

# Research Journal of Pharmaceutical, Biological and Chemical Sciences

## Review on Characterization of Poly Butyl Succinate Based Biodegradable Composites

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### ABSTRACT

Composites are the materials made of reinforcements, matrix and additive fillers. It has various properties like it is lightweight, high strength and stiffness. Composites materials have many applications like automobile and marine industries, civil, military and air craft materials. Use of composites is preferable due to high quality and low cost. The PBS composite had the adequate mechanical rigidity and thermal stability to be recycled and reused. The aim of this review paper is to study the effect of various resins, fabrics and additives on PBS biodegradable composite based on mechanical tests, DSC test and to identify the best suitable property.

**Keywords:** poly butyl succinate, composites

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## INTRODUCTION

Composites are the materials made of two or more materials with different physical and chemical properties but the individual components remain separate and distinct in final product [1]. Poly butylene succinate [PBS] a green colour biodegradable product is famous for renewability and biodegradability, if comparison is with other matrix. In this review paper PBS is mixed with other composites like  $\text{CaCO}_3$  calcium carbonate, Wood polypropylene and pvc, Cellulose whisker and starch nanoparticles, Cotton fiber, Coir fiber, silk fiber, Oil palm mesocarp fiber, Silica, Bamboo and E glass, PLA, Jute fiber and chemically functionalised polypropylene, Graphene oxide, Layered double hydroxide. In this study paper, we study the effects on tensile properties, impact strength, flexural strength, DSC (Differential Scanning Calorimeter), XRD (X-ray and diffraction), and FTIR (Fourier Transform Infrared Spectroscopy), SEM (Scanning Electron Microscopy), TGA (Thermo Gravimetric Analysis), hardness strength and biodegradability with the different constituents. The composition used in the paper are as follows :PBS/ $\text{CaCO}_3$  calcium carbonate(93/7)%, PBS /Wood polypropylene and pvc(54/46)%, PBS /Cellulose whisker and starch nanoparticles.(2%/3%)%, PBS /Cotton fiber(90/10)%, PBS /Coir fiber, silk fiber, (80/20)%, PBS /Oil palm mesocarp fiber(70/30)%, PBS /Silica (80/20)%, PBS /Bamboo and E glass,(80/10/10)%, PBS /Pla (60/40)%, PBS /Jute fiber and chemically functionalised polypropylene(10/20/30)/(90/80/70)%, PBS /Graphene oxide(70/30)%, PBS /Layered double hydroxide.(80/20)%.

## TENSILE TEST

With the addition of 2 wt% Cellulose Whisker, the tensile strength of the PBS/CW-2 Nano composite improved from 26.2 MPa to 29.0 MPa for the neat PBS-F sheet. With the addition of 3% SN, the tensile strength of the PBS/SN Nano composite improved from 25 MPa to 28 MPa [2]. Tensile strength of neat PBS (90%) with cotton fiber (10%) is 30.3mpa. With the addition of 3% concentration of APTMS, TMSPDET, and APTES become 37.8, 36.6 and 34.5mpa resp. For pp Tensile strength is 22.7 MPa. For coir/pp composite, tensile strength is 35.6mpa. For silk/pp composite, tensile strength is 57.2 MPa. With the decrease in wt% of PBS in PLA tensile strength increases.100 wt% PBS TS is 23 MPa and for 0wt% PBS TS is 61.6mpa. For 40wt%/60 wt% PBS/PLA tensile strength is 40mpa. With the addition of 10% concentration in jute fiber and coir fiber-PP, tensile strength increases. For 0/10 %, 10/90%, 20/80%, 30/70% of JF & coir fiber-PP tensile strength increases from 33.45 MPa, 43.03 MPa, 46.58 MPa, and 56.71 MPa respectively. Tensile strength of PBS with E Glass Fiber is 3446 N/mm<sup>2</sup> with 5-26 (micro meter) and for PBS with bamboo is 440 N/mm<sup>2</sup> with 10-330 (micro meter), for PBS with banana is 355N/mm<sup>2</sup> with 70-330 (micro meter). Tensile strength of PBS/OPMF is 13.86mpa. With the increase in temperature tensile strength also increases [3]. For 200c and 210c TS is 16.06mpa and 17.72mpa. Whereas for PBS/SHSOPMF it also increases, for same temperature TS is 16.26mpa and 17.46mpa. With the increase in temperature, tensile properties of wood propylene decreases. Like for -10c TS is 20.2mpa, for 30c TS is 12.9mpa, for 65c TS is 9.1mpa. For PVC also TS decreases, for same temperatures TS is 59.8mpa, 41.7mpa, and 29.5mpa respectively.

