EFFECT OF FIBRE LENGTH ON THE PHYSICAL AND MECHANICAL PROPERTIES OF SISAL/POLYETHYLENE COMPOSITES

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Abstract
Composites of sisal fibres with polyethylene polymer chips were prepared at 50% fibre volume with varying lengths of the sisal fibres and the physical and mechanical properties of the composites were determined. The results of the physical properties show that moisture uptake of the composites initially increases from 0 to 60% as the fibre length increases from 0 to 5% and there after remained slightly the same. Density was observed to initially decrease at 5% and then steadily increased slightly. The hardness was found to slightly increase with increase in fibre content. Thickness was seen to increase with increase in fibre length. Breaking load increases from 10mm fibre length. Breaking extension also increased with increase in fibre length. Young's modulus was observed to increase from about 10 mm fibre length, while work of rupture increased with increase in fibre length from about 5mm.

Keywords: composites, sisal fibre, fibre length, physical properties and mechanical properties.

Introduction
The interest in ligno celllosic fibers in the past few years has increased dramatically, and they are now in great demand because of their attractive properties. They have become the focus of attention to scientists worldwide as they exhibit a combination of high strength with low specific gravity. Plant fiber reinforced composites prove that it is possible to construct high-performance materials with environment friendly resources. Ag Research (2007) reported that, composite materials have been associated with: high continuous operating temperatures up to 200^0C, outstanding durability, corrosion resistance, lower maintenance and replacement cost, low investment in fabrication equipment, high strength to weight ratio, light weight, exceptional formality. Composite materials have gained popularity in high performance products such as aerospace components (wings, tails, fuselages, and propeller), boat and scull hulls, bicycle frames and race car bodies. More mundane uses include fishing rods and storage tanks.

Danladi et al (2008) reported that sisal fibre is obtained from the leaves of the plant called "Sisalana", which was originated from Mexico and is cultivated in East Africa, Brazil, Haiti, India, Indonesia and can also be found dispersed in Nigeria. It is grouped into broad heading of the "hard fibres" among which sisal is second to manila in durability and strength. It is one of the most extensively cultivated fibre in the world and it accounts for almost half the total product of textile fibres. The reason is due to ease of cultivation of sisal plants; it is fairly easy to grow in all kind of environments. The diameter of the fibre varies from 100µ to 300µ; sisal fibre is extracted from the leaf either by retting, by scraping or retting followed by scraping or by mechanical means i.e. decorticators.

Hawe and Sabu (1984) have reported on the use of polyethylene for composites applications. Kumar et al (1994) studied the effect of fibre length on the properties of short fibre composites. It has been argued that if the fibres are longer than the critical length then the strength in the composite will depend on whether the matrix or fibres fail first. Since composite properties are affected by fibre length, this work is intended to study the effect of fibre length on the physical and mechanical properties of sisal/ polyethylene composites.

Methodology

Fibre extraction

The leaves from the sisal plant were crushed and the fibres separated from fleshy pulp by scraping with a blunt edge, washed to a clean state in water and finally dried. With the aid of a ruler and a clamp, the fibres were straightened without over stretching and cut to groups of 5, 10, 15, 20, and 25mm lengths.

Composites formation

Compressing molding method was used in the composites preparation. 50% volume of sisal fibre was used with the varying lengths of fibres. The fibre and the polyethylene polymer chips were mixed and constituents put in aluminum foil paper and placed between two metal sheets on a hydraulic press, the bottom and the top hot plates of the machine were brought together at a pressure of 8psi for 3 minutes at 160^{o}C with the sample between the hot plates. The composites formed were then removed from the hydraulic press and the aluminum paper peeled off and allowed to cool before being cut to various shapes and sizes for analysis.

Measurements

Water absorption was determined by weighing 0.5g of the composite from 5 different portions and kept in a glass cylinder containing water for a period of 24 hours. The samples were then removed and weighed after the 24 hours and the difference in weight calculated. The % water absorbed was calculated using the formula below as reported in BS Handbook of Textiles.

$$\%\ \text{water absorption} = \frac{\text{weight of water absorbed}}{\text{Weight of water absorbed + Original weight of sample}} \times 100$$

Composites density was determined by the displacement method in toluene .

