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Evaluation of Bamboo Paper Properties by Blending Recycled Pulp and Starch

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Abstract: The aims of this study to analyst the change of bamboo paper properties when the bamboo pulp blended with recycle pulp with addition of dry strength additive (DSA). This research will conduct two condition of paper that include with DSA and without DSA. In each condition, 4 parameters will be used that include 100%, 90%, 80% and 70% of recycle pulp. In conducting the material, paper process and testing, TAPPI and MS ISO standard be used to fit the requirement of 120gsm paper. In collecting the result, ANOVA analysis be used to determine the significant change of the testing result. In the tearing testing, the ANOVA analysis show a significant change on the high value at 7.54 m.N.m^2/at 70% recycle pulp. For the busting test and tensile test, the ANOVA analysis shows a not significant result on both test. Busting test recorded the high value is at 2.86 kPa.m^2/g on 100% recycle pulp without DSA and the value is getting decreasing to 2.34 kPa.m^2/g. for the tensile testing, the highest value is at 3. 40N.m/g on 90% recycle pulp with DSA and the value sharply decreasing to 1.12 N.m/g for 80% recycle pulp without DSA. As the result from the ANOVA analysis, 90% recycle pulp is the most optimum and constant result for the testing. From the optimum result, both 90% recycle pulp will be tested morphology surface on the Scanning Electron Microscope (SEM) to analyst the surface properties of the bamboo paper. As the result, the paper with addition of DSA is more structured bonding between of the fiber because the implement of the DSA. In the conclusion, addition of DSA in the bamboo paper properties is more effective in improving the structure and mechanical properties of the bamboo paper. the involvement of the DSA also restructures the bonding between the fiber.

Keywords: Blended, Bamboo Pulp, Recycle Pulp, Dry Strength Additive (DSA)

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1. Introduction

In this century, paper production is getting increased in the market due to the demand in all kinds of industry. This industry includes education, business, agriculture, and others [1]. This increasing demand of paper is due to the ability of paper material in maximizing the need for packaging materials, office users, store retailers and other applications that required paper. Approach the increasing demand for paper worldwide will affect the environment surrounding due to the decreasing tree population. The increased logging activity in the environment will affect air pollution, wasted material and water pollution [2]. The side effect of pollution due to the wood fibre is the main raw material in paper production. In order to reduce the site effect in paper production, blending the primary fibre with secondary fibre commonly reduces the wasted material effect in the environment [3]. Besides reducing the wasted material in the environment, the implementation of secondary fibre in the virgin paper properties is to restructure the bonding of the paper structure.

In the paper industry, wooden fibre commonly is used in paper pulping and paper making. In reducing the site effect in the environment, non-wooden fibre mostly effective solution to be used as raw material. The characteristic structure and mechanical properties of non-wooden fiber bring a possibility to replace wooden fibre in paper production [4]. Among the non-wooden fiber, bamboo is most used in pulping and paper industry. The involvement of bamboo fibre in paper due to the structural properties and mechanical properties of the bamboo fibre is compact with the wood fibre properties in producing the paper. The mechanical properties of bamboo long fibre bring a bright in developing the paper properties. The bamboo fibre properties contain high brightness and contain alpha-cellulose [5].

In reducing the waste material in the environment, recycled paper will be used as the secondary fibre. This implementation of the recycled pulp for rebounding the structure of the paper properties in virgin fiber [6]. The recycled pulp can increase the yield and strength of paper, improving its properties. Besides improving the paper structure, the addition of recycled pulp is willing to improve the quality of the paper [7]. The involvement of quality can be seen from the quality of the fibre is getting an increase when the virgin pulp is blended with recycled pulp.

Dry strength additive be used to increase the strength of the fiber bonding in the paper properties [8]. Cationic starch be used as a DSA in improving the strength of the paper. The involvement of Cationic starch improves mechanical paper strength, fines and filler retention, dusting, water drainage, paper quality, and productivity. The positively charged cationic group attracts negatively charged cellulose fibers and surface particles [9]. The cationic starch is widely used in industry due to its properties, such as pasting, thermal properties, solubility, and ageing resistance, which are more effective than other starches [10].

