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The Making of Eco-Friendly Manila Paper by Utilizing Nata de Coco as Additional Material

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Abstract*: HVS paper waste is excessively abundant and thus requires further processing to reduce the waste level and to improve its utilization value. The advanced processing into manila paper will require other additional materials such as nata de coco due to its relatively high cellulose content. Nata de coco also has relatively short production timing, most of its cellulose product is in the form of sheet, and it is also chemical substance free. The best physical quality in the manila paper production is affected by tearing resistance, tensile resistance, and cracking resistance. All these resistances may be obtained by adding adhesive materials such as Pv Ac. The selection of Pv Ac is due to its high adhesive ability, solvability in water and low price. Besides the influence of tensile resistance, cracking resistance and tearing resistance, the production of manila paper is also affected by the precision of material concentration added. Thus, further research is required to identify the appropriate concentration for both additional materials (nata de coco and Pv Ac adhesive). The method used in this research was Group Random Planning consisting of two factors with two replications. Factor I was nata de coco concentration to paper at 4 levels, namely 40%, 50%, 60%, and 70% w/w. Factor II was adhesive concentration to the mixture of nata de coco and pulp of HVS used paper at 3 levels, namely 0%, 2% and 4% w/w. Physical analysis of manila paper used Analysis of Variance or ANOVA, which involved grammage test, tensile resistance test, tearing resistance test, cracking resistance test, thickness test, and water content test. The use of Multiple Attribute method to achieve the best treatment indicated that the results of the best physical quality of the manila paper were obtained from the treatment using 40% nata de coco concentration with 4% Pv Ac adhesive. Manila paper with 40% nata de coco concentration and 4% Pv Ac adhesive may produce grammage rate of 148.76 g/m^2, tensile resistance of 17.10 kgf, tearing resistance of 5.56 gf, cracking resistance of 1.11 kPa m^2/g, thickness of 0.27 mm, and water content of 3.47%.

***Keywords* : HVS paper waste, concentration, nata de coco, Pv Ac, adhesive**

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I. INTRODUCTION

HVS paper waste in Indonesia increased by 50% per year.

This abundant predicted waste can reach about 5 million tons per year for the category of HVS waste disposal in national scale. The high amount of HVS waste is due to the production of paper which is not comparable to the sewage process resulting from the use of HVS. It can be seen from the paper production estimation which reaches 13.7 million tons per year without being accompanied by increased paper recycling [1]. Therefore, HVS waste requires further processing to reduce the amount of waste disposal and to increase the waste value.

Recycled paper products resulting from HVS paper waste processing include manila paper. Several utilizations of manila paper such as for printing paper (poster or certificate paper), for bag paper products, for food boxes and for art activities have caused high demand for manila paper [2]. In Indonesia the demand for manila paper reaches 5.47 tons or its average is increased by 3.13% per year. To meet the demand, the paper industry needs to increase the production of manila paper by utilizing HVS paper waste.

II. MATERIALS AND METHODS

The processing of HVS paper waste into manila paper has been carried out by some manufacturers in the paper industry. Paper industry generally takes fiber derived from plant cellulose to be turned into manila paper. Unfortunately, the use of chemicals in sewage processing makes the environment polluted. Thus, there is a need of eco-friendly manila paper made with the best physical quality.

Unfortunately, reprocessing waste paper into recycled paper results in a lower level of physical quality than new plant cellulose-based paper. This is because there is re-pulping process of base material in waste paper that declines its fiber quality. In order to increase the quality so that it has equal quality level with the new one, it is necessary to add other additional materials. The required additional materials are those containing cellulose and fibers that can replace the quality of paper waste fibers. The additional material which can be used in papermaking is nata de coco.

According to Hastuti [3], nata de coco is the fermentation of coconut water-based materials composed from Xylinum Acetobacter bacteria compounds. These compounds are converted into cellulose released to the cell surface. The cellulose layers are formed layer by layer which eventually undergo a process of thickening on the surface of pollen fruit, and this thickening is called nata.

According to Sutarminingsih [4], nata de coco can be harvested twice, on 6 days old for 14 days. By this method, nata de coco can be produced with lower cost but higher quality since the bacterial cellulose resulted from nata de coco fermentation has several advantages than plant cellulose. The primacies of bacterial cellulose are that it has a purity of chemicals, contains high cellulose, and produces cellulose in the form of sheet in a relatively short time.

