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Research Article
Enhancement of Compost Quality from Corn Cob and Corn Stem using Different Decomposers

[1,2]Amik Krismawati, [2]Nurul Aini, [2]Sudiarso, [2]Setyono Yudo Tyasmoro and [1]Dwi Setyorini

[1]Organization Research, National Research and Innovation Agency, Cibinong Science Center,
Jl. Raya Jakarta Bogor, KM 46, Cibinong, Bogor, West Java, Indonesia
[2]Department of Agronomy, Faculty of Agriculture, Brawijaya University, Jl. Veteran, Malang, 65145, East Java, Indonesia

Abstract

Background and Objective: Composting corn residues, such as cobs and stems, is an effective strategy to convert agricultural waste into high-quality organic fertilizer, improving soil health and crop productivity. Due to their high lignocellulosic content, these residues require specific decomposers for efficient breakdown. This study aimed to determine the optimal combination of corn residues and decomposers to produce high-quality compost. **Materials and Methods:** The experiment was arranged in a Randomized Block Design with one factor: a combination of corn harvest residues (corn cob, corn stem) and decomposer types (PGPR, Petrofast, M-21, BeKa), comprising eight treatments with three replications. Observed variables included physical characteristics (final weight, volume reduction, color, texture, and odor), chemical properties (water content, pH, organic C, C/N ratio, total N, total P_2O_5, and total K_2O), and composting temperature. Data were analyzed using one-way ANOVA ($p<0.05$) followed by LSD to identify homogeneous treatments. **Results:** Final compost temperatures ranged from 32.13-34.33°C, and weight reduction ranged from 27.63 to 65.41%. BeKa-treated compost produced blackish-brown, crumbly material. Chemical analyses showed that organic C, pH, C/N ratio, total N, total P_2O_5, and total K_2O values met Indonesian organic fertilizer standards (Decision No. 261/KPTS/SR.310/M/4/2019; SNI 19-7030-2004). The combination of corn cob with BeKa (K1D4) produced the highest quality compost, with 45.94% organic C, 1.89% total N, and a C/N ratio of 24.25. **Conclusion:** Composting corn residues is an effective approach to manage agricultural waste. Among the treatments tested, corn cob combined with BeKa decomposer produced the highest-quality compost, meeting national standards for organic fertilizers. This approach is suitable for both small- and large-scale applications.

Key words: Corn harvest residues, corn cob, corn stem, decomposer, compost

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Corresponding Author: Amik Krismawati, Organization Research, National Research and Innovation Agency, Cibinong Science Center, Jl. Raya Jakarta Bogor, KM 46, Cibinong, Bogor, West Java, Indonesia

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Corn (*Zea mays* L.) is one of Indonesia's main food commodities, second only to rice[1]. Corn waste such as husks, cobs, stem, and silk are agricultural residues rich in nutrients and bioactive compounds that are often wasted. In a circular economy, this waste has high potential to be processed into animal feed, organic fertilizer, industrial materials, and even functional food products. Optimizing the utilization of corn waste can increase economic value and reduce environmental impact[2]. Corn cultivation has the potential for waste, but more than 70% of the total corn biomass and waste are not properly utilized. Generally, corn waste is not returned to the soil or burned because it interferes with land management for subsequent planting[3].

Corn cobs are farming wastes that are found abundantly and have not been utilized, but they are potential to be used for making compost. It is presumed that 18 kg of corn cobs produce 100 kg of kernels. Corn cob is a source of cellulose (27.71%), hemicellulose (38.78%), and lignin (9.4%), each of which can be converted into other biological compounds. Cellulose is a major carbon source that microorganisms can utilize as a substrate in fermentation processes to produce organic fertilizers[4]. These compounds will be converted into various bio energies that include bioethanol, biogas, and bio oil. Cellulose is the carbon source that can be used by microorganisms as substrate in the fermentation process to produce organic fertilizers[5,6].

Not only the cobs, the corn stems can also be used as compost. The corn stem contain 42.4% cellulose, 29.6% hemicellulose, and 21.7% lignin. The stem contains 0.92% nitrogen, 0.29% phosphorus, and 1.39% potassium. The chemical contents in corn stem are 35% fibers, 3.7% protein, and minerals such as 0.35% calcium and 0.19% phosphorus[7,8]. The compost produced from these two materials is highly beneficial for agricultural cultivation because it can improve the physical and biological properties of the soil. Compost acts as a nutrient buffer, loosening or crumbling the soil structure, allowing for optimal aeration. It also gradually releases nutrients and promotes optimal microbial activity, ensuring the ongoing mineralization of soil organic matter[9]. The continuous use of corn cob and stem compost in agricultural cultivation is a highly effective, eco-friendly, and sustainable practice that supports organic farming by recycling local, natural waste materials.

The C/N ratio is a critical factor influencing compost quality[10]. The international technical standard has recommended C/N ratio between 20-30[11], this ratio provides the right balance for microorganisms to consume carbon as an energy source and nitrogen to build cell structures. This value ensures efficient microbial activity, produces high-quality mature compost, promoting rapid, efficient decomposition, and prevents N competition between microbes and plants. A high initial C/N ratio leads to slow microbial activity, longer composting times, and nitrogen immobilization. Conversely, a low initial C/N ratio causes excessive nitrogen loss via high Ammonia (NH_3) emissions and odor[12]. The objective of the study was to enhance the quality of compost produced from corn cob and corn stem by evaluating the effectiveness of different decomposer treatments.

