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STUDY ON THE EFFECT OF PRESSING TEMPERATURE AND FIBER LENGTH ON PHYSICOMECHANICAL PROPERTIES OF PREPARED PARTICLEBOARDS DERIVED FROM BETEL NUT FIBER TREATED WITH CASHEW NUT SHELL LIQUID

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Abstract

The objective of the paper is to evaluate the physicomechanical properties of the fabricated single-layer experimental particleboards. Particleboards were made from treated betel nut fiber bonded with 40% modified cashew nut shell liquid. The particleboards were prepared by varying pressing temperature (130 °C, 140 °C, 150 °C, 160 °C, 170 °C and 180 °C). Different lengths of betel nut fiber (0.5cm, 1.0cm, 2.0cm, 3.0cm and 4.0cm) were also used for the preparation of particleboards. The experimental particleboards were tested for their physicomechanical properties such as modulus of rupture (MOR) and density by British Standard Method (BS) and then water absorption (WA) and swelling thickness (ST) according to the procedures defined by Indian Standard Method (IS). The tensile strength (T.S) and hardness of prepared particleboards were also studied by using Tensile Tester and Hardness Tester. The surface morphology of prepared particleboards was analyzed by scanning electron microscope (SEM) to measure the fiber pull out and fracture behavior. Thermal gravimetric analysis was also carried out to study the thermal degradation of prepared particleboards using TG-DTA. The study revealed that the sample of betel nut fiber length 2.0cm and pressing temperature 170°C showed highest MOR, TS and least WA, ST and highest density and hardness when compared with other prepared particleboards due to the physicomechanical properties of 3273 psi (MOR), 3.6 lb (TS) and 9% (WA), 22.28% (ST)and 1.20 gcm^{-3} (density) and 88.75 Shore D (hardness). It was found that the fiber length and pressing temperature have a significant effect on the board properties.

Keywords: Betel nut fiber, modified cashew nut shell liquid, particleboards, physicomechanical properties.

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Introduction

Particleboard (PB) is a wood-based or non-wood-based panel product manufactured under pressure and temperature from particles of wood or other lignocelluloses fibrous materials and a binder. It is used widely in the manufacture of furniture (box, cupboard, tabletop and speech shelf, etc.) and building materials (wall and ceiling paneling etc.) (Palakpuja, 2015). These particleboards are intended for use in the production of furniture and building materials that can be exposed to the action of higher humidity (e.g. kitchens. bathrooms, and laundries) (Wazny 1994).

Betel nut fiber is composed of cellulose with lignocelluloses, pectin, protopectin, wax and ash. Betel nut fiber can be easily and cheaply obtained and found in large amount at regional level. By using these fibers, it can reduce environmental pollution and has no harm to health and can also decrease the final cost of the product (Negsa, 2011). The average betel nut fiber length is 4cm long.The density of particleboard decreases with increase in fiber length (Mirski, 2014).

Cashew nut shell liquid is applied as lignins, paints and laminating resins. By using cashew nut shell liquid in manufacture of particleboards, it can provide particleboard to expose with higher humidity and can also damage the fungal species occurring on the surface of particleboards (Maulida, 2013). Ureaformaldehyde is a good resin for bonding particle and not poisonous in nature. It can be easily obtained with low cost. By using ureaformaldehyde, particleboard has very high tensile strength, the capacity of low water absorption and high surface hardness (Clausen *et al.,* 2003).

The particleboard without using cashew nut shell liquid or laminating favours to fungi growth. Fungi species break down cellulose and cause decreasing mechanical properties. The growth of fungi not only deteriorates aesthetic value and causes weakness of the building structure (Clausen *et al*., 2003) but also affects health of people who lived in that environment (Maulida, 2013).

