Organic fertilizer of coffee peel with PUMAKKAL starter formula for sustainable plantation cultivation

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Abstract. Coffee is a strategic commodity that generates promising foreign exchange, where Lampung is the main coffee production centre which continues to increase its production, and more than 80% of it is smallholder coffee. Between 40% and 55% of coffee, production is coffee husk waste, which has not been optimally utilized. Previous research showed that pineapple liquid waste indigen bacteria (Pumakkal) were able to increase acidity and decompose waste organic matter, and the final result was a suitable fertilizer for plant cultivation. This research will solve the problem of coffee husk waste used as compost by utilizing a starter from the previously tested pineapple liquid waste bacteria (Pumakkal). The research was conducted with the first stage of making coffee skin compost with a starter formula of KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria), the second stage was to test the quality of the coffee husk compost organic fertilizer followed by a pilot plan application using the best formula. The application uses spinach and chilli plants. The result shows that KC is a model the most appropriate coffee skin compost starter formula.

Keywords: Coffee skin, compost, pumakkal

1. Introduction
The problem of unused coffee husk waste has a negative impact due to the high C / N ratio. The amount of coffee husk waste ranges from 50-60% of the harvest. If the coffee produced is around 500-600 kg/ha, then 300-360 kg is coffee waste. Coffee peel waste consist of lignocellulose containing hemicellulose and other chemical compounds [1]. So far, coffee husk waste has not been processed in the factory because only coffee beans are used, which are then turned into instant coffee powder [2]. Coffee shell or what is called Parchmenthull (endocarp) is used for animal feed, and coffee pod skins are allowed to accumulate around the plantation area [3]. Its composition consists of 57.9% cellulose, 21.63% hemicellose, 5.21% lignin, 2.28% pectin and inhibitor substance such as 0.86% caffeine, 4.81% tannins, 3.48% polyphenol [4]. According to Paerl H W et al., the skin of the coffee fruit horn contains 1.27% nitrogen (N), 0.06% phosphorus (P) and 2.46% potassium (K).

The use of coffee bean husks as a raw material in composting will provide multiple benefits. Coffee pulp solids contain only one fifth of the nutrients taken out of the soil by export of the green bean. However, it is a good source of humus and organic soil carbon [5]. Mixture of coffee husk, animal manures and phosphate rock was fermented by two anaerobic and aerobic methods. The compost can be used for soil application after 6 months of composting. The quality of the compost was improved in comparision with before that [6]. Coffee peels also contain higher levels of N, P and K so they can be used as an alternative to using fertilizers. The C-organic content of the coffee fruit skin was 45.3%,
nitrogen content was 2.98%, phosphorus 0.18% and potassium was 2.26% and also contained elements of Ca, Mg, Mn, Fe, Cu and Zn [7]. In addition, other data shows that the Corganic content of coffee fruit skin waste is 10.80%, the nitrogen content is 4.73%, phosphorus is 0.21%, and potassium is 2.89% [8]. The quality of compost depends on fermentation by microbes to break down organic matter.

A consortium is defined as several species or populations of microorganisms functioning in a coordinated, complementary fashion, so that production, growth and nutrient cycling are enhanced over what a single species or population can achieve alone under similar environmental conditions [9]. Concordia is a mixture of bacterial populations in the form of communities that have the potential to be used in the waste treatment process. The waste processing process will be easier with the activity of microorganisms which will break down the substances in the waste into simpler ones. The bacterial consortia used in this study was the pineapple liquid waste (Pumakkal) indigenous bacteria consortium. Pineapple Liquid Waste Indigenous bacteria (Pumakkal), are bacteria that have the potential to act as decomposers and can be used as a starter in waste recovery called Pumakkal. Variation treatment grouped into five treatments, namely starter KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) and KE have 15 types of potential bacteria, namely Bacillus careus, Acinobacter baumanni, and Bacillus subtilis. KE has 15 types of potential bacteria, namely Bacillus careus, Acinobacter baumani, Bacillus subtilis, and Pseudomonas pseudomallei. Bacillus careus bacteria, Acinobacter baumani have the ability to degrade organic acids, then Bacillus subtilis bacteria, and Pseudomonas pseudomallei have the ability to degrade other than organic acids [2]. The purpose of this research is to know the effect of variations in the addition of organic waste to composting coffee husk using pumakkal on the quality of compost. To find out what variations in the addition of organic waste have the best effect on composting coffee husk using pumakkal on the quality of compost.

