# Polymer Blends from Poly(L-lactic acid) and Poly(butylene-succinate-*co*-adipate)

**N. Srisawat[1], S. Pivsa-Art[1], S. Pavasupree[1], N. O-charoen[1], W. Pivsa - Art[1] and N. Suwannamek[2]**

***Abstract*** *- Biodegradable materials can use in many products such as textile, packaging, agriculture and others. PLA and PBSA have been getting more interest due to their biodegradable property. PLA is a hard and transparent polymer with the additional of PBSA or copolyester can increase the flexibility, processability and thermal properties of the compound. The PLA biodegradable process needs water to be hydrolyzed and composed while PBSA can be hydrolyzed and biodegraded faster. In this study, PLA and PBSA were blended at 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 and 0:100. The blends polymer produced from extrusion process and compressed for characterize. Thermal, mechanical and physical properties were measured.*

***Keyword*** – **Biodegradable, PBSA, PLA**

## 1. INTRODUCTION

Textile is the fundamental need for both consumer and industrial markets included with construction and medical application. The textile fiber can be made from natural and synthetic material. Most of them are synthetic fiber from petrochemical industry such as polyester fiber, nylon fiber , acrylic fiber or propylene fiber. As the fiber waste increase every year, there is little amount of them can be recycled. These drive the researcher focus on the biofiber. One of the most promising biodegradable polymer is Poly Lactic acid (PLA), and PLA has mechanical properties for industrial applications [1]. Poly (butylene succinate co-adipate) (PBSA) is obtained by addition of adipic acid. Their molecular weights range from several tens to several hundreds of thousands. The use of a small amount of coupling agents as chain extenders allows the molecular weight to be increased [2]. The main reasons are these biofibers not only can be harvested from renewable resources, but also can be modified to increase there properties compared with synthetic fiber. Fiber melt spinning technique is economical and efficient for manufacture these biofiber. PBSA can be biodegradable faster than PLA. With hydrolysis process, PBSA can degrade and follow by microorganism process. PBSA has good mechanical properties and dyability while PLA can tolerate the moisture. The blend polymer of PBSA and PLA can introduce another way to produce biofiber material for textile industry.

## 2. EXPERIMENTAL

### 2.1 Material

Poly (lactic acid) (PLA; MFI 10-20g/10min, 190°C/2.16 Kg) was obtained from NatureWork® (product name – NatureWork® PLA Polymer 3001D). Polybutylene succinate adipate (PBSA; MFI 1.4g/10 min at 190°C/2.16kg) was obtained from Showa Highpolymer Co.,Ltd. (product name – Bionolle® 3001

### 2.2 Blending processing

Prior to processing, the PBSA and PLA were dried under vacuum at 80°C for 24 hrs. Both polymer were mixed at different ratio of PLA:PBSA; 100:0 ,90:10 ,80:20,70:30,60:40,50:50 and 0:100. The blend polymer was extrude at 80 rpm at temperature of 140, 150, 160, 170 and 165 °C for zone 1, 2, 3, 4 and 5 consequently with a twin screw extruder (Barbender, Duibury, Germany) from 4 of 5 mm diameter holes. The extruder has a screw length 150 mm and a L/D of 20. In order to achieve the desired specimen sample for different measurement and analysis, the blend polymer was cut as a chip and put in the compression mold at 210 C for 10 min of preheat time, full pressure and cooling time. Compression-molded samples were placed in a sealed polyethylene bags to prevent moisture absorption

### 2.3 Measurements

#### 2.3.1 Thermal properties testing

Differential Scanning Calorimetry testing (DSC200 F3, Netzsch, Germany) was used to measure the thermal properties glass transition temperature and melting point of blend polymer.

#### 2.3.2 Physical properties testing

The morphology of the impact fracture surface was observed by a JEOL JSM-S410 LV scanning electron microscope (SEM) with field emission filament. An accelerating voltage of 10kV was used to collect the images. A gold coating was applied on the impact fracture surfaces.

#### 2.3.3 Mechanical properties testing

The melt flow indexer (XRL-400) from Chengde Jingmi Testing Machine, China was performed MFI measuring. For tensile measurement, a mechanical testing machine (Instron® Tensile Tester Model 5560,

[1]N. Srisawat, S. Pivsa-Art, S. Pavasupree, N. O-charoen, W. Pivsa – Art are with Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Thailand

[2]N. Suwannamek is with National Metal and Materials Technology Center, Pathumthani, Thailand

USA) was used to provide tensile strength of the samples according to ASTM D638. The Notched Izod impact strength was measured with a Izod impact machine according to ASTM D256.

