Effect of Chemical Treatment on the Mechanical Properties of Sisal Fibre Reinforced Polyester Composites

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Abstract

The effect of extraction by soil retting and chemical treatment on the mechanical properties of sisal fibre reinforced polyester composites was investigated. The sisal fibre was extracted by soil retting method followed by chemical treatments. Treatments were carried out on the fibre at an elevated temperature of 70°C for 2 hours with 2 molar solutions each of NaOH, KOH, H_2O_2 and Ethanol. Both treated and untreated fibres were used to develop the sisal fibre reinforced polyester composites in predetermined proportions after which they were tested for mechanical properties. From the results, it was observed that, KOH treated fibre reinforced polyester composite followed by Ethanol treated fibre samples gave the best results. KOH treatment was observed to enhance the tensile and hardness properties of the polyester composites than other treatments.

Keywords

Soil Retting; Chemical Treatment; Mechanical Properties; Sisal Fibre; Polyester; Composites.

Introduction

Wood as a building material is as old as mankind and the availability of this natural resource is diminishing. This situation has led to the development of alternative materials of the various synthetic materials that have been explored and advocated. Polymer composites claim a major participation as building materials. Hardware items like door and window frames, flushing cisterns, overhead water storage tanks and water fittings are commercially available.

There has been a growing interest in utilizing natural fibres as reinforcement in polymer composite for making low cost construction materials in recent years [1]. Natural fibres are prospective reinforcing materials and their use until now has been more traditional than technical. Due to the relatively high cost of synthetic fibres such as, glass, plastic, carbon and Kevlar that are being used in fibre reinforced composites, and the health hazards of asbestos fibres, it has become necessary to explore natural fibres. Natural fibres are produced from renewable resources, are biodegradable and relatively inexpensive compared to the traditionally used synthetic fibres. Fibres of this type, for instance, hemp and flax, are successfully used as packaging material, interior panels in vehicles and building components among others. Also, natural fibres like banana, sisal, hemp and flax, jute, coconut, bamboo, sponges, wood dusts and oil palm [2-8] have attracted scientists and technologists for applications in consumer goods, low-cost housing and other civil structures. A number of investigations have also been conducted on several types of natural fibres to study the effect of these fibres on the mechanical properties of composite materials [9]. Recently, natural fibres have proved to be effective reinforcement as simple fillers in thermoplastic and thermo set matrix composites for automotive sectors. Jute fabric reinforced polyester composites were also tested for the evaluation of mechanical properties and compared with wood composite and it was found that the jute fibre composite has better strengths than wood composites [10]. A pulp fibre reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer [11]. The dynamic mechanical testing have been investigated in banana fibre reinforced polyester composites and found that the optimum content of banana fibre is 40% [12]. It was reported that Kraft pulped banana fibre composite has good flexural strength. In addition, short banana fibre reinforced polyester composite was

studied, the study concentrated on the effect of fibre length and fibre content. The maximum tensile strength was observed at 30mm fibre length while maximum impact strength was observed at 40mm fibre length. Incorporation of 40% untreated fibres provides a 20% increase in the tensile strength and a 34% increase in impact strength.

Sisal (*Agave Sisalana*) is a plant that yields stiff fibres traditionally used for rope and twine. It is usually extracted by a process known as decortications. One difficulty that has prevented the use of natural fibres is lack of good adhesion with the polymeric matrix. In particular, the large moisture absorption by natural fibres in hydrophobic matrix adversely affects adhesion and leads to premature ageing by degradation and loss of strength [13]. There are, however, several separation of fibre processing techniques such as mechanical or chemical pulping, whereby lignin is degraded and dissolved, leaving most of the cellulose and hemicelluloses in the form of fibres. This generally has an important effect on both mechanical and chemical properties of the fibres.

This research was carried out to investigate the effect extraction of the sisal fibre by soil retting and chemical treatments at elevated temperature on the constituents of the sisal fibre and hence, the mechanical properties of long and transverse fibre reinforced polyester matrix composites. This is to be able to developed strong, durable and affordable building materials at low cost for replacement in most areas where wood are being used.

Material and Method

The materials and equipment used for this work are; Unsaturated Polyester resin, Methyl Ethyl Ketone Peroxide (catalyst), Cobalt 2% in solution as accelerator, sisal fibre, KOH, H_2O_2, NaOH, Poly Vinyl Acetate, and Ethanol.

