Original Research Article

Properties of Particleboard Manufactured From Commonly Used Bamboo (~~*BambosaVulgaris*~~*Bambusa 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, 846and1024 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,UreaFormaldehyde (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 significantlythroughoutthe world[1]. Among them, the demand of particleboard has been increasingsignificantlybecause ofhouseconstruction, interior decoration, manufacturing of furniture [1-2] flooring, home constructions, countertops, 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 vitalissueofthecontinuous 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 inminimizingthe 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 acceptedforbuilding construction.Ithas a fundamentalrolein industrial and domestic economics in many developing countries.Bambooculm 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 to other countries, value-added laminated bamboo panels were developed in Bangladesh from two common locally found species named*Bambu~~s~~sabalacooa and Bambu~~s~~sa 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 the culm, etc. are left unusedand treated as wastage[8]. These bamboo wastes are mostly used as fuel.These unused portions can be used 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)*of3 years oldwasusedin 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 an oven(SANFA, model: 9101-ISA.Sr no: 5054)for 24 hourswith103±2^{o}C temperature to reduce the moisture content up to4%.Liquidurea formaldehyde glue (48% solid content) was used as a binder. The proportion of urea formaldehyde resin was 15% of dry weight basis of particles. The flower was used as an extender and NH_4Cl was used as a 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.Afterblending the mat of the particleswasformed manually.Themats were then pressed in ahot press (DZ47-63, D32) for 8 minutes at the temperature of 130℃ and specific pressure of 4.5 N/mm^2.Afterhot 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]standardafter conditioning all the specimens for 48 hours at room temperature.Atleast 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 was measured by using Universal Testing Machine(IMAL-IB600).WA andTSsamples 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 is 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, MO~~o~~R and M~~Mo~~OEof three particleboards

Types of Particle	Thickness	Properties

board	(mm)	Density (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)
B_{PB}	12	742^{C} (4.62)	16.8^{C} (0,51)	1995^{C} (100.73)
W_{PB}	12	846^{B} (3.58)	18^{B} (0.41)	2243^{B} (173.6)
WB_{PB}	12	1024^{A} (6.06)	21.6^{A} (1.48)	2752^{A} (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} (5.06)	0.98^{A} (0.01)	32.33^{A} (0.7)
W_{PB}	12	64.3^{B} (2.2)	0.86^{B} (0.065)	19.6^{B} (2.39)
WB_{PB}	12	39.8^{C} (10.77)	0.67^{C} (0.03)	16.3^{C} (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 branches(B_{PB}), bamboo wastes (W_{PB})andbamboo branch-waste mixed (WB_{PB}) were shown in fig. 1.The results showed that WB_{PB}particleboard~~have~~hashigher density than those of the particleboard made from bamboo wastes (B_{PB}) and bamboo branches (W_{PB}) using the same resin as an adhesive. This effect can be due to the raw material's 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}andWB_{PB}wasfound in ANOVA analysis(Table. 1).Compared with other related works the value of these particleboards was substantially higher than that of salineAthel wood particleboard 720 kg/m^3 [15]. But WB_{PB}particleboardshowshigher 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}) wasinthe 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).