The hardness measurements were carried out using a Shore A type Durometer according to ASTM D2240-03.

Composite thickness was determined using the Martindale tester.

Stress–strain measurements were carried out at a crosshead speed of 500 mm/min and gauge length of 50mm on the Hounsfield Tensometer tensile strength tester with Serial No.9873. Ten specimens of 7x1.5cm dimension were cut from each sample. The tensile strength was measured according to ASTM method D412-68.

From the plot of stress – strain curves, the mechanical properties of the composites were determined.

Results and Discussion

Effect of fibre length on moisture absorption

Fig.1 shows that the moisture absorption of the composites increased to about 60% as the fibre length increased from 0 to 5mm. At 0mm, it means no fibre in the composites. Low density polyethylene is known to have about 0% moisture uptake. However as the sisal fibre is introduced, it absorbs water. Sisal fibre has moisture uptake of about 10.5% according to Marjory (1972).

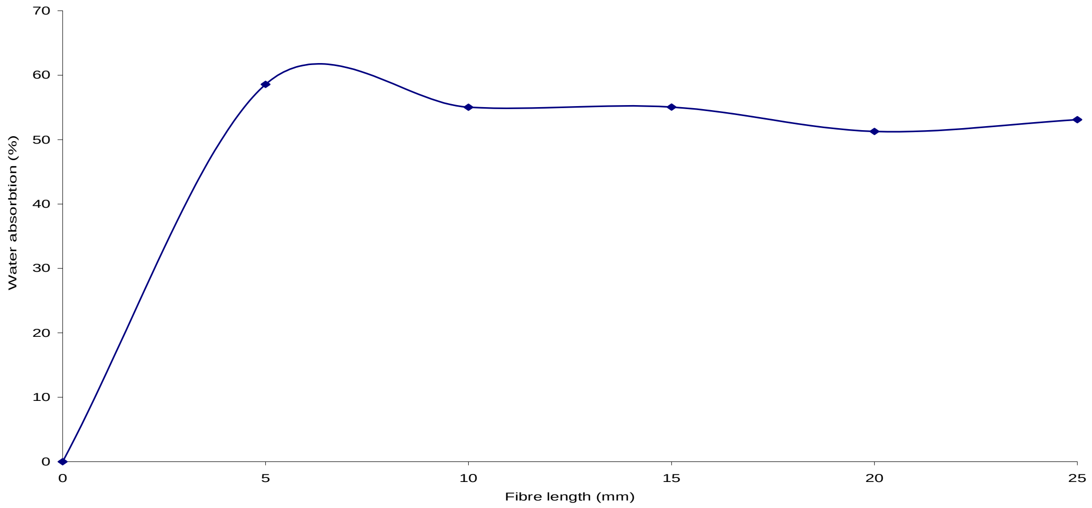

Fig.1: Graph of water absorption against fibre length

As the fibre length increases, the amount of water uptake can be seen to remain about the same. This implies that increasing fibre length above 5mm length has no significant increase on the moisture uptake of the sisal/polyethylene composites.

Effect of fibre length on composite density

The density of the control sample was seen to be about 0.94 g/cm^3. With the incorporation of sisal fibres of about 5mm, the density initially decreased to about 0.7g/cm^3. This can be attributed to the creation of voids which formed air pockets, thus giving larger volume, which eventually lowers the density. As the fibre length increased, the densities of the composites were seen to increase slightly. This may be due to reduction in the voids as a result of greater fibre length in the composite structure.

