DOI: 10.21776/ub.jpacr.2017.006.02.309 *J. Pure App. Chem. Res.*, **2017**, 6 (2), 127-136
5 May 2017

Chemical Composition of Vermicompost Made from Organic Wastes through the Vermicomposting and Composting with the Addition of Fish Meal and Egg Shells Flour

Nurhidayati[1)*], Usman Ali[2)] and Indiyah Murwani[1)]

[1)] Faculty of Agriculture, University of Islam Malang, East Java, Indonesia
[2)] Faculty of Animal Husbandry, University of Islam Malang, East Java, Indonesia

[*)] Corresponding author : Phone : +62-341-551932, Email : nurhidayati@unisma.ac.id

Received 18 December 2016 ; Revised 17 April 2017 ; Accepted 17 April 2017

ABSTRACT

Chemical composition of compost is an important indicator that determines the quality of compost. This study compared the chemical composition of vermicompost resulting from the process of vermicomposting alone with combined vermicomposting and composting with addition of egg shells flour and fish meal. Organic wastes used were the mixture of spent mushrooms waste, coconut husks, cow dung, vegetables residue, and leaf litter. *Lumbricus rubellus* was the species of earthworm used in the vermicomposting process. In the composting process, egg shells flour and fish meal are added into the vermicompost as additives materials. The results indicate that the combined vermicomposting and composting process with addition the additives materials improves the chemical composition of vermicompost compared to using vermicomposting process alone. The change of chemical composition was indicated by a decrease in C-organic content and C/N ratio by 29% and 99%, respectively, while the content of N, P, K and S increased by 52%, 67.5%, 29% and 25%, respectively due to the addition of additives material in the composting process. The largest increase of vermicompost nutrient content occurred in the Ca content by an average of up to 7-fold. While polyphenols, lignin and cellulose content of vermicompost decreased slightly. The treatment of two mixture (a) spent mushrooms waste, cow dung and vegetables residue, and (b) spent mushroom waste, cow dung, vegetables residue, and leaf litter gave the best chemical composition. However, to determine the quality, we need to test the product in a plant growth bioassay as a follow-up study.

Keyword : vermicomposting, composting, organic waste, vermicompost, chemical composition

INTRODUCTION

Every year volume of waste in several Indonesian provinces has increased. According to the State Ministry of Environment (MoE) (2014), every Indonesian generates 0.76 kg/day of municipal solid waste (MSW). Thus, the total MSW produced in 2014 was over 70 million tons. The large amount of waste would cause problems in waste disposal if they were not reused and recycled [1]. These MSW compose of both biodegradable and non-degradable waste. Biodegradable waste is generally in the form of organic waste. Other organic wastes were also found in traditional market, agriculture production, agribusiness of mushroom cultivation such as vegetables waste, coconut husk, harvest residue, cow dung, and spent mushroom waste.

The journal homepage www.jpacr.ub.ac.id
p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733

One solution to reduce landfill of the organic waste was bioconversion of waste into usable product such as soil amendment. The importance of biological processes in waste management has been widely introduced. Biological processes commonly used by the waste management are composting and vermicomposting. Both of these processes are the most efficient for converting organic waste into valuable organic fertilizer [2]. Composting is a form of waste disposal where organic waste decomposed naturally under oxygen-rich condition. Microorganisms found in the composting process are microorganisms that grow naturally in high temperature conditions, known as thermophilic bacteria. Therefore, the process referred to as thermophilic composting [3].

The major problems associated with thermophilic composting are the long duration of the process, loss of nutrients during the prolonged composting process and the frequency of turning of material [4]. However, traditional thermophilic composting give advantages can kill pathogens in the waste because it can take up to a temperature of 45^o-65^oC [5]. Vermicomposting is a simple biotechnological process of composting in the certain species of earthworms which used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways [6]. It is a mesophilic process utilizing microorganisms and earthworm which is active at 10^o-32^oC. This indicates that the vermicomposting process temperature is not high enough to kill pathogenic organisms compared to thermophilic composting [4]. However, the vermicomposting provide another advantage in the process of decomposition of organic material. The earthworms break the organic waste substances; greatly stimulate microbial activity and increase rates of mineralization, rapidly converting the wastes into substances with a finer structure than compost [7,8,4]. The process is faster than composting, because the material passes through the earthworm gut. The process directly affected the decomposition rate of organic matter via the effects of ingestion, digestion and assimilation of the organic matter and microorganisms [9,10]. Earthworm subsequently released casts. The process gives indirect effects that are more closely associated with the presence of unworked material and to physical modification of the egested material [11]. The castings (worm manure) are rich in microbial activity and plant growth regulators [12]. The chemical composition of compost derived from municipal waste in a variety of sizes ranging from <0.2 - 5 mm, showed that the average content of C-organic (11.24%), N (0.78%), P (0.32 %), K (1.04%), and pH (7.16)[13]. Khan and Ishaq (2011) compared the chemical composition of pit compost and vermicompost based on the content of the N-Nitrate (1506 vs. 1494 mg.L-1), K (1520 vs.1575 mg L-1), Ca (11 vs.15 mg L-1) and pH (8.66 vs. 8:41) [14]. These results indicate that the chemical composition of vermicompost relatively better than pit compost.

