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Test of Several Concentrations of Cellulolytic Bacteria and Size of Shredded Material on the Maturity Speed of Rice Straw Compost (*Oryza sativa L.*)

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Abstract.
This study aims to obtain the concentration of cellulolytic bacteria and the size of the chopped material on the speed of maturity of rice straw compost (Oryza sativa L.). The research was conducted at the Soil Science Laboratory, Faculty of Agriculture, Riau University from April to August 2022. This research was conducted experimentally using a non-factorial completely randomized design (CRD) with nine treatment combinations in this study. K1P1: without bacteria rice straw was not chopped, KIP2: without bacteria rice straw was coarsely chopped, KIP3: without bacteria rice straw was finely chopped. K2P1: concentration of cellulolytic bacteria 40% + rice straw was not chopped. K2P2: bacteria with a concentration of 40% + rice straw was coarsely chopped. K2P3: bacteria with 40% concentration + finely chopped straw. K3P1: bacteria with 50% concentration + unshredded rice straw, K3P2: bacteria with 50% concentration + coarsely chopped rice straw. K3P3: bacteria with 50% concentration + finely chopped rice straw. The parameters observed were C-organic, nitrogen, C/N ratio, phosphorus, potassium, pH, temperature, color, and odor. The results showed that the treatment of the level of chopped organic matter with the concentration of cellulolytic bacteria had no significant effect on the observed variables (C-organic, nitrogen, C/N ratio, phosphorus, potassium, pH, temperature, color, and odor). There is a trend in the treatment of fine rice straw shredding rate + 50% concentration of cellulolytic bacteria that produces good compost quality. The treatment has C-organic content: 34.52%, nitrogen: 1.82%, C/N ratio: 19.10, phosphorus: 0.41%, potassium: 4.65%.

Keywords: rice straw, maturity rice, completely randomized design

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1. Introduction

Compost is the result of partial/incomplete decomposition of a mixture of organic materials that can be artificially accelerated by a population of various microbes under warm, moist and aerobic or anaerobic environmental conditions [1]. Compost can increase

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soil fertility which will stimulate healthy rooting. Compost improves soil structure by increasing soil organic matter content and increasing the soil's ability to retain soil water content. Microbial activity that is beneficial to plants will increase with the addition of organic matter. These microbial activities help plants to absorb nutrients from the soil and produce compounds that can stimulate plant growth and disease attack. Plants fertilized with compost tend to have better quality than plants fed with inorganic fertilizers [2]..

One source of organic material that can be composted is rice straw. The content of NPK and S nutrients in rice straw are K (1,2-1,7%), N (0,5-0,8%), P (0,07-0,12%), and S (0,05-0,10%), respectively [3]. Gunarto et al. [4] added that the nutrient levels of P, K, Na, Ca, Mg, Mn, and Cu in composted straw are higher than in raw straw. Therefore, rice straw can be used as a source of plant macro nutrients [5]. The benefits of straw compost are not only seen in terms of nutrient content. Consistent use of straw compost in the long term will increase soil organic matter content and restore soil fertility. In addition, straw compost also has a high C-organic content. However, because the C-organic ratio of rice straw is high and the N content is low, it causes the C/N value of rice straw to be high [6].

Yuwono [7] stated that the C/N ratio of rice straw is 50-70. This causes the straw decomposition process to take a long time so that most farmers consider rice straw to have no economic value and even burn the straw. Therefore, efforts are needed to accelerate the decomposition of rice straw by using a decomposer in the form of cellulolytic bacteria. Cellulolytic bacteria are bacteria that can produce cellulase enzymes to degrade cellulose into derivative compounds such as glucose, maltose and so on [8].

The concentration of bacteria also affects the acceleration of organic matter composting and the nutrient content of the compost. Kurniawan et al. [9] in their research stated that the best bacterial concentration treatment was at a concentration of 50% in composting a combination of jackfruit peel and straw, with a C-organic content of 25,11%, nitrogen 2,55%, C/N content 10,15%, phosphor 0,61% and potassium 0,83% which met SNI standards.

