Biodegradability Behavior on Sorbitol Modified Starch Blended with HDPE

K.S.K. Rao Patnaik, K. Sirisha Devi, V.Kiran Kumar, and K. Sri Harsha

Abstract—**Thermoplastic Starch blend were obtained using urea plasticized starch and HDPE. The effect of plasticized starch (0 – 25 wt % TPS) on the Mechanical behavior of the thin sheet are discussed. The Performance of the sheet is explained on the basis of Mechanical, Structure and Surface Morphological and Biodegradable behavior of the blend. The TPS blend exhibit good Mechanical strength Particular 0 to 10 % TPS blend. After 10% batches there was a significant decrement change in Mechanical Response. Dynamic Mechanical Analysis (DMA) tests are carried out to investigate the viscoelastic deformation of HDPE / TPS Blends with different (0 to 25%) loading of Modified Starch particles. It has been observed that when HDPE filled with Thermoplastic Starch particles the stiffness decrease with increase of TPS content and very little change in Tg was obtained.The performance investigated due to the Strong compatible phage interaction between TPS and compatibilized HDPE matrix phage and plasticizer (urea). Urea brought out a optimization effect in deformation, retrogadation and change in physical, chemical, mechanical, thermal behavior of dry starch. The mechanical strength decreased proportionally with TPS Percentage increases. But Biodegradability performance increases with increasing percentage of TPS in the blend. This output is come out due to disintegration of TPS Structural Molecular Phase.**

Index Terms—**Biodegradation, DMA Plot, HDPE, SEM, Soil Burial Method, Thermoplastic Starch Blends.**

I. Introduction

A number of biological materials may be incorporated into biodegradable polymer [1,2]. Biodegradable polymers are recently developed materials in the field of polymers. Their main characteristic is that they are biodegradable through the action of the microorganism in appropriate environmental conditions [3]. When in contact with the biodegradable polymer, the microorganisms produce enzymes that break down the material in progressively smaller segments; they reduce its average molecular mass, favoring its degradation in the environment [4]. Novel Studies are being conducted to prepare new thermoplastic materials[5], composed of blends of synthetic polymer with natural polymer, that are degraded more easily when discarded in the environment[6]. There is great Potential interest in incorporating biodegradable materials such as starch into conventional plastics such as polyethylene [7]. Starch is a polysaccharide that is gaining great importance in the field of new materials and the environment [8]. Besides improving the biodegradable capacity of the microorganisms, the type of starch used in the making of polymeric blends can interfere directly in the properties of the polymer [9]. The polymeric system composed of a mixture of the conventional plastic with the biodegradable polymer is believed to produce a type of plastic material with different mechanical properties [10], presenting resistance to heat, light and humidity. When this material is discarded into the environment, it can be degraded by microorganism whose natural habitat is the same soil [11].

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II. Materials and Methods

The materials and methods are used for the present analysis is the same on that used for Mechanical behavior of Urea Modified Thermoplastics Starch (TPS) and HDPE Blend described elsewhere and detailed explanation for the procedure is therefore omitted here.

III. Results and Discussion

A. Surface Morphology of Blend:

The surface morphology of corresponding HDPE/Starch blends. `(Fig.1 a, b, c,) Shows uniformly distributed and firmly embedded starch particles into the HDPE matrix. Also, the two phases are not easily distinguished as in the case of HDPE / Starch blends. The difference in the interaction of starch and HDPE is clearly seen from (Fig. 1 d, e) for the HDPE / thermoplastic Starch Blends, where both the firmly embedded starch and loosely dispersed starch granules are seen.