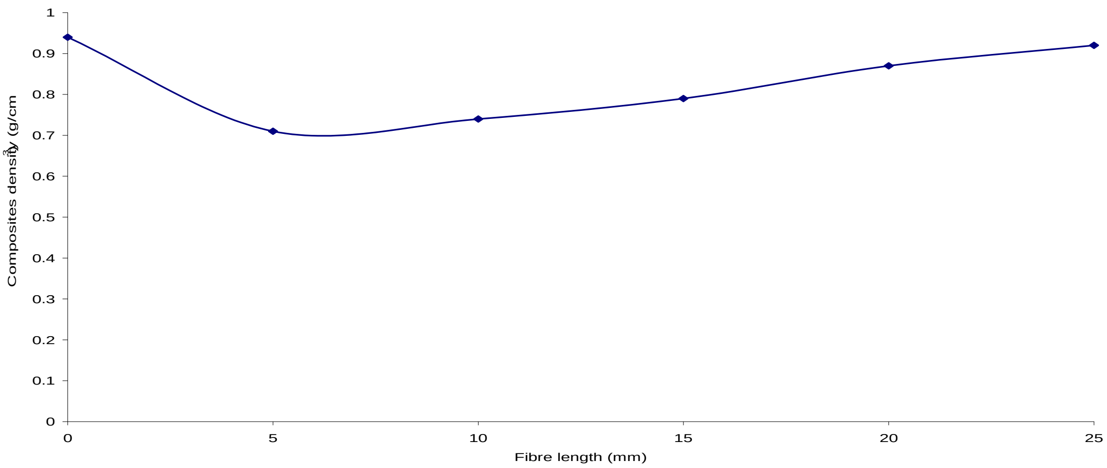

Fig. 2: Graph of composites density against Fibre length

Effect of fibre length on composite hardness

Since the fibre volume was kept constant at 50%, the amount of fibre and polyethylene is the same. However, on increasing the fibre length, the hardness of the composites decreased slightly. The hardness values observed is in the range of 68 to 76 (shore). This implies that composites of sisal with low density polyethylene can be considered to have normal hardness because according to the international hardness scale, materials with hardness values of 10 –35 are considered to have low hardness while those with hardness of 35 – 85 are classified as normal and those with hardness of 85 – 100 are classified as hard as reported by Sighn *et al* (1996).

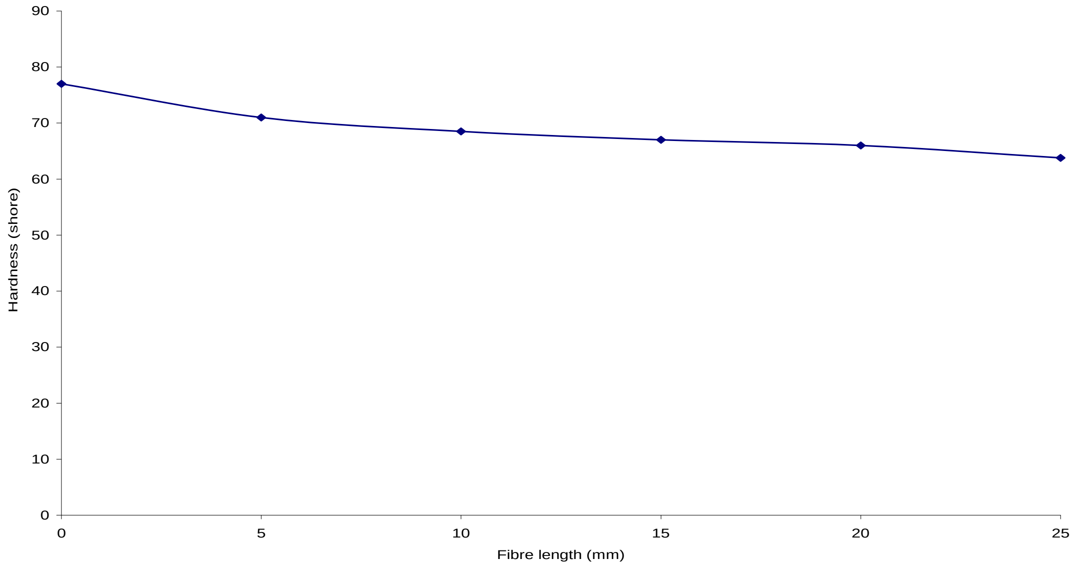

Fig. 3 Graph of hardness against fibre length

Effect of fibre length on composite hardness

The composite thickness can be seen to increase with increase in fibre length even though the fibre content remains same at 50%. As the fibre length increases, there is a higher possibility of the fibres coiling and congregating together, thus giving greater thickness to the composites. The generally low values of the thickness observed, suggest that these composites may probably be used as table tops.