Based on the results of research Hapsoh et al. [10], six potential cellulolytic bacterial isolates were selected from oil palm empty fruit bunches, acacia litter, and rice straw. The six isolates are Proteus mirabilis species from oil palm empty bunches, Bacillus cereus from rice straw, Providencia vermicola and Bacillus cereus from acacia litter that have been consorted.

In addition to cellulolytic bacteria, the particle size of the material also affects the speed of compost maturity. The smaller the particle size of the material, the faster the composting time. Bacterial activity is between the surface area and air. A larger surface area will increase contact between microbes and materials and the decomposition process will run faster. Particle size also determines the amount of space between materials (porosity). To increase the surface area can be done by reducing the particle size of the material [2].

2. Materials and Methods

This research was conducted in the experimental garden of Faculty of Agriculture, Riau University and Soil Laboratory of Faculty of Agriculture, Riau University, Bina Widya Campus KM 12.5 Simpang Baru Village, Pekanbaru, Riau. Some of the materials used in this study consisted of rice straw (Oryza sativa L.) obtained from Kampar Regency, bacterial isolates from oil palm empty fruit bunches genus Serratia and Bacillus, rice straw genus Pseudomonas and acacia litter genus Pseudomonas and Cellvibrio, mixed catalysts (potassium sulfate, copper sulfate and selenium metal), salicylic acid, concentrated sulfuric acid, 85% concentrated phosphoric acid, 40% NaOH solution, 0.1 N mixed indicator, boric acid solution, 0.025 N 4% NaF solution HCl, reagent B, 1N NH_4C, distilled water, 1 N potassium bichromate, iron ammonium sulfate, standard diphenylamine indicator, waste plots/bins and 90 x 100 cm plastic bags. This study used a completely randomized design (CRD) with 9 treatments and 3 replicates. The treatment design was: K1P1 = without bacteria and rice straw was not chopped; K1P2 = without bacteria and rice straw was coarsely chopped; K1P3 = without bacteria and rice straw was finely chopped; K2P1 = concentration of cellulolytic bacteria 40% v/b (raw material 2500 g) + rice straw was not chopped; K2P2 = bacteria with a concentration of 40% v/b (raw material 2500 g) + rice straw was coarsely chopped; K2P3 = bacteria with a concentration of 40% v/b (raw material 2500 g) + finely chopped rice straw; K3P1 = bacteria with a concentration of 50% v/b (raw material 2500 g) + rice straw not chopped; K3P2 = bacteria with a concentration of 50% v/b (raw material 2500 g) + coarsely chopped rice straw; K3P3 = bacteria with a concentration of 50% v/b (raw material 2500 g) + finely chopped rice straw. The data obtained were statistically analyzed using ANOVA and continued with DNMRT (Duncan's Multiple Range Test) test at the 5% level.

2.1. Preparation of compost raw materials

Making compost begins with the provision of compost raw materials, namely rice straw. Rice straw is dried under the sun until the moisture content is less than 10%. After the rice straw dries, it is then chopped according to the treatment factors, namely fine chopping, coarse chopping and without chopping. Furthermore, the straw was weighed according to the treatment.

2.2. Preparation of cellulolytic bacterial decomposer starter

The six isolates of cellulolytic bacteria were grown in 100 ml of 1% soybean litter media and incubated for 3 days at 28°C [11]. A total of 20 ml of the bacterial suspension was transferred into a glass beaker and then added 20 g of sugar and rice washing water until the volume of the solution was 1 L. Then the decomposer starter was allowed to stand for 3 hours [9]. Furthermore, the starter can be used for composting.

2.3. Making compost

Rice straw that had been chopped in accordance with the treatment factor (fine chopping, coarse chopping and no chopping) was weighed as much as 2.5 kg for each compost plot/bak and treatment factor. The two treatment factors were combined and replicated 3 times, resulting in 27 compost plots.

During the composting process, supervision was carried out so that the moisture content always ranged from 40-60%. After composting, C/N ratio, color and pH were measured every 14 days, while temperature was observed every day. At the end of the study, N, P, K, C-organic, C/N, pH and color observations were made.

2.4. Observations

The observed parameters consisted of observations of chemical analysis of raw materials, observations with descriptive analysis and observations with analysis of variance. Observations with descriptive analysis consisted of color observations, temperature observations, acidity (pH) observations and odor observations. Observations with variance analysis consisted of C/N ratio analysis, N-total content, phosphorus (P) analysis, potassium (K) analysis, and C-organic observations.

