__Original Research Article__

Properties of Particleboard Manufactured From Commonly Used Bamboo (*Bambosa Vulgaris*) Wastes in Bangladesh

ABSTRACT

Aims: This paper exploresthe properties of single layer particleboard produced from bamboo wastes and branches.

Experimental: Three types of singlelayer particleboard i.e., branch-waste mixed particleboard (WB_{PB}), bamboo branch particleboard (B_{PB}) and bamboo wastes (shavings obtained during planning operation of bamboo) particleboard (W_{PB}) were manufactured with 15% urea formaldehyde (UF) resin. Physical and mechanical properties of the manufactured particleboards were evaluated according to the ASTM D-1037 standard.

Results: Results showed that the physical properties i.e., density, moisture content (MC), water absorption (WA),thickness swelling (TS), liner expansion (LE) and mechanical properties i.e. modulus of elasticity (MOE) and modulus of rupture (MOR) of bamboo branch-waste mixed particleboard (WB_{PB}) was better than bamboo branch particleboard (B_{PB}) and bamboo wastes particleboard (W_{PB}). It was found that the density of B_{PB}, W_{PB} and WB_{PB} were 742, 846and 1024 kg/m^3, respectively. Thickness swellings of B_{PB}, W_{PB} and WB_{PB} after 24 hours of immersion were 32.33, 19.6 and 16.3%, respectively. Water absorption rate of B_{PB}, W_{PB} and WB_{PB} particleboards were 81, 64.3 and 39.8%, respectively. Modulus of rupture of B_{PB}, W_{PB} and WB_{PB} were 16.8, 18 and 21.6 N/mm^2, respectively.

Conclusion: All these three types of particleboard followed the American National Standard ANSI A208.1 requirements for physical and mechanical properties of particleboard.

Keywords:*Bamboo particles,Urea Formaldehyde (UF)resin, physical properties, bending strength*

1. INTRODUCTION

In the last 40 years successful development of wood based panels with the economic advantage of low cost wood and other lignocellulosic materials is the proficient alternative of solid wood. The demand of composite wood products such as particleboard, plywood, hardboard, oriented standard board, medium density fiberboard and veneer board has hiked significantlythroughout the world[1]. Among them, the demand of particleboard has been increasingsignificantlybecause ofhouse construction, interior decoration, manufacturing of furniture[1-2]flooring, home constructions, counter tops, stair treads,cabinets, tabletops, vanities, speakers, sliding doors, lock blocks, interior signs, displays, table tennis, pool tables, electronic game consoles, kitchen worktops, and work surfaces in offices, educational establishments, laboratories and other industrial products [3]. This huge demand of particleboard accelerates the declining rate of natural forest resources. Consequently, it has raised a vitalissueforthecontinuous supply of raw material to the wood based sectors [4].Thus, the demand of alternative sources of raw materials is increasing ever more. Alternatelignocellulosicmaterials like agricultural residues and non-woody plant fibers may play a major role for minimizingthe demand of manufacturing the composite panels [3].

Bamboo is a giant woody grass andbelongs to group angiosperms and order monocotyledon [5]. There are about 1,200 –1,500 bamboo species under 60 to 70 genera all over the world [6].Bamboo is a renewable raw materialuniversally acceptedfor building construction.It has fundamental role in industrial and domestic economics in many developing countries.Bamboo culm consists most of the woody portion which is straight, cylindrical and hollow-formed of nodesandinternodes.Compared with some commercial wood species, bamboo exhibits equal or better physical and mechanical properties, which offer good potential for processing it into composites (bamboo-based panels) as a wood substitute[7].The bamboo-based industries have developed into a multi-million dollar industry with their variety of products enjoying very high demand domestically as well as internationally. Similarly with other countries, value-added laminated bamboo panels were developed in Bangladesh from two common locally found species named*Bambussa balacooa and Bambussa vulgaris.* The panels made from bamboo have been found suitable for different end-uses [8].But only 3.6m from base of *B. vulgaris* found usable in an economic point of view as laminated bamboo panels. During the production of these products, more than 30% of the bamboo like branches, nodes, rhizomes and lower portion of culm, etc. are left unused and treated as wastage[8]. These bamboo wastes are mostly used as fuel. These unused portions can be use as raw material for particleboard industries. Although many studies have been conducted on bamboo particleboards for development of local bamboo based industries but none of the explores the utilization of bamboo wastage for particleboard production.Therefore, the aim of this study is to produce single layer particleboard with UF resin from the bamboo wastesand branches and evaluation of their properties.

