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DEVELOPMENT OF ECO-FRIENDLY PARTICLEBOARD COMPOSITES USING RICE HUSK PARTICLES AND GUM ARABIC

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Abstract

The use of natural sponge particles (rice husks) as reinforcement for the production of particle board was the thrust of this research work. These fibres being cheap and readily available with low energy demand during manufacturing are strong contenders for this work. The particles, whose mass fraction was the variable in this work were cut down into smaller sizes and mixed with resins and other binders. The resulting slurry was then poured into rectangular moulds, which were compacted until the composite became hard. Microstructure, water absorptivity, and scatter index tests were carried out on the various samples with gum Arabic and formaldehyde (top bond), which showed the best binder combination for effective properties. These tests confirmed the possible use of sponge particles as reinforcement in the production of particle board. The developed particle board composites can be use

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in density particleboards for general purpose requirements like paneling, ceilings, partitioning, etc. Since the properties of particleboard composites used in this area compared favourably with standard.

1. Introduction

The demand for wood in the forest industry has been growing, but the production of industrial wood from the natural forests continues to decline. The decline in forest resources in developing countries is due to the depletion of the resources and in developed countries due to the withdrawal of forest areas from industrial production for other uses such as recreational areas. Also, there is a significant pressure on standing forest resources as a result of higher demand for wood in forest industry due to the increasing population and new application areas. Consequently, there is a need for alternative resources to substitute wood raw material [1-3].

The demand for wood composites from waste wood has been increasing as timber resources in natural forests decline. The use of renewable biomass as a raw material in composites production was one approach and the use of renewable biomass may result in several benefits, such as environmental and socioeconomic [4]. Today renewable biomass are mostly accepted as waste materials and are mostly ploughed into the soil or burnt in the field. According to the end uses of wood-wastes and their possible reuse products, particleboard has found typical applications as flooring, wall and ceiling panels, office dividers, bulletin boards, furniture, cabinets, counter tops, and desk tops [5, 6], and it seems that the manufacture of particleboard from recycled wood-based wastes is the most common way to reuse such waste materials [7].

Also, one of the major challenges associated with wood-based particleboard is the use of formaldehyde resin. Formaldehyde is a volatile, colourless gas with a strong odour that is commonly used in industrial processes, particularly in manufacturing building materials. Pressed wood products, such as wood-based particleboard and medium density fiberboard, are made using adhesive resins containing urea-formaldehyde [8, 9]. Off-gassing levels are at their highest when the products are new, with emissions tapering off as they age. Exposure to formaldehyde in concentrations greater than 0.1 parts per million (ppm) can cause nasal and throat congestions, burning eyes, or headaches as well as increasing the risk of developing cancer [10-14]. Against this background, the present research will develop eco-friendly non-wood particleboard by using rice husk particles, while gum Arabic serves as the binder. In order to make good compare the gum Arabic particleboard, a work with formaldehyde was also carryout. Hence, this work is aimed at producing durable materials for structural applications from locally source materials by using rice husks shell to produce particleboard in conjunction with the binders. This is in effort to reduce the rate of importation of synthetic fibres and make locally made building materials available at a cheaper rate.

Rice husk from paddy (Oryza sativa) is one example of alternative material that can be potentially used for making particleboard. Rice husk is unusually high in ash, which is 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are useful to many industrial applications, such as acting as a strengthening agent in building materials [15-17].

2. Experimental Procedure

2.1. Materials

The materials required for this work were also sourced locally. These include rice husks, gum Arabic, formaldehyde (top bond), rectangular moulds, and water.

2.2. Equipment

The equipments used in this work includes, a weighing balance and two hydraulic jacks. The weighing balance was for accurate measurement of the mixes during mixing and pouring operations as well as the wet and dry weights of the samples.

The hydraulic jacks were used for the compaction of the composite after casting. Other apparatus used were wooden rectangular slash, metal slab, measuring cylinder, table spoons, and wood stirrer and scanning electron microscope (SEM).

2.3. Preparation of materials

Some of the aforementioned materials had to be prepared before they were used for the experimental procedure. The rice husks from the natural plant (Oryza sativa) were milled and sieve to size range of 25-35mm, this was done to avoid balling problem during the mixing and to facilitate homogeneous mixing of the composite.

