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Investigating the influence of alkalization on the mechanical and water absorption properties of coconut and sponge fibers reinforced polypropylene composites

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Abstract

Natural fibers are products made from renewable agricultural and forestry feedstock, which can include wood, grasses, and crops, as well as wastes and residues. There are two primary ways these fibers are used: to create polymers or as reinforcement and filler. Thermoplastic polymer may be reinforced or filled using natural fibers such as coir, sponge, hemp, flax, or sisal. This paper focused on the influence of alkalization (NaOH treatment) on the mechanical and water absorption properties of selected natural fibers (coconut and sponge fibers) reinforced polypropylene composites. In this study, coconut and sponge fiber were extracted from its husk by soaking them in water and was dried before it was cut into 10mm length. Those fibers were chemically treated with sodium hydroxide (NaOH) in a shaking water bath before it was used as reinforcement in polypropylene composite. The reinforced polypropylene composite was produced by dispersing the coconut fibers randomly in the polypropylene before it was fabricated in a compression molding machine where the composite was produced. The fiber content used were; 2%wt, 4%wt, 6%wt, 8%wt and 10%wt. Tensile and flexural properties was observed from universal testing machine while water absorption test was carried out on the samples for seven (7) days. It was observed that the influence of NaOH treatment highly enhanced the Flexural and water absorption properties of sponge fiber reinforced polypropylene composites than coconut fiber reinforced composite samples.

Keywords

Coconut fiber; Sponge fiber; Alkalization; Polypropylene; Mechanical properties

Introduction

Composite material is a material composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents. Matrix phase is the primary phase having a continuous character. Matrix is usually more ductile and less hard phase [1]. It holds the dispersed phase and shares a load with it. Dispersed (reinforcing) phase e.g. fiber is embedded in the matrix in a discontinuous form. This secondary phase is called the dispersed phase. Dispersed phase is usually stronger than the matrix, therefore, it is sometimes called reinforcing phase [2-3].

The interest in natural fibre reinforced polymer composites is growing rapidly due to the high mechanical performance, significant processing advantages, low cost and abundance of natural fibre. Natural fibers are relatively cheap, pose no health hazards and finally, provide a solution to environmental pollution by finding new uses for waste materials [4-7]. As a result of the growing environmental awareness (e.g., increased pollution, increasing demand for biodegradable materials), manufacturers, researchers and scientists are eager to study environmental friendly material [8-10].

However, the main disadvantages of natural fibres in composites are the poor compatibility between fiber and matrix and the relative high moisture sorption [11]. Therefore, alkalization is a means of fiber chemical treatment which intend to modify fiber surface by improving the adhesion between the fiber surface and polymer matrix, in addition, increases fiber strength. The fiber treatment also eliminates the lignin and hemicelluloses hence improving the mechanical properties and reducing water absorption properties [12]. Chemical treatments considered to modify the fibre surfaces properties includes alkali, silane, acrylation, maleated coupling agents, acetylation, benzoylation, etc.

The aim of this research was to investigate comparatively the influence of NaOH treatment on sponge (luffa cylindrica) and coconut (cocos nucifera) fibres reinforced polypropylene composites with respect to their mechanical and water absorption properties. The choice of these fibres is informed by their ready availability, low density and relatively low cost.

Materials and methods

The coconut fiber and sponge fiber used are locally sourced in Akure, Ondo State, Nigeria. Other materials used are Polypropylene (Homopolymer) supplied by Eurochemical, Lagos, Nigeria while sodium hydroxide (NaOH) was supplied by Pascal Scientific, Akure, Nigeria. The coconut and sponge fiber was carefully cut into 10 mm with scissors before carrying out the treatment with the selected chemicals. The equipment’s used for this research work are: weighing balance, beaker, cylindrical flask, compression moulding machine, flexural and tensile mould, shaking water bath, and universal testing machine.

Chemical treatment

The coconut and fibers was chemically treated with sodium hydroxide (NaOH) at 1M concentration level. The process consists of immersing the fibers in sodium hydroxide (NaOH) in shaking water bath maintained at 50°C for 4 hours. The purpose of chemical treatment is to reduce the lignin and hemi-celluloses contents that are present in the fibers for effective binding of the matrix/fibre interface. And also to remove the moisture content of fibers, increase the tensile strength and roughened the surface of the fiber so as to enhance proper bonding with the matrix. After that, the fibers was washed abundantly with tap water and then distilled water to remove the NaOH from the fibers. Then, the fibers were sun dried for 4 days.