The aim of this study is to implement the cationic starch in restructuring the bonding between the bamboo pulp and the recycled pulp in different doses of condition. In implementing the different of results, different types of conditions and doses are used to determine the different results in the study. To fulfil the requirement of the TAPPI and MS ISO, various of doses parameter be used to determine the different type of properties on the paper. After condition the papermaking, the paper will be tested on the structure and mechanical properties according to the TAPPI and MS ISO standard. To determine the data analysis, Analysis of Variance (ANOVA) be used to determine statistical analysis. After the data analysis, a Scanning Electron Microscope (SEM) used to determine the morphology of the structure of the paper.

2. Materials and Methods

2.1 Material

In the study, the material be used is using the Dendrocalamus asper bamboo as a bamboo pulp and office paper as recycle pulp. The Bamboo provided by the supervisor that located at the project packaging lab that located in the UTHM and the office paper is provided by UPP Pulp and Paper (M) Sdn. Bhd. For the DSA, Cationic starch industry grad from QUARTS CHEMICAL SDN. BHD be used to be the DSA in the paper properties. The method used in the study is blended the bamboo pulp and recycle pulp with addition of cationic starch. Figure 1 show the material be used in the study.

(1) (2) (2)

Figure 1: (1) Bamboo pulp, (2) Recycle pulp, (3) Cationic starch

2.2 Pulp Preparation

The method be used in this study is blending the fibre. This method is Mixing different fibres together. In this study, 8 types of sample with different conditions and doses be used in determining the change of each result. The procedure is using 2 L water and blending the pulp together in a Disintegrate Pulp. Table 1 Show the doses and condition of the pulp Air Dry weight.

Table 1: Doses and condition pulp

Paper Doses	No DSA	1.5% cationic starch
100% recycle pulp	86g	92 g
90% recycle pulp 10% bamboo pulp	77g 10g	84g 10g
80% recycle pulp 20% bamboo pulp	70 g 20 g	76g 20g
70% recycle pulp 30% bamboo pulp	62g 30g	66g 30g

2.3 Handsheet formating process.

In formatting the paper sheet, the paper formatting will use 120 gsm standard to fulfill the requirement of TAPPI-205 sp-02 "and ISO 5270:2012 "Pulps – Laboratory sheets determination of physical properties" Forming Hand sheet for Physical Test of Pulp". In the first process, the pulp will be blended in pulp disintegrator with the addition of 2 L of water (Figure 2: (a)). After blending the blending process, the pulp will be filling in the British Hand sheet Former with the addition of 10 L of water. To make sure the pulp mixture in the feeder, time pour and fill be done to ensure the pulp well mixture in the feeder. For the first pour and second pours of the pulp used to the do correction. After the correction paper dry, the paper will be weight in to calculate the correction for the water quantity. After the correction complete, the pulp will start to prepare 10 sheet of sample paper. The pulp will be poured in the stock divider to format the shape of the paper. In the stock divider, the water level will be raises until the level that required and the pulp will mixture before the water will be drain out (Figure 2 (b)). The stock divider will be opened and beating process will be done by using 3 layer of paper and 1 plate. The paper will be roll for 10 times to eliminate the water contain on the paper. After the beating process, the paper will transfer to a piece of paper and will be put between two plates. After complete 10 sample of the paper, the sample will be press with 275 kPa force on a pneumatic sheet press machine with duration time of 5 minute (Figure 2 (c)). The pressing process will conduct 2 times. After the pressing process complete, the sample will be stack in a standard rings, together with a complying paper. A metal block will be add on the top of the rings to prevent the paper edges from drying out. After the drying process, the paper will weight on a scale to determine the grammage of the paper (Figure 2(d)). Figure 2 below show the Hand sheet formatting process.