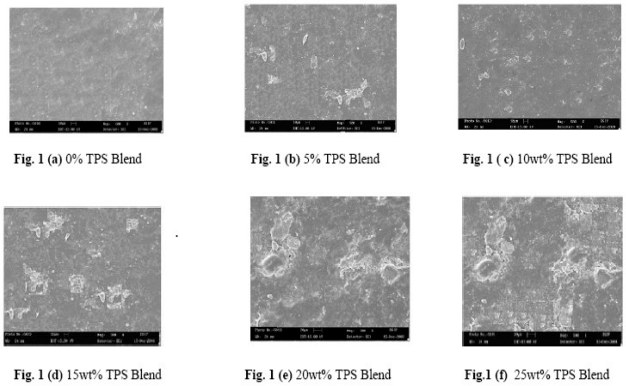


Fig. 1. SEM Micrograph (a to f) of different HDPE / TPS Blends

Figure (Fig 1 f) shows the morphology of HDPE / Starch

blends. Comparison of micrographs of 20wt% and 15% wt% TPS Blend shows that during the fracture process the particles in 20wt% TPS blend are pulled out leaving holes. As such holes were not created in the 15wt % and 10 wt % blends. It is expected to better mechanical properties than the 20wt%TPS Blend. The complete miscibility of the two phases in 5wt%, 10wt% TPS Blends Fig 1. suggests better tensile properties.

B. Biodegradation

In the studies of microbial growth on the starch as sole carbon source, it was observed that the starch degrades responded poorly in HDPE. However, the microbes were found to grow on the starch as well. The plot of the whole batches CO_2 Evolution shows greater degradation of starch in the culture medium In (Fig. 2). This may be attributed to crystallinity and hydrophoabicity of HDPE. Generally, the biodegradation occurs preferably in the amorphous region because of the higher mobility of the chains and their higher accessibility to the microbes. Starch, being less crystalline compared to HDPE, is more prone to microbial attack. Further, its hydrophilic nature promotes swelling in the culture medium enhancing biodegradation.The SEM micrographs of starch blends after biodegradation for 720 hrs. In culture medium.(Fig. 3: b, c, d) shows that starch is readily used as a carbon source by microorganism. Soil burial of HDPE and the blends using microorganism biotic waste compost as well as aqueous medium were carried out as described earlier .It was observed that HDPE as well as blends showed no change in weight in biotic medium. A steady increase in the weight loss was observed with increasing time. (Fig.3: a to f) shows that there is increase in degradation of binary HDPE- TPS blends with increasing starch content. At the end of 30 days, the percentage weight loss in the blends containing 90 wt%,85 wt%, 80 wt% HDPE was found to be 0.198%, 0.369%, 0.563%, 0.589% respectively. The observed higher degradation in soil with increasing starch content may be considered as an evidence for decrease in molecular weight of starch due to fragmentation during the retrogadation. Further, soil from wheat field and biotic compost medium contains various types of microorganisms. The possible degradation pathway of starch may be due to the following particular enzyme secreted by microorganisms, an amylase acting on starch to produce reducing sugars. In comparison of plots of different batches, biodegradation, weight loss, high value of rate constant, 15% 20%, 25%TPS Batches play a dominant role in throughout batches. As the TPS wt % is increased in the blend, the biodegradability rate constant was investigated in increasing order as starch content.

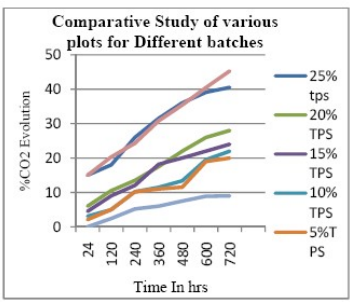


Fig.2. Comparative Study of Biodegradability (CO2 Evolution) For Various Batches in HDPE – TPS Blends.

TABLE 1. BIODEGRADABILITY RATE CONSTANT ("K") AND WEIGHT LOSS PERCENTAGE

TPS %	"k" value	Weight(in gm) before biodegradation	Weight(in gm) after biodegradation	% loss in weight
0	0.03765	0.5340	0.5330	0.1872
5	3.20	0.4595	0.4585	0.2176
10	3.198	0.5050	0.5040	0.1980
15	3.933	0.4065	0.4050	0.3690
20	4.700	0.3550	0.3530	0.5633
25	7.260	0.4580	0.4553	0.5895