In general, the process of waste bio-conversion through two processes namely composting and vermicomposting has been proven to produce better quality compost [15,4]. This study tested the products of the two opposite processes with previous research namely vermicomposting and composting processes as compared with the vermicomposting process alone. The two processes vermicomposting and composting combined would be necessary to provide a high quality product with the addition of additive materials. The objective of this study is to compare the products qualities resulting from the process of vermicomposting alone with combined vermicomposting and composting of organic wastes material compositions.

MATERIAL AND METHODS

Collection of waste

The waste used as vermicompost materials composed of spent mushrooms waste, cow dung, vegetables residue, and leaf litter. They were collected from traditional market, around the campus of the University of Islam Malang, farmland, cattle farm and agroindustry of oyster mushrooms. The spent mushrooms waste made from sawdust. The spent mushroom waste and cow dung were dried and crushed. Leaf litter was chopped using grinder. The waste materials were collected 10 days before vermicomposting process. The vegetables residues were collected from traditional market two days before vermicomposting and chopped with a size of 5 cm. The vegetable residues were collected in a shorter time than waste materials, because it was a fresh material and quickly decompose. In addition, flour of eggs shells and fish meal used as additives materials derived from the waste of broiler breeding industry and fishing industry.

Experimental set up

The experiment was conducted in cylindrical plastic pots (top diameter = 47 cm, bottom diameter = 40 cm, and height = 32 cm). Capacity of each plastic pot is 12 kg of waste. Each plastic pot was perforated by 20 small holes at the bottom. Total 9 treatments from the composition of vermicompost material were tested, The composition were C1 = 6 kg spent mushrooms waste (SMW), 3 kg cow dung (CD) and 3 kg vegetables residue (VR), C2 = 6 kg coconut husk (CH), 3 kg CD, and 3 kg VR, C3 = 3 kg SMW,3 kg CH, 3 kg CD, and 3 kg VR, C4 = 6 kg SMW, 3 kg CD, and 3 kg leaf litter (LL), C5 = 6 kg CH, 3 kg CD, and 3 kg LL, C6 =3 kg SMW, 3 kg CH, 3 kg CD, and 3 kg LL , C7 = 6 kg SMW, 2 kg CD, 2 kg LL, and 2 kg VR, C8 = 6 kg CH, 2 kg CD, 2 kg LL, and 2 kg VR and C9 = 3 kg SMW, 3 kg CH, 2 kg CD, 2 kg LL, and 2 kg VR. Each treatment was replicated three times. Total plastic pots used as many as 27 plastic pots. Spent mushrooms waste and coconut husk serves as bedding of earthworm to provide a favorable environmental condition for the earthworm. The bedding material was placed at the bottom and top of the plastic pot. A mixture of cow dung, vegetables residue and leaf litter was placed at the middle. The materials were feed under earthworm treatment. The amount of bedding material needed for each of is equal 6 kg, while the organic material as much as 6 kg of feed worm. After that, 285 grams of healthy earthworms *Lumbricus rubellus* were introduced in each of plastic pots. According to Ndegwa et al., (1999), the worms feed requirements per day is 0.75 kg/kg worms/day [16]. The moisture content of 80% was maintained during vermicomposting. The plastic pots covered with black cloth to avoid the sunlight. The duration of experiments was four weeks for vermicomposting. After vermicomposting, 500 g of vermicompost was taken from each pot to analyze chemical composition. Furthermore, the materials of vermicompost were composted using porous sacks by adding fish meal and flour of eggshell. The duration of composting was two weeks. After composting, 500 g of vermicompost was taken from each sack to analyze chemical composition again.

