The Influence of Solvent Volume on Raw Material and Cooking Time in the Delignification Process of Paper Making from Kepok Banana Peel Pulp

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Abstract
The potential applications of paper made from kepok banana peel include greeting cards, book covers, and other art and craft projects. The use of kepok banana peel in papermaking adds a new dimension and unique artistic value to the field. Furthermore, it has a positive impact on the environment by reducing agricultural waste that would otherwise be discarded. The purpose of this study was to investigate the effect of the volume of NaOH solution on the mass of kepok banana peel and the ripening time needed to produce the best pulp according to SNI 7274:2008 and SNI 14-6519-2001 standards. The study involved testing different volumes of solvent, ranging from 300 mL to 700 mL, and conducting the delignification process for 60 to 120 minutes with 30-minute intervals. The resulting pulp was then utilized in the papermaking process. Based on the conducted study, the optimum operating conditions were achieved using a solvent volume of 500 mL for a duration of 90 minutes. The analysis revealed a cellulose content of 90.8%, lignin content of 5.02%, water content of 16.85%, and paper tear resistance of 444.584 mN.

Keywords: *Cooking Time, Effect of Solvent Volume, Kepok Banana Peel, Paper, Pulp.*

Abstrak
Kertas dari kulit pisang kepok memiliki berbagai potensi aplikasi seperti kartu ucapan, sampul buku dan lain sebagainya. Dalam konteks seni dan kerajinan kertas kulit pisang kepok memberikan dimensi baru dan nilai artistik yang unik. Penggunaannya juga memberikan dampak positif terhadap lingkungan, karena mengurangi limbah pertanian yang dibuang begitu saja. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh volume larutan NaOH terhadap massa kulit pisang kepok dan waktu pemasakan dalam menghasilan pulp terbaik sesuai dengan SNI 7274:2008 dan SNI 14-6519- 2001. Pada penelitian dan ini menggunakan variasi volume pelarut sebesar 300 mL, 400 mL, 500 mL, 600 mL, 700 mL dilakukan proses delignifikasi selama 60-120

menit (interval 30 menit). Kemudian pulp yang dihasilkan dicetak menjadi kertas. Dari proses yang telah dilakukan diperoleh kondisi operasi optimum pada volume pelarut sebesar 500 mL selama 90 menit. Hasil analisa menunjukkan bahwa kadar selulosa sebesar 90,8%, kadar lignin sebesar 5,02%, kadar air sebesar 16,85% dan ketahanan sobek kertas sebesar 444,584 mN.

Kata Kunci: *Kertas, Kulit Pisang Kepok, Pengaruh Volume Pelarut, Pulp, Waktu Pemasakan.*

1. Introduction

Bananas are one of Indonesia's agricultural products, with a significant annual production. According to the Central Statistics Agency (BPS), banana production in Indonesia reached 9.6 million tons in 2022. Indonesia is home to various types of bananas, including the kepok banana variety. Kepok bananas are characterized by their large size and thick peel. However, in most cases, the peel is discarded without being processed into useful products. The peel of kepok bananas contains 18.7% cellulose and 15.36% lignin (Koni, Therik, & Kele, 2013). The cellulose content in banana peels can be utilized as a raw material in papermaking. Therefore, the use of non-wood biomass waste has started to be considered as an alternative raw material in the paper production industry.

The process used to create pulp from kepok banana peel is called delignification. Delignification is a subprocess of pulping that involves dissolving lignin to obtain a higher yield of fibers. In the delignification process, lignin is degraded by NaOH solution into smaller molecules that can dissolve in black liquor. Several factors need to be considered in the delignification process, including the concentration of NaOH solution, heating time, and the ratio of NaOH solution volume to raw material. Based on the study conducted by Dewi et al. (2019), using a high concentration of NaOH solution and excessively long heating time can result in the hydrolysis of cellulose, leading to a decrease in the quality of the produced pulp. The ratio of solution volume to pulp weight also significantly affects the maturity level of the pulp. A sufficiently high ratio ensures the completeness of the cooking and maturity process. Additionally, it is important to determine the appropriate ratio of NaOH solution to raw material to ensure complete dissolution of lignin. An excessively high ratio may lead to inefficient use of the cooking liquid, while an excessively low ratio could cause lignin precipitation (Bahri, 2015).

