The potential of new bio-decomposers for composting sugarcane waste

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Abstract. The process of composting sugarcane residue by new bio-decomposer consortium formula contain specific microbes with different functions such as ligninolytic and cellulolytic microbes can improve the quality of agricultural waste. These bacteria have the potential to enhance sugarcane litter and other sugarcane residues. The fermentation process led to the C/N ratio of compost serves as a reference for the effectiveness of the decomposition process by bacteria. The research was designed as an alternative to producing organic fertilizers by using four bio-decomposer consortium formulas as ISAFCRI collection and EM4 as commercial bio-decomposer. The physicochemical characterization of 5 composts, including the C/N ratio of compost, is below 12-17, macroelements N, P, K available in compost are relatively high compared to the minimum requirement of SNI. The compost 5 with EM4 bio-decomposer appeared to have lower nutrient yields than compost using other decomposers. Compost 1 with formula one, which contains a consortium of lignocellulolytic bacteria, has excellent potential to be developed as a new bio-decomposer formula for processing sugarcane waste. The pilot test has shown that varieties of composts and organic fertilizers can be made from a mixture of sugarcane residue.

Keywords: cellulolytic, ligninolytic, bacteria, compost

1. Introduction
A significant industrial crop, sugarcane (Saccharum officinarum L.), has a high saccharin concentration and low fiber content. Originated from Asia, this plant can thrive in tropical and subtropical climates. Sugarcane grows best in soil rich in organic matter, wet, and has a pH of 7.5 to 8.5 [1]. Sugarcane bagasse and sugarcane straw waste are the primary forms of biomass created during cane sugar manufacturing. Approximately 280 million tons of sugarcane straw is made from cane waste every year. Currently, sugar factories typically burn sugarcane residue to produce power usage. This biomass can also be utilized as a feedstock for other goods of great value [1, 2]. The biorefinery uses lignocellulosic biomass as its principal feedstock. Processes such as biorefineries ultimately convert biomass to precious chemicals [3, 4]. It means that the technologies used by a biorefinery support a wide variety of areas such as biotechnology, agriculture, and polymer chemistry in general. A raw materials are fractionated to be valued ingredients which can produce valuable chemical products, including organic acids and fertilizers, as well as pigments (bio-pigments), surfactants (biosurfactants) and pharmaceutical products through controlled extraction processes, hydrolysis, fermentation or pyrolyses (biopharmaceuticals) [5–7]. Because biomass fractionation is the fundamental component of bioprocessing, it has several advantages for industries that employ various
raw materials. However, lignocellulosic biomass fractionation is still in its infancy [3, 8]. As a result, the focus is on aerobic composting, which converts waste into organic manure rich in vegetable nutrients and hummus [9], and the biodegradation of lignocellulosic waste via an integrated system of bioinoculant composting and vermicomposting [10–12].

It was discovered by Nakajima-Kambe et al. (1999) [13] that in thermophilic and anaerobic circumstances, microorganisms may colorize molasses wastewater which may then be used for bio-compost. *Pseudomonas, Enterobacter, Stenotrophomonas, Aeromonas, Acinetobacter* and *Klebsiella* are more efficiently isolated and identified in order to decrease chemical oxygen requirements of washing waste [14]. The sugar factories in the nation create large quantities of waste, with waste removal and management the main duties. Agriculture may generate bio-fertilizer and bio-compost as a soil improver, an organic source of nutrients for plants, and a substrate for microbial inoculants. They are often accessible, but because of their bulky nature they require considerable money to deliver to the region. Consequently, the technology to decrease their volumes to cheaper, concentrated goods may be created. The composting process can be used as a nutrient carrier in the fertilizer sector for volume reduction and subsequent composting. Appropriate technologies might be developed to reduce the costs of their huge end products. Composting is a feasible solution to decrease its volumes and can be used as a nutrient carrier in fertilizer businesses following composting [15].

Many artificial techniques have been devised to increase composting efficiency. Several types of research have documented the effectiveness of inoculation during the previous few decades. Many forms of inoculation have been applied in the field. Knežević et al. said [16], white-rot fungi play a crucial role in lignin breakdown. Using *Bacillus licheniformis*, Stanford et al. [17] discovered that it efficiently decomposes protein and avoids a decrease in pH levels during composting therefore promoting the growth of other thermophilic bacteria. Rudnik [18] observed that it is possible to increase the inoculation of microbial, create favorable microbiological communities and improve microbial quality, and develop different desirable enzymes, improving organics’ conversion and minimizing odorous gas emissions. In this study, a biofertilizer formulation technology package created from sugarcane waste with enhanced microbial active components to boost sugarcane output by adding value to sugarcane by-products and re-using them in sugarcane fields.

