Journal of Fibers and Polymer Composites 3 (1): 74-86 (2024)

Journal of Fibers and Polymer Composites

https://journals.gesociety.org/index.php/jfpc/index

THE CHARACTERISTICS OF ART PAPER PRODUCED FROM PALM OIL EMPTY FRUIT BUNCHES AT DIFFERENT COOKING TEMPERATURES

Irvan Adhin Cholilie*,[1], Tcyo Febry Bayu Pratama[1], Abdul Halim[2], Paramita Setyaningrum[1],Wahyu Kamal Setiawan[1]

[1]Department of Agroindustrial Technology, Universitas Internasional Semen Indonesia, Gresik, Indonesia
[2]Department of Chemical Engineering, Universitas Internasional Semen Indonesia, Gresik, Indonesia

*Corresponding author
Email: irvan.cholilie@uisi.ac.id

Abstract. *The demand for paper grows yearly, but it's getting harder to get raw materials made of wood, so we need alternate raw materials. The artistic appearance of art paper is one with many distinct and natural tones. Since cellulose fibers from trees are typically used in the production of art paper, this has an effect on deforestation, which contributes to natural disasters. Papermaking was done as part of this study in May–June 2022 at the Semen Indonesia International University's material analysis lab. The goal of the study is to ascertain the impact of pre-treatment and cooking temperature on the caliber of paper produced from empty fruit bunches and paper trash. The variables used in this study were cooking temperatures of 80ºC, 90ºC, and 100ºC. Parameters observed were appearance, grammage, thickness, moisture content, and water absorption on paper. The results showed that the difference in cooking temperature of empty oil palm fruit bunches affected the quality of the paper produced. The highest grammage was obtained in the cooking treatment with a temperature of 80ºC, which was 208.83 g/m², the highest paper thickness was obtained in the first treatment (A) at 80ºC cooking at 0.16 mm, the highest water content was obtained in the cooking treatment with temperature of 80ºC is 4.27%, and the lowest water absorption is obtained in the cooking treatment with a temperature of 80ºC which is 314.03%, but the fiber characteristics are still stiff.*
Keywords: *Empty fruit bunches; grammage; moisture content; thickness; water absorption*

1. Introduction

Paper is always in demand, but Indonesia in particular sees a surge year after year. While the availability of raw materials, particularly needle-leaved wood, is extremely constrained and even declining from year to year, the development of paper consumption in both industrialized and emerging countries shows a consistent increase of about 1-4% yearly. This is particularly true for tropical nations with little potential for evergreen and broadleaf forests, such as Indonesia, India, Egypt, and Central America. If there is, it is very little, hence non-timber materials including bagasse, straw, bamboo, and others are now being developed to supply the domestic pulp industry's raw material needs. Alternative materials that can be utilized are therefore required. Therefore, substitute resources are required, such as plant fibers and fiber that contain waste, to take the place of wood in the production of paper pulp.

Received January 29, 2023; Accepted March 12, 2023; Published March 29, 2024
https://doi.org/10.55043/jfpc.v3i1.68

In written communication, paper is a medium used to spread information. Currently, it is used for a variety of purposes, including those connected to the packing, packaging, cleaning, insulation, and photographic sectors. Plants that have fiber can serve as the raw material for creating paper [1]. Bark is still a common source of raw material for the paper industry. Given that wood plants take years to mature and can be used as raw material for paper while paper mills need wood every day to generate paper, 1 ton of paper requires 4 hectares of forest, which can produce as much as 20 m3 of wood per hectare. If the missing trees are not replaced, this will result in a serious lack of raw materials as well as severe environmental harm.

Imports continue to satisfy Indonesia's need for paper pulp. Despite the nation's considerable pulp production potential. The palm oil industry was noted as the biomass's largest producer, producing over 23 million tonnes of residues, 90% of which came from plantations and the remaining 10% from mills where the oil was extracted [2]. Oil Palm Empty Fruit Bunches (OPEFB) are the solid residues from the oil palm tree's fresh fruit bunches (FFB), which are mostly grown in Thailand, Indonesia, Malaysia, and other nations. The OPEFB contains the building blocks of cellulose, hemicellulose, and lignocellulose, and is now used to produce compost, biofuels, and fertilizer [3].

