

# **UREA -FORMALDEHYDE FREE PARTICLEBOARDS FROM WOOD WASTES USING GLUTARALDEHYDE MODIFIED CASSAVA STARCH AS BINDER**

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## **Abstract:**

Improved, sustainable and eco-system friendly material is the focus to developed material for construction industry, the study evaluated, the physio-mechanical properties of particleboards manufactured from wood solid waste and modified cassava starch (MSC); as reinforcer. The starch was extracted from liquid waste from cassava processing and dried into powder form, modified with 24% glutardialdehyde solution. Density of boards, thickness swelling (TS) Water absorption (WA); modulus of elasticity (MoE) and modulus of rupture (MoR), were evaluated according to ASTM standards respectively. Density of boards were recorded 0.22 to 0.58g/cm<sup>3</sup>, TS and WS recorded are 2 to 24h immersion, 1.6 67.30% and 31.6 to 140.4%. MoE and MoR, with peak of values 533.5N/mm<sup>2</sup> and 35.7N/mm<sup>2</sup>. The microstructural and elemental analyses of boards were examined with Scanning electron microscope (SEM) and Fourier-transform infrared spectroscopy (FTIR); SEM analysis showed granules of modified cassava starch on the surface of the boards, while FTIR showed presence of eater and aldehyde forms attributed to hydroscopic formation of MCS binder. Particle board manufactured from MCS binder exhibited properties suitable for non-loading bearing capacity with reference to unmodified particleboards.

Keywords: Wood Fiber, Modified cassava starch, Mechanical properties microstructure

## **1.Introduction**

Wood wastes are wood fragments and particle from industrial or saw milling processing industries, forest harvesting, construction and demolition activities. Huge quantities of the post- consumer wood waste are generated in a significant rate and the method and level of recycling is inadequate compared to other

construction and demolition wastes. Several, reports showed that between 8 and 50% of the entire wood-based material being used yearly for various end uses application become wastes. Wood wastes consist of; solid timber, timber shavings, sawdust, off-cut, veneer panels and combination of two or more of them.

Hence, 10% of solid wastes are associated from demolition and construction site, these wastes are majorly dumped in landfills and burnt in combustion chamber, this opposing hazard to the environment, wood waste could be reused by sorting, recycle and utilized as raw material for the development of values added products (particle board and fiber board); those could be utilized as ceiling board, walls, flooring, furniture etc [1][2][3][4]. However, recycling of wood waste with formaldehyde- based resin will generate high leaching of emissions from the virgin product to the environment than expected dose, basically, those will be in two sources, first the breaking down of the formaldehyde in the parent product, secondly formation of the new formaldehyde adhesive utilized for the new products [5][3]. The leaching of formaldehyde will alter the air quality of indoor facilities made from the second-generation products and imposed serious health challenges for the occupants more than older structure. This health problem, however, showed the important role of formaldehyde inducing illness through immune mechanism and toxicity. Hence, to curbed these problems various study has showed approaches to minimized the formaldehyde emission from engineered wood-based products, through chemical modification with natural resins [6][7][8]. Second method involves the utilization of formaldehyde free adhesives, these are vegetable based, which are environmentally clean and friendly, green and could be utilized for engineered wood products without health issues. Natural latex, oxidase, gum Arabic, corn starch, soy-based adhesive, wheat gluten, and nano-modified starch [9][10]. Amongst others, cassava is one of higher source of starch of natural polymers of low cost and largely variable. The processing of cassava to cassava flake and other end- products of cassava generate commercial quantities of the natural polymer for industrial uses [11][10]. Study showed that, cassava starch contained amylose and amylopectin, amylopectin is a polymer of several D-glucose molecules. 80% of amylopectin is present in starch, amylopectin molecules are linked by  $\alpha$ -1,4-glycosidic bonds and  $\alpha$ -1,6-glycoside bonds. It is a water insoluble fraction. Amylose is a polysaccharide made of  $\alpha$ -D-glucose units, bonded to each other through  $\alpha$ (1 $\rightarrow$ 4) glycosidic bonds. It is one of the two components of starch making up approximately 20-30%. Fig 1 showed the chemical structure of amylose and amylopectin. Nigeria is largest producer of cassava in Africa, contributing 30%, it's a source of food in Nigerian and less application industrial end

