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Utilization of rice straw ash during composting of food waste at different initial C/N ratios for compost quality

Utilization of rice straw ash during composting of food waste at different initial C/N ratios for compost quality

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Abstract. The increases in rice productivity and size of paddy areas have led to the huge excess of rice straw in paddy field after the harvesting season. Rice straw can be used as a soil conditioner by composting process instead of on-farm burning that been practice by farmer which can caused pollution. Nevertheless, it required a long time for the decomposition process to happen since the main fraction of rice straw is lignocellulose which was difficult to degrade. Thus, the objective of this study was to evaluate the effect of different initial C:N ratio used (20,25,30) during composting of rice straw ash and food waste towards compost quality in term of pH, temperature, moisture content, C:N ratio and germination index. A laboratory-scale bin composter reactor was used during 30 days of composting period. The composting mixture with initial C:N ratio of 30 maintained the temperature exceeding 55°C for more than 3 days but the composting mixtures with initial C:N ratios of 20 and 25 did not meet the requirement of pathogen destruction. The maximum final C:N ratio and germination index obtained at a composting mixture with initial C:N ratios of 30 compared to the other two composting mixtures. The pH and moisture content value in three composting mixture was recorded in a range of 7-9 and 40-60% for mature compost to establish.

1. Introduction

The increases in rice productivity and size of paddy areas have led to the huge excess of rice straw in paddy field after the harvesting season [1]. The production of paddy was increases years to years, from more than 2.5 million tonnes of paddy was produced 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 [2]. It is a non-edible product, which often left in the paddy field after harvesting process [3]. The elimination of rice straw is frequently carried out by the farmers all over the world by burning it in the field [1,4,5].

The other method to avoid the rice straw from on-farm burning was removing the rice straw from paddy field for others environmental application like composting to produce a good compost used as a soil enhancer back towards the paddy field. 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 [6]. 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). The product from RSA composting known as soil enhancer will be applied back to paddy field soil to recover the nutrient content loss from removing the rice straw for composting process.

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 [7]. Although considerable research has been conducted on composting of rice straw with various organic materials [6, 8, 9, 10, 11, 12], but no information available on the effect of composting rice straw ash with food waste was done.

The objective of this study was to evaluate the effect of different initial C:N ratio used (20,25,30) during composting of rice straw ash and food waste towards compost quality in term of pH, temperature, moisture content, C:N ratio and germination index. The compost quality which is stability and maturity compost cannot be well described by a single property or parameters [13,14]. Thus, the stability of compost during this study will be refers to the changes of pH, temperature, moisture content and C:N ratio. Meanwhile, the maturity of compost will refer to the germination test.

2. Materials and method

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 400°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 pH only.

2.2. Composting experiment

A laboratory-scale of bin composter reactor used for this study was modified from other research [9,15] as shown in Fig.1. The reactor is a cone-shape. The dimension of bin composter is 50 cm height and 40 cm and 30 cm 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.

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.

Three different initial C:N ratios of 20, 25 and 30 was used during the composting process at an aeration rate of 0.6L/(ming.kg) OM. 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: 3.4kg FW: 2kg GD: 1L EM for C:N 30, 1kg RSA: 3kg FW: 2kg GD: 1L EM for C:N 25 and 1kg RSA: 1.6kg FW: 2kg GD: 1L EM for C:N 20. 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.

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 [6]. The moisture content was determined by oven drying 5g fresh sample at 105°C for a period of 24 hours [16]. 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 [17].