The pulp produced and utilized must comply with applicable standards or specifications both nationally and internationally. One example of pulp quality standards in Indonesia is SNI 7274:2008, which states the following:

Table 1. Pulp Quality Standards

Components	Pencetage (%)
Cellulose	Max. 10
Lignin	Min. 40
Ash	Max. 25
Water	Max. 3

Source: SNI 7274:2008.

2. Method

This research was conducted at the Research and Basic Chemistry Laboratory of the Chemical Engineering Department, Politeknik Negeri Samarinda. The raw material used was kepok banana peel obtained from Mangkupalas, Samarinda, East Kalimantan. The tear strength analysis was performed at the Industrial Biotechnology Laboratory of Mulawarman University, Samarinda.

2.1 Sample Preparation

Sample preparation was conducted by collecting 10 kg of kepok banana peel, followed by washing and drying the peel under direct sunlight in an open air until it reached a constant weight. Next, the kepok banana peel was cut into pieces approximately 1-2 cm in size.

2.2 Pulp Making Process with Delignification

The process of making pulp from kepok banana peel starts by weighing 50 g of kepok banana peel and placing it into a glass beaker. Then, a 6% cooking solution (NaOH) is added with varying solvent volumes of 300 mL, 400 mL, 500 mL, 600 mL, 700 mL. Subsequently, the mixture of NaOH solution and raw material is cooked at 100 °C for different cooking times of 60 minutes, 90 minutes, and 120 minutes, while being stirred using a magnetic stirrer. The resulting mixture is then separated into residue and filtrate using a filtering cloth. The formed residue is washed until it reaches a neutral pH using 500 mL of aquadest. Next, the obtained pulp from the process is weighed, approximately 15 g, and then dried in an oven at 105 °C for 2 hours. After 2 hours, the pulp is removed from the oven and cooled in a desiccator for 15 minutes. The final step is to mold the pulp using molds until a uniform pulp surface is obtained. Pulp molding takes the form of a plastic container measuring 210 x 290 mm and the manufacturing process involves flattening it to the thickness of the paper (uniform pulp surface is obtained).

The obtained pulp from the process is then analyzed for cellulose content (using SNI 14-04444-1989 method), lignin content (using SNI 14-0492-2009 method), and moisture content. The paper produced from the molding process is further tested for tear strength using the Elmendorf method (SNI 0436:2009).

3. Result and Discussion

The results of the analysis of moisture content, cellulose content, lignin content, and tear strength in the paper are shown in the Figure 1, 2, 3, and 4.

3.1 The Influence of Solvent Volume and Cooking Time on Moisture Content

Moisture content refers to the amount of water contained in a substance. As seen in Figure 1, if a substance has a high moisture content, the resulting pulp will also not be of good quality, as high moisture content can affect the quality of the paper and accelerate the growth of microorganisms in the paper. Additionally, the paper will deteriorate quickly (Herlina, 2017).

In Figure 1, different water content values were obtained under each delignification condition, which are influenced by relative humidity. Low relative humidity conditions result in lower water content. According to the SNI 7274:2008 pulp quality standard, the maximum water content in pulp should be 10%. Based on the water content values obtained from the research, the highest water content value was 32.6% at a NaOH solvent volume of 300 mL with a delignification time of 120 minutes. On the other hand, the lowest water content value of 7.5% was obtained at a NaOH solvent volume of 700 mL with a delignification time of 60 minutes. Based on the obtained water content values, deviations from the SNI standard can affect the resulting product. The product may experience faster deterioration, accelerated bacteria or mold growth.