2.4. Mould preparation

Wood was used for the construction of the moulds for the casting operation. The moulds were made having a rectangular cross-section measuring 610mm $\times$ 80mm with a height of 15mm. The variable in this work were the various binders/hardeners used, while the mass of the milled rice husks was held constant throughout. The total weight utilized was 150g and in the ratio 150:15:150:35, respectively [15-17].

To produce the composite, the digital weighing balance was used to weigh the particle, gum Arabic, and formaldehyde resin (top bond). These were then thoroughly mixed manually by using wooden stirrer. Thereafter, the mixture was then poured into a wooden mould measuring 25mm $\times$ 15mm. This was later pressed using a heavier medium in four (4) uniform compacts. These however enabled the composite to take the shape of the mould cavity giving it a smooth surface free of voids and air holes. The mould was then carefully broken and the particleboard was carefully removed and allowed to dry naturally on free air.

2.5. Casting and pressing operations

After a homogeneous mixture was obtained, the slurry was poured into the rectangular moulds and labelled with the corresponding mass fraction. Prior to this casting operation, cellophane was also placed on the slurry in the mould before the cover was placed in position. Compression using a hydraulic jack was done to close the mould to 10mm, the desired thickness of the composite slab. Four 10mm thick blocks of wood were used at the composite slab. Four 10mm thick blocks of wood were used at the corners to provide the mechanical stops. Pressing was maintained for 30 minutes before the compacting pressure was removed. In all, fifteen (15) samples were cast, three (3) for each of the mass fraction. The samples were then left to set slowly for 23 hours before they were de-moulded and left to cure for 18 days in the laboratory atmosphere.

2.6. Microstructural analysis

The scanning electron microscope (SEM) JEOL JSM-6480LV was used to identify the surface morphology of the board composite samples. The samples was washed, cleaned thoroughly, air-dried, and coated with 100Å thick platinum in JEOL sputter ion coater and observed SEM at 20kV. Samples was sputter-coated with gold to increase surface conductivity [7-9].

2.7. Scatter-index test

The reliability of a material can be determined by measuring its resistance to fracture, either ductile or brittle and fracture toughness [1-4]. However, scatter-index test reveal both toughness and fracture types. Scatter-index test are known to give a good indication of how reliable the materials is likely to be under conditions of shock. The rectangular composite (particleboard) was placed on the impact machine (Anvil Denser) and the result was recorded in Joules (J).

2.8. Water absorptivity test

Three samples were taken from each mass fraction, weighed, and soaked in water for 24 hours [2-6]. Thereafter, they were removed from water, cleaned, dried, and re-weighed. The obtained data were recorded against each mass fraction and the mean obtained. The percentage water absorptivity was also calculated and recorded against each mass fraction. The percentage water absorptivity was calculated as follows [10-15]:

$$\text{Percentage water absorptivity} = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Initial weight}} \times 100\%.$$

2.9. Bending strength

Bending specimens of 50mm wide and 275mm long were cut from each full particleboard. A concentrated bending load was applied at the center with a span of 15 times the thickness of the specimen. The bending modulus of elasticity (MOE) and modulus of rupture (MOR) were calculated from load deflection curves according to the following formula [6, 10]:

$$\text{MOR} = \frac{3P_b L}{2bh^2};$$

$$\text{MOE} = \frac{P_{bp} L^3}{4bh^3 Y_p};$$

where P_b is the maximum load (N); P_{bp} is the load at the proportional limit (N); Y_p is the deflection corresponding to P_{bp}(mm); b is the width of the specimen (mm); h is the thickness of the specimen (mm); and L is the span (mm).

2.10. Internal bonding strength

The tensile strength perpendicular to the surface was determined by using three conditioned specimens of 50mm × 50mm from each particleboard. The rupture load (P_s) was determined and internal bond strength (IB) was calculated by using the following formula [10-15].

$$\text{IB} = \frac{P_s}{bl},$$

where Ps is the rupture load and l is the length of the specimen.