Table 1. Characteristics of the raw composting materials

Materials	pH	Moisture content (%)	Total Carbon (%)	Total Nitrogen (%)	C:N	Phosphorus (%)	Potassium (%)
Rice straw ash (400°C)	9.859	5.44	37.25	2.00	18.63	0.09	0.49
Food waste		81.92	40.00	2.50	16.00	-	-
Goat dung	7.556 7.997	11.55	18.22	1.01	18.04	-	-
Effective microorganisms	8.021	-	-	-	-	-	-

3. Result and discussion

3.1. pH

The changes of pH in composting of rice straw ash and food waste at different initial C:N ratio was shown in figure 1. The pH values for composting mixture of initial C:N ratio of 20, 25 and 30 increases from initial pH 7.826, 7.428 and 7.508 on day 3 to a maximum pH 9.462, 8.566 and 8.657 on day 24. The releasing of ammonia from ammonification and mineralization of organic nitrogen during the initial phase of composting causing the increases of these pH values [18,19]. At the end of the composting process on day 30, the pH values for composting mixture of initial C:N ratios 20, 25 and 30 decrease to 8.776, 8.332 and 8.165 due to the production of organic and inorganic acids, the decomposition of organic matter and the release of carbon dioxide during the composting process [18]. The pH value of the composting mixture with an initial C:N ratio 20 was slightly higher than the other two composting mixture was possibly due to the lower amount of food waste contained in that composting mixture.

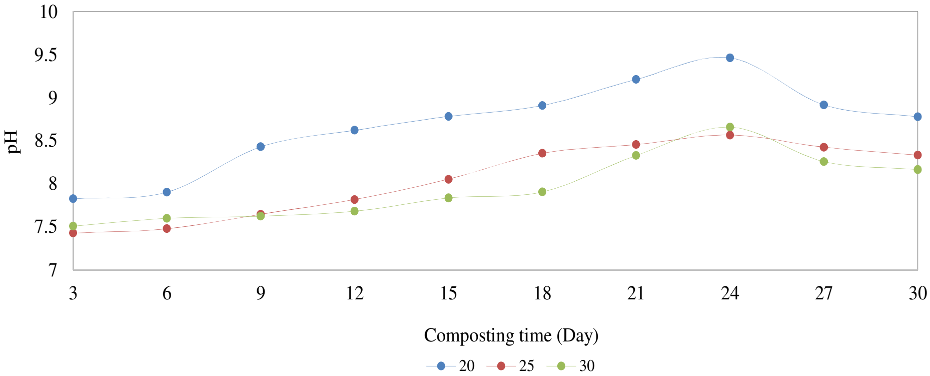

Figure 1. pH variation over composting time

3.2. Temperature

Temperature is a direct parameter to measure the status of the process. It is an indicator of the microbial activities during the decomposition process [13,20]. There are three phases of temperature during the composting process; mesophilic, thermophilic and curing phase. Figure 2, shows the changes of temperature during the composting mixture with initial C:N ratio 20,25 and 30. The temperature in three composting mixture increases rapidly to reach a maximum temperature of 56°C for initial C:N ratio 20,25 and 58°C for initial C:N ratio 30. The increased of temperature was due to the rapid microbial activities that breakdown the available organic matter and nitrogenous compounds in the compost pile [19]. When the organic matter become more stabilize and the easily degradable compound was depleted, the microbial activities in compost pile and the organic matter decomposition rate starting to slowdown. At this state, the composting mixture entering the curing phase causing the temperature slowly to dropped to reach ambient temperature [19,21]. The composting mixture with initial C:N ratio 30 had a longest thermophilic phase for 10 days with maintained the temperature exceeding 55°C for 5 days. It ensured the maximum pathogen reduction and the stabilization of organic matter. To destroy the phatogen and weed seed, all the composting mixture must exceed 55°C for at least for three consecutive days [22]. Although the composting mixture with initial C:N ratio 20 and 25 had a thermophilic phase for 8 and 9 days, but they did not meet the requirement for pathogen destruction because only reach temperature more than 55°C for two days. Beside, composting mixture with low initial C:N ratio of 20 and 25 resulting in a shorter thermophilic phase compared to the initial C:N ratio of 30 caused by the insufficient of carbon source for low C:N [19].