3. Results and Discussion

3.1. Results

Based on the results of chemical analysis conducted, the average value of C-organic ranges from 33.96-40.46% and has met the compost quality standards where the C-organic content in compost is greater than 15% according to PERMENTAN (Regulation of the Minister of Agriculture) No. 70 of 2011. The results of the analysis of variance of rice straw compost showed that the treatment given had no significant effect on the C-organic content. Data from chemical analysis can be seen in Table 1.

Changes in the aroma of composting are obtained, which increasingly smells like soil as the composting time increases. The smell of observation data can be seen in Table 3.

3.2. Discussion

Based on the results of the study, it can be stated that in general the treatment of the level of chopped organic matter with the concentration of cellulolytic bacteria is not significantly different from the observation parameters (Table 1). The results of this study are different from the results of [9] where the study had a significant effect on the content of C-organic, nitrogen, C/N ratio, phosphor and potassium. The treatment of the level of chopped organic matter with the concentration of cellulolytic bacteria produces C-organic content that is not significantly different. Based on the results of the chemical analysis that has been carried out, the average value of total N analysis ranges from 1,41-1,82% and meets the compost quality standards. Badan Standarisasi Nasional [12] states that the minimum level of total N content in mature compost is 0,40%. The results of the analysis of variance of rice straw compost showed that the treatment given had no significant effect on Nitrogen content. Based on the data in Table 1, it can be stated that in general the treatment of the level of chopped organic matter with the concentration of cellulolytic bacteria produces nitrogen content that is not significantly different.

Table 1: Chemical content of rice straw compost with a combination of several levels of rice straw shredding with several concentrations of cellulolytic bacteria.

Treatment	Average C-organic (%)	Average N (%)	Average C/N Ratio	Average P (%)	Average K (%)
(K1P1) Unshredded material + no cellulolytic bacteria	35,70 ab	1,75 a	21,05 ab	0,49 a	4,48 a
(K1P2) Unshredded material + 40% concentration of cellulolytic bacteria	40,46 a	1,59 a	25,70 ab	0,50 a	5,17 a
(K1P3) Unshredded material + 50% concentration of cellulolytic bacteria	33,96 b	1,41 a	24,41 ab	0,51 a	4,14 a
(K2P1) Coarse shredded material + no cellulolytic bacteria	37,28 ab	1,70 a	21,84 ab	0,55 a	5,75 a
(K2P2) Coarse shredded material + 40% concentration of cellulolytic bacteria	36,10 ab	1,75 a	20,57 ab	0,54 a	5,11 a
(K2P3) Coarse shredded material + 50% concentration of cellulolytic bacteria	37,40 ab	1,72 a	21,66 ab	0,41 a	4,35 a
(K3P1) Fine shredded material + no cellulolytic bacteria	39,27 ab	1,74 a	22,77 ab	0,42 a	4,07 a
(K3P2) Fine shredded material + 40% concentration of cellulitic bacteria	37,77 ab	1,44 a	26,71 a	0,45 a	4,17 a
(K3P3) Fine shredded material + 50% concentration of cellulolytic bacteria	34,52 b	1,82 a	19,10 b	0,41 a	4,65 a

Notes: Numbers accompanied by different letters mean significantly different

The average value of C/N ratio ranged from 19.10-25.19. The results of the analysis of variance of rice straw compost showed that the treatment given had no significant effect on the C/N ratio. The treatment of the level of chopped organic matter with the concentration of cellulolytic bacteria produces a C/N ratio that is not significantly different. The average value of total P analysis ranges from 0,42-0,55% and meets the compost quality standards according to SNI, where the minimum level is 0,10% [12]. Total P data was collected at the end of composting. The results of the analysis of variance of rice straw compost showed that the treatment given had no significant effect on the phosphor content. The treatment of the level of chopped organic matter with the

Table 2: Observation of compost color during the composting process with a combination of several levels of organic matter (K) with several concentrations of cellulolytic bacteria (P).

