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Particleboard with Betel Nut (*Areca Catechu*) Frond Fibersbonded by Urea-Formaldehyde Adhesive

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ABSTRACT

This study determined the possibility of making particleboard with betel nut frond fibers using urea-formaldehyde adhesive. The physical and mechanical properties of the particleboards produced were evaluated, alongside with those of the commercially available.

This study used an experimental research method. Methods include preparation of the samples, air and sun drying, cutting, and evaluating the physical and mechanical properties of particleboards with betel nut frond fiber. The researchers prepared three mixing proportions for the 12 mm particleboard samples - PBM1, PBM2 and PBM3 with fiber length combinationsof 1mm+10mm, 1mm+15mm, and 1mm+30mm, respectively.

The ANOVA showed that the different length combinations significantly affected the modulus of rupture and internal bond of the three mixtures. Consequently, the particleboard PBM3 performed better on these tests than the commercially available particleboards. This particle board with dimensions 120cm x 200cm and 1.2cm thick, only costs ₱780.00, cheaper than the commercially available particle boards.

Finally, the researchers concluded that the particleboard made from Areca catechu frond fibers bonded with urea-formaldehyde can be used in making Type 150 or Medium Density Particleboard used in ceiling, cabinet making, wall partition, and shelving.

KEY WORDS: *Particle Board, Areca catechu, Medium Density Particle Board, Betel Nut Frond Fiber, Urea-formaldehyde*

INTRODUCTION

Globally, the construction industry has kept its pace with the increasing population and higher standard of living. Growing construction industries have led to abnormal global climate patterns, generally due to the increase in energy consumption during the construction and operation of buildings and the fabrication of synthetic materials. Therefore, building construction practices for responsible energy consumption and materials with low carbon emission must be used in the industry.

Many scientists and engineers are in search of greener construction ideas in order to support environmental protection. Green and sustainable materials are energy-efficient, durable, and often have low maintenance requirements that allow economic development while conserving for future generations. These materials are free from ozone-depleting chemicals, toxic compounds, and they do not produce toxic by-products. Hence, research communities have focused on finding eco-friendly materials which can give high performance at affordable costs. Fiber composites are such kind of materials.

Areca catechu, a plant that produces fiber material considered as eco-friendly and sustainable, was identified to be used in the manufacture of particleboard. This fiber material comes from piper betel which is commonly known as betel palm or betel nut tree and is believed to originate in the Philippines. It is found abundantly in the province of Northern Samar, specifically in Catarman, Las Navas, San Roque, and Pambujan. There is no specific volume of *Areca catechu*yet available in Northern Samar because it grows scattered in the province.

Betel nut fiber is characterized as extremely strong and light in weight. The fibers are predominantly composed of cellulose and of varying proportions of hemicellulose lignin, pectin, and protopectin. In fact, natural fibers are replacing glass fibers in much utilization achieving equal strength, increased flexibility, and low weight. These fibers have special advantages in comparison to other synthetic fibers because they are abundantly available from a renewable resource and are biodegradable. Moreover, they have low density, high toughness and acceptable specific strength properties, and good thermal property (Choudhury et al., 2006).

Betel nuts,also known as “nganga” in Tagalog and “ma-ma” in “NinorteSamarnon”, are typically found strewn on the ground usually used byFilipino elders as a cigarette-alternate. The unmanaged greenbetel nut and palm left in the plantation causes extreme odor and other decay-related problems. Therefore, an extensive planning for the disposal of huskand palm is necessary.

As aforementioned, due to many environment issues that the world is facing today, choosing an abundant and unmanaged betel nut appears to be one good solution for green building materials, instead of the commonly used commercially available materials which are not environment-friendly. Hence, the researchers further investigated betel nut frond fibers to be used as a material for particleboard in order to explore a new and sustainable building material.

This study will investigate into the appropriate design mixture, strength and properties of the particle board with betel nut frond fibers bonded with Urea-formaldehyde adhesive. This study will help the province utilize the unmanaged natural resources of betel palm which are available in the locality of Northern Samar and will promote natural fiber composites in construction industries, supporting the use of sustainable materials.