The sisal fibre used was obtained from the plant leaves shown in Figure 1 which was gotten from Owo in Ondo State, Nigeria. The fibre strands were obtained by cutting the leaves and buried under ground for 2 weeks so as to allow fermentation to take place. The fermented leaves were washed after which they were sun dried for 5 days.

Figure 1. *Sisal Plant*

The treatments were carried out on equal mass of 30g of the sisal fibre. Each treatment with NaOH, KOH, H_2O_2 and Ethanol respectively was carried out by using 2 molar solutions inside shaker water bath at 70°C for 2 hours. The selected chemicals were some of the commonly used ones from literature but the concentration, temperature and time were chosen based on the observations from these literature survey which showed that these conditions have not being investigated [9-10,13]. The fibres after treatments were allowed to dry naturally in the laboratory (Figure 2).

Figure 2. *Chemical Treatment in Shaker Water Bath*

Both treated and untreated fibres were further prepared by combing the fibres so as to remove scales from the strands before being cut into the needed length. Owing to fact that lots of work has being reported on short fibre reinforcement, long and transverse reinforcement was the focus in this work. The fibre strands were cut into the length of the tensile test specimen mould which was 194mm before they are used.

To produce the composites, 1g each of the catalyst and the accelerator were added to 300g of the unsaturated polyester resin and mixed properly to form gel. This was followed by fibre addition and stirring to allow for proper wetting of fibre within the gel-like mixture. The mixture after adequate stirring was poured into the mould and the fibre was arranged parallel to one another in order to avoid entanglement of the fibres. The cast is allowed to cure before being stripped from the mould and further allowed to cure for 28 days. Several samples of varying fibre content of predetermined proportions of; 3, 4, 5, 6, 7 g were prepared by the same method as shown in Table 1.

Table 1. Formulation Table

Fibre Length (mm)	Weight of Polyester Resin (g)	Weight of Fibre (g)	Weight of Catalyst (g)	Weight of Accelerator (g)
194	300	3	1.00	1.00
194	300	4	1.00	1.00
194	300	5	1.00	1.00
194	300	6	1.00	1.00
194	300	7	1.00	1.00

Mechanical Test

Tensile Testing

In the present study, tensile tests were performed on INSTRON 1195 at a fixed Cross head speed of 10mm/min. Samples were prepared according to ASTM D412 (ASTM D412 1983) and tensile strength of standard and conditioned samples were determined.

Micro Hardness Testing

The sample was indented using Durometer following ASTM procedure No.D2240 and the reading is noted from the calibrated scale.

Results and Discussion

The Results of the Mechanical Property Tests

The result of the ultimate tensile stress for the samples was shown in Figure 3. From the result, it was observed that, KOH treated sample of 6g fibre weight has the highest ultimate tensile stress value of 29MPa followed by the untreated sample of 7g fibre weight with a value of 24MPa and NaOH treated sample of 7g fibre weight with a value of 23MPa.

The result shows that KOH treated sample has the best tensile strength property compared to other samples.

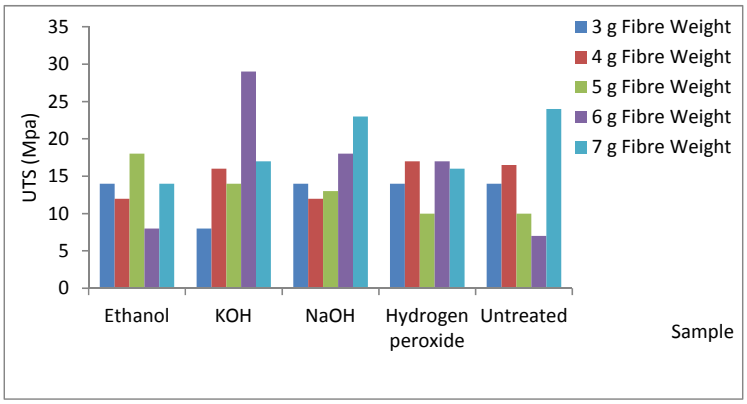

Figure 3. *Variation of Ultimate Tensile Stress with Fibre Weight for different Samples*

Modulus of elasticity is the ratio of tensile stress to tensile strain. From Figure 4, it was observed that ethanol treated samples of 4g and 3g fibre weights has the highest modulus of elasticity values of 689.77MPa and 668.92MPa respectively followed by NaOH treated sample with 3g fibre weight with a value of 634.09MPa. This shows that all these samples have better stiffness property compared to others in the above given order.

