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PHYSICO-MECHANICAL PROPERTIES OF RECYCLED LOW DENSITY POLYETHYLENE/WOOD FLOUR FOR FLOOR TIES APPLICATIONS

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ABSTRACT

Physico-mechanical properties of recycled low density polyethylene (rLDPE) filled wood flour particles has been studied in this research. The composites were produced using two roll milling and compression mould processes. Tensile strength, impact strength, hardness and water absorption properties of the composites were conducted. From the research work carried out on production of polymer matrix composites from rLDPE and sawdust and the results obtained, it was observed that sawdust powder improved tensile strength, tensile modulus and hardness properties of rLDPE. However, percentage elongation at break, impact strength and water absorption properties of the composites decreased with incorporation of sawdust. The results also shown that composition ratio of 30% wood flour at 150 micrometer particle size reinforced recycled Low Density Polyethylene better among others.

KEYWORDS

Physico-mechanical properties, rLDPE, compression mould process, tensile strength, impact strength, water absorption

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INTRODUCTION

Plastics are durable, lightweight and inexpensive materials. They can readily be molded into various products which find uses in a plethora of applications. Every year, more than 100 million tons of plastics are manufactured across the globe. Around 200 billion pounds of new plastic material is thermoformed, foamed, laminated and extruded into millions of packages and products (Darshar *et al*., 2017). It is feared that the growing demand for resources will facilitate an increase in resource consumption and waste generation, contribute to deterioration of the natural environment and climate change, and impact future generations (Ogwo *et al*., 2013).

Around the world, waste constitutes an environmental, health and sustainability burden to man and animals. In order to preserve our environment, there is a need for the development of sustainable means to manage plastic wastes generated from our local communities and industries. Consequently, the reuse, recovery and the recycling of plastics are extremely important (Oyake *et al.*, 2015).

Plastics recycling refer to the process of recovering waste or scrap plastic and reprocessing the materials into functional and useful products. The goal of recycling plastic is to reduce high rates of plastic pollution while putting less pressure on virgin materials to produce brand new plastic products. This approach helps to conserve resources and diverts plastics from landfills or unintended destinations such as oceans (Mika *et al*., 2011).

Agricultural wastes residues during harvest seasons in most African countries are enormous and often constitute environmental menace since they found little or no alternative use. Most of these materials are lingocellulosic and could be used as reinforcements in developing composite materials. These organic fillers can be easily moulded with little or no abrasive action with equipment, and are readily available and cheap. Currently, material scientists around the world are engaged in the synthesis of new green polymeric materials and processes that improve the environmental quality of a number of products. In fact, the renewability, biodegradability, high filling effect, abrasion resistance, acceptable specific strength properties, availability, light weight, ease of separation, high toughness, non-corrosive nature, low cost, good thermal properties, reduced tool wear properties of natural fibres/fillers are making them part of the best reinforcing materials for the synthesis of polymer based composites (Ikpe *et al*., 2011).

Although plastics are known for their good mechanical properties, resistance to chemical attack and corrosion, ease of processing and recycling, cost effectiveness, light weight, and others. However, these properties are affected by many factors such as stress, temperature and environment during their service lives. In fact, this led to vehement objection of some polymers in some specific applications such as aircraft parts. Consequently, recycled plastics could said to be of low mechanical properties due to early exposure to ageing processes during their first service lives. The attempts to overcome these obstacles led to incorporation of fillers (inorganic and organic) into recycled plastics with a view to obtaining a polymer composite whose constituents act synergistically to withstand the challenges, thereby making recycled polymers more reliable during use or processing (Ayo *et al*., 2017). Generally, composite properties are influenced by many factors such as filler characteristics, filler content, and interfacial adhesion and dispersion due to combination of more than one material.

