THE EFFECT OF *Lumbricus rubellus* SEEDLING DENSITY ON EARTHWORM BIOMASS AND QUANTITY AS WELL AS QUALITY OF *KASCING* IN VERMICOMPOSTING OF CATTLE FECES AND BAGASSE MIX

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Abstract

Cattle feces may cause environmental pollution if it is not treated wisely. In order to avoid the negative environmental impact, cattle feces can be converted into valuable organic fertilizer by mean of vermicomposting, a composting process using earthworm as a bioconverter. One of earthworms that can be use for this purpose is Lumbricus rubellus This bioconversion of cattle feces provides two benefits, i.e., Kascing, an organic fertilizer composted with compost substrate and earthworm casting, and biomass of earthworm, a high protein content animal feed. This study was conducted at the Faculty of Animal Husbandry, Universitas Padjadjaran, Indonesia. The objective of this research is to find out the effect of Lumbricus rubellus seedling density on the earthworm biomass, and on the quantity and quality of Kascing in vermicomposting of cattle feces and bagasse mix. This experiment was carried out based on completely randomized design with three treatments of seedling density of earthworm namely of 1.5 kg/m^2, 2 kg/m^2 and 2.5 kg/m^2. The treatments were performed in six replications within 21 days. The result of this study indicates that the seedling density significantly increases the biomass of L.rubellus and decreases the quantity of Kascing. Seedling density of 2.5 kg/m^2 results in the highest earthworm biomass, but in the same time results in the lowest Kascing quantity. Furthermore, the seedling density also increases phosphorus and potassium content of the resulted Kascing significantly, but not the nitrogen content. The resulted Kascing can be used as a source of nitrogen.

Key words: cattle feces, bagasse, vermicomposting, L.rubellus, Kascing

INTRODUCTION

Increasing cattle production means not only increases meat production but also increases feces production, in ratio of 1 to 25 (Sihombing, 2000). It means that the resulted positive impact, i.e., the increase of population meat demand fulfillment may accompanied with negative impact potentially caused by cattle feces, i.e. environmental pollution, either air pollution, water pollution or soil pollution. Those negative impacts have been experienced in some cattle farming areas in Indonesia. Basically, cattle feces is a resource that can be used for fulfilling population needs. It is because of its content of organic matters of about 30% (Gaddie and Douglas, 1975), that can be degraded easily by bacteria, fungi and actinomycetes in the feces itself (Haga, 1990; Harada, et al., 1993) The organic matters consists of carbohydrate, protein, fat, vitamin, nucleic acid and organic acids (McDonald, et al., 1989) which are can be used as raw material of organic fertilizer, biofuel as methane and animal feed (Rusdi, 2004). However, the use of cattle feces in Indonesia up to now has been far from any good management practice, so that the potential of the feces as resource is limited accordingly. Therefore, such kind of feces management practice may harm the environment and should be replaced with environmentally sound management practice. One of the promising management practices of animal waste is vermicomposting, composting process using microorganisms and earthworms to degrade organic matters content of composting substrate (feedstock) (Catalan 1981). There are two benefits obtained from vermicomposting, namely bio mass of earthworms and *Kascing*. Earthworm has been known as high protein content animal feed, while *Kascing* which is a mixture of earthworms casting and degraded feedstock can be used as organic fertilizer.

In vermicomposting process, feedstock is degraded by microorganism first, and than followed by earthworms. However, according to CSIRO (1979) the earthworms has a significant role in accelerated composting process and reduce the particle size of organic matters into soil like substance. There are many species of earthworm can be used in vermicomposting, among others *is Lumbricus rubellus* . This species of earthworm has been known to be the most active organic matters degradator in soil surface.

As living thing, earthworms require adequate nutrient supply. The most important one is C/N ratio (Catalan , 1981). Cattle feces contain 41.4 % of carbon and 4-20% of protein (Gaddie and Douglas, 1975). The high content of protein makes C/N ratio of the feces very low of about 3.45. On the contrary, microorganisms and earthworms in composting process requires C/N ratio of 25 – 30 (CSIRO, 1979). Therefore, in order to provide microorganisms and earthworms with a good living condition, high C/N ratio organic substance should be added. Among organic substance that can be used for this purpose is sugar cane (*Saccharum officinarum*) pulp or bagasse. It is not only due to its high carbon and low nitrogen contents, but also its availability.

