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Optimization of the Use of Farm Waste and Water Hyacinth for Earthworm (*Lumbricus rubellus*) Cultivation Media

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ABSTRACT

This study aimed to determine the effect of water hyacinth addition to farm waste on the number of earthworms, earthworm weight, media shrinkage, vermicompost quality, and the sustainability and sensitivity of earthworm farming. The study was prepared using a completely randomized design with two different factors, the water hyacinth (media without water hyacinth and media with 5% water hyacinth addition) and raw materials from farm waste (chicken and cow manure, and biogas sludge from chicken and cow manure), with three replications for each treatment. The results showed that the addition of water hyacinth to raw materials from farm waste had a very significant effect on the number of earthworms, earthworm weight, media shrinkage, vermicompost quality (except for P_2O_5 level that had no significant increase). When manure is to be added to the cultivation media, it is recommended to use cow manure, while both types of biogas sludge (from chicken and cow manure) are good for the cultivation of earthworm. Based on the study of sustainability, the use of farm waste and water hyacinth as media to raise earthworm gives a positive value in economic and environmental aspects. Therefore, it has great potential.

Keywords: Earthworm, Farm waste, Sustainability, Water hyacinth

Introduction

Organic waste is waste derived from living beings such as livestock waste, agricultural waste, and weed. Farm waste includes chicken and cow manure, chicken manure sludge, cow manure sludge, et cetera, while water hyacinth is one of plant waste (weed) since it is often a highly problematic invasive species. Waste, if not managed properly, can cause negative impacts on the environment, such as pollution of land, water, and air. Conversely, if well managed, waste can provide benefits to mankind. One of the potential benefits which make real use of organic waste is bio-fertilizer. Livestock manure contains organic materials, vitamins, and minerals that can be used as organic fertilizer.

Before being used as fertilizer, chicken and cow manure should go through the aerobic composting process first. Another treatment is the breaking down of organic matter using earthworm, in a process known as vermicomposting. Vermicomposting is alternative waste management that represents environmentally friendly technology.

Chicken manure is an organic material containing nutritional content such as 1.0-2.1% nitrogen, 8.9-10.0% phosphorus, and 0.4% potassium (Sarinadira and Bayu, 2015). The nutrient content and composition allows it to be used as medium and feed material for the earthworms to increase their productivity and reproductivity. Cow manure is also a good material to use as a compost base because it is relatively not contaminated by heavy metals and antibiotics. Cow manure contains high enough organic material, protein, and nutrients to be used as feed for the earthworms.

Chicken and cow manure can also be used for biogas. The byproduct of biogas plant that looks like mud, known as sludge, can also be used as fertilizer because it still contains organic material. According to Tistiana (2011) the 100% dry matter of sludge contains ash (34,08%), protein (10,12%), fiber (37,36%), and fat (1,93%). Viewed from the content of the sludge, it can be used as organic fertilizer and growth media of earthworms.

The media used in the manufacture of vermicompost is the feed to support the life of the earthworms. The feed serves to improve their productivity and reproduction. Another material that can be used as growth medium and worm feed is water hyacinth (Palungkun, 2010).

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant that grows very fast. It can cover the water surface and cause environmental problems, so this plant is considered a weed. However, water hyacinth has the ability to absorb nitrogen and phosphorus compounds from contaminated water so that it can be selected as the potential source of compost or fertilizer (Gerbono and Siregar, 2005). The nutritional value of water hyacinth is as follows: 9.8-12.0% protein, 11.9-23.9% ash, 1.1-3.3% fat, and 16.8-24.6% fiber (Riswandi, 2014).

Earthworms offer many benefits, including accelerating waste decomposition process, fertilizing soil and crops, to be used as feed for livestock and fish, as an ingredient of herbal medicine, as a protein source, organic fertilizer, and cosmetic ingredient. Earthworms, especially Lumbricus rubellus, can also be used as a main raw material for the manufacture of typhus medication, so this type of earthworm has potential to be cultivated. This study aimed to determine the effects of water hyacinth addition to farm waste on the number of earthworms, earthworm weight, media shrinkage, vermicompost quality, and the sustainability and sensitivity of earthworm farming.

Materials and Methods

Materials and tools

The materials used in this research were earthworm *Lumbricus rubellus*, chicken and cow manure, sludge from chicken and cow manure, and water hyacinth. The equipment used included woven bamboo, thermometer, hygrometer, black plastic wrap, tape-meter, analytical balance, pH indicator, camera, gloves, Whatman filter paper, mask, hand sprayer, spectrophotometry, mortar and pestle, test tube, funnel, volumetric flask.