2. EXPERIMENTAL

2.1 Materials preparation

Wastage of mature village grove bamboo (*Bambusa vulgaris)*of 3 years oldwasused in this experiment and branches were collected. Wastage and branches were chipped with animprovisedchipper. These chips were further grinded in a laboratory grinder to convert them into particles. After grinding, each type of raw materials was screened in 1 and 2 mm opening mesh to eliminate the undersized and oversized particles. Particleswere dried in oven (SANFA, model: 9101-ISA.Sr no: 5054)for 24 hourswith 103±2°C temperature to reduce the moisture content up to4%.Liquid urea formaldehyde glue (48% solid content) was used as a binder. The proportion of urea formaldehyde resin was 15% of dry weight basis of particles. Flower was used as extender and NH_4Cl was used as hardener. The wax was added to improve the moisture resistance at a rate of 1% on the dry weight basis of particles.

2.2 Panel manufacturing

The dried particles were manually blended with UF resin. Three different types of particleboards were manufactured i.e., bamboo branch particleboard (B_{PB}), bamboo waste particleboard (W_{PB}) and bamboo branch waste mixed particleboard (WB_{PB}) by following the same process. The ratio of branch and nodeinbamboo branch waste mixed particleboard (WB_{PB}) was 1:1. The target size of the particleboard was 30×20cm with the thickness of 12mm.After blending the mat of the particleswas formed manually.The mats were then pressed in a hot press (DZ47-63, D32) for 8 minutes at the temperature of 130℃ and specific pressure of 4.5 N /mm^2.After hot pressing, the mats were further cool pressed for 15 minutes for avoiding spring back of particleboards. The boards conditioned in a conditioning room for 48 hours prior to stacking to avoid degradation of the urea formaldehyde resins.Finally,the boards were trimmed to reduce the edge effect during testing.

2.3 Laboratory Test

All tests were carried out in accordance with ASTM D-1037 [9]standard after conditioning all the specimens for 48 hours at room temperature.At least six specimens were collected from each type of panel for testing the physical and mechanical properties. Modulus of rupture (MOR), modulus of elasticity (MOE),density, water absorption (WA), linear expansion (LE) and thickness swelling (TS) were measured. The MOR and MOE were measured by using Universal Testing Machine(IMAL-IB600).WA andTS samples were fully immersed in distilled water at 25° C for24 hours.

2.4 Statistical Analysis

Average and standard deviation was calculated for different properties. SAS statistical software (version6.2) was used for the data analysis. ANOVA and LSD (least significant difference) test were carried out to evaluate the significance of differences among the properties of panels.

3. RESULTS AND DISCUSSION

Statistical analysisof physical and mechanical properties of the boards are shown in tables 1 and 2. Analysis of variance (ANOVA) was used to access any co-relation between boards of different particle types (bamboo wastages and branches).

