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Preparation of Sustainable Biobased Compound of PLA/PBAT/PBS: Study on Processability There of

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Abstract

As a result of the overuse of conventional plastic products in daily applications by human being and as per data available only 9-10% is recycles out of whatever is produces to the date, compostable plastics such as poly (lactic acid) (PLA) and poly (butylene adipate-co-terephthalate) (PBAT) have been extensively uses in many applications as an alternative to conventional plastics due to its biologically degradable properties. These plastics offer the circularity of the carbon cycle. However, each of them has advantages and disadvantages. PLA and PBAT are the polymers on which several researches have been done. Compounds of these two polymers have been prepares with and without chain extenders and properties have been studies. Now a days many compostable and biodegradable polymers have been synthesised, irrespective of its monomer root, whether naturally available or fossil bases. One of the newly developed polymer polybutylene succinate (PBS) has also gains the attention of manufacturers due to its unique properties. The ternary blend of PLA/PBAT/PBS are therefore very interesting in terms of phase morphology and their physical properties while offering compostable practices. In this work, we have prepared different blends of PLA/PBAT/PBS with and without use of chain extenders and calcium carbonate as a filler. Study has been done on blown film extrusion machine to evaluate processability.

Keywords: PLA - Poly lactic acid, PBAT - Poly (butylene adipate-co-terephthalate), PBS - Polybutylene succinate, CE – Chain extender

1. Introduction

Poly (butylene succinate) (PBS) one of the newly developed biodegradable polymers was also reported for increasing the ductility of PLA/PBAT-based blends. Interestingly, PLA/PBS blends with a PLA matrix were found to make them interesting for producing films for secondary packaging. Furthermore, study of tri-continuous blends/compounds consisting of PLA, PBAT, and PBS have shown promising for preparing biobased blends with properties similar to poly(ethylene) [1-2s]. Due to phase distribution, it is difficult to control manufacturing. Moreover, in terms of cost and environmentally friendly nature PLA-based blends are more promising, as PLA is derived from natural resources, whereas PBAT and PBS are synthesized from non-renewable resources. As plants for producing succinic acid from biomass have been developed nowadays PBS will soon be produced completely from renewable sources [2]. Also, PBAT may be renewable, as one of its monomers, 1,4 Butane diol is now available from natural resources [3]. The production of flexible films by using compostable plastics can be particularly important because they can be used for preparing low apparent-density packaging, such as pouches or bags, or multilayer packaging. Generally, it is extruded on blown film extruders. Compostable polymers such as PLA, PBS and PBAT are widely used in many applications [4]. PLA is a polymer of lactic acid which is derived from natural resources. Because of its mechanical properties, high brittleness due to its molecular structure which is not suitable for the blown film extrusion process PBAT (polybutylene adipate -co-terephthalate) is blended or compounded with PLA [5-7]. PBAT is one of the finest flexible polymers and also possess biodegradability due to the presence of an adipate unit in it, is the most suitable polymer for compounding and is useful in manufacturing film and likewise application when compounded with PLA [8-12]. During the blown film extrusion process, it is important to maintain melt viscosity and melt strength. In these cases, the use of chain extenders will help in improving melt viscosity and so the melt flow of the ternary blend of PLA/PBAT/PBS. Further addition of $CaCO_3$ is also improves melt strength [13]. Mechanical properties of PLA and PBAT and PBS is mentioned in below Table 1 [14-18].

Table: 1 Mechanical properties of PLA and PBAT and PBS

Sr. No.	Properties	PLA	PBS	PBAT
1	Glass transition Temperature C°	55-60	-32	-30
2	Melting point	155-175	114	115-125
3	HDT	55	97	55
4	Tensile strength	55-70	34	21
5	Elongation at break %	4 to 7	560	670
6	Derived from renewable resources	Yes	Partly	No
7	Biodegradable at 70 C°	Yes	Yes	Yes
8	Biodegradable 30 C°	No	Yes	Yes

In this study, we have replaced a certain % of PLA with PBS to produce different compounds of PLA/PBAT/PBS. The ternary compound of PLA/PBAT/PBS prepared with three different formulations for compounds and also did the blown film extrusion and studied the effect of PBS on processing parameters.

