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Borassus Flabellifer L. Waste for Kraft Paper Production with Kraft Methods

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Abstract. *Borassus flabellifer* L. becomes one of the palm-based commodities in Indonesia that can grow well in dry areas, especially around the north coast of Java Island. An abundant waste of this plant, in the form of leaf midrib and fruit fiber, has a potential as a source of lignocellulose for the paper industry. In the present study, Kraft paper production was conducted to know the influence of the proportion of leaf midrib and fruit fiber of *Borassus flabellifer* L., and the concentration of Polyvinyl Acetate (PVAc) adhesives on the sensory and physical quality of Kraft paper. The research method was a Randomized Block Design (RBD) with two factors. The Friedman test was used to determine the sensory quality of Kraft paper. The ANOVA analysis was used to examine the physical quality of Kraft paper. The results showed that the treatment of raw material proportion and PVAc adhesive concentration had significant effect on color, surface texture, yield, and tensile resistance, but insignificant between treatment of Gramatur and tear resistance. The best treatment of sensory tests was Kraft paper with proportion of 50% leaf midrib pulp, 50% fruit fiber pulp, and 7.5% PVAc adhesive concentration. It has a yield value of 72.11%, Gramatur of 162.80 (g/m^2), tensile strength of 1.70 (%), and tear resistance of 197.6 (gf).

INTRODUCTION

The time goes by, yet the pulp and paper industry still persists and seeks to grow as indicated by the growing demand, leading to the search for new sources and hitherto unexploited sources of cellulosic fibers. As a mega-biodiversity country, in Indonesia, approximately 8000 species of flora are identified and less than a dozen are in commercial use for pulp production. Most of these species are commonly found in plantation enterprises, though not always be favorable in pulp and paper production in terms of fiber quality and wood composition [1].

Borassus flabellifer L. or Siwalan is a palm plant with an amazing adaptation capability, especially in dry area and so assessed fertile land. This plant can grow well in low altitude area, coastal area, and mountainous area that range from 0-800 m above sea level with rainfall rate around 500-5000 mm/year [2]. Generally, Siwalan is used for fruit and juice consumption generated from the tapping process. There are 40-70 pieces of leaf midrib per tree. It is a by-product of plants which often encountered both for the ease of harvesting and maintenance of Siwalan trees. Due to the cellulose content, which reaches 40.86%, it is potential to be used as alternative paper material [3].

Today, most chemical pulps are being produced by Kraft method globally. Sulphite method, a most commonly used method for pulp production, accounts for 10% of the total production, while Kraft method accounts for 80% [4]. The main aim of producing chemical pulp is to breakdown the structure of the middle lamella to separate the fibers individually and cast off the lignin content. During this process, since huge amount of lignin and hemicelluloses in the cell wall are being broken down, the elasticity of the separated fibers increases [5]. Moreover, because mechanical energy is not being used for separating the fibers in chemical pulping methods, mechanical damages on the fiber surfaces cannot be identified. However, papers made from chemical pulps make stronger bonds between fibers and gives higher paper strength properties when compared with mechanical and semi-chemical methods [6].

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In Kraft paper making, to bind the inter-fiber component in the paper forming process, the addition of an adhesive material is required so that the fibers can form a strong paper sheet. The Polyvinyl acetate (PVAc) is an adhesive suitable for paper and wood which is considered to be more environmentally friendly because of its biodegradable rubber polymer, unlimited shelf life, and resistant to microorganisms [7].

The objective of this study is to know the influence of the proportion of raw materials and the concentration of PVAc adhesives on the sensory and physical quality of Kraft paper, as well as to obtain the appropriate proportion of raw materials and adhesive concentrations to produce the best sensory and physical of Kraft paper.

