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RESEARCH ARTICLE

Improving Coffee Husk Compost Quality

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Introduction

In Indonesian, coffee husk is normally burnt on the central coffee production, make pollution such as disease to human and pets to plants. Whereas, in 2018 about 36.72 tons of coffee husk used not efficiently [1]. It is important to consider that coffee husk can contribute to environmental problems. On other hand, coffee farmers used chemical fertilizers for long time, therefore make agricultural residue in fields, an alternative is to make compost.

The use of compost can be important in products based on the principles of eco-sustainable and eco-friendly especially for reduce agricultural residue. Eco-sustainable means of reduce the negative effects of farming on the surrounding environment [2]. While eco-friendly means of treating a variety of organic wastes, from landfilling to make product with the aim to compact global warming and promote nutrient recycling.

Generally, coffee husk has been applied by mixturing with animal manures, other agricultural wastes used as compost and the incubation period of composting has been taken for long time, because most researches used natural microorganisms for composting, which are not effective [3]. In this study the activator for composting used bacterial inoculants (*bacillus*) with the aim for improved compost quality while the methods by incubator with the aim for rapidly compost maturity. [4], reported in their studied that the use of bacterial inoculants (*Bacillus*) in the composting of vegetable products improved the quality compost and takes short time of incubation.

Material And Methods

Review of Compost Vessel

The type of vessel was used incubator. The dimension of compost vessel was shown in (Figure 1). Dimension of the compost vessel: width is 17 cm, depth 20.5 cm and height 16.5 cm.

Figure 1: Dimension of compost vessel

Composting Procedure

The composting took place at a Laboratory in the Prefectural University of Hiroshima, Shobara. The compost process in anaerobic condition with 2 type temperature condition of (30^{0}C and 40^{0}C). The process of composting during two-months (56 days). Anaerobic digestion is a processes by which microorganisms break down organic material in the absence of oxygen. The materials were used coffee husk (100 g) mixed with cow dung (50 g), chicken manure (50 g), and rice grain (25 g), and bacillus activator commercial (EBB) with doses 1ml/100 ml water. The materials were screened through a 4.75 m/m sieve. All material were put into the incubator in each temperature condition (Figure 1). Coffee husk from Solok Radjo Cooperative, West Sumatera Province, Indonesian. Cow dung and chicken manure from Yasaki. Co., Ltd. Japan. Rice grain from Nichino food. Co., Ltd. Japan. *Bacillus* activator is patended by the Food Industry Research Center, and the Industrial Technology Center, Fukuoka Prefectural. Produced by the non-profit organization Eco Cycle Kyushu/Okinawa, Japan.

Analytical Methods

The physical and chemical analysis include: The pH and electrical conductivity (EC) was determined once per week during composting process. The samples were measured using a suspension of 1:5 (w/v) [5]. The pH was measured used IAQUA twin-pH-22B, electrical conductivity (EC) was

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measured used IAQUA twin-EC-33B. Moisture content was determined by drying at 105^{0}C for 24 hours and expressed as a percentage of total weight (Association of Official Agriculture Chemists, 2002). Ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), phosphate (PO_4) were extracted by shaking 1 gram of sample with 10 ml NaCL and concentration were determined in filtered extract by molecular absorption spectrophotometry [6]. Total phosphorus was determined by the spectrophotometry (880 nm). Total carbon and total nitrogen were analyzed with an auto-analyzer (Macro Corder-MT 6).

Phytotoxicity

Seed germination index using distilled water mixed with fresh compost product in ratio 1 : 10 and shaked for 1 hours. The suspension was centrifuged at 5000 rpm for 20 min and the supernatant was filtered. 10 seeds of Japan Spinach seeds (*Spinacia oleracea*) distributed on the filter paper 90 mm (5B) in a petri dish of 10 cm diameter. 10 ml of the extract was added to the petri dish. 10 ml of distilled water was used for control. The test was run in triplicate. Incubated at temperature in dark condition in temperature room for 72 hours [7]. After counting the number of seeds germinated and measuring the length of roots. Seed Germination Index was calculated as follow (HKORC, 2005):

$$\text{Seed Germination index (\%)} = \frac{\text{Germination rate in product mixture x root length}}{\text{Germination rate in control sample x root length}} x\ 100$$