2. Materials and methods

2.1. Preparing consortium bio-decomposer formula as an inoculum.

The new bio-decomposer consortium bacterial formulas have the greatest potency of cellulolytic and ligninolytic bacteria available. These bacteria as ISAFCRI’s bacteria collection was obtained from kenaf soaking water in East Java. Bacterial association tests were performed to see which bacteria might form in the consortium formula. Consortium bacteria were inoculated in nutrient broth medium then incubated at 37 °C for 18 - 24 hours until the number of cells bacteria was around 10^8 – 10^9 CFU/ml.

There were five bio-decomposer consortium bacterial formulas: Formula 1, Formula 2, Formula 3, Formula 4, and Formula 5. As lignocellulolytic bacteria, Formula 1 has the most potential. As cellulolytic bacteria, Formula 2 has the most potential. Formula 3 has the most promise as ligninolytic bacteria. Formula 4 was a consortium of all bacteria as lignocellulolytic, cellulolytic, and ligninolytic bacteria, while Formula 5 included EM4 bio-decomposer as a comparison.

2.2. Composting process

The 25 kg of organic material samples comprises 50% trash sugarcane leaves, 20% bagasse, 10% filter mud, 10% boiler ash, and 10% cow dung, together with four novel bio-decomposer formula and one EM4 commercial bio-decomposer for comparison at 60% humidity (Figure 1). This study was conducted in Malang, 2019. For starting of composting, 10% (20 L) bacterial culture with a final bacterial 10^8-10^9 CFU/ml concentration and bacterial 10^7-10^8 CFU/g bacterial population were inoculated [19]. Compost number 1 was inoculated with Formula 1, Compost 2 was inoculated with Formula 2, Compost 3 was inoculated with Formula 3, and Compost 4 with the mixed culture of all
the Formula 1, 2, and 3, and Compost 5 is controlled by using EM4 bacterial formula. At the start of composting the wet garbage was sprayed over bacterial suspensions, the bagasse and the other material were bent upside down to disperse the bacteria after inoculation. The materials was stirred to control the humidified and temperature daily. The examination of final compost parameter, such as pH, N, P, K, C, C/N, organic material, and the final compost's physical parameter, are comprising temperature, colour, odor, and water content. For the measurement procedure of N was using Kjeldahl digestion methods, total P was measuring by using acid solution, total K was determined by using flame photometrically, total organic and organic carbon from loss of carbon dioxide during composting.

A randomized block design (RBD) was used, in which the treatments corresponded to the variations of the formula used for compost production and then tested by Duncan. For each treatment, 3 replicates were used, resulting in a total of 15 samples. The statistical program SPSS was used.

Figure 1. The step of composting process
3. Result and discussion

Humidity is a crucial composting ingredient and if not well controlled, can become a restrictive factor. This resulted in a weekly monitoring of the moisture contents of the composting process. The optimal range of moisture is 40-60% [20]. At the beginning of the composting process initial humidity by 60% is acceptable; however, this should be decreased to 30% or more in order to ensure that the end product is not biologically active. During this operation, the five composting designs had the optimum humidity range. The five composts, which started with 60 percent humidity, ended up with about 30% moisture, with the control compost having the highest values.

![Figure 2. The temperature profile of 5 compost.](image)

The temperature of the composting process is an essential element in tracking its progress. Throughout the procedure, it was checked weekly. The new bio-decomposer consortium formulas 1, 2, 3, and 4 have a faster composting pattern than compost using the EM4 bio-decomposer. At the sixth week the composting process of Compost 1,2,3 and 4 had ended but Compost 5, using EM4, showed that the temperatures of the biodecomposers were not as low as the soil. This shows that the new bio-decomposer is superior than EM4 formula because it can ferment organic waste into fertilizer faster than EM4. The five composts presented the same temperature profile (Figure 2). The maximum temperature (38°C) was observed in compost 5 till six weeks, and almost four composts achieved the land temperature of 25-26 °C. This lowering of the pH can be connected to low temperature levels and might influence the development and activity of the microorganism. Compostation is a helpful model that examines ecological problems, such as biodegradation succession and competition, and bioconversion of organic matter with temperature gradients.

Three stages occur during the composting process related to temperature. Mesophilic, thermophilic, cooling, and maturation are four key thermal stages of batch composting. The microbial structure of every stage develops in response to temperature and other environmental variables. Mesophilic bacteria degrade organic compounds at moderate temperatures in the initial step. The temperature then rises due to microbial activity, where the temperature rises to approximately 40 °C, then thermophilic conditions, when the temperature rises to between 40-70°C. The temperature is then increased by self-heating as a result of intensive microbial activity. In the thermophilic phase, microorganisms, including pathogens from the mesophilic phase, proliferate. The cooling phase, where microbial activity decreases, caused the scarcity of degradable organic components during the thermophilic phase of waste breakdown. In mesophilic conditions, the presence of acid generating bacteria, breakdown and stabilization occur optimum under thermophilic temperatures, and water is evaporated from the composted material during the cooling phase, resulting in humic acid as final product. Because of the scarcity of degradable organic components during the thermophilic phase of waste
breakdown, microbial activity declines. This cooling phase results in a decrease in temperature, allowing mesophilic bacteria to take over.