Production of composites

The composites were produced using compression molding machine. Random fiber orientation was used with the varied fibers content which are: 2 wt %, 4 wt %, 6 wt %, 8 wt %, and 10 wt %. The samples are varied as shown in Table1 and Table2. The treated fibres was mixed with polypropylene and then produced via the compression molding machine. The mixture was heated up to melting temperature of about 160°C which then caused it to flow in the mould. After, it was then allowed to cool before breaking off.

Table 1. For coconut fibres treated with (NaOH) and polypropylene composition

	CS	CN2	CN4	CN6	CN8	CN0
Sponge fibre %	0	2	4	6	8	10
Polypropylene %	100	98	96	94	92	90

Table 2. For sponge fibres treated with (NaOH) and polypropylene composition

	CS	SN2	SN4	SN6	SN8	SN0
Sponge fibre %	0	2	4	6	8	10
Polypropylene %	100	98	96	94	92	90

where: CS = control sample, N = NaOH, C = coconut fiber, S= sponge fiber, SN = NaOH sponge fiber, CN = NaOH coconut fiber, SN0 = 10% SN, CN0 = 10% CN

After the composite samples were produced via compression molding machine, the composite was chamfered, cleaned and various mechanical testing (tensile and flexural) was carried out on each samples.

Water absorption test

The water absorption property of the composite samples was determined by weighing those samples in air and water. This test was done for 24 hours for the various samples of the composite span for 7 days. This test will help determine the extent at which the composites can absorb water. The percentage water absorption [W%] for test samples was calculated using the formula (1).

$$W\% = \frac{\text{weight of composite in water - weight of composite in air}}{\text{weight of composite in air}} \cdot 100\% \quad (1)$$

Results and discussion

In this research work, the test samples was prepared as per ASTM standards and were tested to evaluate water absorption property and mechanical properties such as tensile strength and flexural strength.

Flexural test

In Figure 1, it was observed that sample denoted as SN6 (6% NaOH sponge fibers + 94% polypropylene) has the highest value which is about 53.352 N/mm^2 followed by SN2 (2% NaOH sponge fibers + 98 % polypropylene) which has the second highest value of about 50.562N/mm^2 while SK0 (10 %KOH sponge fibers + 90 % polypropylene) has the third highest value which is about 50.076N/mm^2. From the analysis, SN6 gave the best flexural strength result. However, NaOH treatment favours sponge fiber reinforced polypropylene composites as it gave the best flexural strength results.

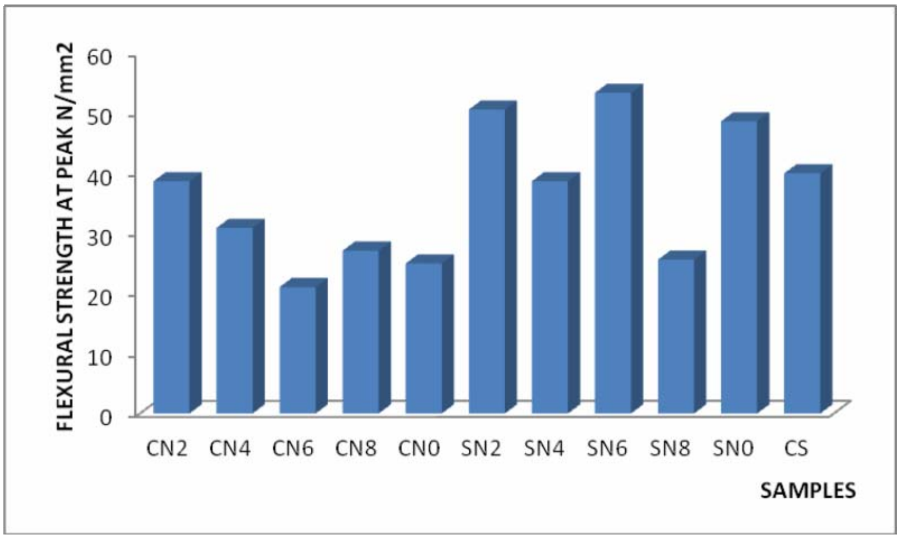

Figure 1. *Microsoft excel chart of flexural strength at peak against samples*

In Figure 2, it was observed that sample denoted as SN6 (6% NaOH sponge fiber + 94%polypropylene) has the highest value of flexural modulus which is about 2786.9 N/mm^2 while sample denoted as SN2 (2%NaOH sponge fiber + 98%polypropylene) has the second highest value of about 2494.2 N/mm^2 followed by SK0 (10% NaOH sponge fiber + 90%polypropylene) which has the third highest value of about 2492.4 N/mm^2. From the analysis, SN6 has the best flexural modulus result. However, NaOH treated sponge fiber reinforced polypropylene composites gave the best flexural modulus results compared with NaOH treated coconut fiber reinforced polypropylene composites and control samples.