Results And Discussion

Elemental analysis of material used for composting as shown in (Table 1). The results of analysis showed that the pH of the coffee husk is lower when compared to cow dung, chicken manure, and rice grain with 5.98, 6.43, 6.48, 6.27 respectively. The pH values of organic wastes suitable for composting is recommended in the range from 5-12 [8]. The conductivity of coffee husk is 0.9 mS cm^{-1}, this is indicates that the coffee husk presence lower of soluble salt content. The phosphorus of coffee husk is highest when compared to cow dung, chicken manure and rice grain with 0.23%, 0.18%, 0.13%, 0.14% respectively. The coffee husk contained high amount of C: N ratio with 105.21 that is highest for uptake to plant. [9], reported that for adjust the C: N ratio for composting, livestock manure are usually mixed with plant materials.

Hemicellulose and lignin of materials used composting as shown in (Table 2). The hemicellulose of coffee husk is highest than cow dung, chicken manure, and rice grain with 14.6%, 12.3%, 8%, 6.3% respectively. The lignin content of coffee husk is also highest when compared to cow dung, chicken manure, and rice grain with 41.25%, 30.25%, 16.50%, 20.16% respectively.

Elemental analysis after composting as shown in (Table 3). The results showed that the C:N ratio of all compost is suitable for improved soil and plant [10]. Based on (Table 1) that cow dung, chicken manure, and rice grain have more nitrogen content. The content of nitrogen is very influenced by the process of composting because microorganisms requiring nitrogen for the maintenance and formation of body cells [11], that it will easy for degradation organic matter [12]. Reported that uncomposted poultry manure is not recommended in horticulture because to avoid contamination of edible plants part [13, 14].

Physical properties

During the composting process a physical change in the compost as shown in (Figure 2). The mature or otherwise compost can be detected by the changing colour to brown, by a pleasant odour [15]. The final physical condition of compost are such as:

Moisture content

Moisture content is an important variable in composting process in order for the bacteria to assimilate their nutrients

Table 1: Elemental Analysis of Raw Materials Before Composting

Parameter	Rice Grain	Chicken Manure	Cow Dung	Coffee Husk
pH	6.27	6.48	6.43	5.98
EC (mS cm^{-1})	15.67	13.47	10.81	0.9
NH_4-N (mg/L)	21.2	14.4	8.3	2.9
NO_3-N (mg/L)	29.8	15.8	11.5	4.5
NH_4-N : NO_3-N Ratio	0.71	0.91	0.72	0.64
PO_4 (mg/L)	38	19.8	34	6.3
Total Carbon (%)	43.42	19.36	29.55	46.26
Total Nitrogen (%)	2.23	2.15	2.39	0.43
C : N ratio	19.4	9	12	105.21
P_2O_5 (%)	0.14	0.13	0.18	0.23
Moisture Content (%)	5.13	8.13	13.93	8.8

EC: Electrical-conductivity

Table 2: Hemicellulose and lignin of Materials Before Composting

Parameter	Rice Grain	Chicken Manure	Cow Dung	Coffee Husk
Hemicellulose (%)	6.3	8	12.3	14.6
Lignin (%)	20.16	16.50	30.25	41.25

Table 3: Elemental Analysis After Composting

Parameter	Compost Standard							Treatment	
	[a]HKORC, 2005	[b]Barker., 1997	[c]Woods End Research Laboratory, 2000	[d]SNI, 19-7030-2004	[e]RAL., 1998	[f]Yusuf, 2008	[g]CPHEEO, 2005	T1	T2
pH	5.5-8.5			6.80-7.49				7.20	7.23
EC (mS cm^{-1})						2.19-9.32		8.51	8.59
NO_3-N (mg/L)		≤ 240						175	71.3
NH_4-N (mg/L)		≤ 200						44.5	31.05
NH_4-N : NO_3-N Ratio	≤ 3.0		[c1]≤ 0.5 [c2]≤ 0.6-3.0					0.25	0.43
Total Carbon (%)								36.50	36.75
Total Nitrogen (%)		1.0-3.0		≥ 0.40				1.78	2.03
C : N ratio	≤ 25							20.50	18.10
P_2O_5 (%)				≥ 0.10			≥ 1.0	2.2	1.7
Seed Germination Index (%)	≥ 80		≥ 80					98	81
Moisture Content (%)				≤ 50				7.95	7.07