3. Results and Discussion

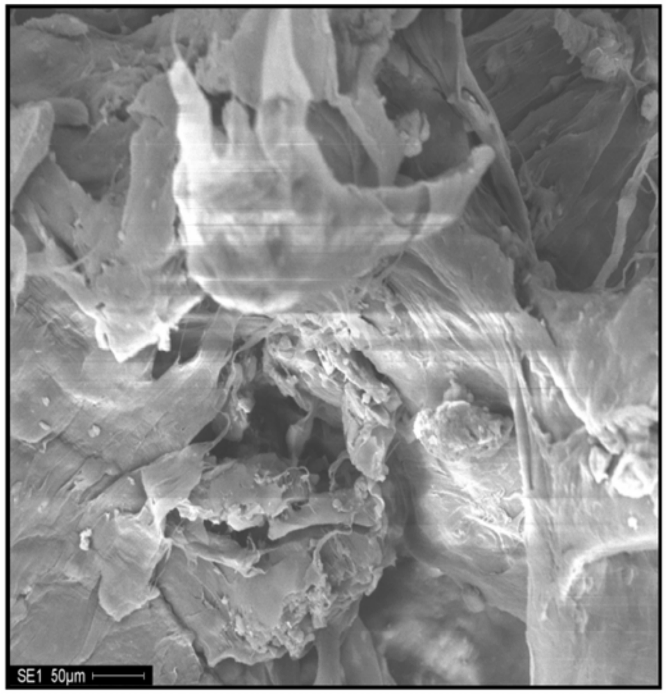
Macrostructural studies of the particleboard composites revealed a uniform distribution of the rice husk particles and the binder (see Figures 1 and 2). The distribution of particles is influenced by compounding of the rice husk particles and binder, which resulted to good interfacial bonding [5-7]. Both binders used in this research shown good surface finishing.

Figure 1. Showing the particleboard with gum Arabic.

Figure 2. Showing the particleboard with formaldehyde resin (top bond).

The morphologies of the particleboard composites by SEM are show in Figures 3 and 4. Morphological analysis using SEM clearly show difference in the morphology of the particleboard composites (Figures 3 and 4). The microstructure clearly shows that when the agro-waste particle was added to the binder morphological change in the structure take place.

The microstructure reveals that there are small discontinuities and a reasonably uniform distribution of particles and the binders [12, 13]. The particles phase is shown as white phase, while the binders phase is dark. The agro-waste particles are embedded within the amorphous matrix composed of randomly distributed in the matrix planar boundaries. The surface of the agro-waste particles is smooth indicating that the compatibility between particles and the binders was good. It can be seen that the agro-waste particles are not detached from the binder surface as the weight fraction of agro-waste particles.



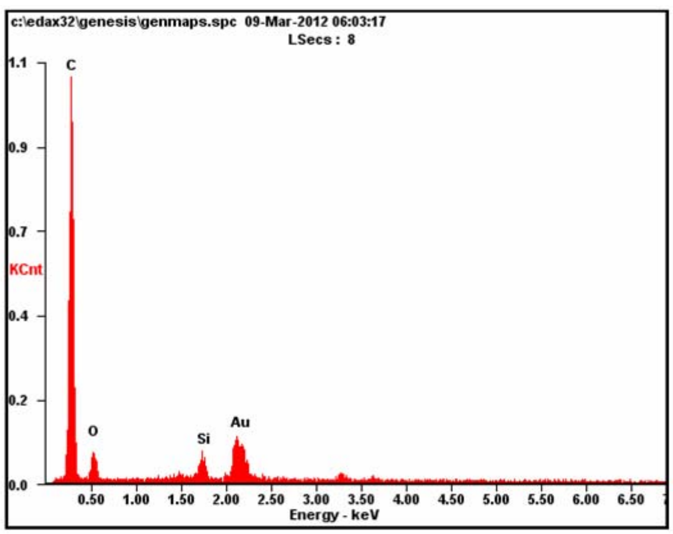


Figure 3. SEM/EDS microstructure of the particleboard with gum Arabic.

