Banana midrib as substitute for pulp production

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Abstract. Short cooking time produces a small amount of cellulose in the pulp production, while a long cooking time causes the cellulose content in the pulp to become damaged. Cooking temperature that is too low produces a small amount of cellulose in the pulp, while the cooking temperature that is too high will damage the cellulose content in the pulp. The faster the stirring the more lignin apart from cellulose, the lower the cellulose content due to weakening of the saccharide bond in cellulose, the lower the yield produced because the product dissolves more and more. In this study, the parameters chosen were cooking time diversity (40, 50, 60, 70, and 80 minutes), cooking temperature (80, 90, 100, 110 and 120 °C), and stirring speed (20, 40, 60, 80 and 100 rpm). Analysis of water, ash, cellulose, lignin content and tensile strength was carried out as pulp quality testing in this study. It turns out that from the results of the study, the optimum value was obtained at 90 °C cooking temperature with pulp yield of 64.09%, water content of 16%, ash content of 2.5%, cellulose content of 73%, lignin content of 8.5%, and tensile strength 1.96 kN/m².

1. Introduction
Pulp is a material in the form of fiber which is obtained through the process of lignin removal from biomass. In addition, pulp is the main product for processing hard and soft wood used for paper making. Pulping is intended to remove lignin from wood (delignification) to obtain pulp that is lignin-free [1].

According to pulp statistics in Indonesia, in 2016 it is estimated that pulp consumption needs reach 4.033 million tons. As a result of that, the need for acacia and pine trees which become raw materials in pulp making will be even greater. Alternative ingredients are needed to reduce dependence on acacia and pine trees by looking for substitute materials such as banana midribs. From the Agricultural Data and Information System Center in 2008 the production of banana fruit in Indonesia reached 6,004,615 tons with a banana plant area of about 107,791 ha [2]. Increased production of bananas in Indonesia causes an increase in banana midribs because of their low lignin content (5%), cellulose (63-64%) and high hemi cellulose (20%), while the fiber is relatively long at around 4.29 mm, so it can be used as ingredients standard for pulp making [3 and 4]. Based on the advantages of banana midrib as explained, the banana midrib is very potential to be used as raw material for pulp making.

This study aims to study the effect of cooking time and temperature diversity, speed of stirrer on the quality of pulp produced from banana midrib. With the potential of the banana midrib, it is hoped that substitute raw materials can be obtained that can produce pulp of the same quality and even better.

2. Method
Banana midrib pulp making in this study was carried out using a reactor as can be seen in figure 1.
Before being processed into pulp, the banana midrib is cut into small pieces, dried and then mashed with the help of a machine. Pulping is done by cooking the smooth banana midrib along with 0.1 N NaOH solution in the reactor with a variation of pulp cooking time of 40, 50, 60, 70, and 80 minutes; cooking temperatures 0, 90, 100, 110, and 120°C; and stirring speeds of 20, 40, 60, 80 and 100 rpm. Tests on pulp produced include water content with the method SNI 0441-2009, ash content with the method SNI 0442-2009, cellulose content with the method SNI 0444-2009, lignin content with SNI 0445-2009 method and tensile strength with SNI 14- 4737-1998.

3. Result and discussion

3.1. Effect of cooking time on pulp quality

The following is figure 2 which shows the effect of cooking time on pulp quality.

Based on figure 2 it can be seen that at the cooking time of 40, 50, and 60 minutes, the pulp yield produced from the pulp reactor increased by 68.50; 70.15; and 73.75%. Increased pulp yield can occur because during pulp cooking the polysaccharide degradation process takes place, where the longer the cooking time, the more polysaccharides degraded into saccharides produce increased pulp yield. But at cooking time of 60 minutes to 70 minutes and 80 minutes, pulp yield produced from pulp reactor decreased from 73.75% to 72.53% and 71.35%. The decrease in pulp yield can occur because pulping of the pulp for too long will damage the cellulose so that lignin and cellulose are dissolved and wasted.
with the solvent into cooking waste which results in reduced pulp yield [4]. The cooking time affects the decrease in pulp yield produced, where the longer the cooking time, the lower the yield [5]. The decrease in water content is due to the decreasing water content in the pulp which results from the longer pulp cooking time and high cooking temperature of 90°C. This cooking temperature approaches the boiling point of water, so that water will evaporate more easily into the air due to phase changes and water vapor pressure that exceeds atmospheric pressure. The longer the cooking time, the lower the water content contained in the pulp. The water content is required to be small, because if the pulp has high moisture content the paper has decreased resistance and easy to tear [6]. There was also an increase in ash content. This is because the longer the cooking time, the breakdown of the polysaccharide also increases, the increase of the saccharide in the pulp causes the increase in ash content in the pulp. The longer the cooking time, the higher the ash content contained in the pulp [6].

The increase in cellulose content also occurs due to the increasing number of degradation processes that occur in polysaccharides of raw materials to produce cellulose due to the longer cooking time, so that the cellulose content in the pulp will increase. But at cooking time of 60 minutes to 70 minutes and 80 minutes, the cellulose pulp content produced from the pulp reactor decreased from 69.74% to 69.43% and 68.67%. The cooking time does not significantly affect the cellulose content produced [7]. This occurs because during the pulp cooking reaction, only a few polysaccharides are degraded. The small amount of polysaccharide degraded is caused by the strong bond of polysaccharide in pulp material.

