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The Effect of Natural Fiber Percentage on the Tensile Strength of Paper Using ANOVA

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Abstract

Paper is generally made of cellulose fibers derived from wood raw materials. Increased demand for production will impact forest exploitation which can lead to environmental stability. Alternative natural fibers containing cellulose fiber are biomass waste such as Galangal Stems (Alpinia Galanga), Pineapple Leaves (Ananas Cosmosus), Banana Stems (Musa Paradisiaca), and others. Using natural fibers can reduce the exploitation of wood as a raw material for paper. This study aimed to determine the effect of natural fibers consisting of galangal stems, pineapple leaves, banana stems, and waste paper on the tensile strength of paper using ANOVA. The ratio of the percentage of fiber passed is galangal stems 50:10 and 50:40, and pineapple leaves 50:10 and 50:40, banana contains 50:10 and 50:40, and waste paper 100% or without comparison. Tensile strength was measured according to ASTM-D638, then data was processed using the Way ANOVA method. The results showed that the highest tensile strength value of banana stem paper and waste paper with a ratio of 50:10 was obtained at 7.04262 MPa resulting in the best tensile strength compared to other fibers. Factors that affect the tensile strength are the length of the fiber and the bonds between the fibers are related to the fiber content. This study concluded that the greater the number of material components in the manufacture of recycled paper, the greater the tensile strength of the report produced.

Keywords: *Galangal Stem, Pineapple Leaf, Banana Stem, Anova, Tensile Strength.*

1. Introduction

Paper is generally made of cellulose fibers derived from wood raw materials. Cellulose fiber, widely used as a raw material for making paper, is a natural wood fiber. Alternative natural fibers containing cellulose fibers are non-wood natural fibers. These non-timber natural fibers can come from biomass such as galangal stems, pineapple leaves, banana stems, etc. The use of non-timber natural fibers can reduce wood exploitation. Biomass used as raw material for making paper can come from biomass waste. This aims to reduce the volume of new biomass waste in Indonesia. In the Aceh Singkil region, there is a lot of biomass waste in the form of galangal stems that have not been utilized.

Galangal stems that come from the garden are just garbage that is thrown away. Alternative materials other than natural fibers in manufacturing paper can use secondary fibers. Secondary fiber is the remaining fiber in its used form. This fiber can still be used as a raw material for recycled paper. Recycled paper making using secondary fibers can be mixed with non-wood natural fibers to improve the quality of the fibers. Cellulose fibers exhibit several properties that meet papermaking requirements, occurring mainly in plant cell walls and woody parts. Cellulose has a role that determines the character of the fiber in paper making. The use of galangal fiber for papermaking needs to be researched to replace wood fiber. This study tested the tensile strength of recycled paper based on the ASTM-D638 testing standard [1]. This research was carried out experimentally and conducted tensile testing of Used Paper and the development of various alternative natural fiber materials containing cellulose fibers to produce good quality paper [2]. Then the paper mixed with sugarcane pulp and banana peels can strengthen the report, and bagasse pulp and newsprint pulp used to make mixed fiber paper can be made into packaging paper [3]. Other researchers have researched the effect of the weight ratio of banana peels to newsprint and corn stalks to newsprint on recycled paper's tensile strength and tear strength [4]. This study used ANOVA to determine the effect of natural fibers of galangal stems, pineapple leaves, banana contains, and waste paper on tensile strength.

2. Literature Review

2.1. Paper

Paper is a thin, flat material produced by the compression of the fibers. The fibers used are usually natural fibers and contain cellulose. Paper is a material that is often used and consistently associated with humans. At least until now, paper is still believed to be the most effective and efficient material as a book medium. Because it is made of organic materials (wood fiber), paper is very prone to rotting, getting wet, flammable and moldy [5][6],[7].