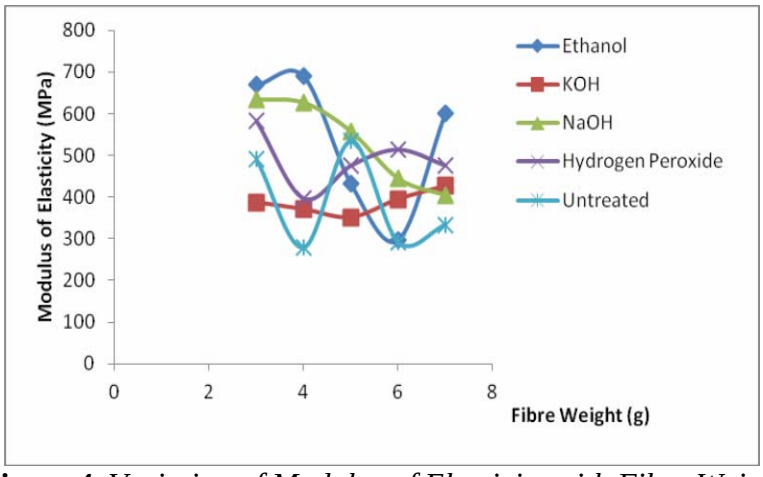

Figure 4. *Variation of Modulus of Elasticity with Fibre Weight*

Yield stress is the stress that causes a permanent deformation in a material at the microstructure level. It is the stress that ends the elasticity nature and the beginning of plasticity of a material. From Figure 5, KOH treated fibre reinforced polyester composite of 6g fibre weight exhibit the highest tensile stress at yield with a value of 33.53MPa. This was followed by the untreated sample at 7g fibre weight with a value of 23.62MPa and sample

treated with ethanol at 5g fibre weight with a value of 19.09MPa. Therefore, KOH treated sample of 6g fibre weight have the highest resistance to plastic deformation.

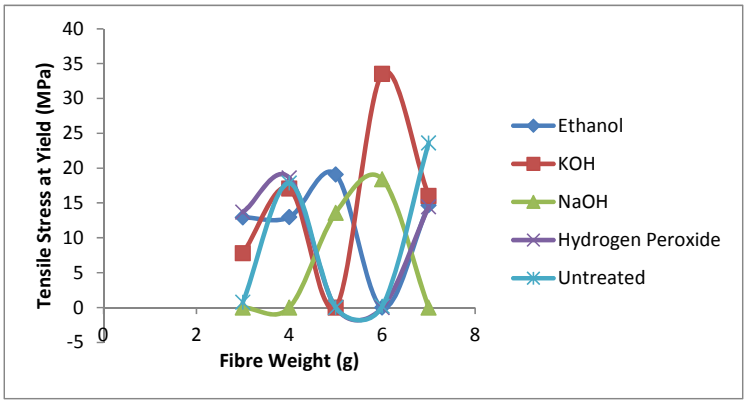

Figure 5. *Variation of Tensile Stress at Yield with Fibre Weight*

Figure 6 shows the tensile stress at break for the samples. It was observed from the figure that, KOH treated fibre reinforced polyester composite sample of 6g fibre weight has the highest tensile stress at break with a value of 33.53MPa followed by NaOH treated sample of 7g fibre weight with a value of 24.27MPa and 7g fibre weight of the untreated sample with a value of 23 62MPa.

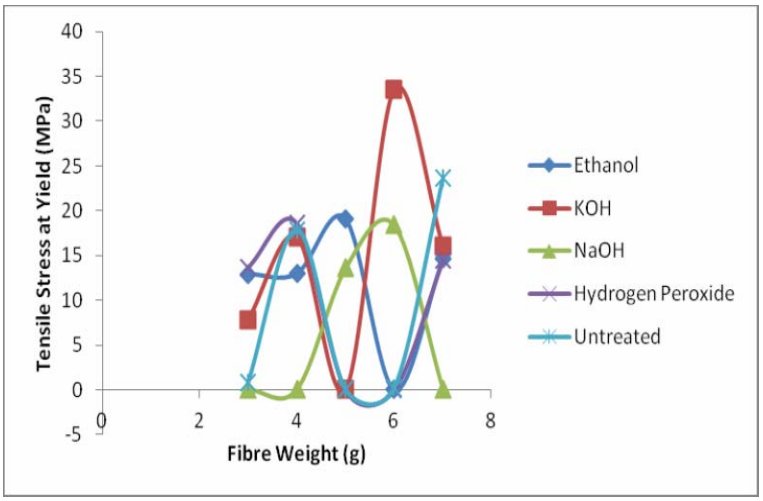

Figure 6. *Variation of Tensile Stress at Break with Fibre Weight*

Tensile strain at yield for KOH treated sample of 6g fibre weight undergoes largest amount of straining at yield when compared to the other samples as shown in Figure 7. The value obtained was 0.14mm/mm followed by the untreated samples at 7g and 4g fibre weights with values 0.11mm/mm and 0.09mm/mm respectively.