## 3. RESULT AND DISCUSSION

### 2.1 Thermal properties

The thermal properties of blend polymer were changed with the ratio of PLA/PBSA. The additional of PBSA to 50:50 has reduced the melting point from 97.5°C to 95°C (Table 1) while at the low percentage of PBSA (90:10), there was no melting point of PBSA. Both polymer has good miscible at lower PBSA percentage also the crystallization of PBSA was increased with additional of PBSA ratio. However, PLA melting points were increased from 151.1°C to 168.6°C and PLA crystallization also increased. For the crystallization after melting point, crystallization temperature (Tc) was found only for the blend polymer between 88.6-91.7°C.

Table 1. Thermal properties of blend polymer chip at different ratio of PLA: PBSA

| Sample | Tm (°C) first peak | Onset (°C) | Tm (°C) | Heat of fusion (J/g) | Tc (°C) |
|---|---|---|---|---|---|
| PLA | - | 143.9 | 151.1 | 28.75 | - |
| PLA50:50 PBSA | 95.0 | 161.3 | 168.6 | 24.54 | 91.7 |
| PLA60:40 PBSA | 95.3 | 162.7 | 171.2 | 30.06 | 89.4 |
| PLA70:30 PBSA | 94.1 | 162.2 | 169.3 | 33.24 | 91.4 |
| PLA80:20 PBSA | 94.6 | 161.7 | 171.4 | 35.58 | 88.7 |
| PLA90:10 PBSA | - | 159.6 | 171.6 | 37.85 | 88.6 |
| PBSA | 97.5 | - | - | - | - |

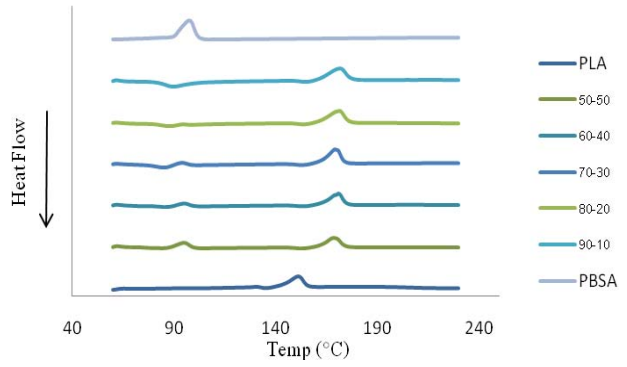


Fig.1. Melting temperature (Tm) from Differential Scanning Calorimetry (DSC)

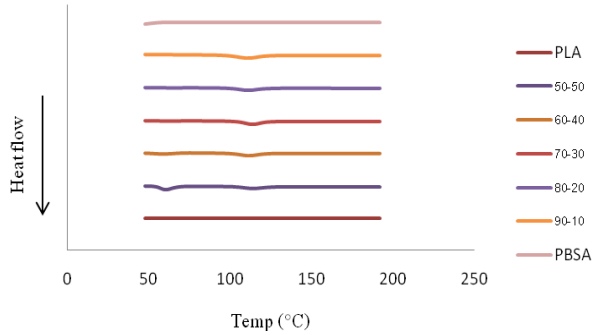


Fig.2. Crystallization temperature (Tc) from Differential Scanning Calorimetry (DSC)

### 2.2 Physical properties

SEM micrographs of the impact fractures surfaces of the sample are represented in Fig.3. The fracture surface of Notched Izod Impact PLA specimen is smooth, no evident of adhesion. The PBSA/PLA blend has rougher surface of adhesion with increasing PBSA ratio.

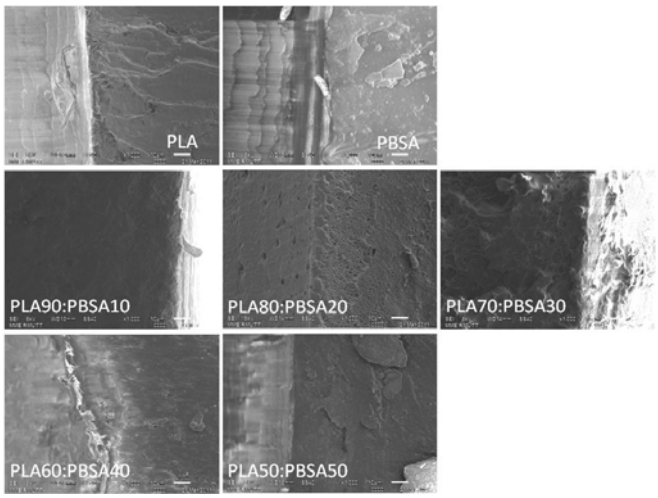


Fig.3. SEM micrographs of impact fracture surface of various ratio of PLA and PBSA (1000X)

### 2.3 Mechanical properties

Melt flow index measurement are represented in Table 2, the MFR of both PLA and PBSA are not different. However, when the blend polymer specimen was test, MFR was increase with PBSA ratio. These came from the amount of PBSA and also the process temperature during mixing which decrease the polymer molecular weight and thermal properties.