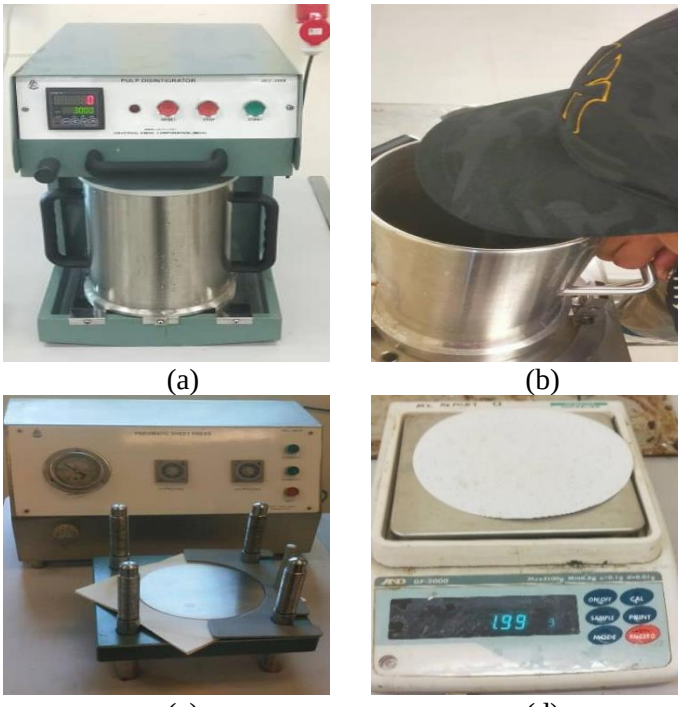

Figure 2: (a) Blending the pulp, (b) Paper formatting process, (c) Pressing Process, (d) Paper weight

2.4 Determination of Pulp and Paper Properties

To determine the properties of the bamboo paper, 5 types of testing included grammage, thickness, tearing, bulking and tensile. The standard of the testing is according to the MS ISO standard. Table 2 below shows the MS ISO standard that is used to determine the structure and mechanical properties.

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Table 2: Structure and Mechanical Properties standard

Testing	TAPPI/ MS ISO
Grammage	MS ISO 536: 2012: Paper and board – Determination of Grammage
Thickness	MS ISO 534:2005: Paper Paper and board - Determination of thickness, density and specific volume
Tearing	MS ISO 1974: 1999: Paper – Determination of Tearing Resistances – Elmendorf Method – Second Revision (ISO 1974: 1990, IDT
Busting	MS 1SO 1974: 1999: Paper – Determination of Bursting Strength (ISO 2758: 2001, IDT
Tensile	MS ISO 1924-2:2008 Paper and board - Determination of tensile properties

2.5 Statistical analysis

ANOVA analysis is doing determine the different properties between pure bamboo paper and the bamboo mixed with recycle paper pulp. These properties be affected from the different doses of recycle paper (70%, 80% and 90%). The experiment scored among of the set hand sheet by comparing with the Turkey's Group Range Test ($P \leq 0.05$).

3. Results and Discussion

3.1 Result

Base on the result testing, they are two types of properties that be tested in this study. These properties include structural properties and mechanical properties. In the physical properties will find the bulking density and the apparent density. Meanwhile, for the mechanical properties, the test will include tearing, busting and tensile.

3.2 Table

Table 3 and Table 4 below show the structure and mechanical properties testing analysis and ANOVA analysis using Turkey's Range Grouping. In the table they are three type of benchmarks that include Recycle Pulp (RP), Bamboo Pulp (BP) and Dry Strength Additive (DSA). The increasing of doses bamboo pulp and addition of Dry Strength additive (DSA) in the paper properties willing to increases the tearing resistance of the paper.

In the structure properties, table 3 below shows the ANOVA analysis for the structure properties. Two type of testing used to determine the structure properties of the paper. The test includes grammage and thickness test. From the grammage result, each of the paper doses quality for the 120 gsm standard that. For the thickness test, the results from Table 3 show that increasing the doses of bamboo pulp and the addition of DSA in the paper properties increases the paper thickness. This is seen through the bulking density, which increases when both the bamboo pulp and DSA are added. The paper parameters on 100% RP with 1.5% cationic starch resulted in the highest increase in thickness, up to 364.22 μm. Furthermore, the addition of DSA to the paper properties has a significant impact on the apparent density, with the value decreasing as the doses of BP increase.

