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Fabrication and performance of hybrid betel nut (Areca catechu) short fibre/ sansevieria cylindrical (Agavaceae) polypropylene composite

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ABSTRACT

The objective of this research was to investigate the mechanical performance (tensile, bending and impact) of Polypropylene (PP) composites filled with betel nut (Areca catechu) short fibre (Bn) at different compositions (3,5,10,20 and 30wt%), using the extrusion and hot press molding technique. Results showed that Bn10:PP90 mixture (BnPP) was found better performance among the composites prepared. Because of the suitability of Sansevieria cylindrica (Sc) as a filler in PP composite as shown in our previous work, Sansevieria cylindrica is subjected to hybridize with betel nut short fibre in fibre in PP composite to achieve superior mechanical performance. Dielectric strength, water sorption capacity, degradation behaviour such as simulating weathering and soil buried test of different composites were also performed.

KEYWORDS

Betel nut;
Sansevieria cylindrical;
Hot press molding;
Hybrid composite;
Mechanical properties.

INTRODUCTION

Usage of natural fibers in the composite circuit is ubiquitous as they become bear fruit due its inborn qualities such as lignocellulose, natural, annually renewable and biodegradable fibres. These are being used for automobiles, aero-space, domestic and packaging applications. This fibre is now increasingly utilized for making diversified and value-added products such as upholstery, furnishing, decorative and secondary apparels. Because of its user-friendly these fibers have gone one step ahead as it become substitute for synthetic counterparts. Therefore, demand for natural fibers will be increasing day by day in the years to come. Usually, textile prepared from jute fall flat as susceptible to yellowing tendency, poor dimensional stability and easy creasing property. Hence, some anticipation is required for improving the look and feel jute fabric in order to promote for value added products[1,2]. The look of the fabric can be aggravated by dyeing and printing but still these fibres become enigmatic.

Due to its sizeable diameter, sisal fibers are uncertain in building interface and subjected to agglomeration which acts as vital role in alleviating strength. By using specific short fibre length in a typical polymer matrix can keep up the poor bonding and deinterface at bay[3]. Quest for new, cheaper and sustainable sources of fibres that can replace or work against with fibres viz., jute, sisal, cotton, flax, ramie, polyolefin, polyesters, polyamides and polyacrylics in terms of economic viability and eco-friendly properties. In the recent past, agro-based waste products have been utilized as natural sources to obtain to suit subjected to given conditions for agro-tech protective clothing[4-9]. Moreover, a broad range of agro-based fibers is being utilized as the main structural components or fillers/reinforcing agents in these composite materials which are used for automotive interior components. A Polyolefin polymer such as polypropylene (PP) is widely used in automobile industry or domestic applications where ductility and low cost have to be combined. Therefore sustainable focus is required in order to underling many of today's renewable resource policies[10-18].

Betel nut (Areca catechu) fruits are covered with a shell and the shell of each betel nut fruit produces nearly 2.55-2.70g of fibre. It is estimated that approximately 1, 30,000 meters per year fibre may available in India only. It is reported that non woven fabrics manufactured from betel nut short fibre (Bn) process excellent dyeing behaviour and virtually excellent substitute for conventional synthetic nets. The fabric have good drape, strength permeability. More over fabric can withstand strong sunlight, heavy rain, storm to hailstorm for considerably long periods. This present effort, therefore, addresses such issues by selecting a novel fibre called short Sansevieria cylindrica Fibre (Sc) to reinforce on PP system. *Sansevieria* (genus) *cylindrica* (species) is a plant which belongs to *Agavaceae* family and it was invented by Bojer Ex Hook. Sc is 2 fold lesser in size and 1.2 times lesser density when compared with sisal fibre and what's more decrease in size and density will brings out novel composite that will suit for specific applications[19]. It is also clear from the perusal of the literature that the PP systems reinforced with novel and innovative besides differently brought up fibres have been little explored and hence there is a need to explore this aspect[20-24]. Aim and the objective of this study is to fabricate light weight, high strength composite that suits for today's transportation systems which brings fuel economy.

