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Aerobic composting of rumen content waste and rice straw at different C/N ratios

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Abstract. The increasing need for organic fertilizers in Indonesia along with the fulfilment of agricultural needs. On the other hand, the raw material of organic fertilizer is abundant and not yet utilized, one of which is Slaughterhouse Solid Waste (SSW). The objective of this study were to produce the quality of organic fertilizer that meets regulation of the Minister of Agriculture Decree No. 70 Year 2011 about Organic Fertilizer, Biological Fertilizer, and Land Improvement. The composting process was done using 20 kg of Madura's cow rumen content and rice straw was placed in each reactor during 50 days. Raw materials were consisted of three variations in composting, i.e., 1) 60% rumen content waste and 40% rice straw, 2) 50% rumen content waste and 50% rice straw, 3) 40% rumen content waste and 60% rice straw. Eight standing reactors of 120 L capacity were used in this research. Each reactor was equipped with a leachate outlet at the bottom, slits for aeration, and sampling. The measured parameters were C/N ratio, macro nutrient (phosphor and kalium), temperature, dan pH value. The results showed that the optimum composition of rumen content waste with addition of rice straw was 40%:60%. In this reactor, C/N ratio was decreased from 15.91 to 13.25, macro nutrients in P concentration increased from 4.27 to 6.12, K concentration gradually increased from 5.46 to 7.55, temperature range was 29.80 oC-33.70 oC, and pH values slightly fluctuated from 6.71 to 6.93.

1. Introduction

As an agricultural country, Indonesia needs large amounts of organic fertilizer and energy resources for agriculture activities. Slaughterhouse solid waste (SSW) is a valuable resource for organic fertilizer [1]. Rumen content are the most dominant SSW generated from slaughterhouse's (SH) activity that not used and generally disposed to landfill. SSW has high organic matter and nutrient (N and P) contents [2]. Fresh SSW is unsuitable to be applied to the soil because of the unstable organic matter. In addition, it also contains pathogens and weed seeds [2].

Composting is one of the most suitable technologies for treating SSW [1]. Composting technology can treat SSW for suitable land application, reduce the mass, destroy the pathogens, and weed seeds and produce valuable end products [3]. Either aerobic or anaerobic composting can be done for treating the SSW. Ratnawati and Trihadiningrum reported that aerobic method is the most appropriate composting for SSW [4]. Product reach stability fastest with the final temperature value of 27.00 oC; pH of 8.05; moisture content of 56.70%; organic C content of 40.86%; total N content of 2.98%; and C/N ratio of 13.71. The products could be categorized as organic fertilizer because it contained high levels of N and P. Organic matter decomposition in aerobic composting will be briefer. In addition, the time period for producing mature end product is fastest and lack of odor. Pathogens indicators (S. Faecalis and total



coliforms) in SSW are easily destroyed under aerobic composting with the removal efficiency until 99.95% [5]. The elements N, P, and K in organic fertilizer are the elements absolutely necessary by plants. Element P can simulate flowering, increase the number, and fruit volume, increase resistance to disturbances in both pests and plant disease. Element N is very important in protein formation, stimulates vegetative growth and increases fruit. Whereas element K plays a role in synthesis of carbohydrates and proteins while strengthening plants so that flowers and fruit are not fall off.

Rumen content waste is rich in organic matter and nutrient (N and P) content [6]. Trihadiningrum et al. stated that the C/N ratio of rumen content waste of 16.60 [5]. The initial condition of C/N ratio which is ideal for composting is 20-30 [7]. Bernal et al. stated that the ideal C/N ratio is 25-35 [8]. Ratnawati and Trihadiningrum reported that the SSW compost was produced after 50 days using anaerobic-anoxic-oxic and five stage sequencing batch reactor (anaerobic-anoxic-oxic-anoxic-oxic) composting process; however, an additional maturation stage was required [9].