MATERIALS AND METHODS

Materials

Siwalan is a native plant of the North Coast of Java Island. It is especially dispersed in several regencies in East Java, Indonesia, among them are Situbondo, Bangkalan, Tuban, Lamongan, and Gresik. As the raw material for this study, Siwalan from Gresik Regency was selected. The materials used in the Kraft paper making process were pulp made from leaf midrib, pulp made from fruit fiber, water and wood glue brand "Rajawali" which is made from Polyvinyl acetate (PVAc). The tool used in this research are knives, scissors, digital scales, pans, stirrer, measuring cups, blenders, tubs / buckets, screen, filter cloth, and oven. Meanwhile, the tool used for physical testing of paper is Paper Tensile Strength Tester.

Methods

The research method was a Randomized Block Design (RBD), which was arranged in a factorial consisting of two factors, namely: the proportion of raw material (P) consisting of three levels and PVAc Adhesive Concentration (L) to the total weight of the material consisting of three levels. The research design is demonstrated in Table 1.

TABLE 1. The research design

Research Design		**P ratio (Pulp of leaf midrib : Fruit fiber pulp)**		
		P1 (25:75)	P2 (50:50)	P3 (75:25)
(L) Adhesive Concentration)	L1: 5%	P1L1	P2L1	P3L1
	L2: 7.5%	P1L2	P2L2	P3L2
	L3: 10%	P1L3	P2L3	P3L3

Sensory quality test was done using a hedonic scale scoring method by considering each attribute, such as color and paper surface texture. The result of Kraft paper sensory quality was analyzed by using Friedman test to know the best treatment from the result, moreover, the best treatment alternative analysis using effectiveness index method was used. Meanwhile, the result of physical quality of Kraft paper will use an ANOVA analysis or Analysis of Variance to know the difference between the treatments.

RESULTS AND DISCUSSION

Siwalan is included in the category of hardwood with blackish wood. It is hard and dense with stringy type of grain. Approximating to siwalan rods, the siwalan midrib has similar characteristics. Main chemical composition of siwalan midrib is determined and shown in Table 2. as shown in Table 2, lignin content of Siwalan midrib is found as 21.48%, which is comparable to those of all types of hardwood (20-25%). The average Holocellulose content of Siwalan is about 73.77% in which the content of most annual plant and coniferous is 68-74%. Subsequently, the α-cellulose in Siwalan midrib (40.86%) is within the range of α-cellulose in hardwood (39-45%).

Some sensory quality tests show that the research design gives a characteristic difference to the sample tested. The average scores of panelist favorites on Kraft paper color are between 1.35 to 4.15. It indicates that the panelist's preference for the color of the Kraft paper is sufficiently good quality. Based on the assessment results, the panelists prefer the Kraft paper type with the proportion of 50% leaf midrib pulp and 50% fruit fiber pulp; and 7.5% PVAc adhesive, indicated by the highest score of 5 (very good). Some panelists consider that the Kraft paper product has a more attractive color than those with other formulations. The Kraft paper of the study has different colors depending

on the proportion of the materials used, in which the paper with higher proportion of fruit fiber pulp tends to be slightly brownish yellow, whereas the paper with a higher proportion of leaf midrib pulp tends to be dark brown. Paper made from Siwalan leaf midrib pulp tends to be blackish due to the dominant wood and bark content [8].

TABLE 2. The result of chemical analysis of Siwalan leaf midrib

Chemical composition	Mean%	Coniferous
Holocellulose	73.77	68-74
α-Cellulose	40.86	39-45
Lignin	21.48	20-25
Ash	0.41	<1

Friedman test results on the color of Kraft paper shows that the value of X2 (count) is greater than the value of X2 table (α = 5%), it can be interpreted that there is a real difference between treatments. It is because the panelists claimed that the colors of the produced Kraft papers are various so that in the assessment, the difference is noticeable as indicated as the effect on the selection of Kraft paper. The result of the respondent preference is shown in Fig. 1.