Mechanical properties of blend polymer were measured in term of Young's modulus, tensile strength and stress at break. The additional of PBSA decrease all three of them. PLA is brittle polymer while PBSA is softer, the blend polymer has to make as the proper properties for specific applications.

Table 2. Melt flow index results from blend polymer chip at different ratio of PLA: PBSA

| Sample | MFR (g/10 min) | MVR ($cm^3$/10min) | Density ($g/cm^3$) |
|---|---|---|---|
| PLA | 31.02 | 32.87 | 0.94 |
| PLA50:50PBSA | 42.42 | 45.26 | 0.93 |
| PLA60:40PBSA | 40.02 | 54.44 | 0.73 |
| PLA70:30PBSA | 41.52 | 42.55 | 0.97 |
| PLA80:20PBSA | 39.24 | 35.58 | 1.10 |
| PLA90:10PBSA | 34.86 | 31.17 | 1.11 |
| PBSA | 31.92 | 35.15 | 0.90 |

Table 3. Tensile results from blend polymer chip at different ratio of PLA: PBSA

| Sample | Young´s Modulus (MPa) | Tensile Strength (MPa) | Stress at Break (MPa) |
|---|---|---|---|
| PLA | 2122.5 | 44.97 | 44.97 |
| PLA50:50PBSA | 1078.5 | 12.67 | 12.35 |
| PLA60:40PBSA | 1329.63 | 20.34 | 20.17 |
| PLA70:30PBSA | 1413.33 | 26.24 | 25.84 |
| PLA80:20PBSA | 1745.7 | 28.70 | 28.44 |
| PLA90:10PBSA | 1828.76 | 30.80 | 30.70 |
| PBSA | 279.43 | 15.58 | 14.34 |