In this work, work done on adding Bn and Sc fibres as fillers on PP hybrid composite matrix were prepared to assess the effect of processing and filler composition and mechanical, dielectric strength, simulating weathering, soil degradation and water sorption behaviour of composites.

EXPERIMENTAL DETAILS

Materials

Polypropylene was supplied by Polyolefin Co. Limited, Singapore. Sc fibre was extracted from the *Sansevieria cylindrica* plant was obtained from the Enumuladoddi forest, near Kalyanadurg, Anantapur (AP) India. The betel nut was collected and subjected to extract fibre from the fruit shell from the local market at Guntakal; Anantapur, India. The extracted fibre was dried at 80° in a vacuum oven for 24h prior to the preparation of the composites. The main chemical composition of the Bn is presented in TABLE 1.

TABLE 1 : Main chemical constitution of betel nut (Areca catechu) fibre.

Composition	Average amount (%)
Alpha cellulose	53.20
Hemi cellulose	32.98
Lignin	07.20
Fat and wax	00.64
Ash	01.05
Other materials	03.12

Betel nut short fibre (Bn) extraction

Betel nut were collected from the plants and then kept in the dark room in moist condition for about 15 days. When natural retting takes place, fibres were then separated by hand stripping. The retted fibres were exposed thoroughly to sunlight for about three days and then brushed to open the fibre strands and clean them.

Extraction of the Sc from the plant

Fibres were extracted from the Sansevieria cylindrica plant, generally seen in home decoration. Leafs were cut and decomposed in a water pot for about one month. Removed from the pot, making sure all lignin, hemi-cellulose, lingo-cellulose materials should be separated when it is washed and repeated the same until fair fibres gets separated. The fibres were washed thoroughly with distilled water and allowed to dry in the sun for about 1day.

Sc and Bn alkali treatment

Two glass trays separately toped with a 5% NaOH solution and further Bn and Sc fibres were added to the tray and allowed to soak in the solution for about 4 hours. As result of that removed all left over lignin, hemi-cellulose and lingo-cellulose which act as antidote in building adhesiveness, interface and bonding. The fibres were washed with water to remove the excess quantity of NaOH sticking to the fibres. Finally the fibers were washed with distilled water and dried in a hot oven at 60°C for 1 h. The fibres were cut into 20mm length with a sharp scissors[14].

Composite fabrication

Composites were prepared by compounding with extrusion and hot press machine. The processing temperature is maintained at 180 ºC and the pressure was almost all constant. The extruded composites were hot pressed under 10MPa for 5min at 185 ºC into sheets of suitable thickness for making the specimens as per ASTM standard. Sheet size and thickness were dependent on the testing methods used in this study. The relative amounts (%wt) of reinforcing materials Bn and Sc were doped on PP matrix mentioned in the TABLE 2.

TABLE 2 : Relative amount (%wt) of reinforcing materials betel nut (Bn) and Polypropylene matrix in composites.

Fillers as reinforcing materials (%)	Polypropylene matrix (%)	Composites
None	PP:100	PP
Bn:3	PP:97	Bn3
Bn:5	PP:95	Bn5
Bn:10	PP:90	Bn10
Bn:20	PP:80	Bn20
Bn:30	PP:70	Bn30
Bn:10 Sc:10	PP:80	BnScPPH
Bn:10 Sc:20	PP:70	BnScPPH-1
Sc:30	PP:70	ScPP

Determination of mechanical properties of the composites

Tensile properties of the composites were determined using a UTM testing machine (Instron, Series-3369) with across head speed of 5mm/min. Tensile strength, three point bending tests were carried out on par with ASTM D 53455 and ASTM-53452, respectively. All the tests were performed in a displacement controlled mode on a closed-loop servo-hydraulic MTS testing machine. Impact strength of samples was measured on the model number of machine Zwick according to ASTM D 53433. All the tests were accomplished at a room temperature of 20 ºC. At least five samples were tested for each composition and results were averaged.