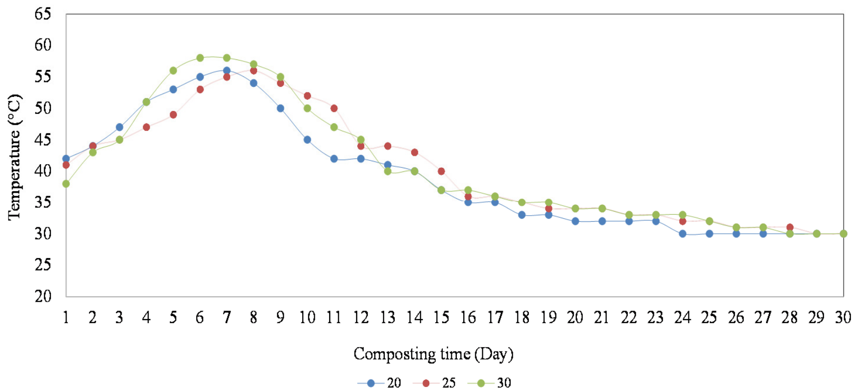

Figure 2. Temperature variation over composting time

3.3. Moisture content

The moisture content during the composting process plays an important role as a medium for transporting dissolved nutrients that are required for the physiological and metabolic activities of microorganisms [23]. Figure 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 initial C:N ratio 20,25 and 30. Based on the values of moisture content obtained, the initial C:N ratio has no significant influence on moisture content. The high amount of moisture content at the end of the composting mixture with initial C:N ratio 20 restricted the decomposition of toxic compounds causing the compost produce in this compost pile slightly toxic and required to extend to a bit longer to form a mature compost [21]. However, according to George, 2010 [24] and Tchobanoglous et al., 1993 [25], the values of moisture content obtained for all the composting mixture was in a range of 40-60-%, which had sufficient to support the growth of microorganisms during the decomposition process.