MATERIALS AND METHODS

Experimental site: The research was conducted in Watugede Village, Puncu District, Kediri Regency, East Java at the coordinates of 07°48'45" South Latitude and 112°10'19" East Longitude and locates at the altitude of 93 m above sea level. Selection of the location was based on some considerations that the area is a corn farming area. Analysis on the chemical content of the compost was conducted at the Laboratory of Soil, Agriculture Instrument Standardization Agency (BSIP) in Malang, East Java, Indonesia.

Research materials and tools: Materials of the research included residues of the harvested corn (cob and stem) (Fig. 1), decomposer (PGPR, Petrofast, M-21, BeKa), bran, molasse, and water. Tools used in the study were tissue, label paper, bucket, wooden stirrer, shredder, oven, macropipette Socorex Calibra 832.10 1-10 mL, macropipette (Gilson 1000 µL, Transferpette; 10-100 µL), calibrated beaker, analytical balance (Mettler AE 100), Whatman paper, desiccator, and other analysis tools.

The research was conducted in Watugede Village, Puncu District, Kediri Regency, East Java, from June to August 2024. The study was arranged in a Randomized Block Design with one factor: A combination of corn harvest residues (corn cob, corn stem) and types of decomposers (PGPR, Petrofast, M-21, BeKa) as shown in Table 1.

Plant Growth-Promoting Rhizobacteria (PGPR) contains microbes Azospirillum (1.0×108), Azotobacter sp. (1.0×108), Bacillus sp. (1.0×108), and Pseudomonas sp. (1.0×108).

Petrofast decomposer contains microbes *Actinomycetes* (lignolytic), *Streptomyces* sp. Strain LD021 (lignolytic), *Streptomyces tumescens* (cellulolytic), and *Trichoderma* sp. (cellulolytic).

The M-21 decomposer contains microbes *Actinomycetes* sp. (lignolytic) (1.0×107 cfu/mL), *Streptomyces* sp. Strain LD021 (lignolytic) (1.0×107 cfu/mL), *Streptomyces tumescens* (cellulolytic) (1.0×107 cfu mL), and *Trichoderma* sp. (cellulolytic) (1.0×104 cfu/mL).



Fig. 1: Corn harvest residues in used in research

Table 1: Comparison and combination of organic material treatment compost

Treatment	Combination of organic material treatment compost
K1D1	Corn cob+PGPR
K1D2	Corn cob+Petrofast
K1D3	Corn cob+M-21
K1D4	Corn cob+BeKa
K2D1	Corn stem+PGPR
K2D2	Corn stem+Petrofast
K2D3	Corn stem+M-21
K2D4	Corn stem+BeKa

Table 2: Characteristics chemical content of composted material

Parameter	Corn cob	Corn stem	SNI 19-7030-2004
Water content (%)	9.77	13.07	Max 50.00
pH	5.90	9.80	7.49
Organic C (%)	50.35	43.98	9.80-32.00
C/N ratio	50.35	47.80	10.00-20.00
Total N (%)	1.00	0.92	0.40
Total P2O5 (%)	0.42	0.61	0.10
Total K2O (%)	1.40	4.13	0.20

BeKa decomposer contains microbes *Bacillus* sp. (22.52×109 cfu/g), *Streptomyces* sp. (30.68×109 cfu/g), *Azotobacter* sp. (6.32×109 cfu/g), Aspergillus sp. (6.30×108 cfu/g), *Trichoderma* sp. (2.7×107 cfu/g), and *Saccharomyces* sp. (28.04×109 cfu/g).

The study comprised 8 treatments with 3 replications. The treatments are described in Table 1.

Characteristics of composted material: The result indicates that the characteristics of corn harvest residues vary. The chemical properties used in the manufacturing compost in Table 2.

Experimental setup: There are some steps in composting process where in wastes of the corn harvest residues (cobs and stems) are cut into small pieces, 1-3 cm. Then, they are crushed to make the surface area becomes smaller to accelerate the composting process. Such reduction in size is done using chopper to chop the corn cobs and the stems. In mixing each sample, it uses 7 kg cobs and stems each, then 2 kg of bran is added to each sample, stirred until evenly mixed. After that, it is added with 50 mL solution of decomposers PGPR/ Petrofast/ M-21/ BeKa that have been added with 100 mL molasse and water. With the annotation that the condition must be crumbly (should not too wet and not too dry). Then, it is stirred again until evenly mixed. After mixing process, the homogenized material is weighed for each sample to determine the initial weight of the compost mixture, and the weighing is adjusted according to each treatment. After weighing process, the materials are put into the composting medium of a 25 kg bucket and not covered too tightly to create an aerobic atmosphere and kept away from direct sunlight. Stirring the compost materials are done every 3 days and it is hoped that aeration and fermentation process will run well evenly. Stirring is crucial factor to control humidity so that the composting will keep in an aerobic atmosphere, balance the temperature and assist the compost maturity. At the time of composting the material temperature conditions also need to be maintained between 40-50°C. The composting takes place for 35 days. The results of compost waste air dried and analyzed for their chemical properties.