2. Methods
The research used experimental methods of the variation of Pumakkal bacterial consortia in making coffee husk compost. The research design used a completely randomized design (CRD) with five treatments, one control and five repetitions. Consortium of LCN bacteria used C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria). Compost is fermented for one month then analyzed the content of carbon (C), C/N ratio, levels of phosphorus (P), calcium (Ca) and potassium (K), pH at the Chemical Laboratory of the Muhammadiyah University of Malang. The data were analyzed quantitatively using the Kruskal Wallis Non-Parametric Anava test.

3. Results and Discussion
Research result Organic Coffee Skin Fertilizer with Starter Formula Indigenous Bacteria Pineapple Liquid Waste (Pumakkal) for Sustainable Plantation Cultivation is presented as follows.

3.1. Level C Organic
The results of testing the levels of C-organic in the organic fertilizer of the coffee husk are five treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermentation. They are presented in Figure 1.
Figure 1 shows that the lowest C-organic content is in the organic fertilizer of KC treatment coffee husk, namely 27% (p <0.05). The low levels of C-organic are due to the use of Pumakkal as a starter for decomposer microorganisms, among other bacillus cereus and able Bacillus subtilis break down organic compounds such as carbohydrates and proteins during the fermentation process into simpler compounds that can be utilized by plants. Organic C is contained in the soil organic fraction, which consists of the cells of microorganisms, plant and animal residues at various stages of decomposition, stable "humus" synthesized from residues, and highly carbonized compounds such as charcoal, graphite and coal (elemental forms of C) [10]. These microorganisms use carbon as an energy source in decomposing organic matter during the fermentation process [2]. During the fermentation or composting process, organic materials undergo severe decomposition by heterotrophic microorganisms, namely bacteria, fungi, actinomycetes and protozoa where carbon is a source of energy for microorganisms and can be seen from the following reactions [3]:

\[
\text{Organic Ingredients} + O_2 \xrightarrow{\text{Microbial Aerobic}} H_2O + CO_2 + \text{Nutrients} + \text{Humus} + E
\]

Then followed by an anaerobic process which takes place gradually. The first stage, several types of facultative bacteria will break down organic material into fatty acids. He was then followed by the second stage, where another group of microbes will convert fatty acids into ammonia, methane, carbon dioxide and hydrogen. The heat generated in the anaerobic process is lower than that of aerobes. The following is a reaction that occurs under anaerobic conditions. With the following reaction:

\[
\text{Organic Ingredients} \xrightarrow{\text{Anaerobic Microbial}} CH_4 + \text{Nutrients} + \text{Humus}
\]

The mixed microbial populations present in the coffee pulp were able to carry out a complete oxidation of such carbon sources and to transform them into CO2 and other small molecular-weight carbon compounds, as reflected by the sharp decrease in organic carbon observed during the first 14 days [7]. Maximum 32% C-organic, so the carbon content in all treatments in this study meets the standard.

3.2. Nitrogen (N) Levels
The results of testing Nitrogen levels in the organic fertilizer of coffee husks in three treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermentation are presented in Figure 2.
Figure 2 shows that nitrogen levels in the KA, KB and KC, KD and Ke treatments increased significantly, with significant differences (p < 0.05) and the best KC. This is thought to be due to the use of Pumakkal and the waste containing protein. From these data, it can be seen that the highest nitrogen content is in the KC treatment, which is 0.90%. The increase in nitrogen levels is thought to be caused by the breakdown of organic matter by bacteria *acinetobacter baumannii* as nitrifying bacteria which convert ammonia to nitrate at the end of the fermentation process. Ammonium is returned to the environment when organisms die, and its fate (and the variety of subsequent forms of nitrogen) depends on whether the local environment contains oxygen [11]. In addition, microorganisms also contribute a number of single-cell proteins which are obtained during the fermentation process. After the decomposition process is complete, nitrogen will be released again as one of the components contained in the compost. Bacteria have the ability to increase the efficiency of N-use in the soil. The bacteria uses free nitrogen for protein cell synthesis in which the protein will undergo mineralization in the soil after the bacteria have died [12]. Various types of nutrients, especially N as a result of the description, will be bound in the microorganism’s body and will return after the microorganisms have died [9]. Here is a reaction to nitrogen formation, according to [13]:

\[
\text{Organic Ingredient} \rightarrow \text{Protein Amino Acid (Amination Reaction)} \\
\text{Amino Acids} \xrightarrow{\text{Ammonification Reaction}} \text{Ammonia (NH}_3\text{)} + \text{Ammonium (NH}_4\text{)}
\]

Ammonia Nitrification Reaction by *Nitrosomonas* and *Nitrococcus nitrate* bacteria. Nitrogen is an element needed by plants in vegetative growth and protein formation, and if the plant is deficient in nitrogen it will cause the plant to become stunted, leaves turn yellow and fall, and limited root growth. The nitrogen content contained in the coffee husk compost with the Pumakkal starter treatment has met internal standards according to [14] i.e. at least 2% (N, P, K).