MATERIALS AND METHODS

Materials

Recycled Low Density Polyethylene (Abuja Metropolis)

Wood Flour (Dambale Sawmill, Zaria, Kaduna State)

Apparatus/equipment

i. Plastic Film Shredder (NILEST, Samaru-Zaria)
ii. Pelletizing Extruder (NILEST, Samaru-Zaria)
iii. Ball milling Machine (ABU, Zaria)
iv. Two roll mill {model: 5183 North Bergen U.S.A} (NILEST, Samaru-Zaria)
v. Compression Moulding Machine (model: 0557) (NILEST, Samaru-Zaria)
vi. Izod Impact tester {model : 6757 pianezz-terino Italy} (ABU, Zaria)
vii. Vickers hardness testing machine {Model : MV1-PC} (ABU, Zaria)
viii. Universal Testing Machine {model : }(ABU Zaria)
ix. Dynamic Mechanical Thermal Analyzer (DMTA) ABU, Zaria)
x. Weighing balance (Nilest, Samaru-Zaria)

Methods

Material Collection and Preparation

Waste Pure Water Sachets (rLDPE) was collected from Abuja Metropolis. It was sorted, washed, sun dried, shredded into smaller pieces and recycled into pellet form using a Pelletizing Extruder. Hardwood Flour (Mahogany) was collected from Danbale Sawmill, Zaria, Kaduna State. The hardwood flour was ball milled into fine particle size and sieved using a sieve of 150 µm. The sieved hardwood flour was treated using 2%w/v NaOH solution for two (2) hours at room temperature.

Collection of Used Pure Water Sachet

Used pure water sachet was collected from various restaurants within Abuja Metropolis. This was done by keeping labeled (water sachet only) waste bin at the appropriate location with the restaurant's premises for continuous collection and gathering of the picked used pure water sachet. The gathered water sachets was transferred into a sack and moved to the plastic recycling workshop at the Department of Polymer Technology, Nigerian Institute of Leather and Science Technology (NILEST), Samara-Zaria, Kaduna State.

Sorting of Used Pure Water Sachet

The used pure water sachet collected was sorted using hand picking method. This process involved removal of foreign matters (materials that are not water sachet) and heavily contaminated used pure water sachets from the pool of collected pure water sachets. This is to reduce contamination of the recycled low density polyethylene that was used for this research to the barest minimal.

Washing of the Sorted Used Pure Water Sachet

The sorted used pure water sachet was washed using soap and water. This was done by fully immersion of the sorted pure water sachets in a prepared soap solution and allowed to stand for 1 hour before the sachets were scrubbed severally to remove any dirt firmly adhering to the pure water sachets. Upon achieving satisfied purification, the washed pure water sachets were removed from the soap solution and rinse severally with clean water until it was free from soapy feeling.

Drying of Washed Used Pure Water Sachet

The washed pure water sachet was weighed and dried under the sun. This was achieved by openly exposure of the sachet to the sun at an open space and spread out the wet sachets such that the sun rays can easily and directly hit the sachet surfaces. The weight of the dried pure water sachets was checked at 24 hours interval until a constant weight was achieved.

Recycling of the Used Pure Water Sachet

The recycled of the used pure water sachet was done using a Pelletizing Film Extruder. The cleaned used pure water sachets were loaded into the hopper of the pelletizing film extruder which processing parameters such as melting temperature, extruding screw speed and pelletizing speed have been set and the machine preheated to allow the heating barrel of the machine attain the set melting temperature of the pure water sachet. Upon attaining the melting temperature of 120 ^{o}C, the machine was operated such that the extruding screw picks the sachets from the hopper and move it through the heated barrel to melt the sachets into molten state and extrude it through the die-head containing narrow orifices that gives a rope like profile to the extrudate. The extrudate was passed through cold water for cooling (solidified) and send to the pelletizing unit of the machine to cut the long profile recycled polyethylene into pellet form (granules).

Collection of Hardwood (Mahogany)

Wood flour from Mahogany was collected from Danbale Sawmill in Samaru-Zaria, Kaduna State. This was achieved by physically present at the Sawmill on the day that hardwood was processed at the Sawmill based on initial arrangement with the sawmill operation manager.

Drying of the Hardwood Sawdust

The hardwood sawdust collected was weighed and dried under the sun to a constant weight. This was achieved by openly exposure of the hardwood flour to the sun at an open space and spread out the wood flour such that the sun rays can easily and directly hit the particle surfaces. The weight of the dried wood flour was first be checked after 24 hours and later checked at 6 hours interval until a constant weight was achieved.

Ball Milling of the Wood Flour

The dried wood flour was ball milled into fine particle size using a ball milling machine. This was done by placing the wood flour in the ball mill ceramic cylinder together with the ceramic balls. The loaded cylinder was placed on the machine rollers and the roller speed translate to the loaded cylinder speed and tumbling of the sawdust and the balls in the rolling cylinder. Tumbling of the balls and the sawdust particle in the cylinder brings about collision between neighbouring balls which produces breaking force of any present wood particles between the colliding balls. This process was done for 12 hours in other to achieve fine particle size of the sawdust.