2.2. Fiber and Pulp

In general, there are two types of fibers: natural and synthetic. Natural fibers can be obtained directly from nature, usually from fiber that can be obtained directly from plants and animals. Humans have widely used these fibers, including cotton, wool, silk, banana fronds, coconut coir, palm fiber, bamboo, and pineapple. Natural fibers have weaknesses. Namely, the size of the fiber is not uniform, and the strength of the fiber is greatly affected by age. Synthetic fibers are fibers made from inorganic materials with a particular chemical composition. Synthetic fibers have several advantages, namely the relatively uniform properties and sizes. Besides that, the fiber strength can strive to be the same along the length of the fiber. Synthetic fibers widely used include glass fiber, carbon fiber, kevlar, nylon, and others [8]. The primary purpose of making wood pulp is to remove fibers which can be done chemically, mechanically, or by combining two types of treatment. The. Typical pulps are chemical, semi-chemical, mechanical, and mechanical. Chemical pulping is a process by which lignin is completely removed until the wood fibers are easily removed upon withdrawal from the digester or at least after a mild mechanical treatment. Nearly all chemical pulp production today is mainly based on sulfite and sulfate processes [9].

2.3. Alpinia galangal Fiber

The community often uses galangal or galangal in terms of treatment because of its antibacterial and antifungal properties. Galangal is an upright plant with a stem height of 2-2.5 meters. Galangal can live in the lowlands to the highlands, approximately 1200 meters above sea level. There are two known types of galangal plants, namely varieties with white tuber rhizomes (roots) and varieties with red tubers. Galangal has a tree trunk consisting of an arrangement of leaf midribs. The leaves are elliptical, and the leaves found at the bottom consist of only the midribs, while the upper part of the stem consists of the fronds complete with leaf blades. The flowers appear at the ends of the plant. Besides being coarse fibrous, the rhizome of galangal tubers also has a distinctive aroma. There has been much use of locally abundant Alpinia galanga natural fiber because agro-waste fiber generally functions as a potential natural-organic filler and exhibits strengthening attributes for specific threads [10]. The galangal stem can be seen in Figure 1a.

2.4. Pineapple (Ananas Comosus) Fiber

Pineapple crested fiber is a type of plant-derived fiber obtained from the pineapple plant leaves. In general, including types of annual plants. There are more than 50 types of pineapple plants in the world. Various kinds of pineapple plants cultivated in Indonesia include Cayenne, Spanish / Spanish, Abacaxi, and Queen. Pineapple (Ananas Comosus) is an alternative fiber-producing plant whose fruit has only been used as a food source. Based on data from the Central Statistics Agency (BPS), the average pineapple production in Indonesia is 1.5 million tonnes/day. Seeing the large number of pineapple plants produced yearly, pineapple leaves have great potential to become waste. Pineapple leaf fiber has a tensile strength almost twice as high as glass fiber, so this fiber is one of the reinforcements for paper making [11]. Pineapple stalks can be seen in Figure 1b.

2.5. Banana (Musa paradisiaca) Fiber

A Banana is a plant that does not branch and is classified as a monocotyledon. The stem that forms a tree is a pseudo-stem, consisting of regularly arranged leaf sheaths, branching plants of the sympodial type (Poko stems are difficult to determine), and elongated tip meristems that form flowers and fruit. The fruit at the bottom of the banana stem bulges in the form of a tuber called a hump. Lateral shoots emerge from the buds on the stump, which then grow into banana plants. Banana plant stems have a layered arrangement from the young part on the inside to the old claim on the outside. Besides being layered, the banana plant contains a refined understanding of fibers. Fiber can be obtained from old banana plant stems or stems with shallow water content, so these fibers can be observed correctly and are easily separated [12]. The banana stem can be seen in Figure 1c [12].

2.6. Waste Paper

Used paper or paper waste that accumulates and is improperly processed can harm the environment. This can be prevented by processing the waste paper into a product that is environmentally friendly, of better quality, and has a sale value. The new product is processed using the paper folding technique, a traditional art passed down from generation to generation and known by the world community. Through the process of exploring paper waste, it is expected to provide several alternatives that can be applied to new products [13][14][15].

Fig 1.a. Galangal

Fig 1.b. pineapple fiber

Fig 1.c. Banana

2.7. Tensile Test

A tensile test is a method used to test the strength of a material by providing an axial force load. The results of tensile testing are significant for engineering and product design because they produce material strength data. Tensile testing is used to measure the resistance of a material to a static force that is applied slowly. Tensile testing is carried out by machine according to the ASTM D638 tensile or universal testing standards. The theory states that a material behaves elastically and exhibits a linear relationship between stress and strain which is called linearly elastic [1],[2],[15[,[16]. The specimen of the testing machine is shown in Figure 2.