The process of making HVS paper waste-based manila paper with nata de coco as the additional material to produce the best physical quality is influenced by several factors such as tearing resistance, tensile resistance and cracking resistance. The high level of tearing resistance, tensile resistance and cracking resistance in the paper can be obtained by adding adhesive material. According to Hardjanto *et al* [5], adhesive material is a material which can bind various components of a particular structure effectively and easily. Adhesive material that can be added as a mixture in paper manufacture is Pv Ac adhesive (Polyvinyl Acetate). The selection of Pv Ac is due to its high adhesive power, light-resistance and abrasion resistance, solubility in water and relatively low cost.

Processing paper waste to manila paper with additional materials of nata de coco and Pv Ac adhesive requires proper proportion. The use of Pv Ac adhesive according to Malo [6] required 2-5% in concentration. However, the exact appropriate concentration of nata de coco and Pv Ac adhesive to produce the best quality of manila paper is still unknown. Therefore, it is necessary to conduct a research to know the precise concentration of nata de coco and Pv Ac adhesive to obtain the best quality of manila paper.

Manila paper resulting from the research is then tested by six parameters: Grammage, tensile resistance, tearing resistance, cracking resistance, thickness and water content tests. Data analysis of the test results is conducted by using Analysis of Variance (ANOVA) to determine if there is a difference or effect on each treatment ($\alpha = 0.05$).

The selection of the best is performed by using Multiple Attribute method. In this method, it is necessary to determine the important attributes of manila paper. The important attributes include grammage, tensile resistance, tearing resistance, cracking resistance, thickness and water content. After that, it is essential to determine the ideal value of each attribute of manila paper.

III. RESULTS AND DISCUSSION

A.Grammage

Grammage is the mass of paper sheet divided by the width in a unit of g/m2. The mean of manila paper grammage resulted from the concentration of nata de coco can be seen in Table- I.

Table- I.The Grammage Mean of Manila Paper Resulted from Nata De Coco Concentration

Nata de Coco (N)	Grammage Mean (g/m2)	Notation	BNT (0.05%)
40%	148.62	A	
50%	152.36	b*	0.30471
60%	153.31	C	
70%	152.28	b*	

It can be seen in Table 1 that the increasing grammage value goes along with the higher concentration of nata de coco. The reason is that the grammage paper value is very dependent on the weight of the sheet. The more the fiber pulp in the paper, the greater the paper grammage will be. Syaichu [7] stated that the rise and fall of the grammage value is greatly influenced by the extent of fiber pulp given. The more the fiber pulp given, the higher the value of grammage will be. Conversely, the less fiber pulp will make the value of the grammage lower.

It can be seen in Table- II that the increasing grammage value comes along with the size of the concentration of adhesive. It was because the adhesive has a density when used as fillers. The more the adhesive given in the paper, the greater the paper grammage will be. Sultonik [8] stated that the Pv Ac adhesive material was able to provide strong adhesiveness if used as filler material, if it was in dried form it can give the density of the material. The greater the filler material added in the mixture of material, the higher the weight of the material.

Table- II. The Grammage Mean of Manila Paper Resulted from Adhesive Concentration

Adhesive (P)	Grammage Mean (g/m^2)	Notation	BNT (0.05%)
0%	149.89	A	
2%	151.41	B	0.30471
4%	153.63	C	

B. Tensile Resistance

Tensile resistance is the maximum resistance of pulp path, paper and cardboard to the tractive power works on both ends of the line until breaking up. Tensile resistance is expressed in units of force per unit width of the test track and is measured at standard conditions.

It can be observed in Table- III that the paper tensile resistance decreases along with the increasing concentration of Pv Ac adhesive. This is due to the addition of too much Pv Ac adhesive. The addition of adhesive in the manufacture of paper can affect the level of paper tensile resistance, which is consistent with Malo's research result (2004) that the level of tensile resistance by adding adhesive in a material was determined by the accuracy of the proportion of the materials used.

Table- III. The Tensile Resistance Mean of Manila Paper Resulted from Adhesive Concentration

Adhesive (P)	Tensile Resistance Mean (kgf)	Notation	BNT (0.05%)
0%	16.11	a*	
2%	17.21	B	0.11770
4%	16.03	a*	

C. Tearing Resistance

Based on Table- IV, it can be seen that the tearing resistance is influenced by the combination of bonds among fibers, i.e. fibers of HVS used paper and fiber of nata de coco. Besides being influenced by the combination of inter-fiber, tearing resistance is also influenced by the proper combination of each fiber. Appropriate treatment with the addition of supporting material on manila paper manufacturing was shown in the treatment of 40% nata de coco as it showed the highest tearing resistance value. The lowest tearing resistance value was obtained on the treatment of 70% nata de coco. The fiber obtained from nata de coco is thin-walled fiber while HVS waste paper contains thick-walled fiber. This was supported by the opinion from Haygreen (1986). The thick-walled fibers will be able to produce high tearing resistance so that the addition of the fiber in the paper will be able to provide physical qualities such as high level tearing resistance. The number of fibers also has a role in long-fiber tearing and inter-fiber bonding.

