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# Effects of Organic Fillers on the Physico-Mechanical Properties of Low Density Polyethylene

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## Abstract
The effects of some animal materials, viz feather, hide and hoof, as fillers for low density polyethylene were investigated. Composites of varying weight percentages of fillers in fixed weight of the polymer resins were produced for each filler type by the injection moulding technique. The physico-mechanical properties of the composites prepared showed variations in the properties such as, tensile strength, elongation at break, compressive strength, flexural strength and surface hardness. The hoof filler is seen to exhibit the best reinforcing properties, followed by hide and lastly feather. These organic materials of animal origin can be used as fillers and mainly as biodegradable fillers for polymer resins and form bio-plastics.

## 1. Introduction

The ever increasing applications of polymer and polymer based materials in day to day uses cannot be ignored. Most materials of commerce though identified as single materials by their generic names are actually not mono-materials. Many additives are usually incorporated to impart desired physico-mechanical/chemical properties on the finished products. These additives (compounding agents) are carefully selected based on the desired performance target [2]. Thus, the polymer of commerce is but a blend of pure polymer chips/resins and additives [3].These additives are materials that are incorporated into the basic polymer resin either as extenders, fillers, plasticizers, impact modifiers, flame-retardants, lubricants, accelerators, heat stabilizers or as aesthetic agents, to achieve special colour or finish [4, 5].

Thus this study is based on how to improve the mechanical properties of low density polyethylene using some organic materials as fillers incorporated into the polymer matrix.

## 2. Materials and Methods

### 2.1. Materials

Low density polyethylene (LDPE) is a polymer of great use to man. The natural fillers of animal origin chicken feather, cow hide and hoof were adapted i.e. washed, cut into pieces and sun dried for two (2) weeks. These were ground to fine powder in the size of 200µm.

## 2.2. Methods

i.) Polymer Composite Production

Pellets of low density polyethylene resins were mixed with each of the fillers at varying percentages. These were extruded as strands and made into small granules. This was done to ensure a homogenous mixing of the fillers and the polymer resins. Later, each composition was fed into the hopper of an injection moulding machine(TL-120-8.50 Model, Made in China),fixed with a rectangular shaped die(with the dimensions of 146mm in length,40mm in width and 5mm in thickness). After melting and compounding, the mixture was injected into the rectangular die and rectangular polymer composite test bars were produced.

ii.) Mechanical Properties Measurement of the polymer composites

The tensile properties of the filled polymer composites of low density polyethylene were measured according to the American Standard Testing and Measurement Method ASTM D638 using the Instron Universal Testing Machine. The compressive and flexural strengths were also measured using the Compressive Strength Testing machine of Model Cat G 43/2 and Flexural Strength testing machine of Model Cat L 18/D and Make Controls, Mikano, Italy, respectively. The readings were automatically recorded and the values computed.

The surface hardness of the polymer composites were determined according to the American Standard Testing and Measurement Method ASTM D2240 by the means of Avery Hardness Testing machine, Type 6406, Number E65226, manufactured by Avery Birmingham, England. The corresponding value of the diameter of the indentation at that surface was recorded and the hardness was calculated with the formula as Birnell Hardness Number measured in $N/mm^2$;

$$BHN = \frac{2P}{nD\ (D\sqrt{D2} - d)}$$

where P = load x 9.81

D = diameter of Indentor (mm) $D^2$

d = diameter of impression (mm) and Λ = 3.142

## 3. Results and Discussion

*Mechanical Properties Tests*

a.) Analysis of Tensile Strength

This is the stress at which the specimen breaks or ruptures, as measured in MPa. Tensile strength is the most common of the mechanical properties of polymers [1].

The polymer composites were characterized using only 1% and 5% filler loading.