Variable and data collection: Observation on physical condition of the compost on the final processing stage (final weight, depreciation, colour, texture, and smell) and chemicals of compost include: Water content, pH, Organic C, C/N ratio, Total N, Total P_2O_5 content, and Total K_2O content as well as temperature of the composting medium. The analysis method of the organic fertilizer is based on SNI 7763:2018[13]. The observed parameters are closely related to quality of the compost such as water content (Gravimetry, Oven), pH [(1:4), Electrometry, pH meter], Total N (Kjeldahl, Titrimetry), Total P_2O_5 (wet ashing of HNO_3+$HClO_4$, Spectrophotometry), Total K_2O (wet ashing of HNO_3+$HClO_4$, AAS), C-organic (dry ashing of HNO_3+$HClO_4$, Furnace), and C/N ratio (Calculation). Standard organic fertilizer composition and content of the organic fertilizers as issued by Ministry of Agriculture in the form of Minimum Technical Requirements of compost quality using quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia Number 261/KPTS/SR.310/M/4/2019 concerning with Minimum Technical Requirements for Organic Fertilizer, Biofertilizer, and Soil Ameliorant (Indonesian Ministry of Agriculture, 2019)[14] and SNI 19-7030-2004 (National Standardization Agency of Indonesia 2004)[15].

Compost chemical analysis: Analysis of the organic carbon content of fertilizers was carried out is based on SNI 7763:2018[13]. Organic carbon content is determined by ashing at a temperature of 550-600°C, converting organic matter to CO_2 and metals to their metal oxides. The weight of the lost material is the organic matter that can be converted to organic carbon content after multiplying by a factor of 0.58. Procedure: (a) Insert the sample into the furnace after determining the moisture content (W_2), (b) Ash first at 300°C for 1.5 hrs and then at 550-600°C for 2.5 hrs or more, (c) Turn off the furnace and allow it to cool, (d) Cool the sample in a desiccator and then weigh it (w_3), Calculation:

$$\text{Water content (\%)} = \frac{W_3}{W_1} \times 100$$

$$\text{Organic matter content (\%)} = 100\% - \text{Water content (\%)} + \text{Ash content (\%)})$$

$$\text{C-organic (\%)} = \text{Organic matter content (\%)} \times 0.58 \times F_c$$

Where:

W_3 = Ash weight expressed in g
W^1 = Sample weight expressed in g
0.58 = Organic matter to organic carbon conversion factor
F_c = Water content correction factor

Weight loss value is calculated using equation:

$$\text{Weight loss (\%)} = \frac{W_0 - W_1}{W_0} \times 100\ (\%)$$

Where:

W_1 = Weight after decomposition
W_0 = Weight before decomposition

Data analysis: One way ANOVA was used to analyze the significant different value for each parameter ($p<0.05$) and followed by Least Significant Difference (LSD) at α 5% to identify the homogeneous treatment. Data of variance and follow up tests were analyzed using DSAASTAT (excel VBA macro), while data of temperature was analyzed descriptively.

RESULTS AND DISCUSSION

Temperature: Figure 2 shown a change in temperature during the decomposition process. The initial differing temperature increase among the eight treatments from day 1 to day 3 suggests varied biological activity. After the third day of composting, the difference in the compost raw materials showed a temperature difference, where the corn stem material had a higher temperature than the corn cob material. At the end of the temperature observation time, which was 35 days of composting, all treatments showed that the temperature conditions were almost the same.

Based on the temperature observation results on compost of corn cobs and stems, initial composting temperature ranged from 30.33 to 34.3° C and increased after 3 days for about 45.00-51.00°C. The increase in temperature on each combination of organic materials was due to microorganism activities in decomposing substrates to produce CO_2 and energy which causes heat. Temperature will decrease when the whole materials have been decomposed. The different temperatures of the compost on each material at the third day, the corn cob compost reached 45.00-46.67°C and the corn stem compost reached 50.67-53.33°C. At the fifteenth day, temperature of the cob compost reached 42.65-44.00°C and the corn stem compost reached 56.33-59.00°C. Decreasing temperature, after the materials were decomposed, showed that the compost has entered the maturity phase. At the final composting process, temperatures of the compost medium were almost equivalent. For cob compost by the treatments are as follow K1D1 = 33.67°C, K1D2 = 34.33°C, K1D3 = 34.00°C and K1D4 = 33.00°C. For stem compost by the treatments are as follow K2D1 = 34.00°C, K2D2 = 32.13°C, K2D3 = 33.00°C and K2D4 = 32.33°C (Fig. 2).

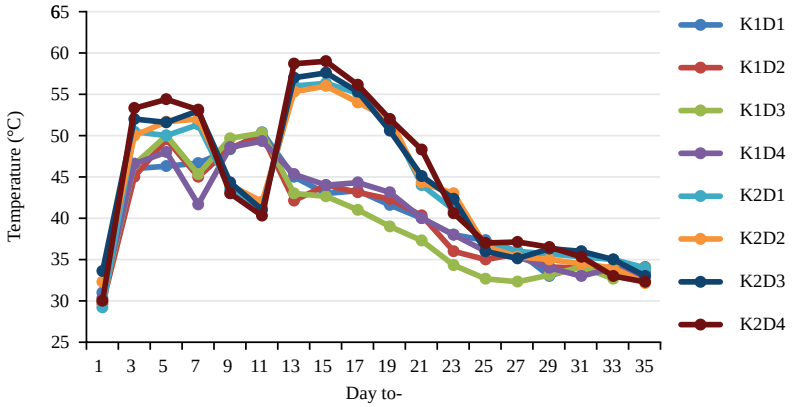


Fig. 2: Temperature changes during the 35-day composting process of corn harvest residues

K1: Corn cob, K2: Corn stem, D1: PGPR, D2: Petrofast, D3: M-21, D4: BeKa. The graph shows temperature variations indicating microbial activity and compost maturity

The increase and decrease in temperatures during composting process indicated that the composting process, which is done by microorganisms, has run well. Microorganisms will decompose the organic compounds such as organic carbon which is available to become CO_2, water vapor and heat (Calor). The longer the composting process, the temperature produced by the compost will decrease, and it indicates that carbon contained in the compost has been used by microorganisms in the decomposing process[16].