Method

Earthworm preparation

The earthworms used were one-month old *Lumbricus rubellus* obtained from worm farmers.

Media preparation

The media used in this research was raw materials of farm waste and water hyacinth. The farm waste in the form of chicken manure and biogas sludge from chicken manure was obtained from chicken farmers in Pakem sub-district, Sleman district, Yogyakarta, while cow dung and biogas sludge from cow dung were obtained from Center of Agro-technology Innovation, Gadjah Mada University, Yogyakarta. Water hyacinth was obtained from Kali Tirto, Berbah, Sleman district, Yogyakarta.

The preparation of earthworm media with the raw material of farm waste and water hyacinth followed the research steps of Brata (2008). First, chicken and cow manure was spread for one month for air drying, so the smell and unwanted gases that might harm the earthworms were removed. Second, biogas sludge from chicken manure and sludge from cow manure were air dried for 1 week, so the water contained in sludge (bio-slurry) was reduced. Third, water hyacinth was cut into small pieces that were 2 cm long, then mashed. Finally, after all the media were ready, they were put into a woven bamboo basket with the size of 38 cm x 22 cm x 14 cm, according to the treatment.

Planting earthworms

After being air-dried to reduce their heat and gases, the media should go through a biological test to determine their suitability as a home for earthworms to live. According to Brata (2008), the biological test was done by inserting 3 earthworms into the media. If within 24 hours the worms were not likely to die or escape, the media could be used as a place for them to live.

The planting of the earthworms to the media was done in accordance with the research treatments. The weight of each medium in each treatment was 3,000 g. Each container was planted with 100 g of earthworms, and the maintenance of the earthworms lasted for 5 weeks. During the research, the watering with hand sprayer was done once a day between 10 a.m. and noon to maintain the temperature stability and the moisture of the media (Brata, 2008).

Population number of earthworms

The population number of earthworms was calculated from the time of planting (week 0) to the harvest time (week 5). The observation was done every 6 days.

Earthworm weight

The earthworms were weighed at the time of planting (week 0) until the harvest time (week 5). The observation was done every 6 days.

Media shrinkage

Media shrinkage was observed at the beginning and the end of earthworm cultivation. The media shrinkage was calculated by following this formula:

$$\text{media shrinkage} = \frac{(\text{initial weight} - \text{final weight})}{\text{initial weight}} \times 100\%$$

Vermicompost quality

The analysis of vermicompost quality was carried out on the chemical properties (C-organic, N total, P_2O_5 and K total) using Atomic Absorption Spectrophotometry (AAS) instrument, in accordance with the *Official Methods of Analysis* (AOAC, 2000). The results were expressed in percentages.

Research design

The treatments in this research included 2 factors. The first was farm waste (L), consisted of 4 levels: L1 (chicken manure), L2 (cow manure), L3 (chicken manure sludge), L4 (cow manure sludge). The second factor was the addition of water hyacinth (E), consisted of 2 levels: E0 (without water hyacinth addition), E1 (with the addition of 5% water hyacinth). The design used was a completely randomized design with factorial arrangements. The two factors: the addition of water hyacinth and the raw materials of farm waste were combined, so we obtained 8 treatment mixtures. Each treatment was done with 3 replications, so we had 24 experiments.

Statistical analysis

The data obtained were analyzed statistically using variance analysis (ANOVA), SPSS (Statistical Package for the Social Sciences), and DMRT (Duncan Multiple Range Test) to determine the difference between treatment means.

Analysis of the economic aspect

The economic analysis of earthworm cultivation business included the calculation of investment cost, production cost, income, profit, and business feasibility of small and medium scale worm farming and vermicomposting (worm castings).

Results and Discussion

Population number of earthworms

The population number of earthworm from week 3 to week 5 increased with the addition of water hyacinth to various raw materials of farm waste. However, in the mixture of chicken manure with water hyacinth addition, there was a decrease of earthworm population from week 0 (planting time) to week 2, and from week 2 to week 5, all of the earthworms died (Figure 1). Figure 1 also shows that the earthworms remained alive until week 5 in the raw material of biogas sludge from chicken manure. This was because chicken manure had undergone an anaerobic process in the digester during biogas production process. Yonathan *et al*. (2012) stated that anaerobic digestion is a process by which microorganisms break down biodegradable materials in the absence of oxygen.