Table 3: Result of Structure properties with Turkey's Range Grouping

Handsheet Properties	100% RP, 0% BP	90% RP, 10% BP	80%RP, 20% BP	70% RP, 30% BP
Structure Properties				
Thickness (μm)				
Non- DSA	262.10^{B}	246.14^{C}	466.62^{A}	311.02^{B}
	(±74.40)	(±7.80)	(±20.46)	(±12.25)
With DSA	255.40^{B}	272.62^{B}	333.40^{B}	360.70^{A}
	(±42.80)	(±11.61)	(±372.5)	(±89.8)
Apparent density (cm^3/g)				
Non- DSA	0.49^{A}	0.48^{A}	0.25^{D}	0.39^{B}
	(±0.10)	(±0.02)	(±0.01)	(±0.15)
With DSA	0.46^{B}	0.43^{B}	0.35^{C}	0.34^{C}
	(±0.07)	(±0.02)	(±0.07)	(±0.06)

Meanwhile in the mechanical properties, the ANOVA analysis show the change of the paper properties brings a significant and not significant result in the testing. This result can be observed from the ANOVA analysis result for tearing, busting and tensile testing of the bamboo paper.

According to the Table 4 below, ANOVA analysis for the tearing test show a significant result between among the condition of the paper. The significant different can be observe when the increasing among of the Virgin fiber in the paper properties. The most height value be recorded at the 7.54 m.N.m^2/ g at the condition of 70% recycle pulp with DSA. This significant be resulted from the virgin fiber contain in the bamboo paper. A research study before [11] state that the increasing of the virgin pulp in the paper properties can improve the tearing strength of the paper.

Base on the result busting testing in the table 4 below, a not significant result be recorded from the busting index. From the following result at table 4, the height result is 2.86 kPa.m^2/g on condition of 100% recycle pulp without DSA and the lowest is 2.34 kPa.m^2/g that recorded at 70% recycle paper. This not significant result can be causes by the minor mistake or error in the paper making and testing process. From the previous research [11], the involvement of the virgin pulp in the analysis should increase the busting index of the paper. This unexpected result may be caused by minor mistake in paper formatting.

The last result base on the mechanical properties is tensile testing. Base on the table 4 below, a significant be observe from the ANOVA analysis. the height result of the tensile index recorded at 3.40 N.m/g on condition 90% recycle paper with DSA and the value sharply decreasing to 1.12N, m/g that recorded on 80% recycle pulp without DSA. This significant result can be explaining by the study of [12] that state the involvement of the DSA in the paper properties improve the tensile index of the paper.

Table 4: Result of Mechanical properties with Turkey's Range Grouping

Handsheet Properties	100% RP, 0%BP	90%RP, 10% BP	80% RP, 20% BP	70%RP, 30% BP
Tearing index ($m.\ N.m^2/g$)				
Non – DSA	3.44^C	4.87^B	2.88^C	4.70^B
	(± 1.06)	(± 0.78)	(±0.21)	(± 0.15)
With 1.5%DSA	6.50^B	7.32^A	6.58^B	7.54^A
	(± 1.42)	(±0.87)	(±2.01)	(±0.92)
Busting index (kPa.m^2/g)				
Non - DSA	2.86^A	2.82^A	2.70^A	2.34^B
	(±0.64)	(± 0.06)	(±0.20)	(±0.23)
With 1.5% DSA	2.81^A	2.75^A	2.44^A	2.34^B
	(±0.18)	(±0.14)	(±0.33)	(±0.17)
Tensile index (N.m/g)				
Non -DSA	3.34^A	3.00^A	1.12^B	2.58^A
	(±0.29)	(±0.21)	(±0.11)	(±0.24)
With DSA	2.70^A	3.40^A	2.84^A	2.68^A
	(±0.51)	(±0.38)	(± 0.71)	(±0.49)

3.3 Figure

Base on following figure below show the change graft of the flow base on the sample result that recorded. This figure will involve mechanical testing that include the tearing index, busting index and tensile index.

Base on the Figure 3 below, the addition of DSA to paper properties significantly increased the tearing index for the 1.5% DSA paper compared to the no DSA paper. The figure 3 below show that the involvement of the virgin pulp and DSA in the paper properties increasing the tearing index of the paper. Condition with DSA domain the height value of the tearing index in the graft. This can be observing from the constant increasing graft when the addition of virgin fiber in the paper properties [11]. Figure 3 show the graph of the sample and the figure 4 show the sample of tearing testing.