Particleboards may be processed from 100°C to 230°C temperature range for duration of up to 30 min. The pressing parameters (temperature, pressure and time) normally lead to the degradation of the fiber's mechanical properties. Control of hot press temperature and duration enhance in service ability cause less degradation of chemical components. Control of exposure of particleboards to high temperature can enhance resistance to moisture absorption, swelling thickness and ultimately durability (Palakpuja, 2015).

The parameters affecting the physicomechanical properties of particleboards are wood type (fiber type), fiber content, fiber length (particle size), resin type, resin content, pressing temperature, pressing pressure and pressing time (Mirski, 2014).

In the form of particleboard composite, many Myanmar researchers have reported as well. However, some known reports are those of Myat Myat Nwe (2008) on preparation and characterization of composite (plaster) board derived from renewable resource Bagasse and Aung Khine Tun (2012) on feasibility study on the production of quality wood adhesive using renewable cashew nut shell liquid.

This paper is concerned with the fabrication of durable particleboards using readily available and affordable cashew nut shell liquid as a composite resin compounded with modified adhesive UF resin at different pressing temperature and using different fiber lengths of betel nut fiber.

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, Rakhine State was prepared by Retting process (Ramachandra and Ashok, 2011).

Betel nut fiber was treated with 2% NaOH followed by cleaning 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 manually cut into fiber lengths 0.5cm, 1.0cm, 2.0cm, 3.0cm and 4.0cm long (Figure1).

Figure 1: Betel nut fiber with different lengths

Cashew nut shell liquid 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) 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).

Methods

Six types of particleboards to study the effect of pressing temperature labelled as (PBT1-PBT6) and five types of boards for effect of fiber length labelled as (PBL1-PBL5) were fabricated by using BNF and modified CNSL. Pre-weighed raw material (120 g of BNF with fiber length 2.0cm) for pressing temperature and 120g of BNF with fiber length 0.5cm; 1.0cm, 2.0cm, 3.0cm and 4.0cm for effect of fiber length was placed separately into HenschelMixer (2.2 HP, 2800 rpm). The glue mixture (40% modified CNSL-UF) was then poured on to the fiber and blended for 5 min at ambient temperature in the Henschel Mixer to obtain a homogenized mixture. The mat configuration was single layer boards measuring (6" x 6") were manually formed and pressed in a hydraulic hot press at 2200psi at 130ºC to 180ºC for pressing temperature effects and pressed only at 170ºC for fiber length effects for 15 min. The experimental design was shown in Table 1.

Table 1: Production Parameters of Single Layer Particleboards

Parameter	**Value**
Pressing temperature (°C)	130, 140, 150, 160, 170, 180
Pressing time (min)	15
Pressing pressure (psi)	2200
Dimension (inches)	6 x 6 (15.24 cm x 15.24 cm)
Thickness (inches)	0.19-0.28 (0.45 cm-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 (Figure2). The particleboards were trimmed to avoid edge effects to a final size of 6" x 6", and then cut into various sizes for property evaluationaccording to IS: 3087-1965 and BS: 1811-1961 (Figure 3)

Figure 2: Finished particleboards during conditioning at ambient temperature

Figure 3: Particleboards samples stored after the assessment

Some physical properties were determined in accordance with appropriate standards density (BS:1811-1961), water absorption (WA) and swelling thickness (ST) after a 24 himmersion in distilled water (IS:3087,1965). The mechanical properties determined were modulus of rupture (MOR) (BS:1811:1961), tensile strength (TS) (Electro-hydraulic Tensile Tester, Philadelphia, USA). For a particleboard, the mechanical properties (MOR) and water absorption (WA) tests are more important since it decides the strength of the material and porosity for a particleboard. Hardness measurement is done using Wallace Micro Hardness Tester: DIN-Normen, 1987.

Each panel was cut to get two WA/ST samples (2.54 cm x 2.54cm), two density samples (2.54 cm x 2.54 cm) and two TS/MOR samples (14 cm x 2.54 cm).

The scanning electron microscope(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, Pyris Diamod TG-DTA High Temp 115 V) was used to measure the thermal stability of particleboard samples.