Chemical Analysis

The sample of vermicompost was collected from 27 plastic pots after vermicomposting and composting. The samples were analyzed for total organic carbon, total nitrogen, pH, lignin, polyphenol and cellulose content, P-available, K-exchangable, S-SO_4, and Ca-exchangable. Total organic carbon was analyzed by Walkley-Black method using dichromate oxidation and titrimetric method. Total N was analyzed by micro-Kjeldahl titrimetric method using Kjeldahl apparatus. pH of vermicompost was determined by digitalpH meter using H_2O extractant by shaking the fresh sample with distilled water at 1:5 w/v (dry weight basis) for 30 min at room temperature by filtration. The fresh extracts were subjected to pH measurements. P-available was analyzed by Olsen method using colorimetric and spectrophotometer [17]. K and Ca-exchangeable parameter were determined by extraction using 1.0 M NH_4OAc at pH 7.0. Potassium content was determined with a flame photometer [18]. The content of $S\text{-}SO_4$ was determined by turbidimetric method using 0.15% $CaCl_2$ as extractant [19]. Meanwhile lignin and cellulose content were determined by acid detergent solution method using cetyltrimethyl ammonium bromide (CTAB) as a surfactant [20].

Statistical Analysis

The collected data was statistically analyzed using analysis of variance (F-Test) at level ($P \leq 0.05$) and the differences of each treatment were adjudged by Tukey test ($P \leq 0.05$) using Minitab Version 14.12.

RESULTS AND DISCUSSION

Vermicompost with vermicomposting and composting produced significantly lower total organic carbon (18.65%) in comparison to vermicompost with vermicomposting alone (24.15%) (Figure 1). Among the treatments using vermicomposting and composting, the mixture of 6 kg SMW, 3 kg CD, and 3 kg LL and the mixture of 6 kg SMW, 2 kg CD, 2 kg LL, and 2 kg VR had the lowest total organic carbon (Figure 1).

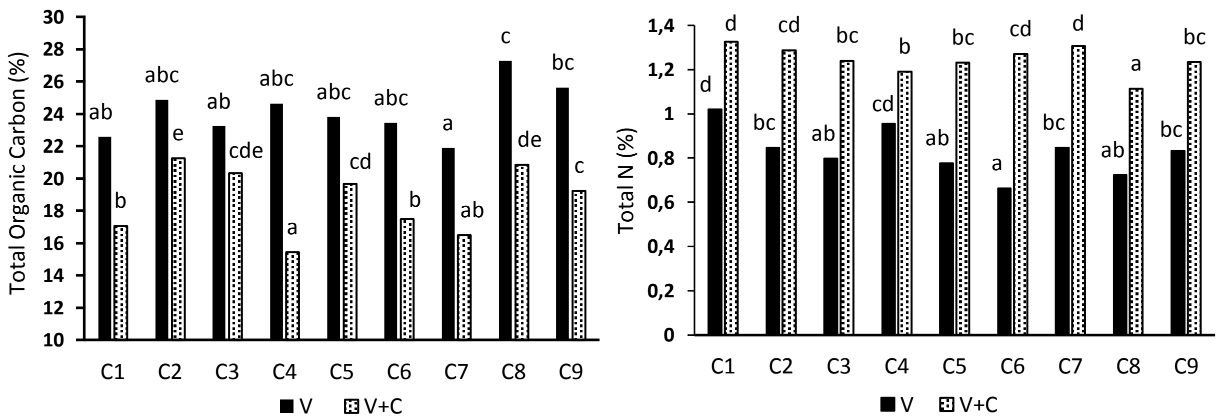

Figure 1. Total organic carbon and total nitrogen in the treatment of vermicomposting alone (V) vs. combination of vermicomposting and composting (V+C) in various composition of vermicompost materials.

The opposite result occurred on total N, i.e. a combination of vermicomposting and composting process increases the total N of vermicompost. The average total N in the treatment of vermicomposting alone by 0.83%, while the combination treatment of vermicomposting and composting by 1.24%. The highest total N of the treatment combination of vermicomposting and composting were found on the vermicompost media composition of 6 kg SMW, 3 kg CD, and 3 kg VR, 6 kg SMW, 3 kg CD, and 3 kg LL, 3 kg SMW, 3 kg CH, 3 kg CD, and 3 kg VR and 6 kg CH, 2 kg CD, 2 kg VR and 2 kg LL (Figure 1).

Vermicompost with vermicomposting and composting produced significantly lower C by N ratio of 15.3 in comparison to vermicompost with vermicomposting alone of 30.5

(Figure 2). Among the treatments of vermicomposting and composting, the mixture of 6 kg SMW, 3 kg CD, and 3 kg VR, 6 kg SMW, 3 kg CD, 3 kg LL, and 6 kg SMW, 2 kg CD, 2 kg VR, and 2 kg LL had the lowest C and N ratio (Figure 3). Vermicompost product produced in this study are presented in Figure 2. Hui et al. (2007) reported that compost made from the mixture spent mushroom waste with livestock manure, and soybean cake had a C/N ratio of 30. The compost was produced through composting alone [21].