products, compared to Asia, which has been major raw material for various end product without affect food value chain of the Asia ecosystems [12][13][11]. Studies showed that, cassava thrive in poor fertile soil unlike other sources of starch like yam etc. Resins in wood -based industries has necessitated the utilization of starch based, but, the main drawbacks of bonded boards are the poor dimensional stability and low bonding properties which are associated in cases involving starch as adhesive [14][15][16][9][17]. The hygroscopicity of cassava-based starch in engineered wood based has gears the current study. Nevertheless, some treatments have been used in some studies to improve the bonding capacity of starch as a doable resin in various wood end uses applications [15][10][11]. Studies, showed chemical modification of starch with low percent of Urea formaldehyde as binder, the mechanical properties of the board indicated higher value in MOR, thickness swelling and density were observed in test sample with modified binder in comparison with unmodified[11] Similarly, study by[18] developed composite material of difference sieved sizes, using wood waste, bonded with chemically modified starch, results showed that, MOR and internal bonding of panels aligned with ASTM Standards. Modifications of starch as constituent in formaldehyde adhesive is to input some functional groups to modified it role in end uses applications. The chemical modifications are basically grafting copolymerization, crosslink reactions. Few studies exist on the utilization of cassava starch obtained from residue of cassava processing and its subsequent modification, being utilized with wood waste from saw milling, demolition and construction site for particle board production. However, the aim of the study is to bridge dearth of knowledge gap in the utilization of cassava modified starch in the production of engineered wood products for sustainable ecosystem.

## 2. Material and methods

### 2.1 Material preparation

Wood wastes were sourced from a local saw mill in calabar, wood chips were from different species of timber material, sorted from metals and debris, the wood chip waste (WC) were firstly air dried and further oven dried at 80°C until reading on the moisture analyzer were  $\pm 5\%$  Moisture content (MC), the wood meal were then sieved and packaged into two sieved sizes of 600 $\mu$ m and 0.08mm respectively. The cassava starch (CS) was sourced locally in a cassava

processing outlet in a powdered form; the cassava starch is basically byproducts waste material from cassava processing as a waste water, the starch is produced from decantation of waste water for cassava during processing, these waste water is allowed to dry, and solidified to form, as CS. Glutardialdehyde solution is an oily liquid and colourless which is used in health facilities as sterilant to disinfect and clean heat- sensitive equipment such as dialysis, as disinfectant, glutardialdehyde is a hardening agent, it was supplied by AliChemical reagent Co., Ltd. Modification of cassava Starch, to Glu-dehyde was in ratio of 1:2(w/w)[3][11] . The CS powder was dissolved in deionized water at 23 to 25°C and stirred manually for consistency of 20% for about 40s. 250ml of glutardialdehyde solution was mixed according [18][11][19]. Mixture was given vigorous stirred for

4min. at temperature of 25°C to produce the modified cassava starch (MCS). The study employed injection method for the production of Particles boards, different ratio(s) was used of the MCS adhesive of 1:5 and 3:5 by mass ratio. The sieved chipped were batch mixed with MCS and injected to a mould of 150×150×30mm, the composition was given a cold press to form mat under 7.7N/m<sup>2</sup> for 48hrs, the composition was hot pressed at a pressure rate of 3N/m<sup>2</sup> using the temperature of 150°C for 2hrs and conditioned in a controlled temperature of 250C and relative Humidity (RH). Test samples were machined from the manufactured boards of two difference variation, for physio-mechanical properties. Water absorption and thickness swelling tests were examined in accordance with ASTM D 3502-76 for 2hrs to 24hrs immersion in water. Water absorption WA and TS were evaluated.

