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Comparative study on the mechanical properties of banana and sisal woven rovings polyester composites

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Natural fiber polymer composites are widely used in many applications. Banana and sisal woven rovings reinforced polyester composites were manufactured by hand lay-up technique. The woven rovings were modified chemically by alkali treatment to enhance the mechanical properties. Tensile strength, flexural strength and impact strength were evaluated for 5%, 10%, 15% and 20% volume fractions of both woven rovings. The results of banana and sisal woven rovings composites were compared and it indicated that sisal woven rovings with higher volume fractions reveals better mechanical strength.

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1. Introduction:

In recent days, environmental awareness is increased due to high negative impact of synthetic materials. Most of the polymer composites are based on synthetic fibers like carbon fibers and glass fibers. These synthetic fibers have serious issues like non-biodegradability, high cost and health hazards. Natural fibers like banana, sisal, jute, flax and hemp have been well recognized for reinforcement in polymers to overcome the drawbacks of synthetic materials [1]. High moisture absorption is the major drawback in the natural fiber composites and chemical treatment is necessary to overcome the solution. Acetylation, benzoylation, silane and triton are the chemical treatments available for fiber surface modification. Alkaline treatment is the common technique used to modify the cellulosic molecular structure. It gives rough surface to fibers thus increase in fiber surface area to better bonding with matrix material [1-3]. The performance of alkali treated date palm fiber composites with untreated fibers are evaluated [4]. Significant improvements in mechanical properties of banana fibers have been observed with alkali treatment [5]. Chemically treated Isora fiber polyester composites are developed and reported with improved tensile and flexural strength [6]. Alkali treatment of pineapple leaf and sisal fibers hybrid composites were observed to improve tensile and impact properties while cyanoethylation improves flexural strength [7]. Banana and glass fiber reinforced hybrid composites were developed. Banana fiber with phenol formaldehyde was observed to show better mechanical property and good adhesion compared with glass fibers [8]. Sisal fiber urea formaldehyde composites show good flexural strength and utilized in future fibre board applications [9]. Mercerization of sisal fibers improves fracture stress by 12.2 % and stiffness by 36.2 % [10]. Sisal/Jute/Glass fibers hybrid composites were developed. The result reveals that mechanical properties are improved by adding sisal and jute fibers with glass fibers [11]. Boopalan et al [12] have investigated the mechanical, thermal and moisture absorption properties of banana and jute based on epoxy hybrid composites. Rule of hybrid mixtures were used to predict the tensile properties of banana and sisal hybrid composites [13]. Vulcanization parameters, process ability characteristics and tensile properties of natural rubber with oil-palm fibers composites were analyzed [14]. Flexural and impact test results improved with modified sisal fibers compared to pure Polyethylene sisal composites [15]. Sisal, hemp and kenaf based on polypropylene composites were comparatively evaluated for tensile strength [16].Woven sisal fabric composites were manufactured by compression moulding and tensile strength of 25 MPa and flexural strength of 11 MPa were observed [17]. Wazzan [18] developed date-palm woven rovings polyester based composite and exhibit 76.9 MPa of tensile strength. Jute fabric with linear low density polyethylene composites showed higher tensile strength compared to jute fabric with natural rubber composites [19]. Tensile and fracture toughness of woven sisal textile based on epoxy and vinyl-ester were investigated and reported that mechanical properties considerably affected by water absorption cycles [20]. The present research is focused on evaluation of mechanical properties on banana and sisal woven rovings polyester based composites.

2. Experimentation:

2.1 Materials:

Sisal and banana fine fibers are purchased from local dealer. Woven sisal and banana fabric were made from hand weaving machine at Coimbatore. Properties of woven rovings given in Table 1. Weaving of banana and sisal fabrics and fabric material are shown in Figure 1. Isothalic polyester resin, accelerator Methyl Ethyl Ketone Peroxide (MEKP) and catalyst Cobalt Naphthalene were obtained from Kovai Seenu Fabrics Ltd, Coimbatore.