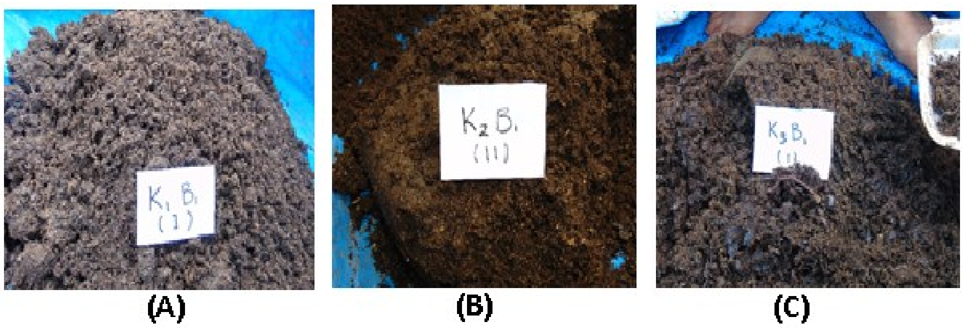

Figure 2. Vermicompost derived from the mixture (A) SMW+CD+VR, (B) SMW+CD+LL, and (C) SMW+CD+VR+LL.

Based on the results of statistical analysis, composition of vermicompost materials affected the total organic C, total N and C/N ratio of the vermicompost. A low quality organic matter such as spent mushrooms waste which initially has a C/N ratio of 78.5 after mixing with other organic materials and vermicomposting, had a lower C/N ratio which was found to be 30.5. It showed that vermicomposting can lead to mineralization process which reduced C by N ratio of vermicompost. Our research was in line with previous report according to the research of Hui et al. (2007) [21]. Majlessi et al. (2012) reported that vermicomposting process due to the depletion of easily degradable carbon compounds and C losses as CO_2[22], Lores et al. (2006) stated that the vermicomposting process involved the activity of earthworms which modify wastes physically and feces excreted by worms can increase the activity of the microorganisms so that the rate of mineralization to be faster [23].

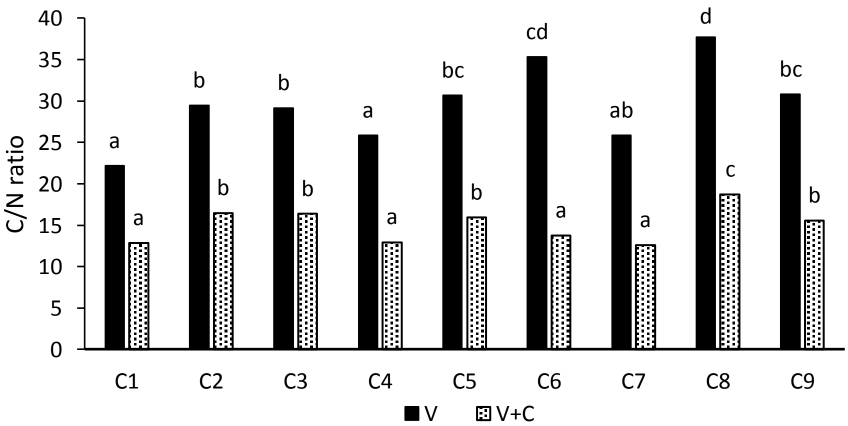

Figure3. C/N ratio in the treatment of vermicomposting alone (V) vs. combination of vermicomposting and composting (V+C) in various composition of vermicompost materials.