The activity of microorganisms in decomposing organic matter produces nutrients and energy in the form of heat, which causes the temperature of the pile to rise. The temperature increases as the microorganism population changes, from the psychrophilic (cool) phase, to the mesophilic (moderate), to the thermophilic (hot) phase. At temperatures of 40-60°C, decomposition is optimal and rapid. The heat produced is reused by the microorganisms, while some is released into the environment. Once the organic matter has largely decomposed (substrate reduction), the temperature will decrease and return to the second mesophilic phase. When the organic matter is fully decomposed, the temperature will stabilize, indicating that the decomposition process is complete[17,18].

Temperature is a direct control as indication of microorganism activities in degrading the available organic carbon contained in raw material of the compost. Based on data of temperature measurement, it showed that at the third day, the composting of corn cobs and stems had risen the temperature to thermophilic temperature above 45°C and pH decreased to be acid. Optimal temperature (35-60°C) facilitates the effective microorganism activities in composting process and accelerate the organic material decomposition. Optimum temperatures vary from 45 to 55°C. The results reported by Azim *et al.*[19] showed that in few days, the internal pile temperature rise quickly from mesophilic (20 to 40°C) to thermophilic stage (>40°C), and then the temperature gradually decreases due to the microorganisms deplete the available nutrients. Some bacteria that commonly found in the mesophilic stage are *Pseudomonas* sp., *Streptococcus* sp. and in the thermophilic stage is *Bacillus* sp. Some fungi that are commonly found in mesophilic and thermophilic stages are *Aspergillus* sp., *Penicillium* sp. and *Trichoderma* sp.

Temperature started to decrease at 23 day up to less than 45°C, and water content is constant because there is no evaporation in the compost. Final temperature of both composts, the corn cob and corn stems, ranged from 32.13-34.33°C. According to Finore *et al.*[20] during the decomposition of organic matter in the compost, the organic matters will be decomposed into NH_3^+, CO_2, water vapor and heat through metabolism system that is assisted by oxygen. After most of the materials are completely decomposed, temperature will gradually decrease and back to normal.

Physical characteristics of compost: The combination treatments of varying decomposer and corn harvest residues showed significant influence ($p<0.05$) on final weight, and decrease in compost volume (Table 3). Combination treatment of cob waste and BeKa (K1D4) decomposer showed the highest final weight 6.61±0.09 kg and the lower depreciation 27.63±2.93% which is significantly different with other treatments. Combination treatment of stem waste and Petrofast (K2D2) decomposer showed the lowest final weight 3.13±0.12 kg and the higher depreciation 65.41±1.43% which was not significantly different with the treatment of K2D1 (corn stem and PGPR decomposer) 3.19±0.12 kg and 64.63±1.37%, K2D3 (corn stem and M-21 decomposer) 3.26±0.03 kg and 64.04±0.89%, K2D4 (corn stem and BeKa decomposer) 3.15±0.06 kg and 64.74±0.68% but it was significantly different with the whole combination treatments of corn cob wastes and types of decomposer (K1D1, K1D2, K1D3, dan K1D4).

Table 3: Physical characteristics of compost from corn harvest residues

Treatment	Initial weight (kg)	Final weight (kg)	Depreciation (%)	Colour	Texture	Smell
Corn cob+PGPR	9.00±0.00	6.27±0.10^{b}	30.67±1.18^{b}	BB	C	SS
Corn cob+Petrofast	9.00±0.00	6.20±0.03^{cd}	31.04±0.46^{b}	BB	C	SS
Corn cob+M-21	9.00±0.00	6.10±0.09^{c}	31.33±2.40^{b}	BB	C	SS
Corn cob+BeKa	9.00±0.00	6.61±0.09^{e}	27.63±2.93^{a}	BB	C	SS
Corn stem+PGPR	9.00±0.00	3.19±0.12^{ab}	64.63±1.37^{c}	B	C	SS
Corn stem+Petrofast	9.00±0.00	3.13±0.12^{a}	65.41±1.43^{c}	B	C	SS
Corn stem+M-21	9.00±0.00	3.26±0.03^{a}	64.04±0.89^{c}	B	C	SS
Corn stem+BeKa	9.00±0.00	3.15±0.06^{a}	64.74±0.68^{c}	B	C	SS
CV (%)	1.42	3.33				
LSD (5%)	0.12	2.77				

Each value is the Mean±SE of three replicates. One-way ANOVA for the significant combination difference ($p<0.05$) and numbers followed by the same letter in the same column are not significantly different at α 5% LSD, B: Brown, BB: Blackish Brown, C: Crumb and SS: Similar Soil

Table 4: Result of chemical properties analysis of compost from corn harvest residue (Means±Standard Deviation)