There was an increased levels of lignin that occur due to the increased process of separating lignin from cellulose due to the longer cooking time [8]. Increased levels of lignin can also result from more and more monomers newly formed due to lignin breakdown. The monomers react with the polymer which is still contained in the pulp which results in the formation of new lignin, so that the lignin content will increase. Lignin content affects the quality of pulp where high lignin produces dark-colored pulp, so that the use of bleaching agents increases, the lowest lignin content is at the lowest cooking time and the highest lignin content is found in the highest cooking time in the cooking time used [5]. So it can be said that the longer the cooking time, the higher the lignin content produced. The pulp will have good physical properties if it contains less lignin [8]. This is because lignin is water-repellent and rigid, making it difficult in the grinding process. However, if the level of lignin is too small it will affect the pulp to be printed into paper reducing its adhesive strength. The best lignin content from this study was achieved at 40 minutes cooking time with 15.83% lignin content. The tensile strength of pulp is increasing. The tensile strength of pulp is related to the content of cellulose in the pulp, this proves that if the cellulose content has increased, the tensile strength of the pulp also increases and if the cellulose content decreases, the tensile strength of the pulp also decreases. Cellulose molecules are all linear and have a strong tendency to form hydrogen bonds, both in one cellulose polymer chain and between adjacent polymer chains [7]. This hydrogen bond causes cellulose to be in a large molecular size, and has high tensile strength properties. At cooking time 70 minutes and 80 minutes produce pulp which has a tensile strength of 0.48 kN/m² and 0.37 kN/m² which shows the tensile strength of the pulp decreases. This is because at the time of cooking, the cellulose content in the pulp also decreases. The decrease in pulp tensile strength can be caused by a decrease in molecular weight and an increase in the level of lignin in the pulp due to too long cooking time, resulting in damage to the cellulose chains in the fiber so that the strength of the fiber also decreases [9]. There are several factors that influence the increase and decrease in the tensile strength of the pulp, namely the dimensions of the fiber which include the length of the fiber, the diameter of the cell wall, and the bond between fibers to the cooking time [10]. Thin cell walls and wide fiber diameters result in easily flattened fibers during pulp making so that the surface area of contact between fibers with solvents will easily decompose polysaccharides as a result the pulp tensile strength will be high, while wide cell walls and thin fiber diameters make it difficult to decompose polysaccharides, so that the tensile strength of the pulp will be low. The optimum tensile strength of pulp is achieved at 60 minutes of cooking time with a tensile strength of 0.93 kN / m². The tensile
strength of the pulp can be increased by adding adhesive material, so that the tensile strength of the pulp at 60 minutes of cooking time can be increased [10].

3.2. Effect of cooking temperature on pulp quality

The following is figure 3 which shows the effect of cooking temperature on pulp quality.

![Figure 3: Effect of cooking temperature on pulp quality](image)

Based on figure 3 it can be seen that at cooking temperatures of 80, 90, 100, 110 and 120 °C resulted in a decrease in pulp yield of 76.60; 64.09; 60.64; 58.30 and 54.49%. This occurs because the higher the cooking temperature is used, the more macromolecular compounds (cellulose, hemicellulose, and lignin) are dissolved in the cooking solution. In this condition also causes the viscosity to decrease due to the breaking of the cellulose chain which results in low yield and strength of the pulp [9]. The highest yield was obtained at a cooking temperature of 80ºC which was 76.60%, while the lowest yield was obtained at a cooking temperature of 120ºC which was 54.49%.

The higher the cooking temperature, the water content tends to decrease. The highest moisture content was obtained at 80 ºC cooking temperature which was 18%, while the lowest water content was obtained at a cooking temperature of 120 ºC which was 11%. High moisture content is not good for pulp. This can affect the viscosity of the pulp, causing the quality of the pulp to decrease [6]. If the pulp is made into paper, it will produce paper that has low durability and is easily torn. It can be seen that when the cooking temperature is 80ºC and 90ºC ash content decreases. This is because the higher the cooking temperature causes the degradation of non cellulose content so that the resulting ash content becomes smaller. However, when the cooking temperature is 100, 110, and 120 ºC, the ash content increases quite high. This is because at high cooking temperatures the breakdown of polysaccharides also increases, increasing saccharides in the pulp causes more ash levels to increase in the pulp. The highest ash content was achieved at a cooking temperature of 120ºC which was 8%, and the lowest ash content was obtained at a cooking temperature of 90ºC which was 2.5%. The increase in cooking temperature in the pulping process will affect the cellulose produced. High cooking temperatures will increase the cellulose produced. The increase is due to the higher cooking temperature making lignin as a cellulose binder separate so that the cellulose concentration gets bigger. However, when the cooking temperature of 120ºC cellulose levels decreases far enough, this is due to the cooking temperature that is too high will cause cellulose to degrade and cause a decrease in cellulose content in the pulp. Cellulose degradation is strongly influenced by pH and temperature. The most important reaction that results in the release of polysaccharides and a reduction in the length of the cellulose chain in pulping is the release and hydrolysis reaction. The highest cellulose content was achieved at a cooking temperature of 110 ºC at 77.7%; while the lowest cellulose content was obtained at a cooking temperature of 120ºC at 68.7%.