Furthermore, earthworms life is also influenced by other factors, namely temperature, pH, relative humidity. Temperature of feedstock should be maintained in the range of 18 to 29^0C (Catalan, 1981), although it may increase up to about 60^0C due to heating process. Temperature will decline when the substrate is turned and sprayed with water. The pH should be about 6.5 to 8.5 (Stofella and Khan, 2001). In the beginning of composting process, pH of substrate declines due to acid formation, and then inclines again along with microbial ammonification reaction, which converts organic nitrogen into ammonia (Merkel 1981). Relative humidity of feedstock is 15-30% (Simanjuntak and Waluyo, 1982), or even higher 40 – 60% (Indriani, 1999). As the temperature of the substrate increases, the relative humidity decreases. Therefore, the substrate should be moist by spraying some amount of water. Oxygen is another influencing factor of aerobic composting process. Poor aeration will turn the decomposition process into anaerobic condition, and organic material will be degraded in slower rate accordingly. To obtain an ideal aeration level, feedstock should be turned in every 3 days.

Finally, if the requirement has been fulfilled, there is another factor that will influence the decomposition process, i.e., population density that counted from number or weight of earthworms per $m^{2.}$. Population density is depending on seedling density. Catalan (1981) suggested that the ideal seedling density is 2 kg/m^2. In low population density condition, the growth of earthworm will be good, but decomposition process wills slowdown. Earthworms will stop eating when full no matter how plenty food available. On the other hand, if the population density is too high, decomposition process runs very fast in the beginning, and slowing down in very short time after word. Earthworms will suffer from feed limitation and their growth will be retarded accordingly. This will reduce the biomass of earthworms. Every earthworm consumes feed 20 times it's body in 10 days or doubled its body weight in 24 hours, in ideal condition (Haukka, 1987).

During composting process, earthworms convert its feed into casting in the ration of 2 : 1. Catalan (1981) proved that in a month, 50 kg earthworms consume 375 kg feed and produce 187.5 kg casting. Casting contains 0.5 – 0.9% of nitrogen, 0.6-0.68 of phosphorus, and 0.1 -1.10% of potassium. (Gaddie and Douglas, 1975). Casting also contains a lot of microorganisms and minerals, and important enzyme such as protease, amylase, lipase, cellulose, as well as chitonase. For practice purposes, in Indonesia the resulted casting usually blended with the composting material, which is also has high nutritive value, called as *Kasting*. However there is no information about the nutritive value of *Kascing* particularly that resulted from specific seedling density of earthworm in feedstock made of cattle feces and bagasse. Therefore it is important to carry out a study on the effect of Lumbricus rubellus seedling density on earthworm biomass and quantity as well as quantity of *Kascing* in vermicomposting of cattle feces and bagasse mix.

MATERIAL AND METHOD

The experiments were undertaken at the Microbiology and Waste Management. Faculty of Animal Husbandry. Universitas Padjadjaran Indonesia.

Preparation and formulation of feedstock. Before formulating feedstock, chemical analysis was done on cattle feces and bagasse. The chemical analysis was done in duplex. The result of the analysis is presented in Table 1.

Table 1. Carbon and nitrogen content of cattle feces and bagasse

Organic substance	Carbon content (%)	Nitrogen content (%)	Water content (%)	C/N
Cattle feces	9.70	0.65	79.40	15
Bagasse	29.13	0.65	24.4	44.81

The feedstock is formulated using the following equation (Richard and Trautmann, 1996):

$$Qb = \frac{Qc \times Nc \times (R - Cc/Nc) \times (100-Mc)}{Nb \times (Cb/Nb-R) \times (100-Mb)}$$

Where, Qb = bagasse (kg), Qc = cattle feces (kg), Nb = nitrogen content of bagasse (%). Nc = nitrogen content of cattle feces (%), Cb = carbon content of bagasse (%), Cc = carbon content of cattle feces (%), Mb = water content of bagasse (%), and Mc = water content of cattle feces.

By substituting the results of chemical analysis on Table 1 into the equation, for every 5 kg of feedstock with 30 of C/N ratio, 3.73 kg of cattle feces was mixed with 1.27 kg of bagasse. The substrate was air dried for 24 hours. This study was divided into two stages. The first stage was composting process for 15 days. Composting method used in this study was Berkeley method that had been developed at California University, USA (CSIRO, 1979). The feedstock was turned every 3 days to maintain oxygen content and sprayed with small amount of water to maintain the relative humidity of the substrate of 40-60%. The second stage was vermicomposting process. In the 15^{th} days, composting substrate was divided into 18 parts of 2520 grams, and placed into plastic container sized of 27.5 cm x 21.5 cm x 12.5 cm. Then vermicomposting experiment started.