Table-1. Statistical analysis of density, MoR and MoE of three particleboards

Types of Particle board	Thickness (mm)	Properties		
		Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)

B_{PB}	12	742^{C}	16.8^{C}	1995^{C}
		(4.62)	(0,51)	(100.73)
W_{PB}	12	846^{B}	18^{B}	2243^{B}
		(3.58)	(0.41)	(173.6)
WB_{PB}	12	1024^{A}	21.6^{A}	2752^{A}
		(6.06)	(1.48)	(290.47)

Values in parenthesis are standard deviation
Values within the same line column by different letters are significantly different

Table-2. Statistical analysis of dimensional stability of three particleboards

Types of Particle board	Thickness (mm) mean	Properties		
		WA (%)	**LE (%)**	**TS (%)**
B_{PB}	12	81^{A}	0.98^{A}	32.33^{A}
		(5.06)	(0.01)	(0.7)
W_{PB}	12	64.3^{B}	0.86^{B}	19.6^{B}
		(2.2)	(0.065)	(2.39)
WB_{PB}	12	39.8^{C}	0.67^{C}	16.3^{C}
		(10.77)	(0.03)	(1.13)

Values in parenthesis are standard deviation
Values within the same line column by different letters are significantly different

3.1 Density

The density of particleboards made from bamboo branch (B_{PB}), bamboo wastes (W_{PB})and bamboo branch-waste mixed (WB_{PB}) were showed in fig. 1..The results showed that WB_{PB}particleboard have higher density than those of the particleboard made from bamboo wastes (B_{PB}) and bamboo branches (W_{PB}) using the same resin as adhesive. This effect can be due to the raw materials density which affects the particleboard density. The density of bamboo 648 kg/m^3 (40.5 lb/ ft3) and higher specific gravity of bamboo ranged from 0.3 to 0.8 [10].Thebamboo culm waste contains shavings of peripheral layer of bamboo and holds greater density because of higherfrequency of vascular bundle present in peripheral layer[11-12].Higher frequency of vascular bundle influence higher density in most of the bamboos[13]. But bamboo branch cell wall contains higher lignin content compared to culm cell wall [14]. This high lignin content maymake up the lignin lacking and resulting greater density of mixed particleboard (WB_{PB}). Significant difference (when F =78.37, df =2, 24, 26 and $P < 0.05$) of density within B_{PB}, $W_{PB}$and$WB_{PB}$was found in ANOVA analysis(Table. 1).Compared with other related works the value of these particleboards were substantially higher than that of saline Athel wood particleboard 720 kg/m^3 [15]. But WB_{PB}particleboard show higher density and remains two show lower densities compared to bamboo waste particleboards [16]. According to American National Standard [17] only bamboo branch particleboard (B_{PB}) wason the range of medium density particleboard (610-800 kg/m^3) and another two types of particleboard i.e., bamboo wastes particleboard (W_{PB}) and bamboo branch-waste mixed particleboard (WB_{PB}) were high density particleboard (above 800 kg/m^3).

