

The Effect of Different Compounding Methods on Microstructure and Rheological Properties of Polylactic acid/Polyolefin Elastomer Blends

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ABSTRACT

In this work, poly lactic acid (PLA)/polyolefin elastomer (POE) blend with various compositions was prepared by different melt compounding methods. The effect of two compounding methods on microstructure and rheological properties of the blends was investigated. In both compounding methods, the droplet-matrix morphology of the blends was observed by the Field Emission Scanning Electron Microscopy (FESEM). Microstructural development of the PLA/POE blends was examined according to the method of compounding. Based on the micrographs, it was observed that the drop size of the dispersed POE phase mixed by the minicompounder compared with an internal mixer was reduced more significantly. Also, it was seen from the rheological measurements that the PLA/POE blends prepared by the minicompounder showed higher elastic properties and a larger melt viscosity. Using the two mixing methods, a significant variation in the results from both the microstructure and the rheological properties for the blends was observed. Finally, the results showed that the blend performance was strongly dependent on the compounding method and composition of the POE in the blend.

Keywords: Minicompounder- Internal mixer- PLA/POE blend- Morphology- Rheology.

1. INTRODUCTION

With the rapid growth of plastic consumption, millions of tonnes of wastes were produced all over the world. In recent years, new materials derived from some renewable sources have been replaced with the traditional petrochemical plastics in order to reduce the wastes and the pollution problems and also decrease the dependence on non-renewable sources.

Poly lactide (PLA) is a thermoplastic aliphatic polymer that derives from renewable sources. Compared with other biodegradable polymers, PLA shows high mechanical properties [1,2]. However, applications of PLA due to its high brittleness, low melt strength and melt stability is limited. To increase the flexibility of PLA, it is possible to add a low molecular weight plasticizer or blending it with a flexible polymer, such as elastomers [3] to [6].

Polyolefin elastomers (POEs) are an excellent impact modifier for plastics, and offer unique performance capabilities for compounded products. Generally, saturated polymers such as polyolefin elastomers produce superior toughness, excellent thermal stability and recyclability [6].

The main objective of the current research is to evaluate effects of different compounding methods and content of POE on the microstructure and rheological properties of poly lactic acid toughened by polyolefin elastomer.

2. EXPERIMENTAL

2.1 Materials

Poly lactic acid is a semicrystalline material purchased from Natureworks. Polyolefin elastomer is an ethylene-1-octene copolymer purchased from the LG Chem. The characteristics of commercial grade polymers employed in this research are illustrated in Table 1.

Table 1. *The specifications of the polymers*

Polymer	Grade	Density (g/cm ³)	MFI(g/10min)
PLA	2003D	1.24	6
POE	LC565	0.78	5

2.2 Methods

Prior to melt compounding, the poly lactic acid was dried for 2 hours at 80°C in an oven.

The samples used in this study are summarized in Table 2, prepared in brabender internal mixer (WTH55) and minicompounder (KARANGIN) at 200°C. The compounding duration for internal mixer and minicompounder were 10 and 2 minutes, respectively. Also the blending, using both internal mixer and minicompounder, were carried out at rotor speeds of 40 and 150 rpm, respectively.

The dynamic rheological properties were characterized with a parallel plate geometry using an Anton Paar MCR 102 rheometer (Graz, Austria).

The morphology was characterized and inspected using FESEM (FEI, NOVA-450, USA). with an acceleration voltage of 5 kV

Table 2. *The sample codes and compositions of the blends mixed in minicompounder and internal mixer*

Sample code	PLA/POE (wt%)	Type of mixer
PLA-m	100/0	Minicompounder
PLA-i	100/0	Internal mixer
P10-m	90/10	Minicompounder
P10-i	90/10	Internal mixer
P20-m	80/20	Minicompounder
P20-i	80/20	Internal mixer
POE-m	0/100	Minicompounder
POE-i	0/100	Internal mixer

3. RESULT AND DISCUSSION

3.1 Microstructure Analysis

To compare the effect of mixing methods, Figures 1 to 2 shows the morphology of the PLA/POE blends with the various compositions that were prepared by these two types of mixers.

Figure 1(a and b) shows the FESEM images of the PLA/POE blends with various composition that were prepared by the minicompounder.