Feedstock with the initial low C/N ratio, the aerobic composting process will require additional longer processing period and increase the amount of SSW treated, but can also increase the loss of nitrogen as ammonia gas [2]. The dominant form of compound was organic N and NO₃-N [10].

Bulking agent is always required to modify the properties of SSW during composting because of the high moisture content and low C/N ratio [2]. Several previous works using bulking agent for composting were grass [10], sawdust [11,12], rice straw [13,14], wheat straw [15], corncob [16], corn stalk [2,3]; straw and dry grasses [17]. The rice straw is rich in carbon and has a low density and low moisture content, making it suitable for use as bulking agent during composting. Tchobanoglous et al. stated that C/N ratio for rice straw of 48 [18]. On the other hand, waste of abundant rice straw residue and unprocessed. The objective of this study was to investigate the composting of rumen content waste with the addition of rice straw as bulking agent addition.

2. Materials and methods

2.1. Feedstocks

Fresh cattle rumen content and rice straw were taken from Gempol's SH, which was located in District of Pasuruan, Indonesia. The samples were air-dried for 3 days until moisture content of 50-60%. Himanen and Hanninen stated that the optimum moisture content for composting process range from 50-70%. Rice straw was shredded into 1 to 5 cm size [19]. The characterization of feedstock were measured before mixing are shown in table 1.

Table 1. Characterization of the rumen contents and rice straw.

Materials	Moisture content (%) ^a	C/N ratio	Organic C (g kg ⁻¹) ^b	TN (g kg ⁻¹) ^b
Rumen contents	54	8	393	51
Rice straw	58	21	520	24

^a Wet weight basis.

^b Dry weight basis.

2.2. Experimental design

The composting reactor were 120 L standing drum figure 1. There were four holes of the reactor: the left side was for aeration, the right side for sampling port, gases adsorbent unit at the top of the reactor, and leachate drainage in the bottom side. Aerobic condition was maintained with 0.80 aeration L kg⁻¹ dry matter min⁻¹.

Eight experimental condition were tested in duplicated within 50 days using laboratory-scale reactors. About 20 kg of Madura's rumen content and rice straw mixed manually were placed in these reactors. The composition of mixed rumen content and rice straw were 60:40 (R1); 50:50 (R2); 40:60 (R3). Reactor control using 100% rumen content waste (RK1). The sample from each reactor was collected on days 10, 20, 30, 40, and 50.

2.3. Sample collection and analytical methods

Solid samples (about 100 g) were taken at the beginning, end of composting process, and every ten days. The sample was analyzed for total nitrogen (TN), organic carbon, macro nutrients i.e. P_2O_5 as phosphorus (P) and K_2O as potassium (K), temperature, and pH value. The TN, organic C, macro nutrients were analyzed in accordance with the standard methods [20]. Organic C content was determined by gravimetric methods, in an oven at 550 °C for 1 h. Organic C was calculated as volatile solids, followed by multiplication with conversion factor of Horwitz [21]. TN was analyzed using Kjeldahl nitrogen digestion and the distilling apparatus was a Gerhardt KBL 8 S (Bonn, Germany). Solid C/N ratio was then computed based on the concentration of organic C and TN. P content was calculated with spectrophotometric method using Spectrophotometer Cecil CX 100. K content was calculated with titrimetric method. Temperatures were recorded using glass thermometer. The pH of each compost was determined by soil tester using a DM-15.

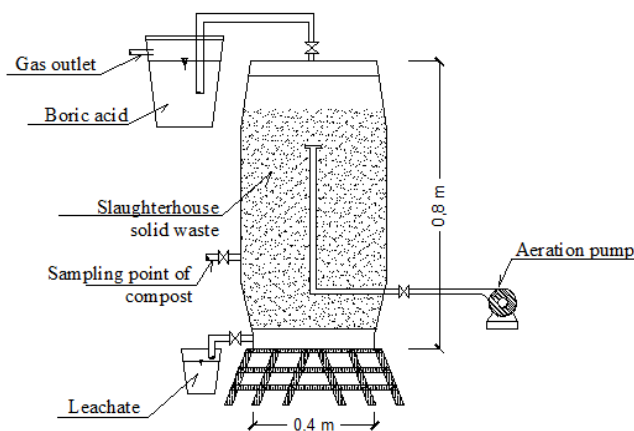


Figure 1. Design of composting reactor [22].