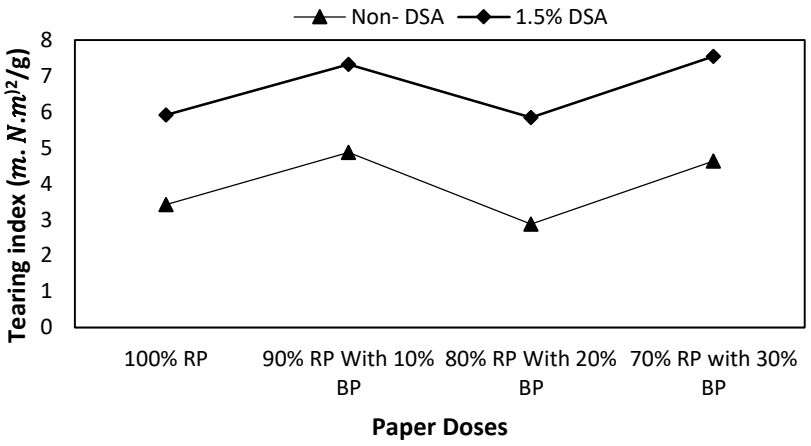


Figure 3: Tearing Index Vs Paper Doses

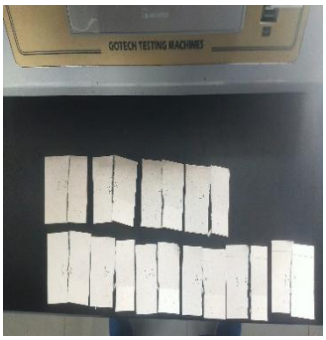


Figure 4: Tearing test Paper

For the busting index, figure 5 show that the result of busting bamboo is decreasing when the parameter of bamboo pulp is increasing. The readings for both sheets decrease as the parameter increases. The most optimum value is on the 100% recycle pulp on both conditions. Base on the ANOVA analysis before, the result of the busting in this research is not accurate with the previous research that conducted by the [11]. This in correct data can be causes by a minor error on paper process and testing process. Figure 5 below show the busting index graft and figure 6 show the sample of the busting test.

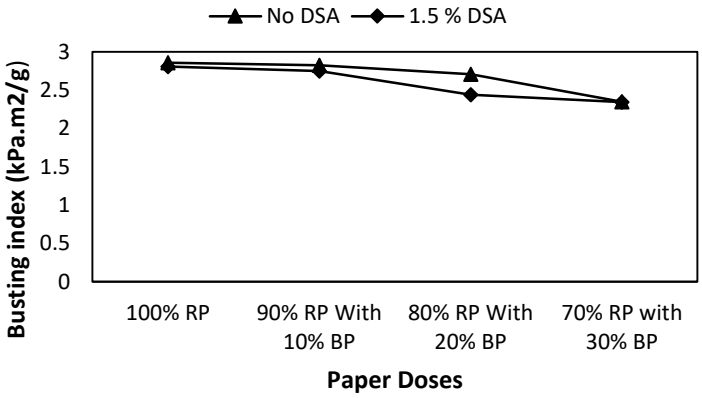


Figure 5: Busting Index Vs Paper Doses

Figure 6: Busting Testing Paper.

The last testing will include the tensile testing of the paper. base on the figure 7 below, the graft of both condition is different with each other. This can be observing from the condition with DSA is domain the height value of the tensile index. From the graft below, the 90% recycle pulp with DSA is the most optimum result for the tensile index. This significant result can be seen from the previous research [12] that claim of the involvement of the DSA in the paper properties improve the tensile index of the paper. Figure 7 below show the graft of the tensile and figure 8 show the ssample of the tensile testing.