Treatment Code	**Week 2**	**Week 4**	**Week 6**
Raw materials		**Yellowish**	
K1P1	yellowish brown	dark yellowish brown	dark yellowish brown
K1P2	Yellowish brown	dark yellowish brown	very dark brown
K1P3	dark yellowish brown	dark yellowish brown	very dark brown
K2P1	dark yellowish brown	dark yellowish brown	very dark brown
K2P2	dark yellowish brown	dark yellowish brown	dark brown
K2P3	dark yellowish brown	dark yellowish brown	dark yellowish brown
K3P1	dark yellowish brown	dark yellowih brown	dark yellowish brown
K3P2	dark yellowish brown	dark yellowish brown	dark yellowish brown
K3P3	Brown	dark yellowish brown	very dark brown

Table 3: Observation the smell of compost aroma during the composting process with a combination of several levels of organic matter (K) with several concentrations of cellulolytic bacteria (P).

Treatment Code	**Week 2**	**Week 4**	**Week 6**
K1P1	+	++	+++
K1P2	+	++	+++
K1P3	+	++	+++
K2P1	+	++	+++
K2P2	+	++	+++
K2P3	+	++	+++
K3P1	+	++	+++
K3P2	+	++	+++
K3P3	+	++	+++

Note: + = like the original smell
++ = pungent odor
+++ = soil-like odor

concentration of cellulolytic bacteria resulted in the content of phosphorus that was not significantly different.

The average value of total K analysis ranges from 4,05-5,75% and meets the quality standards of compost according to SNI, where the minimum content is 0,20% [12]. The results of analysis of variance of rice straw compost showed that the treatment given had no significant effect on potassium content. The treatment of the level of chopped organic matter with the concentration of cellulolytic bacteria produced C/N ratios that were not significantly different. The average pH data ranges from 5,76 to 7,19 and has met the criteria for mature compost. Kementerian Pertanian [13] states that the standard criteria for mature compost have a pH between 4-9. The average temperature ranges from 30,66-32.66°C. Based on the results of color observations that have been made, it is obtained that the color of composting is getting darker as the composting time increases. However, in the K1P2, K1P3, K2P1, and K3P3 treatments the color changes were better because they had a very dark color. Compost is said to be mature if during the composting process it shows a change in color which becomes darker and has an earthy smell [14].

The difference in research results obtained is thought to be because in the research of Kurniawan et al. [9] used urea fertilizer and rabbit manure as additional treatments. The provision of urea can increase bacterial activity so as to produce a significant difference in the observation parameters produced. Haidla et al. [15] stated that additional nitrogen from urea fertilizer can stimulate microorganisms in decomposing organic matter. The use of urea as a nitrogen source aims to suppress mold growth and increase nitrogen levels to supply the needs of microbes [16]. The results shown in Table 1 are not significantly different, it can be restated that there is a trend in the treatment of finely chopped organic matter + 50% bacterial concentration (K3P3) which produces good compost quality. The treatment showed a decrease in C-organic which was lower than the other treatments. Kurniawan et al. [9] stated that cellulolytic bacteria work to break down cellulose contained in compost constituent materials into glucose monomers. The high concentration of cellulolytic bacteria at 50% causes C-organic to decrease because glucose monomers have been used by bacteria in their activities to bind free nitrogen. Organic compounds will decrease while inorganic compounds will be formed more and more, besides that there will be a release of carbon dioxide during the composting process due to the activity of microorganisms so that it can reduce C-organic [17].

One factor that affects the decomposition process is the particle size of organic matter. The smaller the particle size, the greater the contact of microbes with the material, which will increase the decomposition process [2]. Particle size will also affect the porosity of the material. Smaller particle size will increase the porosity of the material, more pore space and more oxygen will be available so that bacterial activity takes place well which will increase the decomposition process. The high concentration of bacteria supports the decomposition process of organic matter [2]. During the decomposition process, bacteria require large amounts of nitrogen to synthesize protein compounds and nitrogen will be released again after the decomposition process is complete [18] which resulted in the K3P3 treatment producing a higher nitrogen content than the other treatments (Table 1).