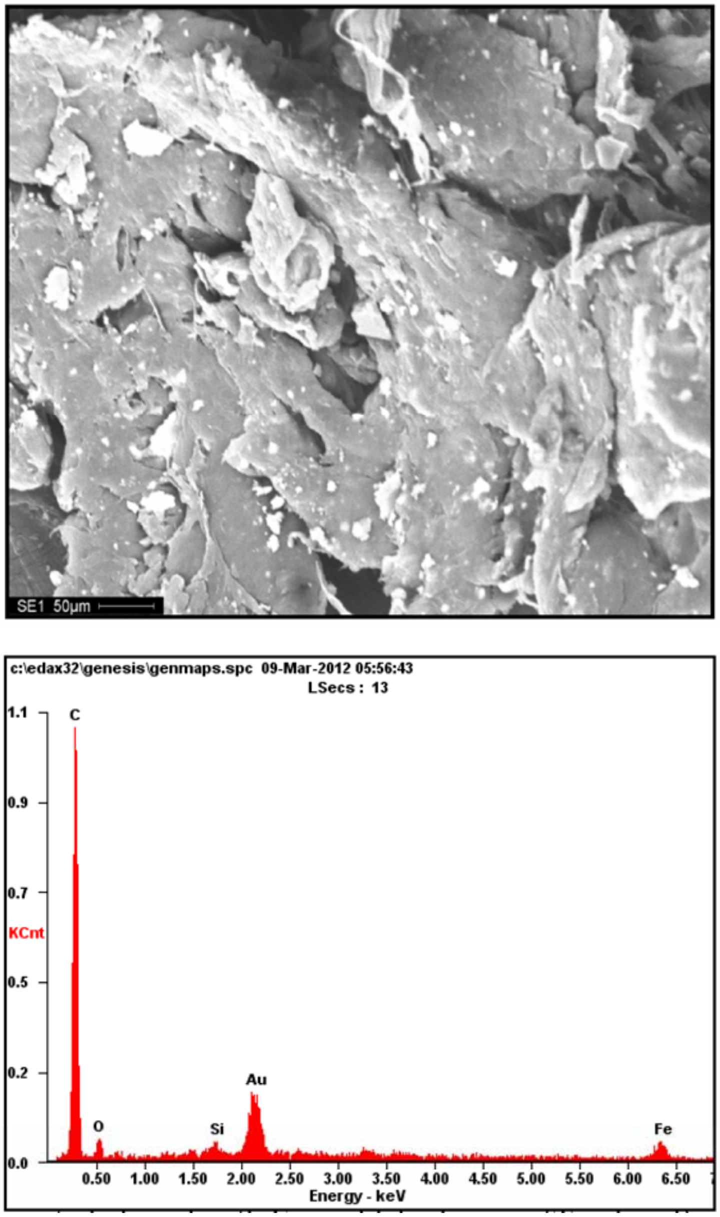


Figure 4. SEM/EDS microstructure of the particleboard with formaldehyde resin (top bond).

The results of the scatter index of the developed particleboard for the two binders are shown in Figure 5.

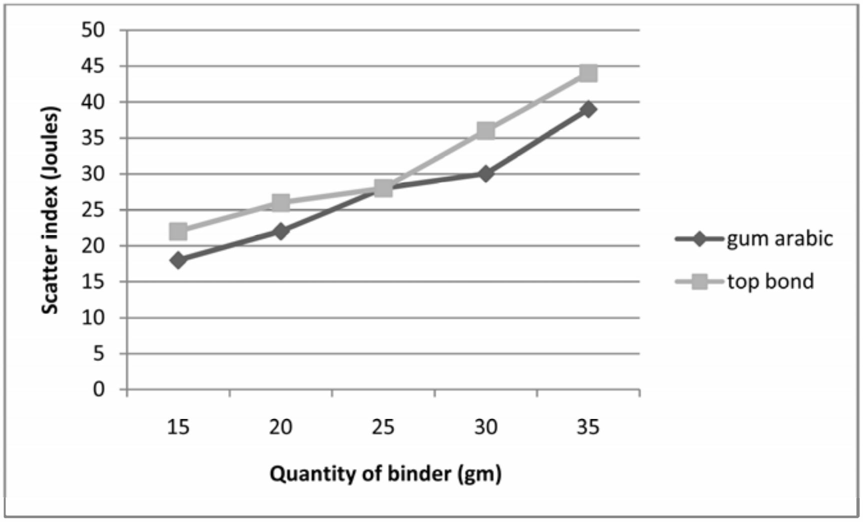


Figure 5. Variation of scatter index (J) with quantity of binders.

From Figure 5, it was observed that using gum Arabic as a binder, it is clear that the scatter index increases with the quantity of binder in the particleboard produced. However, the increase was due to the strength of the binder in the board compressed, which was directly proportional to the mass of the rice husk used. The tests also serve as guide during the utilizations of the particleboard especially in the applications of automobiles, ceiling, utensils, and other structural applications [13-15].

It was also observed that gum Arabic compared favourably with the top bond required at 25gm addition to the rice husk particle, which has scatter index of 28 joules (see Figure 5).

Water absorptivity tells us the amount of water a particular material can absorbed before failure in service. In view to this, it was carried out on the particleboard produced by using rice husk and binders (gum Arabic and top bond). The results of water absorptivity are presented in Figure 6.