Results and Discussion

Some physicochemical properties of betel nut fiber are determined according to moisture content by TAPPI-T 210 om.86, 1992-93, Ash content by ASTM test method (D- 1102, 1986), fat and waxes content by Soxhlet extraction Method, cellulose content by AOAC method, pH by pH meter, lignin content by TAPPI method (TAPPI, 1992) hemicelluloses content by TAPPI method (TAPPI, 1992) and bulk density by Tapped method 1.

Table 2: Physicochemical Properties 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 and Ashok, (2011)

Effect of Pressing Temperature on the Physicomechanical Properties

The thickness of the prepared particleboards (PBT 1 – PBT 6) ranged from 0.46cm to 0.65cm. The density ranged from 0.92 $gcm^{-3}$to 1.24gcm^{-3}. The average water absorption and swelling thickness of the specimens following a 24h immersion ranged from 18.20% to 4.54% and 37.50% to 19.92% respectively. Particle board (PBT6) had the highest board density due to highest pressing temperature. The WA and ST values increased with decreasing the board density. The MOR ranged from 2516 psi to 3273 psi for PBT 1– PBT 6respectively. Particleboards having the greatest values of densities had the greatest values of MOR except (PBT6). The TS ranged from 2.1lb to 3.6 lb respectively. It was found that PBT 6 (180ºC) had the less MOR and TS than PBT 5 (170ºC) due to the more brittleness of fiber and resin, as expected. It can be suggested that the particleboard density plays a very important role on the bending strength. The pressing temperature increased which tend to increase the density of boards, as expected. The physicomechanical properties of prepared particleboards are shown in Table 3 and variation of properties at different pressing temperatures are shown in their respective figures 4.

Table 3. Physicomechanical Properties of Prepared Particleboard at Various Pressing Temperatures

Physicomechanical Property	PBT1	PBT2	PBT3	PBT4	PBT5	PBT6
Thickness (cm)	0.65	0.57	0.53	0.50	**0.50**	0.46
Density (gcm^{-3})	0.92	0.98	1.07	1.12	**1.20**	1.24
Water Absorption (%)*	18.20	15.80	14.43	13.04	**9.0**	4.54
Swelling Thickness (%)*	37.50	30.29	29.77	28.50	**22.28**	19.92
Hardness (Shore D)	81.25	85.00	86.75	88.00	**88.75**	90.7
Tensile Strength (lb)	2.1	2.5	2.6	3.5	**3.6**	3.1
Modulus of Rupture (psi)	2516	2537	2544	2731	**3273**	3237

Pressing Temperature = 130º C, 140º C, 150º C, 160º C, 170º C, 180º C

Pressing Time = 15 min

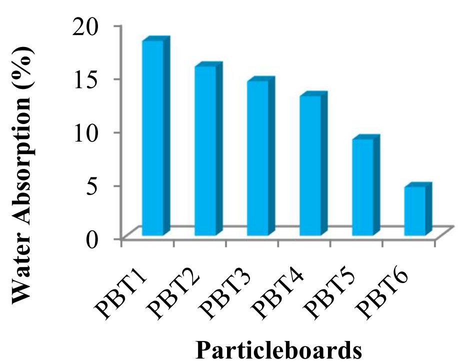
Fixed loaded Pressure = 2200 psi

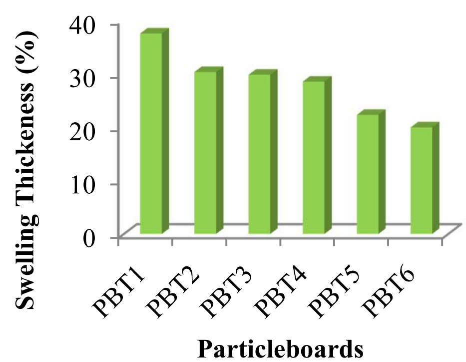
Fixed Fiber Length = 2- cm, Adhesive = CNSL – UF

