Physico-Mechanical Properties of Polypropylene – Filled Waste Natural Leather

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ABSTRACT
Reinforcement of polymers through composite plays an important role in the improvement of the mechanical and physical properties of high performance materials. Hence, the mechanical behavior of waste leather/polypropylene composites was studied in order to develop a raw material for industrial application. Waste leather particles were thoroughly blended with polypropylene. Particles of the reinforcement was weighed with different weight fractions (5, 10, 15, 20, and 25) wt.% was added to 95g, 90g, 85g, 80g, and 75g corresponding weight of polypropylene, also 100% polypropylene which serves as the control sample was also weighed. For the 5% weight of reinforcement, there was a corresponding 95g of polypropylene used. The samples were made at first, by crushing the waste leather and then divided it into two portions. The portions were milled to fine powder at 0.5 meter mesh and 1.0 meter mesh using Thomas Wiley laboratory mill machine (model 4), electrically powered plate grinding machine and sieve through a mesh size of 70µm and 150 µm respectively. Mould casting and the mechanical properties of the developed composites were evaluated. The ultimate tensile strength of 37.74 MPa was obtained for the 0.5µm particulate polypropylene composite, while that of 1.0µm particulate polypropylene composite was 35.31MPa. The highest impact strength value for 0.5µm particulate polypropylene composite was 1.02J, while that of 1.0µm particulate polypropylene composite was 0.29J. The highest hardness value for 0.5µm particulate polypropylene composite was 98.33 BHN while that of 1.0µm particulate polypropylene composite was 96.33 BHN. The morphology of the fillers dispersion into the matrix was observed, through scanning electron microscopy, for control sample, 0.5µm and 1.0µm. It was observed that SEM macrograph taken at higher magnification of 750x gave excellent bridging effect in the interfacial region of the filler.

Keywords: Polypropylene, waste leather, polypropylene waste leather composite, mechanical properties, microstructure properties

INTRODUCTION
Polymer composites are plastics within which fillers or particles are embedded. Our study evaluates the mechanical properties of solid waste generated from different types of natural leather product basically footwear’s, bags and belts.
In addition to waste leather substitutes, polymer composites based on leather wastes as fillers are reported to be useful for many applications. Products from such composites find applications in construction materials, automobile interior moldings, heat and sound insulating boards, shoe soles and flooring materials. Moldings with good antistatic properties, air permeability and good appearances have been prepared from thermosetting resins and powdered leather. Leather is a natural fiber with a lot of chemicals incorporated into it during processing. When this become waste and is dumped, chemicals are released to the environment, resulting to environmental pollution. After preparing the waste leather into composite, it reduces the environmental pollution. Leather is transformed into chemically and physically stable material by chemical and mechanical process, (Ahmed, 2009).

Leather is natural polymer of amino acid monomer. For thousands of years, leather, as one of the collagen materials, has been among the most dominant fibrous materials used by humans. Leather is a general term for hide or skin with its original fibrous structure more or less intact (Ozgunay et al., 2007). Several researchers studied on leather waste have found that approximately 200 kg leather is manufactured 1 tone of wet-salted hide. More than 60% of rawhide weights are disposed to the environment by leather factories without turning them to good use. According to the Food and Agricultural Organization (FAO) data, it has been reveals that approximately 8.5 million tons of solid waste is generated during the production of 11 million tons of raw hide processed in the world. For that in this study an attempt was taken to recycle this waste leather for valuable composite. This composite will be fibrous composite. Dispersed phase of this composite is fiber which will improve strength, stiffness and fracture toughness of composite (Islam, 2009).

Polypropylenes were commercial materials obtained from local market in Zaria, Kaduna state. Polypropylene products are commonly used in commodity production due to their special chemical properties (resistance to organic and inorganic solvent, hydrophobic properties) and physical characteristics (lightness, mechanical strength, electro- and thermal insulating capabilities). In the methods of making products such as composites with the use of Polypropylene films or fibers as reinforcing components, a serious drawback of these materials is their low free surface energy, which results in weak molecular interactions between the composite components. The free energy of Polypropylene material surface can be increased by creating new functional chemical groups in the material surface layer. This task has been fulfilled by exploring different approaches such as chemical, electrochemical, physical and plasma methods (Urbaniak, 2011).

Polypropylene is one of the most versatile commodity thermoplastics with low cost, high thermal stability and low density. The polymer is used in a wide variety of applications, including packaging, textiles, stationery, plastic parts and reusable containers of various types, laboratory equipment, automotive components, and polymer banknotes. For over a decade, there have been a number of researches related to polyolefin composites reinforced with wood-based filler. Though it is a nonpolar polymer and has a poor interfacial adhesion, this disadvantage is improved by using a coupling agent or increasing the surface roughness of fibers during the compounding process (Hisham, 2016).

**EXPERIMENTAL METHOD**

**Materials:**

Matrix polymer

The thermoplastic polymer, polypropylene - type virgin was obtained from local market at Zaria, Kaduna State of Nigeria.

