PHYSICAL AND MECHANICAL PROPERTIES OF *Sansevieria zeylanica* (CEYLON BOWSTRING HEMP) FIBER REINFORCED COMPOSITES

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INTRODUCTION

There are many fiber yielding plants in Sri Lanka, which can be used in diverse fields. Sansevieria zeylanica (Ceylon Bowstring Hemp) is such a type of non-conventional leaf fiber. There are more than 70 varieties of Sansevieria species available and the Sansevieria zeylanica (Ceylon Bowstring Hemp) is a very common type available in Sri Lanka, which is grown as an ornamental plant in homes. In recent years, there has been a growing interest in the use of natural fibers as reinforcing components in composites for various industrial applications as they are eco friendly and light in weight, have higher mechanical properties, and are bio degradable and economical to produce [1-4]. Sansevieria zeylanica (SZ) fibers can be utilized as a reinforcement fiber in polymer composites because of its inexpensive cost, extensive availability, high specific strength, renewability, low density, and ecological aspects. There is no research yet in Sri Lanka on the application of this leaf fiber for composites. Therefore, this research investigated the physical and mechanical properties of SZ fiber reinforced composites made with Epoxy and Unsaturated Polyester resins.

METHODOLOGY

Fiber extraction

Fibers were extracted from SZ leaves using the water retting method over four weeks. During this period, the non-fibrous cementing elements, primarily pectin and hemicellulose, are consumed by retting microorganisms. The degradation of the less resistant intercellular adhesive molecules gradually softens the leaves. The fibers may be easily separated from the leaves after the fermentation has reached the suitable level. However, the retting process must be closely monitored at regular intervals to avoid fiber damage. Extracted SZ fibers were dried under sunlight for 3-4 days.

Treatment with Mild NaOH

At the next phase, a part of the extracted and dried fibers were washed thoroughly to remove any traces of pulp adhering to the fibers and were added to a 5% NaOH bath (alkali treatment) for one hour, at room temperature, to remove non-cellulosic composites and improve fiber density and fiber matrix adhesion. After that, small bundles of SZ leaves were immersed in a water bath with a liquor ratio of 1:20 for 1 hour and allowed to dry for 3-4 days under sunlight.

Preparation of Composites

Treated fibers were combed and cut into nearly 10mm length to make composites based on the literature survey [2-4]. Thereafter, the cut fibers were hand-laid in multi-directions in the prepared stainless steel mold (size of 24cm x 25cm x 0.5cm) as a fiber web. In preparation of composites, 20%, 30%, 40%, and 50% fiber ratios (weight % basis) were considered and, accordingly, first the fiber batt was laid and pressed. After oneday, the batt was removed and weighed. The batt was then again laid in the mold. The prepared resin (Unsaturated Polyester with hardener or Epoxy with catalyst) was poured carefully on to the batt to fill up to 100% volume. After that, the mold was allowed to cure under pressure in line with their curing times.

Physical and Mechanical Properties Testing

Physical properties of extracted SZ fibers

Following are the properties of thr extracted SZ fibers before and after mild NaOH (alkali) treatment.

(a) Staple fiber length
The staple length of fibers was measured using a bundle of long fibers, excluding their tips. Before measuring, the fiber bundle was placed parallel to the hand doubling and drawing method, and placed on a black velvet pad in a straight form using a ruler.

(b) Fiber bundle tenacity
This was measured using a standard Pressley fiber bundle tester according to the ASTM D1445-05 Standard test method.

(c) Single fiber strength
The strength of a single filament was measured using a standard Tensile Strength tester at a dry state according to the ASTM D3822 standard.

(d) Moisture regain and moisture content
These were determined according to the ASTM D2495-01 standard.

Properties of SZ reinforced composites

The following physical and mechanical properties of composites prepared with Unsaturated Polyester and Epoxy resins under selected fiber ratios were measured:

(a) Tensile strength of composites
The tensile strength of composites was measured using the standard Tensile Strength tester suitable for composite testing and done according to the ASTM-D3039 –Standard.