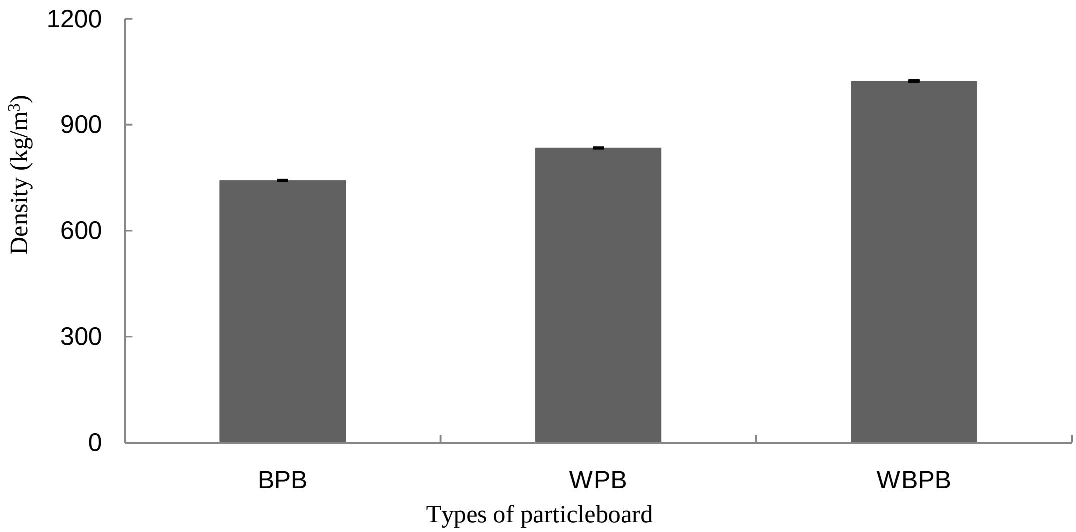

Fig.1. Density of three types of particleboard

3.2 Modulus of Elasticity (MOE)

Modulus of Elasticity of B_{PB}, W_{PB}andWB_{PB} particleboards were showed in fig. 2. Modulus of Elasticity affected similarly by density. Increasing board density increases modulus of elasticity; increasing surface density and surface particle alignment also increases modulus of elasticity. From the ANOVA,it has been observed that, there was significant difference present (when $F = 29.21$, df = 2, 12, 14 and $P < 0.05$), between theB_{PB},W_{PB} and WB_{PB}particleboards (Table. 1).It wasalso observed that the mean Modulus of Elasticity of B_{PB}andW_{PB}particleboardwas lower compared with the MOE of Malaysan bamboo *Gigantochloascortechinii*particleboard(2696 N/mm^2)[18]and it was found that only the MOE of $WB_{PB}$was higher. The MOE of these three boards were also compared with the MOE of Athel wood particleboard [10] and bamboo waste particleboards [16].It was found that the MOE of B_{PB}waslower but MOE of W_{PB} and WB_{PB}washigher (Fig. 2). According to American National Standard [17] MOE of particleboard range from 1725-2750 N/mm^2 and all the three types of particleboard follow the range of the standard.