Making art paper typically involves the use of cellulose fiber from trees, which affects deforestation, and contributes to natural catastrophes. As a result, finding substitutes for trees as a source of raw materials for papermaking, such as empty palm oil bunches, is important (EFB).EFB has almost the same amount of cellulose as hardwoods, but less lignin and a disproportionately larger amount of pentosans and hemicellulose [4]. Table 1 shows that there is a very wide range of cellulose concentration in EFB, from high to low class. However, the average result is close to 40%, indicating that the EFB cellulose concentration falls into the moderate category. EFB has an extractive content that is comparatively high. Cooking chemicals will be consumed more frequently throughout the pulping process, which will lower the quality of the paper that is produced [5].

Table 1. Classification of EFB chemical components [5]

	High	Moderate	Low
Cellulose,%	>45	40-45	<40
Lignin, %	>33	18-33	<18
Pentosans, %	>24	21-24	<21
Extractives, %	>4	2-4	<2
Ash, %	>6	0.2-6	<0.2

Oil palm empty fruit bunches can be utilized as a substitute material for creating art paper because of their plentiful supply and high cellulose content. The limited availability of natural materials encourages the utilization of other materials such as waste materials that have not been widely utilized for paper raw materials. Indonesia produced EFB-based paper products including printed papers and cement bags to reduce the import of paper waste using the EFB fibre through semi-chemical pulping [6].

Due to the specific qualities of non-wood fibers, the pulping process needs to be handled carefully, especially by performing a pre-treatment before the pulping process. Physical/mechanical action, hydrothermal, chemical, and/or biological therapy are all possible forms of pre-treatment. The non-wood chemical contents, including cellulose, hemicellulose, and lignin as well as other chemical elements, are affected differently by each process. However, the main goal of this pre-treatment is to carry out subsequent non-wood processing procedures that are simpler and more effective while also raising the caliber of the finished goods [7]. It has been claimed that pre-treating EFB by submerging it in a sodium hydroxide solution at a specific concentration increases the pulp yield of EFB refiner mechanical pulp (RMP) [8].

The process of making pulp from EFB has been investigated by various methods, which are soda, soda anthraquinone, alkaline peroxide, aerosol, pre-hydrolysis soda-AQ, and chemical mechanical [6]. However, advanced technology can be a game-changer in the pricing structure as the pulp and paper making from EFB is cost-efficient compared to other woodfree pulp. The total of woodfree pulp from EFB generated up to 10 % of pulping capacity in pulp and paper-making production which keeps increasing faster than wood pulp [9]. Paper is recycled to be utilized as a mixed material with oil palm bunch waste to become material for art paper products and at the same time, help reduce the impact of paper waste on the environment. Therefore, research is needed to determine the effect of cooking temperature and the best pretreatment temperature of palm empty fruit bunches (EFB) on the quality of paper made from empty bunches and paper waste.

2. Methods

2.1. Research Location and Timing

Utilizing variables such as variations in the cooking temperatures of empty fruit bunches, the research was conducted by producing paper from palm empty fruit bunches (EFB) and paper waste. The following characteristics of the paper were noted: compactness (color and texture), grammage, thickness, moisture content, and water absorption capability. Based on the characteristics of paper we have a diagram flow to create an art paper in Figure 1.

2.2 Resources and Tools

The following are some of the resources used in this study: palm empty fruit bunches (EFB), white HVS paper waste, NaOH 5%, NaOH 2%, Na_2S 4%, and water.

The following are some of the resources used in this study: shears, gloves, a plastic bottle, a blender, analytical equilibrium, a stovetop (heater), a glass beaker, a glass stir stick, a glass watch, a spoon, ovens, a gauge screw, screen printing, wood board (as a base when printing paper) and blanco fabric (as a basis for printing pulp on a wooden board).