The vermicomposting experiment was carried out based on Completely Randomized Design with three treatments of earthworm seedling density, namely of SD_1 = 1.5 kg/m^2 (50 gr earthworms), SD_2 =2 kg/m^2 (66 gr earthworm), and SD_3 = 2.5 kg/m^2 (83 gr earthworm). The treatments were performed in six replications within 21 days. Temperature and pH of the substrate were measured every day. After 21 days, earthworm's biomass and *Kascing* were weighted. Chemical analyses, nitrogen, phosphorus and potassium were performed to know the quality of *Kascing* . To know the effect of every treatment, the obtained data were analyzed using one way Analysis of Variance (ANOVA), this analysis was then followed by Tukey T-Test to know the inter treatments effect differences (Gaspersz, 1991).

RESULTS AND DISCUSSIONS

After 21 days of vermicomposting, every earthworm seedling treatment increases the earthworm's biomass. The treatment of SD_1, SD2 and SD3 respectively resulted in earthworms biomass increase of 70.5 gr, 79.17 gr, and 92.5 gr. Based on ANOVA, it is known that the seedling density significantly affect the increase of earthworm biomass reared in cattle feces and bagasse mix differently ($P<0.05$). To know the different effect between the treatments, Tukey T-Test was performed. The result of the test is presented on Table 2.

Table 2. The result of Tukey T-Test on the effect of earthworm seeding density on the *L. rubellus* biomass increase

Treatment	Earthworm Biomass (gr)	Significance (α 0.05)
SD_3	92.5	a
SD_2	79.17	b
SD_1	70.5	c

Table 2 shows that every treatment provides different effect on *L. rubellus* biomass increase, the higher the seedling density gives the higher increase of L *.rubellus* biomass. It is easy to understand, because the composting and vermicomposting processes were run perfectly based on the temperature and pH of the substrate shown on Table 3.

Table 3. The range of temperature and pH of substrate during composting and vermicomposting process

Process	Temperature (^{0}C)	pH
Composting	21 - 27	6.3 – 7.3
Vermicomposting	23 - 26	6.5 – 7.3

Table 3 shows that during composting process the temperature and pH of substrate are in the range of 21- 27 ^{0}C and 6.5 – 7.3, while during the vermicomposting are of 23 – 26 ^{0}C and 6.5 – 7.3 respectively. These obtained data are agreed with the requirement of composting process for temperature and pH, i.e. 18 – 29 ^{0}C and 6.5 – 8.5 (Catalan 1981; Stofella and Khan, 2001). The two measures indicate that all reactions in the processes are taken place normally. Its mean that there is no physical and chemical limitation during the two processes that may retard activity and earthworm growth as well.

The average weight of *Kascing* biomass resulted from the treatment of seedling density of earthworm treatments are varies. The highest *Kascing* biomass was provided by SD_1 (1633 gr) and lowest provided by SD_3 (1,350 gr). An analysis of variance was performed for the treatments and the result shows that every seedling density significantly affected the biomass of resulted *Kascing* (P<0.05). Significant differences were identified by means of Tukey's T–test, and the result is presented on Table 4.

Table 4. The result of Tukey's T-Test on the effect of earthworm seedling density on the biomass of resulted *Kascing*

Treatment	*Kascing* Biomass (gr)	Significance (α 0.05)
SD1	1,663	a
SD2	1,500	b
SD3	1,350	c

Based on Table 4, it is known that the different seedling densities significantly affect the biomass of the *Kascing*. The effect of SD_1 is significantly differing from the effect of SD_2 and SD_3, and the effect of SD_2 is significantly differing from that of SD_3. The high *Kascing* biomass resulted from SD_1 (1,633 gr) is due to the lowest earthworm biomass. Earthworm body weight influences the weight of feed consumed. Basically, the lowest earthworm body weight the less feed consumed. Therefore, there is more feedstock that had not been consumed by the earthworm. On the contrary, the low *Kascing* biomass resulted from SD_3 is related to the high earthworm biomass. In this treatment more feedstock consumed by the earthworm and retained in earthworm body. Therefore, there is less feedstock left unconsumed and become part of *Kascing* biomass.