Reinforcing filler

The reinforcing filler used was waste leather obtained from different shoe maker stands and from waste dump. The particle sizes of the filler were reduced into pieces respectively.
Methods
Sample preparation
Waste natural leather samples are collected from the waste dump sites, different shoe maker shops and stands in Samaru and its environs. The authenticity of the leather was confirmed by subjecting the sample to burning test. The collected waste leather samples were contaminated with some amounts of possible pigment, stabilizer and labelling dye etc.

The collected waste samples were cleaned and washed with hot aqueous detergent solution at 60°C and this was followed with cold water rinse. At this temperature the labelling inks removed. The cleaned sample was subsequently dried under direct sunlight for 72 hrs to ensure complete moisture removal. Now the waste natural leather is ready for further processing.

For composite preparation, the waste leather was divided into two portions. The portions were milled to fine powder in 0.5 metre and 1.0 metre mesh using Thomas Wiley laboratory mill machine (model 4), electrically powered plate grinding machine and finally sieved through a mesh size of 70µm and 150 µm respectively.

0.5µm particle size
Compounding is a process where matrix (polypropylene) and filler (waste leather) are mixed homogenously. Composite mixtures were prepared by using two roll mills. The two roll mills consist of two horizontal, parallel, heavy metal rolls. Compression molding is the oldest mass production process for polymer products. The main reason for this choice of Compression molding is because it is simple, discontinuous technique using a mold inserted between heated metal plates in a hydraulic press. After compounding, the materials are placed on the lower die. The dies are heated up to 95°C. Then upper die is compressed against the lower die at 20kN. Then it is allowed to cool in the die itself for half an hour. The die size is 270x130x3mm. Using the ejector pin the material is taken out from the die. A final thickness of 4 mm was obtained for the samples to be used in mechanical tests. To find out the properties of the fabricated composites sheets, sheets were punched to dumb bell shape to get ASTM standard for tensile testing properties, flexural strength and impact test.

**Tensile Test**
Monsanto tensometer (type „w”) S/no 9875, of ASTM D5083 standard was used for the tensile test of the composite samples for both 0.5µm, 1.0µm and control samples. Test procedures: The various dumbbell shapes of the sample were cut and fixed on the Monsanto device. The various indentations on the Monsanto graph sheets were noted at the point of rupture. The breaking force and elongation/ultimate tensile strength/modulus of the various samples were calculated.

**Impact Resistance Measurement**
The notched charpy impact strength tests were conducted according to ASTM D 256-97 at room temperature. Each value obtained represented the average of three samples.

**Hardness Measurement**
A Tensometer “W” type by Monsanto was used to perform Brinell hardness test. The test samples were cut in rectangle shapes of 50mm by 30mm and placed in the machine. The values obtained represented the average of three samples.
Scanning electron microscopy (SEM)
This is the most widely used type of electron microscope. It examines microscopic structure by scanning the surface of the sample. SEM image is formed by a focused electron beam that scans.

RESULTS AND DISCUSSION

Figure A: Ultimate tensile strength of particulate reinforced polypropylene/waste leather composites

Figure B: Tensile Strain against Percentage filler loading of PP filled with waste leather
Figure C: % Elongation against Percentage filler loading of Polypropylene/waste leather composite

Figure D: Hardness against Percentage filler loading of Polypropylene/waste leather composite.
Figure E: Flexural Strength against Percentage filler Ratio of Polypropylene/ waste leather composite

Figure F: Impact Strength against Percentage filler Ratio of Polypropylene/ waste leather composite
Figure G: Water absorption against Percentage filler loading of Polypropylene/waste leather composite.
Plate 1: SEM image (750 x) control sample of PP/Leather composite
Plate 2: SEM image (750 x) 0.5 µm sample of PP/Leather composite
Plate 3: SEM image (750 x) 1.0µm sample of Polypropylene/waste Leather composite
Tensile Strength
Figure A shows the result of the tensile test of the polypropylene/waste leather composites of particle sizes 0.5 µm and 1.0 µm. It shows the variation of the tensile strengths of the composites with filler weight fraction. The 0.5 µm waste leather particles reinforced composite show higher ultimate tensile strength (37.74 MPa at 20 wt. %) compared to 1.0 µm. This is as a result of increase in the surface area. This may also account for the good distribution and dispersion of the waste leather particles in the polypropylene matrix resulting in strong particles-matrix interaction. The good particles dispersion improves the particles matrix interaction and consequently increases the ability of the particles to restrain gross deformation of the matrix.

Strain
In figure B, both composites show decreasing strain (Elasticity) as reinforcement concentration increases. The highest strain values of 0.23 and 0.24 at 5wt % for both 0.5µm and 1.0µm reinforcement of polypropylene/ waste leather particles were obtained. The ductility at break decreased upon filler addition for composites regardless of the nature of the filler. As reinforcement concentration increases, elasticity of the matrix reduces. This enhances rigidity and causes a decrease in tensile strength and ductility as a result of restriction in the polymer matrix movement.