2.3 Research Methodology

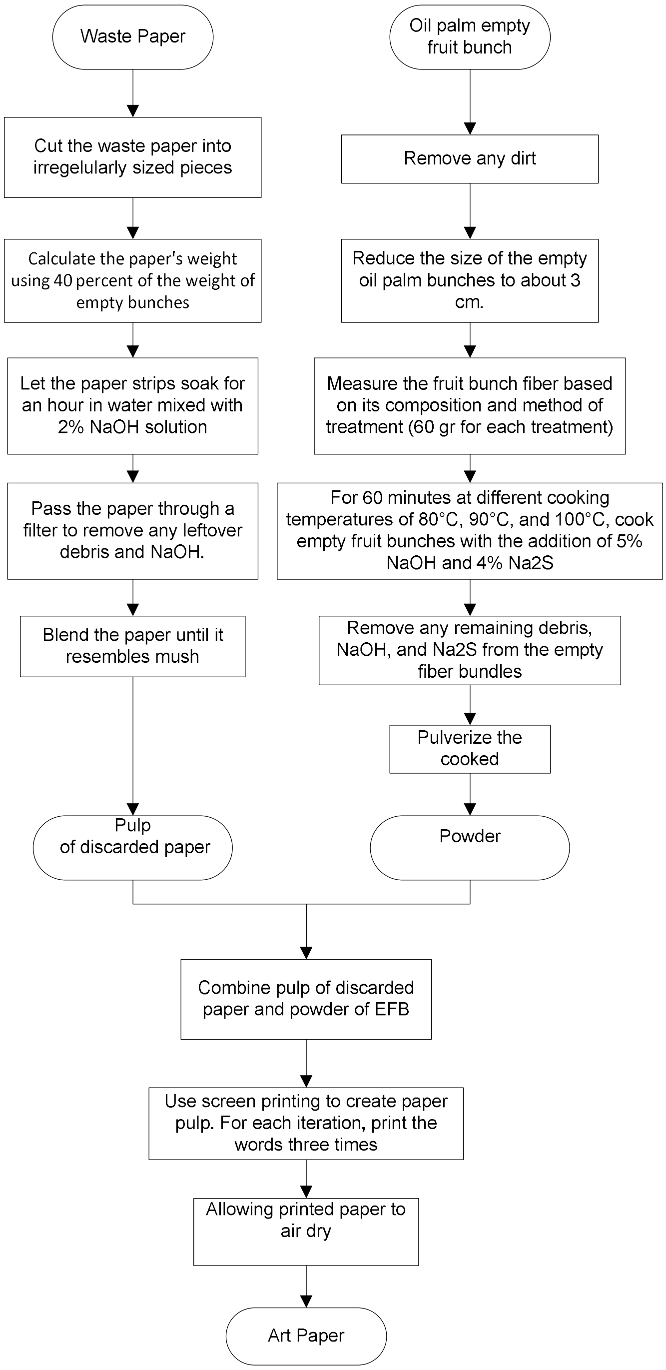

Figure 1. Flow Diagram of Art Paper Making

2.3.1 Producing Pulp from Paper Waste

Following are the steps for producing pulp from paper waste: Pick raw materials like white HVS type paper; Using scissors, cut the meat into irregularly sized pieces; Calculate the paper's weight using 40 percent of the weight of empty bunches [10]; Let the paper strips soak for an hour in water mixed with 2% NaOH solution; Pass the paper through a filter to remove any leftover debris and NaOH; Blend the paper until it resembles mush.

2.3.2 Making pulp from the empty oil palm bunches

The steps for making pulp from empty palm oil bunches are as follows: Remove any dirt from the empty oil palm bunches; Reduce the size of the empty oil palm bunches to about 3 cm; Measure the fruit bunch fiber based on its composition and method of treatment (60 gr for each treatment); For 60 minutes at different cooking temperatures of 80°C, 90°C, and 100°C, cook empty fruit bunches with the addition of 5% NaOH and 4% Na2S (Rizki, 2019); Remove any remaining debris, NaOH, and Na2S from the empty fiber bundles; Pulverize the cooked, empty palm oil bunches into a powder.

2.3.2 Making paper from a combination of paper waste and empty palm oil bunches

Following are the steps for making paper from a combination of used paper and empty palm oil bunches; Combine the pulp from paper waste and the pulp from empty palm fruit bunches; Use screen printing to create paper pulp. For each iteration, print the words three times; Allow the printed paper to air dry; Conduct exams on paper according to the guidelines; and Analyze the data.

