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PEMANFAATAN LIMBAH PERKEBUNAN SIWALAN (*BORASSUS FLABELLIFER* L.) UNTUK PRODUKSI *PAPER KRAFT*

UTILIZATION OF SIWALAN (*BORASSUS FLABELLIFER* L.) PLANTATION WASTE FOR KRAFT PAPER PRODUCTION

Azmi Alvian Gabriel, Yunita Siti Mardhiyyah

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ABSTRACT

Borassus flabellifer L., one of the palm-based commodities in Indonesia grows in dry areas especially around the north coast of Java Island. An abundant waste of this plant is a leaf midrib and fruit fiber have an opportunity as a source of lignocellulose for the paper industry. In this study, Kraft paper production was conducted to know the influence of the proportion of *Borassus flabellifer* L. leaf midrib pulp and the fruit fiber pulp, and the concentration of Polyvinyl Acetate (PVAc) adhesives on the sensory and physical quality of kraft paper. The research method used was Randomized Block Design (RBD) with two factors. The Friedman test was used to determine the sensory quality of kraft paper. The physical quality of kraft paper was used ANOVA analysis. The results showed that the treatments of raw material proportion and PVAc adhesive concentration had significant effects on color, surface texture, yield, and tensile resistance, but not significantly different between treatment of gramature and tear resistance. The best treatment of sensory tests was kraft paper with proportion of leaf midrib pulp 50% and fruit fiber pulp 50% and a 7.5% PVAc adhesive concentration. It has a yield value 72.11%, gramature 162.80 g/m^2, tensile strength 1.70 %, and tear resistance 197.6 gf.

1. INTRODUCTION

As the times progressed, the pulp and paper industry persisted and sought to grow as indicated by the growing demand that led to the search for new sources and hitherto unexploited sources of cellulosic fibers. Indonesia as a megadiversity country only about 8000 species of flora are identified, less than a dozen are in commercial use for pulp production. Most of these species, commonly found in plantation enterprises, though not always be favorable in pulp and paper production with respect to fiber quality and wood composition.

Borassus flabellifer L. 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 ranged from 0-800 m above sea level with rainfall rate around 500-5000 mm/year. Generally, Siwalan is used for fruit and juice consumption resulting from the tapping process. There are 40-70 pieces of leaves midrib per tree. It was a by-product of plants that are often encountered both for the ease of harvesting and maintenance of Siwalan trees. Due to the cellulose content which reach 40.86%, it was likely to be alternative paper materials.

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%. The main aim of producing chemical pulp is to breakdown the structure of the middle lamella to separates the fibers individually and cast off the lignin content. During this process, since huge

Azmi Alvian Gabriel*, Yunita Siti Mardhiyyah
Department of Agro-industrial Technology, Faculty of Industry and Agro-industrial Technology
Universitas Internasional Semen Indonesia,
Jl. Veteran, Gresik 61122, Indonesia
*E-mail: azmi.gabriel@uisi.ac.id

amount of lignin and hemicelluloses in the cell wall are being broken down, elasticity of the separated fibers increases. Because mechanical energy is not being used for separating the fibers in chemical pulping methods, mechanical damage are not seen on the fiber surfaces. 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.

In kraft paper making, to bind the inter-fiber component in the paper forming process requires the addition of an adhesive material so that the fibers can form a strong sheet of paper. PVAc (Polyvinyl acetate) is an adhesive suitable for paper and wood, and PVAc adhesives are considered more environmentally friendly because PVAc is a biodegradable rubber polymer, unlimited shelf life, and resistant to microorganisms.

The objective of this study was 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 obtaining the appropriate proportion of raw materials and adhesive concentrations to produce the best sensory and physical of kraft paper.

2. MATERIALS AND METHODS

Materials

Siwalan has natural spread area on around the North Coast Java Island. Especially, it spreads on Situbondo, Bangkalan, Tuban, Lamongan, and Gresik District. As the raw material for this study, Siwalan was selected from Gresik District, East Java. The materials used in the kraft paper making process were pulp of leaves midrib, fruit fiber pulp, water and wood glue brand "Rajawali" which is made from Polyvinyl acetate (PVAc). The tool used in this research was, knives, scissors, digital scales, pans, stirrer, measuring cups, blenders, tubs/ buckets, screen, filter cloth, and oven. While the tool used for physical testing of paper was Paper Tensile Strength Tester.

Methods

The research method used was Randomized Block Design (RBD) which was arranged in a factorial consisting of 2 factors, namely: The proportion of raw material (P) consisting of 3 levels and PVAc Adhesive Concentration (L) to the total weight of the material, consisting of 3 level. The research designs shown in Table 1.

