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Effect of Mixing Three Lignocellulosic Materials with Different Cement Ratios on the Properties of Cement Bonded Particleboard

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ABSTRACT: This study investigated the effects of nine different mixtures of three lignocellulosic materials and four ratios of cement to lignocellulosic materials (LCM) (2.5:1, 3:1, 3.5:1 and 4:1) on the properties of cement bonded particleboard. The materials were (sunt) *Acacia nilotica* saw dust, bagasse and cotton stalks. They were collected from different locations in Sudan. Reasonable panel properties were obtained from the three lignocellulosic materials either pure or mixed using different cement/lignocellulosic materials (C/LCM) ratios (3:1, 3.5:1 and 4: 1). The mean values of water absorption percent (WA %) and the thickness swelling percent (TS %) for both the two hours and 24-hours soaking tests, conform favorably to figures reported in previous studies.The highest bending strength (MOR) and modulus of elasticity (MOE) were attained by100% sunt particles with all cement/lignocellulosic materials ratios.

KEYWORDS: *mixing, lignocellulosic materials, cement, ratios, particleboard, properties.*

INTRODUCTION

A rapid growth of the wood - based industry has been reported in the recent literature. The annual survey of the wood based panels by World Wood Journal (Anonymous 1988) shows a renewed strength in particleboard and more interest in mineral boards and panels made from bagasse.

Wood particles bonded with ordinary Portland cement are becoming more prevalent in a number of countries around the world. Expanding its material base, discovering new methods of manufacturing technologies and modifying the inorganic binders are some of the aspects that are gaining momentum (Subiyanto, and Kawai 1996).

Extensive studies on the expansion of the raw material base have demonstrated the feasibility of producing cement bonded particleboard using tropical hardwood species, some agricultural waste and industrial residues as well (Evan, 2000, Fernandez and Taja-on 2000 , Eusebio 2003). Cement– bonded particleboards seem attractive in extending the use of wood waste and agricultural residues. Several attempts were made in the past to mix different types of raw materials for particleboard manufacture. This was done to make use of lignocellulosic residues and or to improve or modify the quality of particleboard.

Previous studies have indicated that some lignocellulosic materials are not suitable for the manufacture of cement bonded particleboard. This characteristic varies with the type of material. The variation arises due to adverse effects on cement setting due to the presence of certain extractives (Kumar 1981),(Sandermann *et al*. 1960), (Sandermann and Kohler 1964). The ability of wood to combine with Portland cement is termed compatibility. The compatibility of lignocellulosic materials with cement can be enhanced by several treatments. Hot water and weak alkali are among the common treatments used to extract the inhibitory substances in wood. Calcium chloride is one of the widely used accelerators of cement setting. These treatment methods were chosen to be used in this study as a preliminary compatibility test. They are relatively cheap and easy to use.

The present study was set to i) examine the effects of blending wood and non-wood lignocellulosic materials on the properties of cement bonded particleboard and ii) compare properties of various board types to the minimum property requirements specified in the commercial standards for cement bonded particleboards.

MATERIALS and METHODS

Manufacturing process

The lignocellulosic materials used were sunt (*Acacia nilotica*) sawdust, bagasse and cotton stalks. They were collected from different locations of Sudan; EL Suki Sawmill, EL Gunied Sugar Factory and fields in EL Kamlin locality, respectively. Ordinary Portland cement (produced by Al Amria Company, Egypt) was used as a binder. Bagasse was processed by a hammer mill, cotton stalks were processed first in a chipper and then hammer milled. Then the three lignocellulosic materials were screened using laboratory sieves. The particles which passed a sieve size of 4mm and retained on a sieve size of 1mm (- 4 +16mesh), were used for cement bonded boards manufacture.

Preliminary hydration tests were carried out to enhance the the compatibility of the lignocellulosic materials under investigation with cement. The best common effective treatment was found to be 1% NaOH solution (24 hours soaking) and 3 % $CaCl_2$ as an additive or accelerator for cement setting. The maximum hydration temperatures reached were above 60°C. Hence this treatment was chosen for the furnish treatment of cement bonded particleboards.

The mixtures of the three lignocellulosic materials are shown in table 1. They were blended in ratios of 2.5:1, 3:1, 3.5:1and 4:1 with cement to wood.