a. Hongkong Organic Resource Centre, 2005
b. Barker, 1997
c. Woods end research and laboratory, 2000
c1. Very mature
c2. Mature
d. National Standard of Indonesia (SNI), 19-7030-2004
e. German Waste Association (RAL). 1998
f. Yusuf, 2008
g. Central Public Health and Environment Engineering Organization (CPHEEO), 2000
EC: electrical conductivity (mS cm^{-1})
T1: The compost by temperature of 30^0C
T2: The compost by temperature of 40^0C

Figure 2: A coffee husk, B: T1 (The compost by temperature of 30^0C), C: T2 (The compost by temperature of 40^0C)

that could be dissolved in water because it increases the rate of metabolisms. The moisture content for the compost samples were found to be 45.1% and 48.1% for T1 and T2, respectively. Which is between recommended range from 45% to 60% at the initial of composting [16] (Table 4).

Adequate moisture is essential for microbial activity and as a source of oxygen supply. When the moisture content of compost below <45%, it will inhibit microbial metabolism leading the activity of microorganisms will be slow and the degradation phases cannot be completed and was occurred unstable composting in final product. If moisture above (>60%), the water will saturate the pores and interfere oxygenation through the materials compost (Farmer`s compost handbook, 2015). The final of composting were found to be 7.95% and 7.07%, for T1 and T2, respectively as shown in (Table 5). Epstein et al., (1997) reported that the reduction in the value of moisture content at the end of composting is an indicator degradation of organic matter and mature composting. The moisture content for the maturity compost which is recommended below ≤ 50% [17, 18].

Table 4: Hemicellulos and Lignin After Composting

Parameter	Treatment	
	T1	T2
Hemicellulose (%)	9	12
Lignin (%)	30.25	29.33

T1: The temperature of 30^0C, T2: The temperature of 40^0C

Table 5: The moisture content of initial and after composting

Parameter	Initial Composting			After Composting		
	Farmer`s compost handbook, 2015	**T1**	**T2**	**SNI, 19-7030-2004**	**T1**	**T2**
Moisture Content (%)	45-60	45.1	48.1	≤ 50	7.95	7.07

T1: The compost by temperature of 30^{0}C, T2: The compost by temperature of 40^{0}C, Farmer`s compost handbook, 2015, SNI, 19-7030-2004

pH Scale

The pH values cannot be considered as a good parameter to assess compost maturity [19], but the pH is the key affecting microbial succession and activity during composting. Based on the (Figure 3), the pH values of all composts increased from day 1 until day 7. The increase in pH values indicates that the decomposition of organic matter inside compost medium was occurred and ammonium was formed. The characteristics of the ammonia is alkaline [20]. The pH pattern of (T1) was slightly different from (T2) where the values decreased until reaching slightly neutral condition as reaching from day 7 until day 28 with 7.21, while for (T1) from day 7 until day 14 with 8.1. The decrease in pH values caused by formation of carbon dioxide gas and organic acid during composting [21].

The compost of (T1) where the pH values increased again from day 14 until day 21. This is caused the degradation of organic acids, and the formation of NH_3 from the mineralization of amino acids and protein [22]. The change of the pH values during composting is due to metabolic activities resulted in the production of organic acids and release of ammonia (Nobili and Petrussi, 1988), and showed activity of microorganisms for degradation organic matter [23].