The lignin content of the pulp tends to increase along with the increase in temperature, but when the cooking temperature is 90ºC the lignin content has decreased. The lowest lignin level when
cooking temperature is 90 °C which is 8.5%, and the highest lignin level when cooking temperature is 120 °C which is 18%. At cooking temperatures of 80°C and 90°C the lignin content decreases, this is because at that temperature lignin is separated from cellulose. But at cooking temperatures of 100, 110, and 120 °C the lignin levels continue to increase. This is because lignin which was already separated from the raw pulp with the help of NaOH will again dissolve and blend with the pulp due to a high cooking temperature. In addition, high cooking temperatures also cause more new monomers to form due to lignin breakdown. The monomers react with the polymer which is still contained in the pulp, resulting in a new polymer or new lignin [6]. This increase in lignin levels indicates that the pulp produced has a low quality. Pulp with high lignin content has a dark color. However, if the level of lignin is too small it will affect the pulp to be printed into paper reducing its adhesive strength. The pulp will have good physical or strength properties if it contains little lignin. This is because lignin is water-repellent and stiff. The best 8.5% lignin level was achieved at 90 °C cooking temperature.

The effect of cooking temperature on the tensile strength of the pulp produced tends to decrease with increasing cooking temperature. When the cooking temperature is 80°C and 90°C the tensile strength of the pulp increases quite high, this is because the lignin content in the pulp decreases, while the tensile strength of the pulp continues to decrease when the cooking temperature is 100, 110, and 120 °C because at that time the lignin content in pulp continues to increase. The highest tensile strength of pulp at a cooking temperature of 90°C is 1.9614 kN/m², the lowest tensile strength of pulp at a cooking temperature of 120 °C is 0.081725 kN/m². The tensile strength of pulp is influenced by the content of cellulose and lignin. The higher the cellulose content, the higher the tensile strength of the pulp, while lignin which is bound in the pulp product can cause a decrease in pulp strength [8].

3.3. Effect of stirring speed on pulp quality
The following is the effect of stirring speed on pulp quality as shown in figure 4.

Based on figure 4 it can be seen that the highest yield percentage of 65.65% was obtained at a stirring speed of 20 rpm, while the lowest yield percentage of 54.40% was obtained at a stirring speed of 100 rpm. The speed of the stirrer affects pulp yield, because the faster the stirring, the lower the pulp yield is produced. This is because the faster the stirring causes the more breakdown of the molecules and fibers contained in the product, so that more dissolved products [5].

The resulting moisture content in the pulp tends to decrease at high stirring speeds. The highest water content of 19.5% was obtained at a stirring speed of 60 rpm, while the lowest water content of 10.5% was obtained at a stirring speed of 100 rpm. This is because the faster the stirring, the more water content is evaporated. The speed of the stirrer is directly proportional to the collisions between particles and the surface area of the material. However, when the stirring speed is 60 rpm, the water content has increased because the pulp has high cellulose content so that the water evaporates slightly because it is retained in the pulp fibers. Based on figure 4 it can be seen that the faster the stirring, the
ash content in the pulp tends to rise. This is because the stirring speed causes the breakdown of polysaccharides into saccharides, so that the ash content increases. The highest ash content of 9.5% was achieved at a stirring speed of 60 rpm, while the lowest ash content of 2.5% was achieved at a stirring speed of 20 rpm. Cellulose levels tend to decrease at high stirring speeds. The highest cellulose content of 71.30% was achieved at a stirring speed of 60 rpm, while the lowest cellulose content of 63% was achieved at a stirring speed of 100 rpm. This decrease in cellulose content occurs due to cellulose damage caused by weakening of the saccharide bond in the pulp due to the faster the stirring, so that the cellulose dissolves. The lowest lignin content of 9.5% was achieved at a stirring speed of 100 rpm, while the highest lignin content of 18.5% was achieved at a stirring speed of 20 rpm. The decrease in lignin levels occurs due to the increased process of separating lignin from cellulose due to faster stirring. However, if the lignin content in the pulp is too low, then the resulting paper decreases its adhesive strength. The lowest tensile strength of 0.33 kN/m² is achieved at a stirring speed of 100 rpm, while the highest tensile strength of 1.31 kN/m² is achieved at a stirring speed of 60 rpm. Tensile strength is strongly influenced by cellulose content. The more cellulose, the stronger the fiber bond in the pulp.

4. Conclusion
Based on the research that has been carried out, it can be concluded that the banana midrib can be used as raw material for pulping. The optimum value of pulp making from banana midrib was obtained at a cooking temperature of 90 °C with pulp yield of 64.09%, water content of 16%, ash content of 2.5%, cellulose content of 73%, lignin content of 8.5%, and tensile strength of 1.96 kN/m².

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