The C/N ratio of vermicompost produced is still relatively high by average C/N ratio of 30.5. Hoitink and Boehm (1999) reported that C/N ratio is one of parameter used for measuring compost maturity [22]. Reseachers have suggested various ideal C/N ratios ranging from >12 to <25 [25,26,27]. According to Gomez-Brandon et al. (2008) the stabilized compost has a C/N ratio from 10 to 15 [28]. Majlessi et al. (2012) showed that to produce a stable vermicompost of food waste needed 7 weeks of the process duration. The vermicomposting duration in our research was four weeks and then continued by composting for two weeks [22]. Domiguez (2011) reported that the decaying organic in vermicomposting system is a spatially and temporally heterogeneous matrix of organic resources with contrasting qualities that result from the different rates of degradation, occur during decomposition [29]. This means that the vermicompost still needs the composting process. To improve the quality of generated vermicompost, the systematic study of composting process and the addition of additives material such as fish meal and egg shell flour was conducted. After the composting process, the quality of vermicompost increased which marked by a lower C/N ratio of vermicompost (average 15.3). The decrease in C/N ratio was caused by the decomposition process of microorganisms during the composting process. During decomposition process, soil microorganisms burn carbon as a source of energy, but not all of the carbon remains in its body; a certain amount is lost as carbon dioxide during respiration.[30].The decrease in C/N ratio of compost improve the compost quality. Frankenberger and Abdelmagid (1985) states that the organic matter with a value of C/N ratio lower than 20 include high quality of organic matter and will undergo mineralization in the soil [31]. Majlessi et al. (2012) stated that the vermicompost with low C/N ratio (14-30) indicate a mature and stable vermicompost [22].

Polyphenols and lignin concentration of vermicompost which was generated through a vermicomposting and composting process were not significantly different from the vermicompost which was produced from the vermicomposting alone, while the cellulose content decreased after the composting process. However, among the treatments of vermicompost media composition tested, the treatments of vermicomposting and combination of vermicomposting and composting showed significant differences. The mixture of 6 kg SMW, 3 kg CD, 3 kg LL and the mixture of 6 kg SMW, 2 kg CD, 2 kg LL, and 2 kg VE have the lowest polyphenols and lignin, but this treatment had relatively high cellulose content (Table 1). Sawdust or spent mushroom waste made primarily of lignin and cellulose [32]. The spent mushroom waste made from sawdust may be difficult to produce high quality compost because it contains low nitrogen so that difficult to supply sufficient inorganic N for plant growth [32]. Igbokwe et al. (2015) showed that the mixing sawdust with the other organic waste in composting process can increase N content of the organic fertilizer [33]. The mixing sawdust with cow dung increase N content. Increase in N content lower the C/N ratio.

The quality of organic matter is determined by nutrient content, C/N ratio, composition of organic matter especially lignin, polyphenols and cellulose concentrations. Organic matter with higher concentration of nutrients and lower concentrations of lignin, polyphenols and cellulose decompose more rapidly and net mineralization begin earlier [34; 35]. The vermicompost materials did not significantly affect the pH of vermicompost on the treatment of vermicomposting alone before composting, but after composting, the vermicompost materials significantly affected the pH of vermicompost (average pH 6.8). Among the treatments of vermicomposting and composting, the mixture of 6 kg SMW, 3 kg CD, and 6 kg LL, 6 kg SMW, 2 kg CD, 2 kg LL, and 2 kg VR, 6 kg husk, 2 kg CD, 2 kg LL, 2 kg VR and 3 kg SMW, 3 kg CH, 2 kg CD, 2 kg LL, 2 kg VR had the highest pH (average pH 7.05) (Table 1). Darlington (2007) stated that most compost has a pH between 6 and 8. A low pH is an indication of poor composting which result in the formation of potentially toxic organic acids [36]. Ideally, the pH of compost product should be neutral to slightly acid (6.0 – 7.5) and if it exceeds about 8.5, so it need some efforts to control it [37]. A pH in the 6 to 8 pH range indicates more mature compost [38].

Table 1. Polyphenol, lignin, cellulose content and pH of vermicompost in the treatments of vermicomposting alone vs. combination of vermicomposting and composting in various composition of vermicompost materials.

Treatments	Vermicomposting				Vermicomposting + Composting			
	Polyphenol (%)	Lignin (%)	Cellulose (%)	pH	Polyphenol (%)	Lignin (%)	Cellulose (%)	pH
C1	0.49 a	17.74 a	37.21 d	6.57	0.45 a	17.71 a	34.29 d	6.63 b
C2	1.07 c	23.53 b	28.67 a	6.33	0.69 a	23.36 b	25.99 ab	6.33 a
C3	0.98 c	24.01 b	35.19 bc	6.43	0.97 ab	23.63 b	30.66 bc	6.63 b
C4	0.47 a	17.55 a	35.34 bcd	6.77	0.46 a	16.59 a	30.94 c	6.97 cd
C5	1.52 d	28.87 d	33.53 b	6.83	1.45 b	27.44 c	30.11 bc	6.53 ab
C6	0.94 c	24.49 b	36.46 cd	6.33	0.89 ab	23.93 b	31.75 cd	7.20 d
C7	0,45 a	18.16 a	34.00 b	6.50	0.45 a	17.33 a	30,20 bc	6.93 c
C8	1.68 d	27.14 c	29.46 a	6.57	1.64 c	26.47 c	24.81 a	7.00 cd
C9	0.67 b	24.17 b	35.50 bcd	6.50	0.64 a	23.88 b	28.34 b	7.03 cd
HSD 5%	0.21	1.37	2.01	ns	0.57	1.87	2.58	0.26

Remark : Means followed by different letters in the same column for each treatment are statistically significant different at Tukey- test ($P<0.05$).