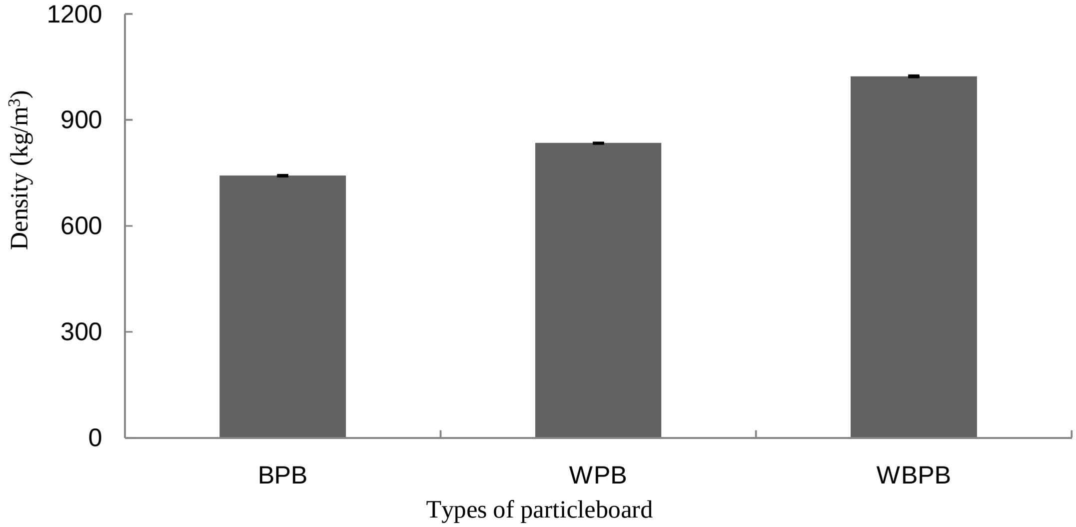

Fig.1. Density of three types of particleboard

3.2 Modulus of Elasticity (MOE)

Modulus of Elasticity of B_{PB}, W_{PB} and WB_{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 the B_{PB}, W_{PB} and WB_{PB} particleboards(Table. 1).It wasalso observed that the mean Modulus of Elasticity of B_{PB} and W_{PB} particleboardwaslower compared with the MOE of Malaysian bamboo *Gigantochloascortechinii*particleboard(2696 N/mm^2)[18]and it was found that only the MOE of WB_{PB} washigher. The MOE of these three boards was also compared with the MOE of Athel wood particleboard [10] and bamboo waste particleboards [16].Itwas found that the MOE of B_{PB} waslowerbut 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.