As shown in (Figure 4), the compost of (T1) from day 49 until final composting, where the pH values decreased from 8.02 to 7.20. While for (T2) from day 35 until final composting decreased from 7.60 to 7.23, which indicating that the composts was occurred cooling and maturity on the stationer phase [24], and due to the nitrification process (Huang et al., 2004, Bustamante et al., 2014) leads the nitrate values was

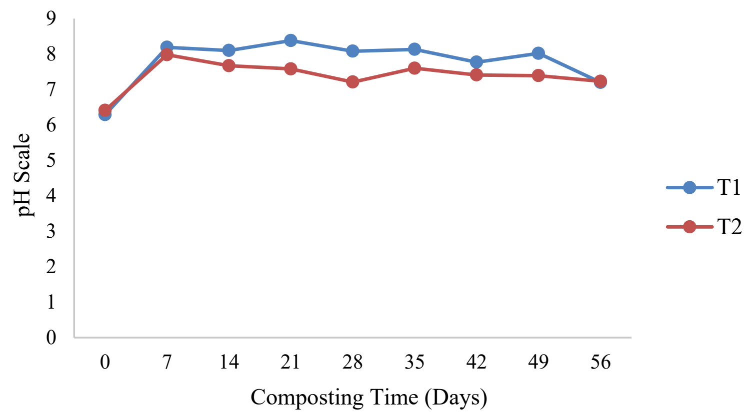

Figure 3: The pH values during composting

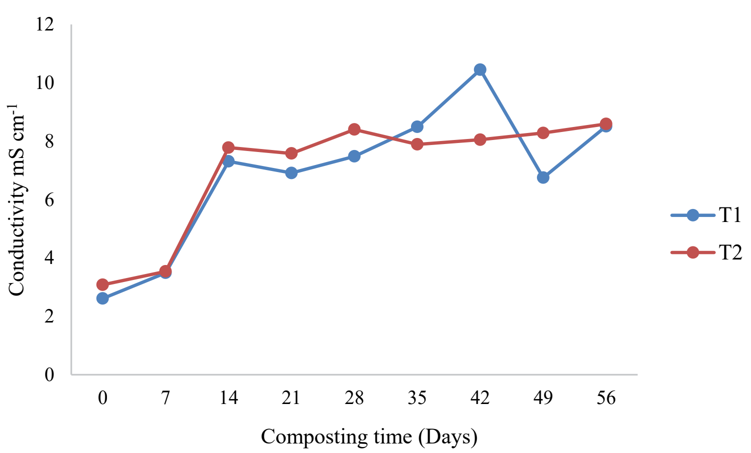

Figure 4: The EC values during composting

increased (Table 6). [25], (2017) reported that compost needs to be at a pH compatible with requirements or sensitive of the plants. The final pH values which recommended in the range 5.5-8.5 (HKORC, 2005), and 6.80-7.49 (SNI, 19-7030-2004).

Salinity (EC)

The values EC are indicative of concentration of soloube salt in the compost. The general tendency of EC values for all compost was to increase during the composting process. Usually a higher value of EC could be an indication of high nutrient elements presence, or a slower decomposition of the organic matter therefore a lower release mineral salts into the solution in the process of composting [26]. Study by Anandavalli et al., (1998) on recycling of banana pseudo stem as compost also show similar EC increment as the composting proceeds [27].

There was a fluctuating change in EC values observed during the composting process for T1 and T2. The initial EC values both of compost sample (T1 and T2) with 2.61 and 3.08 mS cm^{-1}, respectively which was increased until day 14. The increase could be caused by the release of mineral salts such as phosphate and ammonium ions through the decomposition of organic substances [28, 29]. While the decrease in EC values may be attributed to the reduction of water-solule substances such as organic acids during the composting process [30].

The EC values indicates that all compost will not damage to the crops/vegetables. [31], reported that the salinity of the compost is recommended in the range 2.19-9.32 mS cm^{-1}. The EC values on final composting for T1 with 8.51 mS cm^{-1} and T2 with 8.59 mS cm^{-1}. The higher and the lower of EC values is not conductive to plant growth. Excessive of EC values in compost can be problematic in growing media, as it can be slow growth, especially in young plant [32], may cause salt damage, and impart to the plant roots are dehydrated resulting in burning phenomenon [33] and could be potentially inhibit plant growth, affect on germination and plant yield. Mamo (1998), reported that majority of plants could not withstand soluble salt content beyond 4000 mS cm^{-1}. While if the low of EC values will affect the plant absorption and utilization of mineral elements from the soil lead plants cannot grow normally [35].