(b) Hardness of composites
This was measured using the standard Rockwell Hardness Tester using the ASTM- D0785-03 standard. Hardness was measured in HRB in the hardness tester with a ball as the indenter.

(c) Compressive strength test
This was measured using the universal material tester with suitable grips according to the ASTM-D5024-01 standards.

(d) Flexural strength test
The three-point bending principle was used to measure the flexural strength of the prepared composite samples using the ASTM-D5023-01 standard. For these experiments, the standard tensile strength tester with suitable set-up accessories were used.

(e) Impact resistant test
To measure the impact resistance of the prepared composites, the standard Pendulum test method was used, following the Izod test principle. This was carried out according to the ASTM-D256 – 04 standard.

(f) Moisture absorbency test
The moisture absorbency of the prepared composites was measured according to the ASTM D5229 standard to determine their Moisture Regain and Moisture Content.

RESULTS AND DISCUSSION

Physical properties of extracted SZ fibers

(a) Effective fiber length
The effective fiber length of the fibre bundle was measured at 30cm , which was important to laying the fibers in a web form for the composites.

(b) Tenacity of alkali treated and untreated SZ fibers

Tenacity test results, in averages, are given in Table 1 using the Pressley bundle tester. According to these results, the alkali-treated SZ fiber depicted a 28.48% higher tenacity than untreated fiber. As the NaOH treatment removes waxes, oils, hemicellulose, lignin, and other impurities, it leads to a closer packed cellulose polymer chains, due to the release of internal tension to increase tenacity. Furthermore, the treatment also roughened the surface of the fiber and improved fiber-matrix adhesion [2, 3, 4]. These changes will provide benefits in composite manufacturing.

Table 1: Tenacity variations of treated and untreated fiber bundles

Fiber treatment	Bundle strength (lb)	Bundle weight (g)	Pressley Index (lb/mg)	Tenacity (g/tex)
Untreated	5.6	0.966	5.7972	31.073
Alkali-treated	5.833	0.7833	7.447	39.92

(c) Single fiber strength alkali treated and untreated SZ fibers
The single fiber strength of alkali-treated and untreated fibers are given in Table 2.

Table 2. Single fiber strength of treated and untreated SZ fibers

Fiber treatment	Breaking force (gf)	Elongation (%)
Untreated	2.337	1.572
Alkali-treated	2.551	1.302

According to the results, the breaking force increased by 9.12% and elongation reduced by 17.18% in the alkali-treated fibers compared to the untreated fibers. This is due to fiber bundle strength.

(d) Moisture absorption of alkali-treated and untreated SZ fibers
Moisture absorption was determined in the terms of moisture content and moisture regain . The following table depicts these results for alkali-treated and untreated SZ fibers.

Table 3. Moisture content and regain of alkali-treated and untreated SZ fibers

Fiber treatment	Moisture regain (%)	Moisture content (%)
Untreated	9.40	8.59
Alkali-treated	9.91	9.02

According to the data in Table 3, moisture absorption increased after alkali treatment and took comparatively high values. As alkali treatment changes the fiber structure during moisture absorption, cellulose polymer chains in SZ fiber may be pushed apart by the absorbed water molecules, allowing for more absorption. Based on the physical and mechanical properties of the SZ extracted fibers, treated fibers can be used to develop composites with good mechanical properties for industrial uses.

Physical and mechanical properties of SZ fiber reinforced composites

Composites were molded with Polyester resins and Epoxy resins separately with different fiber ratios such as 20%, 30%, 40%, and 50%, and the following properties were tested:

(a) Tensile strength of SZ reinforced composites
Figure 1 depicts the tensile strength variations of composites made with two resins types with four different fiber ratios of SZ fibers. Tensile strength was measured in Mpa.