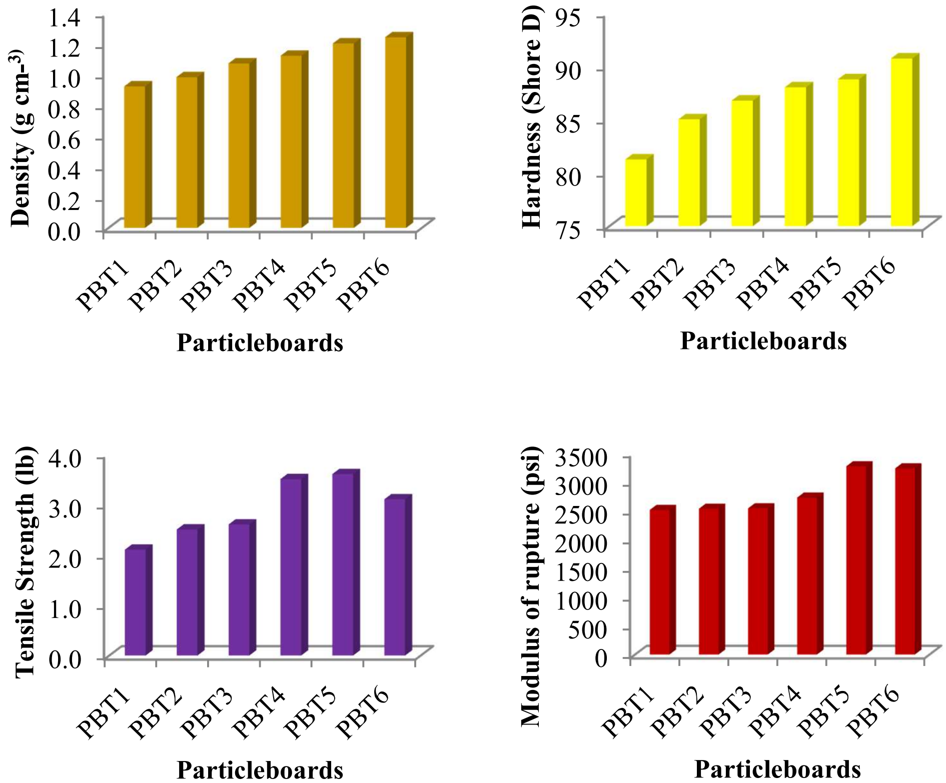
* = after 24 h

PBT1 = PB (130º C) PBT2 = PB (140º C) PBT3 = PB (150º C)

PBT4 = PB (160º C) PBT5 = PB (170º C) PBT6 = PB (180º C)







PBT1 = PB (130º C) PBT2 = PB (140º C) PBT3 = PB (150º C)

PBT4 = PB (160º C) PBT5 = PB (170º C) PBT6 = PB (180º C)

Figure 4: Variation of physicomechanical properties of particleboards at different pressing temperatures

Effect of Fiber Length on the Physicomechanical Properties

The thickness of prepared particleboards (PBL 1-PBL 5) ranged from 0.45cm to 0.67cm. The density ranged from 0.88gcm^{-3} to 1.29gcm^{-3}. The average water absorption and swelling thickness of the specimens following a 24 h immersion ranged from 9% to 38.1% and 22.28% to 56.69% respectively. The PBL 5 had the highest board density due to the shortest fiber length. The WA and ST of PBL3 (2.0cm) was less than that of the others.