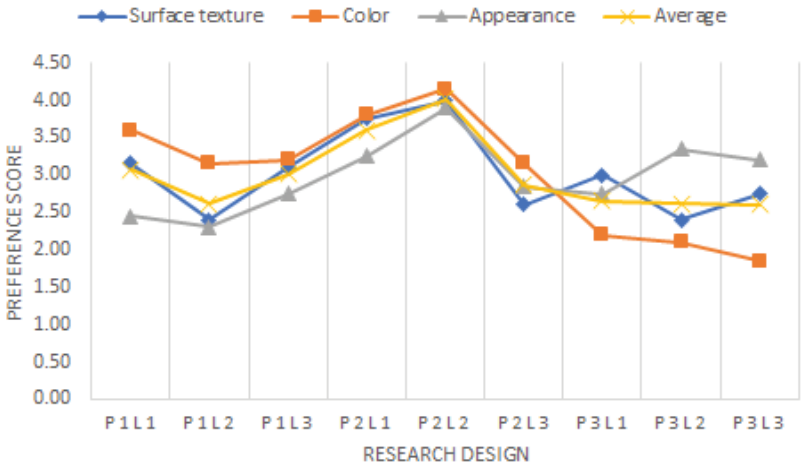

FIGURE 1. The result of sensory quality.

The average value of the panelist preference score for the texture of Kraft paper surface is between 1.85 and 4.15. The value shows that the produced Kraft paper has a fairly good to very good quality. Based on the results of the assessment, it can be declared that the most preferred formulation for paper surface texture is the proportion of 50% pulp leaf , 50% fruit fiber pulp , and 7.5% adhesive PVAc with a total score of 4. The surface texture of Kraft paper is influenced by the type of fiber owned by medium-sized Siwalan leaf midrib and supported by PVAc adhesives that have strong adhesion to produce a regular or solid surface texture. The regular surface texture of Kraft paper has unique properties and higher values compared to those of other Kraft paper products [9].

The result of Friedman's test on Kraft paper surface texture shows that the value of X2 (count) is higher than X2 table value (α = 5%), which means that the combination of treatment has a significant effect on the quality of Kraft paper surface texture. According to [1], surface texture is concerned with the quality of the paper surface determined by the relative size of the fiber's dominant cells.

Yield of Product

The result of variance analysis showed that the proportion of raw materials and the interaction of two factors of raw material proportion and PVAc adhesive concentration had a significant effect on the yield, but PVAc adhesive concentration had insignificant effect on the 5% significance level. The average value of the yield of Kraft paper

made from siwalan leaf midrib pulp and fruit fiber pulp ranged between 51.42% - 85.54%. The average value of yield due to interaction of raw material proportion and PVAc adhesive concentration can be seen in Table 3.

TABLE 3. The effect of raw materials proportion and PVAc concentration on the yield of Kraft paper

Research Design	Average of Yield (%)	Notation
P3L1	51.42	a
P3L2	55.29	a
P3L3	63.38	b
P2L1	68.41	b
P2L2	72.11	c
P2L3	74.92	c
P1L1	80.78	c
P1L2	84.87	d
P1L3	85.54	d

Description: The mean with the same notation shows no significant difference ($\alpha = 0.05$).

The higher the proportion of siwalan leaf midrib pulp, the lower the yield of the Kraft paper. It is because the cellulose content of fruit fiber pulp (56.73%) is higher than that of Siwalan leaf midrib pulp (40.86%). [10] also stated that the cellulose content of the fiber can be used to estimate the amount of the produced yield, in which the greater the cellulose content, the greater the yield.

Gramatur of Product

The result of variance analysis on Gramatur showed that the proportion of raw materials has a real effect and the interaction between material proportions and adhesive concentration has no significant effect. The Kraft paper Gramatur is between 162.8 - 390.1 g/m^2. Fibers that have larger diameter will be more suspended above the screen during the filtering process, while fibers that have a smaller diameter will be relatively skipped and affect the decrease of Gramatur paper [11]. Table 4 shows the data of the effect of the proportion of raw materials on Gramatur.

TABLE 4. The effect of material proportion on the Gramatur mean of Kraft paper

Ratio of Pulp (%) (Pulp of leaf midrib: Fruit fiber pulp)	Gramatur Mean (g/m^2)	LSD 5%
72:25	390.1^{b}	
50:50	162.8^{a}	11.76
25:75	188.5^{ab}	

Description: The mean with the same notation shows no significant difference ($\alpha = 0.05$).