Sieving of the Wood Flour

The wood flour was sieved using an ASTM 150 µm. It was filled into the sieve and place on the electric sieve shaker and shake for 30 minute and the particles that successfully passed through the sieve was collected and used for the research while the residue left in the sieve was kept for possible later use.

Table 1: Formulation Table

S/N	Recycled Low Density Polyethylene (rLDPE) (g)	Wood Flour (g)
1	100	-
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50

According to the formulation as shown in the formulation table1, the composites samples were produced by a mixing process involving the introduction of the polymer while the rolls of the two rolls mill machine were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 150°C. Upon achieving a band and bank formation of the polymer on the front roll, the prepared treated sawdust was introduced gradually to the bank, cross mixed and allowed to mix for 3 minutes. The composite was sheeted out and labeled accordingly.

Hot Pressing

The composite obtained from the mixing process was placed into a metal mould of dimensions 120mm x100mm x 3.2 mm and was placed on the hydraulic hot press (Compression Moulding Machine) for shaping at temperature of 130^{o}C and pressure of 2.5 MPa for 5mins. It was then be cooled and labeled accordingly.

Tensile Strength

The tensile strength was carried out accordance with ASTM D-638. A dumbbell shaped samples were subjected to a tensile force and tensile strength, tensile modulus percentage elongation at beak for each sample were calculated and recorded automatically by the machine and the results were on the certificate.

Impact Strength

The impact test was carried out according to the standard specified ASTM D-156. The specimen was cut to dimensions 64 mm x 12.7 mm x 3.2 mm and 45^o notched was inserted at the middle of the test specimens from all the produced composite samples. The impact energy test was carried out using Izod Impact Tester (Resil impactor testing machine). The specimen was clamped vertically on the jaw of the machine and hammer of weight 1500 N was released from an inclined angle 150°. The impact energy for corresponding tested specimen was taken and recorded. Impact strength was calculated and recorded accordingly using equation 3.2

Average Impact Energy = (J) ……………………………………….(Eq. 3.1)

Impact Strength = (J/mm) …………………………….....................(E.q 3.2)

Sample thickness = 3.2 mm

Hardness

The hardness test was carried out in accordance with ASTM D2240 on a Mico Vicker Harness Tester. The test was carried out at different positions on each sample and average hardness was calculated using equation 3.3.

Average Hardness = (Hv) …………………………………………….. (Eq. 3.3)

Water absorption

The water absorption was carried out in accordance with (ASTM D570). Specimens were prepared with dimension 50mm x 50mm x 3.2 mm. Water absorption test was done by total immersion of specimens in distilled water at room temperature for 7 days. The water absorbed was determined by weighing the samples at regular intervals of 24 hours, with the aid of digital weighing balance. The percentage water absorption of the composite samples was calculated using the equation 3.4.

% Water Absorbed = ………………………………………….. ……….(Eq. 3.4)

RESULTS

Tensile Strength Results

Figure 1: Effects of wood flour loading on the tensile strength of polymer matrix composites

Figure 1 shows the tensile strength test results for the produced sawdust/recycled low density polyethylene. Tensile strength is a property of material that describes its ability to withstand deformation under tension.

The results show a steady increase in tensile strength of the composites produced as the wood flour loading increases until it reaches a peak of 23.08 MPa at 15 % wood flour loading. Thereafter, a steady decrease in the tensile strength was observed with further increase wood flour loading beyond 15%. The increase in the tensile strength of the composites from 10 % to 30 % wood flour loading could be related to the better interfacial adhesion between the fillers (wood flour) and the matrix (rLDPE) which might have aided stress transfer within the composite system of matrix thereby help in stress distribution within the matrix as the sample experiences tensile forces. However, the decrease in the tensile strength from 40 % to 50 % wood flour loading could be due to high percentage ratio of filler to the matrix which may lead to low bonding strength between the filler and the matrix due to filler agglomeration resulting to poor interfacial adhesion between the fillers and the matrix. Hence, stress transfer reduces and the tensile strength.