Table (1): Properties of banana and sisal woven rovings

Description	Banana woven rovings	Sisal woven rovings
Areal density A_f [g/m^2]	88	140
Density of fiber ρ_f [g/cm^3]	1.30	1.41

(a) (b) (c)

Figure (1) : (a) Weaving fabric (b) banana woven rovings and (c) sisal woven rovings

2.2 Sample preparation:

Woven Sisal and banana fabric were treated with 5% NaOH solution for 2 hours. Then fabrics were washed by pressurized water for 5 times and dried in sunlight for a week. The dried mats were followed by oven drying kept at 70^{0}C for 6 hours. Hand layup technique was used to fabricate the composites. Alkali treated sisal and banana woven rovings were used to prepare the specimen. The required number of layers for different volume fractions are calculated by the below laminate equation.

$$V_f = (n\, A_f)/(\rho_f\, t)$$

where V_f is Volume fraction of fiber, n is number of layers, A_f is Areal density of fiber, ρ_f is density of fiber and t is laminate thickness. Volume fraction and layers for different specimens are given in Table 2. A mould size of 300mm x 300mm x 5mm is prepared by using mild steel material. Polyester resin, Catalyst and Accelerator are mixed in the ratio of 1: 0.02: 0.02.PVA coat is applied over the mould surface for easy removal of specimen. Resin mixture was applied over the mould surface. First layer of fabric laid in the mould. Again the required amount of resin was applied over the fabric as second layer. Roller was used to remove the air bubbles. Subsequently remaining layers of fabric and resin were applied over one another with the same procedure. Finally these specimens were taken to the hydraulic press to remove the air gaps and excess resin from the composite specimens and kept for several hours to dry. After the curing process, the specimens were neatly cut according to the ASTM standards.

Table (2): Volume fraction and number of layers in banana/sisal polyester composite

Specimen	Volume fraction V_f	No. of layers n	
		Banana	Sisal
A	5%	4	3
B	10%	7	5
C	15%	11	8
D	20%	15	10

2.3 Mechanical Testing:

2.3.1 Tensile Test:

The tensile test specimens were prepared according to ASTM D638 standard. Eight different specimens were prepared according to number of layers and are shown in Figure 2. The prepared specimens were placed in the machine and tensile load was applied until it fractures. During the application of tension, stress against strain and load against displacement were recorded.

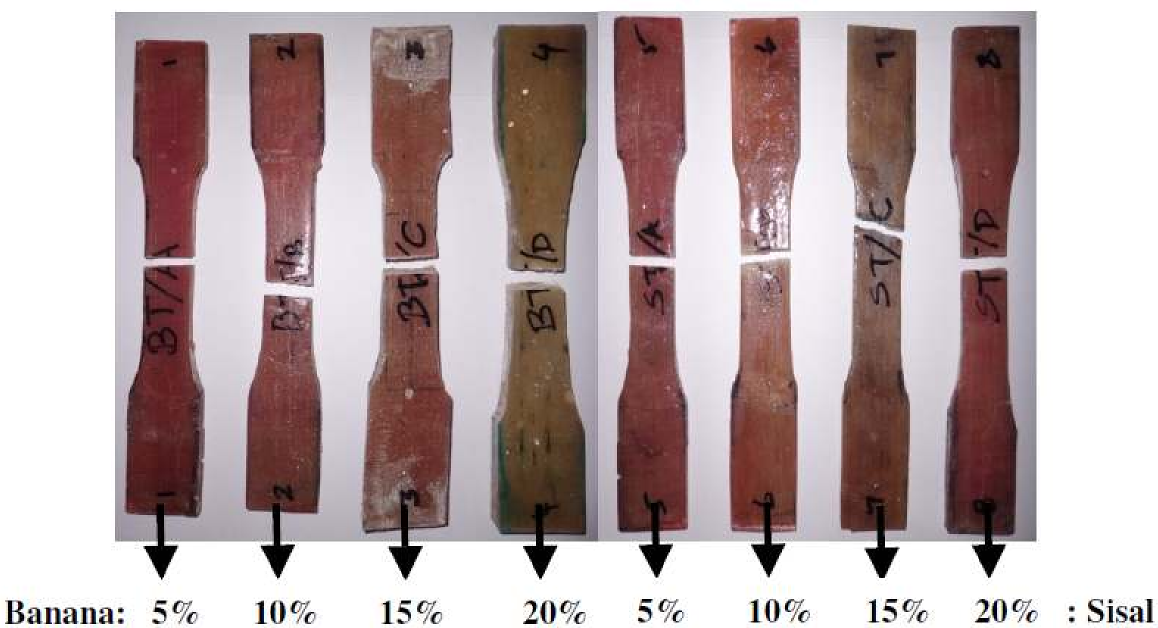

Figure (2): Tensile specimens of banana and sisal fabric reinforced polyester composites