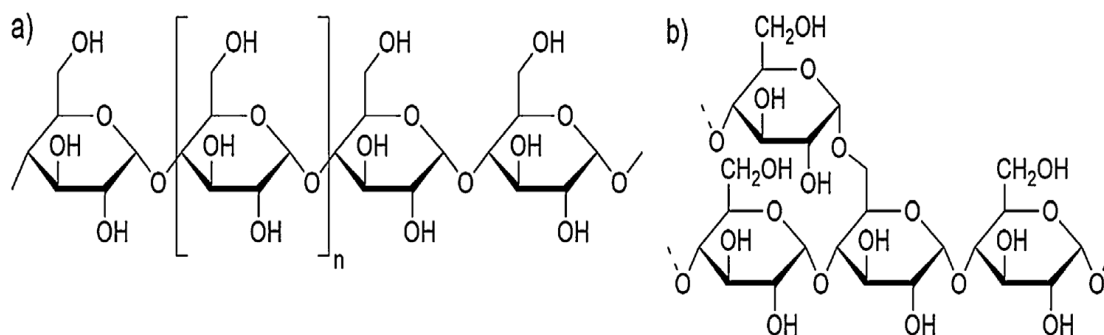


Fig 1: Molecular structure of (a) amylose and (b) amylopectin (Sandra et al, 2018, Akinymiet at, 201

**Table 1**  
**Mix ratio design of particleboard**

Particle board	Wood particle sizes (mm, µm)	Vol.(%) of binder	Type of adhesive
D	0.08	1.5	CS
I	0.08	1.4	MCS
R	0.0.8	1.2	CS
W	600µm	2.0	MCS
A	600µm	2.0	MCS
N	0.08	1.5	CS
G	600µm	1.5	MCS

The mechanical properties were carried out, with Universal Testing Machine (UTM); with max tension range of 50kN, stroke resolution 0.001mm, (Model, No M500-50AT); the Modulus of rupture (MoR) and Modulus of Elasticity (MoE) were evaluated

respectively (ASTM D 198-05). Fracture test samples were examined using field emission scanning electron microscope (FESEM); at a magnification of 10,000 and 12,000 with acceleration potential of 16kV. Functional group of modified CS and crosslinking

group were determined using FTIR spectra (Shimadzu FTIR-8400S Spectrophotometer) [19]. Figure 2 shows

particle produced from MCS. Results were analyzed via standard deviation and one-part ANOVA



**Figure 2: Particles board manufactured from MCS.**

### 3.0 Results and discussion

#### 3.1. Results of physical properties evaluated

Table 2 showed the density of the particle board ranged from 0.28 to 0.58g/cm<sup>3</sup>, boards produced from sieve sized 600µm having a higher value to particle size of 0.8mm, the values reflected [19][20][21]. Results of density showed higher density with board fabricated from MCS adhesive matrix of 1.2 to 1.5 ranges of dosages. Ratio of adhesive to matrix increase it interfacial bonding (Van der Waals force); these factors contributed to improved mechanical strength of board, some studies has shown that, density is closely related to some mechanical properties of engineered wood panels (bending strength) [21][19][22]. Stability of material is a determinant of

its utilization. Starch from studies is hygroscopic nature, the behaviour was observed after modification with glutaraldehyde. Water absorption of board fabricated from MCS exhibited low uptake of moisture compared to samples fabricated from CS. WA uptake for 2hrs ranged from 31.6 to 122%, variation in uptake were observed in respect to sieved sized, 24hrs WA recorded an increase in water uptake ranged from 45 to 140%. The variation of difference uptake is indication that, MCS create a film that prevent water movement in internal bonding network of boards. Water absorption and thickness swelling recorded high-density board with MCS in comparison with low-density board fabricated with CS. Developed particle boards of MCS could be utilized for agricultural building, as well as interior purposes in residential building.