## OTHER MECHANICAL TEST

For pp Tensile strength is 95. For coir/pp composite, tensile strength is 96. For silk/pp composite, tensile strength is 97. For 45°C orientation of bamboo fiber, hardness strength is 51 but if we add bamboo with E glass fiber, for the same orientation hardness strength increases to 52 MPa. The hybrid fibres shows very good hardness values if compared to pure bamboo FRP composites. For pp Tensile strength is 5.1kJ/m<sup>2</sup>. For coir/PP composite, tensile strength is 10.8kJ/m<sup>2</sup>. For silk/pp composite, tensile strength is 18.3kJ/m<sup>2</sup>. With the increase in wt% of PBS concentration, impact strength increases [4]. For 0 wt% PBS impact strength is 1.1 MPa and for 100 wt% PBS is 2.3 MPa. For 60 wt%/40 wt% PBS/PLA impact strength is 2 MPa. For 45 degree orientation of bamboo fiber, impact strength is 21kJ/m<sup>2</sup> but if we add bamboo with E glass fiber, for the same orientation impact strength increases to 81kJ/m<sup>2</sup>. When compared to pure bamboo FRP composites, the hybrid composites expressed very high impact strength. Impact strength of OPMF is 32.56 MPa with an error of 0.48. In case of SHSOPMF impact strength is 74.70J/m with an error of 0.54 [5]. Flexural strength of OPMF is 27.26 MPa with an error of 0.99. In case of SHSOPMF flexural strength is 65.75J/m with an error of 3.08. With the addition of 10% concentration in jute fiber and Coir Fiber-PP, flexural strength also increases. For 0/10 %, 10/90%, 20/80%, 30/70% of JF & Coir Fiber-PP flexural strength increases from 56.51mpa, 61.85mpa,

69.21mpa, 77.32mpa respectively. For 45 degree orientation of bamboo fiber, flexural strength is 80N/mm<sup>2</sup> but if we add bamboo with E glass fiber, for the same orientation flexural strength increases to 380N/mm<sup>2</sup>.

### THERMAL ANALYSIS

The melting crystallization curves of pure PBS and PBS-nano-CaCO<sub>3</sub> composites at a cooling rate of 10°C/min. For the pure PBS crystallisation temperature is 83°C. If we add SN (starch Nano composite) to PBS composite temperature of crystallization decreases by 0.3-0.4°C [6]. This phenomenon indicated that the Nano- CaCO<sub>3</sub> might not have played an active role in the heterogeneous nucleation of PBS matrix. For PBS sn7 (7% of caco3) gives the maximum melting temperature of 114.5c. The glass transition temperature of WPC and PVC is -10c & 78c. At 0c cooling temperature of PBS with graphene oxide crystallisation peak temperature is 93c. But as the cooling temperature decreases, crystallisation peak temperature also decreases. At 20c cooling temperature of PBS with GO crystallisation peak temperature is 72c. For the 100% PLA glass transition temperature is 63.9c. And for PBS melting temperature is 109c. 80% PLA and 20% PBS shows the highest glass temperature 63.9c. And with 40% PLA and 60% PBS shows the highest melting temperature of 109.5°C. The equilibrium melting temperature values of neat PBSA and Nano composites are calculated to be 101.47 C for PBSA and 99.13, 98.48, and 97.87°C for 1, 3, and 5 wt% loadings of m-LDH, respectively. Neat PBS melting point is 114°C. If we add 10 wt% of cotton fibre in 3% APTMS, melting point of composite without APTMS is 112.8 but with APTMS, it increases to 113.4. Melting temperature (T<sub>m</sub>), heat of fusion (DH<sub>m</sub>) and degree of crystallinity of PBS fiber is 113.3c, 81.7j/g 74.1%. The data of PBS/CW-2 is 115°C, 84.3j/g, 78.0% and for PBS/SN-5 is 117.2°C, 84.3j/g, 80.4%. PBS with 0.1% of CACO<sub>3</sub> demonstrates the most elevated disintegration temperature of 406°C [7]. In PBS/Coir Fiber composites, two pinnacles were seen at 345°C and 400°C, which relates to the debasement of cellulose, and disintegration of the PBS network separately. At 400°C, the rate weight misfortunes of treated PBS/Coir Fiber composite was 60% and for untreated PBS/Coir Fiber composites was 66%. The silane treated composite has lower weight reduction than the treated composite. The underlying decay temperature of PBS composite is 396°C, and the temperature of warm corruption is 455°C and in correlation, to the underlying deterioration temperature of PLA is 375°C, and the temperature of warm debasement is 411°C. The warm security of PLA/PBS composite is higher contrasted with the slick PLA. The distinction in morphology conduct brought about the weight reduction of PLA/PBS (40/60wt %) which was lower than unadulterated PLA.