C. SEM after Biodegradation:

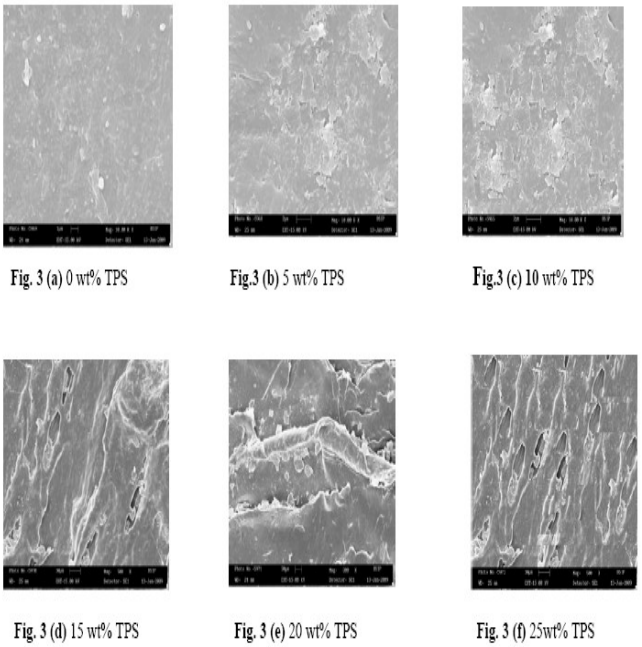


Fig. 3 (a) 0 wt% TPS Fig.3 (b) 5 wt% TPS Fig.3 (c) 10 wt% TPS

Fig. 3 (d) 15 wt% TPS Fig. 3 (e) 20 wt% TPS Fig. 3 (f) 25wt% TPS

Fig. 3. SEM Micrograph after biodegradation of different HDPE / TPS Blends

D. Soil Burial Test

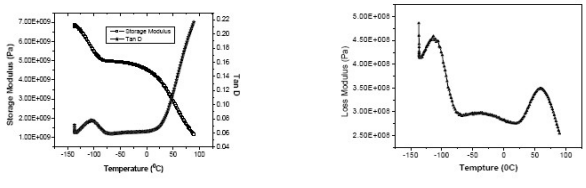
The biodegradability of sorbitol modified starch blended with HDPE was estimated using soil burial method. Table 2 predicts the biodegradation of the blends containing different amounts of TPS / HDPE Blends in soil by investigating starch removal. The dry weight loss of the samples after burial in soil for two weeks was determined. The weight loss observed at each time point over the two weeks was larger with increasing TPS Content in the blend. It clarifies that the microorganisms consume starch and create pores in the PE matrix. The rate of weight loss is depended upon the starch content, time duration, nature of base polymer.

TABLE 2. WEIGHT LOSS OF THE BLENDS AFTER SOIL BURIAL.

S.N.	Samples % TPS + HDPE	Percentage(%) of weight loss			
		4 days	7days	10days	14days
1	0	0.003	0.013	0.030	0.083
2	5	0.195	0.210	0.217	0.225
3	5	0.197	0.213	0.216	0.223
4	10	0.210	0.225	0.235	0.243
5	10	0.209	0.227	0.232	0.240
6	15	0.225	0.238	0.245	0.260
7	15	0.227	0.236	0.242	0.258
8	20	0.238	0.248	0.262	0.286
9	20	0.240	0.251	0.263	0.289
10	25	0.255	0.264	0.285	0.303
11	25	0.251	0.268	0.288	0.310

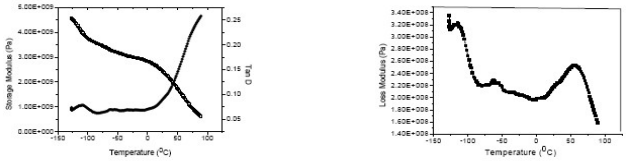
E. Dynamic Mechanical Analysis (DMA)

The viscoelastic behavior of neat HDPE resin and HDPE / TPS Blends were characterized by DMA.The storage modulus of the Blend s (Fig 4. a to f) with increasing % of modified starch in base polymer were being noted in decrease. However Storage Modulus is decreased with accordingly Temperature range from Tg of base polymer to 100^0C. Loss Modulus of different batches was estimated a little change in modulus than base polymer (HDPE) with temperature variation. In initial, in decreasing order, in later, a little increase in value with temperature, in short all batches showed a little flow variation in plots w.r.t. Temperature range. 5 % TPS batch were noted a few change in viscoelastic nature as comparison to pure HDPE batch. But 10 % TPS and 15 % TPS Batches (as in Fig. 4 c to d) predicted changes in modulus nature, loss modulus after some temperature value were increased to a little high value .But Storage Modulus showed a consistency in nature with increased % of modified starch particle in HDPE base polymer. 20% and 25 % TPS batches was observed in similar for output in according with storage, loss modulus properties. In all batches TPS-HDPE value was predicted as increasing order, TPS-HDPE value showed a consistent in order of result. A little changes in Tg was predicted for blends with % of TPS content in base polymer. Pure polymer HDPE chains are stiffness in nature, high crystalline, denser than modified starch blended batches; denser, crystalline polymer has restriction for mobility, freely movement of chains. So polymer morphology does not feel degree of freedom for movement. Therefore polymer (pure) has high modulus in viscous properties than starch blended polymer. As the % of TPS are incorporated in HDPE Base polymer, Disintegration, Retrogadation of pure starch molecule dispersed in HDPE chains. More % of TPS (15, 20, 25) incorporated in base polymer shows decrement in modulus properties accordingly with composition.



