Study On Preparation, Performance And Application Of Particleboard Derived From Betel Nut Fiber (Areca catechu) And Modified Cashew Nut Shell Liquid (Anacardium occidentale)

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Abstract

The objective of this paper is to evaluate the mechanical performance (Modulus of rupture, tensile, hardness) and physical performance (density, thickness, water absorption, swelling thickness, moisture content) of modified cashew nut shell liquid (CNSL) composites filled with betel nut fiber (BNF), using hot press molding technique. Cashew nut shell liquid is a cheap agro by-product and a renewable resource, which consists mainly of substituted phenols. A CNSL-based reactive resin was used in this study as a binder for particleboard. The agro-wastes from betel nut harvesting are also employed as reinforcement in this study. The results showed less moisture content (3.83%), water absorption (9%) and better strengths 3.6 lb tensile strength, 3273 psi modulus of rupture. Due to the presence of CNSL, fungi cannot grow on the surface of board and tend to increase binding capacity. It also reduces the environmental pollution by using BNF. It was found that estimate cost of prepared particleboard (2′x2′) sq ft was 751.5 kyat, not including cost of machine. The average cost of commercial particleboard (2′x2′) sq ft was 1200 kyat. Therefore, the prepared particleboard was cost effective, quality grade and could be used commercially.

Key words: Betel nut fiber, modified cashew nut shell liquid, hot press molding technique, particleboard, mechanical performance, physical performance

Introduction

As the world's population is increasing day by day, the demand on wood materials are increase rapidly with the forest product industry. This causes the forest depletion and the green house effect. The earth's climate is also affected by the green house effect in some area of the world. The plastic materials are widely used instead of the wood materials almost around the world. To preserve the forest depletion and to cure the plastics uses, natural fiber particleboards and composites are considered to have potential use as reinforcing material in polymer matrix composites because of their good strength, stiffness, low cost, renewable, environmental friendly and biodegradable Residue reutilization has been increasing thus researchers have been investigating the characteristics of particleboards produced with these residues.

Among the various natural fibers, betel nut fiber is characterized as extremely strong and low weight. The fibers are predominantly composed of cellulose and varying proportions of hemicelluloses, lignin, pectin and protopectin. These fibers have special advantages in comparison to other synthetic fiber in that they are abundantly available from a renewable resource and also biodegradable (Choudhury and Harzarika, 2006). The betel nut fruit husk or shell for each fruit can produce approximately 2.50 - 2.75 g betel nut shell fibers. Betel nut fiber can be obtained via de-husking technique or by manually stripping the fibers from the husk part (Yusriah *et al*., 2012). The betel nut palm is believed to have originated in the Philippines which grown in much of the tropical pacific Asia and parts of east Africa

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(Hemantha, 2010). The palms have been cultivated as gardens and hedges in Thaninthayi Region, Bago Region, Mon State, Kayin State and Rakhine State in the Myanmar.

Urea-formaldehyde is the commercial resin popularly used for wood-based and non-wood based peel product (Lee *et al*., *2*011). Urea-formaldehyde resin is mostly used to glue wood together because of its chemical properties. UF is also used when producing electrical appliances casing also desk lamps. It is widely chosen as an adhesive because of its high reactivity, wonderful performance and low price. It is also used in agricultural field as a source of nitrogen fertilizer (Clausen *et al*., 2003).

Cashew nut shell liquid (CNSL) contains a high proportion of phenolic compound. It has potential industrial application such as for resins, friction, lining materials and surface coating (Lubi and Thachi, 2006). Resin containing CNSL, tannin and urea-formaldehyde is used in particleboard production (Biscnda *et al*., 2003).

Particleboards are widely used because they enable wood particles or non-wood particles from relatively useless small size and or low grade timber to be transformed into useful large panels. When phenolic resins are used as binders, particleboards are characterized by good physical and mechanical properties (Lubi and Thachi, 2007).