Generally, this study aimed to determine the potential of using *Areca catechu* frond fibers in making particleboard. Specifically, this study determined:

1. The physical and mechanical properties of particleboard made from betel nut frond fibers with different fiber length combinations; and
2. If betel nut frond fibers can be used in making low cost particleboard.

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MATERIALS AND METHODS

Particle board fabrication, physical and mechanical property tests in this study were all conducted in Forest Products Research and Development Institute-DOST (FPRDI-DOST) at Forest Products Laboratory, University of the Philippines- Los Baños, Laguna, Philippines.

This study employed an experimental research designwith three treatments (fiber mixturecombination factor) and three replications to determine the physical and mechanical properties of particle boards made out of betel frond fibers of different lengths bonded by urea formaldehyde adhesive.

Five (5) sacks of betel nut fronds were collected in some areas in Northern Samar and soaked in seawater for three (3) weeks. After soaking, the fibers were extracted from the fronds to gather the required material and the fibers were air-dried for twenty-four (24) hours and sun-dried for 15 days.The fibers were cut into 1mm, 10mm, 15mm, and 30 mm lengths. After cutting, the fibers of different lengths were oven-dried for thirty minutes.The fibers were combined as follows: 1 mm mixed with 10 mm (PBM 1), 1 mm mixed with 15 mm (PBM 2) and 1 mm mixed with 30 mm (PBM 3). The researchers prepared six (6) 168 grams of Urea-Formaldehyde adhesive in clean empty containers enough for the six board samples.

The researchers made two (2) pieces of 30cm by 30cm board samples for each of the three (3) fiber combinations following the mixture proportions shown in Table 1.

Table 1. Experimental Layout for Making the Particleboard.

MIXTURE	FIBER LENGTH COMBINATION	THICKNESS OF THE BOARD	RATIO OF DIFFERENT FIBERLENGTH	% of Urea Formaldehyde Adhesive
PBM1	1mm and 10mm	12 mm	50:50	12
PBM2	1mm and 15mm	12 mm	50:50	12
PBM3	1mm and 30mm	12 mm	50:50	12

The betel nut frond fibers and the urea formaldehyde were mixed manually in a basin. The researchers transferred the mixed materials to a 30 cm by 30 cm rectangular molding frame with a particular depth to achieve the desired dimension of the particleboard sample and placed it in the hot press machine for ten (10) minutes applying a temperature of 150ºC and 30 kg/cm² loadabove the form cover. The cover plate acted as a stopper to maintain the constant 1.27cm thickness of the board while compressing.

The physical properties of the sample particle boards with frond fibers of different length combinations were determined following the procedures as follows:

1. Density

The densities of the particle boards with betel nut frond fibers with different length combinations were determined separately. The researchers placed the sample particle boards in an empty container, weighed it using the digital weighing scale, and record the results. The modified method of De Boodt et al. (1974) was used to get the density.

$$\rho = \frac{m_2 - m_1}{v}$$

Where:

D = Density of Betel Nut particleboard, (g/cm3)
m_1= Weight of Container, (g)
m_2 = Weight of Container + Specimen, (g)
v = Volume of the specimen

2. Moisture Content

The researchers weighed the specimen particle boards with dimensions 50 mm by 120 mm and placed it in the drying oven for thirty (30) minutes. Afterwards, the researchers weighed the oven-dried specimen and compared the results using this formula to get the percentage of moisture content.

$$M.C.\% = \left(\frac{W_2 - W_1}{W_3 - W_1}\right) \times 100\%$$

where:

M.C. = Moisture Content, (%)
W_1= Weight of Empty Container, (g)
W_2 =Weight of container + sample, (g)
W_3 =Weight of container + dry sample, (g)