2.3.2 Flexural Test:

The flexural test specimens were prepared according to ASTM D790 standard and are shown in Figure 3. The 3-point flexural bending tests were conducted for eight different specimens. The fabricated specimens were placed in the universal testing machine and the load was applied at the centre until it breaks. During the test, load against the displacement were recorded.

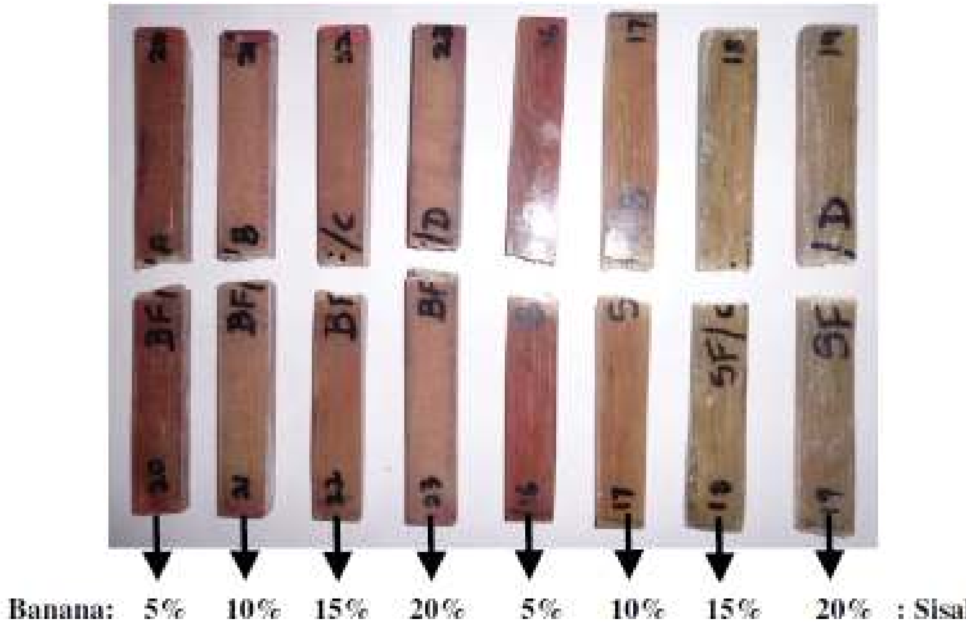

Figure (3): Flexural specimens of banana and sisal fabric reinforced polyester composites

2.3.3 Impact Test:

The impact test specimens were prepared according to ASTM A370 standard. The fabricated specimens were placed in the Impact test machine and allowed the pendulum to strike until it breaks. Impact energy was measured for eight different specimens. The fabricated specimens are shown in Figure 4.