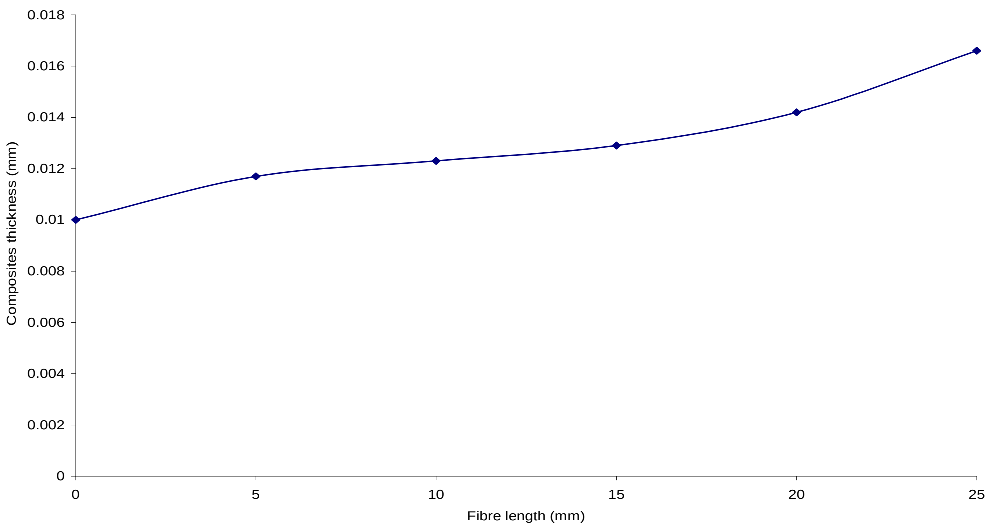

Fig. 4: Graph of composites thickness against fibre length

Effect of fibre length on breaking load

The breaking load of the composites was seen not to be affected by increase in fibre length from 0 to about 10mm. However as the fibre length increase from about 10 to about 25mm, the breaking load of the composites was seen to steadily increase. Since breaking load indicates the maximum load a composite can bear before it is ruptured, it means that the breaking load of sisal/polyethylene composites is affected by increase in fibre length. As the fibre length and load are increased, there is more fibre length to bear the increase in load before the composite eventually fails.

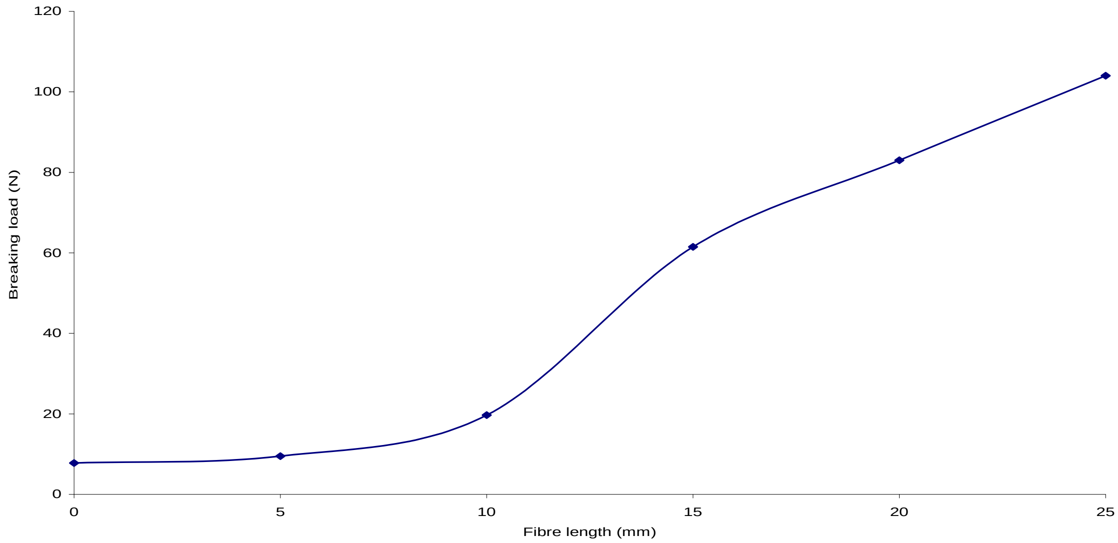

Fig. 5: Graph of breaking load against fibre length

Effect of fibre length on breaking extension

Breaking extension is the extension of the specimen at the breaking point. From the illustrated results in Fig. 6, it can be seen that as the fibre length increased from 0 to about 20mm, the breaking extension increase. Although, the values obtained can be seen to be low. This means that the composites extend to low values as they are loaded before failing. This observation may be attributed to the low extension values of the sisal fibres as typical of natural cellulosic fibres as reported by Booth (1982), since low density polyethylene as reported by Moncrieff (1975) is known to have high elongation of about 45-50%. The sisal fibres therefore provide a sort of stiffening effect on their composites with low density polyethylene.