Total Nitrogen (%)

Nitrogen is the first most important macro nutrient for successful plant production and role in various physiological process. The concentration and availability of nitrogen in compost is a very important factor to be assessed when applied to agricultural systems. The fertilizers are absorbed directly by plants or converted into various other forms through the oxidation process [36]. Nitrogen produce rapid early growth, improve fruit quality, enhances the growth of leafy vegetables, it encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant [37].

Finally, the content nitrogen value all of compost samples (T1 and T2) with 1.78% and 2.03%, respectively. These results are supported with the findings of Barker (1997), which is recommended in the range 1-3%, and over 0.4% (SNI, 19-7030-2004). All compost had total nitrogen over 0.4%, which indicates that compost was matured and it can be used in agriculture without additional nitrogen. The compost over 3% total nitrogen is usually found to be immature and ammoniacal. While, if low the nitrogen values is better used as mulch (Barker, 1997).

Available Nitrogen as NO_3-N

More than 90% of nitrogen in compost is organically bound and the most available form to plants when nitrogen is converted into an inorganic from and exists as NO_3-N [38]. Most plants take nitrogen in the inorganic form as nitrate (NO_3-N) [39].

Based on (Table 6), the nitrate-nitrogen values of all compost increased until compost maturity. The overall nitrate nitrogen content was high and its maximum only 240 mg/L (Barker, 1997). The earlier stages of composting, the nitrate nitrogen values was relatively low because heat and excessive ammonia nitrogen may decreased the nitrifying bacterial activity (Huang

Table 6: Nitrate-Nitrogen Analysis Initial and After Composting

Parameter	Compost Standard	Initial Composting		After Composting	
	Barker, 1997	T1	T2	T1	T2
NO_3-N (Mg/L)	≤ 240	4.4	7.5	175	71.3

T1: The compost by temperature of 30⁰C, T2: The compost by temperature of 40⁰C

Table 7: Interpretation of available Nitrogen as NO_3-N in compost

NO_3-N (mg/L)	Interpretation
0-15	Deficient
16-25	Low
26-50	Satisfactory for seedling and nursery stock
51-80	Satisfactory for pot plants and bedding plants
81-130	Satisfactory for tomatoes, cucumbers and carnations
131-200	
201-300	Unnecessarily high for all crops
Over 300	Excessive

Source: Environment Agency, 2000

et al., 2004). While, at the end of the composting process the nitrate-nitrogen values greater than the concentration of ammonium-nitrogen, this is indicates that the process took place under adequate conditions of aeration and that mature compost was produced [40]. The UK Environment Agency`s interpretation of concentrations of available NO_3-N in compost when used in growing Media as shown in (Tabel 7).

Available Nitrogen as NH_4-N

Ammonia-nitrogen concentration was also an indicator of compost maturity. In anaerobic process, the ammonia was low due to slow decomposition. Mostly ammonia-nitrogen present during aerobic composting was derived from rapidly decomposition of waste [41]. When ammonia concentration decreases and nitrate appears in composting material and is considered ready to be used as compost [42].

Based on (Table 8), the amonium-nitrogen values both of compost sample in the range of composting standard. Barker (1997), reported that the maximum ammonium-nitrogen above ≤ 200 mg/L. The high ammonium-nitrogen value can be occur phytotoxic, especially on seedlings [43]. The UK Environment Agency`s interpretation of NH_4-N concentration in compost when used in growing media as shown in (Table 9).

Carbon to Nitrogen ratio

The carbon to nitrogen ratio used for the degree of maturity in the composting process. Composts with high C:N ratios can damage to plants by tying up available nutrients in the soil [44]. Reduction of carbon was greater as compared to nitrogen in all types of composting process caused microorganisms used carbon as the source of energy and nitrogen for building cell structure in decomposition process [45].