The present work is concerned with the preparation and performance of particleboards derived from treated betel nut fiber and modified cashew nut shell liquid. The mechanical and physical properties (performance) of these prepared particleboards were determined by some machines and different sophisticated analytical instruments. These composite particleboards are non- toxic, low cost, environmental friendship and applied for use as interior furnishing including furniture and building materials at dry conditions. The laminated particleboards can also be used in the production of furniture that can be exposed to the action of higher humidity such as laundries, both rooms and kitchens.

Materials and Methods

Materials

The raw materials utilized for the process are betel nut fiber (BNF), cashew nut shell liquid (CNSL) and ureaformaldehyde (UF) resin. The betel nut fiber collected from Min Bya Township, RakhineState was prepared by Retting process (Ramachandra, 2011).

Betel nut fiber was treated with 2% NaOH followed by cleaned with dilute acetic acid to neutralize excess NaOH. The treated betel nut fibers were dried for 7 days under ambient conditions to 10.7% moisture content, before use. The fibers were cut into fiber length 2.0cm, long Figure1 (a).

Cashew nut shell liquid as shown in Figure 1(b) was collected from Myeik, Thaninthayi region. It was extracted from cashew nut shell by hot oil bath process. Moisture content of reddish brown cashew nut shell liquid was 4.84%. Ureaformaldehyde (UF) as shown in figure 1 (c) was collected from Wartara glue factory, Yangon, Myanmar. Cashew nut shell liquid was modified with ureaformaldehyde with solid content of 58%, in the ratio of (1:1) by weight to improve the strength and the bonding between matrix resin and fibers. Betel nut fiber (120g) was blended with (40%) modified cashew nut shell liquid (40g CNSL and 40g UF).

Figure 1(a) Betel Nut Fiber   Figure 1(b) Cashew Nut Shell Liquid Figure 1 (c) Urea formaldehyde

Some physicochemical properties of betel nut fiber are shown in Table1.

Table 1 PhysicochemicalProperties of Betel Nut Fiber

No	Characteristics	Observed value	Reported value *
1	Moisture content % (w/w)	10.7	10.92
2	Ash content % (w/w)	2.14	1.05
3	pH	6.1	-
4	Bulk density (g cm^{-3})	0.04	-
5	Fats and Waxes (%)	0.05(fats)	0.64
6	Lignin % (w/w)	12.31	7.20
7	Hemicellulose % (w/w)	17.52	32.98
8	Cellulose %(w/w)	70.17	53.20 (α-cellulose)

* Ramachandra*et al.,* (2011)

Methods

Particleboard was fabricated by using modified CNSL as bonding adhesive. The batch process to produce a particleboard, modified CNSL (80 g) was sprayed on 120 g of BNF length 2 cm in the Henschel Mixer (2.2 HP, 2800 rpm). This mixture of BNF and modified CNSL and was added slowly to produce a homogenized BNF and modified CNSL for 5 min at ambient temperature, the whole mass was blended. The bended mixture was then poured into (6" x 6") configuration mould so as to produce a single layer board and wedged between two steel plates. The single layer wet board was pressed in a hydraulic hot press at 2200 psi at temperature 170°C for 15 min. The experimental design was shown in Table 2.

Table 2 Production Parameters of Single Layer Particleboards

Parameter	Value
Pressing temperature (°C)	170
Pressing time (min)	15
Pressing pressure (psi)	2200
Dimension (inches)	6 x 6 (15.24cm x 15.24cm)
Thickness (inches)	0.19-0.28 (0.45cm-0.67cm)
Number of boards of each type	2

Two replicate panels were made for each board type. After pressing under hydraulic hot press for 15 min, each board was pressed under cool press for 5 min. The particleboards were then conditioned at ambient temperature for one week in a vertical position. The particleboards were trimmed to avoidedge effects to a final size of 6" x 6", and then cut into various sizes for properly evaluation according to IS: 3087-1965 and BS: 1811-1961.

Some mechanical properties determined were modulus of rupture (MOR) (BS; 1881-1961), tensile strength (Electro-hydraulic Tensile Tester, Philadephia, USA). For a particleboard, the mechanical properties tests are very important since it decides the strength of the material and porosity for a particleboard. Hardness measurement was done using Wallace Micro Hardness Tester ; DIN-Normen, 1987. Some physical properties of particleboards were determined in accordance with appropriate standards density (BS: 184-1961), water absorbation and swelling thickness after a 24 hours immersion in distilled water (IS: 3087-1965).