2. Experimental:

2.1. Material:

Compounds of PLA, PBAT, and PBS namely A1, A2, and A3 were prepared at Sunny Enterprises having a composition as per Table 1. Melt flow indexes (MFI) of the compounds A1, A2, and A3 were as per given in Table 2. The filler masterbatch of $CaCO_3$ was purchased from Vision industries. The Blends of A1, A2, and A3 with filler masterbatch of CaCO3 were prepared. The Blends of PLA, PBAT, and Chain extender and the Blends of PLA, PBAT, and Chain extender with the Filler masterbatch of CaCO3 were also prepared to compare processing parameters as per Table 3.

Sr. no.	PLA	PBAT	PBS	CE
A1	30	60	10	0.2%
A2	20	60	20	0.2%

A3	10	60	30	0.2%

Table 1

Compound	**A1**	**A2**	**A3**
MFI 190°C, 2.16 Kg	7.94	8.98	12.12

Table 2

Sr. no.	**PLA**	**PBAT**	**CE**	**$CaCO_3$ Filler**
B1	30	70	0	0
B2	30	70	0.2%	0
B3	30	70	0.2%	20%

Table 3

The composition of Blends of A1, A2, and A3 with Filler masterbatch of $CaCO_3$ was as shown in Table 4.

Sr. no.	**Compound A1**	**Compound A2**	**Compound A3**	**$CaCO_3$ Filler**
B4	100	0	0	0
B5	0	100	0	0
B6	0	0	100	0
B7	100	0	0	20
B8	0	100	0	20
B9	0	0	100	20

Table 4

2.2. Preparation of Blown Film:

Blown films of blends of compounds and compounds with $CaCO_3$ were shown in Table 3 and Table 4 were extruded using a blown film extrusion machine (Five-star engineers, 45 mm). The temperature of different zones of the extruder was as per Table 5.

Zone	1	2	3	4	5
Temperature °C	135	152	155	152	155

Table 5

The extruder die with a diameter of 125 mm and a die gap of 1.8 mm was used for the experiment. The L/D ratio of the screw was 28:1. The blow-up ratio (BUR) of the blown film was 1.3.

As seen in Table 3 and Table 4, we have prepared all the blends. Before taking it to the blown film extrusion process, we dried all the blends in a hopper drier @ 75^{0} C for 3 hours. After drying, as seen in table 3 blown film of blend B1 was extruded at 500 to 510 rpm. After that blown films of B2, and B3 blends were extruded respectively by keeping the heat profile and screw rpm constant, and thickness was measured.

We have done the blown film extrusion process of blends B4, B5, and B6 at 500 to 510 rpm by keeping the heat profile of the extruder unchanged. After that, we have done the blown film extrusion of blends B7, B8, and B9 at same rpm by keeping the heat profile of the extruder unchanged (B4, B5 and B6 with a 20% $CaCO_3$ masterbatch). The thickness of all film extruded from all the blends was measured. It was observed that films extruded from PLA/PBAT blend have the highest thickness.

3. Result and discussion:

When compound B4 was extruded as seen in table 4, where we have replaced 10% of PLA by PBS, thickness decreased compared to B2. Further reduction in thickness was observed when compound B5 in which 20% of PLA was replaced by PBS and compound B6 in which 30% of PLA was replaced by PBS. Data obtained for the thickness of the film extruded of compounds and blends were noted and are shown in table 6.

Blend	B1	B2	B3	B4	B5	B6	B7	B8	B9
RPM	507	510	508	511	508	515	508	511	510

LOAD (A)		12.8	14.3	15.6	10.9	10.5	10.1	14.6	13.2
Thickness (μ)	48.9	56.2	65.58	39.05	36.96	34.28	62.6	57.02	53.66

Table 6

From the data obtained it is observed that when a blend of PLA and PBAT, B1was extruded at 507 rpm the film thickness obtained was 48.9 microns. After that, keeping all parameters like the main motor speed at 510 rpm and take up roller speed unchanged, and the heat profile of the extruder unchanged, with 0.2% chain extender load of main motor and thickness increased. Similarly, when B2 was extruded with 20% $CaCO_3$ masterbatch again load of main motor and thickness increased.