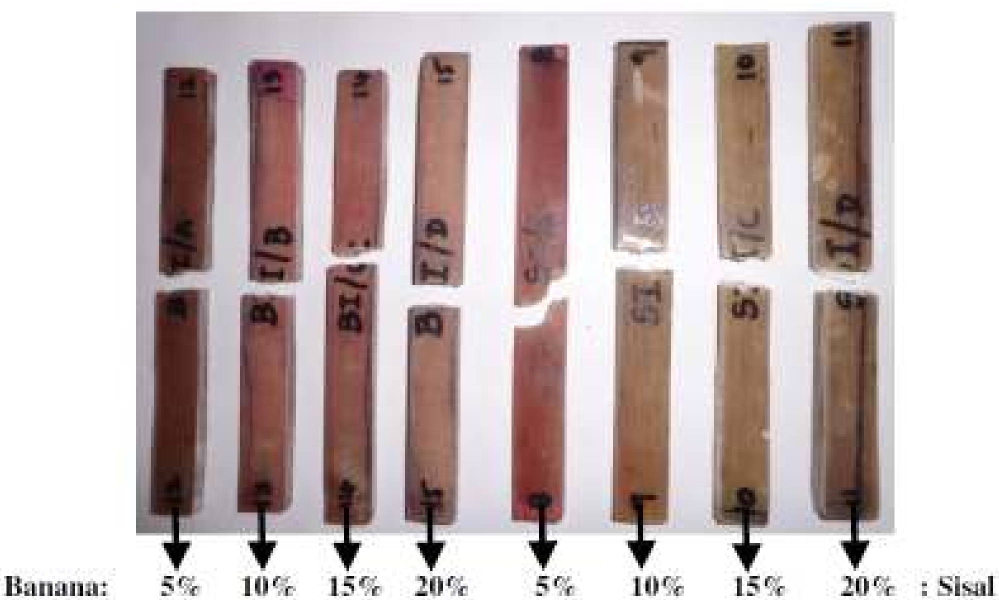

Figure (4): Impact specimens of banana and sisal fabric reinforced polyester composites

3. Results and discussion:

3.1 Tensile Test:

The fabricated specimens were tested in the universal testing machine. The specimens were tested until it breaks. Stress against strain and ultimate tensile strength were recorded. Stress-Strain curve for banana and sisal fabric polyester composites with 5%, 10%, 15% and 20% volume fractions are presented in Figure.5. Ultimate Tensile strength of 17.874MPa, 20.698MPa, 22.360MPa and 24.529MPa for 4 layers, 7 layers, 11 layers and 15 layers of banana fabric polyester composites were recorded respectively. Ultimate Tensile strength of 21.843MPa, 30.833MPa, 32.657MPa and 39.234MPa for 3 layers, 5 layers, 8 layers and 10 layers of sisal fabric polyester composites were recorded respectively. The result indicated that 15 layers (20% V_f) of banana fabric and 10 layers (20% V_f) of sisal fabric composites have better tensile strength and 15% V_f of both are considerable. Consolidated tensile strength for different volume fractions of banana and sisal woven rovings polyester composites are shown in Figure (6).