### MORPHOLOGICAL TEST

Morphological study of the composites can be done by Polarised optical microscopy, x- ray diffraction, scanning electron microscopy and transmission electron microscopy. Depending upon the magnification and resolution needed, any of the above mentioned test can be chosen. POM has most minimal determination and amplification though TEM has higher determination and amplification. The composite without silane treatment has numerous voids and free broad strands at first glance. This demonstrates the collaboration between the coir fiber and PBS network is weedy, resultant in less interfacial security. Then again, the crevices are conservative and firmly sewed surface is seen in the silane-treated composites [8]. This proposes the similarity between the Coir fiber and PBS is improved when coir fiber is salted with the silane coupling operator APTMS. Coir fiber haul out is very higher and the holding between coir fiber and PP is bad. Little holes are apparent in the framework close to the coir fibers. Scanning electron micrographs of the 10/90, 20/80, and 30/70 JF/ coir fiber-PP composites highlight that the JFs are deeply embedded in and covered with coir fiber-PP matrix in JF/coir fiber-PP composites, with no voids and gaps, indicating that the reinforcing JFs have developed efficient, strong, and stable interfacial adhesion with the coir fiber-PP matrix in the JF/coir fiber-PP composites. The dispersion state of silica fillers in the PBS matrix was examined by SEM show clearly the difference in primary particle size that leads to higher surface area in the case of the AEROSIL. Among the silica fillers, untreated AEROSIL displayed largest aggregate size, indicative of strong particle–particle interaction. The surface morphologies of OPMF and SHSOPMF are inspected by SEM examination. The untreated OPMF shows a smooth surface with a few polluting influences, for example, waxy and sleek substances packaging its surface. Be that as it may, a while later SHS treatment, those polluting influences are expelled and the surface of the fiber gets to be bumpier and surfaced. The silica particles and microfibers can clearly be seen on the fiber surface. These spaces are useful in bio composite generation as it might disentangle the infiltration of thermoplastic into the fiber thus make a decent mechanical interlocking between the thermoplastic and fiber. The crystalline segment of Cellulose Whisker, and Starch Nano composite additionally showed very crystalline

attributes, in particular two unmistakable diffraction crests situated at around 168 and 238 of  $2\theta$  and numerous lesser force tops situated at around 348 of  $2\theta$ . The perception unmistakably uncovers that Layered Double Hydroxide layers are equitably dispersed in the steady PBSA framework and have completely lost their stacking orders [9]. Those outcomes demonstrate that the selective stacked lamellar structure of Layered Double Hydroxide can be modified to shape the unsystematic disengaged morphology in the PBSA framework. Likewise, the peeled morphology saw by TEM test is in great concurrence with the WAXD comes about. the Nano composites filled with Graphene Oxide show some fine scattered nanoparticles additionally exceptionally enormous masses are available, on account of the solid van der Waals strengths, which are liable to act damagingly on the physicochemical properties of the Nano composite example. On the distinctive hand, the circular Nano fillers that were utilized for the arrangement of the Nano composite specimens, were segregated all the more consistently in the lattice. The totals that are framed are significantly lesser in those examples, particularly in Nano composites with silver and Silicon dioxide nanoparticles, a reality which will enhance the final properties. Unmistakably the spherulite size of the PBSA/m-LDH Nano composites diminish and the quantity of spherulites increments with the stacking of 3 wt% Layered Double Hydroxide. The collection of 3 wt% Layered Double Hydroxide incites nucleation destinations for PBSA crystallization and results in the restricted improvement of PBSA spherulites. This infers the blend of the Layered Double Hydroxide up to 3 wt% into PBSA could incite assorted nucleation and change the crystallization conduct of PBSA. However, the spherulite size of 5 wt% PBSA/Layered Double Hydroxide Nano composite gets to be bigger, and the quantity of spherulites turns out to be less at the stacking of 5 wt% of Layered Double Hydroxide. This outcome demonstrates that high substance of Layered Double Hydroxide can oblige the sub-atomic movement of PBSA chains because of the interface of natural modifier and Layered Double Hydroxide, bringing about the lessening of nucleation. On account of the Nano composite specimens, the measure of the spherulites is littler because of the higher number of nucleating locales inside the example. Along these lines, nucleation thickness has expanded and the heterogeneous nucleating impact due to the nanoparticles is solid.

