Physical Properties of Particleboard Produced from Residues of *Musa paradisiaca pseudostem*, *Theobroma cacao* and *Ceiba pentandra*

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ABSTRACT

This study determined the physical properties of particleboards manufactured from four agro-forest residues using cassava starch and urea formaldehyde as adhesives. Physical properties of the particleboard were determined in accordance with ASTM D 1037-99. The result indicate that the values of the physical properties of the manufactured particleboards from the selected agro-forest residues were acceptable according o the limit set by ANSI A208.1 and EN 312 standards. Hence, the selected biomass made an acceptable particleboards for interior application, fitments and other furniture to be used in dry conditions.

BACKGROUND

- Many drivers including wood shortage as a result of the depletion of forest areas, environmental awareness and generation of large quantities of agro-forest residues which have disposal challenges have increased the need for the substitution of wood as a major raw material for the production of furniture and other wood products with particleboard.
- The demand for particleboard products has increased substantially throughout the world, representing 57% of the total consumption of wood-based panels, a percentage that is continuously growing at a rate of 2 - 5% annually. As a result of this, each year, about 28.4 million m^3 of particleboards are produced in Europe mainly for furniture and building applications.
- Residual fibres are annually renewed, often in sustainable volumes that could supply for composite panel production.
- Although the technical feasibility of non-wood particleboards is generally accepted, further research is needed to fully understand how the intrinsic properties of the raw materials can contribute to enhancing the overall performance of the engineered materials.
- Formaldehyde resins and other synthetic resins constitute waste disposal problem because they are non-biodegradable and also not recyclable. Thus the objective of this study is to determine the physical properties of particleboards manufactured from residues of *Musa paradisiaca* pseudostem, *Theobroma cacao* stem and pod, and *Ceiba pentandra* sawdust using cassava starch as adhesives.

Bulk density and moisture content of biomass materials

Biomass material	Bulk density (kg/m^3) Mean	Bulk density (kg/m^3) SD	Moisture content (%) Mean	Moisture content (%) SD
Ceiba pentandra	94.41	1.53	3.67	0.34
Musa paradisiaca pseudostem	96.63	1.38	3.61	0.50
Theobroma cacao pod	323.96	1.13	5.01	0.37
Theobroma cacao stem	89.90	3.00	3.52	0.43

MATERIALS AND METHODS

Materials

Musa paradisiaca pseudostem
Theobroma cacao stem
Theobroma cacao pod
Ceiba pentandra saw dust
Cassava Starch
Urea formaldehyde.

Adhesive Preparation

Urea formaldehyde was purchased for the study and cassava starch was prepared

Peeled fresh cassava

Cassava starch

Materials Preparation

Musa paradisiaca pseudostem with pith removed

Musa paradisiaca pseudostem sap removed

Musa paradisiaca pseudostem particles

Felling *Theobroma cacao* stems

Debarked *Theobroma cacao* stems

Theobroma cacao stems particles

Scooped and cleaned *Theobroma cacao* pod

Dried *Theobroma cacao* pod

Theobroma cacao pod particles

Ceiba pentandra stem

Ceiba pentandra saw dust

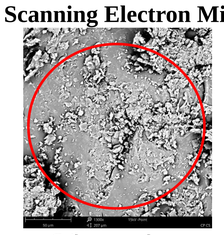
Particleboard manufacturing processes

Collection of Agro-forest residues
↓
Cleaning of Agro-forest residues Agro-forest residues
↓
Milling
↓
Drying
↓
Particles classification
↓
Blending
↓
Cold pressing
↓
Hot pressing
↓
Finished and cooling
↓
Conditioning
↓
Specimens preparation
↓
Testing