Vermicompost with vermicomposting and composting produced significantly higher nutrient content in comparison to vermicompost with vermicomposting alone (Figure3 and 4). The average increase in the content of available P, exchangeable K, exchangeable Ca, and SO_4^{2-} concentrations was 67.5%, 29%, 700% and 25%, respectively. Among the treatments of vermicomposting and composting, the mixture of 6 kg SMW, 3 kg CD, and 3 kg VR, 6 kg SMW, 3 kg CD, and 3 kg LL, 6 kg SMW, and the mixture of 2 kg CD, 2 kg LL, and 2 kg VR had the highest P-available content. The highest exchangeable K content was found on the mixture of 6 kg CH, 3 kg CD, and 3 kg VR, 3 kg SMW, 3 kg CH, 3 kg CD, and 3 kg VR and the mixture of 6 kg CH, 3 kg CD, and 3 kg LL (Figure 3).

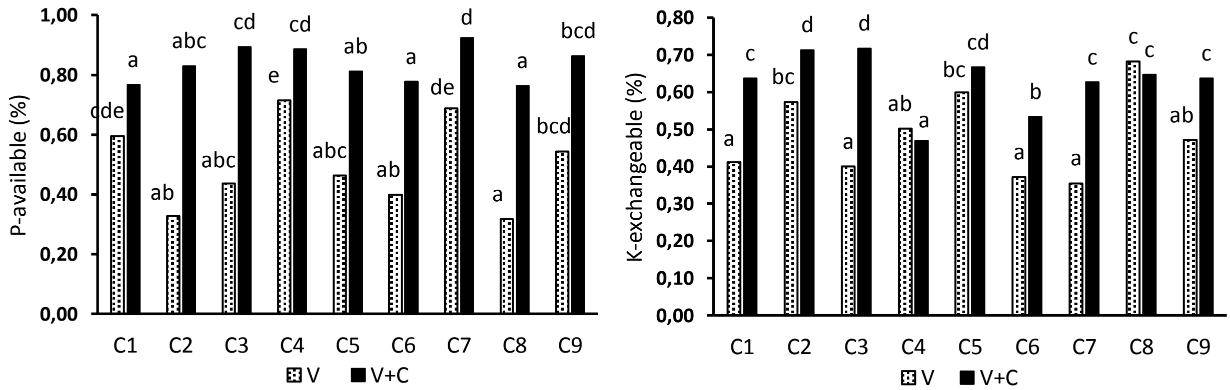

Figure 3. P-available and K-exchangeable in the treatment of vermicomposting alone (V) vs. combination of vermicomposting and composting (V+C) in various composition of vermicompost materials.

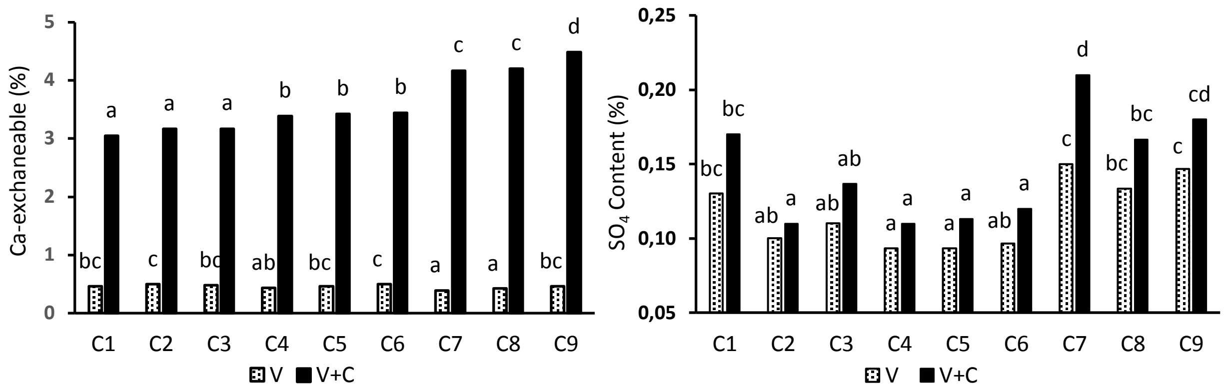

Figure 4. Ca-exchangeable and SO_4^{2-} content in the treatment of vermicomposting alone (V) vs. combination of vermicomposting and composting (V+C) in various composition of vermicompost materials.