2.4 Research Parameters

2.4.1 Grammage (g/m2)

The weight of paper per unit area is measured in grams. The grammage of a piece of paper can be used to gauge its physical toughness. The weight of a sheet of paper that covers a one-meter square area is known as its paper grammage. using SNI 14-0439-1989 for testing. Paper is sold or acquired by weight, hence determining the paper's grammage is crucial. The price per unit decreases with decreasing paperweight. The physical, mechanical, chemical, and optical characteristics of the paper are all impacted by the paper's weight.

2.4.2 Thickness

The paper's thickness or under normal circumstances, thickness is determined by measuring the angle at which the two surfaces of the paper are perpendicular to one another. Sheet grammage, fiber properties, filler content, pressing, calendering, moisture content, and other factors all have an impact on paper thickness. A screw micrometer can be used to gauge the paper's thickness. An instrument used to gauge an object's diameter or thickness is a screw micrometer.

2.4.3 Moisture Content

The water on the paper is the denser water relative to the paper. The amount of water in the paper can have an impact on how the paper turns out. In most cases, the material is dried in an oven set between 100 ^{O}C and 105^{O}C for three hours to determine its moisture content. The amount of water evaporated can be determined by comparing the weights before and after drying.

2.4.4 Water Absorbency

One of the characteristics of paper material that demonstrates the paper's capacity to absorb water is its absorption capacity for water. This test was conducted using SNI 080-7070-2005 as a guide. The paper sample was subjected to this test by being soaked in 100 cc of water and left to stand for 10 minutes. The amount of water absorbed is determined by the weight difference between before and after immersion.

3. Results and Discussion

3.1 Paper's Physical (Appearance)

The oil palm EFB is a type of woody biomass with a calorific value of 4,400 kcal/kg-dry and is considered an anon-toxic and promising biomass resource for industrial and farming applications including pulp and paper manufacturing [11]. Due to the abundance of fibers that rise to the surface of the paper, which is made from a blend of empty fruit bunches and paper waste, the paper has a pleasing appearance. To classify this paper as kraft paper, a specific kind of art paper that can be used for specific purposes. This paper is designated as art paper and can be further processed to make other items including paper bags, packing materials, picture frames, and other things. Figure 2 shows the results from the paper.

Figure 2. Results of Paper Produced from Empty Bunches and Paper Waste

Because it is made of empty bunches that are composed of 60:40 paper waste, the paper from this study appears pale white in the image above [10]. This paper does not have any pressing or pressing processes on it, thus it is somewhat waved or wrinkled before ironing. Another look is that the paper appears to have an empty bunch of fibers that have not yet fully been crushed; these developing fibers provide this art paper beauty or aesthetic appeal. However, paper cooked between 80 and 90^{O}C seems stiffer in the fiber texture than paper cooked at 100^{O}C, which may be related to the sluggish rate of delignification [12].

The purpose of using NaOH in the production of paper is to facilitate the softening and decomposition of empty fiber bunches. Generally, cellulose fiber typically has two types of regions: crystalline and amorphous. The outer layer and the amorphous region burst out when OPEFB fiber is steeped in the NaOH solution, causing the cellulose to inflate. The lignin, hemicellulose, and lower molecular fractions dissolve in alkali solutions as a "black liquor," which increases the yield of the cellulose fiber obtained. NaOH solution breaks down the hydrogen bonds between the lignocellulosic component [13]. Additionally, the temperature at which something is cooked also has an impact; raising the temperature will accelerate delignification (removal of lignin). However, cellulose breakdown occurs at temperatures exceeding 160 °C [12]. Since there is not already a quality standard for art paper, it is vital to compare the quality of paper waste and empty fruit bunches to commercial goods. Printing paper A and duplex cardboard are the products on the market that are utilized for comparison.