The result of chemical analysis on nitrogen content of *Kascing* shows that SD_3 provides nitrogen content of 3.22 %, SD_2 of 3.10 % and SD_1 of 3.01 %. However, these nitrogen contents are not differing significantly according to the result of ANOVA as mentioned on Table 5.

Table 5. ANOVA of the earthworm seedling density effect on nitrogen content of Kascing

Source of variance	Degree of freedom	Quadrate Total	Mean Quadrate	F	F_{table} 0.05
Treatment	2	0.135	0.067	2.577^{ns}	3.68
Error	15	0.394	0.026		
Total	17	0.529			

ns = non significant

The different between the treatment effects are not significant, it is due to the nitrogen content of the feedstock which had been set to be the same for all composting processes that indicated by the same C/N ratio. Nitrogen in the feedstock was initially in the form of protein either in the cattle feces or in the bagasse. This protein is being degraded by microorganisms during the decomposition process. Since there are no additional sources of protein, other than cattle feces and bagasse, the nitrogen content was remaining the same. When the vermicomposting was started, the earthworms started feeding the substrate. Nitrogen that taken up and released back to the feedstock by the earthworm seemingly proportional to the seedling density. The difference of nitrogen content is not influencing the quality of the *Kascing* as organic fertilizer, because all concentration of the nitrogen are higher than its standard according to National Standardization Agency of Indonesia (2004), that is ≥ 0.04%. The nitrogen contents are also higher than that of cattle dung biocompost according to TNAU (2008), i.e., 0.3 – 0.4%. It means that the *Kascing* can be used as a source of nitrogen fertilizer.

Phosphorus content of *Kascing* resulted from seedling density treatments are increasing as the seedling density of the earthworm increases from SD_1, SD_2, to SD_3, i.e. 0.048%, 0.087% and 0.192% respectively. According to the ANOVA result, these treatments are significantly affecting the phosphorus content of *Kascing*. The difference between the treatments is clearly defined by the result of Tukey's T-Test as shown on Table 6.

Table 6. The result of Tukey T-Test on the effect of earthworm seeding density on phosphorus content of Kascing

Treatment	P-content (%)	Significance (α 0.05)
SD_1	0.048	A
SD_2	0.087	B
SD_3	0.192	C

Based on Table 6, it is found that the SD_3 significantly provides more phosphorus content of *Kascing* than that of SD_2 and SD_1, and SD_2 significantly provides more phosphorus content than that of SD_1. Similar to nitrogen, phosphorus availability is resulted from mineralization by microorganisms. However, since phosphorus is not volatile as nitrogen, so that the concentration of phosphorus remain constant. According to Foth (1995). There is no phosphoric acid loss from animal feces by mean of volatilization. This study used cattle feces and bagasse mix as feedstock. Initially, during the composting process, indigenous microorganisms of the substrate degraded the material, so that the phosphorus content of the material is converted into available content. In the vermicomposting process, earthworm degrades organic matters of *Kascing* into a simpler form that can be use by microorganism in forming organic phosphorus. Therefore, more earthworms resulted in more phosphorus content. Unfortunately, all concentrations of phosphorus in the *Kascing* are below its standard, namely ≥ 0.1 % (National Standardization Agency of Indonesia, 2004). Its mean, in term of phosphorus content, the resulted *Kascing* is not recommended as a single organic fertilizer, except the one resulted from SD_3. This resulted *Kascing* is also along with the typical value of phosphorus content of cattle dung biocompost which is in the range of 0.1 – 0.2% (TNAU, 2008).

The result of chemical analysis on potassium content of *Kascing* indicates that SD_3 result in the highest potassium content of *Kascing* (0.253 %), followed by SD_2 and SD_1, i.e. of 0,113 and 0.063. Furthermore, the result of ANOVA shows that the seedling density of earthworm significantly affect the potassium content of *Kascing*. This brings to the result of Tukey's T-Test as presented on Table 7.