#### FOURIER TRANSFORM INFRARED SPECTROSCOPY

The types of Nano fillers dominated the number of hydroxyl groups and directly affected the distribution of hydrogen bonded carbon monoxide in the ordered and amorphous regions of the Nano composites. With the addition of only 2 wt% Cellulose Whisker or 5 wt% Starch Nano composite filler, PBS/CW-2 and PBS/SN-5 Nano-composites shows a strong crystalline CO vibration, which shows that there was a strong intra molecular hydrogen-bond reaction between the Nano fillers and PBS molecules. MAH group present on the coir fiber-PP matrix reacts with the hydroxyl groups present on the components of JFs resulting in the formation of covalent ester linkage and secondary hydrogen bonds. These reactions take place at the interface of JF/coir fiber-PP composites. Two new bands one at  $1739\text{cm}^{-1}$  and another at  $1114\text{cm}^{-1}$  in the FTIR spectroscopy of JF/coir fiber-PP composite that are not present in the PP matrix indicate formation of esters and confirm the esterification reaction between the hydroxyl groups of JF and anhydride group of coir fibre-PP matrix [10]. The presence of moisture on JF due to its hydrophilic nature is confirmed by the bending vibration of  $\text{-OH}$  groups indicated by the presence of band at  $1640\text{cm}^{-1}$  present in the spectrum of JF/coir fiber-PP composite. The peaks of methyl groups, which appear around  $2920\text{cm}^{-1}$  and  $2820\text{cm}^{-1}$ , indicate that surface modification was successfully performed. The OPMF at temperature of  $220^\circ\text{C}$  treated for 60 min was utilized as a delegate for super warmed steam of OPMF in light of its tractable properties. The noteworthy contrasts between these two spectra are plainly seen at pinnacles of  $1730\text{cm}^{-1}$ , and  $1245\text{cm}^{-1}$ . The absorbance of these crests on the super warmed steam of OPMF range was radically lessened in contrast with that of the OPMF range. This outcomes that Super-Heated treatment evacuated hemicellulose and lignin in part. What's more, the absorbance of crests at  $2925\text{cm}^{-1}$  and  $2853\text{cm}^{-1}$ , comparing to C-H extending of cellulose and hemicellulose in the super warmed steam of OPMF range is additionally diminished in light of the evacuation of hemicellulose. It is likewise seen that the hydrophilicity of Super-Heated steam of OPMF was diminished in contrast with that of OPMF as confirmed by a reduction in the absorbance of tops at  $3391\text{cm}^{-1}$  and  $1645\text{cm}^{-1}$ , comparing to OH extending and OH bowing of ingested water, individually.

#### BIODEGRADABILITY TEST

For initial 30 days, the corruption of unadulterated PBS was slower than PBS/coir fiber composites showing that Coir Fiber enhanced the debasement of PBS. In examination between the composites with and without silane treatment, the untreated composite demonstrated higher debasement rate of 65% than the

treated composite at 60%. Following 30–50 days, the silane-treated composite given better aftereffect of larger amount of biodegradation than the untreated composite [11]. Following 60 days, the levels of biodegradation for unadulterated PBS was 60% and for PBS/coir fiber composite sheets was 90%. Amid 90–100 days, the biodegradation rate of both treated and untreated PBS/coir fiber (60/40) were 95%. Which demonstrates that silane treatment of coir fiber had not influenced the biodegradation rate of the composites. In this test, at first TS of coir/pp composite, is 35.6mpa following 4 weeks it gets to be 30.4 MPA, then following 4 weeks it gets to be 27.1mpa, following 4 weeks it is 26.3mpa. Be that as it may, if there should arise an occurrence of silk/pp composite, TS is 57.2 MPA, following 4 weeks it gets to be 55.3MPA, following 4 weeks 51.7 MPA, following 4 weeks it is 50.3MPA.

### CONCLUSION

PBS/silk/PP composite is having the highest hardness of 97 RHN among all composite carried out in this paper. PBS with bamboo and E-glass fiber is having the highest flexural strength and impact strength of 380 MPa and 81KJ/m<sup>2</sup> respectively among all composites. PBS with silane treated composite shows the highest thermo gravimetric temperature of 455°C. PBS with bamboo fibre has the highest tensile strength of 440mpa. PBS with Caco3 (7%) is having the highest thermal temperature reading of 115°C. From the above reviews, PBS with bamboo fiber showed the best results among all the composites.

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