The lignocellulosic particles were weighed and mixed with the determined amounts of dry ordinary portland cement . Then the right amount of $CaCl_2$ for each mixture was dissolved in a predetermined amount of water. The solution was added to the blend of cement and lignocellulosic materials and thoroughly hand mixed in plastic containers for about 5 minutes. The amount of water used for furnish mixing was calculated according to the relationship developed by Simatupang (1979).

Table 1.Different mixtures of the three lignocellulosic materials

Board type	Bagasse %	Cotton stalks %	Sunt %
M1	100	0	0
M2	0	100	0
M3	0	0	100
M4	50	50	0
M5	50	0	50
M6	0	50	50
M7	25	25	50
M8	25	50	25
M9	50	25	25

Open top boxes consisting of a frame from beech wood, a base and cover of veneer plywood coated with phenolic films, were made. The bases were fixed and released from the frames by means of nails and screw drivers. The boxes were designed to give 30 x 30 cm for the base from inside and a frame height of 3.2 cm. and a cover with a thickness of 2.2 cm to fit tightly in the frame and to give a thickness of one centimeter for the intended boards.

The mixture of cement, water, and lignocellulosic materials with the additive were formed in each box, by hand. Then the square covers of the veneer plywood were placed on the top of the mixture to press it and ensure the desired thickness of boards. Three replicates were made from each of the nine mixtures of the four ratios. The panels were 30 cmX 30 cm X1cm in dimensions and with a targeted density of 1.2 g/cm^3.

The boards were pressed in a cool hydraulic press (Carver, model 2699) under constant pressure .The amount of pressures used were, 27.7 Kg/cm^2, 22.2 Kg/cm^2,16.67 Kg/cm^2 and 11.11Kg/cm^2 depending on the cement wood ratios used. The boards were pressed for few minutes until the required pressure is reached. Then the boxes containing the boards were removed and clamped overnight in a locally made manual clamp.

Following the 24 hours setting period, the boards were carefully released from the moulds, misted with water and wrapped in cellophane to enhance hydration .The boards were then racked vertically at ambient room temperature and left to cure for 28 days.

Testing the Physical and mechanical properties

Density was determined according to DIN, EN 323.1993 E. Moisture content was determined according to (ASTM 1037).

Thickness Swelling (TS) and water absorption (WA) for two and twenty four hours were carried out as specified by the European standards (EN 313:1993) and (EN 324-1:1993).

The specimens for static bending test were prepared and tested according to the American Standard for Testing and Materials (ASTM D-1037) with some modifications due to the limited size of boards. The dimensions of the specimens were 25cm x 5cm x 1 cm. The span was 23 cm. The test was carried out using Lloyd testing machine and modulus of repture (MOR) of cement and mean bending strength (MOR) were accordingly computed.

Statistical Analysis

Analysis of variance (ANOVA) and Duncan's Multiple Range Test were conducted to study the significance of the differences between treatments using Statistical Analysis System (SAS) institute Inc. (1990).

RESULTS and DISCUSSION

Physical properties

Table 2 shows the overall means of water absorption (WA) and thickness swelling (TS) four cement bonded particleboard under four different cement/lignocellulosic materials ratios C/LCM).

Table 2. Mean Water Absorption (WA) and Thickness swelling (TS) values for cement bonded particleboards for all sets of board types by cement/lignocellulosic materials (C/LCM) ratio.

(C/LCM) Ratio	M.C.%	Density g/cm^3	WA_2 (%)	WA_{24} (%)	TS_2 (%)	TS_{24} (%)
2.5:1	12.61	1.19	22.51	25.03	3.04	4.2
3:1	11.04	1.26	24.09	26.16	2.4	3.5
3.5:1	10.04	1.22	22.78	24.48	1.66	3.05
4:1	11.59	1.3	16.57	18.48	0.87	1.5