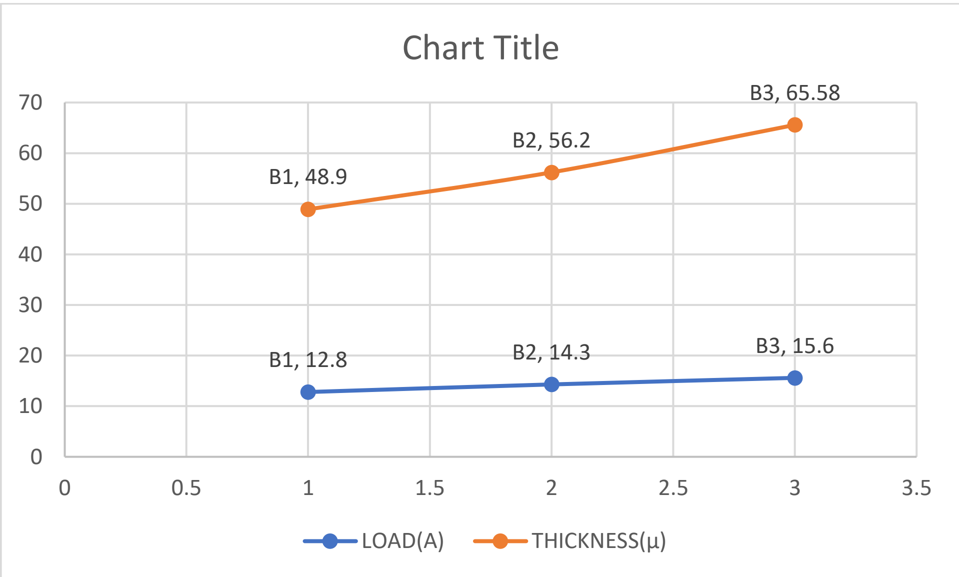

Fig. 1 Comparison of load and thickness for compound B1,B2 and B3 s

Now 10% PLA replaced by PBS in compound B2 (compound B4) the thickness was reduced to 39.05 microns. When we replaced 20% and 30% PLA with PBS, compound B5 and B6, the thickness was further reduced to 36.96 microns and 34.28 microns respectively. It shows that with an increase in the quantity of PBS in PLA, PBAT and PBS compound with CE 0.02%, the output of the extruder dropped and so did the thickness of the film.

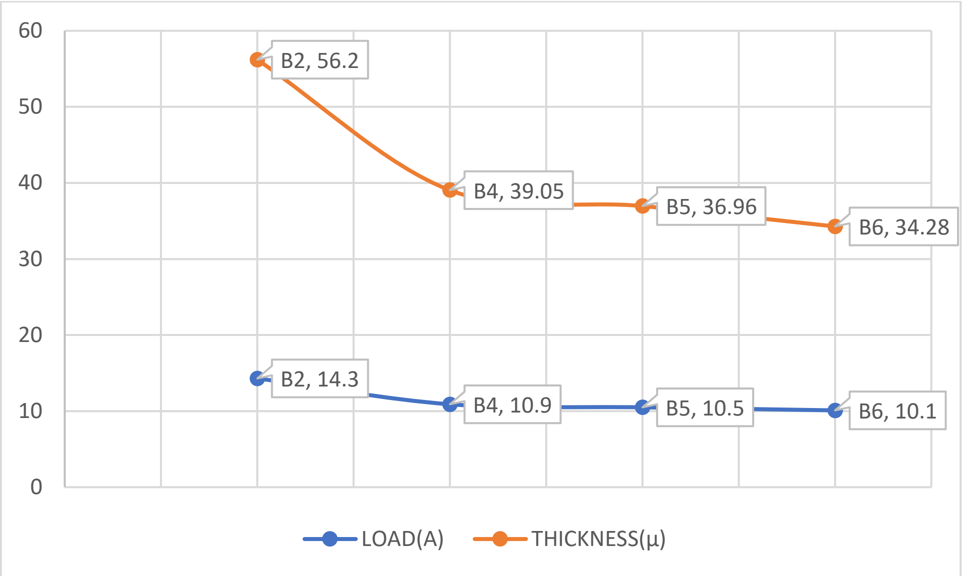

Fig. 2 PBS % v/s Thickness (μ)