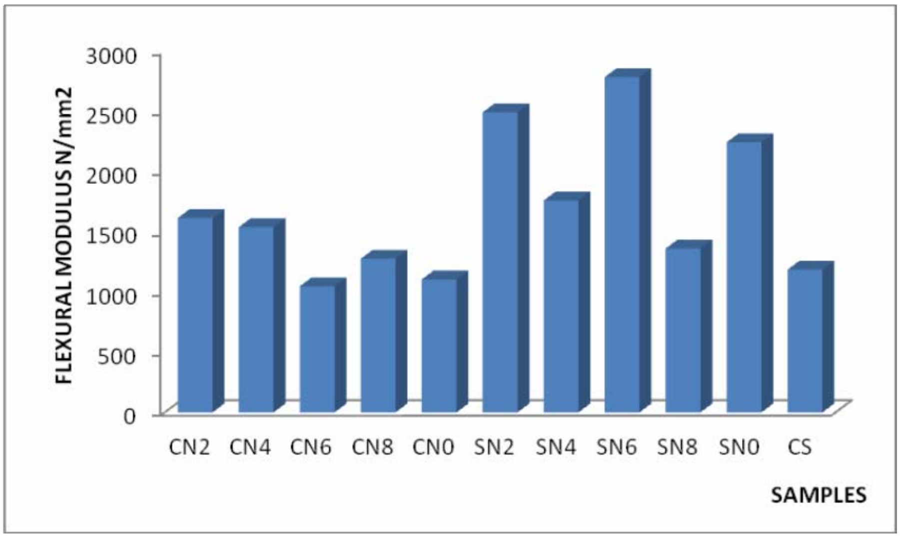

Figure 2. *Microsoft excel chart of flexural modulus against samples*

Tensile test

In Figure 3, it was observed that among the NaOH treated samples, sample denoted as SN4 (4%NaOH sponge fiber + 96%polypropylene) has the highest value of about 23.094 N/mm^2 while SN2 (2% NaOH + 98 % polypropylene) has the second highest value which is about 21.099N/mm^2, followed by CN6 which has the third highest value of about 17.928. From the analysis, it was observed that NaOH treated sponge fiber reinforced polypropylene composite gave the best results.