As shown in Table 1, the nutrient content of compost produced by composting Formula 1, Formula 2, Formula 3, and Formula 4 has the SNI-recommended level of nutritional value. Compared to others composts, Compost 1, which employed the novel bio-decomposer Formula 1, had the most outstanding results in terms of macroelements analysis. The results show that the compost used in the EM4 decomposer has lower nutrient outputs than the compost with the use of other bio-decomposers.

Table 1. The physicochemical characterization of 5 composts

| Parameters       | Unit   | std of National Indonesia | Comp1 | Comp2 | Comp3 | Comp4 | Comp5 |
|------------------|--------|---------------------------|-------|-------|-------|-------|-------|
| Humidity         | %      | 50                        | 30    | 34    | 38    | 32    | 42    |
| Temperature      | °C     | 25-26                     | 25    | 26    | 25    | 25    | 38    |
| Color            |        | Black                     | Black | Black | Black | Black | Black |
| Odor             |        | Damp earth                | Damp  | Damp  | Damp  | Damp  | Damp  |
| pH               |        | 6.8                       | 7.49  | 7.4   | 7.3   | 7.4   | 7.3   |

Macroelements

| Organic material | %      | 27    | 58    | 43.64 | 40.33 | 42.20 | 32.19 | 34.58 |
| Carbon (C)       | %      | 9.80  | 32    | 25.23 | 23.31 | 24.39 | 18.61 | 19.99 |
| Nitrogen (N)     | %      | 0.40  | -     | 1.74  | 1.75  | 1.61  | 1.53  | 1.49  |
| C/N              | 10     | 20    | 14.5  | 13.3  | 15    | 12.2  | 13.4  |
| P2O5             | %      | 0.10  | -     | 0.47  | 0.49  | 0.49  | 0.43  | 0.39  |
| K2O              | %      | 0.20  | -     | 0.46  | 1.29  | 0.37  | 1.27  | 1.25  |

A new bio-decomposer recipe for processing sugarcane waste might be created using Formula 1, which comprises lignocellulolytic bacteria in a consortium. Lignocellulolytic bacteria may destroy cellulose and lignin at the same time. Composted fertilizers are more effective and efficient because of the capabilities of these microorganisms. To generate nutrients, cellulose, hemicellulose and degrade lignin continue to be broken down by bacteria. After around 1.5 months, the physical transformation in the raw material reveals that the process of composting was finished. Table 1 shows the physicochemical characteristics of five composts. Compost has a C/N ratio less than 12-17, which is less than the SNI 20 maximum standard. The macro elements N, P, and K present in compost are relatively high compared to the SNI minimum need. The accessible N element in sugarcane waste compost is on average greater than 1%, which is greater than the minimal SNI requirement of 0.4%. The macro element P is greater than 0.33% and greater than the minimum requirement of 0.1%. Elements of K that exceed the SNI 0.2 percent minimum threshold. Sugarcane leaves and bagasse, including cellulose, lignin, hemicellulose, and a trace of pectin, are utilized in the composting process.

The microorganisms utilized in the breakdown process include cellulose and lignin-degrading bacteria, the most prevalent components of sugarcane waste. such as bagasse and sugarcane leaves. The using of microorganisms is one option for improving agricultural waste recycling. Bacteria having specific activities, such as ligninolytic and cellulytic microbes, can enhance agricultural waste quality. Bacterial metabolism, which occurs during breaking down organic waste during composting, is essentially a form of bacterial respiration that occurs as part of the carbon cycle. Organic matter can be overhauled in both aerobic and anaerobic conditions [21]. Aerobic composting generates CO2, H2O, heat, nutrients, and some hummus as by-products. CH4, CO2 and many intermediate chemicals, including H2S and organic sulfur, are end products for the anaerobic composting process which can both emanate unpleasant odors [22]. The lignocellulose and hemicellulose linkages of sugarcane leaves and bagasse are disrupted during fermentation. Ligninolytic microorganisms assist in modifying...
lignocellulosic linkages so that ligninase enzymes may liberate cellulose and lignin from these bonds. Compounds are not only broken down, but also synthesized during the decomposition process. The process of mineralization is the final phase in the breakdown process when plant minerals N, P, K, Ca, Mg, S, and microelements as organic matter components are released by plants to produce organic compounds in body tissues.

4. Conclusion
Four novel bio-decomposer consortium formulas as IAARD bacterial collection and EM4 for the composition of sugarcane residual products as a commercial bio-decomposer can enhance the breakdown of sugarcane litter and other sugarcane residue. The physicochemical characterization of 5 composts, including the C/N ratio of compost, is below 12-17, macroelements N, P, K available in compost are relatively high compared to the minimum requirement of SNI. Compost 1, which comprises a lignocellulolytic bacteria consortia, has enormous potential for development as a novel type of decomposing for sugarcane waste processing. Compost 5 with EM4 decomposer seemed to produce fewer nutrients than compost with other bio-decomposer.

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