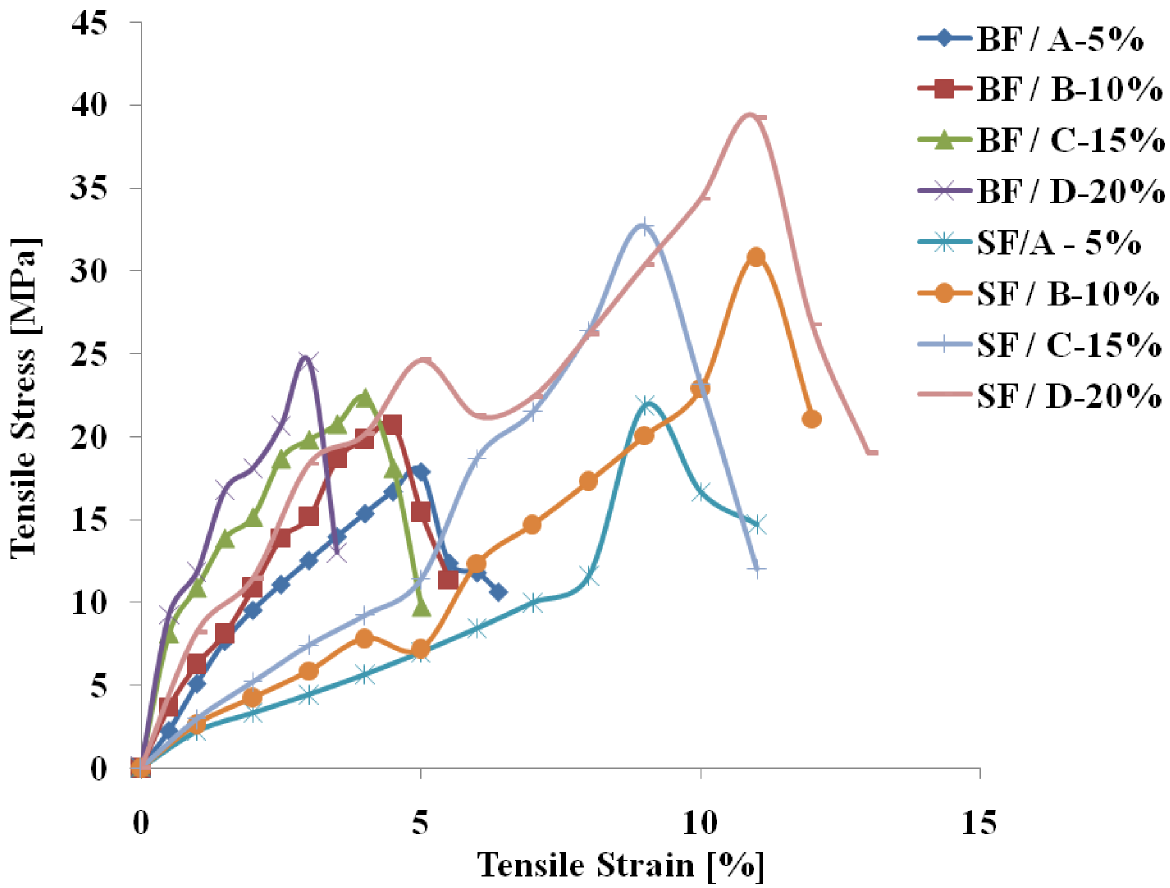

Figure (5): Stress strain curve for different volume fractions of banana and sisal woven rovings polyester composites

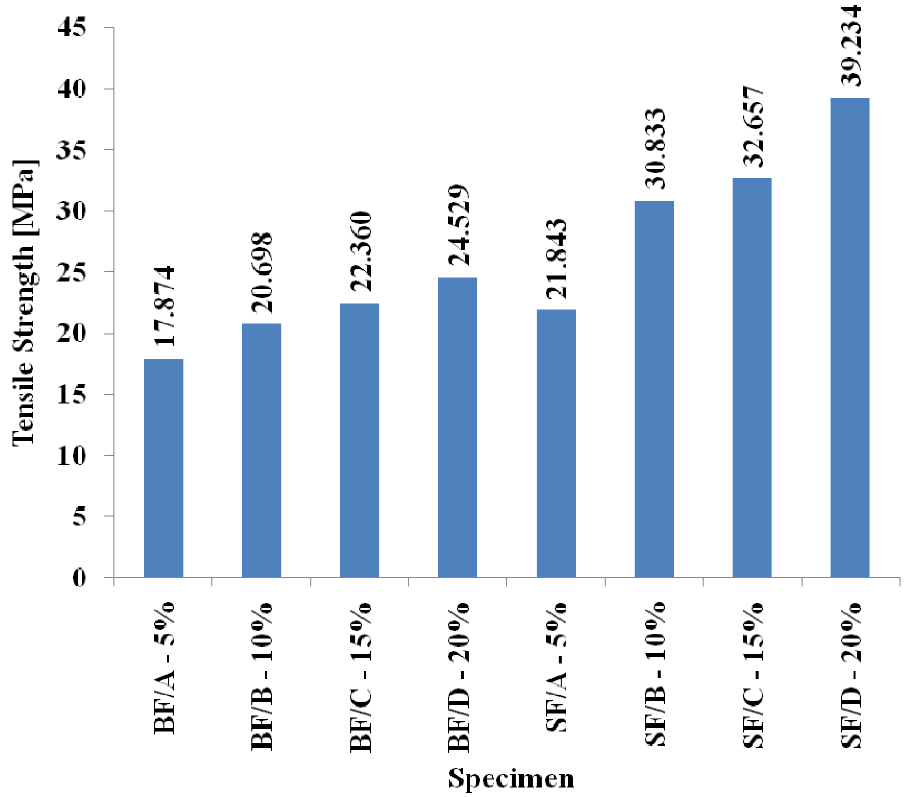

Figure (6): Tensile strength for different volume fractions of banana and sisal woven rovings polyester composites