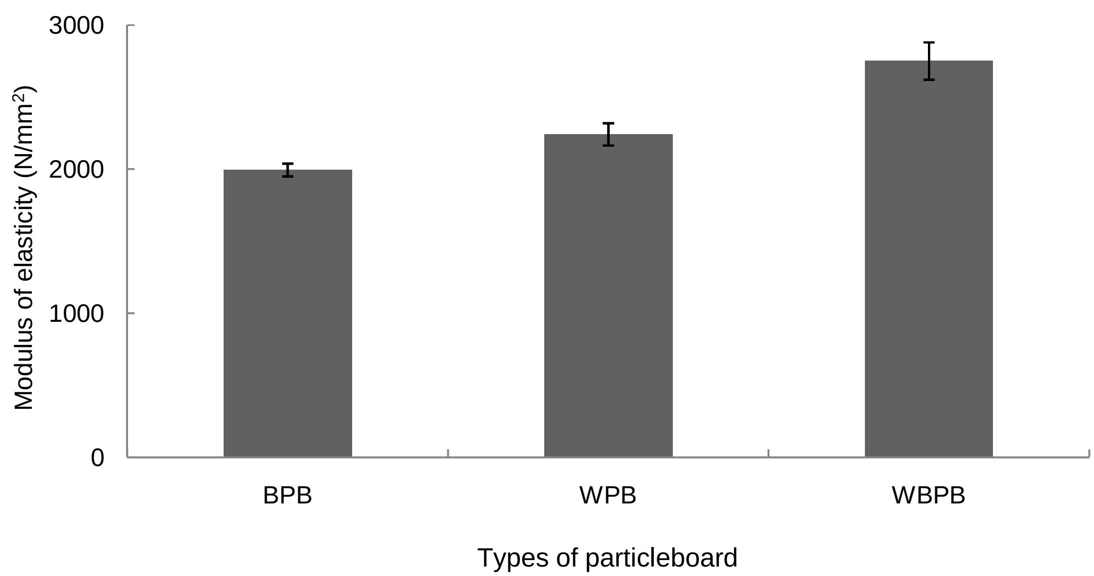

Fig. 2. Modulus of elasticity (MOE) of three types of particleboard

3.3 Modulus of Rupture (MOR)

The MOR of B_{PB}, W_{PB} and WB_{PB} particleboard were presented in fig. 3.Itis observed that the mean Modulus of Rupture of B_{PB} and W_{PB} particleboardswerelowerexcept WB_{PB} particleboard compared with particleboard made from *Bambusavulgaris*bamboo waste particleboards [16].It was found that only B_{PB} is lower, W_{PB} is nearly equal and WB_{PB} is greater than *Bambusavulgaris*bamboo waste particleboard. From the ANOVA it has been observed that, there was significant difference (when F =29.28, df = 2, 12, 14 and $P < 0.05$) present for MOR between B_{PB}, W_{PB} and WB_{PB} particleboard (Table. 1).According to American National Standard [17] MOR of particleboardsranges from 16.5-23.5 N/mm^2 and all the three types of particleboard are on this rangeof the standard.

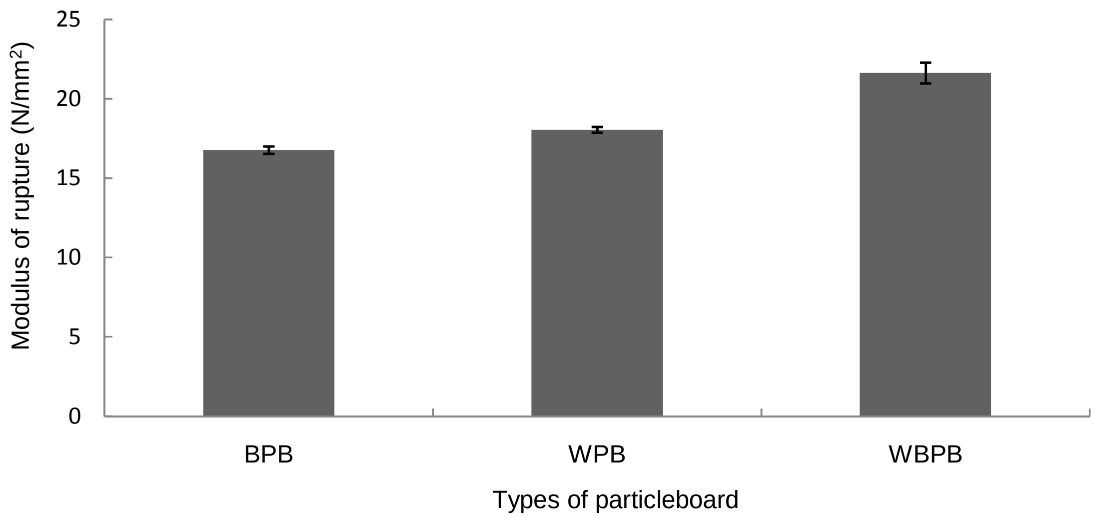

Fig.3. Modulus of rupture (MOR) of three types of particleboard

3.4 Dimensional Stability

In general, the water absorption, thickness swelling, and linear expansion value of particleboard made from bamboo branch, bamboo waste and the mixed particleboard increased with increasing in soaking time. It was found that after 24 hours the percentage of water absorption capacity of B_{PB} particleboard, W_{PB} particleboard and WB_{PB} particleboard were 81%, 64.3% and 39.8% respectively. Swelling percentage in length of B_{PB}, W_{PB} and WB_{PB} particleboard were 0.98%,0.86%and 0.67% respectively and the percentage of thickness swelling of B_{PB} particleboard, W_{PB} particleboardand WB_{PB} particleboard were 32.33%, 19.6% and 16.3% respectively(Fig. 5-6).According to American National Standard [17] the mean linear expansion and thickness swellingvalues for all three types of board will exceed the critical value of 0.35 percent and 1.6 percent.