Sensory quality test was determined by hedonic scale scoring method by considering each attribute such as color and paper surface texture. Friedman's test was used to analyze the sensory quality score for each paper. While the best treatment from sensory quality test results was analyzed using the effectiveness index method.

Table 1. The research design

Adhesive concentration (L)	Proportion of raw material (P) (leaves midrib: fruit fiber)		
	P1 (25:75)	P2 (50:50)	P3 (75:25)
L1: 5%	P1L1	P2L1	P3L1
L2: 7.5%	P1L2	P2L2	P3L2
L3: 10%	P1L3	P2L3	P3L3

ANOVA analysis (Analysis of Variance) was used to determine the effect of experimental design on the results of the physical quality of kraft paper.

Kraft Paper Processing

The stages of making Siwalan kraft paper begin with the delignification process on the leaves midrib and the fruit fibers to produce pulp. Both of materials which had been reduced in size were then boiled separately by heating for ± 120 minutes and NaOH was added by 10% of the weight of the material to produce pulp. The pulp from the both of materials was then weighed according to the proportion of the research design and put into a blender added with water to mix and blend for ± 2 minutes until the slurry became homogeneous.

The fiber slurry resulting from blending was mixed with adhesive (PVAc) with the specified composition, then blended for ± 1 minute. The mixed slurry was poured into a 60-mesh screen size 15 x 20 cm, placed in a tub filled with water to facilitate the process. Then the pulp was flattened and stirred by hand.

Wet paper was covered with a filter cloth, coated with a plywood plate and drained using a sponge. This was done to facilitate the release of paper from the screen print. The next step was to remove the paper from the screen and pressed using presses to flatten and reduce the moisture content on the kraft paper. Pressed kraft paper was then dried using an oven for ± 100 minutes with a temperature of ± 80°C (up to 5% moisture content). Dry paper on the screen can be removed and trimmed by using scissors.

3. RESULT AND DISCUSSION

Siwalan was included in the category of hardwood with blackish wood. It was hard and dense, with stringy type grain. Approximating to

siwalan rods, the siwalan midrib has similar characteristics. Main chemical composition of siwalan midrib were determined and shown in Table 2. As shown in Table 2, lignin content of Siwalan midrib was found as 21.48%, which was comparable to all hardwood (20-25%). The average holocellulose content was found 73.77%, most annual plant and coniferous were 68-74%. Then, the α-cellulose in Siwalan midrib (40.86%) was on range of α-cellulose in Hardwood (39-45%).

Some sensory quality test, shown that the research designs gives characteristic difference to sample tested. Average score of panelist favorites on kraft paper color between 1.35 to 4.15. This indicates that the panelist's preference for the color of the kraft paper was of sufficiently good quality. Based on the assessment results, the panelists favored the kraft paper type with the proportion of leaf midrib pulp (50%) and the fruit fiber pulp (50%), and the 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 kraft paper with other formulations. The kraft paper of the study has different colors depending on the proportion of the materials used, the paper with the proportion of higher 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 leaves midrib tend to be blackish due to black dominant wood and bark.

Table 2. Some chemical analysis result of Siwalan midrib

Chemical composition	Mean Score		Coniferous
	Fruit fiber	midrib	
Hemicellulose (%)	21.69	26.11	-
α-Cellulose (%)	35.61	38.36	39-45
Lignin (%)	15.02	20.01	20-25
Fiber length (mm)	1.08	1.83	1.0 – 1.3
Fiber width (μm)	14.88	21.17	18-19

Friedman test results on the color of kraft paper shows that the value of X2 (count) was greater than the value of X2 table (α = 5%), can be interpreted that between treatments there was a real difference. This were because the panelists judge that the color of kraft paper tested was of varying color so that in the assessment it has a noticeable effect on the selection of kraft paper. The result of respondent preference calculation was shown in Figure 1.

The average value of the panelist preference score for the kraft paper surface texture was between 1.85 and 4.15. The value obtained shows that the resulting kraft paper has a pretty good to very good quality. Based on the results of the assessment it was found that the most preferred formulation for paper surface texture was the proportion of pulp leaf (50%) and the fruit fiber pulp (50%), and the adhesive PVAc 7.5% with a total score of 4. The surface texture on kraft paper was influenced by the type of fiber owned by medium-sized Siwalan leaves 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 other kraft paper products.

The result of Friedman's test on kraft paper surface texture shows that the value of X2 (count) was bigger than X2 table value (α = 5%), which means that the combination of treatment has a significant effect on the average of kraft paper surface texture. According to Lopez *et al.*, surface texture was concerned with the quality of the paper surface determined by the relative size of the fiber's dominant cells.