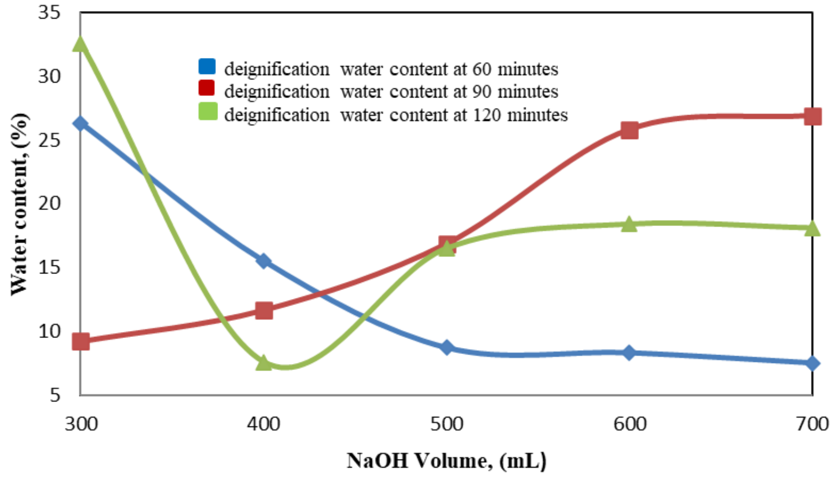

Figure 1. Influence of NaOH Volume and Cooking Time on Water Content

3.2 The Influence of Solvent Volume and Cooking Time on Cellulose Content

In Figure 2, it can be observed that increasing the volume of NaOH used as a cooking solution will affect the obtained cellulose content. This is because the larger the solvent volume, the more lignin, which acts as a binder for cellulose, will be separated. As a result, the cellulose content will increase.

On the Figure 2, it can be observed that there is a decrease in cellulose content after 500 mL of NaOH volume. This is due to the regular open structure of cellulose and the dispersion of cellulose molecules freely in the solvent (NaOH). With the cellulose structure dispersed freely in the solvent, cellulose is likely to dissolve and be carried away by the solvent during the filtration process (Siregar et al., 2014). The fluctuation in cellulose content along with the increase in NaOH volume is also caused by the non-selective attack of the OH radicals on the lignocellulosic bond. During the initial reaction, OH radicals break the lignin-cellulose bond, causing the partially open structure of the lignin that wraps the cellulose structure. The exposed part of the structure facilitates better contact between the radical and cellulose. When the radical comes into contact with cellulose, it can break the cellulose bond, resulting in the formation of glucose. Therefore, during the delignification process, there are two possible reactions for lignocellulose: lignin bond cleavage and cellulose degradation (Inggrid et al., 2011).

Based on the study, the highest cellulose content obtained was 90.8% with the addition of 500 mL of NaOH solution and a delignification time of 90 minutes. On the other hand, the lowest cellulose content obtained was 52.6% with the addition of 600 mL of NaOH solution and a delignification time of 120 minutes. These cellulose content values are within the quality standards for pulp according to SNI 7274:2008, which sets a minimum cellulose content of 40%.