The mean values for thickness swelling decreased with the increase of cement/lignocellulosic materials ratios (C/LCM), (Table 2).
The highest values were observed with the 2.5:1 ratio and the lowest were seen with the ratio of 4:1. These figures show that the properties of dimensional stability of all the ratios of cement bonded panels such as mean water absorption percent (WA %) and thickness swelling percent (T S %) values for both the 2-hours and the 24-hours water soaking test conform favorably to figures reported in past studies. (Badejo,1989), compiled averages that ranged from 32.95% to 46 % and 0.35% to 5.47% for water absorption and thickness swelling tests, respectively. Prestemon, (1976), reported mean water absorption range values of 28.1% to 65.8 % for 25 mm thick cement bonded particleboards following 24 hours soaking in cold water. Table 3 shows the minimum and maximum values of water absorption (W A) and thickness swelling (TS) for the different board types. It is clear from the table that the minimum water absorption of all board types and ratios was 12.25% attained by board (M6) of the cement wood raio 4:1 and the maximum (WA) was 43.8% attained by board (M8) of the cement/wood ratio 2.5:1. The minimum thickness swelling for all board types and ratios was 0.42% attained by board (M7) 0f the wood cement ratio 4:1 and the maximum thickness swelling was13.05% attained by board type (M1) of the wood cement ratio 2.5:1

Table 3. Minimum and maximum values of water absorption (WA) and thickness swelling (TS) for the different board types by cement/wood (C/W) ratio

C/W Ratio	Min.W A_2%	Max,W A_2 %	Min. WA_{24}%	Max.W A_{24}%	Min. TS_2%	Max. TS_2%	Min. TS_{24} %	Max. TS_{24} %
2.5:1	12.93 (M8)	42.4 (M1)	15.78 (M8)	43.76 (M1)	0.92 (M3)	1.64 (M1)	1.51 (M3)	13.05 (M1)*
3:1	11.59 (M3)	32.86 (M9)	13.28 (M3)	34.76 (M9)	1.32 (M3)	3.4 (M9)	1.5 (M3)	5.56 (M9)
3.5:1	15.37 (M3)	33.29 (M1)	16.95 (M3)	34.31 (M1)	0.73 (M7)	2.59 (M1)	1.56 (M5)	4.3 (M1)
4:1	12.25 (M6)	22.33 (M4)	14.05 (M3)	23.97 (M4)	0.42 (M7)	1.67 (M4)	0.91 (M7)	2.51 (M7)

Figures in parentheses are board types corresponding to water absorption and thickness swelling values.

The analysis of variance for water absorption and thickness swelling for both the 2 hours and 24 hours tests were highly significant (P = 0001) for all mixes and ratios .for the mean separation test and Duncan's group of some properties. (figures 1- 8).

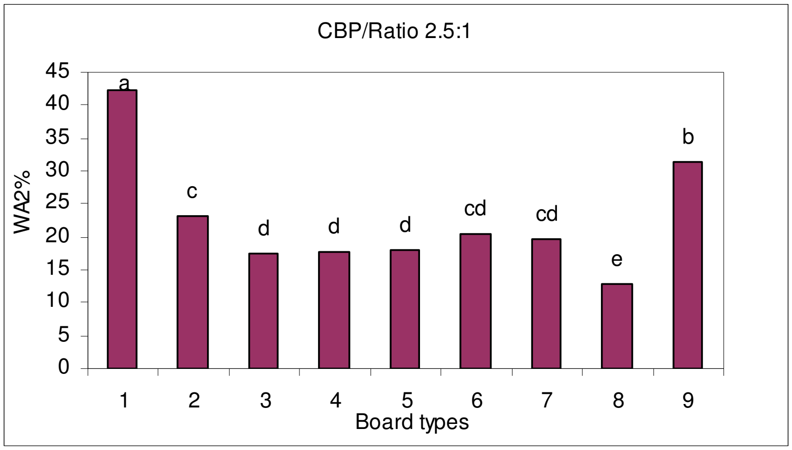

Figure 1. Mean values of water absorption after two hours (WA_2) for different board types of cement bonded particleboard (CBP), at cement/LCM ratio 2.5:1. Bars with the same letters are not significantly different.