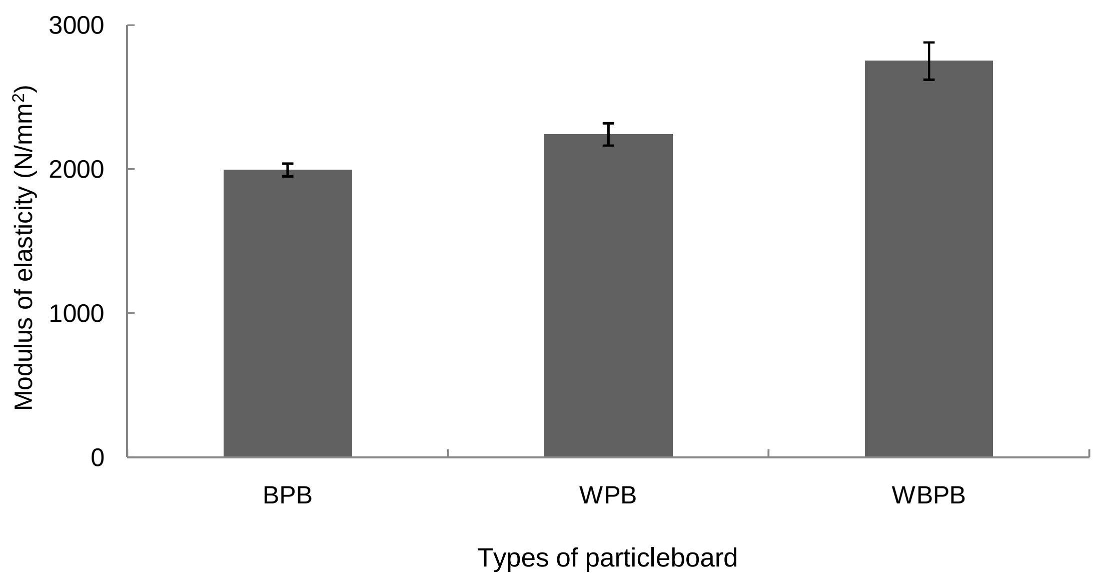

Fig. 2. Modulus of elasticity (MOE) of three types of particleboard

3.3 Modulus of Rupture (MOR)

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

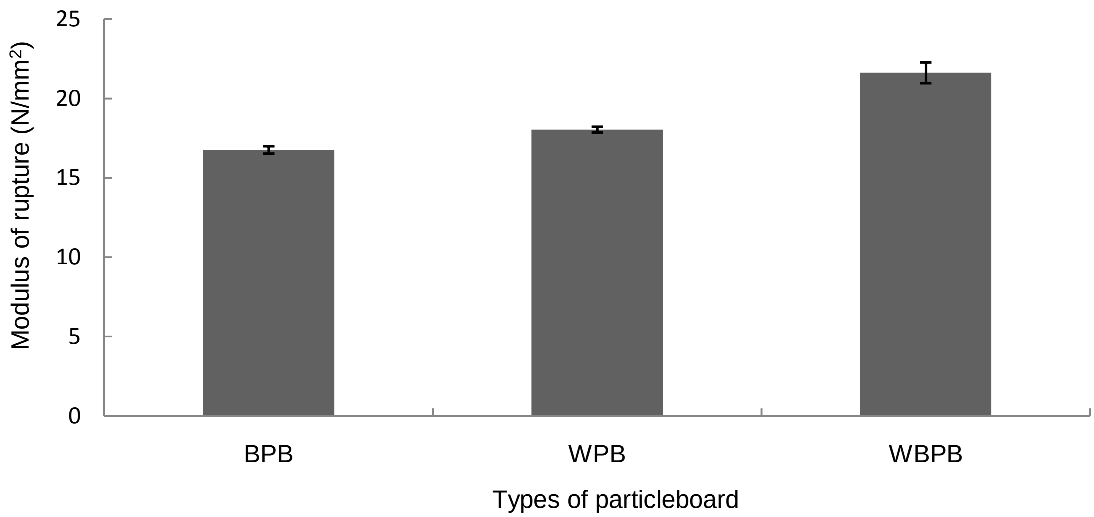

Fig.3. Modulus of rupture (MOR) of three types of particleboard

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}particleboardand 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, andthe percentage of thickness swelling of B_{PB}particleboard,W_{PB}particleboardandWB_{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 swellingvaluesfor 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].Forall formulations, 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 increases porosity will decrease. So here high density board WB_{PB} has absorbed less water than the other two types of board(Fig. 4).Used urea formaldehyde adhesive haswater affinity characteristics and absorbs moisture when it'sexposedtomoist conditions [16].

Tomalang*etal.*[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 linear expansion of particleboard. Higher density board absorbs less water than a lower density board, so the thickness swelling and the linear expansion percentage of higher density WB_{PB} is lower than other two particleboards (Fig.5-6).EspeciallyB_{PB}absorbsmore water and it may happenin chemical composition varies between bamboo and bamboo branch.Analysis of variance shows significant difference was present betweenB_{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*bamboowaste particleboards [16] where all show higher water absorption and thickness swelling.Itis also observed that the mean linear expansion of B_{PB}, W_{PB} and WB_{PB}were0.98%, 0.86% and 0.67%.Comparedtobagasseparticleboard [22] 0.92%, it was found that only WB_{PB} is higher but B_{PB}

and $W_{PB}$are lower than the bagasse particleboard.The findings of the 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].