3.3. C/N ratio
The results of the calculation of the C/N ratio of the coffee husk organic fertilizer in five treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermented is shown in Figure 3.
The results of the analysis showed that there were significant differences and had a significant effect (p <0.05), the best nine bacteria consortia treatment. The role of organic carbon and inorganic nitrogen for cell synthesis, growth and metabolism in all living organisms, is critical. For proper nutrition, carbon and nitrogen must be present in the substrate at the correct ratio [15]. The C/N ratio is the ratio of the mass of carbon to the mass of nitrogen in a substance. New organic material has a C/N ratio higher than the C/N ratio after the composting process. This means that composting is an effort to reduce the C/N ratio of organic matter so that it has a C/N ratio that can be absorbed by plants. Each organic material has a different C/N ratio. In the late study, Increase in wastewater C:N ratio increased both microbial biomass and carbohydrate (acid minus water-extractable), which was accompanied with a decrease in hydraulic conductivity [16]. The higher the C/N ratio of a material, the longer its decomposition time will be. Organic matter that can be absorbed by plants is the organic matter with a C/N ratio close to the C/N ratio of the soil, which is around 12-15 and the temperature is almost the same as the ambient temperature. C/N ratio contained in the compost of shrimp pond sediment with Pumakkal starter treatment ranging from 8-10, it has met internal standards [14] which is less or equal to 25.

3.4. Content of Phosphor (P)
The results of the research on phosphorus content (P) inorganic fertilizer from coffee peels in three treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermentation is presented in Figure 4.

Figure 4. shows that coffee skin organic fertilizer in treatment A, B and C there was an increase Phosphor and break difference (p, 0.05). Based on [14] that is at least 2% is a combination of N, P and K, treatment C is 0.65%. Although the fermentation process has been running optimally due to the Pumakkal starter [17]. There is an increase in several types of nutrients by microorganisms, especially nitrogen, phosphorus, and potassium. These nutrients can be returned through weathering the remains of living things when these microorganisms die. In soils, concentrations of available P in soil solution are typically low (<0.01 to 1 mg L⁻¹ in highly fertile soil) due to comparatively low content of pin the parent material, but also due to high reactivity of Pi that result in strong retention by soil’s mineral matrix. This has led to microorganisms developing a wide range of strategies to enhance P availability in soil [18]. Among the phosphate solubilizing microbes, strains from the bacterial genera Pseudomonas, Bacillus and Rhizobium and fungi such as Pencillium, Aspergillus, Fusarium, Helminthosporium, Alternaria etc. are the most powerful phosphate solubilizers [19]. Bacteria, fungi and actinomycetes, algae such as cyanobacteria and mycorrhiza have also been reported to show P solubilization activity. The existence of soil fauna activity makes it easier for microorganisms to utilize organic matter so that the mineralization process runs faster and the supply of nutrients for plants is better [13]. Plants use phosphorus to accelerate root growth, accelerate flower formation and accelerate fruit ripening and increase grain production.
3.5. Content of Calcium (Ca)
The results of the research on the content of Calcium (Ca) in organic fertilizer from the coffee peel in three treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermented is shown in Figure 5.

Figure 5 shows that the coffee husk organic fertilizer on treatment A, B and C has an increase in calcium and is significantly different (p <0.05). Calcium have the main role for plant calcium thus has to be considered in relation to three growth mechanisms: the mitoses in the apical meristem, the initiation of the cell elongation, determining the rate of cell elongation, and the factor limiting the duration of elongation [20]. And so the calcium ion is now firmly established as a second messenger in numerous plant signaling pathways, conveying a wide range of environmental and developmental stimuli to appropriate physiological responses [21]. The results of the research all met these criteria, and the highest was in the KC treatment, namely 0.53%. Giving KC starter with nine isolates resulted in the best digestion due to the potential microbial content to break down organic matter. Microbes that play a role in dissolving phosphate and calcium are bacteria, fungi and actinomycetes. Among the bacteria groups: Bacillus firmus, B. subtilis, B. cereus, B. licheniformis, B. polymixa, B. megatherium, Arthrobacter, Pseudomonas, Achromobacter, Flavobacterium, Micrococcus and Mycobacterium. Pseudomonas is a genus of the Pseudomonadaceae family. These bacteria are chemoorganotrophic aerobic bacteria, in the form of straight or curved rods, the size of each bacterial cell is 0.5-0.1 μm x 1.5- 4.0 μm, does not form spores and reacts negatively to Gram stain. In the soil, the amount is 3-15% of the bacterial population. Pseudomonas is divided into groups, among which are the sub-group fluorescent (Fluorescent) which can secrete the pigment phenazine.