***Table 1.*** *Values of tensile strength of PE composites.*

| Polymer Composites | Tensile Strength (MPa) | Extension (mm) | Elongation (%) | Break Load (KN) |
|---|---|---|---|---|
| 0% PE | 9 | 79.89 | 54.72 | 1.45 |
| 1% Feather | 8 | 62.50 | 43.10 | 0.94 |
| 5% Feather | 8 | 16.40 | 11.31 | 1.32 |
| 1% hide | 8 | 30.90 | 89.77 | 1.45 |
| 5% Hide | 9 | 74.88 | 51.65 | 0.90 |
| 1% Hoof | 11 | 78.31 | 54.01 | 1.30 |
| 5% Hoof | 8 | 23.63 | 16.3 | 0.70 |

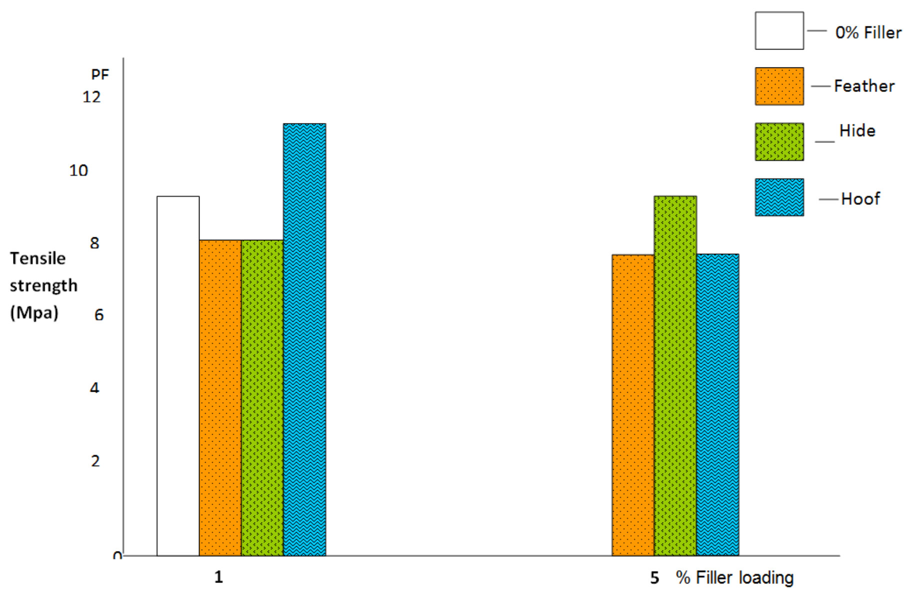


***Fig. 1.*** *Effects of filler loading on the tensile strength of PE composites.*

It is seen, from Table 1 that at 1% filler loading only hoof showed some substantial increase in the tensile strength of the composite. In fact both feather and hide decreased the strength vis-à-vis the unfilled polyethylene. Even at higher loading (5%), the three fillers did not make any visible impact on polyethylene resin. The effects of these fillers could be seen as a result of two opposing effects present when reinforcing filler is added. This may be explained thus, as the filler loading increases, the possibility of formation of voids in the polymer layer next to filler surface also increases, causing tension concentration at the voids vicinity, generating the fractures, thus, a reduction in the tensile strength, resulting from an increase in filler loading. The variations in the values of the tensile strength of the composites observed may be linked with the degree of adherence of the fillers to the polymer matrix as explained by Bueche [6] and Flemmert [7]. These authors believe that the filler particles tie polymer chain bundles together by filling interstitial voids, thereby restricting molecular slippage on application of tensile force. At the same time, the filler particles assist in distributing any induced stress more equitably. This also reduces the chances of “break or craze” to propagate along the molecular chain, leading to mechanical failure. By the same mechanism, elongation should be hindered, especially with increasing filler loading [8].

b.) Analysis of Compressive Strength

This is the ability of a specimen to resist compression under an applied force.

***Table 2.*** *Values of compressive strength of PE composites.*

| Polymer Composites | Test force (KN) | Compressive strength (N/mm$^2$) |
|---|---|---|
| 0% PE | 210.50 | 65.80 |
| 1% Feather | 89.40 | 27.90 |
| 5% Feather | 83.90 | 26.80 |
| 1% hide | 49.30 | 15.40 |
| 5% Hide | 83.30 | 26.00 |
| 1% Hoof | 50.10 | 15.70 |
| 5% Hoof | 95.50 | 29.80 |