About 4.5% of the residual oil in EFB fiber is located at the fiber's tip and surface [14]. Although it doesn't contain oil, the oil gets into the EFB by osmosis via the fiber wall when the fruit is boiled and separated from its bunches in the CPO mill [15]. EFB's oil concentration has the potential to pitch issues that result in stains and possibly even pinholes on the paper that is produced. Therefore, it is necessary to reduce the oil content of EFB as much as feasible. To lessen this pitch issue, EFB fibers can be pretreated with lipase enzymes before the pulping process [16]. Lipase enzymes can also be used to adjust pitch in the production of paper. Additionally, pulp and paper mills can use mechanical pitch removal employing a multistage cleaning system [17].

4.2 Grammages

To perform this grammage test, a sample of paper that has been cut into a square with a length of 10 cm on each side and an area of 10 cm2 is obtained is weighed. According to the study's findings, the variation in EFB (Empty Fruit Bunch) cooking temperature has an impact on the weight of the paper. Table 2 shows the findings of the experiment investigating the impact of variations in EFB cooking temperature on paper grammage for each treatment.

Table 2. Examines the impact of varying cooking temperatures on paper gramage.

Temperature	Treatment	mass (g)	area (cm2)	grammage (gr/m2)	Average (gr/m2)
80º	A	2,1963	100	219,63	208,83
	B	2,2538	100	225,38	
	C	1,8148	100	181,48	
90º	A	1,896	100	189,6	181,21
	B	1,6595	100	165,95	
	C	1,8808	100	188,08	
100º	A	1,8564	100	185,64	180,18
	B	1,8412	100	184,12	
	C	1,7078	100	170,78	

Table 1 shows that the manufactured paper has a grammage value that ranges from 165 to 225 gr/m2. The cooking treatment at 80^{O}C produced the highest average grammage value of

208.83 g/m2, while the second treatment (B) produced the highest grammage value of 225.38 g/m2. The 100^{O}C treatment had the lowest gramage average value, 180.18 gr/m2, after that. However, the second treatment (B) at 90^{O}C had the lowest grammatical value, at 165.95 gr/m2. The unevenness throughout the paper printing process, which results in some portions of the paper being thin and some parts being thick, is what causes the inconsistent grammage values on the paper.

According to [1] obtained grammage readings ranging from 361.59 to 401.28 gr/m2 using a 10% NaOH concentration for two hours at a maximum cooking temperature of 120 °C. This is so that empty palm oil bunches might be processed into cardboard rather than paper. The addition of additives (tapioca adhesive, kaolin filler, and retention of alum sulfate) in the pulp suspension before sheet formation can also contribute to the high grammage. There is also a study from [10] where one of the treatments had the same material composition as this study, specifically a 60:40 split between paper trash and empty fruit bunches. The final paper grammage from this study was 269.03 gr/m2. However, because a gas stove was employed for the cooking process in this investigation, the cooking temperature was unclear.

The paper developed for this study has a grammage value above 100 g/m2, therefore when it is compared to the specifications for printing paper A (19608 SNI-7274-2008), which call for grammage values between 50 and 100 g/m2, it does not fulfill the standards. The resultant paper turns into cardboard since it is quite thick when compared to the grammage value of duplex cardboard (3116 SNI-0123-2008), which has a grammage of 225-500 g/m2. This paper is regarded as art paper and will be used in the production of other items, including paper bags, packing materials, picture frames, and others.

The large grammatical value is caused by the use of manual tools, specifically in the form of screen printing for printing paper. Additionally, the grinding process affects the grammage of this paper because when the paper is ground (to remove water), the thickness becomes uneven and there is no pressing or pressing process applied to the paper, resulting in a large grammage [10].

3.3 Paper Thickness

A screw micrometer is used to measure the paper's thickness in order to test its thickness. Measurements are performed by taking the average of three separate points (sections) of paper. It has been determined that the screw micrometer will be utilized with zero inaccuracy before the investigation is started. The screw micrometer utilized in this study had a zero inaccuracy of 0.19 mm. As a result, every measurement will be shrunk by 0.19 mm. Each measurement has been lowered by 0.19 mm in Table 3 below.