					Macro nutrients (%)		
Treatment	Water content (%)	pH	Organic C (%)	C/N ratio	Total N	Total P_2O_5	Total K_2O
Corn cob+PGPR	14.55±0.03^{d}	7.53±0.06^{a}	45.45±0.28^{c}	29.47±4.68^{ab}	1.57±0.25^{b}	0.69± 0.01^{d}	2.43±0.07^{a}
Corn cob+Petrofast	14.45±0.12^{d}	7.53±0.06^{a}	45.56±0.20^{cd}	29.78±7.50^{ab}	1.60±0.42^{b}	0.67±0.06^{d}	2.36±0.06^{a}
Corn cob+M-21	11.23±0.06^{c}	7.50±0.10^{a}	45.40±0.05^{c}	25.8±3.74^{a}	1.78±0.24^{b}	0.68±0.10^{d}	2.27±0.11^{a}
Corn cob+BeKa	11.31±0.17^{c}	7.50±0.10^{a}	45.94±0.35^{d}	24.25±1.13^{a}	1.89±0.08^{b}	0.64±0.14^{cd}	2.29±0.14^{a}
Corn stem+PGPR	10.83±0.02^{b}	9.83±0.21^{b}	39.21±0.22^{a}	37.60±2.75^{c}	1.05±0.08^{a}	0.49±0.06^{ab}	3.69±0.09^{b}
Corn stem+Petrofast	10.94±0.24^{b}	9.83±0.21^{b}	39.20±0.43^{a}	36.03±1.91^{bc}	1.09±0.06^{a}	0.56±0.05^{bc}	3.62±0.16^{b}
Corn stem+M-21	10.05±0.09^{a}	9.97±0.12^{b}	39.70±0.04^{b}	39.55±2.53^{c}	1.01±0.07^{a}	0.47±0.04^{a}	3.73±0.12^{b}
Corn stem+BeKa	10.08±0.16^{a}	9.93±0.06^{b}	39.57±0.15^{ab}	34.05±2.11^{bc}	1.11±0.10^{a}	0.53±0.02^{ab}	3.81±0.24^{b}
CV (5%)	1.21	1.22	0.57	12.62	15.47	8.53	4.06
LSD (5%)	0.25	0.19	0.43	7.09	0.38	0.09	0.22
Indonesian ministry of agriculture's decision No. 261/KPTS/SR.310/M/4/2019	8-20	4-9	Min 15	≤25		Min 2 (N+P+K)	

Each value is the Mean±SE of three replicates. One-way ANOVA for the significant combination difference ($p<0.05$) and numbers followed by the same letter in the same column are not significantly different at α 5% LSD

Treatment using compost produced weight around 3.13±0.12 to 6.61±0.09 kg. Average weights of organic matters decreased during the decomposing process due to the presence of microbes in the compost that convert the organic matters into smaller particles. The decrease in volume of the organic matters in the compost ranged from 27.63±2.93 to 65.41±1.43%. On average, organic matters decrease during the decomposing process due to the presence of microbes in the compost that convert the organic matters into smaller particles. According to Ramnarain *et al.*[21] differences in weight was also influenced by combination of organic matters treatment.

Changes in the final weight of the compost indicate that the decomposition process has occurred. Composting reduces both the volume and mass of raw materials. In a well-managed process, the final weight can be reduced due to the conversion of organic matter into carbon dioxide (CO_2), water vapor, and heat. Microorganisms consume carbon-based materials as a primary food source for energy. As this carbon is utilized for respiration and cell formation, it is released as reducing the overall mass of the pile. In this process, anabolic and catabolic reactions take place and release CO_2, water and thermal energy so that weight of the organic matters decrease[22]. Results of the analysis showed that corn cob has low protein level (<4.64%), but high cellulose and lignin levels[23]. The use of bio-decomposers (microorganisms) significantly accelerates the composting process, leading to a noticeable reduction in the height and volume of a compost pile. In the process of decomposing organic material, microbes require water, oxygen from the air, and nutrients from the organic material as energy sources. During this process, microbes release CO_2, water, and heat energy, ultimately causing a decrease in the weight of the compost material[24].

During the composting process, the color gradually changes. Brownish green turns into deep brown. At the end of the composting process, the color turns into blackish brown due to the formation of humic acid. During the process, not only the color changes, but also unpleasant odor smells due to the decomposition process of organic matters is taking place. However, at the final composting, the compost has pleasant and earthy smell[25]. Observation on character of the compost odor ranges from medium to earthy smell. Stinky odor is not smelled as was smelt during the initial composting

because the sulfuric compounds are consumed by the bacteria and they are having dioxide process inside the bacterial body and turned into sulfuric acid, so that the stinky odor gradually disappears[26].

Chemical characteristics of compost: Results for analysis of variance relating to the application of decomposer on cob and stem wastes had a significant influence ($p<0.05$) on the final water content of the compost in Table 4. The higher water content was derived from the treatment of K1D1 (corn cob and PGPR decomposer) 14.55±0,03% which was not significantly different from the treatment of K1D2 (corn cob and Petrofast decomposer) 14.45±0.12%, but it was significantly different from other treatments (K3D1, K4D1, K2D1, K2D2, K2D3 dan K2D4), and the lower water content was derived from the treatment of K2D3 (corn cob and M-21 decomposer) 10.05±0,09%. Results of the research showed that water content on those eight treatments using compost have met the quality standards for solid organic fertilizers, following the decision of the Ministry of Agriculture, Republic of Indonesia, is about 8-20%.