This suggests that vermicompost materials composed of coconut husk contains a high K-exchangeable. The highest Ca content was found in the mixture of 3 kg SMW, 3 kg CH, 2 kg CD, 2 kg LL, and 2 kg VR. The addition of egg shell flour increase the Ca content of vermicompost up to 7 fold. The calcium content of eggshell meal was 35.2 % [34]. Yashothai and Kavithaa (2014) reported that egg shell is highly rich in calcium (90%) with little percentage (less than 5%) of phosphorus [39]. Khan et al. (2012) reported that fish meal contains a high crude protein by 60% and a crude lipid ranged from 9.9% to 29.5%. One of the crude lipids is a phospholipid containing phosphor [40]. Ponce and Gernat (2002) stated that fish meal is rich in protein, calcium, phosphorus and iron. The sulfur content in the compost was more influenced by the rate of mineralization of compost material [41]. The mixture of 6 kg SMW, 2 kg CD, 2 kg VR, 2 kg VR and the mixture of 3 kg SMW, 3 kg CH, 2 kg CD, 2 kg VR and 2 kg LL have the highest content of SO_4^{2-}. This is due to the quality of vermicompost materials support the faster rate of mineralization.

CONCLUSION

According to the present results, it was found that the combined vermicomposting and composting process improves the vermicompost quality when compared to using vermicomposting process alone. Vermicompost produced by the combined vermicomposting and composting process showed higher contents of nutrients and lower total organic carbon and C/N ratio compared to that of the vermicomposting process alone. Meanwhile, polyphenols, lignin and cellulose content decreased slightly. It suggest that the combined vermicomposting and composting process is a process of making vermicompost more appropriate and produce a better quality of vermicompost. The best quality of vermicompost was found in the treatment of mixture of 6 kg spent mushroom waste, 3 kg cow dung and 3 kg vegetable residue and the mixture of 6 kg spent mushroom waste, 2 kg cow dung, 2 kg VR, and 2 kg LL.

ACKNOWLEDGMENTS

We gratefully acknowledge the financial support from the Directorate of Research and Community Service, the Ministry of Research, Technology and Higher Education Indonesia through a scheme of excellent university research grant and the Department of Agrotechnology, Agriculture Faculty, Islamic University for facilitating this research.