Each panel was cut to get two tensile strength and modulus of rupture samples (14cm x 2.54cm), two WA/ST samples (2.54 cm x 2.54cm), and two density samples (2.54 cm x 2.54 cm).

The scanning electron microscopes (SEM: JSM 560 LV, JEOL, Ltd Japan) was used to identify the tensile fractured morphology of particleboard samples. The thermogravimetric differential thermal analysis (TG-DTA, PyrisDiamod TG-DTA High Temp 115 V) was used to observe the thermal stability of particleboard samples.

Results and Discussion

Comparison for performances of prepared particleboard with commercial particleboards

The mechanical and physical performances of prepared particleboard PPB and commercial particleboard CPB1 (China- Grade 1) and CPB2 (China – Grade 2) are summarized in Table 3 and figures 2, 3 and 4. On the comparison of the prepared particleboard and commercial particleboards, it was obviously seen that the MOR value of commercial particleboard cpb1 was higher than other particleboards because of more compatibility.

Moreover, it was obvious that moisture content of CPB1 was highest among them. The water absorption of CPB1 was higher than prepared particleboard. The moisture content and water absorption of boards greatly depend on the choice of raw materials and types of fiber used to prepare the particleboards. In this study, particleboard prepared by using betel nut fiber had the least water absorption and moisture content whereas the highest tensile strength. It would possess good water resistance.

Table 3 Mechanical and Physical Performances of Prepared Particleboard and Commercial Particleboards

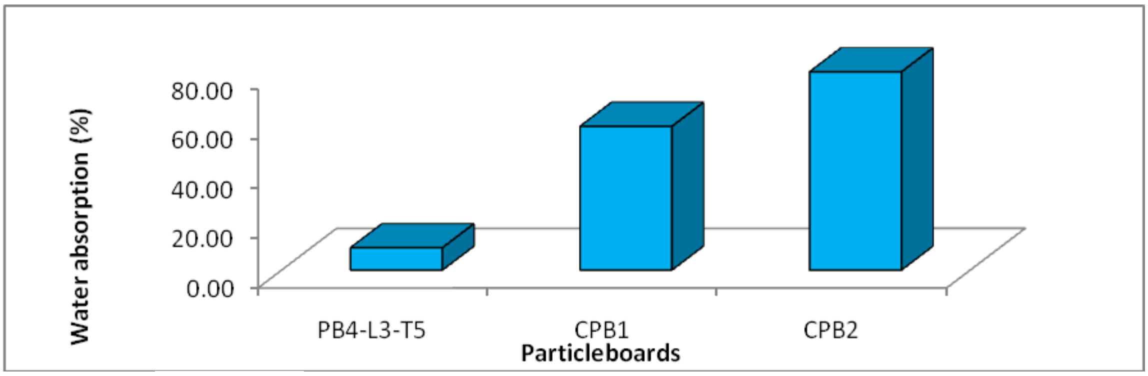
Performances	PPB	CPB1 (China G-1)	CPB2(China G-2)
Fiber or Wood Type and Adhesive	BNF & CNSL-UF	Wood & UF	Paper pulp & UF
Modulus of rupture (psi)	3273	4484	1047
Tensile Strength (lb)	3.60	1.40	1.50
Thickness (cm)	0.50	0.30	0.60
Water absorption* (%)	9.00	58.00	80.00
Swelling Thickness* (%)	22.28	21.27	8.29
Moisture content (%)	3.83	11.38	9.24
Density (gcm^{-3})	1.20	0.89	0.71
Hardness (Shore D)	89	87	85

PPB =Particle board prepared from BNFand modified CNSL

CPB1 =Commercial particle board prepared from wood and UF (ChinaGrade1)