Water plays an important role as a medium for microorganisms to work, dissolve nutrients, and produce heat during the composting process. Too low or too high water content may inhibit the microorganism activities and slow down the decomposition process. The decrease in water content indicates that the composting process has run well. According to a study by Ali *et al.*[27] percentage of water content will decrease along with the rise of temperature during the composting process. The increase in temperature is inversely proportional to the water content of the compost. Water content influences the compost decomposition rate and temperature parameter because microorganisms require optimal water content to decompose organic matter. Values of the final water content of the compost have met the quality standards for solid organic fertilizers, following the decision of the Ministry of Agriculture, Republic of Indonesia, 8-20%.

Results for analysis of variance showed that the application of decomposers on corn cob and stem waste has a significant influence ($p<0,05$) on the final pH of the compost (Table 4). The treatment of K1D1 did not show a significant difference from other treatments of K2D1, K2D2, K2D3, and K2D4. pH for all treatment combinations of corn cob wastes and types of decomposers range from 7.50±0.10 to 7.53±0.06; however, pH values for all treatment combinations of corn stem wastes and types of decomposers range from 9.83±0.21 to 9.97±0.12. pH value of compost made of corn stem wastes and types of decomposers did not meet the quality standard of organic fertilizer, pH value of compost made of corn cob wastes and types of decomposers (K1D1, K1D2, K1D3, K1D4) met the quality standards for solid organic fertilizers following the decision of the Ministry of Agriculture, Republic of Indonesia[14]. It indicated that compost made of cob wastes can be applied in the field because essential nutrients are already present in that pH range.

The change in pH during the composting process indicates the activities of microorganisms in decomposing organic compounds in the raw material of the compost. At an early stage, organic acids were formed because microorganisms broke down the organic compounds in the raw materials of the compost. Such acidic conditions support the growth of *Actinomycetes* sp. and the breakdown of lignin and cellulose. These bacteria are active when the temperature of the compost pile increases and assist in decomposing organic matter. In the composting process of corn cobs and stems, the fungi start to grow at the fifth day. In the composting process, microorganisms break down the organic matter into organic acids. These organic acids support the growth of fungi and the breakdown of lignin and cellulose, so that the composting process will run well and efficiently.

The composting process typically involves a pH drop in the first week due to the production of organic acids (e.g., acetic, lactic, and butyric acids) by microorganisms breaking down easily degradable compounds. Following this, the pH increases significantly often rising to an alkaline range (8.0-9.0). The causes of this increase in pH are an increase in alkaline ammonia (NH_3)[28,29], the decomposition of organic matter and the degradation of acidic compounds, and the mineralization of organic compounds, such as proteins, amino acids, and peptides. Microorganisms actively decompose organic nitrogen into ammonia[30,31]. Factors influencing pH changes, in addition to microbial activity, include the C/N ratio, aeration, and temperature. The optimal pH for bacterial growth is 6.0-7.5, while fungi prefer a pH range of 5.5-8.0. This final decline in pH is driven by the depletion of easily degradable materials and the maturation of the compost, which reverses the early, high pH ammonia phase[32,33]. This pH change is an important indicator of biological activity and the level of compost maturity.

The final values of pH for corn cob compost range 7.50-7.53, while the corn stem compost ranges 9.83-9.97. During the composting process, pH of the compost is stable on pH neutral. The stable value of pH on pH neutral is good for the growth of the decomposing microorganisms. It was presumed that the change in average pH on each treatment from acid to neutral was due to the organic acid formation as a result of decomposition and mineralization of organic

matters. Too high pH will cause nitrogen in raw material of compost convert to ammonia, and conversely, too low pH or acid may cause microorganisms to die. Likewise, the results reported by Siagian *et al.*[34] based on the research results specifically relating to modified aerobic reactor composting of food and fruit waste over 30 days, indicated that the pH of the material changed throughout the process, ultimately reaching a stable, neutral, or near neutral range. The 30-day composting process demonstrated stable pH dynamics at the end of the phase (days 20-30) with a neutral range of 7.0-7.4. This stage indicates that the activity of decomposing microorganisms is working effectively, converting organic acids into stable organic matter. Fluctuations in pH are normal but must remain within the normal range (acidic to neutral) to indicate compost maturity. In the final phase (days 20-30), the pH approaches neutrality (7.0-7.4), indicating that the compost is mature and ready for use. The organic acids formed initially are degraded by microorganisms and increasing the material's stability. A stable, near neutral pH is a key indicator that the composting process has ended and the compost is ready for use.

Based on the quality standards for solid organic fertilizer stipulated in the Decree of the Minister of Agriculture of the Republic of Indonesia, the required pH value is between 4.0 and 9.0. Corn cob compost meets the quality standards for solid organic fertilizer as stipulated in the Decree of the Minister of Agriculture of the Republic of Indonesia because its pH is in the range of 4.0-9.0, indicating maturity and proper chemical characteristics. However, corn stem compost does not meet the quality standards. This is generally caused by an incomplete decomposition process or a C/N ratio that has not yet reached the standard, even though the corn stem material actually has the potential to be composted. This pH match is crucial because good organic fertilizer is odorless, black compost-like soil, blackish-brown in color, has a C/N ratio $\leq$ 25, and has a certain moisture content.