3. Results and discussion

3.1. C/N ratio

The initial C/N ratio during the composting process for R1, R2, R3, and RK1 were 10.70; 13.85; 15.91; and 4.83, respectively (figure 2). The reactor with the largest addition of rice straw 60% (R3) has the highest C/N ratio compared the others, which is 15.91. Rini et al. reported that initial C/N ratio with the variations in composition of the raw materials, i.e. [10]: 40% rumen content, 40% grass feed residue, 20% rice straw were 11.15-11.96.

The C/N in all reactors gradually increased until at the end of composting. Changes in C/N ratio indicate the decomposition process of organic matter during composting. C/N ratio is one way to determine the maturity of compost, where the final C/N ratio is 20 has indicated the maturity of compost. Carbon content is useful as a food ingredient in the decomposition process of organic materials by microorganisms [22].

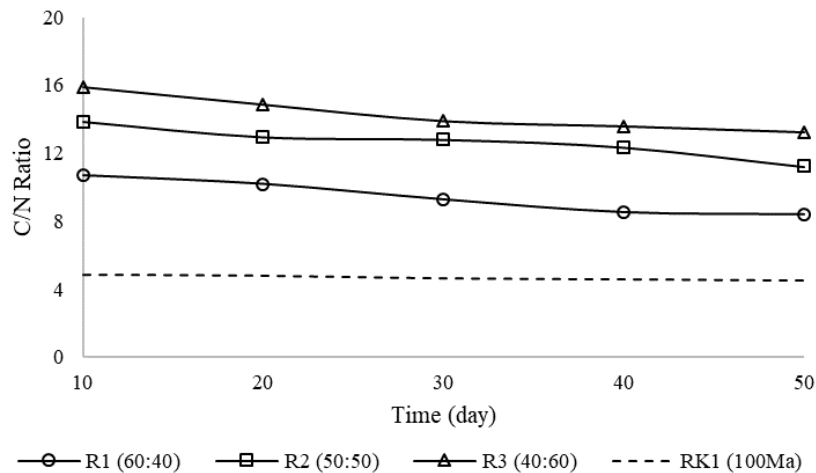


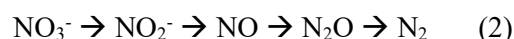
Figure 2. C/N ratio during composting process.

While nitrogen is a source of nutrients to form new microorganism cells. During composting, carbon content (carbohydrates, fats, and amino acids) will degrade rapidly in the active phase composting, then cellulose, hemicellulose, and lignin separate will degrade in the cooling phase where the temperature decrease in mesophilic and carbon content will continue to decline until the maturity process [23].

The transformation and transfer nitrogen during composting process which causes nitrogen concentration decreased. De Guardia et al. reported that the processes were biological transformation, transfer to leachate, transfer to atmosphere and conversion to NH_3 , N_2O , N_2 [24]. The transformation of nitrogen concentration occurs through various processes, namely: ammonification, nitrification, denitrification, and immobilization. Ammonification process which is organic nitrogen concentration converted to NH_3 or $\text{NH}_4^+\text{-N}$. During nitrification process, NH_3 or $\text{NH}_4^+\text{-N}$ is converted to NO_2^- by *Nitrosomonas*. Then NO_2^- is converted to NO_3^- by *Nitrobacter*. *Nitrosomonas* and *Nitrobacter* need energy for cell growth and maintenance, with reaction:



Elimination of nitrogen occurs through denitrification process. Nitrification process not removed nitrogen concentration from solid waste, yet. Nitrogen gas in denitrification process is released from solid waste in the form of N_2 gas, as described by Salimin dan Rachmadetin [25]:



The final C/N ratio for R1, R2, R3, and RK1 were 8.38; 11.19; 13.25; and 4.51. The final C/N ratio of compost products from all reactors met the Indonesian quality standards SNI 19-7030-2004 for compost quality (C/N ratio= 10-20), but didn't met with regulated in the Minister of Agriculture Decree No. 70 for organic fertilizer (C/N ratio= 15-25) [26,27].