There are more voids between the longer fiber, so WA and ST of PBL1 (4.0cm) and PBL2 (3.0cm) increased. But there are greater surface area contacting with water for the shorter fiber, so WA and ST of PBL 4 (1.0cm) and PBL 5 (0.5cm) increased, as expected. The MOR and TS ranged from2095 psi to 3273 psi and 1.90 lb to 3.60lb respectively PBL3 (2.0cm) had the greater values of MOR than others (PBL 1 (4.0cm), PBL 2 (3.0cm))which had more voids and PBL4 (1.0cm), PBL 5 (0.5cm) had greater surface area. The hardness ranged from 79.38 Shore D to 91.70 Shore D for PBL1-PBL5. It was found that the hardness of particleboard increases with decrease in fiber length when compared to other fiber lengths. The fiber length was important factor to determine the quality of product particleboard. The physicomechanical properties of prepared particleboards are shown in Table 4 and variation of properties at different fiber lengths are also shown in respective figures 5.

Table 4: Physicochemical Properties of Prepared Particleboards at Various Fiber Lengths

Physicomechanical Property	PBL1	PBL2	PBL3	PBL4	PBL5
Thickness (cm)	0.67	0.55	**0.5**	0.5	0.45
Density (gcm^{-3})	0.88	0.96	**1.20**	1.25	1.29
Water Absorption (%)*	32.5	30.5	**9.0**	37.5	38.1
Swelling Thickness (%)*	34.17	30.43	**22.28**	48.24	56.69
Hardness (Shore D)	79.38	80.38	**88.75**	90.50	91.70
Tensile Strength (lb)	3.05	3.30	**3.60**	2.30	1.90
Modulus of Rupture (psi)	2095	2776	**3273**	2387	2148

Fixed Pressing Temperature = 170º C

Pressing Time = 15 min

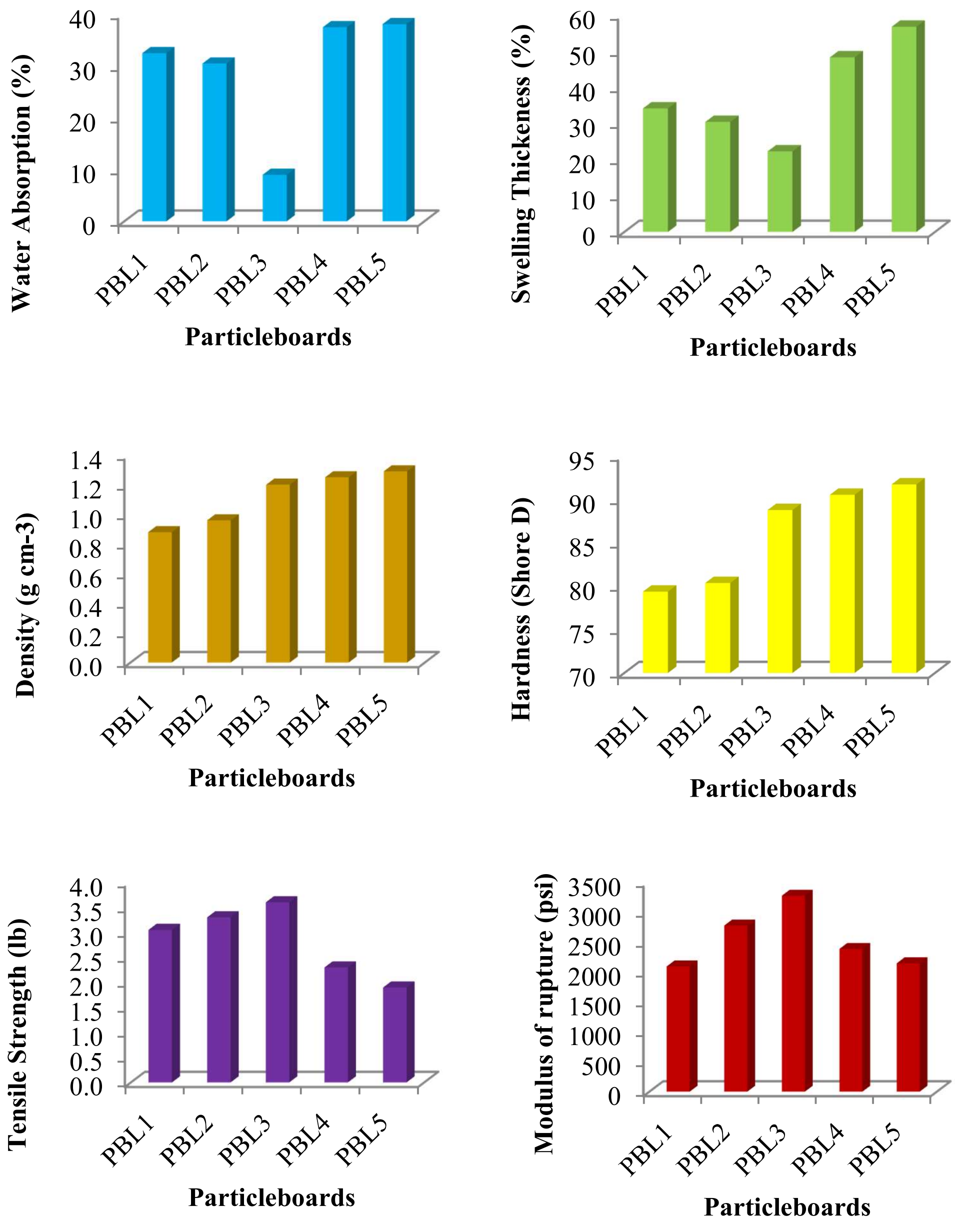
Fixed loaded Pressure = 2200 psi Adhesive = CNSL – UF