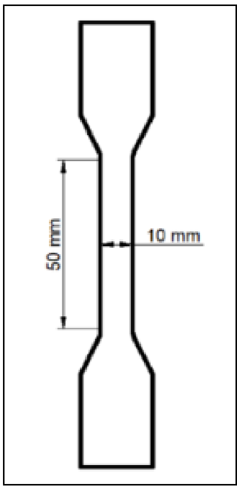

Fig 2. Testing specimens

2.8. One-way Anova (One Way ANOVA)

It is called a one-way analysis of variance because the analysis uses friction, and the observed data is the influence of one factor. We take a random sample from each population independently, size n1 from the first population, n2 from the second population, and so on, size nk from the k population. Sample data will be expressed with Yij, which means the jth data in the sample taken from the i-th population [17], [18], [19]. The one-way ANOVA test aims to compare more than two means. In contrast, the point is to test the ability of generalization. That is from the significance of the research results. If proven to be different, the two samples can be generalized (sample data is considered representative of the population). One-way ANOVA can see comparisons of more than two groups of data. The Anova table can be seen in Table 1.

Table 1. One-way ANOVA

Source of Variation (SV)	The sum of Square (SS)	Degree of freedom (df)	Mean Square (MS)	F_{count}
Between groups (A)	$A = \sum_{i=1}^{k} \frac{(\sum X_{Ai})^2}{N_{Ai}} - \frac{(\sum X_\tau)^2}{N}$	$A - 1$	$S_1 = JK_A / db_A$	S_1 / S
In groups (D)	$G = \sum_{i=1}^{k} \sum_{j=1}^{n} (X_{ij} - \bar{x}_{Ai})^2$ or, G = T - A	$N - A$	$S = JK_D / db_D$	
Total	$T = \sum_{i=1}^{k} \sum_{j=1}^{ni} X_{ij}^2 - \frac{(\sum X_t)^2}{N}$	$N - 1$		

2.9. Least Significance Different (BNT)

The BNT test is the most straightforward and commonly used procedure for testing differences between treatment means. This method was introduced by Fisher (1935), so it is also known as Fisher's LSD (Least Significance Difference) Method. To use the BNT test, the attributes we need are the mean square within (KTG) value, significance level, degrees of freedom (DB) of error, and student t-tables to determine the critical value of the comparison test.

The BNT test tests the treatments in pairs. For example, if there are six treatments to be compared, it means that there are = 10 test pairs where each pair has a type I error probability of. This means that the greater the number of treatments to be compared, the greater the error must be borne. The formula used in the BNT test is:

$$BNT(\alpha) = \frac{t\,\alpha}{2};db_g \text{ x } \frac{\sqrt{2\,KTG}}{r} \qquad (1)$$

3. Method

3.1. Tools and materials

The tools used in this experiment included gas stoves, pans, coconut shaving machines, paper molds, paper drying racks, scissors, basins, spoons, knives, rulers, and buckets. While the materials used in this experiment were galangal stems, pineapple leaves, banana stems, waste paper, chlorine, and Noah.

3.2. Method of Analysis

This study used an experimental method in the laboratory of the Master of Mechanical Engineering, University of North Sumatra. The design used in this study was a non-factorial, Completely Randomized Design (CRD) consisting of 7 treatments and five replications. The treatment carried out in this study is as follows:

a. Galangal stems fiber with a ratio of 50:10, where 50 is galangal fiber, and 10 is waste paper.
b. Galangal stems fiber with a ratio of 50:40, where 50 is galangal stem fiber, and 40 is waste paper.
c. Pineapple leaf fiber with a ratio of 50:10, where 50 is pineapple leaf fiber, and 10 is waste paper.
d. Pineapple leaf fiber with a ratio of 50:40, where 50 is pineapple leaf fiber, and 40 is waste paper.
e. Banana stem fiber with a ratio of 50:10, where 50 is banana stem fiber, and 10 is waste paper.
f. Banana stem fiber with a ratio of 50:40, where 50 is banana stem fiber, and 40 is waste paper.
g. 100% waste paper without comparison is where to find the strength of the used form without a mixture of natural fibers.4.

4. Results and Discussion

This data was obtained from the results of the paper tensile test with five trials of seven treatments. The Tensile test tool used is Tensilon with the ASTM-D638 Test standard. The data on the results of the paper tensile test can be seen in Table 2.