**Table 2: Physical properties of the board**

Particle board	Wood particle sizes (mm, µm)	Density (g/cm <sup>3</sup> )	2hrs WA (%)	24hrs WA (%)	2hrs TS (%)	24hrsTS (%)
D	0.08	0.22(0.02) <sup>a</sup>	31.6(4.3) <sup>a</sup>	86.6(4.6) <sup>a</sup>	8.0(0.4) <sup>a</sup>	15.3(1.8) <sup>a</sup>
I	0.08	0.43(0.03) <sup>b</sup>	67.4(5.4) <sup>b</sup>	57.5(5.4) <sup>b</sup>	3.0(1.4) <sup>f</sup>	67.3(0.04) <sup>e</sup>
R	0.0.8	0.52(0.03) <sup>c</sup>	90.7(5.7) <sup>b</sup>	58.7(6.4) <sup>c</sup>	1.6(0.04) <sup>c</sup>	35.5(0.09) <sup>a</sup>
W	600µm	0.47(0.01) <sup>e</sup>	37.6(2.7) <sup>d</sup>	45.5(4.5) <sup>c</sup>	1.6(0.05) <sup>b</sup>	23.7(0.04) <sup>a</sup>
A	600µm	0.58(0.02) <sup>e</sup>	45.6(3.5) <sup>c</sup>	124.4(5.6) <sup>c</sup>	23.4(4.6) <sup>e</sup>	24.5(0.04) <sup>e</sup>
N	0.08	0.37(0.01) <sup>f</sup>	74.6(4.6) <sup>b</sup>	123.1(2.5) <sup>b</sup>	13.5(0.6) <sup>b</sup>	8.5(0.5) <sup>r</sup>
G	600µm	0.26(0.02) <sup>d</sup>	122.7(3.6) <sup>c</sup>	140.4(2.6) <sup>a</sup>	8.6(0.03) <sup>c</sup>	11.5(0.6) <sup>a</sup>

Values in parenthesis show standard deviation while different latter shows significant difference between group within the same columns at  $p \leq 0.05$

#### 3.2 Mechanical properties

Variation in mechanical properties of boards shown higher mechanical strength on Modulus Rupture and Modulus of elasticity with MCS Adhesive, this study postulate that, aldehyde groups react with the starch granules and hydroxyl group of the wood particle. This bonding was possible due to capability of hydroxyl group found in wood chip, which enhance self-polymerization and formed cross linking reaction with aldehyde groups [23][19]. Resistance to mechanical shear exhibited by boards were enhanced due to cross linking reaction between the wood fibers and the starch granules. Reports by [23][24] shows wood fracture of fiber under influent of mechanical forces on particle boards, the glue line in the experimentation was reported intact, this implied that stronger bond was developed with MCS, which was observed stronger to conventional adhesive used in wood-based industry. Difference test samples of particleboards exhibited difference structural behaviors under same loading conditions, test samples I, W, A, and G bonded with modified cassava starch (MCS) exhibited the

following MOR and MOE results; 1813.6 and 20.5N/m<sup>2</sup>, 1875.6 and 192N/m<sup>2</sup>, 146.7 and 35.7N/m<sup>2</sup>, and 533.5 and 19.9N/m<sup>2</sup>. Faber sizes and adhesive dosages has significant influence on the mechanical properties examined. Increased in material strength was noted from manufactured boards from 600µm sieved sized, these implied that, there proper interfacial bonding between reinforcer and matrix (MCS), and equally aid the curing time. The results from samples manufactured from CS with modification were reported with low MOE and MOR as followed respectively D, R, N;126.2 and 15.8N/mm<sup>2</sup>; 90.7 and 19.2 N/mm<sup>2</sup>; lastly 33.0and 14.7N/mm<sup>2</sup>. In comparison boards manufactured from CS exhibited lower strength performance under the same structural conditions with boards manufactured with MCS. Furthermore, manufactured sample W and G met with minimum ASTM standards for fiber reinforced composite. Inclusion, the polar constituent in wood particle surface equally aided effective bonding.