3.2. Macro nutrients P concentration

Initial P concentration in R1, R2, R3, and RK1 were 2.71%; 3.46%; 4.27%; and 1.14%. P concentration tended to gradually increase until the end of composting period (figure 3). P concentration in R3 (reactor with composition rumen content:rice straw of 40:60) has the highest P concentration. The P concentration is a compound that is needed by plants. The use of P in plants for root growth, helping assimilation, breathing, and accelerates flowers, seeds, and fruits. Sufficient availability of P for plants associated with the growth of these plants.

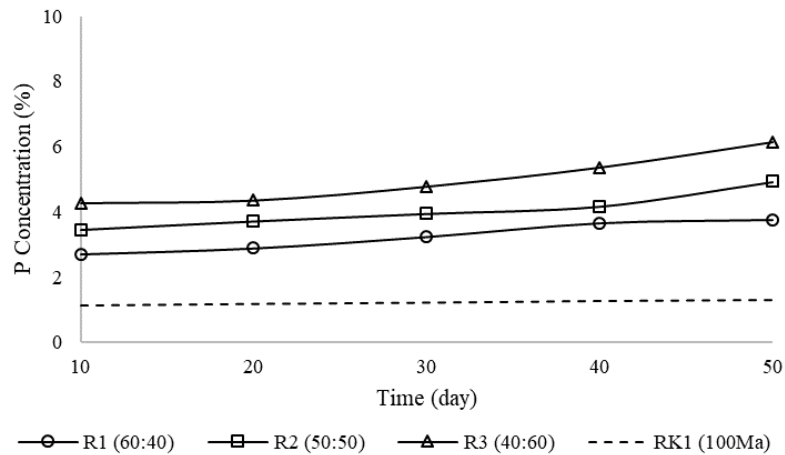


Figure 3. Macro nutrient (P) value during composting process.

P concentration includes macro nutrients very important for plant growth. Plants absorb P concentration from the soil in space P ions, especially H_2PO_4^- and $\text{H}_2\text{PO}_4^{2-}$ which contained in a soil solution. Besides ions the plant can absorb deep P concentration form of nucleic acid, phytine and phosphohumat. The P contained in organic fertilizer play a role for plants in the process of respiration and photosynthesis, nucleic acid preparation, establishment of plant seeds and fruit producers. In addition, P concentration is also able to stimulate root development so the plant is resistant against drought and accelerate the period harvest [28].

The polyphosphate accumulating organism (PAOs) need source C content to produce $\text{PO}_4^{3-}\text{-P}$ and store it in polyhydroxyalkanoates (PAH) form, using that energy produced during the process of hydrolysis of intracellular polyphosphate. Some PAOs are referred to as denitrifying PAOs (DNPAOs) oxidize intracellular PAH with $\text{NO}_3\text{-N}$ or $\text{NO}_2\text{-N}$ as electron acceptor and produce energy for P concentration uptake levels. This matter explained that the C content source produced was used by PAOs for the denitrification process. PAOs grow and produce orthophosphate by using stored PHA as a source of C and energy [29]. PAOs play a role in making up to meet needs metabolism and store P concentration in the body as a polyphosphate polymer.

The P concentration final in R1, R2, R3, and RK1 were 4.64%; 5.78%; 7.55%; and 2.30%, respectively. The P concentration final in all reactors met the Indonesian quality standard SNI 19-7030-2004 for compost quality (P concentration minimal 0.10%), but only both reactor R2 and R3 met with regulated in the Minister of Agriculture Decree No. 70 for organic fertilizer (P concentration= minimal 4%) [26,27].