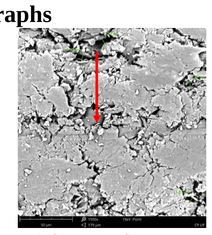
Test conducted

Moisture content
Density
Thickness swelling
Water absorption

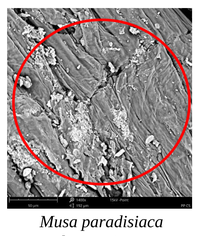
Scanning Electron Micrographs



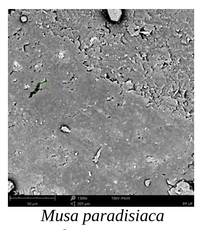
Ceiba pentandra + cassava starch



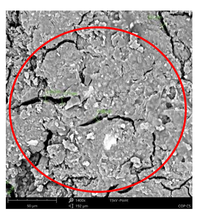
Ceiba pentandra + urea formaldehyde



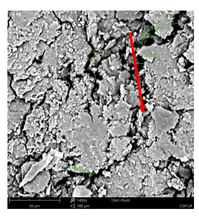
Musa paradisiaca pseudostem + cassava starch



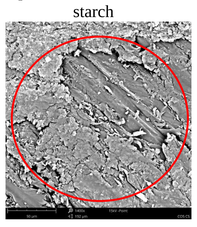
Musa paradisiaca pseudostem + cassava starch



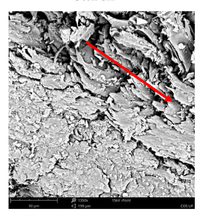
Theobroma cacao pod + cassava starch



Theobroma cacao pod + urea formaldehyde



Theobroma cacao stem + cassava starch



Theobroma cacao stem + urea formaldehyde

Scanning Electron Micrographs of cassava starch and urea formaldehyde bonded particleboards. 1400x - 1500x magnification range. Red circle represent area of enhanced particle-adhesive interactions. Red arrows indicate porous areas to allow water absorption.

RESULTS

Density of the manufactured particleboard

Biomass materials	Density (kg/m^3) 100% Cassava starch	Density (kg/m^3) 100% Urea formaldehyde
Ceiba pentandra	536^{a} (11.69)	472^{a} (67.86)
Musa paradisiaca pseudostem	543^{a} (32.25)	493^{a} (84.83)
Theobroma cacao pod	598^{b} (34.31)	557^{b} (30.90)
Theobroma cacao stem	497^{a} (26.24)	421^{a} (62.47)

Figures with the same letters are not significantly different ($p > 0.05$) according to Tukey's multiple test

Water absorption

Biomass material	Water absorption (%) 2-hour Cassava starch	2-hour UF	24-hour Cassava starch	24-hour UF
Ceiba pentandra	19.15^{c} (3.16)	13.07^{b} (1.82)	50.08^{d} (1.63)	30.97^{b} (1.07)
Musa paradisiaca pseudostem	9.86^{a} (0.84)	7.66^{a} (1.49)	23.79^{a} (3.13)	18.17^{a} (1.58)
Theobroma cacao pod	22.41^{c} (1.21)	14.98^{b} (1.57)	59.46^{d} (1.04)	43.80^{c} (5.09)
Theobroma cacao stem	12.65^{b} (1.83)	8.10^{a} (1.32)	30.82^{b} (2.46)	22.08^{a} (1.64)

Figures with the same letters are not significantly different ($p > 0.05$) according to Tukey's multiple test

Thickness swelling

Biomass material	Thickness swelling (%) 2 Hours Cassava starch	2 Hours UF	24 Hours Cassava starch	24 Hours UF
Ceiba pentandra	5.03^{b} (1.04)	3.91^{a} (0.05)	17.27^{c} (2.23)	13.22^{b} (2.62)
Musa paradisiaca pseudostem	3.51^{a} (0.31)	3.38^{a} (0.28)	11.47^{a} (4.52)	9.37^{a} (1.03)
Theobroma cacao pod	6.31^{b} (1.15)	4.75^{a} (0.77)	21.49^{d} (2.57)	16.17^{c} (1.14)
Theobroma cacao stem	3.67^{a} (1.34)	3.61^{a} (0.53)	13.93^{b} (3.42)	11.24^{a} (2.11)
EN standard	8		15	

Figures with the same letters are not significantly different ($p > 0.05$) according to Tukey's multiple test

CONCLUSIONS

- *Ceiba pentandra*, *Musa paradisiaca* pseudostem, *Theobroma cacao* pod and *Theobroma cacao* pod could be used for manufacturing particleboards for interior application, fitments and other furniture to be used in dry conditions.

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