Earthworm weight

In various raw materials of farm waste with water hyacinth addition, the weight of earthworms from week 3 to week 5 had decreased. The decrease of weight also happened in the mixture of chicken manure and water hyacinth addition: from week 0 (planting time) to week 2, and from week 2 to 5, the earthworms died completely, as shown in Figure 2. Manurung *et al*. (2014) stated that age factor could be one of the causes of the earthworm weight decrease. The earthworms in question are the ones that have reached their final adult age. Based on the result of this research, the decrease of the earthworm weight might be caused by the decrease of nutrient quality in the media, so it could no longer provide the required nutrition to support the life of the worms. And if the nutrient supply rate is too low, it might lead to the death of the earthworms.

Yunitasari *et al*. (2015) stated that the growth process of the earthworms is affected by pH, temperature, humidity, and feeding. The amount of feed and environmental conditions play an important role in the growth process of the earthworms. The results of Apriliani (2017) study suggest that the worm weight is low in the media that are not friable, tend to be sticky, clumpy, and have bad aeration. Such conditions reflect the loss of nutrients from the media.

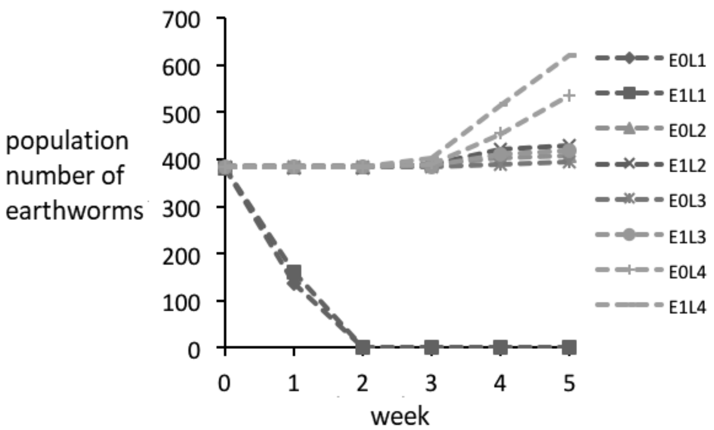

Figure 1. The increase of earthworm population living in various media of farm waste with the addition of water hyacinth for 5 weeks. E0L1 = without water hyacinth + chicken manure, E0L2 = without water hyacinth + cow manure, E0L3 = without water hyacinth + biogas sludge from chicken manure, E0L4 = without water hyacinth + biogas sludge from cow manure, E1L1 = addition of 5% water hyacinth + chicken manure, E1L2 = addition of 5% water hyacinth + cow manure, E1L3 = addition of 5% water hyacinth + biogas sludge from chicken manure, E1L4 = addition of 5% water hyacinth + biogas sludge from cow manure.

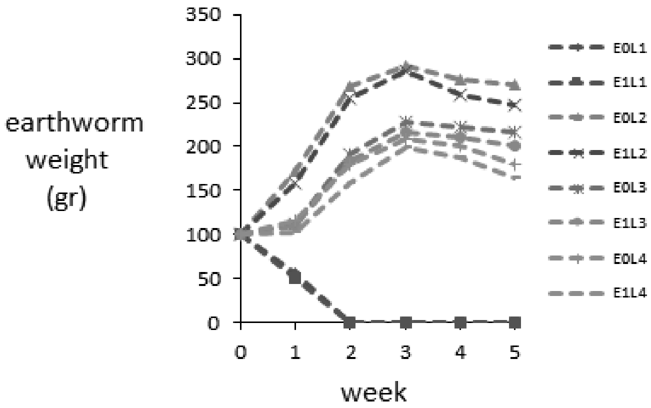

Figure 2. The Increase of the weight of earthworms living in various media of farm waste with the addition of water hyacinth for 5 weeks. E0L1 = without water hyacinth + chicken manure, E0L2 = without water hyacinth + cow manure, E0L3 = without water hyacinth + biogas sludge from chicken manure, E0L4 = without water hyacinth + biogas sludge from cow manure, E1L1 = addition of 5% water hyacinth + chicken manure, E1L2 = addition of 5% water hyacinth + cow manure, E1L3 = addition of 5% water hyacinth + biogas sludge from chicken manure, E1L4 = addition of 5% water hyacinth + biogas sludge from cow manure.

Media shrinkage

The addition of water hyacinth to various raw materials of farm waste had a significant effect on media shrinkage. The results of the study showed that the highest rate of media shrinkage (87.7%) occurred in the mixture of biogas sludge from cow manure with the addition of 5% water hyacinth, while the lowest shrinkage occurred in chicken manure media with or without the addition of water hyacinth (Figure 3). This might be due to media condition or feed that affected the population number of the earthworms that can live in the media.