The water absorption in the 24-hour water soak test was highly correlated with the board density [19], particle hygroscopicity, spring back and water absorption affinity of the binding materials[16].For all formulation, the higher compaction ratio always absorbed a lower amount of water than the lower compaction ratio. Water entry into the higher density boards occurred at a slower rate due to the decreased porosity and the increased wood material [20]. If density increase porosity will decrees. So here high density board WB_{PB} has absorbed less water than other two types of board (Fig. 4). Used urea formaldehyde adhesive haswater affinity characteristics and absorbs moisture when it exposed to moist condition[16].

Tomalang *et al.* [21] described that higher holocelluose content of bamboo mainly responsible for the water absorption of particleboard. The density and water absorption capacity have more effect on thickness swelling and liner expansion of particleboard. Higher density board absorbs less water than lower density board, so the thickness swelling and linear expansion percentage of higher density WB_{PB} is lower than other two particleboards (Fig. 5-6). EspeciallyB_{PB} absorb more water and it may be happen for chemical composition variation between bamboo and bamboo branch.Analysis of variance show significant difference was present between B_{PB}, W_{PB} and WB_{PB} particleboard in water absorption, thickness swelling and linear expansion (F = 43.79, df= 2, 12, 14 and $p < 0.05$ for WA, F= 1.064, df = 2, 12, 14 and $p < 0.05$ for LE and F = 14.85, df= 2, 12, 14 and $p < 0.05$ for TS)(Table. 2).WA and TS of three types of particleboard were compared with*Bambusavulgaris*bamboo waste particleboards [16] where all show higher water absorption and thickness swelling.It is also observed that the mean linear expansion of B_{PB}, W_{PB} and WB_{PB} were0.98%, 0.86% and 0.67%.Comparedtobagasse particleboard [22] 0.92%, it was found that only WB_{PB} is higher but B_{PB} and W_{PB} is lower than bagasse particleboard. The findings of properties of this study are comparable to the commercial particleboard produced in Bangladesh and much higher than the results of experimental particleboards as reported by Ashaduzzaman and Sharmin [23].