Water absorption test

Sample of a dumbbell specimens were used for the measurement of water absorption. After being Oven-dried at 105ºC for 24h then the specimens were kept in the desiccators at room temperature. Then, the specimens were weighed before being immersed in distilled water. Mass of the sample was recorded prior to immersion. The specimens were periodically taken out of the water, surface dried with absorbent paper, reweighed and immediately put back into the water. Water absorption was evaluated on par with ASTM D 5229/D 5229M-92.

Simulated weathering test

The composites were treated by using a simulated weathering tester from Q-panel Co. (model Q.U.V., USA). The weathering test was performed in alternating cycles of sunshine over 4h (65±2 ºC) and dews and condensation 2h (65±2 ºC). This treatment was carried out for a period of about 720h.

Soil degradation test

Cellulose possesses the tendency to be degraded when buried in soil (having at least 25% moisture). For this purpose, the composite samples are weighed individually and buried in soil for 1-16weeks. There after, samples were carefully withdrawn, washed with distilled water, and dried at 105 ºC for 20min and kept for 24h and then weigh is recorded. Finally weight loss of various degraded samples is calculated.

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Dielectric strength

The composite specimens were made as per the ASTM D 149 to measure the dielectric strength. The specimens having dimensions of 120mmx120mmx3mm are reinforced with fibres in a single direction along 120mm length. The dielectric break down voltage is determined at five points for each specimen and average value is considered for analysis. The points selected are distant enough so that there is no flashover. The test is carried out at 50Hz frequency and room temperature. Digital micrometer of 0.001mm least count is used to find the thickness of the specimen at break down point and the test was repeated for all specimens fabricated from different kinds of fibres.

RESULTS AND DISCUSSIONS

Mechanical properties of betel nut short fiber (Bn) PP composites

Tensile strength and elongation at break

Tensile properties such as tensile strength and elongation at break(Eb) of the betel nut polypropylene composites containing 3%,5%, 10%, 20% and 30% Bn as filler were measured and the results are presented in the Figure 1 & 2, respectively. It is observed that with an increase in filler content from 3% to 10%, the tensile strength gradually increased but the tensile strength of the composites is found to decrease with increasing filler loading by weight fraction from 20% to 30 % (W/W).