Media shrinkage is caused by worm activity in consuming media as its nutrient source. The organic matter eaten by earthworms will be broken down into molecular particles in the worms' digestion. After being digested, the unusable components will be expelled into manure or castings (Noviansyah, 2015). Casting is one of the results of vermicomposting. Vermicomposting is a process of aerobic, bio-oxidation, and non-thermophilic stabilization of the decomposition of organic waste using earthworms to break down, mix and enhance microorganisms (Damayanti *et al*., 2017).

Vermicompost quality

The nutrient content of vermicompost in all treatment media had fulfilled the criteria of Indonesian National Standard (SNI) for compost, except for C/N ratio in chicken manure media which was lower than the SNI standards. The equation of the standards is important to ensure the feasibility of vermicompost being sold to the communities, especially for the farmers to offer the high-quality organic fertilizer products. The SNI criteria for compost is presented in Table 1. The table shows that the acquisition of C/N differed in each treatment. The addition of water hyacinth can increase the carbon element so the value of C/N ratio can be improved.

C-organic content (%) of vermicompost

The addition of water hyacinth to various raw materials of farm waste had a significant effect on the content of C-organic in vermicompost. The lowest C-organic content (13,11%) was found in chicken manure media, while the highest (23,33%) was in cattle manure media. The results showed that the addition of 5% water hyacinth could increase C-organic content in vermicompost (40.75%), compared to the media without the addition of water hyacinth (18.98%). The differences of the composition might be due to the respiratory and assimilation activities of the microorganisms and worms during the vermicomposting process (Rahmawati and Welly, 2016). These activities convert the available C-organic into CO_2 (Suthar and Gairola, 2014). Aini and Nengah (2013) stated that C-organic content in water hyacinth is 21.23%.

Total N content (%) of vermicompost

The addition of water hyacinth to various raw materials of farm waste increased the total N content of vermicompost, where chicken manure media had high enough N content (2.08%), while the mixture of chicken manure with the addition of 5% water hyacinth contained the highest N level (2.25 %). This was due to the high protein nutrient contained in chicken manure. Wangliang *et al*. (2017) stated that nitrogen content in chicken manure (3.48%) is higher than in cattle manure that only contains 1.7% of nitrogen.

Fernandez *et al*. (2010) stated that the total N content in the fermentation process might decrease. It is because, in the process of fermentation, N compound becomes nutrient for bacteria. The decrease of total N also occurs in harvest time of castings, possibly due to the consumption of nitrogen by worms which convert it into protein.

Table 1. The influence of water hyacinth addition to various raw materials of farm waste on nutrient content in vermicompost based on Indonesian National Standard (SNI)

*Treatment*s	C-organik (%)	Total N (%)	C/N ratio	P_2O_5 (%)	Total K (%)
E0L1	11,76	1,94	5,98	2,49	1,72
E0L2	22,81	1,31	18,45	1,47	1,73
E0L3	20,32	1,76	11,54	1,92	0,74
E0L4	19,97	1,83	10,91	1,87	0,57
E1L1	14,45	2,25	6,42	2,65	1,74
E1L2	23,86	1,16	19,75	1,88	2,01
E1L3	22,55	1,94	11,70	2,46	0,69
E1L4	21,69	1,68	12,97	1,73	0,50
SNI	9,8-32	min 0,4	10-20	min 0,10	min 0,2

E0L1 = without water hyacinth + chicken manure, E0L2 = without water hyacinth + cow manure, E0L3 = without water hyacinth + biogas sludge from chicken manure, E0L4 = without water hyacinth + biogas sludge from cow manure, E1L1 = addition of 5% water hyacinth + chicken manure, E1L2 = addition of 5% water hyacinth + cow manure, E1L3 = addition of 5% water hyacinth + biogas sludge from chicken manure, E1L4 = addition of 5% water hyacinth + biogas sludge from cow manure.

