1. Effect of pH during the composting process

The changes of pH in composting of rice straw ash and food waste at different aeration rates are shown in Figure 2. 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 from 7.206, 7.106 and 7.228 to a maximum value of 8.426, 8.569 and 8.529. The increases of pH in composting mixtures were due to the release of ammonia from ammonification and mineralization of organic nitrogen during the initial phase of composting [20]. After that, the values of pH dropped at the later stages with the values of 8.201, 8.391 and 8.392 at aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg. The decreased of pH at the later stages was caused by the decomposition of organic matter, volatilization of ammonical nitrogen and the production of organic and inorganic acids [21]. The values of pH in all composting mixtures were in a range of 7-9 in which, acceptable for mature compost.

![Figure 2. pH variation over composting time.](image_url)

3.2. Effect of temperature during composting process

Figure 3 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 [22,23]. There are three phases of temperature need to be achieved during the composting process which; mesophilic, thermophilic and curing phase.

According to Zhang and He [24], all composting mixture must exceed 55°C for at least for three consecutive days to destroy the pathogen and weed seed. The temperature in three composting mixture increases rapidly to reach a maximum temperature of 56°C for aeration rates of 0.4L/min.kg and 0.6L/min.kg and 50°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 9 days with maintained the temperature exceeding 55°C for 3 days. Composting mixture with aeration rate of 0.4 L/min.kg had a thermophilic phase for 7 days and maintained the temperature exceeding 55°C for 2 days. It ensured the maximum pathogen reduction and the stabilization of organic matter for composting mixture with aeration rates of 0.4 L/min.kg and 0.6 L/min.kg. Although the composting mixture with aeration rate of 0.8 L/min.kg had a thermophilic phase for 4 days, but it not meets 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 [25].
3.3. Effect of moisture content on composting process

The Figure 4 shows the changes values of moisture content. The values of moisture content at aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg increasing at the early stage of composting process before decreased at the later stage for all composting mixture. The moisture content is important as a medium in transporting the dissolved nutrients that are required for the physiological and metabolic activities of microorganisms [26]. Thus, the different aeration rates used not directly affected the values of moisture content obtained. According to George [27] and Tchobanoglous et al. [28], the values of moisture content must be between in a range of 40-60% to form a mature compost. All the composting mixture of aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg satisfied this statement which obtained a values of moisture content in that range and the compost had mature after 30 days of the composting process.

Figure 4. Moisture content variation over composting time.

3.4. Effect of C:N ratio on composting process

Table 2. shows the result of composting mixture with different aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg and end C:N ratio on day 30 of the composting process. The C:N ratio was important to be used to assess the compost maturity during the decomposition process [29]. The end C:N ratio for all composting mixture were decreased to 14 for aeration rates 0.4 L/min.kg and 0.8 L/min.kg at the end of the composting process on day 30. Meanwhile, the end C:N ratio for aeration rate 0.6 L/min.kg was decreased to 11. This decreased was due to the mineralization of organic matter [30]. During the composting process, the C:N ratio appeared stable in maturation stage. According to Bernal et al. [5], 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 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg can be defined as mature and can be used without restriction.

Table 2.
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 |
|-------------------------|-------------------|---------------|
| 0.4                     | 20                | 14            |
| 0.6                     | 20                | 11            |
| 0.8                     | 20                | 14            |

3.5. Effect of germination index on composting process

Germination test is a sensitive indicator of maturity and often conducting to evaluate the phytotoxicity of compost produced [31,32]. The changes of germination index in composting of rice straw ash and food waste at different aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg are shown in Figure 5. 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 [29,33].

The GI values was increased for all composting mixture with increase the composting time but did not reach and over 80% at day 30 of the composting process. The values of GI at day 30 for aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/min.kg was 60.06%, 75.89% and 70.05%. It resulting that all the toxic materials like volatile fatty acids mainly acetic acid and ammonia was not decomposed completely [34]. To produce a mature compost, the time for decomposition process need to be extend until the values of GI exceed 80%.

![Figure 5. Germination index variation over composting time.](image-url)

4. Conclusions

The stability and maturity of compost quality during composting of rice straw ash with food waste have been investigated with initial C:N ratio of 20 at three different aeration rates of 0.4 L/min.kg, 0.6 L/min.kg and 0.8 L/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 0.4 L/min.kg and 0.6 L/min.kg maintained the temperature exceeding 55°C for 2 days and 3 days during the composting but the composting mixture with aeration rate 0.8 L/min.kg only reach the thermophilic phase but the temperature not exceeding 55°C for pathogen destruction. Unfortunately, the final GI value in all composting mixture did not reach 80%. The final C:N ratio for all composting mixtures also obtained in a range that acceptable for mature compost.

Therefore, the stability in composting mixture with aeration rate of 0.6 L/min.kg was superior to those in composting mixtures of aeration rates of 0.4 L/min.kg and 0.8 L/min.kg in term of temperature. In term of maturity, the compost had not enough mature because the values of germination index did not reach and over 80%. However, to overcome this problem, the composting time for all composting mixtures for all aeration rates need to be extended until the values reach 80%. The compost can be used without any restriction based on the results of temperature achieved for
composting mixture at aeration rate of 0.6 L/min.kg because all pathogen and weed seed has been eliminated.

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