Tensile Strength

The result of variance analysis showed that the proportion of raw materials, PVAc adhesive concentration, and the interaction of two factors had significant effect on tensile strength at 5% significance level. The higher the proportion of siwalan leaf midrib pulp, the lower the mean value of tensile strength, whereas the higher the proportion of the fruit fiber pulp, the higher the mean value of paper tensile strength. It is because the fruit fiber pulp has a larger fiber diameter and cellulose content more than those of the leaf midrib pulp. The bond between the fibers is influenced by the characteristics of the fiber. Higher cellulose-containing fibers will increase fiber strength [12]. The average value of tensile strength due to the interaction between the proportion of raw material and the concentration of PVAc adhesive can be seen in Table 6.

Tearing Resistance

The result of variance analysis to the tear resistance of Kraft paper showed that the material proportion and concentration of PVAc adhesive had a significant effect on tear resistance at 5% significance level, while the interaction of two factors did not give a significant difference. The higher the leaf midrib pulp content, the lower the mean tear resistance, whereas the higher the proportion of fruit fiber pulp, the higher the mean value of Kraft paper tear resistance. The effect of the proportion of raw materials on tear resistance can be seen in Table 5.

TABLE 5. The Effect of Material Proportion on Typical Tearing Resistance of Kraft Paper

Ratio of Pulp (%) (Pulp of leaf midrib: Fruit fiber pulp)	Tearing Resistance (gf)	LSD 5%
72:25	330.4[ab]	
50:50	197.6[a]	232.76
25:75	144.8[a]	

Description: The mean with the same notation shows no significant difference (α = 0.05)

According to [13] suggested that fibers with thin and large diameter cell walls have a bond between large fibers so that the tensile strength and tear resistance are higher (Table 6). Conversely, fibers that have small diameter tend to retain their shape during the formation of thick sheets and pipe-like shape, which is still visible on the sheet of paper. Due to the lack of extensive inter-fiber contacts, the resulting paper has relatively low tensile and tear resistance. The widespread use of PVAc can produce good adhesive strength thus it is especially appropriate for adhesives in the manufacture of Kraft paper sheets. The strong tensile properties lead to greater binding rates so that PVAc can support the tensile strength and tear resistance of paper [9]. The resulting bond of PVAc is very strong and not easily damaged by organic solvents, therefore, the required PVAc usage is relatively small compared to other binder types [9].

TABLE 6. The effect of raw material proportion and PVAc concentration on the tensile strength of Kraft paper

Research Design	Average of Yield (%)	Notation
P3L1	1.17	a
P3L2	1.39	b
P3L3	1.42	b
P2L1	1.63	d
P2L2	1.70	e
P2L3	1.76	e
P1L1	1.53	c
P1L2	1.61	d
P1L3	1.71	e

Description: The mean with the same notation shows no significant difference (α = 0.05).

The Best Treatment

The selection of the best treatment alternatives is done based on the value of the products obtained from the calculation of effectiveness index. The value of Kraft paper products ranged from 0.017 to 0.638. The best alternative calculation as presented in Table 7 shows the highest product value is obtained at P2L2 treatment with the product value of 1. It indicates that this alternative is the most favored paper by the panelists. This alternative has better color and surface texture than others.

TABLE 7. The best treatment alternatives

Research Design	Score	Priority of Alternatives
P2L2	0.638	1
P1L3	0.386	2
P2L3	0.317	3
P1L2	0.253	4
P1L1	0.217	5
P2L1	0.159	6
P3L3	0.082	7
P3L2	0.055	8
P3L1	0.017	9

CONCLUSION

The treatment of diverse proportion of raw material and PVAc adhesive concentration has significant effect on the color, surface texture, yield, and tensile resistance, but insignificantly different between treatment of gramatur and tear resistance. The best treatment of sensory tests is Kraft paper with proportion of 50% Siwalan leaf midrib pulp , 50% fruit fiber pulp and a 7.5% PVAc adhesive concentration. It has a yield value of 72.11%, gramatur of 162.8 (g/m^2), tensile strength of 1.70 (%), and tear resistance of 197.6 (gf).

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