Table 3. The Impact of Variations in Cooking Temperature on Paper Thickness

Temperature	Treatment	(1)	(2)	(3)	Average (mm)
80°	A	0,15	0,20	0,13	0,16
	B	0,07	0,05	0,09	0,07
	C	0,05	0,10	0,04	0,063
90°	A	0,05	0,03	0,07	0,05
	B	0,06	0,12	0,05	0,077
	C	0,07	0,03	0,05	0,05
100°	A	0,05	0,08	0,06	0,063
	B	0,06	0,04	0,07	0,057
	C	0,07	0,04	0,03	0,047

The thickness values of the paper generated range from 0.047 to 0.16 mm, as can be shown in Table 3. The first treatment (A) at cooking with a temperature of 80^{O}C yielded the maximum average thickness value of 0.16 mm. The third treatment (C) at 100^{O}C cooking temperature yielded the lowest average thickness value, which is 0.047 mm. Because of the unequal distribution throughout the paper printing process, some areas of the paper are thin and some are thick, which results in inconsistent thickness values on the paper.

According to research by [1], the paper thickness varied between 0.86 and 0.90 mm when 10% NaOH was used for 2 hours at a maximum cooking temperature of 120 °C. This is because the research was carried out to transform empty palm oil bunches into cardboard rather than paper, making the difference in thickness very substantial. The resulting grammage has an impact on the paper's thickness; if the grammage is high, the paper will also be thicker.

3.4 Paper Moisture Content

Weighing a mass of about 2 grams is used to determine the amount of water present. The sample utilized in this investigation was a piece of paper that was weighed. This test involves weighing the sample's initial mass before heating it in an oven at 105°C for three hours to lower its water content. The sample is weighed once more following the oven's completion to compare the sample's mass before and after the oven. Table 4 displays the findings of the experiment investigating the impact of variations in EFB cooking temperature on paper moisture content for each treatment.

The water content value of the paper produced ranges from 3.76 to 4.50%, as can be shown in Table 4 . The cooking treatment at 80 ^{O}C produced the highest average water content value of 4.27%, while the initial treatment (A) produced the maximum water content of 4.50%. The 100 ^{O}C treatment had the lowest average water content (3.97%), and the initial treatment (A) had the lowest water content (3.76%). The proper water content can generate the desired paper quality, but a high water content can result in a paper that is easily torn, while a low water content can result in a paper that is challenging to print and may tear when put through the printer.

Table 4. Moisture Content and Cooking Temperature Differences

Temperature	Treatment	Initial Mass (g)	After Oven Mass (g)	Moisture Content (g)	Moisture Content (%)	Average (%)
80º	A	2,1963	2,0974	0,0989	4,50	4,27
	B	2,2538	2,162	0,0918	4,07	
	C	1,8148	1,7379	0,0769	4,24	
90º	A	1,896	1,8179	0,0781	4,12	4,19
	B	1,6595	1,5888	0,0707	4,26	
	C	1,8808	1,8022	0,0786	4,18	
100º	A	1,8564	1,7866	0,0698	3,76	3,97
	B	1,8412	1,768	0,0732	3,98	
	C	1,7078	1,6365	0,0713	4,17	

According to research by [1], the water content on paper ranged from 6.16 to 7.29% when treated with 10% NaOH for two hours at a maximum cooking temperature of 120 °C. The water content in the paper is different from this research since the research was done to turn empty palm oil bunches into cardboard rather than paper. The amount of water in the paper will increase with the thickness and grammage of the product.

3.5 Absorption of Water

Paper measuring 5x5 cm was cut and its mass was measured for this water absorption test. The paper was then removed and weighed after being soaked in 100 ml of water for 10 minutes. The findings of the study demonstrate that the EFB's capacity to absorb water is affected by variations in the cooking temperature. Table 5 displays the findings from experiments examining the impact of varying EFB cooking temperatures on the paper's ability to absorb water for each treatment.