3.3. Macro nutrients K concentration

Initial K concentration in R1, R2, R3, and RK1 were 2.94%; 4.08%; 5.46%; and 2.07%, respectively (figure 4). K concentration gradually increased in the beginning of composting until the end in all reactors. The function of K is for growth and development plants, i.e. open and close the affected stomata by C_2O content and photosynthesis process, the process of transporting nutrients from root to leaf, accumulation, and sucrose translocation, play a role in filling of seeds, tubers, and root growth, as well cellulose synthesis, strengthening cell walls, stem, and the system enzymatic, plant resistance, protein synthesis, and pH regulation. If K elements are not enough for plants, then can result in low growth and production plants [30].

The K concentration increased because microorganisms need time to adjust to the environment during the composting process. The metabolic process requires food derived from C and organic matter to carry out activities and increase cell size. The more microorganisms in the degradation process cause the C chain to be broken down into simpler C chains, the breakdown of the C chain causes increased P and K concentrations [31].

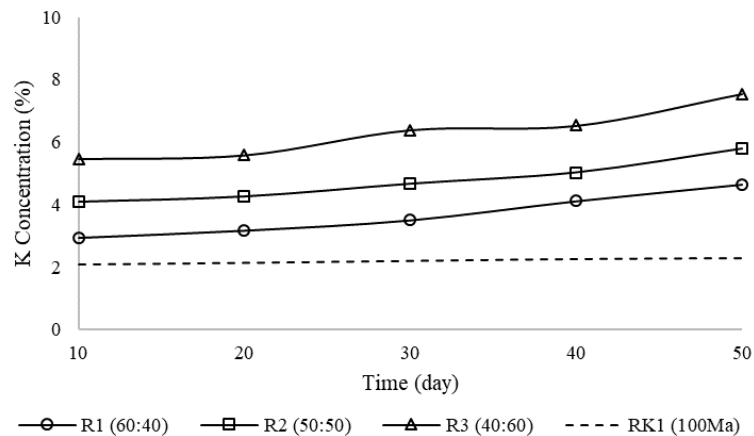


Figure 4. Macro nutrient (K) value during composting process.

According to Indriani, this occurs because the weathering results in the release of K^+ ions from the cation exchange site and decomposition of dissolved organic matter in the rumen contents [32]. The K concentration is used by microorganisms in substrat material as a catalyst, with the presence of bacteria and their activity will greatly affect the increase in K concentration [33]. According to Makiyah, many K is found in young cells or parts of plants that contain lots of protein, the nucleus of the cell does not contain potassium [34]. The K concentration can be bound and stored in cells by bacteria and fungi. Potassium is needed to accelerate the process of assimilation of carbohydrates and the growth of roots and stems, nutrient deficiency in potassium can cause patches of leaves or wrinkles on the leaves and eventually the leaves will dry out.

The K concentration final in R1, R2, R3, and RK1 were 4.64%; 5.78%; 7.55%; and 2.30%, respectively. The K concentration final in all reactors met the Indonesian quality standard SNI 19-7030-2004 for compost quality (K concentration minimal 0.20%) and met with regulated in the Minister of Agriculture Decree No. 70 for organic fertilizer (P concentration= minimal 4%) in R1, R2, and R3 [26,27].

3.4. Temperature value

Temperature values during composting are shown in table 2. Initial temperature of all reactors has a value range from 28.70-29.50 °C. During composting, temperature gradually increased until the end of composting. Temperature value in all reactors during composting is in the mesophilic temperature with a range of 29.00 °C-33.70 °C. Change in temperature is an indicator of the running of composting process.

Table 2. Temperature value.