Table- IV. Tearing Resistance Mean of Manila Paper Resulted from Nata de Coco Concentration

Nata de Coco (N)	Tear Resistance Mean (gf)	Notation	BNT (0.05%)
40%	5.20	D	
50%	4.71	B	0.05353
60%	4.86	C	
70%	4.46	A	

Based on Table- V, the tearing resistance of manila paper tends to increase with the rising concentration of Pv Ac adhesive. Increased concentration of Pv Ac adhesive was able to provide strength on inter-fiber bonding against tearing resistance. This result was consistent with Smook [9] that the strength of the paper was strongly influenced by the inter fiber bonding and the fiber integration contained in a sheet of paper. To strengthen the paper itself adhesives is usually added.

Table- V. The Tearing Resistance Mean of Manila Paper Resulted from Adhesive Concentration

Adhesive (P)	Tensile Resistance Mean (kgf)	Notation	BNT (0.05%)
0%	4.12	A	
2%	4.99	B	0.05353
4%	5.31	C	

D. Cracking Resistance

Cracking resistance is the force required to crack a piece of paper stated in kilogram/cm2 or kPa. It can be seen on Table-VI that cracking resistance is influenced by the addition of nata de coco fiber. The least cracking resistance value was from nata de coco concentration of 60% whereas the highest value was obtained by the concentration of 40%. The addition of 0% Pv Ac adhesive resulted in smaller cracking resistance value than the addition of 2% and 4% adhesive

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Table- VI. The Cracking Resistance Mean of Manila Paper Resulted from the Interaction Factor of Nata de Coco Concentration and Adhesive Concentration

Nata de Coco (N)	Adhesive (P)	Crack Resistance Mean ($kPam^2/g$)	Notation	BNT (0.05%)
	0%	0.91	Ba	
40%	2%	0.94	Bc	
	4%	1.11	Cb	
	0%	0.82	B	
50%	2%	0.88	Ac	
	4%	0.89	Ad	0.00242
	0%	0.80	A	
60%	2%	0.86	D	
	4%	0.89	Ca	
	0%	0.83	C	
70%	2%	0.87	Ab	
	4%	0.96	Bd	

Adhesive added to the making process of manila paper provides physical qualities such as high cracking resistance. The strength of cracking, according to Nursyamsu and Uzair [10], is influenced by the length of the fiber where the longer fibers has a higher cracking resistance. Furthermore, it is also influenced by the nature of the adhesive fibers which is able to bind the components. The dried processed adhesive makes it have stronger binding capacity than others [5].

E. Thickness

Based on Table- VII, the concentration of nata de coco significantly affected the thickness of manila paper sheets because there was an additional material, nata de coco which contains fiber. Nata de coco has a thickness of about 1-1.5 cm, but when added in paper making process, it was crushed (made it into smaller pieces) first. According to Ariyanto [11], nata de coco fiber contains cellulose about 0.55 to 0.67%, so the addition of nata de coco affected the thickness of the paper.

Table- VII. The Thickness Mean of Manila Paper Resulted from Nata de Coco Concentration

Nata de Coco (N)	Thickness Mean (mm)	Notation	BNT (0.05%)
40%	0.27	a	
50%	0.28	c*	0.00065
60%	0.28	c*	
70%	0.27	b	

It can be seen in Table- VIII that the thickness values do not vary much, only around 0.27 to 0.28 mm. The reason was that the form of Pv Ac adhesive used was gelatin which then was diluted during the mixing process so that the liquid had no thickness and when dried, it would change into a solid form. Sultonik [8] stated that Pv Ac adhesive was also able to strengthen the material when it was used in dried conditions.