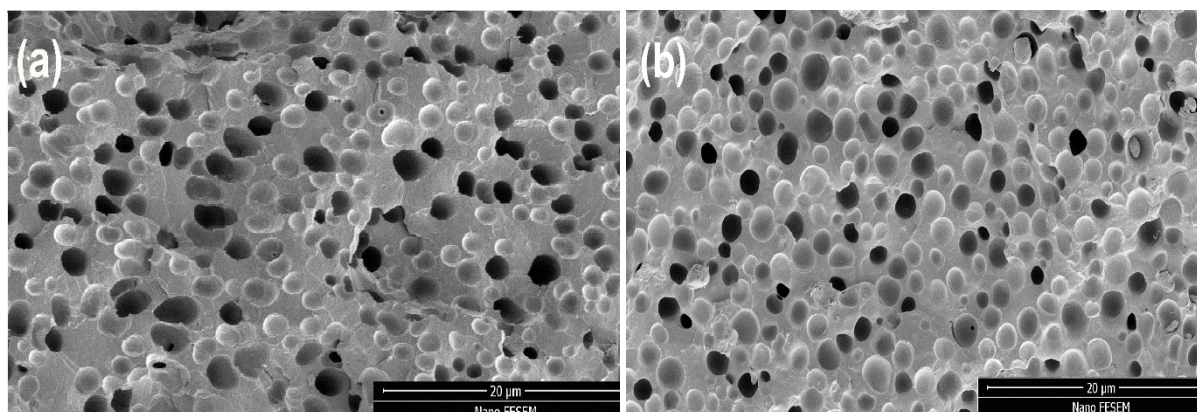


Fig. 1. *FESEM micrographs at 8000x magnification of PLA/POE blends prepared by minicompounder*

(a) 90/10 (b) 80/20

Figure 2(a,b) shows the FESEM image of the PLA/POE blends with various composition that were prepared by the internal mixer.

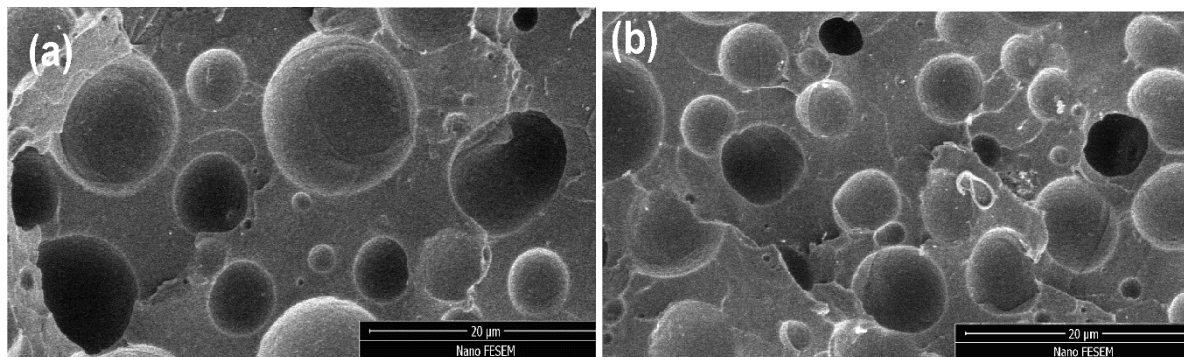


Fig. 2. FESEM micrographs at 8000x magnification of PLA/POE blends prepared by internal mixer

(a) 90/10 (b) 80/20

The images obviously show that the droplet-matrix morphology, which is a typical morphology of immiscible polymer blends. The FESEM images of the fracture surfaces show that the POE droplets are uniformly distributed within the PLA matrix. Figures 1(a,b) and 2(a,b) illustrate that the size of the dispersed POE phase is significantly decreased with increase in POE composition.

By comparing Figures 1 and 2, it can be observed that for the PLA/POE blends at the same composition, the droplet sizes of the POE dispersed phase is larger than the POE droplets in the blends that prepared by the minicompounder. Thus, the mixing type provided by minicompounder can reduce the size of the dispersed phase and allow the formation of morphology with a larger interface between PLA and POE in these blends. Also it can be concluded that the type of mixer only changes the size of dispersed phase.

3.2 Rheological Behavior Analysis

Figure 3 and 4 show the rheological properties of the pure samples and PLA/POE blends with various compositions prepared with minicompounder and internal mixer, respectively.

Figures 3a and 4a show the influence of the various compositions on the complex viscosity for the blends which prepared by minicompounder and the internal mixer method, respectively. As is demonstrated in these Figures, all the blends demonstrate shear thinning behavior and the complex viscosity of PLA increases with the POE content.

Figures 3(b,c) and 4(b,c) exhibit a unique frequency dependence with a general terminal behavior at low frequencies for the storage and loss moduli. While it is observed for the high frequency domain, the addition of POE to PLA can almost lead to a decrease in the slope of diagrams. For the blend containing 20 wt% of POE compared with the other compositions and the neat PLA, the rheological properties are significantly increased. One of the reasons for this increase is the reduction of droplet size in the dispersed phase (Figures 1b and 2b), which results in improving the adhesion between the droplet and matrix phases, leading to the higher values of the rheological properties for the PLA/POE 80/20 blend. So, a good agreement is observed between the rheological behaviors and the corresponding morphological images of these blends.