3. Water Absorption

The researchers measured the initial weight of board specimens with dimensions 50 mm by 50 mm. After soaking in water for twenty-four (24) hours,the final weight was measured. The change in weight was tabulated and the formula below was used to get the percentage of water absorption:

$$W.A\% = \left(\frac{m_2 - m_1}{m_1}\right) \times 100\%$$

where:

WA% = Water Absorption Percentage, (%)

M_1 = Initial Weight, (g)

M_2 = Final Weight, (g) after soaking

4. Thickness Swelling

The researchers measured the initial thickness of sample particle boards with dimensions 50 mm by 50 mm before completely soaking in a container with water for twenty-four (24) hours. After soaking, they measured and tabulated the change in thickness using Vernier caliper. The following formula was used to get the percentage of thickness swelling.

$$TS\% = \left(\frac{t_2 - t_1}{t_1}\right) \times 100\%$$

where:

TS% = Thickness Swelling Percentage, (%)
t_1 = Initial Depth, (mm)

t_2 = Final Depth, (mm)

The mechanical properties of the sample particleboards with *Areca catechu*frond fibers and a commercially available particleboard (serving as control) were determined following the procedures as follows:

1. Modulus of Rupture

The researchersused ASTM D 1037 "Standard Test Methods for Wood Based Fiber and Particle Panel Materials" using Universal Testing Machine (UTM) to determine the Modulus of Rupture of the particleboard with dimensions of 56.7mm by 120mm and used the formula below to compute the Modulus of Rupture:

$$R = \left(\frac{3PL}{2bd^2}\right) \times 100$$

Where:

R = Modulus of Rupture, (MPa)

P = Maximum Load, (N)

b = width of specimen, (mm)

d = depth of specimen, (mm)

2. Screw Withdrawal Test

ASTM D 1037 "Standard Test Methods for Wood Based Fiber and Particle Panel Materials" using Universal Testing Machine (UTM) determined the screw withdrawal strength of particleboards. The researchers prepared the specimen with dimensions 50mm by 120mm and performed the test with the assistance of the laboratory's professors. The screw holding strength (SWS) were calculated using the formula below:

$$SWS = \left(\frac{P_1 + P_2}{2}\right)$$

Where:

SWS = Screw Holding Strength, (kgf)

P_1 = Load at failure at left side, (kgf)

P_2 = width of specimen, (kgf)

3. Internal Bond Test

ASTM D 1037 "Standard Test Methods for Wood Based Fiber and Particle Panel Materials" using Universal Testing Machine (UTM) determined the internal bond strength of particleboard. The researchers prepared the sample particleboard with dimensions 50mm by 50 mm and performed the test with the assistance of the laboratory's professors. The results were calculated using the formula below:

$$IBF = \left(\frac{P}{LW}\right)$$

Where:

IBF = Internal Bond Strength, (kg/sq.cm)
P = Load at failure, (kgf)
L= Length of specimen, (cm)
W= Width of specimen, (cm)

The one-way analysis of variance with 0.05 level of significance was used by the researchers to determine if there are significant differences between the mechanical properties of particleboards made from betel nut frond fibers with different length combinations and the commercially available particleboard. The Duncan's Multiple Range Test was performed to determine specifically which mean values of the mechanical properties are different.

Finally, the economic benefit of using betel nut frond fibers was determined by comparing the particleboard made from betel nut frond fibers with Urea-formaldehyde adhesive and the commercially available particleboard in terms of their prices and board production costs.

RESULTS

Table 2 shows the different physical properties of the particle boards with betel nut frond fibers with different length combinations. PBM1 has a highest average density of 0.71242 g/cm^3 while of PBM2 has the lowestaverage density of 0.66076 g/cm^3. PBM2 has the highest moisture content of 14.88% while PBM1 has the lowest moisture content of 14.03%. PBM1 has the highestwater absorption (31.0342%) nd PBM3 has the lowest water absorption (29.8623%). Finally, in terms of thickness swelling, PBM1 has the highest (15.5659%) while PBM3 has the lowest (14.4183%).