Table 5. Differences in cooking temperatures' impact on water absorption

Temperature	Treatment	Initial Mass (g)	Mass After Soaking (g)	Moisture Content (g)	Moisture Content (%)	Average (%)
80º	A	0,5984	2,4084	1,8100	302,5	314,03
	B	0,4365	1,8316	1,3951	319,6	
	C	0,5119	2,1502	1,6383	320,0	
90º	A	0,3482	1,6146	1,2664	363,7	401,73
	B	0,3482	1,6408	1,2926	371,2	
	C	0,3482	1,9858	1,6376	470,3	
100º	A	0,3482	1,8738	1,5256	438,1	398,2
	B	0,3482	1,8886	1,5404	442,4	
	C	0,3482	1,4418	1,0936	314,1	

Table 5 shows that the range of water absorption in the final paper is between 302.5 and 470.3%. The cooking treatment at a temperature of 90^{O}C produced the highest average value of water absorption, which was 401.73%; the second treatment (B), which produced the highest average value of water absorption, was 470.3%. The 8 ^{O}C treatment had the lowest average water absorption rate of 314.03%, and the initial treatment (A) had the lowest water absorption capacity of 302.5.

4. Conclusions

The following findings are based on the research that has been done:

1. The quality of the paper produced is impacted by variations in the cooking temperature of empty palm fruit bunches (EFB). The cooking treatment at 80^{O}C produced the highest grammage, 208.83 g/m2, and the cooking treatment at 100^{O}C produced the lowest, 180.18 g/m2. The first treatment (A) during cooking at a temperature of 80^{O}C produced the thickest paper (0.16 mm), while the third treatment (C) at cooking with a temperature of 100^{O}C produced the thinnest (0.047 mm). The cooking treatment at 80^{O}C yielded the maximum water content (4.27%), whereas the treatment at 100^{O}C yielded the lowest (3.97%). Additionally, the cooking treatment at 90^{O}C produced the largest water absorption (401.73%), whereas cooking at 80^{O}C produced the lowest absorption (314.03%).
2. It has the highest grammage value, highest thickness, lowest water absorption, and the highest water content value according to the A printing paper standard at 80^{O}C cooking temperature, yet the fiber properties are still stiff.

References

[1] D. Anggraini and H. Roliadi, "Pembuatan Pulp dari Tandan Kosong Kelapa Sawit untuk Karton pada Usaha Skala Kecil," *Jurnal Penelitian Hasil Hutan*, vol. 29, no. 3, 2011, https://doi.org/10.20886/jphh.2011.29.3.211-225

[2] F. N. M. Padzil, S. H. Lee, Z. M. A. Ainun, C. H. Lee and L. C. Abdullah, "Potential of Oil Palm Empty Fruit Bunch Resources in Nanocellulose Hydrogel Production for Versatile Applications: A Review," *Materials*, vol. 13, no. 5, 2020, https://doi.org/10.3390/ma13051245

[3] M. Vakili, M. Rafatullah, M. H. Ibrahim, B. Salamatinia, Z. Gholami and H. M. Zwain, "A review on composting of oil palm biomass," *Environment Development and Sustainability*, vol. 17, no. 4, 2014, http://dx.doi.org/10.1007/s10668-014-9581-2

[4] S. D. Mohieldin, "Pretreatment Approaches in Non-wood Plants for Pulp and Paper Production: A Review," *JOURNAL OF FOREST PRODUCTS & INDUSTRIES*, vol. 3, no. 2, pp. 84-88, 2014, https://www.researchgate.net/publication/281610820_Pretreatment_Approaches_in_Non-wood_Plants_for_Pulp_and_Paper_Production_A_Review

[5] L. Indriati, N. Elyani and S. F. Dina, "Empty fruit bunches, potential fiber source for Indonesian pulp and paper industry," *IOP Conference Series: Materials Science and Engineering*, 2020, https://doi.org/10.1088/1757-899X/980/1/012045

[6] H. Risdianto, T. Kardiansyah, and A. Sugiharto, "Empty fruit bunches for pulp and paper production : The current state in Indonesia," *Journal of Korea Technical Association of the Pulp and Paper Industry*, vol. 48, no. 6, pp. 25-31, 2016, http://dx.doi.org/10.7584/JKTAPPI.2016.12.48.6.25

[7] S. D. Mohieldin, "Pretreatment approaches in non-wood plants for pulp and paper production : a review," *Journal of Forest Products & Industries*, vol. 3, no. 2, pp. 84-88, 2015, https://www.researchgate.net/publication/281610820_Pretreatment_Approaches_in_Non-wood_Plants_for_Pulp_and_Paper_Production_A_Review