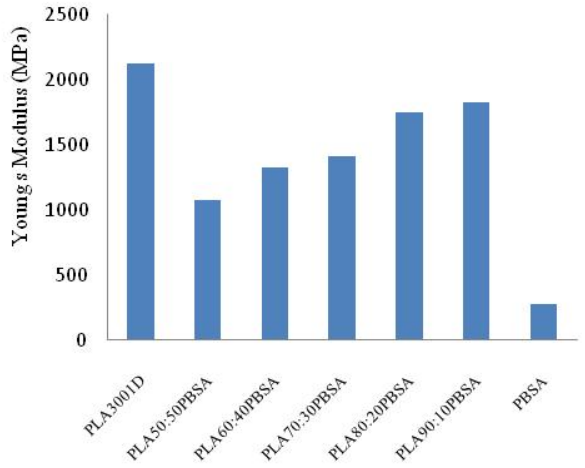


Fig.4. Young's modulus (MPa) at different ratio of PLA: PBSA

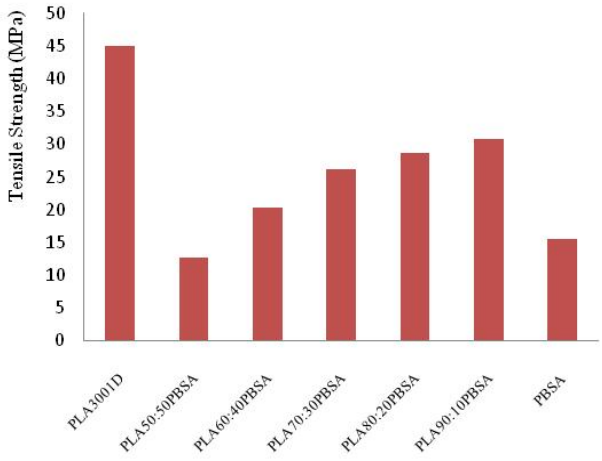


Fig.5. Tensile strength (MPa) at different ratio of PLA: PBSA

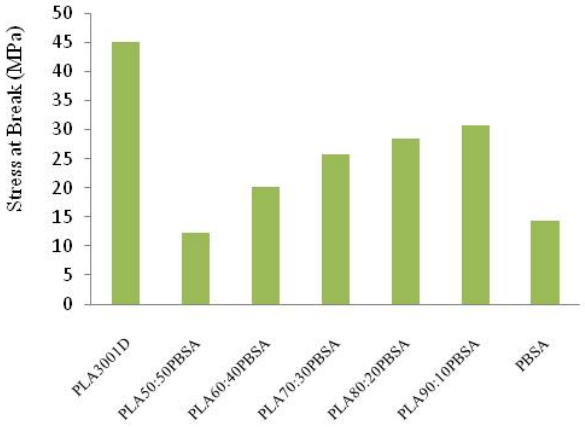


Fig.6. Stress at break (MPa) at different ratio of PLA: PBSA

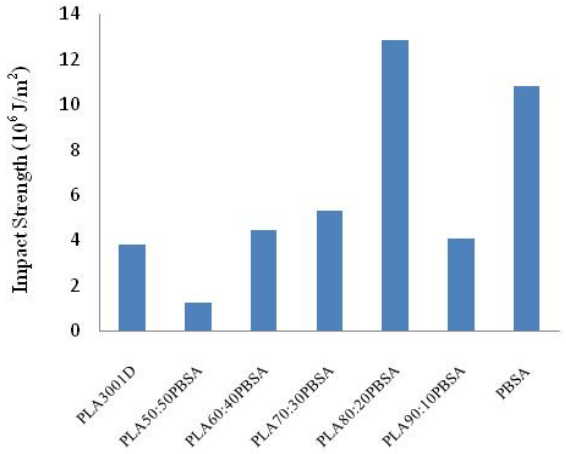


Fig.6. Impact strength ($10^6$ J/m$^2$) at different ratio of PLA: PBSA

The notched izod impact strengths of various PLA and PBSA are shown in Table 4 and Fig.7. As seen in Table 4, the impact strength of PBSA has the highest at 19.062 J/m and the impact strength of PLA is 7.794 J/m. When two polymer were blended, the 80:20 PLA:PBSA is 14.470 J/m which higher than PLA (7.794 J/m) which represented the addition of PBSA can change the crystalline structure of the matrix in some way, which increase the impact strength.

Table 4. Izod impact strength at different ratio of PLA: PBSA

| Sample | Izod impact (J/m) |
|---|---|
| PLA | 7.794 |
| PLA50:50PBSA | 6.384 |
| PLA60:40PBSA | 7.236 |
| PLA70:30PBSA | 9.388 |
| PLA80:20PBSA | 14.470 |
| PLA90:10PBSA | 6.396 |
| PBSA | 19.062 |

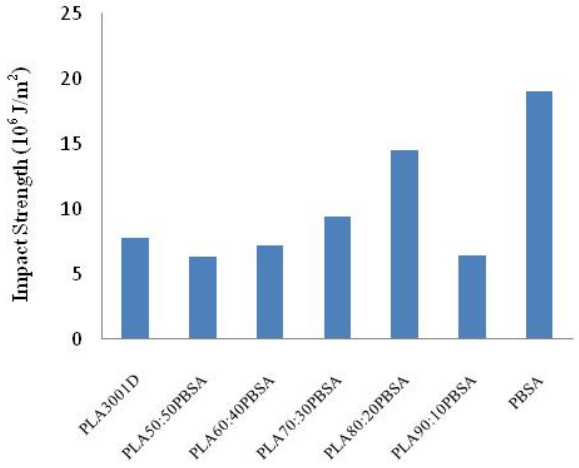


Fig.7. Izod impact strength (MPa) at different ratio of PLA: PBSA

## 4. CONCLUSIONS

The mechanical and thermal properties of the blend polymer PLA/PBSA were investigated and are compared with that neat resin. There are the slightly different of thermal properties of neat and blend polymer. The melt flow index of polymer blend was increased with PBSA ratio. Compare to the PLA polymer, the tensile, young's modulus and the impact strength of polymer blend were significantly high as a result of PBSA.

## ACKNOWLEDGMENT

The authors would like to thank Bioplastic Program (BP21/52) under support from National Innovation Agency (NIA) / Kasatsart University (KU) for financial support.

## REFERENCES

[1] Guo, W.; Ashida M. *J Appl Polym Sci.* **1993**; 50, 1435.

[2] Takiyama, E.; Fujimaki, T. *Biodegradable Plastics and Polymers*; Doi, Y., Fukuda, K., Eds.; Elsevier: Amsterdam, The Netherlands, 1994; Volume 12, p. 150.