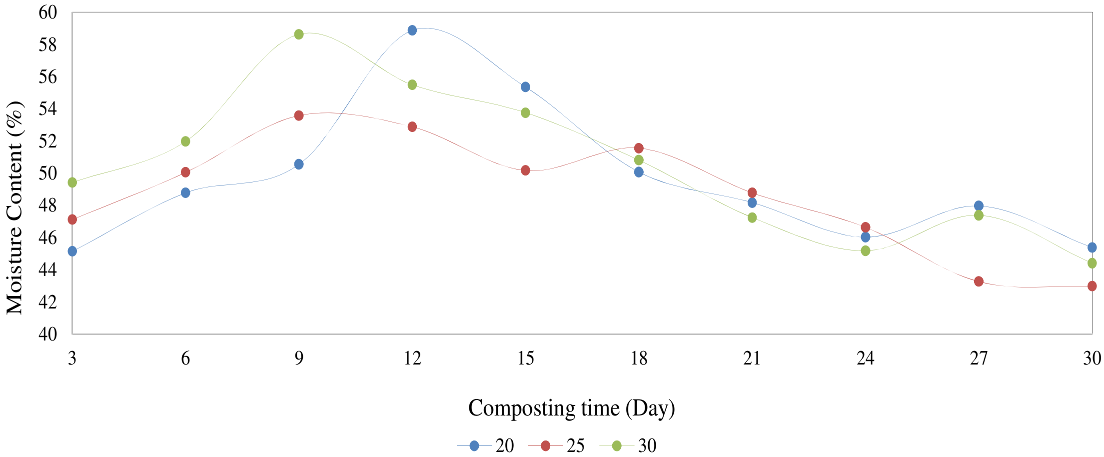

Figure 3. Moisture content variation over composting time

3.4 Germination Index

According to Gariglio et al., (2002) [26] and Brewer and Sullivan, (2003) [27], 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 [28,29]. Figure 4 demonstrates the changes of germination index throughout the composting mixture with initial C:N ratio 20,25 and 30 for 30 days composting period. 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 [30]. At the end of the composting process, the GI for composting mixture with initial C:N ratio 30 and 25 were higher than initial C:N ratio 20 with the values over 80% suggesting that the compost produce was free from toxic substance and enough mature. Composting mixture of initial C:N ratio 20 was never over 80% at day 30 which only reach 70.02% of GI value. It showed that composting mixture with initial C:N ratio 20 was slightly contain toxic materials due to the incomplete decomposition of volatile fatty acids and ammonia. Thus, a longer time was required to form mature compost when a low C:N ratio was used. Similar suggestions were also reported by others researcher during co-composting of spent pig-manure sawdust litter and pig sludge [31], composting of pig manure by two static aerobic piles with initial C:N ratios of 15 and 30 and co-composting of pig feces and corn stalks with initial C:N ratio 15, 18, 21 [21].

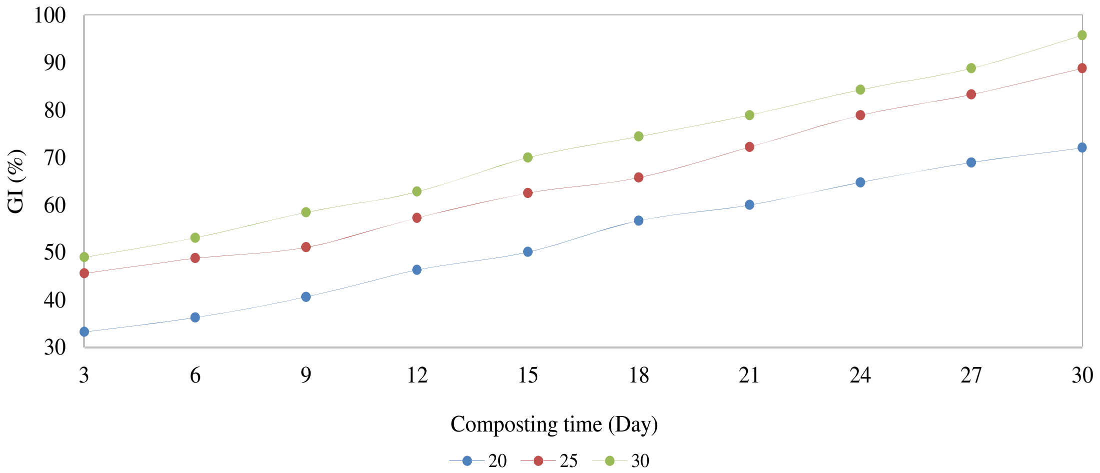

Figure 4. Germination index variation over composting time

3.5 C:N ratio

Table 2 shown the result of composting mixture with different initial C:N ratio of 20,25 and 30 and end C:N ratio on day 30 of the composting process with constant aeration rate of 0.6L/(min.kg). The end C:N ratio for all composting mixture were decreased due to the mineralization of organic matter [33]. Saha et al., (2010) [34] stated that an initial C:N ratio of 30:1 is ideal for feedstock mixtures. It then, decreases to less than 20:1 at the end of the composting process as obtained by the composting mixture with initial C:N ratio 30 in this study. Composting mixture with initial C:N ratio 20 and 25 shown a bit poorer decomposition process because of a smaller decreases of C:N at the end of the composting time especially for initial C:N ratio 20. However, Bernal et al., (2009) [13] stated that when C:N ratio decreased below 15, the compost had satisfied an acceptable standard of maturation. Thus, all the composting mixture with initial C:N ratio 20,25 and 30 can be defined mature, but compost produce from composting mixture with initial C:N ratio 20 and 25 must be used with precaution because of the bit poorer decomposition process.