Tensile Modulus Results

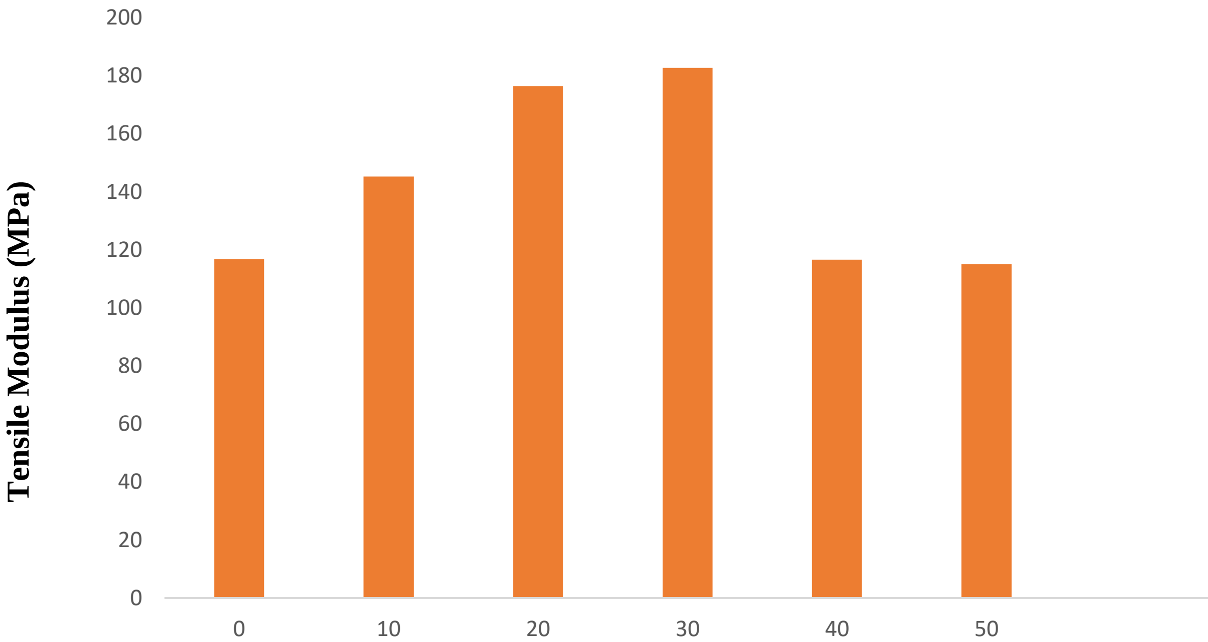

Figure 2: Effects of wood flour loading on the tensile modulus of polymer matrix composites

Figure 2 represents the results of tensile modulus of the composites produced. Tensile modulus is a measure of the stiffness of solid material. It could be seen that the results show a similar trend as obtained for tensile strength. The highest peak of 182.70 MPa at 30 % wood flour loading for recycled low density polyethylene (rLDPE). Further increase in sawdust loading lead to a steady decrease in the tensile strength. The increase in the tensile strength of the composites with wood flour loading could be related to the better interfacial adhesion between the fillers (wood flour) and the matrix (rLDPE) which might have stiffen the composite system of matrix core thereby enable the composites resistance to stretching. The decrease in the tensile modulus with further increase in sawdust loading could be due to high percentage ratio of filler in the matrixes which may lead to low bonding strength between the filler and the matrix due to possible filler agglomeration resulting to poor interfacial adhesion between the fillers and the matrix. Hence, reducing the tensile modulus.