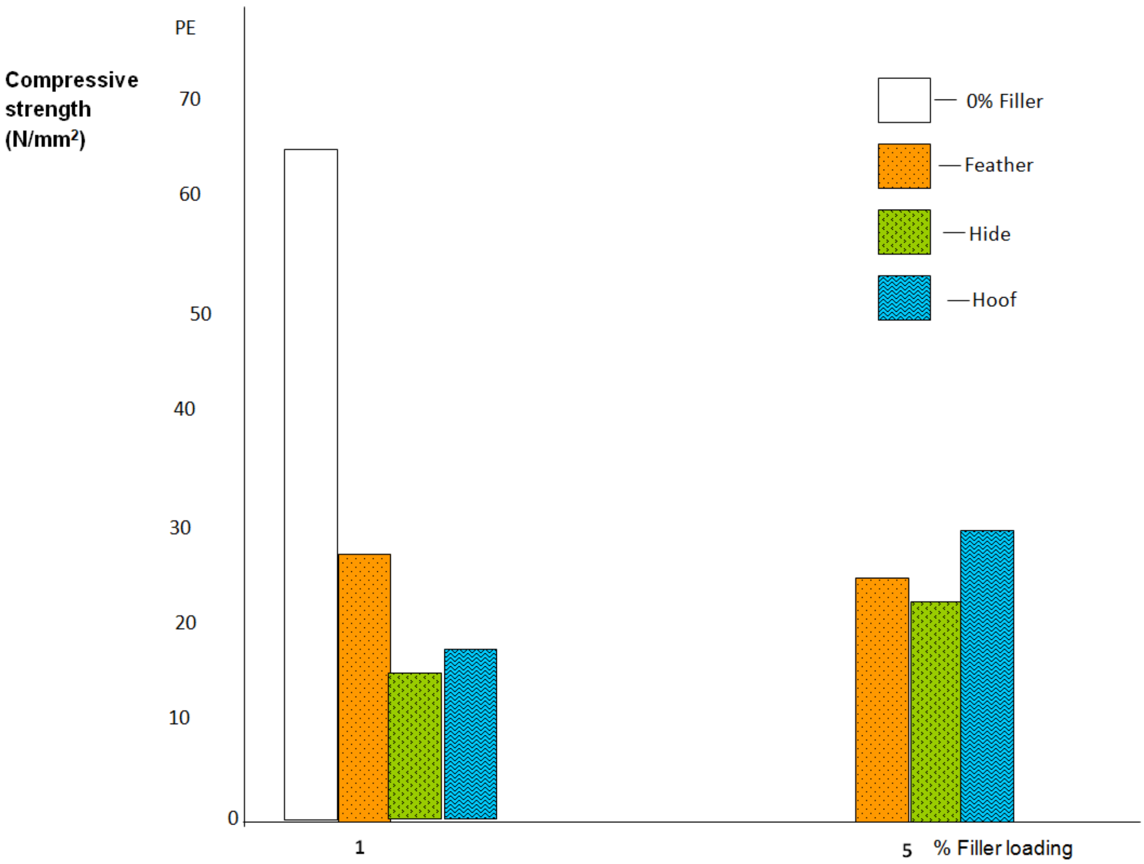


***Fig. 2.*** *Effects of filler loading on compressive strength of PE composites.*

It was observed, from Table 2, that the value of the compressive strengths of unfilled polyethylene test-piece is higher than those of the filled composites. In other words, incorporation of these fillers into the polymer matrices decreased the compressive strength. But among the filled composites, hide and hoof fillers increased the compressive strength as filler loading increased, while feather filler decreased it. This decrease in compressive strength is a positive effect on the polymer composites since compressive strength of a material is its ability to resist compression. Thus, the fillers can be used to improve the ability of utility polymers on the compressive strength especially polyurethane materials.

c.) Analysis of Flexural Strength

This is the ability of a sample to resist bending.

***Table 3.*** *Values of flexural strength of PE composites.*

| PE Polymer Composites | Test force (kN) | Flexural strength (N/mm$^2$) |
|---|---|---|
| 0% | 0.65 | 2.29 |
| 1% Feather | 0.19 | 0.67 |
| 5% Feather | 0.28 | 0.98 |
| 1% hide | 0.78 | 2.74 |
| 5% Hide | 0.53 | 1.86 |
| 1% Hoof | 0.45 | 1.58 |
| 5% Hoof | 0.18 | 0.63 |