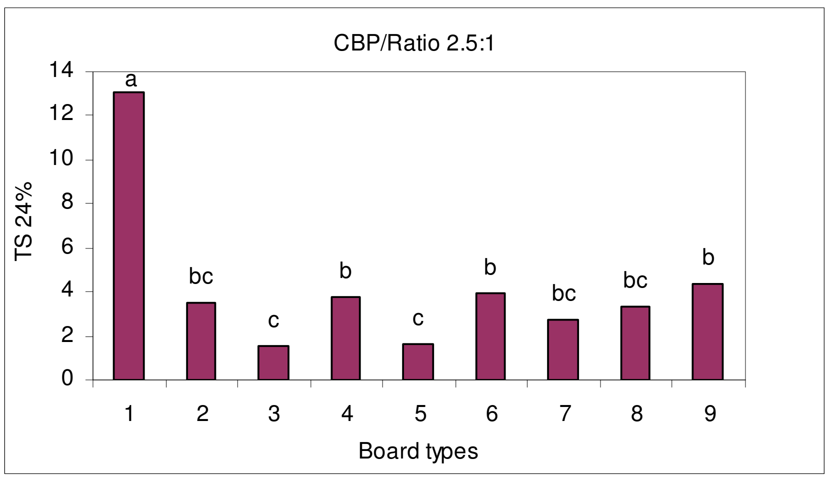

Figure 2. Mean values of Thickness Swelling after twenty-four hours water soaking (TS24 %) for cement bonded particleboard (CBP), at cement/LCM ratio 2.5:1. Bars with the same letters are not significantly different.

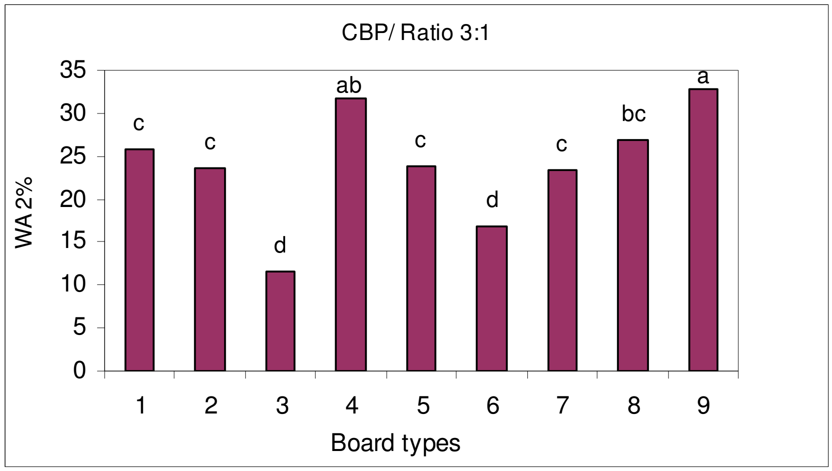

Figure 3. Mean values of Water absorption percent after two hours water soaking (WA2%) for cement bonded particleboard (CBP) types at cement/LCM ratio 3:1 Bars with the same letters are not significantly different.

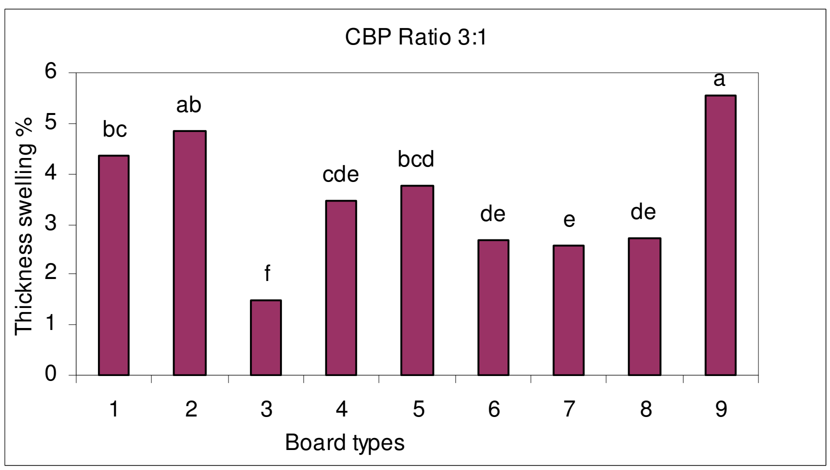

Figure 4. Mean values of thickness swelling after twenty four hours water soaking (TS24%) for cement bonded particleboard (CBP), at cement/LCM ratio 3:1. Bars with the same letters are not significantly different.