Water content, temperature, and pH are essential in the composting process because they influence activities of the microorganisms that decompose organic matter. Optimal water content, appropriate temperature, and suitable pH will create an environment that supports the efficient decomposition process. Appropriate water content will enable microorganisms to access and utilize the organic matters. Proper temperature will support the enzymatic activities of microorganisms in breaking down the organic matters. Suitable pH creates an environment that support growth and activities of the microorganisms.

Based on the research results (Table 4), the application of decomposer on corn cob and stem wastes had significant influence ($p<0.05$) on organic C (Table 4). The treatment of K1D4 (corn cob and BeKa) resulted higher organic C, 45.94±0.35%, and it was not significantly different from the treatment of K1D2 (corn cob and Petrofast), 45.56±0.20%, but it was significantly different from the combination treatments of composts K1D1(corn cob and PGPR), 45.45±0.28%, K1D3 (corn cob and M-21), 45.40±0.05%, K2D1(corn stem and PGPR), 39.21±0.22%, K2D2 (corn stem and Petrofast), 39.20±0.43%, K2D3 (corn stem and M-21), 39.70±0.04%, and K2D4 (corn stem and BeKa), 39.57±0.15%. The treatment of K2D2 had the lower organic C (39.20±0.43%, on average). Results of the research showed that percentage of organic C in compost made of corn cob and stem wastes along with types of decomposers, have met the quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia, at least 15%.

The organic C analysis was carried out at final composting process. In early composting process, organic C contained in corn cob was 50.35%, while the corn stem was 43.98% (Table 4). As a whole, organic C contained in corn cob compost and corn stem compost tend to decrease until it reaches a mature condition which is a minimum of 15%. During the decomposition process, carbon is used as source of energy by the decomposer, while nitrogen is assimilated into the cells as protein and other compounds. The microbes oxidize the carbon source completely and convert it into CO_2 and other low molecular weight carbon compounds, so that carbon contained in the decomposed organic matter will decrease[35]. Microbes use organic carbon as source of energy to obtain energy in the composting process[36].

Results for analysis of variance showed that the application of decomposers on corn cob and stem wastes had significant influence ($p<0.05$) on C/N ratio of the compost (Table 4). The value of the C/N ratio on treatment of the decomposer application on corn cob wastes (K1D1, K1D2, K1D3, K1D4) were significantly different from the treatment of decomposer on stem wastes (K2D1, K2D2, K2D3, K2D4). On the treatment of compost made of corn cob wastes and types of decomposers, average values of C/N ratio ranged from 24.25±1.13 to 29.78±7.50, while the treatment of compost made of corn stem wastes and types of decomposers, average values of C/N ratio ranged from 34.05 ± 2.11 to39.55±2.53.

The C/N ratio of the K1D4 have met the quality standards for solid organic fertilizer according to the decision of the Ministry of Agriculture of the Republic of Indonesia, which requires a C/N ratio of $\leq$25. The other treatments did not met the standards because their C/N ratios are higher than 25. The C/N ratio is the ratio between the amount of carbon (C) and the amount of nitrogen (N). This is also an important aspect in

composting because it can determine the activity of microorganisms in decomposing organic matter. A high C/N ratio, or a higher carbon content than nitrogen, will result in decreased microbial activity and a longer composting time.

The C/N ratio of the compost is essential parameter to determine maturity and quality of the compost. C/N ratio is influenced by carbon (C) and nitrogen (N) contained in raw materials of the composting. In early composting process, C/N ratio of the corn cob was 50.35%, while the corn stem was 47.80%. After the composting process was completed, compost of the corn cob and BeKa decomposer reached C/N ratio as implied have met the quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia, that is $\leq$25%. Priyati *et al.*[37] reported that C/N ratio plays important role in compost decomposition process. C/N describes the microorganisms in compost that oxidize carbon as energy source and consume nitrogen for protein synthesis.

The change in C/N ratio during the composting process was due to the use of carbon as energy source for microorganisms to grow and then released as CO_2 while nitrogen was used by microorganisms for protein synthesis process and body components formation of microorganisms and worms[38]. The process caused carbon gradually decreases so that C/N ratio becomes low[39]. The decrease in C/N ratio was because, in the decomposition process, there was a change in CHON to CO_2 and H_2O, while nitrogen become NO_2 (nitrite) and NO_3 (nitrate)[40]. Appropriate C/N ratio is very essential to ensure that the decomposition process has run well and efficient. Too high ratio (more carbon) will inhibit the growth of microorganisms, while too low ratio (more nitrogen) will create unpleasant smell or the release of ammonia. Balanced C/N ratio ensure that microorganisms could decompose organic matters in the compost effectively, produce beneficial nutrients for crops and environment.

The research showed that different types of decomposers have significant influence on Total N content of the compost ($p<0.05$) (Table 4). The combination of corn cob and types of decomposers K1D1, K1D2, K1D3, K1D4 along with Total N content were 1.57±0.25, 1.60±0.42, 1.78±0.24, 1.89 0.08%, respectively, and significantly different from the treatment of decomposer on corn stem and types of decomposers K2D1, K2D2, K2D3, K2D4 along with Total N content were 1.05±0,08, 1.09±0,06, 1.01±0,07, 1.11±010%, respectively. High Total N content on the treatment of K1D4 (corn cob and BeKa) compared to other treatments, affects quality of organic matter and type of decomposers combination. The treatment of K2D3 (corn stem and M-21) showed the lower Total N content. The Total N content of the whole combination treatments of compost have met the quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia.