(b) Hardness of SZ reinforced composites
Figure 2 depicts the hardness of the prepared composites. Hardness was measured in HRB units. The 40% composites had the highest tensile strength among the treated SZ fiber composites, indicating a robust interfacial bond between the SZ fiber and Polyester or Epoxy matrix, while it was reduced at the 50% fiber ratio, indicating lower interfacial bonding between fiber and

matrix. Higher tensile strength was reported with Epoxy resins at all fiber ratios because Epoxy resin itself has a higher tensile strength than Unsaturated Polyester resins, according to the literature [2-4]. Thus, the 40% composites had the highest hardness as the distribution of the fiber into the matrix minimized the voids and also demonstrated a better interfacial bond between the SZ fiber and matrix. Further, the Epoxy resin-based composites showed higher hardness values compared to Polyester-based composites. This is because Epoxy resin has a higher modulus than polyester resins, as indicated in the literature [4]. Therefore, Epoxy-based SZ composites with a 40% fiber ratio show good resistance to shape deformation due to applying loads.

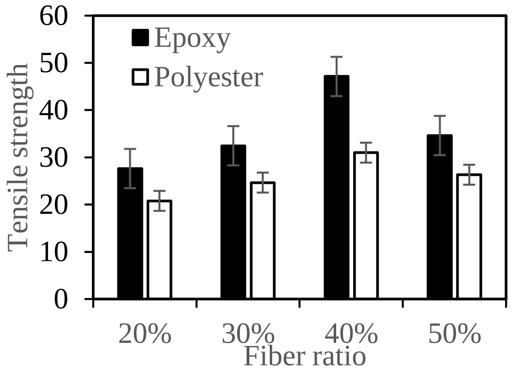

Figure 1. Tensile strength of composites

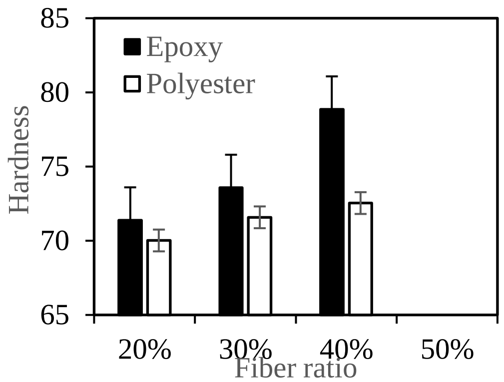

Figure 2. Hardness of composites

Thus, at the 50% ratio, it was observed that the intender and intender body of the Rock well hardness tester penetrated through the composite sample, which shows that there is not enough hardness in composites due to an insufficient amount of matrix in the composites.

(c) Flexural strength of SZ reinforced composites

Figure 3 depicts the flexural strength of the prepared composites, which was measured in MPa.

(d) Impact resistance of SZ reinforced composites

Figure 4 depicts the impact resistance (in J/m^2) of the composites.

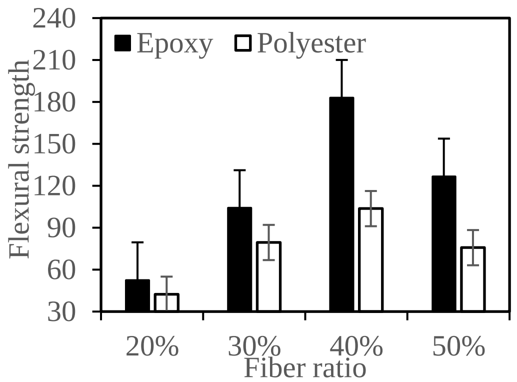

Figure 3. Flexural strength of composites

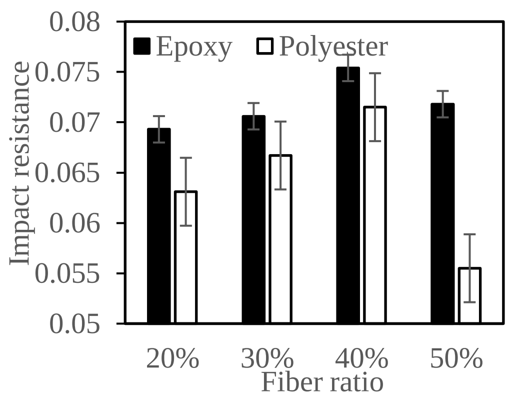

Figure 4. Impact resistance of composites

The 40% fiber ratio showed higher flexural strength than other composites, which shows better interfacial bonding, resulting the resistance against flexural forces; further, it may have reduced internal voids in the composites at the 40% fiber ratio. The 50% fiber ratio showed comparatively low interfacial bonding with the matrix and developed internal voids to give lower flexural properties than the 40% fiber ratio. Thus, the 40 composites have indicated better impact strength than other composites due to its greater absorption ability of the amount of energy to inhibit fracture development. The 50% fiber ratio showed inadequate interfacial bonding, which causes micro spaces between the filler and the matrix, which will make crack propagation in the samples under impact force. Further, Epoxy-based composites showed higher impact resistance and flexural strength due to the higher toughness reported with the Epoxy matrix than with the Polyester matrix.