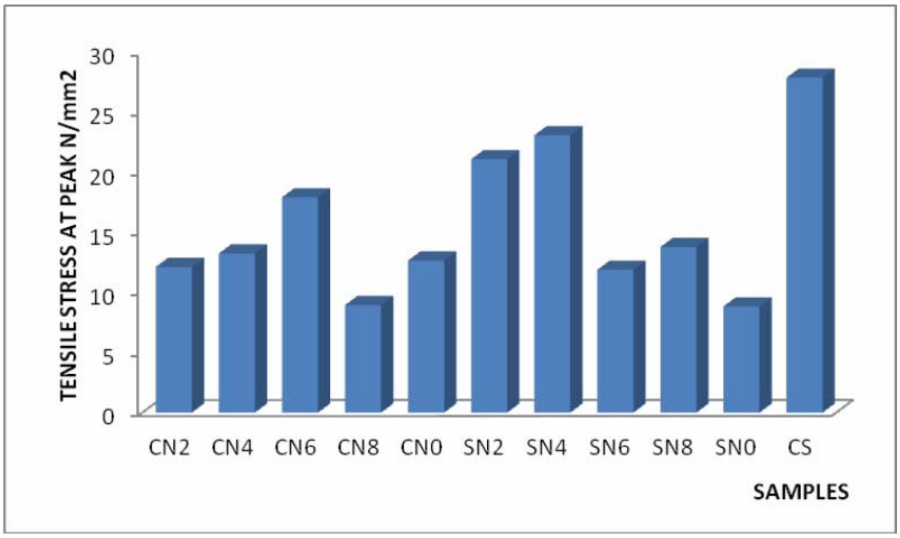

Figure 3. *Microsoft excel chart of tensile strength at peak against samples*

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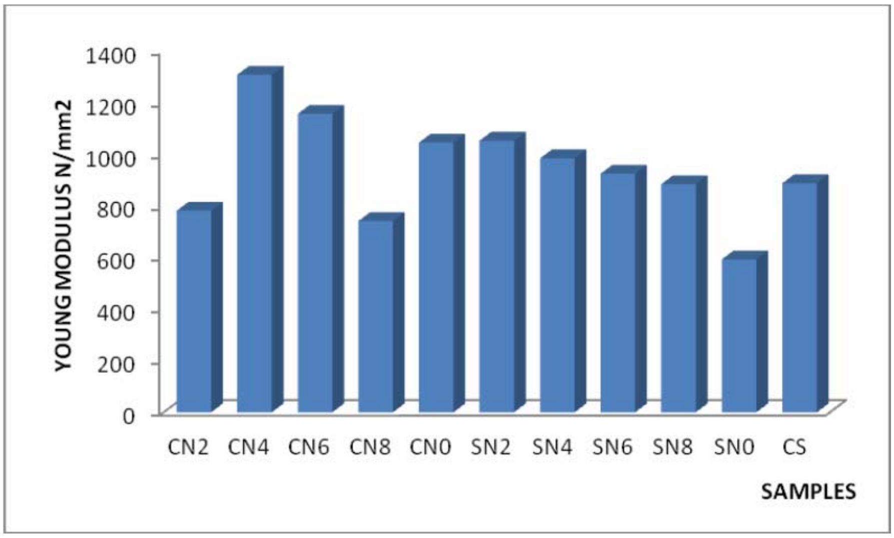

Figure 4. *Microsoft excel chart of young modulus against samples*

In Figure 4, it was observed that sample denoted as CN4 (4% NaOH coconut fiber + 96%polypropylene) has the highest value which is about 1308.3 N/mm^2 while CN6 (6% NaOH coconut fiber + 94 % polypropylene) has the second highest value of about 1157 N/mm^2 next by SN2 which has the third highest value of about 1052.6 N/mm^2. From the analysis, NaOH treated coconut fiber reinforced polypropylene composites perform better as it gave the best young modulus results compared with NaOH treated sponge fiber reinforced polypropylene composite and control sample.

Water absorption test

In Figure 5, it was observed that sample denoted as SN2 (2% sponge fiber + 98% polypropylene) has the best water repellent property followed by SN6 and SN8.

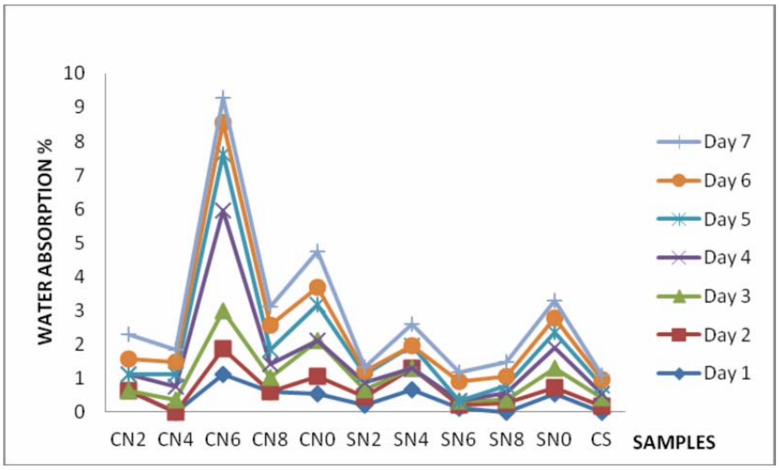

Figure 5. *Microsoft excel chart of water absorption % against samples*

However, in general NaOH treated sponge fiber reinforced polypropylene composites gave the best water repellent results compare with NaOH treated coconut fiber reinforced polypropylene composites.

Conclusion

In conclusion, the NaOH treatments carried out on the fibers has brought about enhancement in their mechanical and water absorption properties of the coconut and sponge fiber reinforced polypropylene composites compared with the control sample. However, It was observed that NaOH treatment highly enhance the flexural and water absorption properties of sponge fiber reinforced polypropylene composites than coconut fiber reinforced composite samples. This implies that in the selection of appropriate chemical treatment for natural fiber targeted for polymer based composites, NaOH treatment of sponge fiber will give the best result. The result has actually show that by treating natural sponge with NaOH, the flexural properties of the reinforced polypropylene can be enhanced while the water absorption tendency will be reduced. The treatment on coconut samples show that, the tensile modulus can be enhanced by NaOH treatment.

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