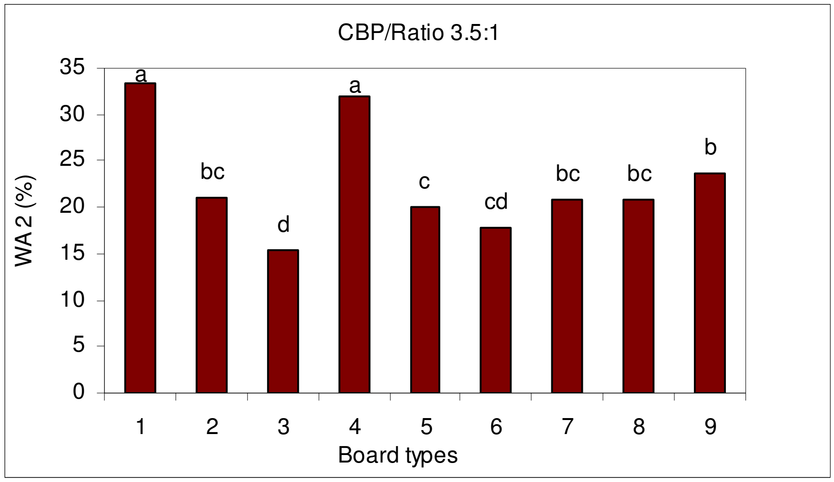

Figure 5. Mean values of Water absorption percent after two hours water soaking (WA2 %) for cement bonded particleboard (CBP) types at cement/LCM ratio 3.5:1. Bars with the same letters are not significantly different.

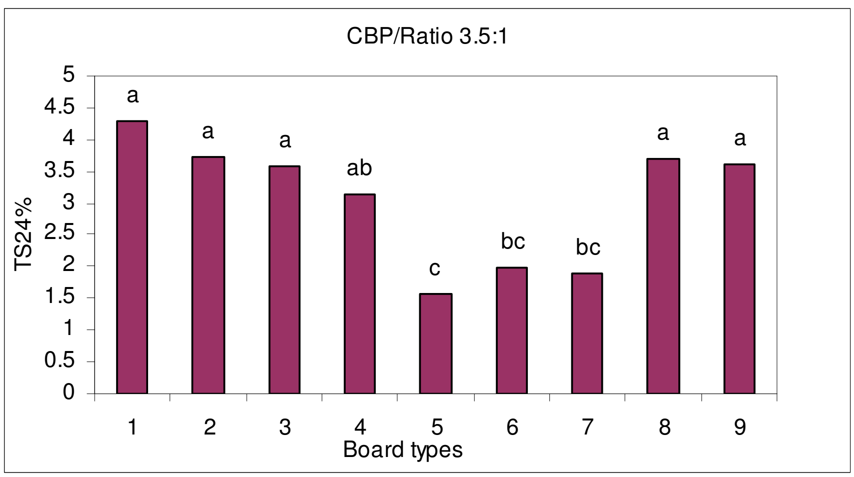

Figure 6. Mean values of thickness swelling after twenty four hours water soaking (TS24%) for cement bonded particleboard (CBP), at cement/LCM ratio 3.5:1. Bars with the same letters are not significantly different.

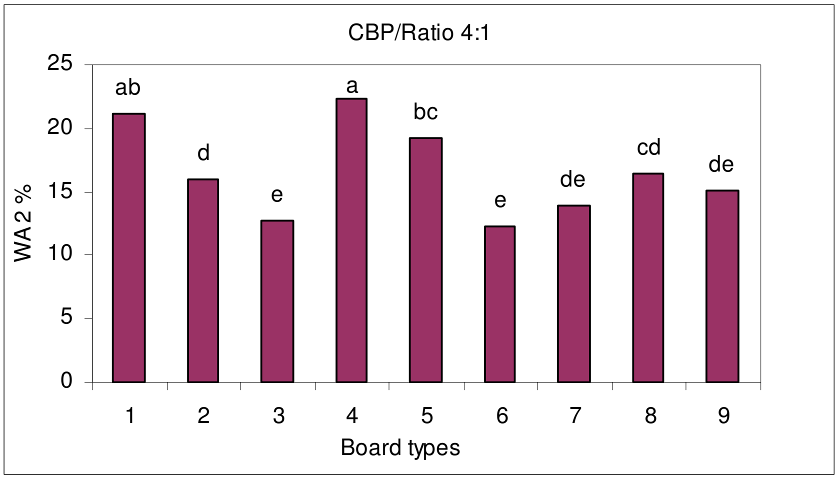

Figure 7. Mean values of Water absorption percent after two hours soaking (WA2%) for cement bonded particleboard (CBP) types at cement/LCM ratio 4:1. Bars with the same letters are not significantly different.