3.6. Kalium (K) Content
The results of the research on the content of Kalium (K) inorganic fertilizer from coffee peels in three treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermentation is presented in Figure 6.
Kalium is needed by plants to regulate the mechanism of photosynthesis, protein synthesis, and the opening of stomata and the supply of carbon dioxide. If there is a lack of potassium in the plant, it can cause the leaf segments to shorten, the edges of the leaves are brown, and the plant cannot grow [22]. The results of testing the levels of potassium in the organic fertilizer of the coffee peel of the five treatments significantly different (p <0.05). The increase in potassium levels in the highest KC treatment was due to the decomposition process carried out by decomposer microorganisms from Pumakkal. This is reinforced by [13]. There is an increase in several types of nutrients by microorganisms, especially nitrogen, phosphorus, and kalium. These nutrients can be returned through the decay of the remains of living things when these microorganisms die.

Result analysis of the kalium has been done obtained a potassium content of 0.478%. The results obtained have met the standards based on [23] amounting to at least 0.20%. The presence of potassium in the compost is because a lot of potassium comes from organic matter. Organic materials can increase the cation exchange capacity, and this is related to the negative charges that come from the group -COOH and OH which dissociate to form COO- and H+ and O- + H+.

3.7. Degree of Acidity (pH)
The results of the study of the degree of acidity (pH) in the organic fertilizer of coffee husks in five treatments, namely control (KO), KA (3 bacteria), KB (6 bacteria), KC (9 bacteria), KD (12 bacteria) and KE (15 bacteria) after fermentation is presented in Figure 6.

![Figure 6. Graph of Average degree of acidity (pH) fertilizer organic coffee skin](image)

Figure 6. shows that the liquid organic fertilizer treated using the Pumakkal bioremediation experienced an increase in pH, the highest in the KC and KE treatments, namely pH 7.2. The results obtained have met the standards based on Canfield D E et al., which is equal to 6.80-7.49. The change in pH to neutral is due to an acid-base reaction that is formed between the Pumakkal bio activators when they experience decay during the fermentation process with the following reaction:

\[ H_2O \rightarrow H^+ + OH^- \]

In general, nutrients will be easily absorbed by plants at a pH of 6-7, because at that pH most of the nutrients will dissolve easily in water. The pH degree in the soil also indicates the presence of elements that are toxic to plants [24]. The Pumakkal bio activator contains bacteria *Acinetobacter baumannii* and *Pseudomonas pseudomallei*, which has the ability to decompose organic acids in waste [25]. The effect on pH in fertilizers is very important in determining the absorption of nutrient ions by plants. If fertilizer is applied and causes the soil to become acidic, there will be many elements of aluminium (Al) which can poison plants and bind phosphorus so that it cannot be absorbed by plants, while in alkaline conditions there will be many elements of Na (sodium) and Mo (Molybdenum) which can poison plant. The pH conditions also determine the development of microorganisms, at a pH of 5.5 - 7 fungi and bacteria that decompose organic matter will grow well [23]. Pumakkal as a bio activator is able to decompose shrimp pond sediment into compost that meets the criteria of the content of C, N, C/N, P, Ca, K and pH.
4. Conclusion

The research conclusions are the pumakkal pineapple liquid waste bioremediator is able to degrade fertilizer organic coffee skin from the parameters of activated carbon, C / N ratio, Nitrogen, Calcium, Kalium and the degree of acidity (pH). The most effective treatment was Konsorsia C (9 isolates) with the best average yield. Treatment of the Consortium C (KC) yielded 6% organic C yield, for a C / N ratio of 6.9; Nitrogen (N) 8%, Pospor 650 mg / 100g, kadar Kalium treatment 478.506 mg / 100g, levels of Calcium (Ca) amounting to 530 mg / 100g and pH 7.2. The results of bioremediation of shrimp pond sediment are suitable for compost according to Minister of Agriculture Regulation No.261 / KPTS / SR.310 / M / 4/2019 concerning Minimum Technical Requirements for Organic Fertilizers, Biological Fertilizers and Soil Improvement and Specifications for compost from domestic organic waste SNI 19-7030-2004.

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