Table 7. The result of Tukey T-Test on the effect of earthworm seeding density on Potassium content of *Kascing*

Treatment	K-content (%)	Significance (α 0.05)
SD_1	0.063	a
SD_2	0.113	b
SD_3	0.253	c

Seedling treatment of SD_3 significantly provide potassium content of *Kascing* (0.253%) higher than SD_2 (0.113 %) and SD_1 (0.063%), and SD_2 significantly provide potassium content of *Kascing* higher than that of SD_1. Musnamar (2003) indicated that the availability of potassium is due to microorganisms activities. The activities of microorganisms are influenced by many factors, among other is nutrient particularly carbon as energy source and nitrogen used in cell development. All feedstock used in this study had been design to have C/N ratio of 30, only seedling density treatments which differentiate them. As the seedling density increases, more organic matters are degraded by earthworm which released back to the *Kascing.* Similar to the nitrogen content, the concentrations of potassium are also higher than the standard, i.e. ≥ 0.02 % (National Standardization Agency of Indonesia, 2004). The resulted *Kascing* is adequate to be used as an organic fertilizer based on its content of potassium. However, only the potassium content of *Kascing* resulted from treatment SD2 and SD3 which are along with the typical content of potassium according to TNAU (2008), that is 0.1 – 0.3%.

CONCLUSIONS

The result of this study indicates that the seedling density significantly increases the biomass of L.rubellus and decreases the quantity of *Kascing*. The highest earthworm seedling density gives the highest the biomass of *L.rubellus*, and the lowest the quantity of *Kascing* as well. Seedling density of 2.5 kg/m^2 results in the highest earthworm biomass, in the same time provides the lowest *Kascing* quantity. Furthermore, the seedling density also increases phosphorus and potassium content of the resulted *Kascing* significantly, but not the nitrogen content. The seedling density of 2,5 kg/m^2 is also provided *Kascing* that can be used as NPK fertilizer.

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REFERENCES

[1] Catalan, Earthworms, A New Science of Protein. Philippine Earthworms Center, Manila, 1981.

[2] CSIRO, Composting Making Soil Improver from Rubbish, Discovering Soil No. 3. CSIRO Division of Soil. Melbourne. 1979.

[3] Foth, H.D., Basics Soil Science, translated to Bahasa Indonesia by. Endang Dwi Purbayanti, Dwi Retno Lukiwati and Rahayuningsih Trimulatsih, Gajahmada University Press, Yogyakarta, 1995

[4] Gaddie, R.E. and D.E. Douglas, Earthworm for Ecology and Profit, Vol I, Bookworm Publishing Company, Ontario, 1975

[5] Gaspersz, V., Technical Analysis in Experimental Study. Transito, Bandung, Indonesia, 1991.

[6] Haga, K., Development of Composting Technology in Animal Waste Treatment, Proceeding Pre-Conference Symposia, The 8th World Conference on Animal Production, South Korea.,1998

[7] Harada, Y.K., T. Osada, and M. Koshino. 1993. Maturiting Process of City Refuse Compost During Piling. Soil Science Plant Nutrition, No 27. 357 -364.

[8] Haukka, J.K., Growth and Survival of Eisinia foetida (sav) (Oligochaeta: Lumbricidae) in Relation to Temperature, Moisture and Presence of Enchystraeus Albidus (Henle) (Enchytraidae), J. Biology and Fertility of Soil, (1987)3. 99-102

[9] Indriani, Y.H., Making Compost Quickly, PT. Penebar Swadaya, Jakarta, 1999.

[10] McDonald, P., R.A. Edwards and J.F.D. Greenhalgh, Animal Nutrition, John Wiley and Sons Inc., New York, 1989.

[11] Merkel, J.A., Managing Livestock Wastes. AVI Publishing Company Inc., West Port, Connecticut, 1981

[12] National Standardization Agency of Indonesia, Specification of organic garbage compost, SNI 19-7030-2004.

[13] Richard, T. and N. Trautmann, C/N Ratio, in Cornell Composting, Science and Engineering, Cornell Waste Management Institute, Cornell University, Ithaca. 1996

[14] Rusdi, U.D., The Potency of Microbes in Animal Waste Bioconversion as a Resource and Its Implication on Food Security, Universitas Padjadjaran, Banding, 2004, pp 2-3 and 11-21.

[15] Sihombing, D.T.H., The Potency of Earthworms in Industry and Animal Husbandry Sector, Media Peternakan. IPB. Bogor, 2000

[16] Simanjuntak, A.K. and Waluyo, Cacing Tanah, Budidaya dan Pemanfaatannya, PT. Penebar Swadaya, Jakarta. 1982.

[17] Stofella, P.J. and B.A. Khan, Compost Utilization in Horticultural Cropping System, Lewis Publishers, London. 2001

[18] TNAU. Organic Farming: Composting. Tamil Nadu Agricultural University, Coimbatore, 2008