Analysis on total N was conducted at final composting process. In early composting process, Total N of corn cob and stem was 1.00 and 0.92%, respectively. As a whole, Total N of compost tends to rise until it reaches mature condition >0.4%, it conforms to the SNI 19-7030-2004. In accordance to Xie *et al.*[41] the increase in nitrogen may occur due to the volatile solids or degraded materials are greater than the volatile NH_3. The increase of nitrogen in the system may occur due to several factors. One of them is greater degraded organic matters compared to the amount of the released NH_3 as output of the process. It means that more nitrogen is bound in degraded organic matter than is released in the form of ammonia. Besides that, solid volatilization process evaporation of solids may also increase nitrogen level.

Results of the research showed that the application of decomposer on corn cob and stem wastes have significant influence ($p<0.05$) on Total P_2O_5 content of the final compost. The treatment of decomposer on corn cob wastes of K1D1, K1D2, K1D3, K1D4 along with Total P_2O_5 content are 0.69±0.01, 0.67±0.06, 0.68±0.10, 0.64±0.14%, respectively, and significantly different from the treatment of decomposer on corn stem wastes of K2D1, K2D2, K2D3, K2D4 along with Total P_2O_5 content are 0.49±0.06, 0.56±0.05%, 0.47±0.04, 0.53±0.02%, respectively. The highest Total P_2O_5 of the compost was found on K1D1 (0.69±0.01%), and the lowest one was found on K2D3 (0.47±0.04%). The Total P_2O_5 content of the whole combinations of compost have met the quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia.

Analysis on Total P_2O_5 was carried out at the final composting process. In early composting process, Total P_2O_5 in corn cob and stem was 0.42 and 0.61%, respectively. As a whole, Total P_2O_5 contained in compost tend to rise until it reaches mature condition > 0.1%, it conforms to the SNI 19-7030-2004. Based on the analysis results, it concludes that the entire treatment combinations of compost increase Total P_2O_5 after the composting process. Nurdiansyah *et al.*[42] reported that P increases with the occurrence of weathering of the composted organic matters. At the compost maturation stage, microorganisms will die and P contained in microorganisms will mix with the compost material which will directly increase phosphorus content in the compost.

Results for analysis of variance showed that the application of decomposer on corn cob and stem wastes have significant influence ($p<0.05$) on Total K_2O of the compost. Furthermore, results of testing showed that the treatment of

decomposer on corn cob wastes of K1D1, K1D2, K1D3, K1D4 along with Total K_2O values are 2.43±0.07, 2.36±0.06, 2.27±0.11, 2.29±0.14%, respectively, and significantly different from the treatment of decomposer on corn stem wastes of K2D1, K2D2, K2D3, K2D4 along with content K_2O are 3.69±0.09, 3.62±0.16, 3.73±0.12, 3.81±0.24%, respectively. The treatment of K2D4 showed the higher Total K_2O than other treatments, 3.81 ± 0.24%, and the lower from the treatment of K1D3 is 2.27±0.11%. Content of Total K_2O of the whole treatment of compost combinations have met the quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia.

Analysis on Total K_2O was conducted at the final composting process. In early composting process, Total K_2O in corn cob and stem was 1.40 and 4.13%, respectively. When compost in mature condition, Total K_2O in compost of the corn cob tends to rise, while in corn stem tends to decrease, but it conforms to the SNI 19-7030-2004 that is >0.2%. Divya *et al.*[43] reported that during the composting process, potassium tends to rise because it is used by microorganisms as catalyst, and the existence and bacterial activities will influence the increase in potassium.

CONCLUSION

Treatment on composting by the addition of decomposers could increase quality of the compost. Combination of treatment using corn cob and BeKa (K1D4) has average values of water content (11.31±0.17%), pH (7.50±010), C-organic (45.94±0.35%), Total N (1.89 ± 0.08%), Total P_2O_5 (0.64±0.14%), Total K_2O (2.29±0.14%) and C/N ratio (24.25±1.13%), the resulted compost has met the quality standards for solid organic fertilizers following decision of the Ministry of Agriculture Republic of Indonesia The combination of treatments other than K1D4 has not met the quality standards of solid organic fertilizer because the C/N ratio value is > 25. On average, physical properties of compost are brown to blackish brown, crumb, and earthy smell. Based on the research, diverse combinations of organic wastes from corn harvesting residues and types of decomposers affect chemical properties of the compost. Combinations of wastes from corn harvesting residues and types of decomposers used to produce compost in both small and large scales that can be applied on farming land.

SIGNIFICANCE STATEMENT

Corn harvest waste is generally underutilized by the community, and much of it is even discarded from the fields. Utilizing corn harvest waste not only reduces unused crop residue but also increases crop production. One such use is processing it into organic fertilizer, a zero waste and environmentally friendly approach, as it transforms agricultural waste while creating a sustainable agricultural cycle. The process involves the decomposition of organic matter by microorganisms into high quality fertilizer, which can improve soil structure and fertility. Identifying the quality of compost from corn harvest waste is crucial for calculating plant nutrient requirements. This research focuses on analyzing the quality of composting results using different types of decomposers.

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