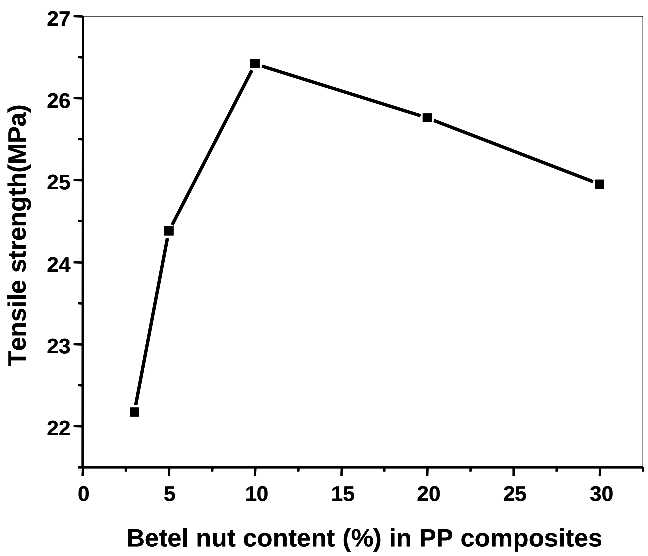

Figure 1 : Tensile strength of the composites

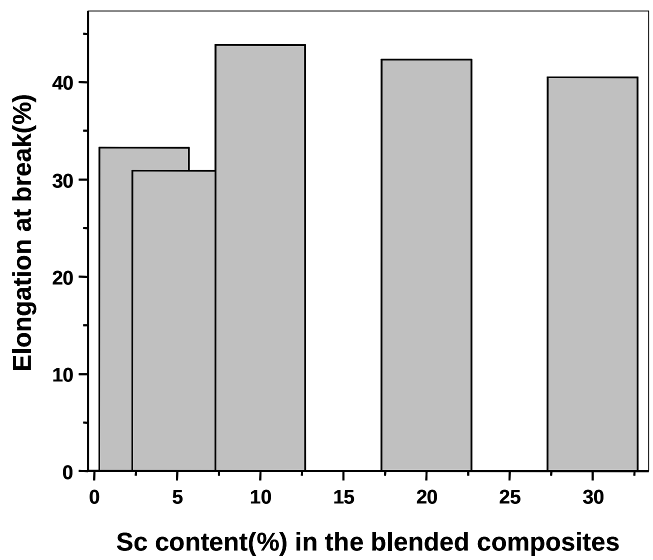

Figure 2 : Elongation at break (%) of the composite

This may be due to lack of stress transfer from the matrix PP to Bn filler. The elongation at break of the composite shows a similar trend as shown for the 10% Bn sample for tensile strength performance and maximum elongation at break. An increase of the elongation at break of the composites increases the toughness and ductility of the composite[22]. The composite might be present as moderate physical-mechanics adhesion (better known as inter-diffusion that allows a kind of bonding between two polymers surfaces via diffusion of the macromolecules both polymers[5].

Bending strength

The bending strength of the different composites is depicted in Figure 3, in which, enhancement of tensile strength, the trends for bending strength enhancement of the composites have been observed. The most obvious reason for the identical results of the tensile and bending properties is due to Bn fiber content in different proportions. Bending strength increases up to 10% Bn and thereafter remains constant.

Impact strength

On considering the impact strength of the composites as shown in Figure 4, is an increasing trend with increasing Sc content from 3% to 10% is observed, followed by a decreasing trend. It is envisaged that as the size of the filler becomes smaller, greater interaction between the filler and matrix could result in better and more efficient stress transfer which intern could increase the impact strength of the composite[23]. The optimum filler content varies with the nature of the filler and matrix, filler aspect ratio, filler/matrix interfacial adhesion etc. the low value at high filler content may be due to the presence of so many filler ends in the composites, which could cause crack initiation and hence potential composite failure[10]. In view of the above results, it is noted that the composite of 10% Bn content exhibits better mechanical behaviour.

