Development and study of biodegradable composite materials of poly(butylene succinate) with hemp fibers and shives

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Introduction:

In recent years, research about the use of cellulosic fibers as substitutes of synthetic fibers has increased due to their biodegrability, low cost and good mechanical properties.

Composite materials of the fully biodegradable polyester poly(butylene succinate) with hemp fibers of 0.5cm length and hemp shives of 1mm maximum diameter were prepared with the use of a twin-screw extruder.

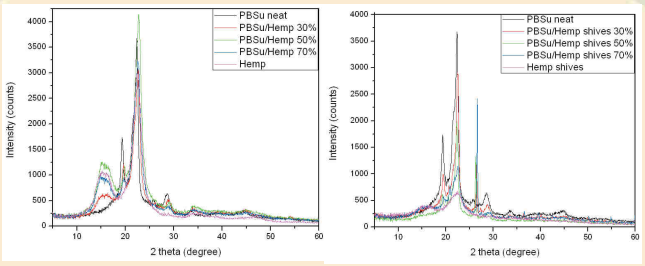
Experimental:

Poly(butylene succinate) (PBSu) composites containing 15, 30, 50, 60 and 70% hemp fiber and hemp shives respectively were prepared by melt mixing in a Haake-Buchler Reomixer at 130°C at 35 rpm for 10 min. The polyester and the fillers were dried under vacuum prior to the melt mixing. Films of the samples were received using a hydraulic press, set at 130°C.

Results and discussion:

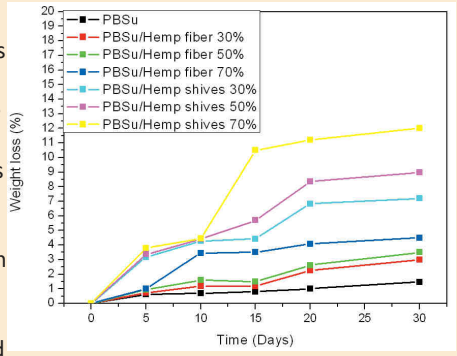
Sample	Tensile strength (MPa)	Elongation (%)	Young's Modulus (MPa)	Impact strength (J/m)	Impact strength (J/m^2)
PBSu	21.03	1.08	1950	77.14	216.35
PBSu/Hemp fiber 15%	9.22	0.5	1708	35.44	124.07
PBSu/Hemp fiber 30%	2.5	1.26	2346	36.62	153.85
PBSu/Hemp fiber 50%	3.35	2.74	2764	48.62	205.13
PBSu/Hemp fiber 60%	4	0.22	1920	52.91	269.91
PBSu/Hemp fiber 70%	-	-	-	22.73	111.89
PBSu/Hemp shive 15%	3.5	0.26	1345	25.97	100.88
PBSu/Hemp shive 30%	3.7	0.27	1438	32.26	126.10
PBSu/Hemp shive 50%	3.5	1.6	2290	37.04	144.23
PBSu/Hemp shive 60%	3.4	0.14	2625	42.64	162.56
PBSu/Hemp shive 70%	-	-	-	-	-

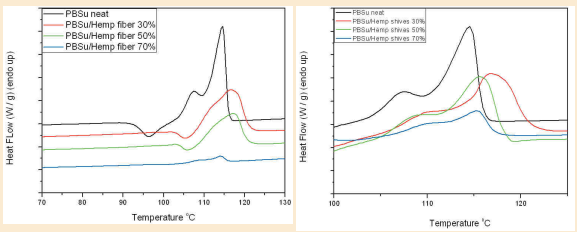
PBSu is a strong brittle material, due to it's nature it breaks before the yielding point. The slightly lesser mechanical properties of the composite samples are expected and are attributed to the fact that the natural fibers and shives are hydrophilic in nature whereas the polyester has a hydrophobic character which results in poor interaction between them. The high percentage in Hemp fibers act as points of stress concentration that promote material failure. Impact strength decreases in the composites. It increases with increasing fiber and shive content, except for PBSu/Hemp 70. The general decrease could be attributed to the presence of so many fiber ends and shive particles that cause crack initiation and finally failure due to the poor interaction between the hydrophobic polymer and the hydrophilic fiber.



XRD shower that the unit cell of the crystalline PBSu α form is monoclinic. PBSu/Hemp fiber composites showed the peaks from both PBSu and Hemp fibers. Hemp shives showed less intense peaks, which means they are less crystalline than fibers. PBSu/Hemp shive composites show peaks from both their components.

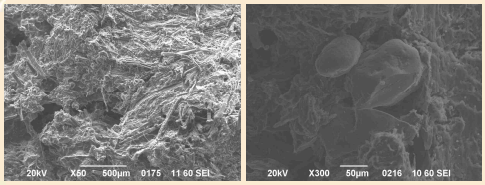
The presence of Hemp fibers and Hemp shives in PBSu promotes its biodegradation. As the concentration of the filler increases, there is an increase in the biodegradation rate. The higher degradation in composites, in comparison with neat PBSu, can be explained by the initiation of enzymatic degradation of the cellulosic chains in fibers. Higher water absorption occurs in the composites with higher fiber/shive content.





The DSC study showed a slight increase in the Tm of the composite materials and a small reduction in the Tg. The crystallinity was generally reduced, except from PBSu/Hemp shive 30 and 50%, probably due to their particle-like shape that caused a nucleating effect.

Sample	T_m (°C)	T_g (°C)	T_c (°C)	ΔH (J/g)	Crystallinity (%)
PBSu	114	-35	72.5	81,3	38,6
PBSu/Hemp fiber 30%	116	-25	79	65,3	31,1
PBSu/Hemp fiber 50%	117	-32	80	56,4	26,9
PBSu/Hemp fiber 70%	114	-31	78.5	6,2	3,0
PBSu/Hemp shive 30%	117.5	-30.5	72.5	90,9	43,3
PBSu/Hemp shive 50%	116	-34	73	121,2	57,7
PBSu/Hemp shive 70%	115	-30	78	72,9	34,7



The composites depict homogenous dispersion and lack interfacial adhesion, as can be seen by SEM.

Conclusions:

The composites showed good dispersion, that means the conditions in the extruder were satisfactory. The lack of interfacial adhesion led to worsening of the mechanical properties. XRD showed no changing in the crystal planes. The rate of biodegradation increased in the composites, more in those with Hemp shives.