[8] M. Y. N. Aqeela, Z. M. A. Ainun, and M. Jawaid, "Effect of pretreatmen concentration on pulp blending bertween oil palm empty fruit bunch and citronella leaf fibers in terms of pulp and paper properties," *IOP Conference Series : Materials Science and Engineering*, vol. 368, 2018, https://doi.org/10.1088/1757-899X/368/1/012010

[9] A. B. M. Aripin, " Potential of non-wood fibres for pulp and paper-based industries," Universiti Tun Hussein Onn Malaysia, 2014, https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://core.ac.uk/download/pdf/42956116.pdf&ved=2ahUKEwjqiK2ykZWFAxUExzgGHZRkCu4QFnoECB4QAQ&usg=AOvVaw0nk8y3Nb3ybOsCLaVyXPGg

[10] A. Endah, "Karakteristik Kertas Berbahan Baku Tandan Kosong Kelapa Sawit dan Sampah Kertas," Universitas Sumatera Utara, Medan, 2013, https://repositori.usu.ac.id/handle/123456789/54160

[11] H. Harsono *et al.*, "Preparation of dissolving pulp from oil palm empty fruit bunch by prehidrolysis soda-anthraquinone cooking method," *Journal of Wood Science*, vol. 62, pp. 65-73, 2016, https://doi.org/10.1007/s10086-015-1526-3

[12] I. Wibisono, H. Leonardo, Antaresti, and Aylianawati, "Pembuatan Pulp dari Alang-alang," *Widya Teknik*, vol. 10, no. 1, pp. 11-20, 2011, https://doi.org/10.33508/wt.v10i1.156

[13] N. F. Sayakulu and S. Soloi, "The Effect of Sodium Hydroxide (NaOH) Concentration on Oil Palm Empty Fruit Bunch (OPEFB) Cellulose Yield," *Journal of Physics: Conference Series*, vol. 2314, pp. 1-7, 2022, https://doi.org/10.1088/1742-6596/2314/1/012017

[14] Z. Ibrahim, A. A. Aziz, R. Ramli, K. Jusoff, M. Ahmad, and M. A. Jamaludin, "Effect of treatment on the oil content and surface morphology of oil palm (Elaeis guineensis) empty fruit bunches (EFB) fibers," *Wood Research*, vol. 60, no. 1, pp. 157-166, 2015, https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=http://www.centrumdp.sk/wr/201501/15.pdf&ved=2ahUKEwiO3taYi5WFAxW4xzgGHfWkCrEQFnoECA4QAQ&usg=AOvVaw0g6dzU0Kxc5oalRcqDECns

[15] Erwinsyah, A. Afriani, and T. Kardiansyah, " Potensi dan peluang tandan kosong sawit sebagai bahan baku pulp dan kertas: studi kasus di Indonesia," *Jurnal Selulosa*, vol. 5, no. 2, pp. 79-88, 2015, http://dx.doi.org/10.25269/jsel.v5i02.79

[16] Erwinsyah and A. Afriani, " Tandan Kosong Sawit: Karakteristik dan Potensinya sebagai Bahan Baku Pulp," *Prosiding Seminar Teknologi Pulp dan Kertas*, pp. 23-32, 2014, https://docplayer.info/52758867-Prosiding-seminar-teknologi-pulp-dan-kertas-2014-savoy-homann-bidakara-hotel-bandung-22-oktober-2014-dewan-penyunting.html#google_vignette

[17] L. Indriati, "Sistem pembersihan stok multi tahap untuk penghilangan pitch dari pulp kayudaun (the multistage cleaning system removal for hardwood pulp pitch)," *Jurnal Selulosa*, vol. 45, no. 1, pp. 9-15, 2016, https://scholar.google.com/scholar?q=+intitle:%27SISTEM%20PEMBERSIHAN%20STOK%20MULTI%20TAHAP%20UNTUK%20PENGHILANGAN%20PITCH%20DARI%20PULP%20KAYUDAUN%20(THE%20MULTISTAGE%20CLEANING%20SYSTEM%20REMOVAL%20FOR%20HARDWOOD%20PULP%20PITCH)%27