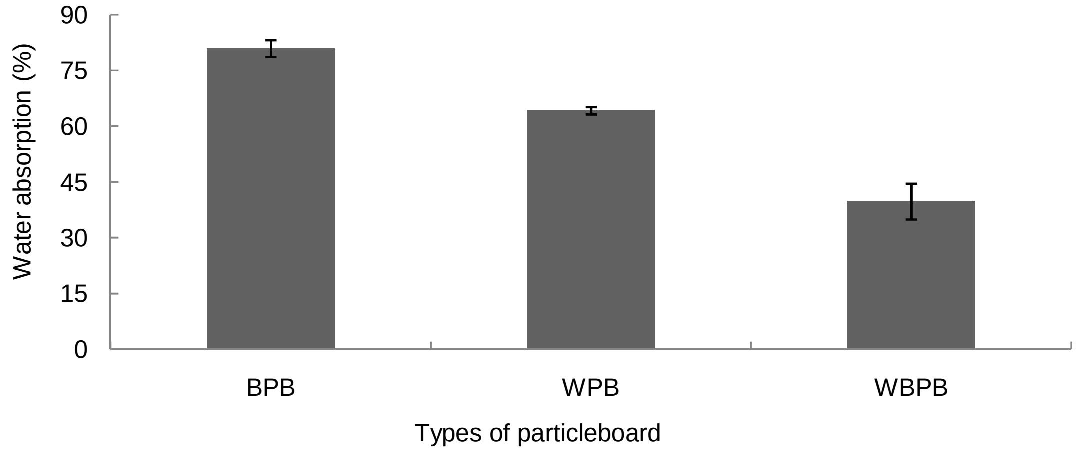

Fig. 4. Water absorption of three types of particleboard

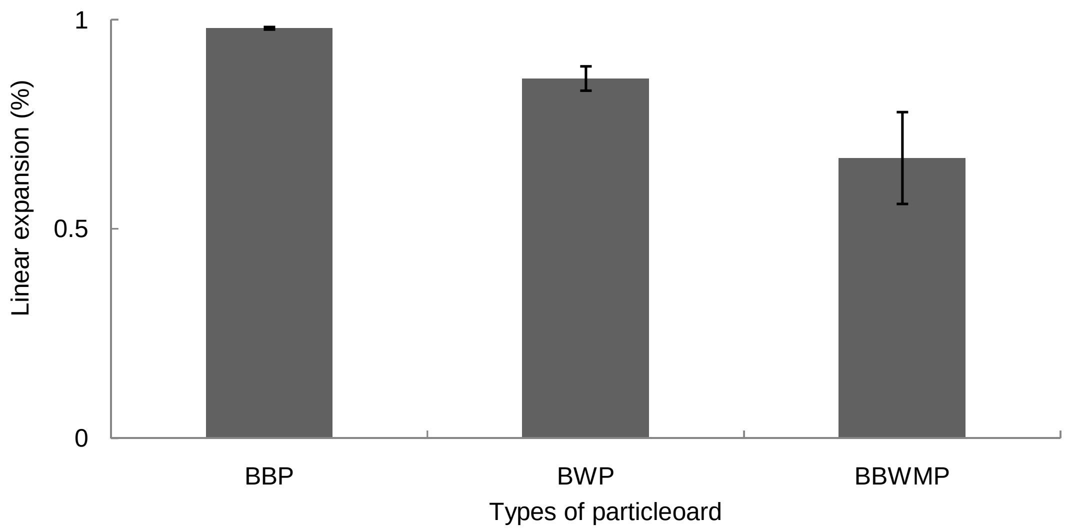

Fig. 5. Linear expansion of three types of particleboard

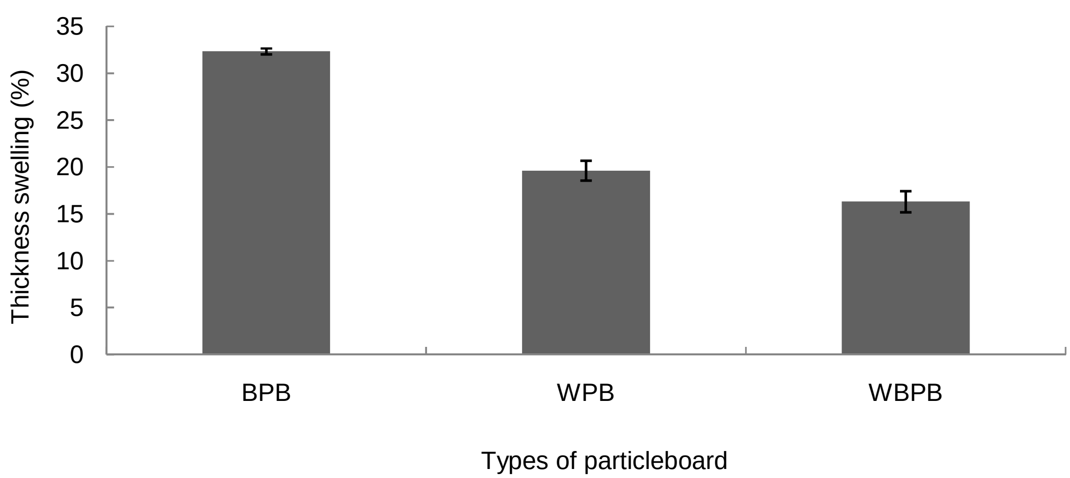

Fig. 6. Thickness swelling of three types of particleboard

4. CONCLUSION

The study investigated the properties of single layer particleboardsmanufacturedfrom branch and thewasteof*Bambusavulgaris*withUF resin. The above results suggest that the produced particleboard from the branches and wastages istechnicallyfeasible, 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 a 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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