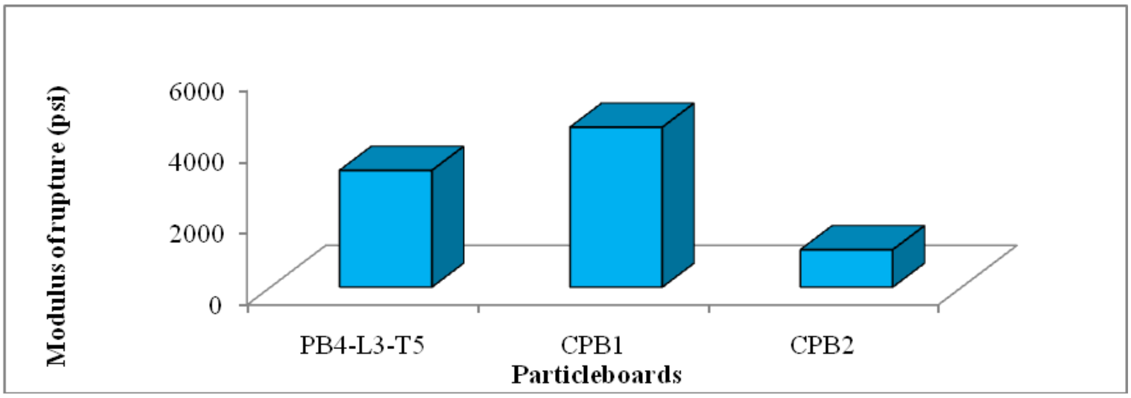
CPB2 =Commercial particle board prepared with paper pulp and UF (China Grade2)

* = after soaking period 24 h



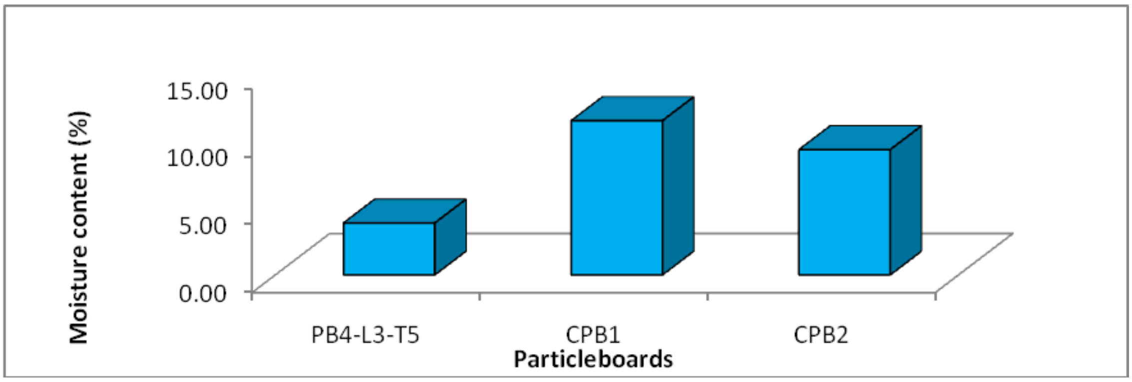
PPB

Figure 2 Comparison of water absorption of prepared particleboard and commercial particleboards



PPB

Figure 3Comparison of modulus of rupture of prepared particleboard and commercial particle boards



PPB

Figure 4 Comparison of moisture content of prepared particleboard and commercial particleboards

TG-DTA thermograms of prepared particle board (PPB) and commercial Particle boards (CPB1 and CPB2)