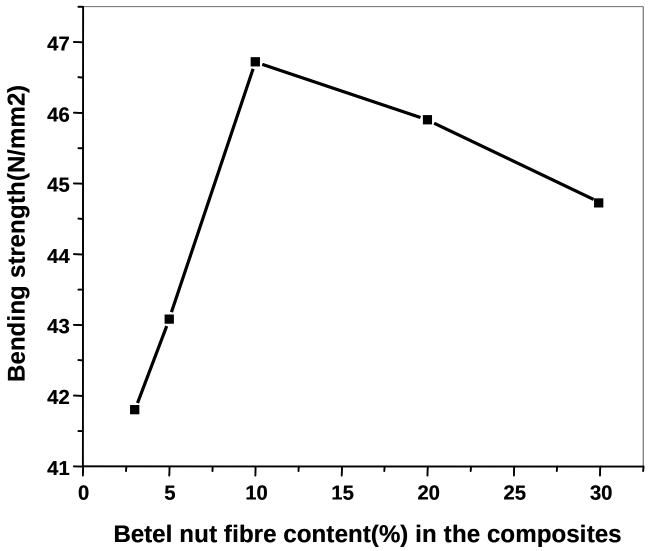

Figure 3 : Bending strength of the composites

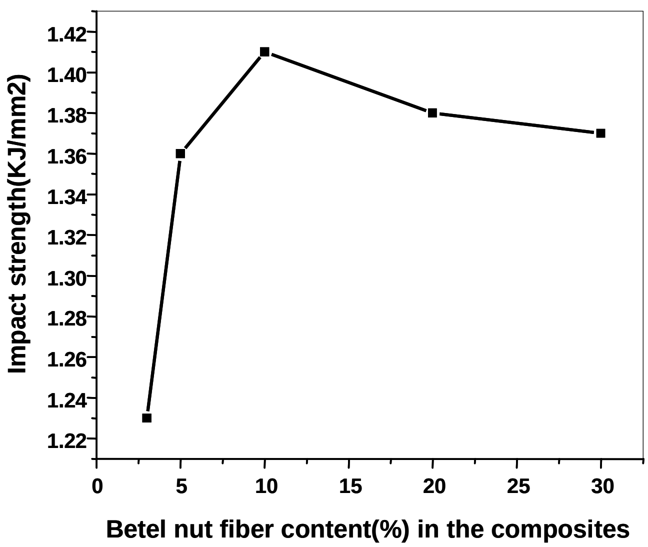

Figure 4 : Impact strength of the composites

Tensile and bending modulus

The tensile and bending modulus of the Bn PP composites increase with increasing filler loading as compared with 100wt% PP (Figure 5), while the filler loading more than 10% Bn has adverse effect on tensile strength, at the same time, it has a direct proportional effect on tensile modulus and bending modulus. Both effects may due to the high stiffness of the Bn short fibre composites.

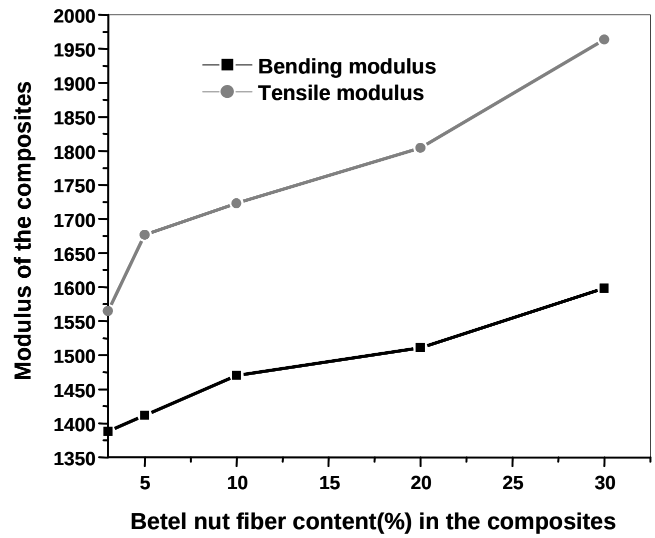

Figure 5 : Tensile modulus and bending modulus of the composites

Hybrid composites

As a link to previous work[21], *Sansevieria cylindrica* (Sc) has been chosen as another filler to prepare hybrid composite with betel nut fibre(Bn) in PP and, thereafter, two hybrid composites, BnScPPH and BnScPPH-1 were prepared by the formulation of 10%Bn, 10%Sc with 80% PP and 10%Bn, 20% Sc with 70% PP, respectively. There is considerable enhancement of the tensile behaviour exhibited by the hybrid composites, as shown in Figure 6. The highest tensile strength(2.77MPa), maximum elongation at break value(46%) and young's modulus(EM)(1.59GPa) have been produced by the hybrid composites BnScPPH and there is no significant results obtained by another composite Bn ScPPH-1 as shown in Figure 7, which proved that the BS and IS values of the hybrid composites are significantly higher than those of the other composites. The enhancement of the hybrid composites may be caused due to better compatibility of the two fibers and PP matrix, in particular BnScPPH composites. The remarkable behaviour on elongation at break (Figure 8) of the hybrid composite supports the increased fiber/ matrix adhesion and better fiber dispersion which demonstrated hybrid reinforcing effect as well as the positive hybrid effect[16]. Further research is required for better interpretation of the activities of hybridization in the hybrid composite during extrusion and hot press molding process.