Elongation at Break
Figure C, represents %Elongation at break for 0.5µm first decreases from point 27 to 19 .which indicates that up to this composition (decreasing region) the ductility is decreasing, in another word stiffness is increasing. The increase in %Elongation up to 21 indicates that up to this composition (increasing region), the ductility is increasing before its finally decrease to 15 and Elongation at break for 1.0µm decreases as the ratio of the filler (waste leather) increases to 25 wt%. This is due to the amount of crosslink density. If the amount of crosslink density is decreased due to the loss of interfacial adhesion among the constituent phases in the blends, the tensile strength value is reduced they by increasing the elongation at break.

Hardness Test
Figure D, the influence of the filler weight fraction on the hardness of the composite indicates 0.5µm particle size of waste leather powder reinforced polypropylene shows progressive hardness increase as the filler increases to a maximum of 98.33 at 20 wt. %. The peak hardness of 96.33 was attained at 25wt % for 1.0 µm particle size of waste leather powder reinforced polypropylene. Do to the larger surface area of 0.5 µm particle size composite it has a better bonding structure compare to 1.0 µm particle sizes because of its interfacial bonding strength. Also the hardness values of the composites are higher than the pure polypropylene (control sample) value of 92.24 at 0 % wt.

Flexural Strength
Comparison of the flexural strengths of composite materials is shown in Figure E. It is clearly indicated that composites Wt 15 of 0.5 µm and wt 10 of the same 0.5 µm exhibited maximum flexural strength (60.19 and 43.51 MPa) when compared with 1.0 µm filled composites. This may be due to good compatibility between filler and matrix because of the larger surface area of 0.5 µm compared to 1.0 µm which results to strong polypropylene/waste leather interface adhesion.

It is also noticed that flexural strength of composites increases with the increase in fiber loading except in a few cases were flexural strength of composites decrease due to non uniform distribution of filler materials to increased effective bonding between filler materials and matrix.

Charpy Impact Strength Test
The Charpy impact test method was conducted at room temperature. The notched specimens were tested and the results obtained are as shown in Figure F. The results obtained indicated increase filler loading which resulted to the stiffening and hardening of the composite thereby increasing the impact energy of the composite. It indicates that the resistance to impact loading of polypropylene filled waste leather composites improves with increase in filler loading. Strong adhesion between the filler and matrix interface can cause better stress transfer from the matrix to the filler and this leads to higher impact strength.
Water Absorption
Generally, the rate of water absorption is greatly affected by the composite’s density and void content. Longer the fibre, the higher is the water absorption. Similarly, it is also evident from the Figure G that the rate of water absorption increases with increase in fiber content. 1.0 µm polypropylene filled waste leather Composites with 25 wt. % coir fibre content shows more water absorption rate of 1.75 compared to 20 wt. % fibre content with water absorption rate of 1.69 for 0.5µm polypropylene filled waste leather composite. The reason may be due to the fact that coir fibres contain more polar hydroxide groups, which result in the high moisture absorption level of natural fibre based polymer composites.

SEM Analysis
Plate 1, 2 and 3 present Scanning electron micrographs (SEM) photomicrographs of the tensile fracture surfaces of the PP/waste leather composite. For both the Plate 1, 2 and 3 samples composite does not modify the basic fracture mechanism of the PP matrix. The composite failed, predominantly, by transversal fracture in the plane of the matrix, showing similar fracture, surface roughness and the presence of conic marks. However, one can see that due to the presence of polypropylene/waste leather, the matrix surface results to pull-out and breakage of the fillers. In this manner the fracture morphology of the composites shows some differences according to the Polypropylene/waste leather ratios of 0.5µm and 1.0µm.

CONCLUSION
The study carried out involves composite production from polypropylene/waste leather. Waste leather particles improved the Hardness property of the polypropylene matrix composite. A general increase was observed in the hardness trend of the 0.5µm particles reinforced polypropylene composites, with a peak value 98.33J at 20 % wt of waste leather reinforcement. The toughness of the composites dropped as the concentration of waste leather particles increased in the polymer matrix. This indicates that shock absorption reduces with increasing reinforcement. The microstructure analysis shows a good dispersion of the waste leather/polypropylene composite which is responsible for the increase in strength. The tensile strength increased up to a maximum value of 37.74MPa at 20 wt % of reinforcement 0.5µm particle size. In terms of strength, the 0.5µm particle size reinforced composite is better than the 1.0µm. The results of the tensile strength obtained from this study showed that the composite is good for shoe sole and automobile interior decoration. This also confirms that waste leather/polypropylene composite is a good material for engineering applications. Scanning electron micrographs (SEM) of these composites showed smooth surface and better matrix-fibre adhesion. In comparison of the two surface areas, 0.5 µm particle size have proven to be a better particle size when compared with 1.0 µm because of its mechanical and microstructure property result, which may be as a result of more better interfacial bond in 0.5 µm. This will reduce the consumption of raw materials; increase the level of general use and recovery. Equally it is a source of steady income for companies and an opportunity to create new jobs. So it can be concluded that pollution creating waste leather can be reused and recycled into semi biodegradable composite which can reduce environmental pollution and also composite that can be used as industrial raw material in composite production.

REFERENCES