Table 2**.** The average values of the physical properties of theParticle Board with Betel frond fiber combinations.

Physical Properties	Mixtures	Average Values	Philippine National Standard			Remarks
Density (g/cm^3)	PBM1	0.71242	≤0.35	**>0.35, ≤0.8**	≥0.8	Medium-Density
	PBM2	0.66076	≤0.35	**>0.35, ≤0.8**	≥0.8	Medium-Density
	PBM3	0.71002	≤0.35	**>0.35, ≤0.8**	≥0.8	Medium-Density
Moisture Content	PBM1	14.03		<15		PASSED
	PBM2	14.88		<15		PASSED
	PBM3	14.40		<15		PASSED
Water Absorption	PBM1	31.0342		≤40		PASSED
	PBM2	30.7517		≤40		PASSED
	PBM3	29.8623		≤40		PASSED
Thickness Swelling	PBM1	15.5659		≤20		PASSED
	PBM2	15.3582		≤20		PASSED
	PBM3	14.4183		≤20		PASSED

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Table 3 shows the results of different tests for the mechanical properties of the particle boards with combination of different lengths of *Areca catechu* fibers. In terms of the average modulus of rupture, PBM3 has the highest (17.7545 MPa) and PBM1 has the lowest (14.6522 MPa). For the screw withdrawal test, PBM3 has the highest with 49.10 kgs while PBM1 has the lowest with 43.47 kgs. For the internal bond test, PBM3 has the highest average pressureof 4.55 kg/cm^2 and the PBM1 has the lowest with 1.31 kgs/cm^2.

Table 3. The mechanical properties of Particleboard made from different mixtures of Betel frond fiber lengths.

Mechanical Properties	Mixture	Average Value	PNS Passing Percentage	Remarks
Modulus of Rupture (MPa)	PBM3	17.7545^a	13.72391	PASSED
	PBM2	15.526^b	13.72391	PASSED
	PBM1	14.6522^b	13.72391	PASSED
Screw Withdrawal (kgf)	PBM1	43.37^a	≥40	PASSED
	PBM2	47.38^a	≥40	PASSED
	PBM3	49.10^a	≥40	PASSED
Internal Bond (kgs/cm^2)	PBM3	4.55^a	≥3	FAILED
	PBM2	3.96^{b-c}	≥3	PASSED
	PBM1	1.3033^c	≥3	PASSED

*Means of the result with the same letters did not differ significantly with each other.

Table 4 shows that PBM3 has the highest average modulus of rupture (17.7545 MPa) while Brand X had the lowest (13.10 MPa). On the screw withdrawal test, Brand X had the highest average result (102.0583 kgf) while PBM1 had the lowest (43.47 kgf). As regards internal bonding, PBM3 and Brand X had the highest average values (4.55 kgs/cm^2) while Brand Y had the lowest (0.45 kg/cm^2).

Table 4. A comparison of the average values of the mechanical properties of particle boards produced by the different experimental treatments and the commercially available particle boards.

Mechanical Properties of Particle Boards	Particle Boards Produced by the Different Eperimental Treatments			Commercially Available Particle Boards	
	PBM1	PBM2	PBM3	Brand X	Brand Y
Modulus of Rupture (MPa)	14.6522^b	15.526^b	17.7545^a	13.10^c	14.00^{b-c}
Screw Withdrawal (kgf)	43.47^e	47.38^d	49.10^c	102.0583^a	52.99^b
Internal Bond (kgs/cm^2)	1.3033^d	3.96^c	4.55^a	4.55^a	0.45^e

*Means on the row with the same letters did not differ significantly with each other.

Table 5 shows that the particleboard made from Betel Nut Frond Fiber *(Areca catechu)* bonded with Urea Formaldehyde (BNFF-PB) had lower cost of manufacturing of Php 780.00 while the commercially available particleboard Brand X and Y had higher prices of Php 1,200.00 and Php 1,050.00, respectively.

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Table 5. Cost comparison between BNFF-PB and commercially available particle board.