From Figure 6, it is obvious that as the quantity of gum Arabic added, increases the percentage of water absorptivity also. This means that the amount of water absorb depends on the amount of the binder added. Between 30gm of the binder, the percentage of the water absorbed became constant. This implies that at 30gm of gum Arabic is the peak of the binder, the particleboard can withstand in order to serve its purpose.

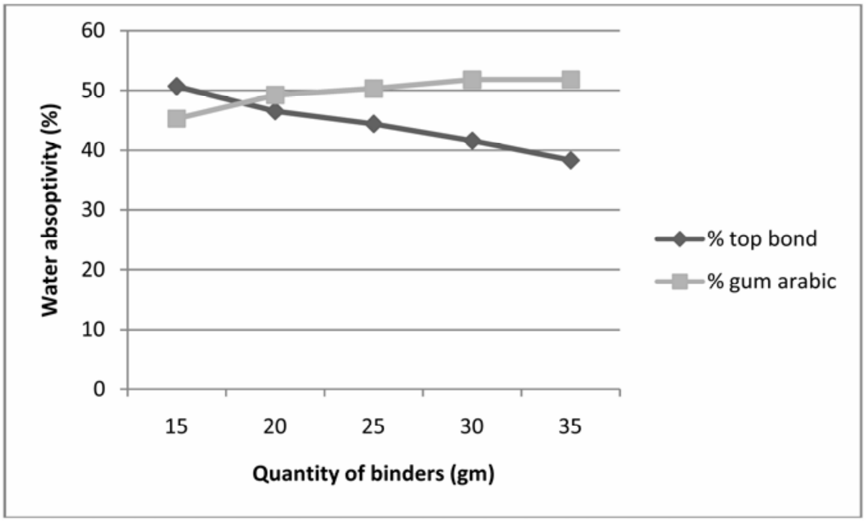


Figure 6. Variation of water absorptivity with quantity of binders.

The values of modulus of elasticity (MOE), modulus of rupture (MOR), and internal bond (IB) strength are shown in Figures 7-9, respectively. The increase in modulus elasticity with increasing binders addition is expected, since the addition of binders to the rice husk particles increases, the stiffness of the particleboard composites (see Figure 7).

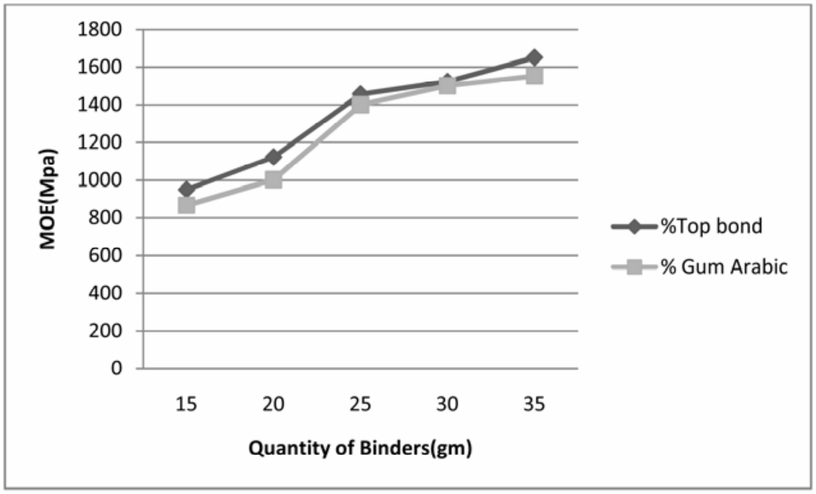


Figure 7. Variation of modulus of elasticity with quantity of binders.

The MOR ranged from 5.78 to 12.5N/mm^2 (Figure 8). The MOR requirements of 11.5N/mm^2 for general purpose boards by EN 312-2 [10, 11]. Particleboards made from less than 25wt% binders had MOR lower than the requirement for general purpose. In addition, although increasing of binders addition increasing the MOR.