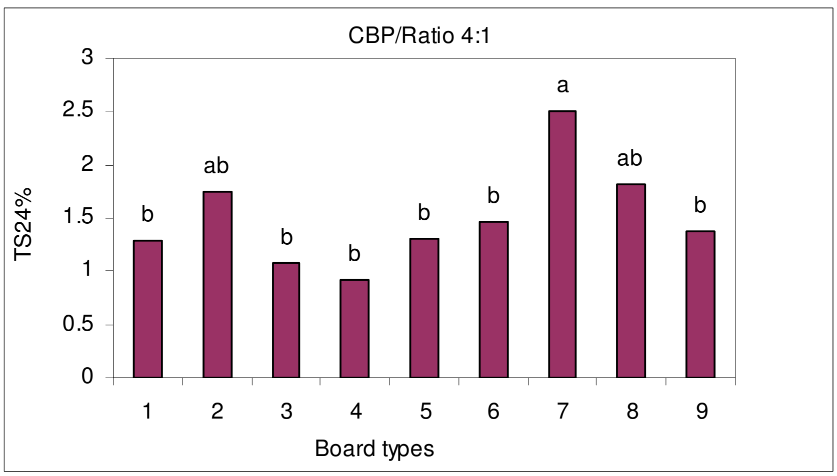

Figure 8. Mean values of Thickness swelling percent after twenty - four hours water soaking (TS_{24}%) for cement bonded particleboard (CBP) at cement/LCM ratio 4:1. Bars with the same letters are not significantly different.

Modulus of rupture (MOR)

Average values of modulus of rupture (MOR) for cement bonded particleboards and Duncan's' grouping are shown in figures 9, 10, and 11.The average MOR values of the ratio 3:1 are generally higher than the average values of the ratios 3.5:1 and 4:1. This result is in agreement with findings reported by Moslemi and Pfister (1987). They indicated that all MOR values are inversely related to cement / wood ratio in the case of type 1 cement (Ordinary Portland Cement).

The MOR of 100 % sunt wood-cement boards (M3) of the ratio 3:1 surpassed all other boards in all ratios used. The MOR of sunt-cement mixture of the ratio 3:1 attained an average value of 103.214 Kg/cm^2 (10.12 MPa) which was the highest among all the boards made in all ratios. This MOR value compares favorably with past research results. Sudin and Ibrahim (1989) reported that the Malaysian standard

(MS934) specifies a minimum requirement of 9.0 MPa for bending strength. It was observed that the boards with high proportions of sunt wood in the mixture attained higher MOR values in comparison to other mixtures.
The MOR values in the ratios 3.5:1 and 4:1 of all board types are generally low. This may be due to the higher cement /wood ratios and the use of calcium chloride. It was reported by some researchers that reduction of the cement to wood ratio increased the bending strength Moslemi and Pfister (1987) and when calcium chloride was used lower bending strength was observed (Sudin and Ibrahim, 1989) . The boards made of 100 % sunt-cement mixture in these ratios still hold onto the lead for MOR values. The analysis of variance for MOR of all set of boards and with all ratios is highly significant at (0.0001) level of probability.

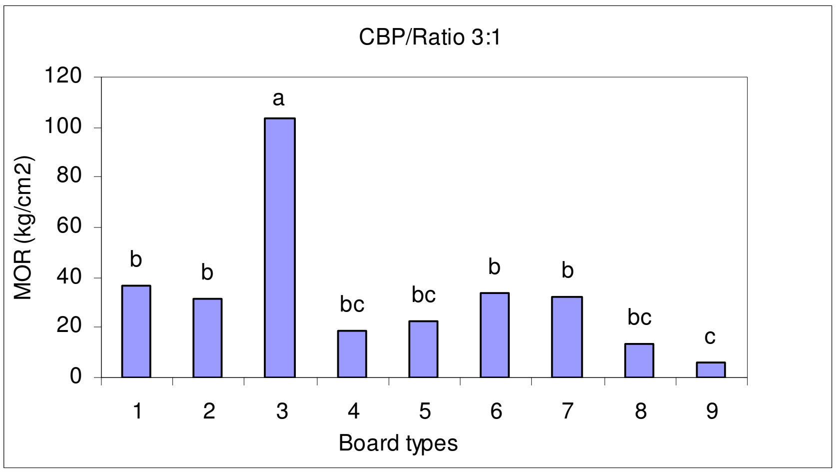

Figure 9. Mean values of modulus of rupture (MOR) of cement bonded particleboard (CBP) made from mixtures of cement and lignocellulosic materials at cement/LCM ratio 3:1. Bars with the same letters are not significantly different.