a (i) a(ii)

Fig. 4 (a). DMA Plot of pure HDPE (0% TPS)

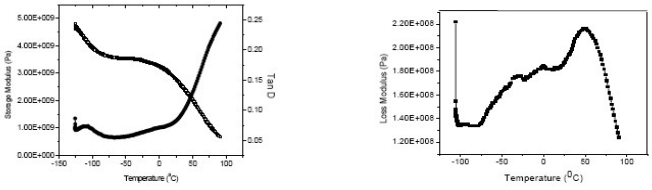


b(i) b(ii)

Fig.4 (b). DMA Plot of 5% TPS + HDPE

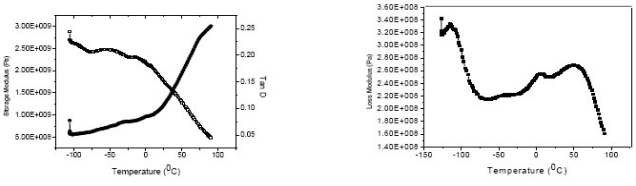
c(i) c(ii)

Fig. 4 (c) . DMA Plot of 10 % TPS + HDPE



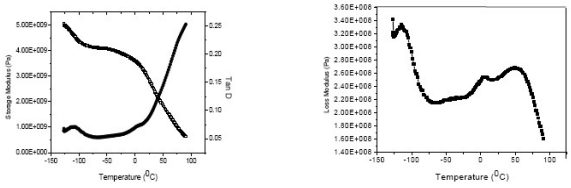
d(i) d(ii)

Fig. 4 (d). DMA Plot of 15 % TPS + HDPE



e(i) e(ii)

Fig. 4 (e). DMA Plot of 20 % TPS + HDPE



f (i) f(ii)

Fig. 4 (f). DMA Plot of 25 % TPS + HDPE

Fig. 4 (a to f). DMA Plots of different HDPE / TPS Blends Showing Storage Modulus, Loss Modulus, Tan D with Respect to Temperature range

IV. CONCLUSIONS

The study revealed that biodegradable plastics from starch soluble, HDPE were successfully produced through a melt mixing method. It was observed that modification of starch leads to an increase in the thermoplastic character, thermal stability, hydrophoabicity and crystallinity.

Starch exhibited a crystalline nature which was confirmed by SEM micrograph and a sharp melting point. The smooth surface of granular starch is modified rough which leads to improved adhesion. Among the binary HDPE / Starch Blends , 20 wt%, 25 wt% TPS Blends was found to show poor mechanical properties due to poor interaction which can be seen from the morphology.

Chemical, Water absorption behavior of HDPE – TPS blend helm decrease with increase the TPS percentage due to degradation, deterioration of starch molecule through moisture and starch hydrophilic nature. Biodegradability of TPS blend increased with the % of TPS in blend, since starch concentration associates the degradation through microorganism in aqueous medium. Higher concentration of TPS causes considerable compatibility between bacterial phase and chemical strength of plastic.

DMA tests show that the storage modulus dramatically decrease by about 15%, 20%, 25% TPS particle in HDPE polymer. Stiffness, Modulus nature was being observed as minimum for more loading of starch content.

Glass Transition Temperatures were noted a few degree changes for high TPS % content batches for minimum value. 5% , 10% TPS Batches did play a significant role in viscoelastic properties, No gradual changes were observed for both batches in reference with modulus, stiffness etc. in comparision with pure HDPE Base Resin are recommended.

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