REFERENCES

[1] Ministry of Environment, **2015**. Arrangement waste management regulations. http://www.menlh.go.id. Accessed on September 21st, 2016.
[2] The Center for Agriculture, Food and the Environment. **2016**. "Waste Management and Composting". The UMass Center for Agriculture, Food and the Environment is the home of UMass Extension and the Mass. Ag. Experiment Station. CDLE Pub.09-57. https://ag.umass.edu/fact-sheets/waste-management-composting. Accessed on September 21st, 2016.
[3] Jenkins, J. Thermophilic Composting as A Sanitation Alternative Givelove Org Project, Santo Village, Leogane, Haiti – A Case Study. **2015**. Postal address : 143 Forest Lane, Grove City, PA 16127 USA.
[4] Alidadi, H., A.R. Parvaresh, M.R. Shahmansouri, and H.Pourmoghadas, *Iran. J. Environ. Health. Sci. Eng.,* **2005**, 2, 251-254.
[5] Dominguez, J. and C. A. Edwards, Biology and Ecology of Earthworm Species Used for Vermicomposting, **2011**, Taylor & Francis Group, LLC. p.27-40.
[6] Gandhi, M., V. Sangwan, K.K. Kapoor, and N. Dilbaghi, *Environ. Ecol.,* **1997**, 15(2), 432 – 434.
[7] Elvira, C., J. Domínguez, and S. Mato, *Appl. Soil Ecol*., **1996**, 5, 97–103.
[8] Atiyeh, R. M., N. Arancon, C. A. Edwards, and J. D. Metzger, *Bioresour. Technol***.,** **2000**, 75, 175-180.
[9] Monroy, F., M.Aira, and J. Dominguez, *Appl. Soil Ecol*, **2008**, 39, 127-132.
[10] Aira, M., L. Sampedro, F. Monroy, and J. Domínguez, *Soil Biol. Biochem*., **2008**, 40, 2511–2516.
[11] Aira, M., M. Gómez-Brandón, C. Lazcano, E. Baath, and J. Domínguez, *Soil Biol. Biochem*., **2010**, 42, 12, 2276-2281.
[12] Lavelle, P. and A.V. Spain, Soil Ecology, **2001**, Kluwer Academic Publishers Dordrecht, Dordrecht, Netherland.
[13] G. Neata, R. Teodorescu, L. Dinca, A. Basaraba, *Agric. Agric. Sci. Procedia.*, **2015**, 6, 486-491.
[14] Khan, A., and F. Ishaq, *Asian J Plant Sci Res*, **2011**, 1 (1), 116-130.
[15] Ndegwa, P. M., and S. A. Thompson, *Bioresour. Technol*., **2001,** 76, 107-112.
[16] Ndegwa, P. M., Thompson, S. A. Das, K. C., *Bioresour. Technol*., **1999**, 71(1), 5-12.
[17] Soil Survey Staf, Soil survey laboratory methods manual, Soil survey Investigations Report 42, **1992**, USDA-SCS, National Soil Survey Center, Lincoln, NE.
[18] Schulte, E. E. and R. B. Corey*, Soil Sci Soc Am Pro*, **1963**, 27, 358-360.
[19] Verma, B. C., K. Swaminathan, and K. C. Sud, *Talanta*, **1977**, 29, 49-50.
[20] Anderson, J. M. and J. S. I. Ingram, Tropical Soil Biology and Fertility : A Handbook of Methods of Analysis, **1993**, Second Edition, CAB International, 157(4), 98-109.
[21] Hui, Z., L. Jianhua, D. Jianqing, C. Meiyuan, and C. Yi, The alternative uses of spent mushroom compost, **2007**, Fujian mushroom R&D Station, 350005, Fuzhou, P.R. China. www.tuinbouw.nl/sites/default/files/documenten/00026610.pdf, Accessed on September 21st, 2016.
[22] Majlessi, M., A. Eslami, H.N. Saleh, S. Mirshafieean, and S. Babaii, *Iranian J Environ Health Sci Eng*., **2012**, 9, 1-6.
[23] Lores, M., M. Gomez-Brandon, D. Perez-Diaz, and J. Dominguez, *Soil Biol. Biochem,* **2006**, 38, 2993-2996.
[24] Hoitink, H. A. J. and M. J. Boehm, *Annual Rev Phytophatol*, **1999**, 37, 427-446.
[25] Jimenez, E. I. and V. P. Garcia, *Biol Waste,* **1992**, 27, 115-142.

[26] Erhart, E. and K. Burian, *Compost Sci. Util.,* **1997**, 5, 15-24.
[27] Brewer, L.I. and D.M. Sullivan, *Compost Sci. Util.*, **2003**, 11, 96-112.
[28] Gomez-Brandon, M., C. Lazcano, and J. Domingueza, *Chemosphere*, **2008**, 70, 436-444.
[29] Dominguez, J., The Microbiology of Vermicomposting, **2011**, Taylor & Francis Group, LLC.
[30] Frankenberger, W .T. and H. M. Abdelmagid, *Plant Soil*, **1985**, 87, 257-271.
[31] Thomas, M. B. and M. I. Spurway, *Combined Proceedings International Plant Propagators Society,* **1998**, 48, 66-71.
[32] Igbokwe, P. K., C. O. Asadu, E. C. Okpe, and S. E. Okoro, *Int. J. Novel Res. Phys. Chem. Mathematics,* **2015**, 2 (3), 6-15.
[33] Mtambanengwe, F. and H. Kirchmann, *Soil Biol. Biochem*, **1995**, 27, 1639-1651.
[34] Tian, G. L., Brussaard, and B. T. Kang, *Applied Soil Ecol.***1995**, 2, 25-32.
[35] Darlington, W., *Soil& Plant Laboratory*, Inc. Orange Office, **2007**, 714, 282-877.
[36] Walton, H. V. and O. J. Cottrill, *Poult Sci,* **1972**, 51, 1884.
[37] Ahmad, R., A. Khalid, and M. Mahmood, *Pak J Bot*, **2007**, 39 (2), 541-549.
[38] Louisa, M. A., and G. Taguiling*, ESJ*, **2013**. 9 (36), 319-341.
[39] Yasothai, R. and N.V. Kavithaa, *IJEST,* **2014**, 3(4), 1436-1439.
[40] Khan, T.A., N. Khan, M. Ashraf, N.A. Qureshi, M.S.Mughal, and G. Abbas, *J. Vet. Anim. Sci,* **2012**, 2, 65-71.
[41] Ponce, L.E. and A.G. Gernat, *Poult Sci*, **2002**, 81, 1045-1049.