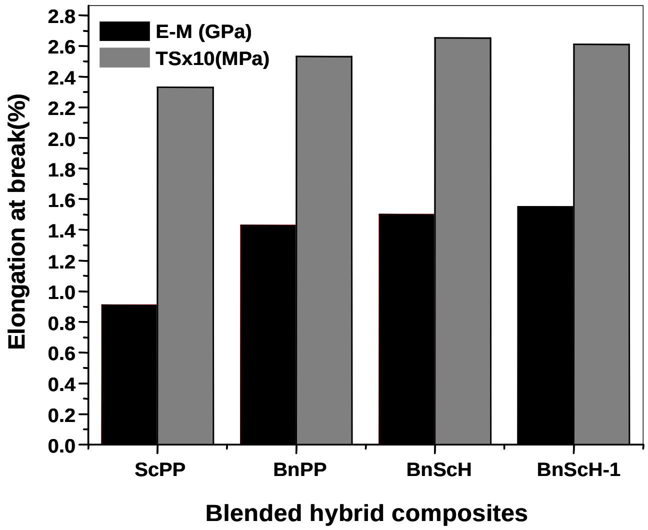

Figure 6 : Mechanical properties of hybrid composites

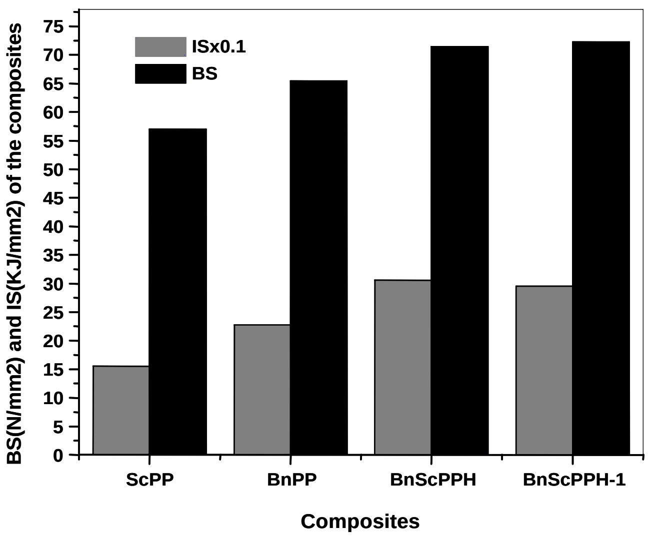

Figure 7 : Bending strength (BS) and impact strength (IS) of hybrid composites.

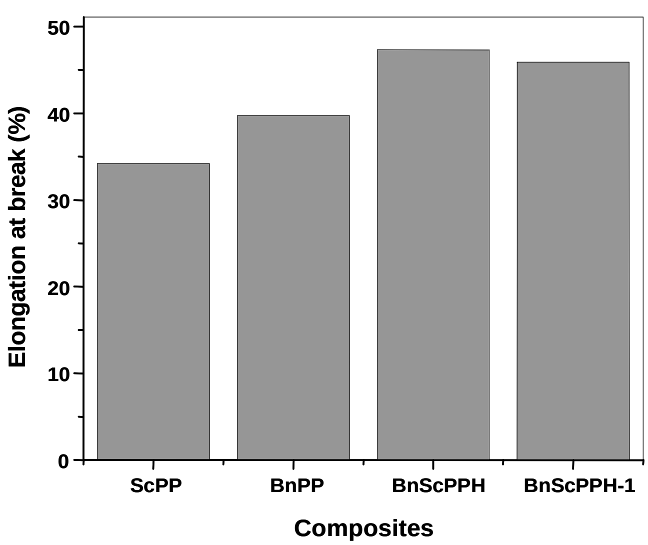

Figure 8 : Elongation at the break of the hybrid composite

Water sorption test

The influence of water environment on the sorption characteristic of BnPP composites have been studied by immersion of distilled water at 28 ºC. The effect of fiber loading on the sorption behaviour is evaluated. The results of the water up take are shown in the Figure 9 as water up take versus soaking time. In fact it is observed that initially the absorption is linear, subsequently gradual and finally reaches a plateau. From Figure 9, it is evident that the initial rate of water absorption and equilibrium uptake of water increases with increasing fibre content. Therefore, the water uptake is found to increase with fiber loading, owing to the increased cellulose content[11]. Hence, as ex-