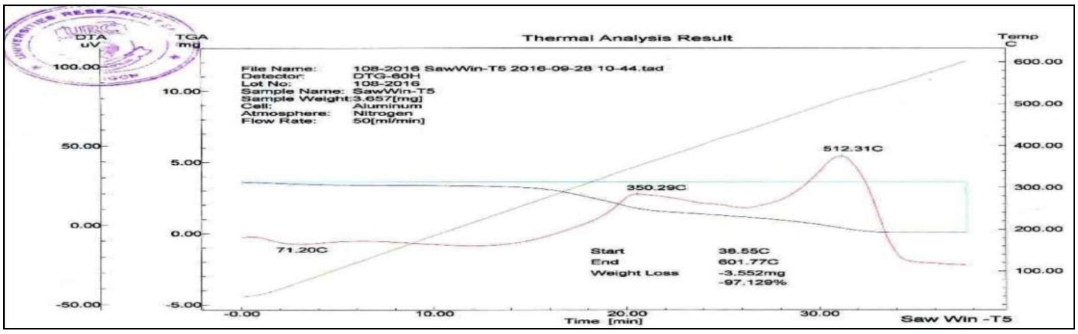


Figure 5 TG –TDA Thermogram of PPB

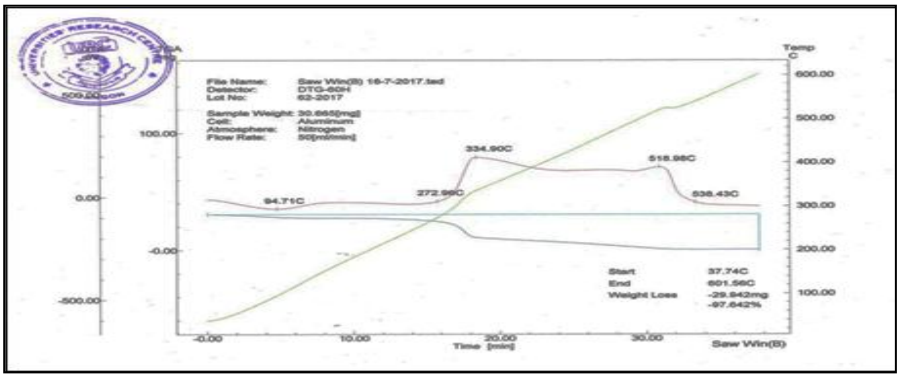


Figure 6 TG –TDA Thermogram of CPB1

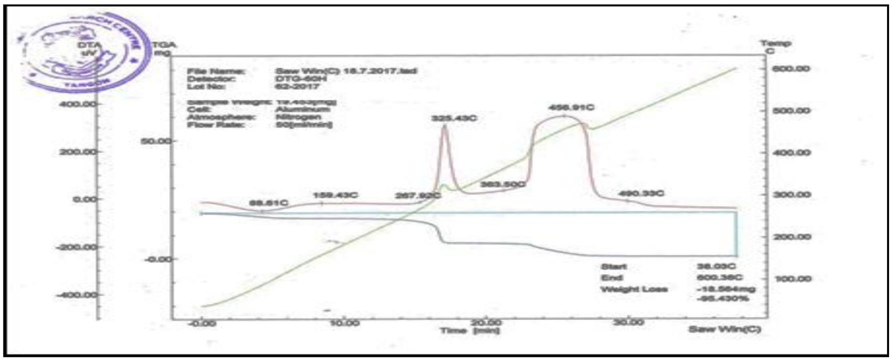


Figure 7 TG –TDA Thermogram of CPB2

The rmal decomposition of each sample takes place in the programmed temperature rangefrom 38 ºC- 602ºC.

On the basis of the ther malanalysisdatain Table5, three stages of decomposition of particleboards were observed. The first stage decomposition was due to the dehydration of surface waterand absorbed waterofthe particleboards. In the first stage decomposition, prepared particleboard (PPB) is the most thermally stable due to the least weight loss (7.03 %). In the second stage, PPB is also thermally most stable up to 450 ºC due to the weight loss (65 %), when degradation and combustion of backbone materials take place.

Finally commercial particleboard (CPB2) is the most thermally stable due to the highest residual weight (4.57 %).

Study on surface morphology of prepared particleboard (PPB) and commercial particleboards (CPB1 and CPB2)

SEMmicrographs of PPB, CPB1and CPB2 are shown in Figures 8, 9 and 10.

Figure 8 SEM micrograph Figure 9 SEM micrograph Figure 10 SEM micrograph

of PPB CPB1 CPB

It was found that surface fracture of prepared particle board (PPB) is less micropores, micro cracks and not fiber pull-out from the surface. It tends to be more uniform and compatibility the surface of boards. The compatibility and uniform of board stend to enhance mechanical and physical properties and decrease water absorption and moisture content. The fungi which breakdown cellulose cannot grow on the surface. There are more fiber pull-out from the surface of CPB1 and CPB2 and cause more surface roughness, more micropores and microcracks.The fungi can grow on the surface and cellulose can be broken.