K3P3 treatment with a high concentration of bacteria resulted in a higher degradation process of C for energy sources and N for protein synthesis, resulting in a rapid decrease in the C/N ratio. The data in Table 1 shows that the K3P3 treatment produces a lower C/N ratio than the other treatments and has met the criteria for mature compost, which is <20 [2]. When viewed from the time of decreasing the C/N ratio of rice straw compost in this study requires a long time, because the C/N ratio is one of the criteria for mature compost. Organic materials that have a high C/N ratio will cause the decomposition process to take a long time. Yuwono [7] stated that the C/N value of rice straw is 50-70, which causes the straw decomposition process to take a long time. The composting process requires a substrate balance between carbon and nitrogen.

During composting some of the carbon will turn into CO_2, therefore in the cell the carbon content must be much greater than nitrogen. Increased temperature causes biochemical reactions to take place actively. Materials that contain too little nitrogen will not be able to generate heat to decompose the material quickly [19]. The results of chemical analysis of rice straw organic matter before composting only amounted to 1.04%. The decrease in C/N value can be done with special treatment by adding materials that contain many nitrogen compounds [20]. It is suspected that the length of composting time in this study is due to not using materials that contain many nitrogen compounds so that the decrease in the C/N ratio is slow.

Compost that has a low C/N ratio will contain a lot of ammonia (NH_3) produced by ammonia bacteria. This ammonia compound can be further oxidized into nitrate and nitrite which are easily absorbed by plants [21]. During the composting process there was an increase in Nitrogen, Phospor and Potassium nutrients from rice straw organic matter before composting. This is in accordance with the statement of Gunarto et al. [4] which states that the nutrient content of composted rice straw is higher than raw rice straw. The increase in nitrogen levels in the composting process can occur because the volatilized solids or degraded organic matter are greater than the volatilized NH_3 [22]. Nitrogen is needed by microorganisms for the formation of body cells. The more nitrogen content, the faster organic matter decomposes [23]. The activity of microorganisms in decomposing organic matter requires large amounts of nitrogen (N) to synthesize protein compounds and nitrogen will be released again after the decomposition process is complete [18].

The K3P3 treatment has a low phospor content. The low phospor content is caused by several factors including the evaporation of nutrients in the compost or dissolved in water during the composting process and the microclimate that occurs during composting can affect changes in nutrients [24]. According to Buckman et al. [25] the main source of phospor in organic matter is derived from proteins, lignin, and polysacharides. During the composting process, microorganisms use some of the phosphorus for their growth so this causes the low content of phosphorus in the compost.

The phospor content is also caused by the activity of phospor-dissolving (proteolytic) bacteria. During the composting process, these bacteria are able to break down proteins in compost raw materials into amino acids. According to Setyati et al. [26], proteolytic bacteria have the ability to produce protease enzymes that are secreted into the environment. Extracellular proteolytic enzymes work to hydrolyze protein compounds into oligopeptides, short chain peptides and amino acids. This causes phosphate bound in long chains to dissolve in organic acids produced by P-solubilizing bacteria. It is known that in the bacterial consortium used in this study there are phospor-solubilizing bacteria, namely Providencia vermicola bacteria [27].

K3P3 treatment showed a high content of Potassium nutrient which amounted to 4.65%. The composting process resulted in the formation of Potassium due to the activity of K solubilizing bacteria [28]. It is also stated that K is a compound produced by microbial metabolism, where in its activity the bacteria use free K+ ions present in the compost organic matter [29]. During the composting process, bacterial activity when agitating organic matter requires one hydrogen atom which will lower the pH as a result of the formation of organic acids [30]. In this case, it indicates that the decomposition process has not yet entered the maturation stage because there is still decomposition by bacterial activity.

When viewed in the K3P3 treatment, it can be seen that there is an increase in pH value, in week 2 it has a low pH value of 5.80, and an increase in weeks 4 and 6, namely 6.06 and 6.16. The small particle size will increase bacterial contact with larger organic matter coupled with a high number of bacterial concentrations (50%) thus increasing bacterial activity. In week 2 with a low pH value due to microbial activity still occurs significantly, with a high number of bacterial concentrations will certainly require large amounts of oxygen and increased production of organic acids or nitrification processes that will reduce pH. Whereas in the observation of weeks 4 and 6 the pH value increased, due to the decomposition of proteins there was mineralization of organic nitrogen into ammonia nitrogen which caused the pH value to increase and changes in pH value were also influenced by the exchange of ammonium ions [2]. The increase in pH is also due to the demineralization of microelements Mg^{2+}, K^{+}, and Ca^{+} - these cations will bind with acids formed in the composting process [31].