Fiber lengths = 0.5 cm, 1.0 cm, 2.0 cm, 3.0 cm, 4.0 cm

* = after 24 h

PBL1 = PB (L = 4.0 cm) PBL2 = PB (L = 3.0 cm) PBL3 = PB (L = 2.0 cm)

PBL4 = PB (L = 1.0 cm) PBL5 = PB (L = 0.5 cm)



PBL1 = PB (L = 4.0 cm) PBL2 = PB (L = 3.0 cm) PBL3 = PB (L = 2.0 cm)
PBL4 = PB (L = 1.0 cm) PBL5 = PB (L = 0.5 cm)

Figure 5: Variation of physicomechanical properties of particleboards at different fiber lengths

Screw holding (SH) and connection of boards

The screws and nails were strongly held by particleboards without breaking, racking and brusting (Figure 6).

Figure 6: Photographs of screw holding for PBT6 (or) PBL3

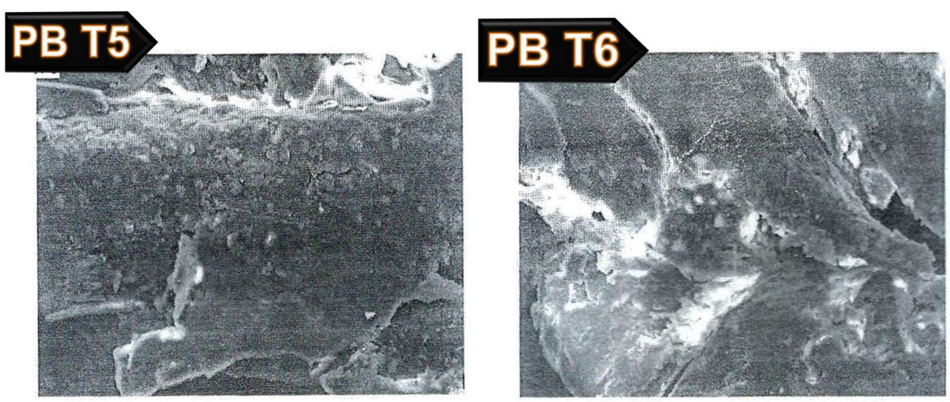


Figure 7: SEM micrographs of PBT5 and PBT6 particleboards

The surface of PBT 5 (170°C) was more uniform than that of others. It also had less micropores and microcracks than PBT6. It was found that the more uniform and less micropores, microcracks as more compactability and tend to enhance more MOR and less WA and ST.