(e) Compressive strength of SZ reinforced composites
During the compression testing procedure, both polyester and epoxy composites samples had not cracked under the maximum force of 10KN under the 5mm/min to 100mm/min speed. Therefore, it was concluded that SZ fiber reinforced composites with 20 - 50% fiber ratios, made using Epoxy and Polyester resins, exhibit good compressive strength. This may be due to good toughness reported in the matrix materials as well as the multi directional laying of the reinforcement fibers in the composite preparation.

(f) Moisture regain and moisture content of SZ reinforced composites
Figure 5 and 6 depict the moisture regain and moisture content of developed composites.

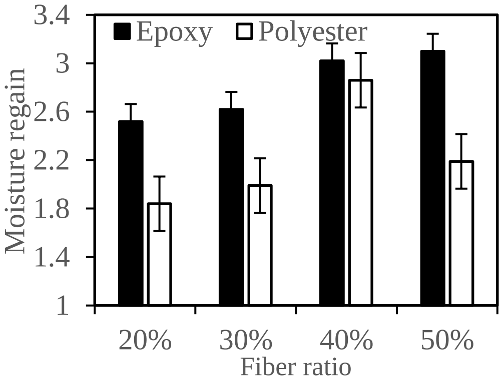

Figure 5. Moisture regain of composites

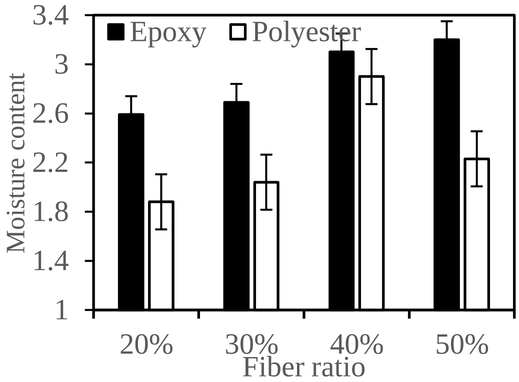

Figure 6. Moisture content of composites

According to Figures 5 and 6, moisture absorbency increased with the amount of SZ fibers included in the composites in the case of using Epoxy resins. This is because the moisture absorption of both the SZ fiber, which is much higher, and Epoxy. Thus, Epoxy-based composites showed comparatively higher moisture absorbency than other composites in all fiber ratios experimented. Epoxy itself has a moisture regain of 3% and that of polyester is almost 0%, based on the literature. However, Polyester-based composites have shown maximum absorption with 40%. After that, at the 50% fiber ratio, it reduced due to there being more hydrophobic matrix material available in the composites.

CONCLUSION

In this research, the physical and mechanical properties of SZ fiber-based composites, prepared with Epoxy and Unsaturated Polyester, were investigated. Alkali-treated SZ fiber composites showed higher bundle strength and single fiber strength, and had lower breaking elongation and higher moisture absorbency properties. With the alkali-treated SZ fiber-based composites, tensile strength, hardness, impact strength, and flexural strengths were higher at the 40% fiber ratio than with the other ratios. However, compressive strength exhibited good behavior in all the tested fiber ratios. Further, Epoxy-based reinforced composites have indicated much better physical and mechanical properties than Polyester-based composites. Therefore, it is recommended to use alkali-treated SZ-based composites with a 40% fiber ratio and Epoxy matrix for industrial applications such as cladding boards, automobiles, aircraft, home appliances, and aeronautical appliances. Thus, the results from the prepared composites show similar patterns of variations, in line with previous research on Sansevieria composites.

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