Percentage Elongation at Break Results

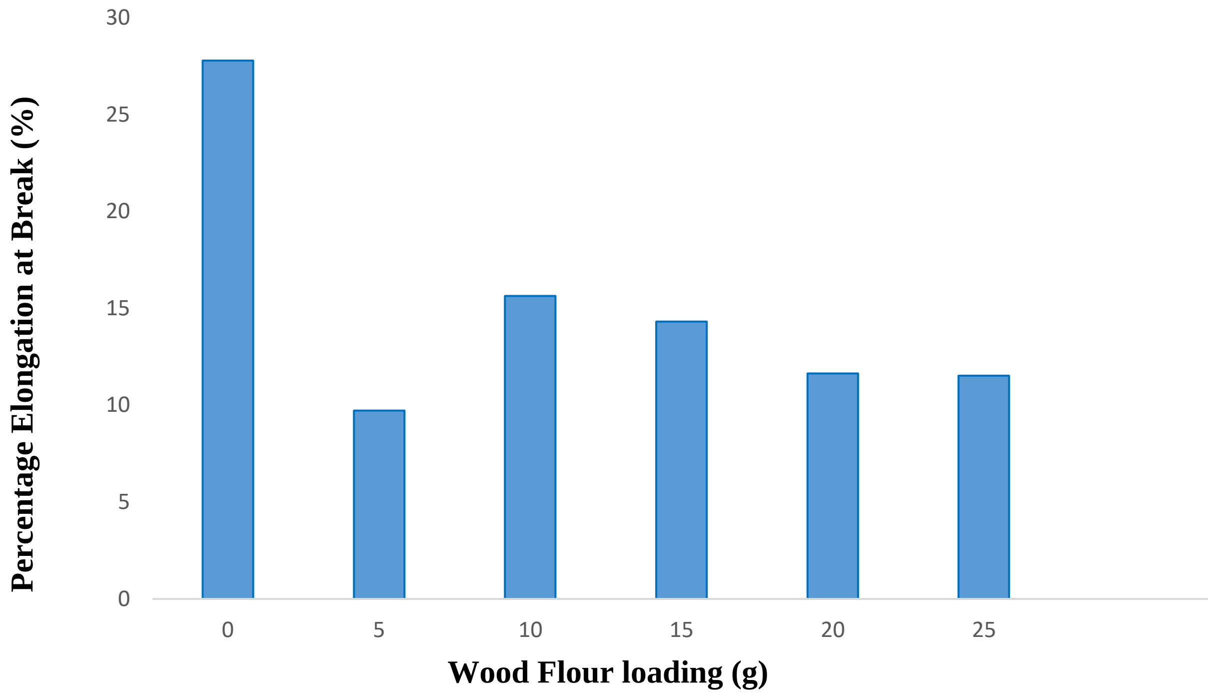

Figure 3: Effects of sawdust loading on the percentage elongation at break of polymer matrix composites

Percentage elongation is the extent to which a solid material under tension will increase in gauge length before rupture. It is described as the ratio of the change in length to the original length of 100%. The result in figure 3 Indicates decrease in the percentage elongation with the increase wood flour in the composites. The percentage elongation decreased from 27.79 % to 11.53 % as the wood flour loading increases from 0 % to 50 %. These results show that presence of wood flour in plastic matrix (low density polyethylene) stiffen the core of the matrix thereby restricted chain mobility and hence, the extensibility decreased.