C/N ratio of vermicompost

The addition of water hyacinth to the raw material of farm waste had a significant effect on C/N ratio of vermicompost, where the lowest level was found in chicken manure media without the addition of water hyacinth (5.98) and 6.42 with the addition of water hyacinth. Pratiwi (2013) stated that the change of C/N ratio is due to the use of carbon as an energy source and turned into CO_2 so that carbon content is reduced. The decrease of C/N ratio also occurred in harvest time of worm castings. The decrease of C/N ratio indicated the activity of microorganisms and earthworms in decomposing the organic material as a source of energy to live and maintain their body metabolism in order to thrive. The results of the study by Singh and Suthar (2012) stated that the best C/N ratio for vermicompost is less than 20. Elidar (2009) confirmed that a considerable C/N ratio indicates a substrate that is difficult to compose; on the contrary, the low C/N ratio indicates a substrate which is easy to compose.

The content of P_2O_5 (%) in vermicompost

The addition of water hyacinth to various raw materials of farm waste and the interaction between both of them showed no significant difference to the content of P_2O_5 in vermicompost. Similar results were also found in Pratiwi (2013) study which stated that media difference in *Lumbricus rubellus* cultivation does not affect the phosphorus content. Badruzzaman *et al*. (2016) enhanced that the level of phosphorus element in the media is related to N content in the media. The higher the nitrogen contained, the multiplication of microorganisms that break down the phosphorus will increase, so the phosphorus content in the media will also increase. The phosphor content in the media will be used by a most microorganism to build their cells. The breaking down of organic matter and phosphor assimilation process occur because of enzyme phosphatase produced by some microorganisms.

Total K content (%) of vermicompost

The addition of water hyacinth to various raw materials of farm waste significantly affected total K content, where the highest value was found in cow manure media. Wahyuni (2008) stated that the content of K in cow manure is 1.11% higher than chicken manure (1.05%), and sludge (1%). The addition of 5% water hyacinth gave an increase of 1.24%, higher than the media without the addition of water hyacinth which had 1.19%. Sittadewi (2007) stated that the growing media of water hyacinth contains 2.24% K element. The different level of total K is caused by the enzyme activity of microorganisms and the chemical composition of the media (Banu *et al*., 2008). Badruzzaman *et al*. (2016) added that the high level of K is affected by the type of material used.

Sustainability study

In this research, sustainability study covered the economic and environmental aspects. The economic analysis was conducted to determine the feasibility of earthworm farming business that used water hyacinth and farm waste as raw material for earthworm cultivation media. Based on the results of this study, the good earthworm media is the sludge-based media (both sludge from chicken manure and from cow manure). The best manure to be used is cow manure, while the media from chicken manure is not suitable for worm cultivation. The studies on environmental aspects showed that the use of water hyacinth and farm waste as worm media material to produce vermicompost provides benefits to the environment. It can reduce environmental damage and can be developed as a business of worm cultivation.

The result of the economic analysis in Table 2 showed that the cultivation of earthworms with water hyacinth and farm waste gave NPV value (positive) > 0, B/C ratio > 1, and IRR > interest rate (15%). It means that the investment

Table 2. The results of economic analysis of earthworm cultivation

Description	Value of Feasibility of Earthworm Cultivation on Cow Manure Media
Investment costs	Rp22.100.000
Production cost per year	Rp61.550.250 /year
Production capacity of earthworms	430 /4 months
Production capacity of castings	200 kg /4 months
Income per year	Rp78.000.000 /year
NPV	Rp15.458.482,37
B/C ratio	1,09
ROI	9,51%
IRR	41,58%
BEP cost/kg	Rp32.566,26 /kg
BEP production/year	1.025,84 kg /year
PBP	4,03 years

NPV: Net present value, BEP: Break event point, ROI*:* Return of investment, IRR: Internal rate of return.

of earthworm cultivation is profitable or economically feasible. Based on sensitivity analysis, earthworm cultivation is sensitive to the changes of earthworm price, sensitive enough to the changes of earthworm production capacity, and is not sensitive to changes of raw material prices. The study of economic sensitivity suggested that if there is a decrease of earthworm price and earthworm capacity by 15%, the earthworm cultivation should be stopped since it is not feasible, viewed from various aspects of economic feasibility.

Conclusion

Based on the results of this study, it can be concluded that the addition of 5% water hyacinth and raw material from cow manure sludge can increase the population of earthworms for five weeks. Earthworm cultivation media from cow manure sludge with the addition of 5% water hyacinth produced worm castings (vermicompost) that fulfilled Indonesian National Standard for organic fertilizer. Its composition was as follows: 21.69% C-organic content, 1.68% N total, C/N ratio of 12.97, 1.73% P_2O_5, and 0.50% K total. Based on the study of sustainability, the use of water hyacinth and farm waste as raw material for earthworm farming media gives positive values, especially in economic and environmental aspects.

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