Application of prepared particleboard

The particle boards prepared by using treated betelnut fiber and modified cashew nut shell liquid was found to be successful inmaking of household articles and value-added products such as box, tabletop, pencilbox,ceiling boards and floor underlayment. Figure 11 shows the photographs of various household articles and value-added products.

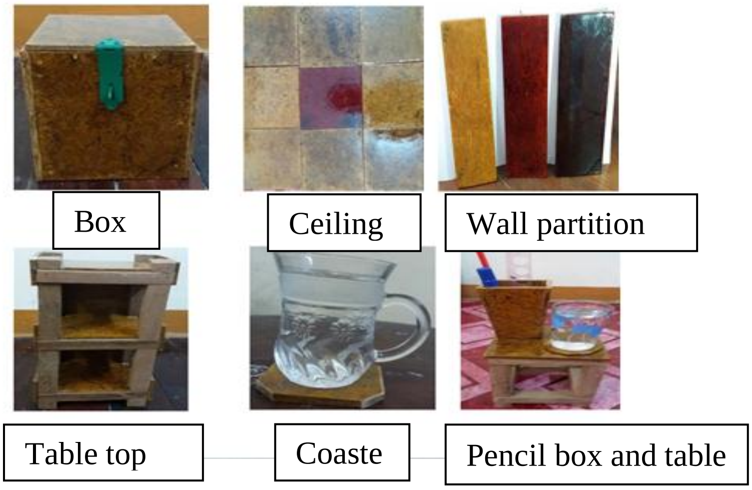


Figure 11 Photographs of value-added products

Comparison on the Cost of Prepared Particleboard and Commercial Particleboards

The cost of prepared betel nut fiber and modified cashew nut shell liquid particle board is shown in Table 6. The cost of before laminating prepared particle board dimension with (2´x2´) sq ft was 751.5kyat, not including cost of machine usage. The cost of before laminating commercial particle board (China Grade1) dimension with (2´x2´) sqft was 1200kyat. The cost of prepared particle board and comer cialparticle board sare presented in Table 8. The cost of after laminating (polishing) prepared particle board dimension with (2´ x2´) sq ft was 1000 kyat and that of after laminating (polishing) commercial particle board dimension with (2´ x 2´) sq ft was 1500 kyat.

Conclusion

From the comparison of prepared particle board (PPB) and commercial particle boards (CPB1 and CPB2), MOR value of PPB (3273psi) was less than that of CPB1 (4484psi) but was more than CPB2 (1047psi). Although, MOR was less, the greatest hardness 89 (ShoreD) was possessed. The lowest water absorption value (9 %) and the lowest moisture content (3.83%) are good properties for particle board. The high content of moisture caused to grow fungi on the surface and cellulose couldbebrokendown. Tensile strength of prepared particleboard is nearly two times greater than that of commercial board (China). The decreasing mechanical properties not only deteriorate aesthetic and weak enbuilding properties but also affect the health of people who lived in that environment. The fibers were pulled-out from the surfaces of CPB1 and CPB2 but not pulled - out from the surfaces of PPB. The uniform surface tends to be less water absorption and moisture content. The weight loss of PPB was the least (66 %) up to 470 ºC. It was found that estimated cost of particle board (2´x2´) sq ft size was 751.5 kyat, omitting the cost of machine usage and that of commercial particle board CPB1 (China-grade1) (2´x2´)sq ft size was 1200 kyat. Therefore, prepared particle board was cost effective and quality grade particleboardfor making valued-added products. In addition to these facts, the prepared particleboards from waste products are not only helpful in protecting our environment by means of using modified cashew nut shell liquid but also in manufacturing cost effective particleboards. Hopefully, the prepared natural fiber composite particleboard can be used in producing mirror casing, paper weight, sailing boats, mail-box, helmet, doors, windows and various parts of car interior together with truck cabins. Therefore the number of conventional plastic materials and wood are replaced with natural polymer fiber blends and composite particleboards. The present work will contribute to the technological needs for our country, reduce the non- biodegradable pollutants, preserve the forest depletion and reduce the greenhouse effect.

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