PARTICLEBOARD	SIZE (cm)	PRICE (Php)
BNFF-PB	120x200x1.2	Php 780.00
Brand X	120x200x1.2	Php 1,200.00
Brand Y	120x200x1.2	Php 1,050.00

DISCUSSION

Table 2 shows that there are numerical differences in the average values of the physical characteristics of particle boards with Betel frond fibers.However, the one-way ANOVA did not show significant differences between these average values. It only shows that these properties are not affected by the mixing of the different lengths of betel frond fibers.

The same table shows the physical properties of the fabricated particleboard in terms of relative density and based from the PNS 230:1989 (Specifications for Particleboards), it was determined that all specimens were classified as Type 150 or Medium Density (640-880 kg/m³). For the Moisture Content test, all samples passed the maximum 15% moisture content standard for particleboards. For Water Absorption and Thickness Swelling, all specimen with different length combinations were able to meet the standard for Water Absorption which is 40% and Thickness Swelling and 20% from the PNS 230:1989 (Specifications for Particleboards) for Type 150 or Medium Density Particleboard.

As regards the mechanical properties, Table 3 shows that PMB3 has significantly higher modulus of rupture and internal bonding than PBM1 and PBM2. However, the same tale shows that that different mixture treatments do not significant differences in terms of screw withdrawal test results. The results of the one way ANOVA revealed that as the length of the betel frond fiber mixed with 1 cm betel frond fiber increase, the modulus of rupture and internal bonding increase. The ANOVA showed also that the screw withdrawal test results were unaffected by the length of betel frond fiber mixed with the 1 cm betel frond fiber. In terms of Philippine National Standards, all the mixture treatments passed the modulus of rupture and screw withdrawal tests. However, the particle board with 30 cm betel frond fiber failed in the internal bond test.

The different length combinations significantly affected the modulus of rupture and internal bond of the three mixtures. PBM3 showed better performance than the other length combinations in terms of modulus of rupture test and internal bond. On the other hand, the different combination has no substantial effect in particleboard in terms of screw withdrawal test.

A comparison of the mechanical properties of the particle boards of the experimental treatments and commercially available particle boards is shown in Table 4. It can be gleaned in this table that the particle boards produced in this study had higher Modulus of Rupture than those commercially available ones. This means that the particle boards produced by the different experimental mixture treatments can resist higher flexural stress that that of the commercially available particle boards. On the other hand, the commercially available particle boards had higher Screw Withdrawal Test results than those particle boards of this study. This means that it is easier to pull off embedded screw from particle boards produced in this study than to pull a screw from the commercially available particle board. For internal bonding, PBM3 and Brand X particle boards had very high internal bonding which failed based on Philippine National Standards. It seems that the mixing of 30 mm to 1 mm betel frond fibers resulted to this finding.This means that there are significant differences in the mechanical properties of particle boards made from *Areca catechu* frond fiber with different length combinations and the commercially available particleboard.

The particleboard made from *Areca catechu* frond fibers, specifically, PBM3, performs better than the commercially available particleboards in terms of modulus of rupture and internal bond strength. On the other hand, the result shows that Brand X has a very high performance compared with PBM1, PBM2, PBM3, and Brand Y in terms of screw withdrawal test.

The researchers concluded that the particleboard made from *Areca catechu* frond fiber bonded with Urea-formaldehyde based adhesives can be used in making Type 150 or Medium Density A particleboard which can be used for ceiling, cabinet making, wall partition and shelving. It is also more economical with a price Php 780.00 per 120 cm x 200 cm x 1.2 cm board compared to commercially available brands X and Y particleboard which cost Php 1200.00 and Php 1050.00, respectively.

It is recommended that the same study may be repeated with length combinations of 1 mm + 15 mm, 1mm + 20mm, 1 mm + 25mm and 1 mm + 30mm to pinpoint the best combination. Another study that is recommended to be implemented is to replace 1mm fiber length with 1.5mm or 2mm.

ENDNOTE

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