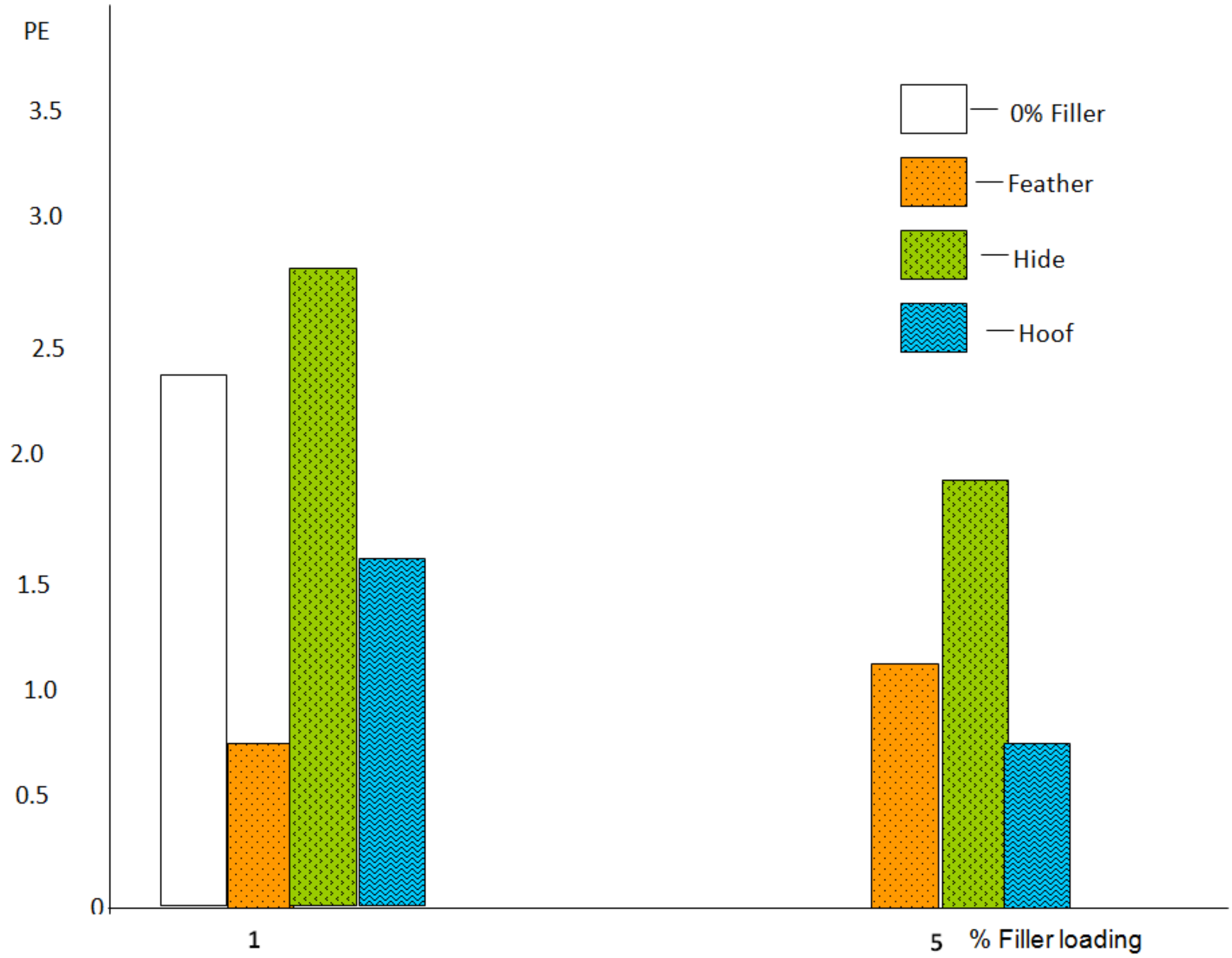


***Fig. 3.*** *Effects of filler loading on flexural strength of PE composites.*

Polyethylene composites filled with hide at 1% filler loading increased the flexural strength when compared with the unfilled polyethylene test-piece, but showed a decrease as the filler loading increased, while hoof and feather fillers gave values below that of the unfilled test-piece, meaning a reduction in the flexural strength. This is in accordance with the observations previously made by some other researchers [9, 10]. Since these fillers can reduce the flexibility of polyethylene, hence making it brittle than being elastic and this could also explain the reason for the decreased values of elongation at break of the polyethylene composites.

d.) Analysis of Surface Hardness Test

This is a measure of the resistance of a fabricated product to surface indentation.