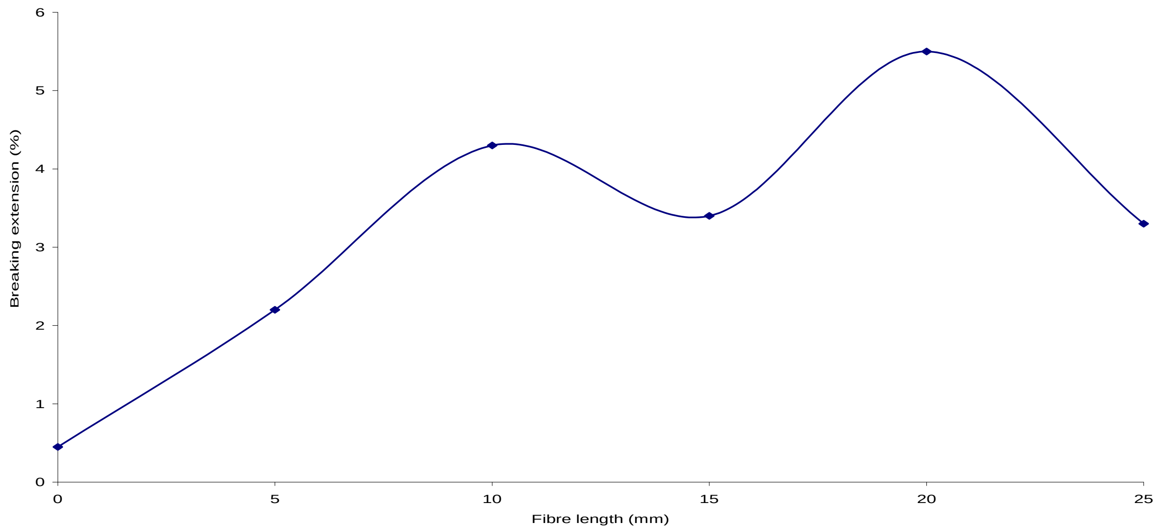

Fig. 6: Graph of breaking extension against fibre length

As the fibre length is increased, the low extensible fibres may have higher tendency to coil and loop in the composite structure, so when the composite is loaded, the fibres tend to stretch out thus providing for the increase in the extensibility of the composites.

Effect of fibre length on Young's modulus

Initial modulus of a material tells how well the material resists deformation. High modulus indicates inextensibility while a low modulus represents great extensibility. Results in Fig.7 show that the initial Young's modulus of the composites of sisal fibre/polyethylene composites is not much affected by the fibre length as it increases from 0 to about 10mm. However from above 10mm fibre length, the modulus values were seen to increase. It means that these composites will have high inextensibilities, while those with less than 10mm length will have high extensibility values.