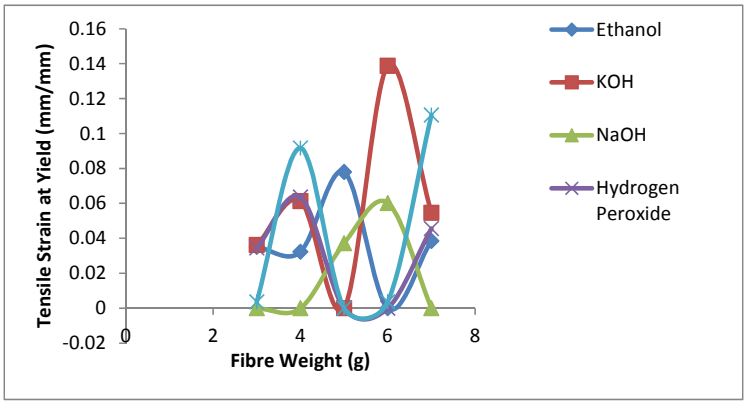

Figure 7. *Variation of Tensile Strain at Yield with Fibre Weight*

Figure 8 shows that KOH treated fibre reinforced polyester composite with 6g fibre weight exhibit the highest extension before break with a value of 7.57mm followed by the untreated samples at 7g and 3g fibre weights with values 5.55mm and 5.43mm respectively.

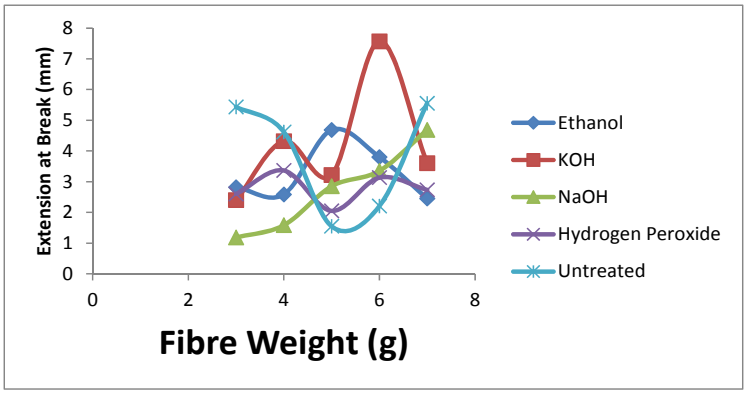

Figure 8. *Variation of Extension at Break with Fibre Weight Fraction*

Figure 9 reveals the variation of energy at break with fibre weight. From the result, KOH treated sample of 6g fibre weight absorbed the greatest amount of energy with a value of 8.40J followed by NaOH treated sample of 7g fibre weight with a value of 3.86J and untreated sample of 7g fibre weight with a value of 3.39J.

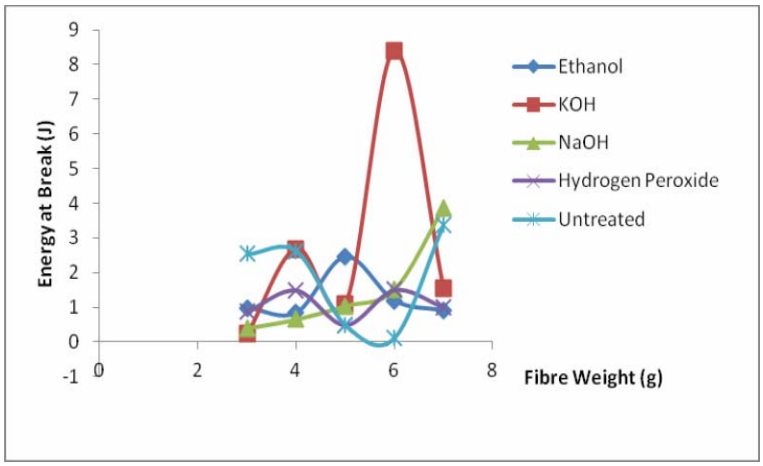

Figure 9. *Variation of Energy at Break with Fibre Weight Fraction*

Figure 10 reveals the variation of time at break with fibre weight. KOH treated sample of 6g fibre weight takes longer time before breakage with a time value of 45.4 seconds. This was followed by the untreated samples at 7g and 3g fibre weights with values of 33.3 seconds and 32.6 seconds respectively.