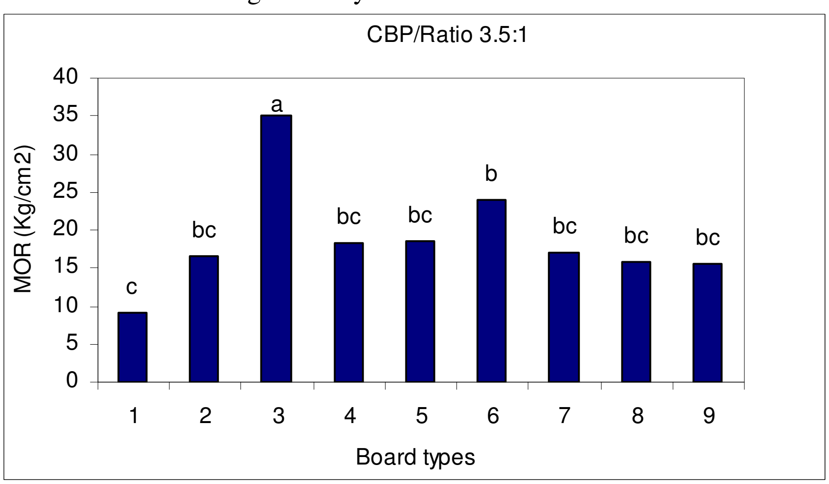

Figure 10. Mean values of modulus of rupture (MOR) of cement bonded particleboards (CBP) made from mixtures of cement and lignocellulosic materials at cement/LCMod (C/W) ratio 3.5:1. Bars with the same letters are not significantly different.

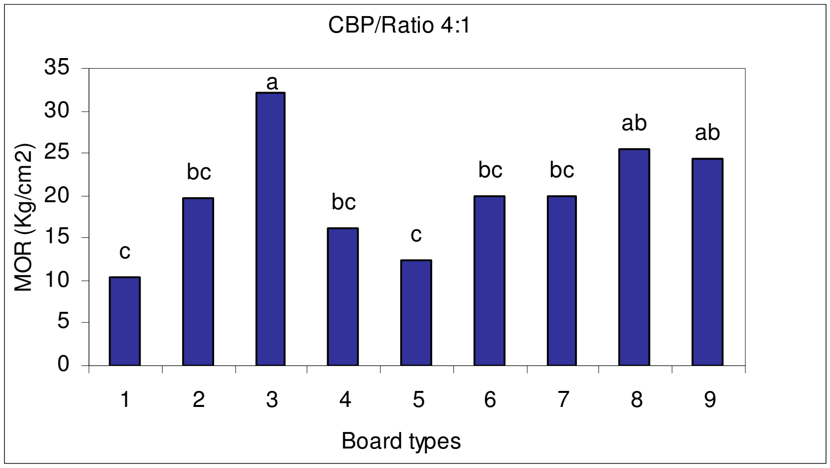

Figure 11. Mean values of modulus of rupture (MOR) of cement bonded particleboards (CBP) made from mixtures of cement and lignocellulosic materials at cement/LCM ratio 4:1. Bars with the same letters are not significantly different.

CONCLUSION

* Cement-bonded particleboard can be made from the three lignocellulosic materials either pure or mixed in different proportions after weak alkali-treatment and addition of Calcium chloride as an accelerator.

- Generally the highest water absorption and thickness swelling values of cement-bonded particleboards were always associated with boards having high proportions of bagasse particles.
- The lowest water absorption and thickness swelling values of cement bonded particleboards were always associated with boards of high proportions of sunt sawdust particles.
- The cement / wood ratio (3:1) attained generally the highest Bending strength (MOR) values compared to the other ratios tested (3.5:1 and 4:1) especially with sunt sawdust.
- Thickness swelling percent (TS %) generally decreases with the increase of cement /wood ratio.

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