Table- VIII. The Thickness Mean of Manila Paper Resulted from Adhesive Concentration

Adhesive (P)	Thickness Mean (mm)	Notation	BNT (0.05%)
0%	0.27	a*	
2%	0.28	a*	0.00065
4%	0.28	B	

F. Water Content

Water content is the difference between the weight of the material before and after heating. It can be seen in Table- IX that the highest water content of paper manila was obtained on the treatment using 40% of nata de coco concentration, i.e. 3.78%. On the other hand, the smallest water content was obtained in the treatment using 70% of nata de coco concentrations, i.e. 3.54%. Concentration of nata de coco gave real effect on manila paper sheet because the high water content in nata de coco decreased due to the drying process. According to Ariyanto [11], the goal of drying process in papermaking was to lower the water content of the materials used.

Table- IX. The Water Content Mean of Manila Paper Resulted from Nata de Coco Concentration

Nata de Coco (N)	Water Content Mean (%)	Notation	BNT (0.05%)
40%	3.78	c*	
50%	3.70	b	0.01565
60%	3.77	c*	
70%	3.54	a	

G. Determination of the Best Treatment

The selection of the best treatment on manila paper with additional materials such as nata de coco and Pv Ac adhesive was conducted using multiple attributes, by calculating the error value and the minimum value of L. The ideal value for each parameter was conducted by setting up the minimum value of grammage, maximum tensile resistance, maximum tearing resistance, maximum cracking resistance, maximum thickness, and minimum water levels The results of the best treatment were indicated by 40% nata de coco concentration and 4% Pv Ac adhesive concentration (N1P3) which have the grammage value of 148.76 g/m^2, tensile resistance of 17.10 kgf, tearing resistance of 5.56 gf, cracking resistance of 1.11 kPa m^2/g, thickness of 0.27 mm and water content of 3.47% .

The treatment of additional 40% nata de coco concentration and 4% Pv Ac adhesive concentration in HVS waste paper to make manila paper (N1P3) produced better grammage than the control treatment, i.e. pure manila paper which only had the grammage of 151.09 g/m2. The ideal grammage value of manila paper is at least 100g/m^2, so the grammage value of manila paper of 148.76 g/m2 has met the target in accordance with SII. Tensile resistance value of manila paper with 40% nata de coco concentration and 4% of Pv Ac adhesive concentration of 17.10 kgf is better than the tensile resistance of control treatment (pure manila paper) which only has the value of 15.99 kgf. The value also has met the SII standard minimum value of 1.18 kgf.

The tearing resistance value of manila paper containing 40% nata de coco concentration and 4% Pv Ac adhesive concentration had the value of 5.56 gf, which was higher than the tearing resistance of control treatment (pure manila paper) which only had the value of 4.15 gf. The value also meets the SII minimum standard of 1.20 gf. The same condition also meets the tearing resistance parameter. The tearing resistance value of manila paper (N1P3) containing 40% nata de coco concentration and 4% Pv Ac adhesive concentration was higher than that of the control treatment (pure manila) which only had the value of 1.02 kPa m^2/g. In addition, the value was also higher than the SII minimum standard value of 1 kPa m2/g.

The treatment of additional 40% nata de coco concentration and 4% of Pv Ac adhesives on HVS waste paper in order to produce manila paper (N1P3) produced better thickness compared to the control treatment of pure manila paper which had the thickness of 0.26 mm. The thickness of manila paper (N1P3) was good because its value had met the target in accordance with the SII minimum standard of 0.23 mm. Finally, the water content of manila paper (N1P3) was lower than the water content of the treatment control which was 3.05%. This value was also below the SII maximum standard of 6%. The best treatment is presented as in the Table- X.

Table- X. The Best Treament

Parameter	Unit	Target	Pure Manila Paper	The Best Treatment of Manila Paper	SII
Grammage	g/m2	Low	151.09	148.76	100-150
Tensile Resistence	Kgf	High	15.99	17.10	Min 1.18
Tearing Resistence	gf	High	4.15	5.56	Min 1.20
Cracking Resistence	kPa m2/g	High	1.02	1.11	Min 1
Thickness	mm	High	0.26	0.27	Min 0.23
Water Content	%	Low	3.05	3.47	Max 6

IV. CONCLUSION

Based on this research, we concluded that the best physical quality of manila paper was the one treated with 40% nata de coco concentration and 4% Pv Ac adhesive concentration. Manila paper with 40% of nata de coco concentration and 4% of Pv Ac adhesive produced 148.76 g/m2 for grammage value, 17.10 kgf for tensile resistance, 5.56 gf for tearing resistance, 1.11 kPa m2/g for cracking resistance, 0.27 mm for thickness and 3.47% for water content.

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