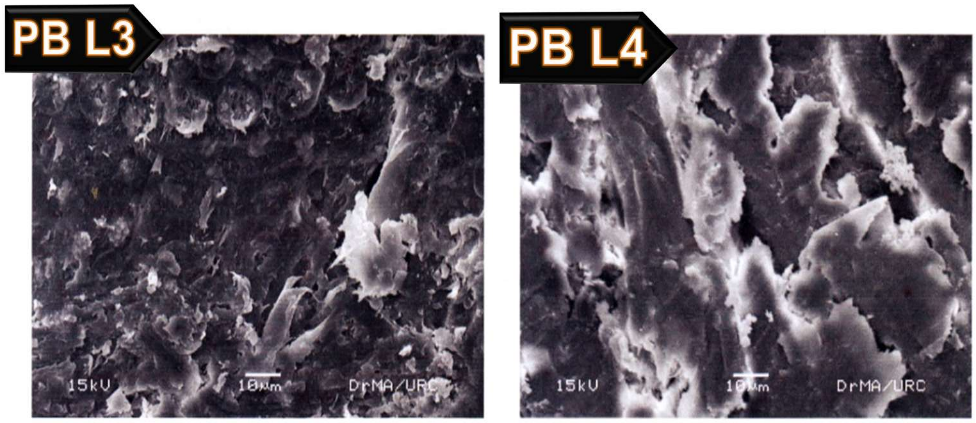


Figure 8: SEM micrographs of PBL3 and PBL4 particleboards

From the SEM analysis it was found that the long fibers PBL 3 (2.0cm) can withstand maximum stress, and showed better strength compared to short fiber (PBL 4 (1.0cm)). The short fibers (PBL4) were not uniformly distributed in the specimen resulted in lesser strength. PBL3 had agglomerate structure tend to compact and enhance MOR. The PBL4 had cluster form with less compact and decrease MOR. The SEM photo images of fractured surface of the particleboards were shown in Figures7 and 8.

TG-DTA Thermograms of PBT 5 and PBT 6

TG-DTA Thermograms of PBT 5 and PBT 6 are shown in Figure 9.

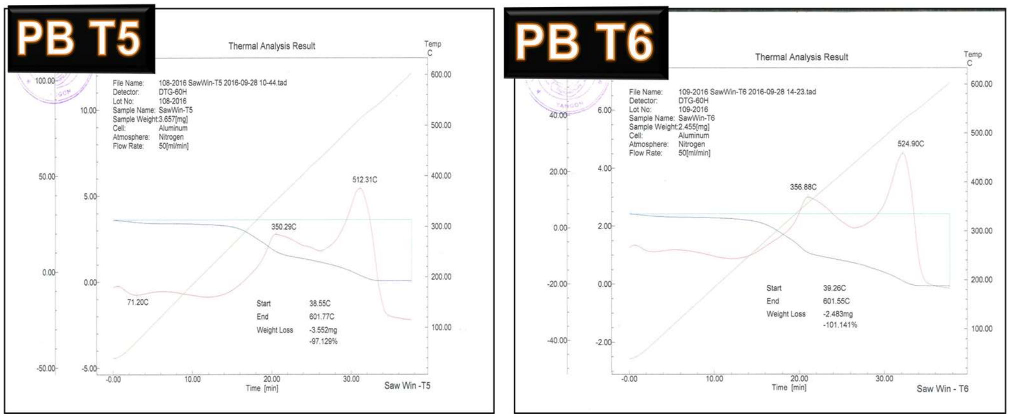


Figure 9: TG-DTA thermograms of PBT5 and PBT6 particleboards

PBT 5 (170°C) was more thermally stable due to the less weight loss than PBT 6 (180°C) until 440°C.

TGD-TA Thermograms of PBL 3 and PBL 4

PBL 3 (2.0cm) was more thermally stable (or) more thermally resistant due to the less weight loss than PBL 4 (1.0cm) Figure 10.