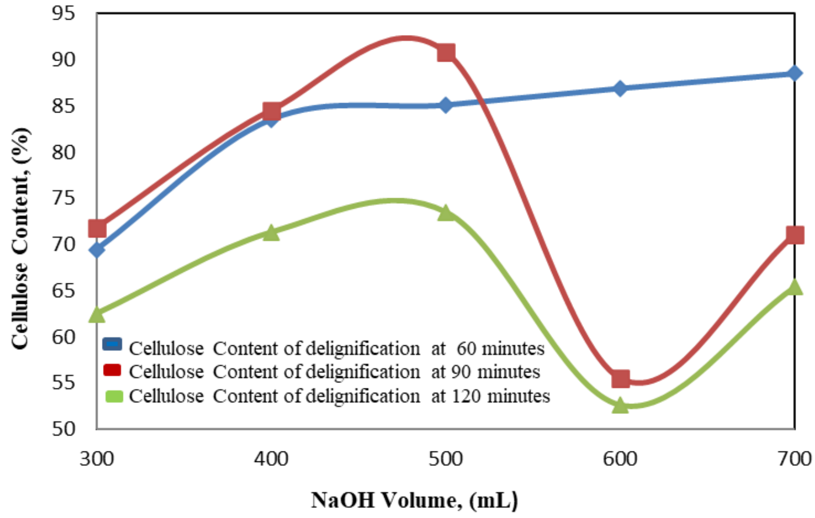

Figure 2. Graph of the Influence of NaOH Volume and Cooking Time on Cellulose Content

3.3 The Effect of Solvent Volume and Cooking Time on Lignin Content

In the process of pulp production, delignification (removal of lignin) occurs. This reaction involves converting lignin polymers into their constituent monomers and dissolving them in the cooking solution. Low lignin content indicates better quality pulp, while high lignin content can result in darker colored pulp. Additionally, high lignin content would require higher amounts of bleaching agents during the bleaching process, leading to increased production costs. Pulp with low lignin content exhibits better physical properties because lignin is water-repellent and rigid, which can make the grinding process more challenging (Veronika, 2016).

In Figure 3, it is shown that the percentage of lignin content in the pulp decreases as the volume of NaOH solution increases. This indicates that lignin undergoes complete degradation with the increasing volume of NaOH solution used as a solvent.

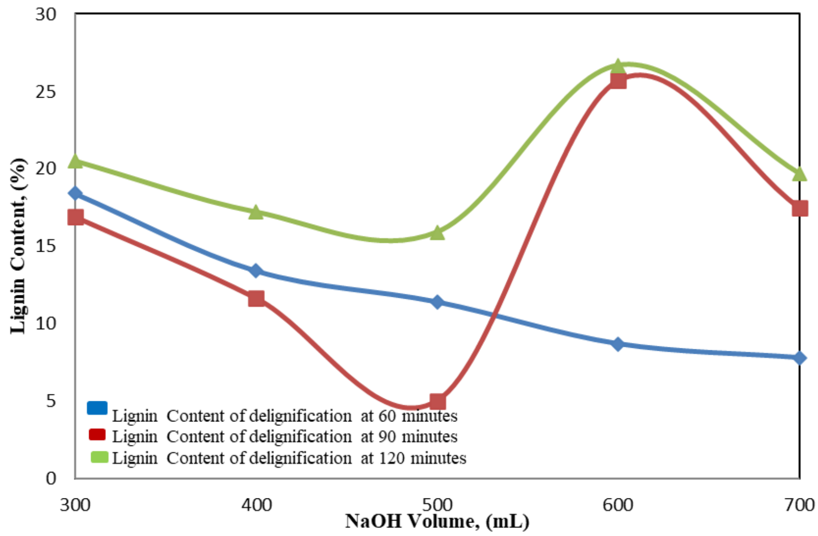

Figure 3. The Influence of NaOH Volume and Cooking Time on Lignin Content

It can be observed that with the addition of NaOH volume exceeding 500 mL, there is an increase in lignin content. This is due to the lysis of lignin structure, which causes partial condensation and precipitation of its molecules. The presence of precipitated lignin molecules will affect the accumulation of average molecular weight and result in an increase in lignin weight (Matsushita, 2004). According to Widodo et al. (2013), the increase in lignin content is caused by the degradation of cellulose during the delignification process. The decrease in cellulose content leads to an increase in lignin content that was initially associated within the lignocellulosic bond. Lignin can also undergo structural changes at high temperatures, indicating that the lignin in this study may not have been completely degraded due to relatively low temperatures during the delignification process.