Table 2. Tensile properties of Natural Fiber and Waste paper

Sample	Nature fiber and dan waste paper (Mpa)						
	(BL) 50:10	(BL) 50:40	(DN) 50:10	(DN) 50:40	(BP) 50:10	(BP) 50:40	(KB) 100
1	4,2573	2,5808	1,4353	1,6073	6,4221	3,9496	1,5924
2	4,1202	0,4624	2,3983	2,4358	7,2573	5,8015	1,5371
3	4,6133	0,9334	1,3941	1,929	6,3689	4,9896	1,3115
4	3,7123	2,5442	1,9035	2,1971	8,1032	5,7411	1,7389
5	4,6560	0,796	1,8256	1,8602	7,0616	5,6374	0,4401

Where: BL is Alpinia Galanga L. Swartz Fiber, DN is Ananas Cosmosus fiber, BP is Musa Paradisiaca fiber, and KB is waste paper.

From the data on the results of the tensile strength of the paper in Table 2, a calculation was then carried out using one-way ANOVA with seven treatments with each ratio of natural fibers and five replications. The results obtained with one-way ANOVA can be seen in Table 3.

Table 3. Calculation results using two-way ANOVA.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	Statistic F
Treatment	7 – 1 = 6	149,4	24,90	
Error	35 – 7 = 28	11,3	0,405	F = 61,48
Total	42 – 8 = 34	160,7		

Based on the results of the tests that have been carried out, as shown in Table 3, it can be seen from the results of the calculation of the tensile strength using One Way ANOVA that the treatment degrees of freedom are 6, the degrees of freedom for error is 28, and the total degrees of freedom is 34. The sum of the squares of the treatments is 149.4, the absolute squared error is 11.3, and the total squared sum is 160.7. While the average squared treatment was 24.90, and the average squared error was 0.405. So that F0 is obtained at 61.48, it can be concluded that at = 0.05, it is obtained F0 = 61.48> 2.45, then H0 is rejected.
After calculating using one-way ANOVA, it is carried out with a follow-up test with the LSD (Least Significance Difference) Test. The BNT test calculations are:

$$S\partial = \frac{\sqrt{2\,(\text{KT Galat})}}{r}$$

$$S\partial = \frac{\sqrt{2\,(0{,}405)}}{7}$$

$S\partial$ = 0,340168026

Table t 0,05 = 2,04841

BNT 0,05 = Tabel t (0,05) x $S\partial$

= 2,04841 x 0,340168026

= 0,6968

Then after the BNT value is known, sort the average from the largest to the smallest, then find the difference. If the difference between the two treatments < BNT, then accept H0; if the difference between the two treatments > BNT, then reject H0. BNT values can be seen in Table 4.

Table 4. Order of the average BNT from largest to smallest

(BP) 50:10	(BP) 50:40	(BL) 50:10	(DN) 50:40	(DN) 50:10	(BL) 50:40	(KB) 100
7,04262	5,22384	4,27182	2,00588	1,79136	1,46336	1,324

Based on the results of the follow-up test with BNT, it can be seen that 15 treatments have different effects on natural fiber tensile strength, namely: Comparison (BP) 50:10 with a ratio (BP) 50:40, ratio (BP) 50:10 with a ratio (BL)) 50:10, ratio (BP) 50:10 to a percentage (DN) 50:40, ratio (BP) 50:10 to a ratio (DN) 50:10, ratio (BP) 50:10 to a ratio (BL) 50:40, comparison (BP) 50:10 to comparison (KB) 100, comparison (BP) 50:40 to comparison (BL) 50:10, comparison (BP) 50:40 to comparison (DN) 50:40, comparison (BP) 50:40 to a ratio (DN) 50:10, a ratio (BP) 50:40 to a ratio (BL) 50:40, a ratio (BP) 50:40 to a ratio (KB) 100, a ratio (BL) 50:10 with a percentage of (DN) 50:10, a ratio (BL) 50:10 with a balance (BL) 50:40, and a ratio (BL) 50:10 with a ratio (KB) 100.

5. Conclusion

Based on the analysis of the test results that have been carried out, the conclusion obtained from this study is that overall, banana stems have a significant effect on the tensile strength of paper (7.04262 MPa), followed by galangal contains (4.27182 MPa), pineapple leaves (2.00588 MPa), and waste paper (1.324 MPa).

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