**Table 3 Results of Modulus of Elasticity and Modulus of Rupture**

Manufactured Boards	Modulus Of Elasticity (N/Mm <sup>2</sup> )	Modulus Of Rupture(N/Mm <sup>2</sup> )
D	126.2(312.3) <sup>c</sup>	15.8(2.6) <sup>d</sup>
I	1813.6(2272) <sup>v</sup>	20.5(1.9) <sup>c</sup>
R	90.7(33.5) <sup>d</sup>	19.2(2.2) <sup>a</sup>
W	1875.6(13.4) <sup>c</sup>	5.3(0.06) <sup>g</sup>
A	146.6(7.7) <sup>a</sup>	35.7(0.06) <sup>e</sup>
N	33.0(374.2) <sup>b</sup>	14.7(4.1) <sup>d</sup>
G	533.5(24.2) <sup>b</sup>	19.9(2.3) <sup>c</sup>

Values in parenthesis show standard deviation while different latter shows significant difference between group within the same columns at p α0.05

### 3.3 Microstructural analysis of boards

Particleboards microstructure were study. SEM revealed presence of whitish granules scattered on the surface of the manufactured boards with glutardialdehyde modified with cassava starch, granules were shown mixed with wood chips resulting to higher bonded network formation over the particleboards. The cross linking between the wood chips and granules covered void areas, these improved the mechanical properties, reduced water uptake as recorded in some boards, and showed dimensional stability of particle boards. Some of the boards equally exhibited weak bonding due to surface roughness of

wood particles. The micrograph of the modified cassava starch bonded with wood particle board is shown in fig 3. Furthermore, FTIR spectra analysis is presented in fig 4. These shows the water intake of bonds at it peak [1][25]). Spectra analysis proven successful modification of cassava starch. The formation of carboxyl starch and dialdehyde starch is as the result of crosslinking of glutardialdehyde. Chromophores of carboxyl starch aligned with aldehyde modified starch as link between wood fiber and MCS. From the study, the aldehyde and esters forms were at peak of carbonyl chromophores [26][27][19]. FTIR spectra analysis is shown in fig. 4 the absorption peaks.



Figure 3: Micrograph of particle board, MCS spotted with blue arrow

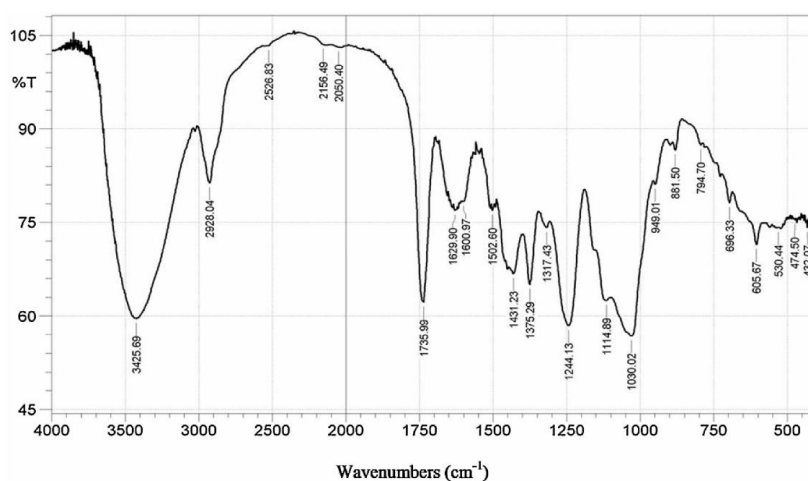


Figure 4: FTIR of particles board

## Conclusion

Improved, sustainable and eco-system friendly material is the focus, the study evaluated the modification of cassava starch granule with glutardialdehyde to minimized the hygroscopic nature of cassava starch to improved it bonding properties for the production of particle board. The study showed improved material properties exhibited in various particles sizes and aligned with some standards ASTMs for particleboards. Though there are variation

in dimensional stability as result of water intake recorded with some of the particleboards with respect to particle sizes and matrix dosages. Variation across all the boards tested shows a significant difference with matrix (MCS). Inconclusion, the utilization of MCS and wood particles in particleboard production could harness the waste generated during the production of cassava and wood processing, for valued added products and it utilization in construction, furniture manufacturing and wall paneling

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