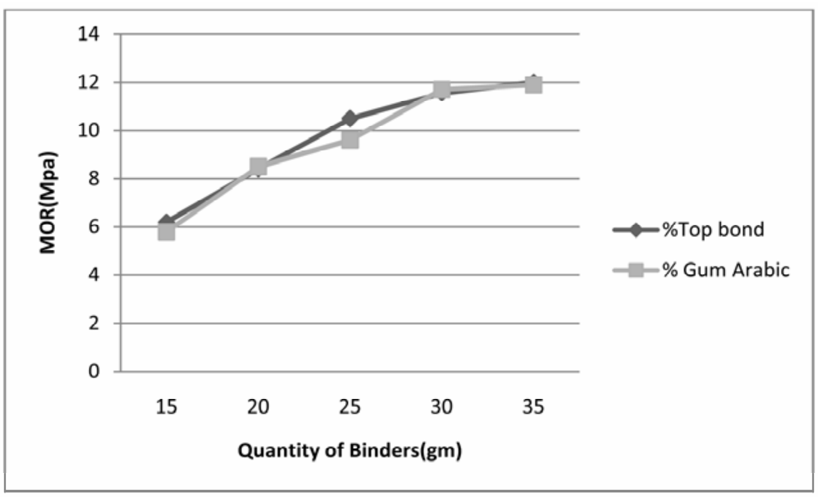


Figure 8. Variation of modulus of rupture with quantity of binders.

The range of data in IB was from 0.34 to $0.67N/mm^2$ (see Figure 9). The IB requirements of $0.24N/mm^2$ for general purpose boards, $0.35N/mm^2$ for interior fitments, load-bearing boards and $0.50N/mm^2$ for heavy duty load bearing boards [10-17], respectively.

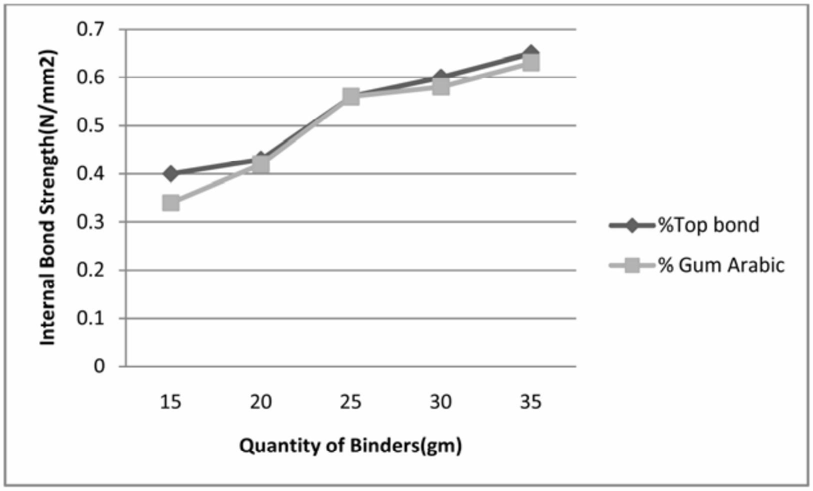


Figure 9. Variation of internal bonding strength with quantity of binders.

The rice husk board surpassed the mechanical strength requirements for general purpose applications specified by European standard. All of the particleboards produced from are within the recommended standard, i.e., for general purpose, interior fitments, load-bearing boards, and heavy-duty load bearing boards.

Also, the amount of top bond required for the production of the same board using rice husk. As the quantity of the binder is increased, the percentage of water absorptivity decreases until at 30gm and above, the decrease seems to be constant as the binder increases. This is also tells us that for a particular applications, the amount of binder to be used in order to obtained the desired properties. This was in par with the work of also Idris et al. [13], who investigated the suitability of maize cob particles and recycled low density polyethylene (RLDPE) as a raw material for particleboard manufacturing. There board was produced by varying RLDPE from 30-70wt% at 10wt% interval. The microstructure, physical (thickness swelling (TS) and water absorption (WA)), and mechanical (modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond (IB)), properties of particleboards were determined. There results showed that the WA and TS values were moderate, the MOR exceed the minimum requirements of the European standards, for general purpose. They concluded that maize cob particles and RLDPE can be used as a substitute to wood-formaldehyde based particleboard for general purpose applications.

4. Conclusion

From the results of the tests carried out, the following conclusions can be drawn:

(1) This work shows that successful fabrication of rice husk particleboard composites by simple compressive moulding techniques.

(2) The percentage of water absorption increased in increasing the weight of the gum Arabic.

(3) The uniform distribution of the particles and the binders in the microstructure of the board composites is the major factor responsible for the improvement in the properties.

(4) The developed particleboard composites can be use in density particleboards for general purpose requirements like paneling, ceilings, partitioning, etc. Since the properties of particleboard composites used in this area compared favourably with standard.

(5) The gum Arabic binder is biodegradable, environmentally friendly and in fact, environmental compliance, which has no effects on our society.

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