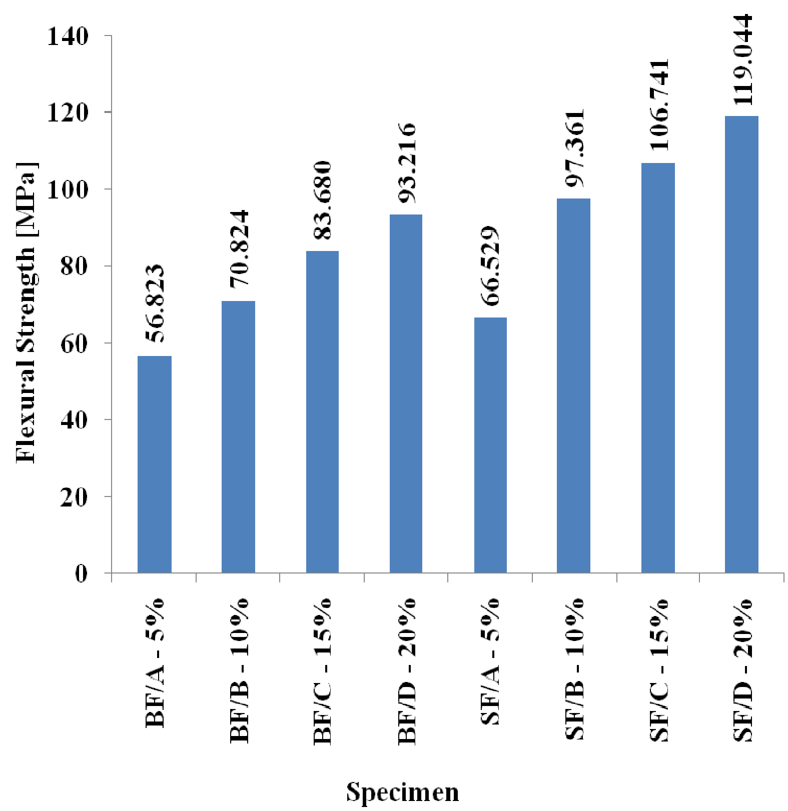

Figure (7): Flexural strength for different volume fractions of banana and sisal woven rovings polyester composites

3.2 Flexural test:

The fabricated specimens were tested for flexural strength in universal testing machine. Maximum displacement against load was recorded. The comparative results of different volume fractions of banana and sisal woven rovings polyester composites are presented in figure 7. Flexural strength of 56.823MPa, 70.824MPa, 83.680MPa and 93.216MPa for 4 layers, 7 layers, 11 layers and 15 layers of banana fabric composites were recorded respectively. Similarly Flexural strength of 66.529MPa, 97.361MPa, 106.741MPa and 119.044MPa for 3 layers, 5 layers, 8 layers and 10 layers of sisal fabric composites are recorded respectively. The result indicated that20% V_f of both woven rovings yields more flexural strength.

3.3 Impact test:

Charpy Impact test was carried out for the present investigation. Impact strength for different volume fractions of banana and sisal woven rovings polyester composites are shown in Figure 8. Impact strength of 4.62kJ/m^2,6.92 kJ/m^2, 8.85 kJ/m^2 and 11.03 kJ/m^2 for 4 layers, 7 layers, 11 layers and 15 layers of banana fabric composites were recorded respectively. Impact strength of 9.62kJ/m^2,10.90 kJ/m^2, 12.56 kJ/m^2 and 16.03 kJ/m^2 for 3 layers, 5 layers, 8 layers and 10 layers of sisal fabric composites were recorded respectively. The result indicated that 20% V_f of both woven rovings yields more impact strength. However, sisal fabric composites of 10 layers produced higher impact strength compared to banana 15 layers.