Mature compost has a pH value that is close to neutral [2]. When viewed from the average pH in the data above is the optimum pH in composting which ranges from 5.5 - 8.0 because pH is an important indicator of the composting process [32]. There are variations in temperature by each treatment. At low temperatures, it means that bacterial activity is not optimal so that oxygen consumption is also low because in this case there is a relationship between temperature and oxygen consumption. High temperature will increase oxygen consumption, and low temperature will decrease oxygen consumption [33]. Meanwhile, a high temperature means that the bacteria have worked optimally so that it affects the temperature caused by the consumption of large amounts of oxygen by the bacteria.

There is an increase in temperature compared to week 2. In this case, there is an increase in temperature because the microorganisms are working actively. The increase in temperature is due to the accumulation of heat released by microbes that are degrading organic matter. The average temperature that occurred in week 4 observations was 31.70°C and in week 6 the temperature decreased due to microbes not working actively in degrading organic matter. At this stage, the organic matter that has been decomposed is followed by a decrease in organic C content, resulting in the energy needed by the bacteria for activity is also reduced so that the bacteria do not work optimally. With reduced bacterial activity, the temperature of the compost also decreases, and the compost has entered maturation [34].

Based on the results of the data above, the temperature did not reach the maximum limit because it was caused by several factors such as piles of composted materials, but bacterial activity continued [2]. In addition, the material used has a high C/N ratio, this situation shows that the increase in temperature is also influenced by the type of material used [35]. Color is a physical property that marks decomposition by microoragnism in the composting process. Compost that has been established has a blackish brown color resembling the color of the soil. If the color of the compost is still like the original color (organic material before composting) then the compost is not mature [36]. In this study, color measurement was carried out with the munsell book as a standard reference in color observation.

Based on the color data of the compost observation above, it can be seen that there is a change in the color of the compost in the interval of two weeks. It can be seen that in the 6th week of composting the color of the compost is blackish brown which shows that the compost is ripe. However, in the K1P2, K1P3, K2P1, and K3P3 treatments, the color change is better because it has a very dark color. Compost is said to be mature if during the composting process it shows a darker color change and smells of soil [14]. Color changes occur due to bacterial activity in degrading organic matter. In its activity, the bacteria will need oxygen to produce organic acids that increase or the nitrification process that will lower the pH. Thus, the microclimate becomes acidic. In acidic conditions, the green chlorophyll pigment in raw organic materials will be unstable and turn blackish brown [2].

The odor or aroma produced in the composting process is a sign that there is material decomposition activity by microbes. Microbes break down the organic material into ammonia, so that the gas produced can affect the odor in the material. The odor can also come from materials that are too wet [37] so it needs to be reversed. The pungent smell at the peak point of composting occurs because during the process of breaking down the compost material (rice straw) releases gas in the form of NH3 while the smell like soil is because the composting process has entered the final phase of breaking down the compost material (rice straw). This reaction includes oxidation reactions whose results are in the form of ammonia gas, water and heat energy, causing the smell in the treatment to become pungent. The odor that appears is also caused by the presence of H_2S compounds. Furthermore, at the end of composting the pungent odor disappears so that the smell of compost resembles soil because sulfur is consumed by bacteria and in bacteria is oxidized into sulfuric acid [14].

4. Conclusion

In general, the treatment of rice straw shredding rate + cellulolytic bacteria concentration had no significant effect on the observed parameters (C-organic, Nitrogen, C/N Ratio, Phosphorus and Potassium). The observation parameters produced during the composting process have met the standard criteria for mature compost. There was an increase in the nutrient content of Nitrogen, Phosphorus and Potassium from rice straw before composting to after composting. There is a tendency in the treatment of fine rice straw chopping level + 50% cellulolytic bacteria concentration that produces good compost quality. The treatment has C-organic content: 34.52%, Nitrogen: 1.82%, C/N Ratio: 19.10, Phosphorus: 0.41%, Potassium: 4,65%.

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