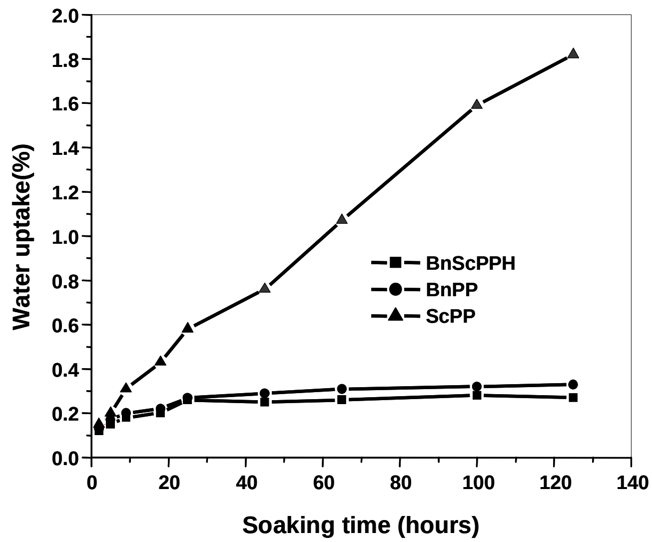

Figure 9 : Water uptake of the composite

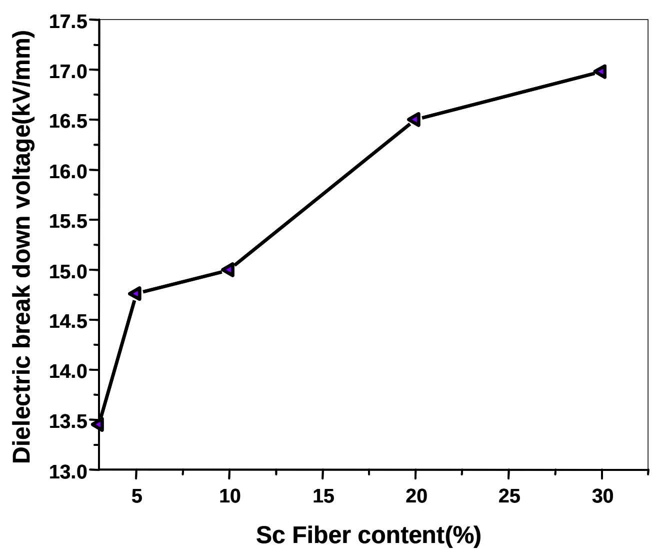

Figure 10 : Dielectric strength of composites as a function of fiber length.

pected, as the samples uptake the highest amount of water compared with the other samples depending on the filler loading in the composites. The lowest uptake of water by the composites indicates that more OH groups of cellulose content in the fibers of the composites are being blocked by their interaction with the PP matrix, hence hindering them from being accused by water[17]. It is also worth noticing that the dielectric strength of Bn fibre composites (Figure 10) increases with increase in volume fraction of fibre in the composite in the present study. This is a very rare phenomenon which is not observed in many of the natural fibre composites. Hence, based on the availability, cheaper and good dielectric strength of Bn fibre composites investigated in the present research work, the composite can certainly be considered for electrical insulation applications.

Simulating weathering effect

The three types of composites betel nut composites (BnPP), *Sansevieria cylindrica* PP composite (ScPP) and betel nut/ Sc hybrid composite (BnScPPH) were exposed to accelerating weathering tester over a period of about 720h to study the degradation properties. The loss of weight and tensile properties (TS &Eb) of the samples due to weathering is shown in the TABLE 3. The loss of TS of the ScPP composite is about 7.1% while that of the BnPP is about 7.9% and for the hybrid composites BnScPPH is about 5.8%. Similarly Eb loss is 26% for the ScPP sample and 24% and 20.5% for the BnPP and BnScPPH samples, respectively.