Impact Strength Results

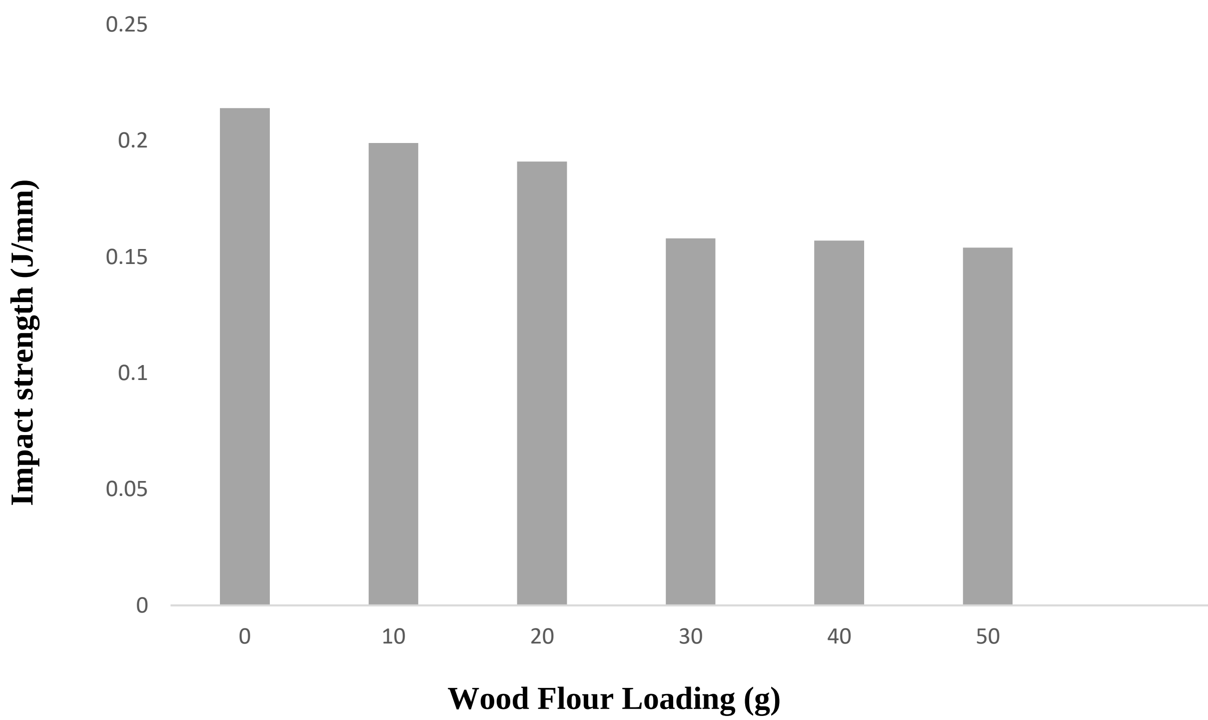

Figure 4: Effects of wood flour loading on the impact strength of polymer matrix composites

Impact strength is a measure of how much energy a material will absorb under sudden shock before fracture. Generally, polyolefin such as low density polyethylene have appreciable impact strength due to their flexible and ductile properties. Figure 4 shows the impact strength of the produced composites. It could be seen that the impact strength decreased with the increase in wood flour loading.

The decrease in the impact strength with increasing sawdust loading could be attributed to particle nature of the sawdust which may likely create void within the composite system due to agglomeration.

Hardness Results

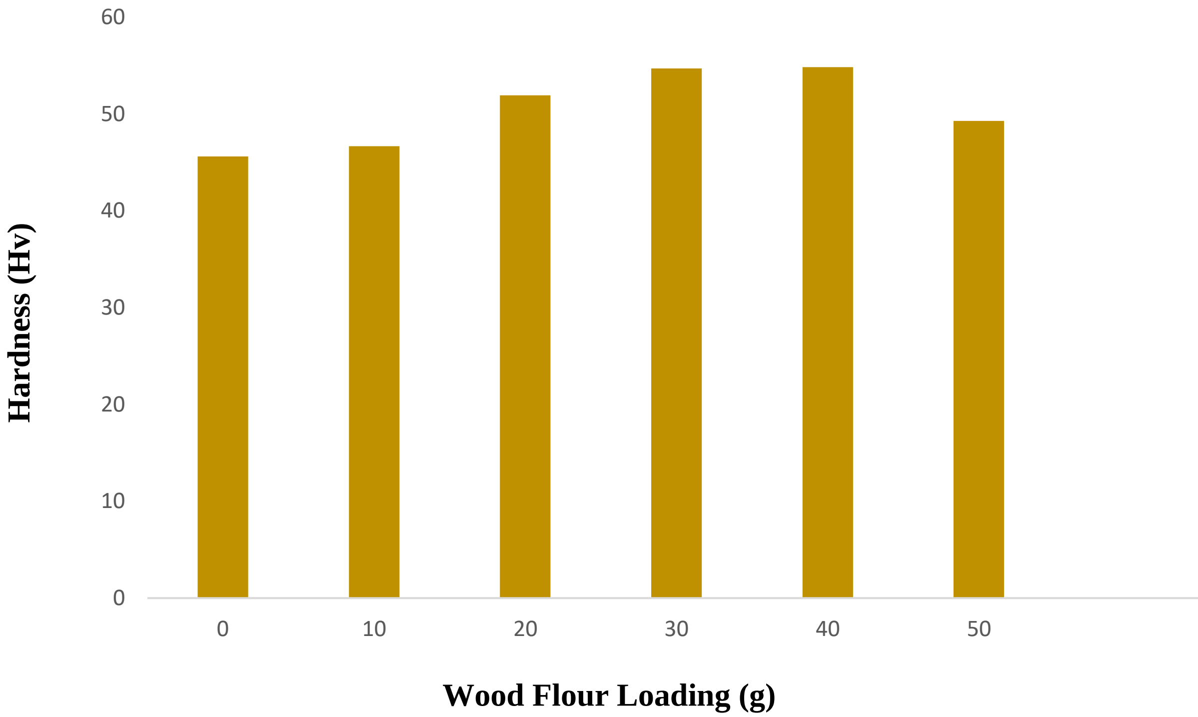

Figure 5: Effects of wood flour loading on the harness of polymer matrix composites

Hardness property is a measure of the resistance of material to deformation induced by either mechanical indentation or abrasion. Figure 5 shows the hardness results of the produced wood flour filled recycled low density polyethylene composites. It was found that there is gradual increase in the hardness of the composites with the increase wood flour loading until maximum peak of 54.86 Hv at 40 % wood flour loading before a decline trend was observed from 50 % wood flour loading.