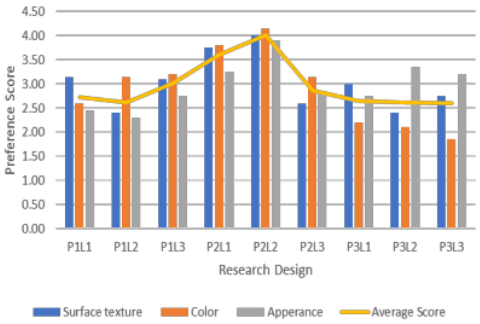

Figure 1. The result of sensory quality

Yield of Product

The result of variance analysis showed that the proportion of raw materials and the interaction of two factors used (raw material proportion and PVAc adhesive concentration) had a significant effect on yield, but PVAc adhesive concentration had no significant effect on the 5% level. The average value of yield on kraft paper made from raw mixture of 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.

Gramature of Product

The result of variance analysis on gramature

showed that the proportion of raw materials has a real effect, but PVAc adhesive concentration, and the interaction between material proportions and adhesive concentration has no significant effect. The kraft paper gramatures were between 162.8 - 390.1 g/m2. Fibers that have larger diameter will be more suspended above the screen when the filtering process, while fibers that have a smaller diameter will be much missed and affect the decrease gramature paper. Table 4 showed the data of the effect of the raw materials proportion on gramature.

Table 3. The effect of raw materials proportion and PVAc concentration on yield of kraft paper

Research Design	Average of Yield (%)
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 (α = 0.05).

Table 4. The effect of material proportion on kraft paper gramature

Ratio of Pulp (%) (Pulp of leaves midrib: Fruit fiber pulp)	Gramature (g/m²)	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 (α = 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 used had significant effect on tensile strength at 5% level. The higher proportion of Siwalan leaf midrib pulp resulted in a decrease in the mean value of tensile resistance, whereas the higher the proportion of the fruit fiber pulp used resulted in the higher average kraft paper drag resistance rate. This was because the fruit fiber pulp has a larger fiber diameter and cellulose content more than the leaf midrib pulp. The bond between the fibers was influenced by the individual nature of the fiber. Higher cellulose-containing fibers will increase fiber strength. The average value of tensile strength due to the interaction of raw material proportion and PVAc adhesive concentration can be seen in Table 5.

Tearing Resistance

The result of variance analysis to tear resistance of kraft paper showed that material proportion and concentration of PVAc adhesive had a significant effect on tear resistance at 5% level, while the interaction of two factors used did not give a real effect. The higher leaf midrib pulp content results in a decrease in the mean tear resistance, whereas the higher the proportion of fruit fiber pulp results in a higher mean value of kraft paper tear resistance. The effect of the materials proportion on tear resistance can be seen in Table 6.

Table 5. The effect of raw materials proportion and PVAc concentration on kraft paper tensile strength

Research Design	Average of Yield (%)
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).

Table 6. Effect of Material Proportion on Typical Durability of Kraft Paper Torn

Ratio of Pulp (%) (Pulp of leaves 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).

Mulyana *et al.,* 2007, suggests that fibers with thin and large diameter cell walls have a bond between large fibers so that tensile strength and high tear resistance were produced. Conversely fibers that have small diameter, tend to retain their shape during the formation of thick sheets and pipe-like shape that was 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 so it was especially appropriate for adhesives in the manufacture of kraft paper sheets. The strong tensile properties lead to greater binding rates so that PVAc can add tensile and tear resistance to paper. The resulting bond of PVAc was very strong and not easily damaged by organic solvents, therefore the required PVAc usage was relatively small compared to other binder types.

The Best Treatment

The selection of the best treatment alternatives was selected based on the value of the products obtained from the calculation of effectiveness index. The value of kraft paper products ranged from 0.017-0.638. The best alternative calculation results in Table 7 show the highest product value obtained at P2L2 treatment with the product value being 1. It indicates that this alternative was most favored 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

4. CONCLUSION

The treatment of raw material proportion and PVAc adhesive concentration had significant effect on color, surface texture, yield, and tensile resistance, but not significant different between treatment of gramatur and tear resistance. The best treatment of sensory tests was kraft paper with proportion of siwalan leaves midrib pulp 50% and fruit fiber pulp 50% and 7.5% PVAc adhesive concentration. It has yield value of 72.11%, gramatures of 162.8 g/m^2, tensile strength of 1.70 %, and tear resistance of 197.6 gf.

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