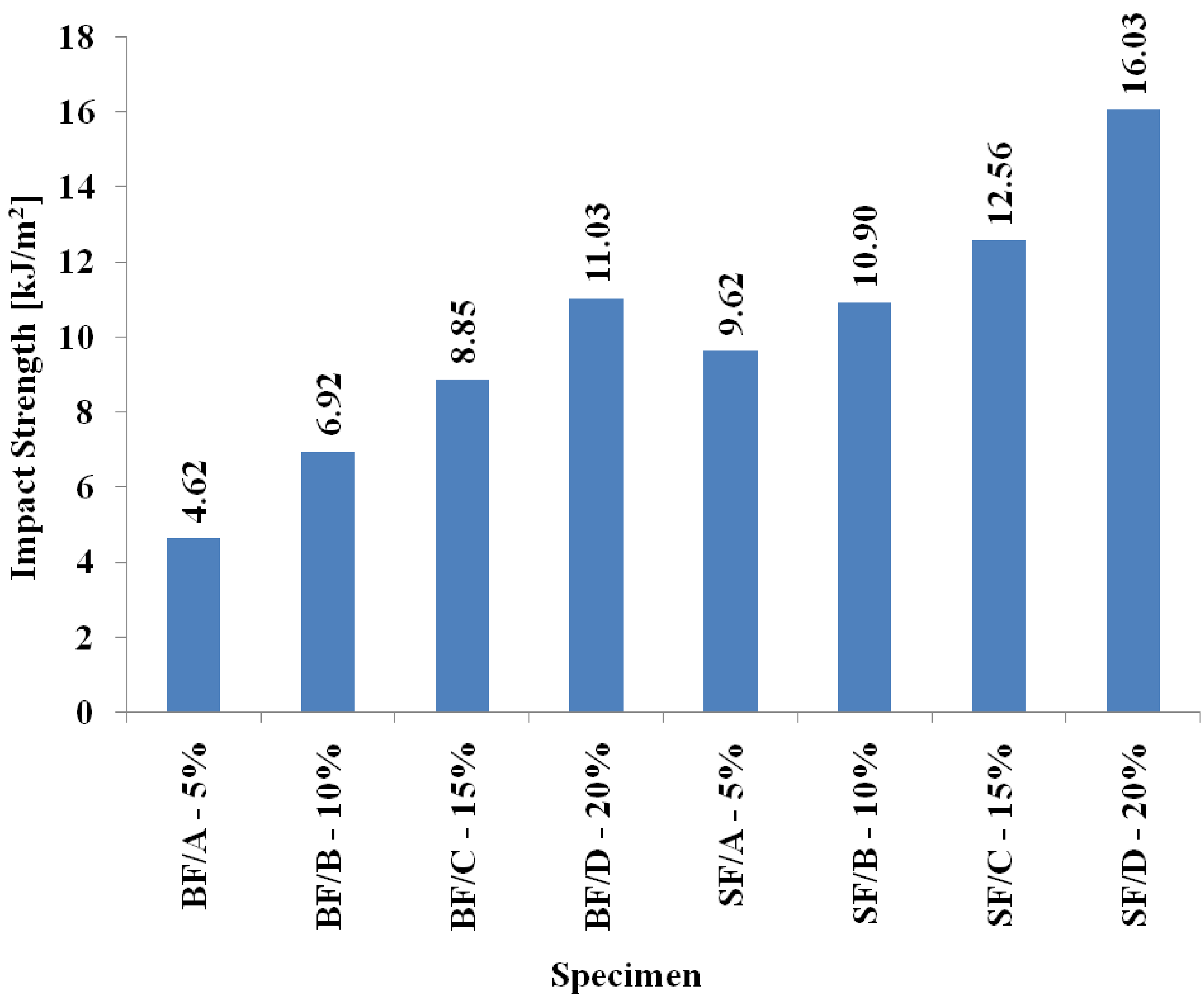

Figure (8): Impact strength for different volume fractions of banana and sisal woven rovings polyester composites

4. Conclusions:

In this paper, mechanical property of various volume fractions of banana and sisal woven rovings polyester based composites are evaluated. The following conclusions are made from this study. Fabrications of natural fiber composite by banana and sisal fabric as reinforcement in polyester resin were prepared successfully. Ultimate tensile strength, flexural strength and impact strength are found comparatively higher in sisal fabric composites than banana fabric composites. 20% V_f of fabrics produces better results and 15% V_f of fabrics are considerable.

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