Based on the results of the study, the highest lignin content obtained was 26.7%, while the lowest lignin content obtained was 5.02%. The highest lignin value does not meet the quality standards for pulp according to SNI 7274:2008, which specifies a minimum lignin content of 25%.

3.4 The Influence of Solvent Volume and Cooking Time on Paper Tear Strength

Based on the research results on the tear strength test of paper made from delignified kepok banana peel, the data obtained are shown in Figure 4.

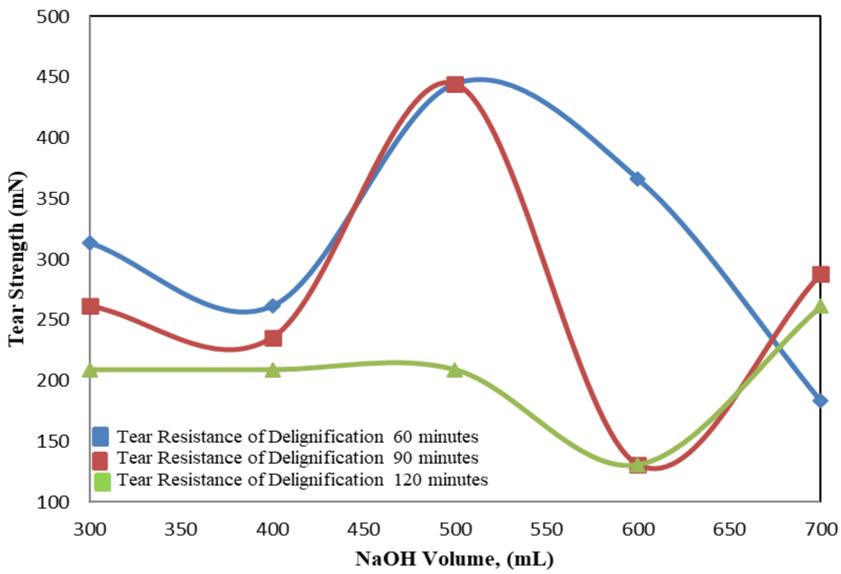

Figure 4. The Influence of NaOH Volume and Cooking Time on Tear Strength

From the research results, it is known that the highest tear strength is obtained at a NaOH solution volume of 500 mL with a delignification time of 90 minutes, with an average tear strength of 444.584 mN, while the lowest tear strength is obtained at a NaOH solution volume of 600 mL with delignification times of 90 minutes and 120 minutes, with an average tear strength of 130.76 mN. From the above test results, it can be observed that increasing the NaOH volume and prolonging the cooking time can result in higher tear strength, in accordance with existing theories. The high presence of cellulose fibers enables them to bond to form strong paper (Dewi, 2009). This occurs because the cellulose concentration in the 500 mL sample is higher than the cellulose concentration in the 600 mL sample (a larger volume of solvent with the same amount of cellulose will produce a different concentration).

Another factor that affects the tear strength of paper is the pressing process. Thickness plays a role in paper testing, where thinner paper tends to have lower tear strength. In this study, the variation in tear strength is also caused by the unevenness of the paper during printing and pressing. Since the printing and pressing processes were done manually, they resulted in uneven paper texture and uneven paper thickness.

Based on the research results, a tear strength value of 444.584 mN was obtained, which meets the SNI 14-6519-2001 standard with a reference standard value of 392 mN.

4. Conclusion

Based on the research results of making paper from kepok banana peel using alkali treatment process, it was found that the higher the volume of solvent used, the higher the cellulose content obtained and the lower the lignin content. The variation in cooking time also affects the cellulose content produced, as longer cooking time results in complete degradation of lignin. However, an optimum time is required to prevent degradation of cellulose. From this study, the best results were obtained with a solvent volume of 500 mL and a delignification time of 90 minutes, which resulted in a cellulose content of 90.8%, lignin content of 5.02%, moisture content of 16.85%, and tear strength of 444.584 mN.

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