***Table 4.** Readings of surface hardness of PE composites.*

| S/No | Specimen | Diameter of indentor D, (2mm) | Load (5Kg) | Diameter of indentation d, (mm) | BHN (N/mm$^2$) |
|---|---|---|---|---|---|
| 1 | PE 0% Filler | 2mm | 5kg | 0.4mm | 4.1139 |
| 2 | PE1%Feather | 2mm | 5kg | 0.4 | 4.1139 |
| 3 | PE 5% Feather | 2mm | 5kg | 0.4 | 4.1139 |
| 4 | PE 1% Hide | 2mm | 5kg | 0.6 | 4.2332 |
| 5 | PE 5% Hide | 2mm | 5kg | 0.5 | 4.1722 |
| 6 | PE 1% Hoof | 2mm | 5kg | 0.4 | 4.1139 |
| 7 | PE 5% Hoof | 2mm | 5kg | 0.4 | 4.1139 |

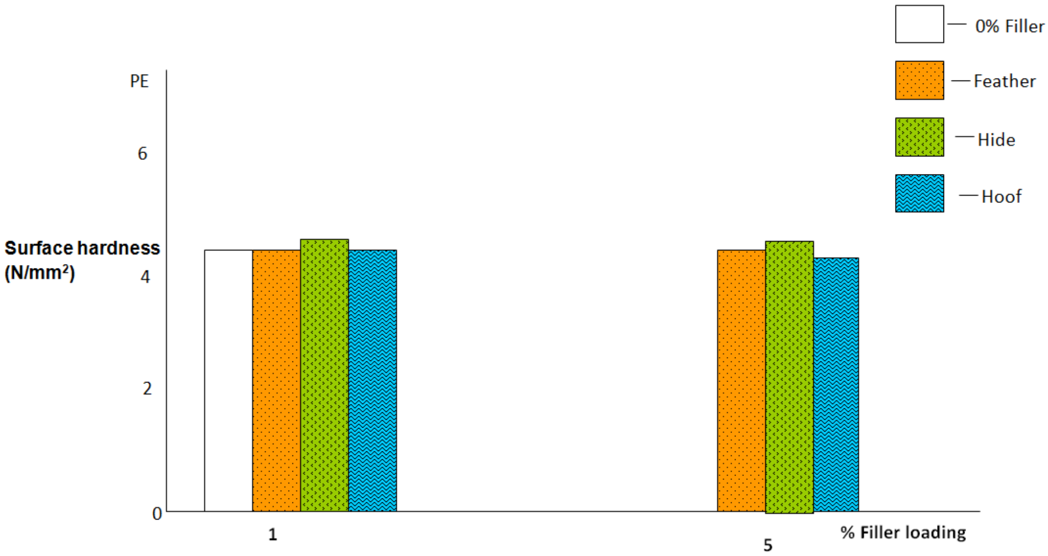


***Fig. 4.** Effects of filler loading on surface hardness of PE composites.*

Similar values of the surface hardness were observed among the three fillers used in the production of the polyethylene composites as shown in Table 4. This could be attributed to the fact that the addition of these fillers to the polymer matrix affected the adhesion strength between the polymer and fillers. This can be explained by means of an analysis of polymer-filler interactions. The presence of electrons in the fillers and polymer may have caused repulsion that affected the surface hardness, since there was no donor or acceptor of electrons, thereby reducing crosslinking density and consequently, there was no additional physical crosslinks within the polymer network, Thus, it could mean that the fillers were evenly distributed on the polymer matrix, thereby showing slight surface resistance [11].

## 4. Conclusion

These fillers namely, feather, hide and hoof have shown their effects on the prepared composites at different filler loadings. Thus, the mechanical properties of the composites produced were found to depend on polymer matrix-filler interaction, particle size and distribution of the fillers particles within the matrix. Hoof filler exhibited better reinforcing performance on the polymer resins, followed by hide and lastly feather. The qualities exhibited by these fillers could be attributed to their nature and high keratin content. These fillers are proteinous materials that can decompose and degrade. So the need to use them as biodegradable fillers incorporated into polymers (plastics which litter the environment and seen at landfills) is strong, to help in keeping the environment clean. Also, they can be used to form bio-plastics due to the mechanical strength property, they displayed; thereby reducing dependence on the polymer resins produced from petrol.

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