TABLE 3 : Loss of weight and mechanical properties of the composites due to simulating weathering

Weathering time(h)	Weight loss (%)			Loss of TS (%)			Loss of Eb (%)		
	BnC	ScC	BnScHC	BnC	ScC	BnScHC	BnC	ScC	BnScHC
24	1.9	3.2	1.8	0.9	1.1	1.0	1.9	2.2	1.9
48	3.4	5.1	2.3	2.9	1.5	3.9	3.8	4.7	3.3
72	5.2	7.5	5.9	1.6	3.4	1.2	6.8	8.1	5.2
96	7.0	9.6	6.4	3.2	4.5	2.1	9.5	10.8	8.6
120	8.9	12.5	5.1	3.9	4.9	2.4	14.0	14.5	11.7
240	10.9	13.4	8.7	3.8	4.2	2.7	18.0	20.4	16.9
480	12.8	16.0	9.4	5.2	6.2	4.3	23.0	26.5	21.2
720	15.4	18.0	10.7	7.1	7.9	5.8	24.0	26.0	20.5

Soil degradation

Composites such as betel nut fibre PP composite (BnPP), *Sansevieria cylindrica* composite (ScPP) and betel nut fiber/ *Sansevieria cylindrica* PP hybrid composite (BnScPPH) were buried in soil (25% water) for a period of 16 weeks in order to study the effect of environmental condition on the degradability of the samples. Weight loss and tensile properties (TS and Eb) of the composite samples were periodically measured and the results are given in TABLE 4. Minimum weight loss is for the hybrid composites (BnScPPH) (7.5%) as compared with other composites samples. Also, TS and Eb loss due to degradability is minimum for the hybrid composites at the maximum period of observation.

TABLE 4 : Loss of weight and mechanical properties of the composites due to soil degradation

Degradation time (weeks)	Weight loss (%)			Loss of TS (%)			Loss of Eb (%)		
	BnC	ScC	BnScHC	BnC	ScC	BnScHC	BnC	ScC	BnScHC
1	3.2	3.8	1.5	3.4	2.7	3.8	3.5	4.5	3.2
2	5.2	5.9	3.9	5.8	7.5	4.3	6.0	6.8	3.7
4	8.1	8.3	5.2	9.3	11.0	7.4	8.4	10.2	8.6
8	9.2	11.0	7.9	9.9	11.2	8.4	12.3	13.2	12.0
16	10.5	13.2	7.5	12.3	14.9	9.6	19.2	22.4	18.6

Abbreviation: BnC= Composite formulated by 10% betel nut fibre and 90% PP; ScC= Composite formulated by 20% Sansevieria cylindrica and 80% PP; BnScHC=composite formulated by10% betel nut fibre,10% Sansevieria cylindrica and 80%PP

CONCLUSIONS

The results of the study showed that extrusion and hot press molding process could be used to produce betel nut short fiber polypropylene composites with remarkable mechanical properties. From the above experimental observations it is clear that tensile properties decreased as the % of the filler increased a trend which completely followed our earlier work with *Sansevieria cylindrica*[15]. However, the results demonstrated that the prepared composite with10% content of Bn exhibits better mechanical properties. Dielectric strength was observed remarkable at 10% of Bn. The results also indicate that it is possible to enhance mechanical performance of hybrid fibre reinforced composites through hybridization of betel nut fibre and *Sansevieria cylindrica* with PP matrix at optimized ratio (Bn10:Sc10: PP: 80) of the fiber matrix formulation. The results discussed above can be used to prepare composites/hybrid composites using Bn and *Sansevieria cylindrica* in PP, which may be find diverse applications as structural materials where strength and cost considerations are important.

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