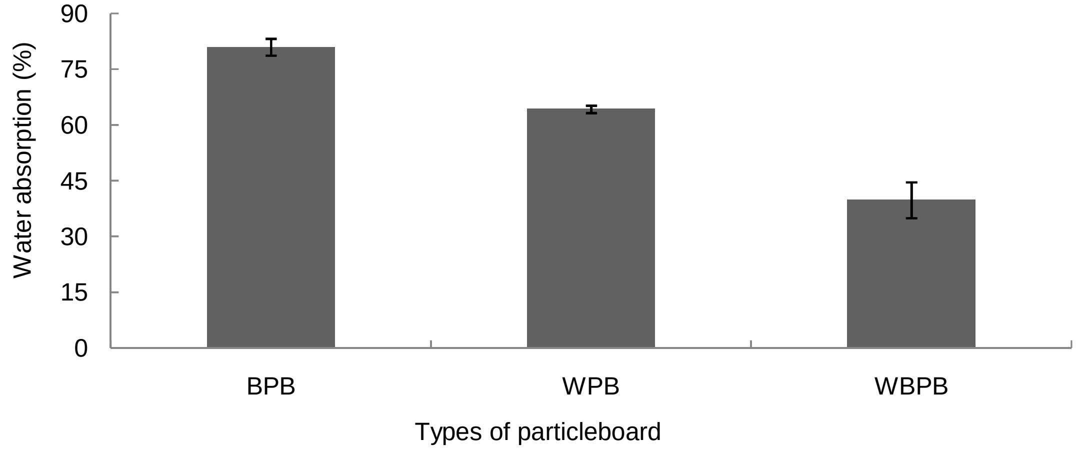

Fig. 4. Water absorption of three types of particleboard

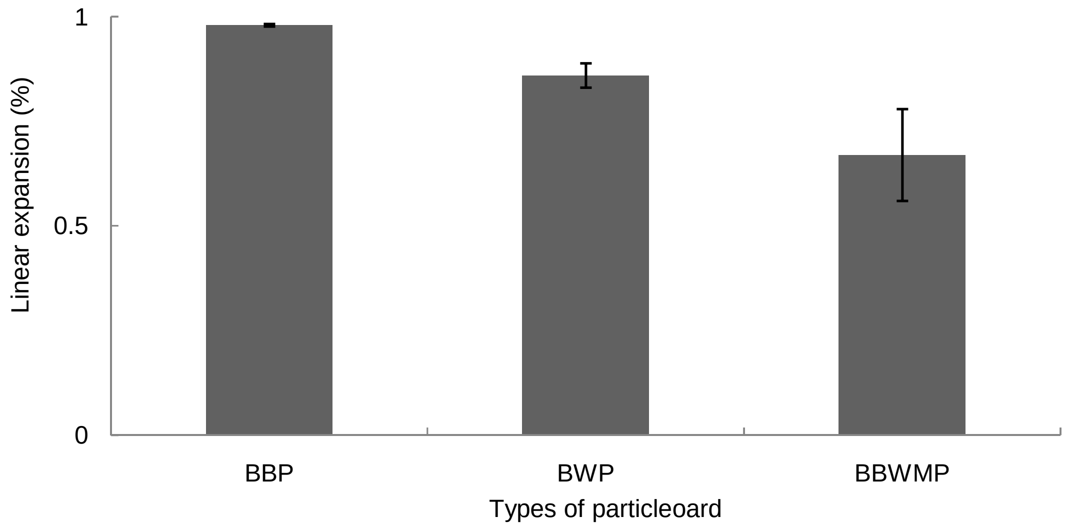

Fig. 5. Linear expansion of three types of particleboard

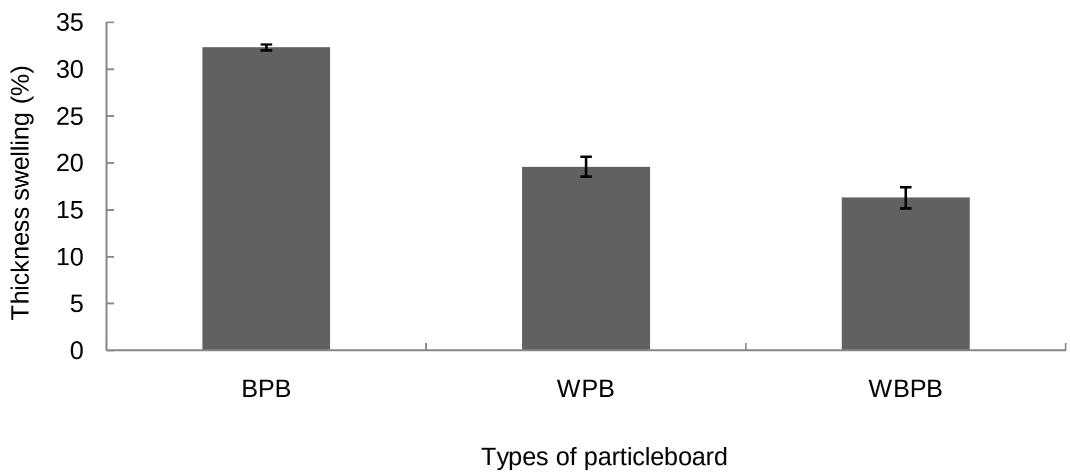

Fig. 6. Thickness swelling of three types of particle board

4. CONCLUSION

The study investigated the properties of single layer particleboardsmanufacturedfrom branch and wasteof*Bambusavulgaris*with UF resin. The above results suggest that the produced particleboard from branches and wastages istechnically feasible which ensures the optimum utilization of renewable biomass. From the results and discussion, thefollowingspecific conclusion can be drawn:

1. Bamboo culm waste showed greater density, MOE and MOR than bamboo branch particleboard. But mixture of culm waste and branch at same content showed much greater density, MOE and MOR between three type particleboards.
2. Particleboard with higher strength and dimensionally stable can be produced from the bamboo wastes particleboard.

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