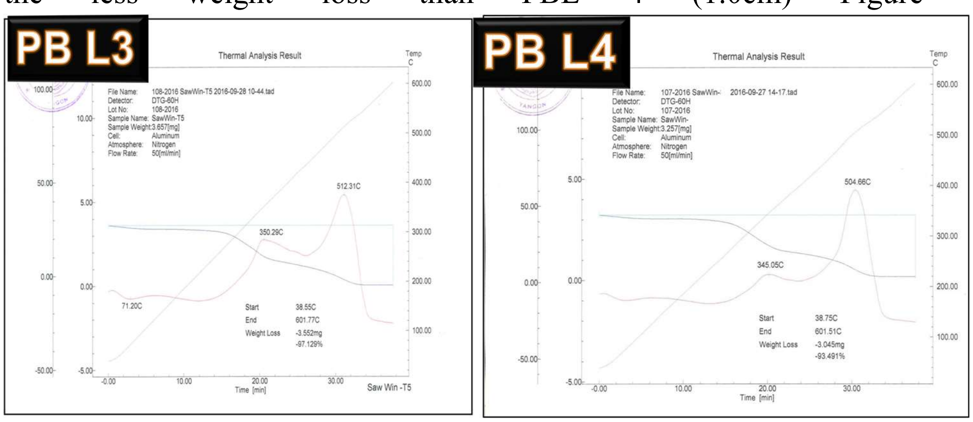


Figure 10: TG-DTA thermograms of PB L3 and PB L4 particleboards

Table 5: Thermal Analysis Data of Prepared Particleboards

Item	TG Break in Temp: (°C)	TG Weight Loss (%)	DTA Peak Temp: (°C)	DTA Nature of Peak	Remark
PBT5	38.55-170	7.030	71.20	Endo	Loss in weight due to dehydration
	170-440	58.820	350.29	Exo	Due to combustion
	440-601.77	31.219	512.31	Exo	Due to combustion Residual weight is 2.87%
PBT6	38.57-180	7.093	-	-	Loss in weight due to dehydration
	180-466.70	58.947	344.44	Exo	Due to combustion
	466.70-601.51	33.318	536.98	Exo	Due to combustion. Residual weight is 0.634%
PBL3	38.55-170	7.030	71.20	Endo	Loss in weight due to dehydration
	170-440	58.820	350.29	Exo	Due to combustion
	440-601.77	31.219	512.31	Exo	Due to combustion Residual weight is 2.87%
PBL4	38.75-140	7.890	-	-	Loss in weight due to dehydration
	140-430	58.333	345.05	Exo	Due to combustion
	430-601.51	27.268	504.66	Exo	Due to combustion Residual weight is 6.509%

Surface finish

After formation of particleboard, the surface can be made attractive by using sun mica laminates since the particleboard are laminated with different lamination films, different finished touches, can be given like teak wood finish, padauk wood finish, mahogany wood finish etc. Some of surface finishes are shown in Figure 11.

Figure 11: Photographs of surface finishes for PBT5 (or) PBL3

Application

Some of the application of the particleboards (PBT5 or PBL3) made from betel nut fiber and modified cashew nut shell liquid are shelves, furniture, boxes and cupboards ceilings etc., are shown in Figure 12.

Figure 12: Photographs of box and ceiling for PBT5 (or) PBL3

Conclusion

The results presented here suggest that it is completely feasible to manufacture acceptable or high quality particleboard using betel nut fiber as an alternative lignocellulosic raw material. Since particleboards produced with pressing temperature at 170ºC had the most desirable quality, the production of such pressing temperature is recommended for the milling of the culms. Fiber length (2.0cm) was also found to have a great effect on the properties of modified CNSL-UF bonded betel nut fiber particleboards. The use of renewable materials such as betel nut fiber for manufacturing particleboards, could help to alleviate the scarcity of raw material for the particleboard industry.

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