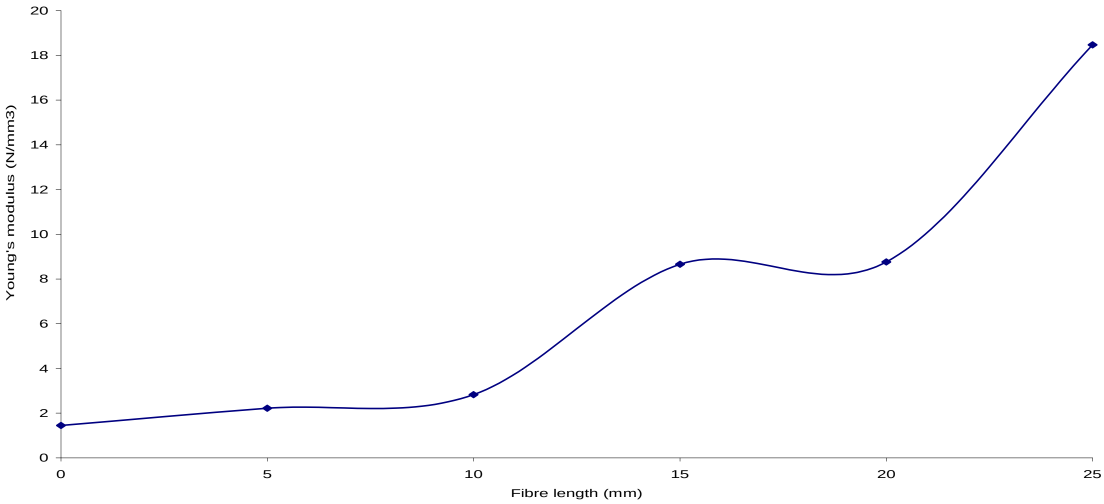

Fig. 7: Graph of Young's modulus against fibre length

Since low density polyethylene has high extensibility, it means that incorporating fibres of less than 10mm length have little effect on changing the extensibility of the polyethylene matrix. Higher fibre length of sisal fibres allow for the composites to bear more load before extending, thus making them stiffer which was manifested in higher initial modulus.

Effect of fibre length on work of rupture

Work of rupture is a measure of toughness of a material. It is a measure of the energy a material can absorb before it breaks. The area under the load-elongation or stress-strain curves represents the work done in stretching the specimen to breaking point. The higher the work of rupture of a material, the tougher is the material. Work of rupture value will indicate the resistance of the material to sudden shocks.

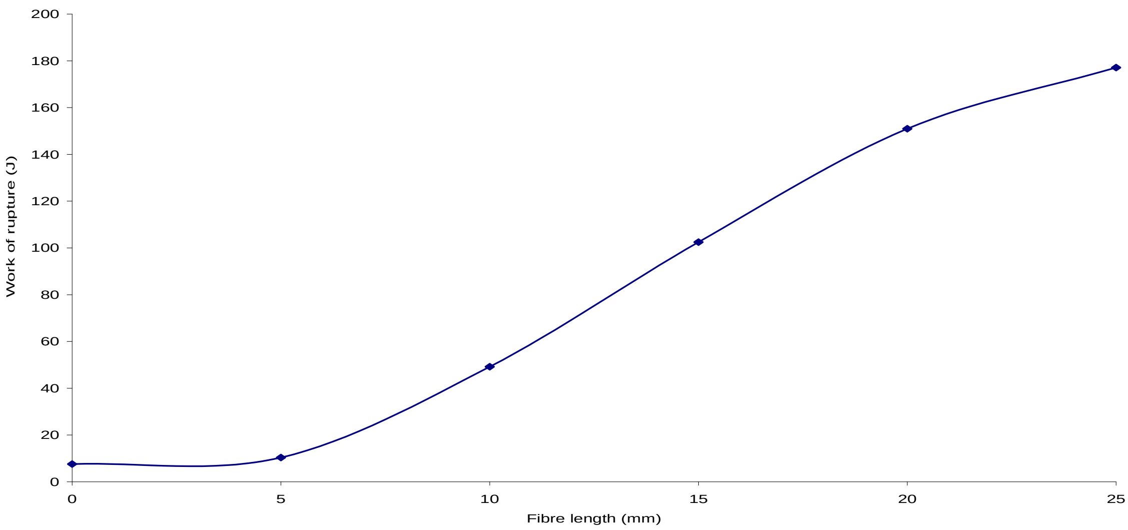

Fig.8: Graph of work of rupture against fibre length

Fig.8 shows that as the fibre length increase from 0 to 5 mm, the work of rupture of the composites is not affected. As the fibre length increased from 5 to about 25mm, the value of the work of rupture increases. Since the load bearing capacity of composites is determined by critical fibre length of the fibre as reported by Jules *et al* (2008). In this work it can be seen that 5mm is about the critical length of the sisal fibres in these composites. Above the critical length of 5mm, the composites bear more loads and therefore high work is needed to rupture the composites.

Conclusion

From the results of this work, it can be seen that composites of sisal fibres can be successfully processed up to a fibre load of about 25%. The composites have good and promising properties that can merit them for consideration in many domestic operations like table tops, ceiling and partition materials. The properties studied compare well with those of similar fibre composites.

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