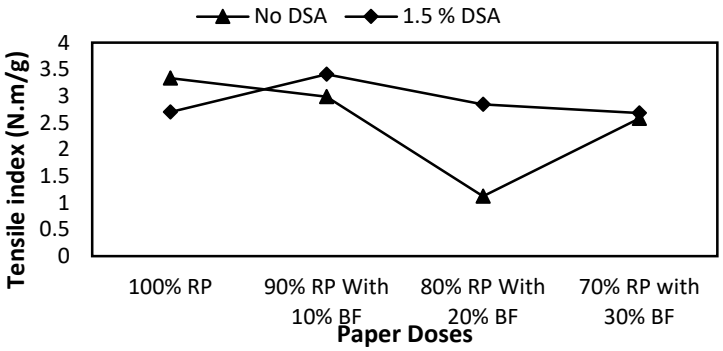
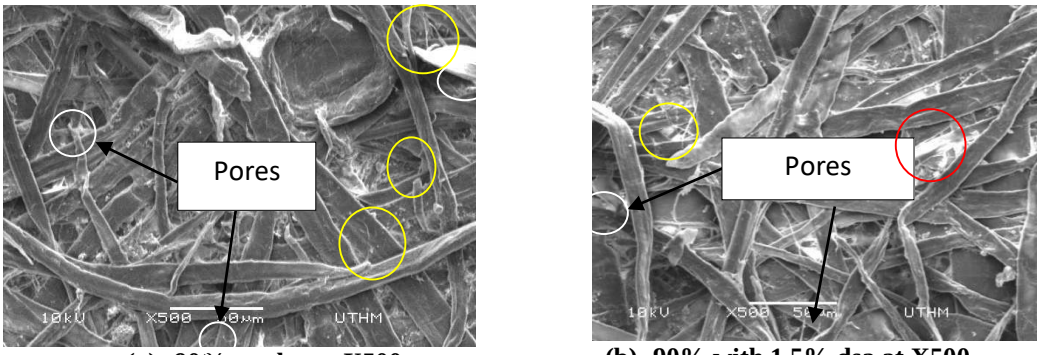


Figure 7: Tensile Index Vs Paper Doses

Figure 5: Tensile Paper testing.



(a) 90% no dsa at X500 **(b) 90% with 1.5% dsa at X500**

Figure 9: Image of Morphology surface.

Base on the circle in the Figure above, 3 typese of circle be defined from it a colour that include white line circle is (pores), yellow line circle is (broken fiber) and Red line circle (DSA). The control for the Morphology surface in the analysis is 90% recycle pulp and 10% bamboo pulp with the magnitude of X500. From the Figure 9 (b) the pores and the broken fiber is smaller and the bonding of fiber is structure well. Meanwhile, on Figure 9 (a) the Pores and the broken fiber is widely on the fiber and this bring an unstructured bonding between of the fiber. According to [13], the paper increasing bond strength results from the higher density when the paper's properties are blended with DSA.

4.0 Conclusion

The aim of this study is to identify the change in Pulp and papermaking properties involving blending two types of fibre including the Dendrocalamus asper fibre with the recycled paper fibre. In seeing the comparison between of the paper, the addition of cationic starch as the dry strength additive be used. The doses include 100%, 90%, 80% and 70% of recycle pulp and 10%, 20%and 30% of bamboo pulp be used in the study. As exchanges of the properties, the first objective successfully be achieved due to the complete all of the handsheet with different doses and condition.

All of the testing above uses TAPPI and MS ISO standards to achieve the structure and mechanical properties testing. From the tests, all of the tests prove that the involvement of DSA in the paper properties improves the performance of the paper. This significant result can be observed from the tearing index that recorded the value of the highest at 7.54 $N.m^2/g$ on the paper with 70% recycle pulp and 30% bamboo pulp with the addition of DSA. Meanwhile, for the 70% recycle pulp and 30% recycle paper without the addition of DSA recorded at 4.70 $N.m^2/g$. This brings a significant change on same doses paper. In the other tearing result, the result consistently increases. For the busting and tearing index, the result between both conditions is not significant. In the Busting strength, the result is getting to decrease if the doses of the bamboo fiber are getting increasing in the paper properties. The highest result recorded at 100% of recycle pulp without DSA that reaching 2.86 Kpa. m^2/ g and the lowest value recorded 2.34 Kpa. m^2/ g at both condition 70% recycle pulp and 30% bamboo pulp. In busting index, the graft is not consistently increasing and decreasing. The highest value is recorded at 3.40 N.m/g on 90% recycle pulp and 10% bamboo pulp with addition of DSA and the lower value is recorded at 1.12 N.m/g for 80% recycle pulp and 20% bamboo pulp without DSA. The value of the result is not consistently when reaching 80% recycle pulp for no dsa paper.

In determining the Morphology analysis of the sample, 90% recycle paper be selected to analysis the structure of the bonding. 90% RP with 20% BP was selected in the testing. The paper with DSA has a good structure surface and fewer pores then the no DSA paper. The involvement DSA in the paper properties increase the bonding of the fiber. This involvement of bonding. willing to connect the secondary fiber with the virgin fiber and increase the strength off the paper. In the conclusion, the involvement of DSA in the paper properties improve the structure and mechanical properties of the bamboo paper.

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