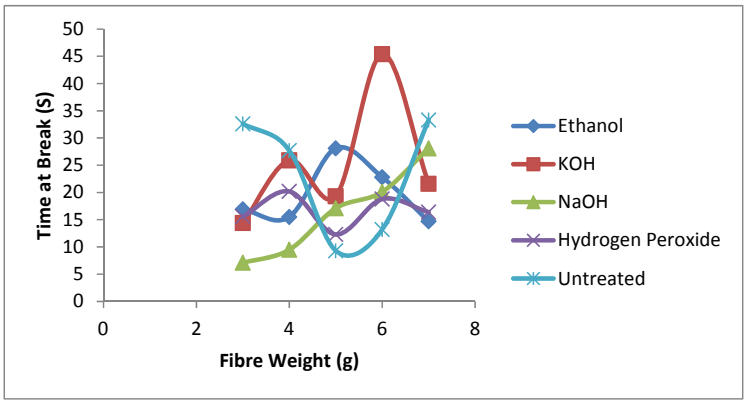

Figure 10. *Variation of Time at Break with Fibre Weight*

The Hardness Value Result

Hardness of a material is the measure of the resistance to indentation. From Figure 11, it was observed that KOH treated sample of 4% fibre weight has the highest hardness value of 258.59 BHN followed by NaOH treated sample of 7% fibre weight with BHN of 258.39. Ethanol and the untreated samples at 5% and 7% fibre weights have the same value of 201.28 HBN.

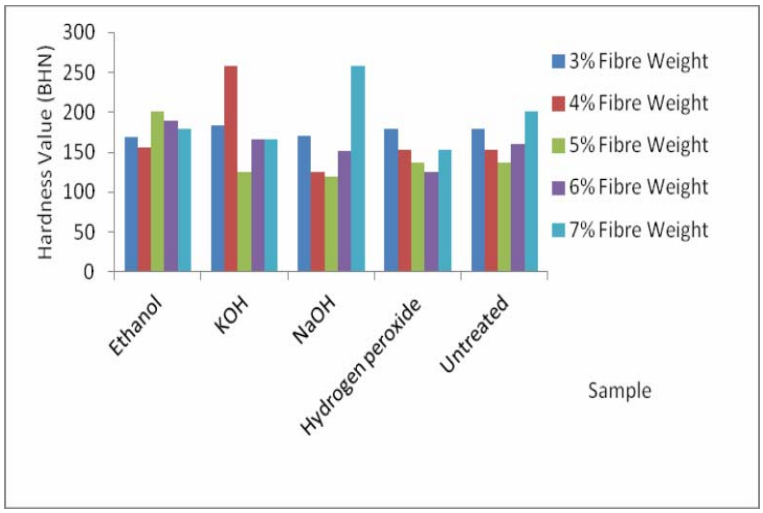

Figure 11. *Variation of Hardness Values with the Samples*

Conclusions

The results of the investigation of the effect of chemical treatment on the mechanical properties of the sisal fibre reinforced polyester composites revealed that the chemical treatment actually enhanced the mechanical properties. The observed enhancement was due to the strong bond that exists between the treated fibre and the polyester matrix. The treatment removed the lignin and hemicelluloses which acts as obstructions being a matrix in the natural fibre. The analysis of the results, showed that:

- KOH treatment has the best tensile and hardness properties. The treatment gave the best results in all the tensile properties examined at 6g fibre weight except in the modulus of elasticity where Ethanol treated sample of 4g fibre weight has the highest modulus of elasticity with a value of 685MPa.
- The treatment as well as the fibre weight of 6g gave the optimum result while the best hardness result was obtained at 4g fibre weight. Therefore, combination of 70°C and 2M KOH treatment was observed to be good for the enhancement of the mechanical properties of polyester matrix composite when reinforced with 4g and 6g fibre weights.
- Soil retting of sisal fibre meant for use as reinforcement in polyester matrix composites can be extracted by using soil as a medium for fermentation process. This technique can also be adopted for the extraction of sisal fibre meant for use as reinforcement in other polymer matrix composites.

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