The final of C:N ratio values both of compost sample (T1 and T2) with 20.50 and 18.10, respectively. For a succesful composting, the C:N ratios should be considered and it can be used for plants if the C/N ratio below ≤ 25 (HKORC, 2005). If the C:N ratios is higher can cause phytotoxins which can burn plant roots and thereby inhibit plant growth due to shortage of nitrogen.

Total Phosphorus

Phosphorus is the second most important macro nutrient after nitrogen that plays significant role in physicological and biochemical reactions such as photosynthsis and transfer characteristics on the plants [46].

Based on (Table 10), the phosphorus values for all compost increased for (T1) which ranging from 0.56% to 2.2% while for (T2) which ranging from 0.76% to 1.7% and which positively correlated with seed germination index as shown in (Table 3). The increasing of phosphorus content might be attributed to the so-called "concentration effect", which occurs when carbon, hydrogen and nitrogen are lost with the exit gas as CO_2, H_2O and NH_3, respectively, but phosphorus is retained in the samples [47]. The phosphorus values for final composting which range above 0.10% (SNI, 19-7030-2004) and above ≥ 1.0% [48].

The Maturation Stage

The results obtained indicated that all composts have matured within two-months (56 days). By comparison, it was far faster than the anaerobic composting by normal condition (6 months to 1 year) and aerobic composting by normal condition (3 months to 6 months) (Gabhane et al., 2012). Measurement of phytotoxic present in the compost is an accurate and efficient method to check the maturation of compost [49]. A mature compost should not contain toxic compunds on seed germination or plant growth or the environment. Maturity is

Table 8: Ammonium-Nitrogen Analysis Initial and After Composting

Parameter	Compost Standard	Initial Composting		After Composting	
	Barker, 1997	T1	T2	T1	T2
NH_4-N (Mg/L)	≤ 200	4.36	7.16	44.5	31.5

T1: The temperature of 30⁰C, T2: The temperature of 40⁰C

Table 9: Interpretation of available Nitrogen as NH_4-N in compost

NH_4-N (mg/L)	Interpretation
0-20	Low, normal for composts in use
21-50	Normal
51-100	Normal values for unused composts
101-150	Normal values for unused, high nutrient composts
151-200	High may harm young plants
Over 200	Very high

Source: Environment Agency, 2000

Table 10: Total Phosphorus Analysis Initial and After Composting

Parameter	[a]SNI, 19-7030-2004	[b]CPHEEO, 2000	Initial Composting		After Composting	
			T1	T2	T1	T2
P_2O_5 (%)	≥ 0.10	≥ 1.0	0.56	0.76	2.2	1.7

a. SNI, 19-7030-2004, b.Central Public Health and Environment Engineering Organization (CPHEEO), 2000, T1: The temperature of 30⁰C, T2: The temperature of 40⁰C

Table 11: Changes of hemicellulose and contents after composting

Parameter	Initial composting		After Composting	
	T1	T2	T1	T2
Hemicellulose content (%)	23.3	15	9	12
Lignin content (%)	53	49.5	30.25	29.33

a measure of the degree of completeness of the composting process.

Seed germination index for final compost (T1 and T2) with 98% and 81%, respectively. This is indicates that all compost have matured if seed germination index is higher than 80% (HKORC 2005, Woods End Research Laboratory 2000) which was positively correlated with the NH_4-N : NO_3-N Ratio (Table 11) [50-62]. It is important that compost is allow to fully mature so that it can be bagged and sell to the horticultural market. Immature compost will reheat and spoil if it stored for a period of time. Compost maturity generally relates to the agricultural value of the compost in relation to its effect on the soil and plants response to its application [63-80].

Conclusion

The pH values, C:N ratio, Available nitrate-nitrogen, available ammonium-nitrogen and germination index of the 2 temperature condition showed satisfactory values. In our work, coffee husk was incubation for two-months (56 days), it was faster and good quality if comparison with anerobic and aerobic by normal condition.

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