We have also used 20% of the $CaCO_3$ filler master batch along with compounds B4, B5, and B6 which is shown in table 6 as compound B7, B8 and B9. When the blend of these compounds was extruded along with 20% CaCO3 calcium filler masterbatch, the thickness of the extruded film obtained was 62.6,57.02 and 53.66 microns. These results were also in line with previous results.

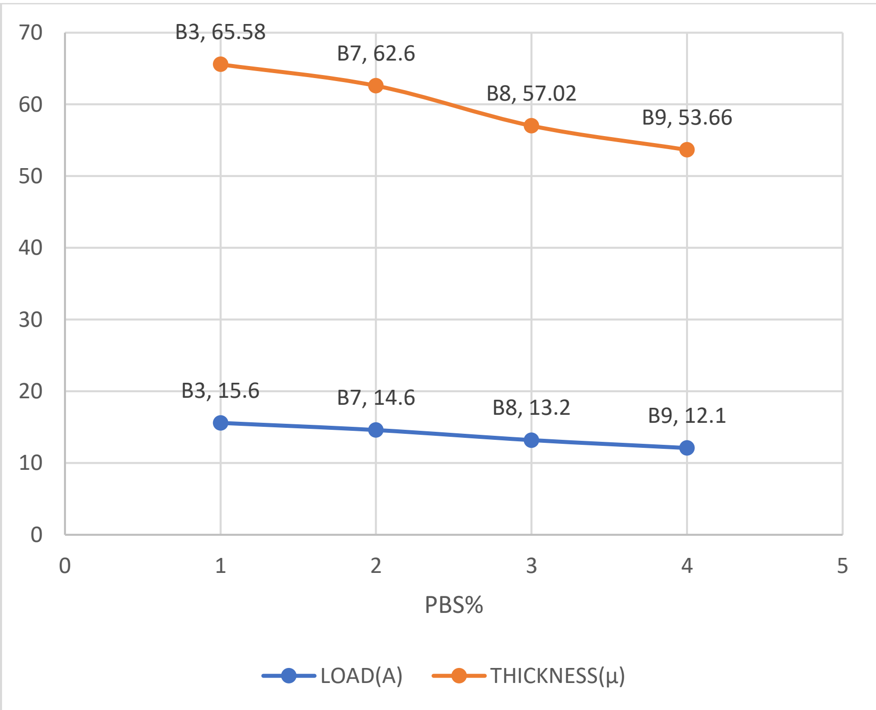

Fig. 3 B3, B7, B8, B9 Thickness (μ) and Load (Amp).

4. Conclusion:

So, from all the above observations and results obtained, we can conclude that an increase in the concentration of PBS % in PBAT/PLA blends or compounds reduction in the thickness of the film extruded and ampere load of the extruder motor was reduced at constant rpm of extruder motor and take up rolls and so the production was also decreased.

Similarly, we also come to the conclusion that the effect of chain extender and $CaCO_3$ masterbatch when added to PLA/PBAT compound and PLA/PBAT/PBS compound, thickness as well production increased compared to without addition of chain extender and $CaCO_3$ masterbatch in the same. In short addition of a chain extender provides good compatibility among PLA/PBAT and PLA/PBAT/PBS so the melt flow index (MFI) improves. Due to improvisation in MFI, ampere load of the main motor increased and so the output also increased. With the incorporation of CaCO3 into the compatibilized blend, some agglomeration of $CaCO_3$ was observed in the polymer matrix. Due to agglomeration ampere load of the main motor increased and so did the overall production.

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