Time (day)	Temperature value (°C)			
	R1 (60:40)	R2 (50:50)	R3 (40:60)	RK1 (100)
10	29.00	29.50	29.80	28.70
20	29.80	30.00	30.60	29.00
30	30.20	31.30	31.80	30.00
40	30.80	32.00	32.70	30.50
50	31.80	32.40	33.70	31.50

At the beginning of composting process, microorganisms adapted to the environment. Microorganisms will thrive because of food availability and degrade the substrate fastly causing it to occur a slow increased in temperature from mesophilic range (20 °C-45 °C) to termophilic (45 °C-65 °C). Ratnawati et al. reported that temperature value during aerobic composting process of rumen content were in the

mesophilic temperature with a range from 27 °C-43 °C [4]. Abouelwafa et al. stated that composting process occurs at a temperature of 30 °C-35 °C and is included in the optimum temperature of composting [35]. Temperature increased during composting indicated the occurrence increased microorganisms activity that degrade organic materials and produce heat [8]. Microorganisms will fastly degrade organic materials from group of carbohydrate, fats, and amino acids [23]. This process occurred until compost product in maturity stage where the compost temperature has stabilized which indicate the organic matter degradation process by microorganisms has been completed [36].

The final temperature in all reactors still didn't indicate a stable temperature because still increasing. The final temperature in R1, R2, R3, and RK1 were 31.80 °C; 32.40 °C; 33.70 °C; and 31.50 °C, respectively. Temperature value decreased in the end of composting process and approaches the maturity stage, which indicated the activity of microorganisms slowing down [23]. The organic matter has been degraded, compost product is in the stage maturity and temperature will slowly drop [2].

3.5. pH value

The pH variation during the composting are shown in table 3. Initial pH value has a range from 6.93 to 7.63. The pH of the control reactor (RK1) has a higher value than the reactors with variations in composition of the raw material for adding rice straw (R1, R2, R3). Ratnawati et al. (2016a) reported that the pH value in composting of rumen content was 8.34-8.60. The initial pH value is quite high occurs in raw materials from animal waste [36].

Table 3. pH value.

Time (day)	pH value			
	R1 (60:40)	R2 (50:50)	R3 (40:60)	RK1 (100)
10	7.00	6.95	6.93	7.63
20	6.90	6.76	6.84	7.41
30	6.93	6.82	6.75	7.59
40	6.84	6.79	6.71	7.42
50	6.74	6.70	6.82	7.35

Tchobanoglous et al. stated that the hydrolysis process that occurs at the beginning of composting changes the organic materials (fats, proteins, polysaccharides, and nucleic acids) become bonds the simpler ones (fatty acids, monosaccharides, amino acids, purines) [18]. When the decomposition process occurs, microorganisms convert carbohydrates in compost to produce H₂O and CO₂. Then this molecule will react to form H₂CO₃, which then ionized into HCO₃⁻ and CO₃²⁻. In nitrification process where microorganisms are *Nitrosomonas* dan *Nitrobacter* convert NH₄⁺ become NO₂⁻ and NO₃⁻ will release H⁺ ion which can increase pH value of compost [25].

The final pH value for R1, R2, R3, and RK1 were 6.74; 6.70; 6.82; and 7.35. The final pH value from all reactors met the Indonesia quality standard SNI 19-7030-2004 for compost quality (pH value= 6.80-7.49) and regulated in the Minister of Agriculture Decree No. 70 for organic fertilizer (pH value= 4-9) [26,27].

4. Conclusion

This research showed that the optimum composition of rumen content waste with addition of rice straw was 40%:60%. In this reactor, C/N ratio was decreased from 15.91 to 13.25, macro nutrients in P concentration increased from 4.27% to 6.12%, K concentration gradually increased from 5.46% to 7.55%, temperature range was 29.80 °C-33.70 °C, and pH values slightly fluctuated from 6.71 to 6.93. All parameters (except C/N ratio) met the Indonesia quality standard SNI 19-7030-2004 for compost quality and regulated in the Minister of Agriculture Decree No. 70 for organic fertilizer [26,27].

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