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	20	13
0.6	25	11
0.6	30	12

4 Conclusions

The compost quality during the composting of rice straw ash and food waste have been investigated at initial C:N ratio of 20, 25 and 30 in term of pH, temperature, moisture content, germination index and C:N ratio. The composting mixture of initial C:N ratio 30 was maintained the temperature exceeding 55°C for 5 days but the composting mixtures with initial C:N ratios of 20 and 25 did not meet this requirement of pathogen destruction. The final germination index in composting mixture of 30 and 25 was over 80% with 95.56% and 88.79% compared to the initial C:N ratio 20 that was not reach over 80% of GI value. The maximum final C:N ratio was recorded at the composting mixture of 30 due to a larger decrease of C:N ratio rather than initial C:N ratio 20 and 25 that had a smaller decreases of C:N at the of the composting process. The value of pH and moisture content, in a range of 7-9 and 40-60% for all composting mixture obtained in a range that acceptable for mature compost to establish. To economically manage the increasingly quantities of rice straw ash and food waste produced each year, composting of these two waste materials with initial C:N ratio 30 is recommended with aeration rate of 0.6L/(min.kg) and burning the rice straw at 400°C for 30 minutes.

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References

[1] John A 2013 *Agricultural and Food Policy Studies Institute, Malaysia* **18**.
[2] FOASTAT 2017 http://www.fao.org/faostat/en/#data/QC
[3] Lal R 2005 *Environ. Ent.* **31** 575.
[4] Gadde B. *et al Environ. Pollut.,* **157** 1554.
[5] Rosmiza M Z *et al* 2014 *Malaysian Journal of Society and Space,* **10** 5.
[6] Zhou C *et al* 2015 *Waste. Manage.* **40** 150.
[7] Kathirvale S *et al* 2003 *Renew. Energ.* **29** 559.
[8] Zhu N 2007 *Bioresource Technol.* **98** 9.
[9] Li X *et al* 2008 *Bioresource Technol.* **99** 6271.
[10] Roca-Perez L *et al* 2009 *Chemosphere,* **75** 781 .
[11] Rashad F M *et al* 2010 *Bioresource Technol.* **101** 5952 .
[12] Qian X *et al* 2014 *Waste Manage.,* **34** 901.
[13] Bernal M P *et al* 2009 *Bioresource Technol.* **100** 5444.
[14] Nolan T *et al* 2011 *Bioresource Technol.* **102** 9425.
[15] Andersen J K *et al* 2010 *Waste Manage.* **30** 2475 .
[16] International A 2003 *Standard Test Methods for Moisture, Ash and Organic Matter of Pest and Other Organic Soils.*
[17] Zucconi F *et al* 1981 *Biocycle* **22** 2.
[18] Wong J W C *et al* 2001 *Bioresource Technol.* **76** 99.
[19] Gao M *et al* 2010 *Bioresource Technol.* **101** 3808.
[20] Li Z *et al* 2013 *Chemosphere.* **93** 7.
[21] Guo R *et al* 2012 *Bioresource Technol.* **112** 171
[22] Zhang Y *et al* 2006 *Bioresource Technol.* **97** 1061
[23] Kumar M *et al* 2010 *Waste Manage.* **30** 4
[24] George W D 2010 *Extension Horticulture Specialist*
[25] Tchobanoglous G *et al* 1993 *Engineering Principles and Management Issues*
[26] Gariglio N F *et al* 2002 *J. Crop. Hort.* **30** 135
[27] Brewer L J *et al* 2003 *Compost Sci. Util.* **11** 2
[28] Tiquia S M *et al* 2010 *Environ. Pollut.* **110** 535
[29] Wei Y S *et al* 2000 *Resour Conserv and Recy.* **30** 203
[30] Fang M *et al* 1999 *Bioresource Technol.* **67** 19
[31] Tiquia S M *et al* 1998 *Bioresurce Technol* **65** 43
[32] Huang G F *et al* 2004 *Waste Manage.* **24** 8
[33] Rasapoor M *et al* 2009 *Waste Manage.* **29** 2
[34] Saha J K *et al* 2010 *Waste Manage.* **30** 2