This is expected because the sawdust used as filler was obtained from hardwood wish is expected to exhibit it inherent characteristic of hardness in the composites. However, the drop in hardness at higher wood flour loading could be due to filler bulkiness in the matrix wish might have created voids as point of failure in the composites at the higher loading.

Water Absorption Test Graph

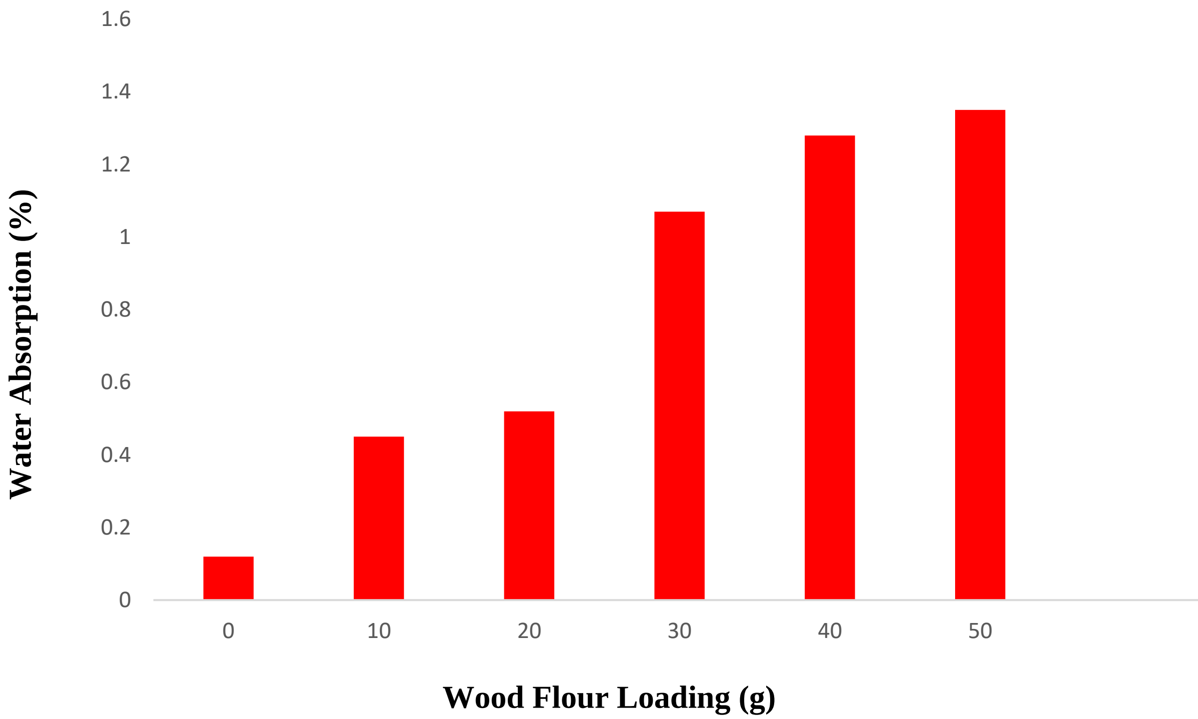

Figure 6: Effects of wood flour loading on the percentage water absorption of polymer matrix composites

Water absorption test results for the sawdust filled recycled polyethylene composites are shown in figure 6. It can be seen that the water absorption of the composites increases from 0.12 % to 1.35 % with the increase in wood flour loading. This trend could be related to the inherent property of the filler (wood flour) which is hydrophilic in nature been obtained from plant.

CONCLUSION

From the research work carried out on production of polymer matrix composites from recycled low density polyethylene (rLDPE) and sawdust and the results obtained, it was observed that sawdust powder improved tensile strength, tensile modulus and hardness properties of recycled low density polyethylene. However, percentage elongation at break, impact strength and water absorption properties of the composites decreased with incorporation of sawdust. The results also shown that composition ratio of 30% wood flour at 150 micrometer particle size reinforced recycled low density polyethylene better among others.

Consequently, the possible use of wood flour particles as filler for reinforcement of recycled low density polyethylene and its possible limitations have been established in this work.

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