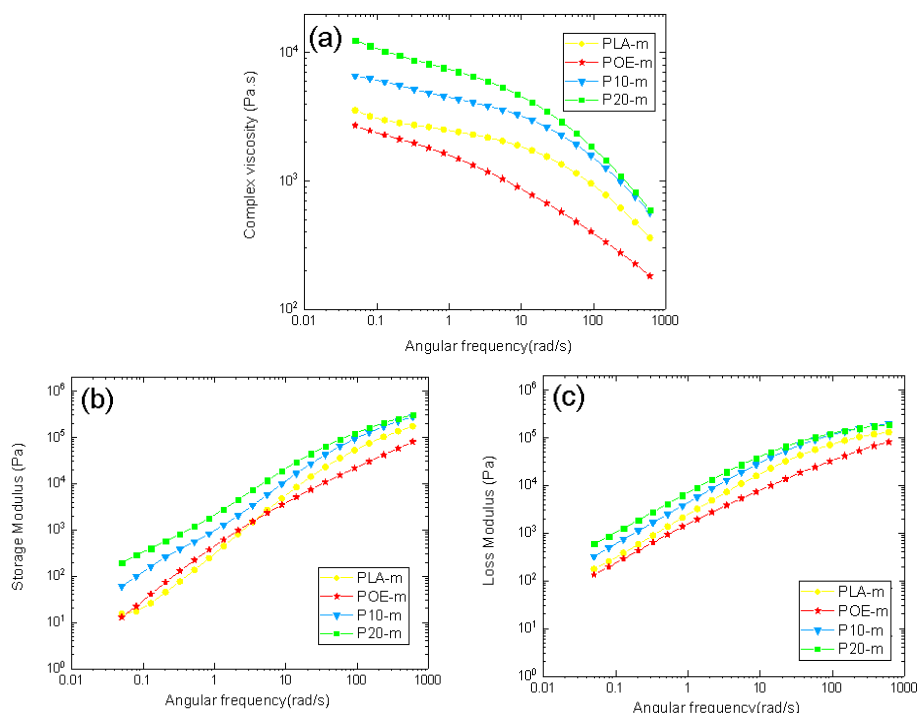


Fig. 3. (a) Complex viscosity (η^*), (b) Storage modulus (G') and (c) loss modulus (G'') as a function of frequency for pure samples and PLA/POE blends prepared by minicomponenter

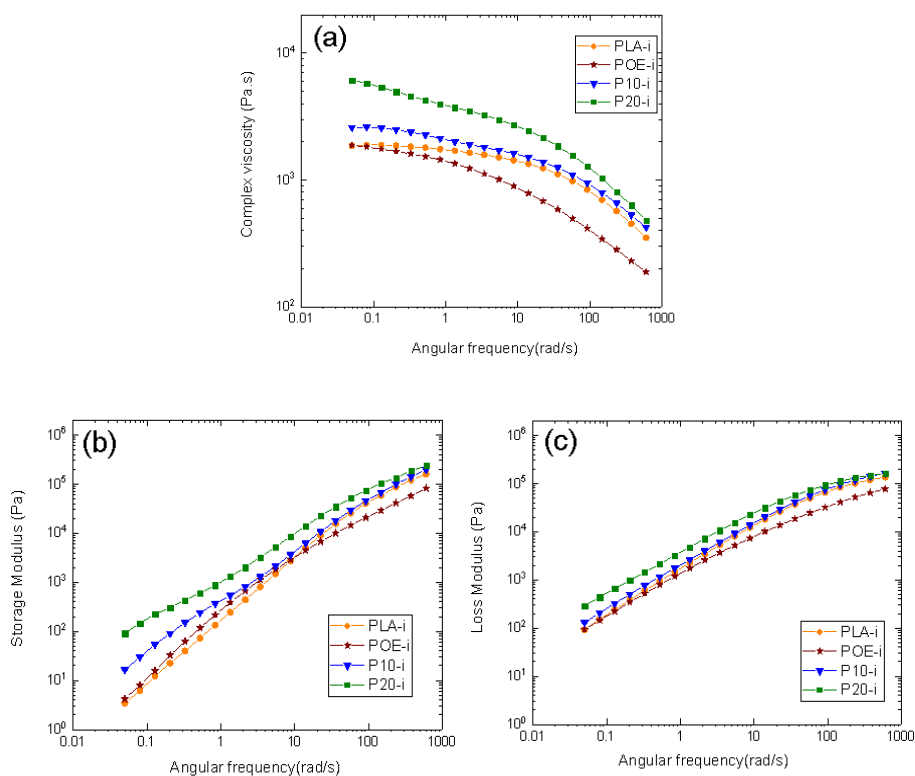


Fig. 4. (a) Complex viscosity (η^*), (b) Storage modulus (G') and (c) loss modulus (G'') as a function of frequency for pure samples and PLA/POE blends prepared by internal mixer

To compare the effect of mixing methods, Figure 5 show the storage modulus of the PLA/POE blends with the various compositions that were prepared by the two types of mixers.

As can be observed from Figure 5, the melt behaviors of the blends are varied through their preparation by the different mixing methods. The storage and loss moduli of blends that prepared by minicompounder is higher than those prepared by internal mixer. Moreover, it is clear that complex viscosity of the prepared blends by minicompounder is higher than that by the internal mixer. This may be the result of the different morphology formed and processing conditions that takes place in the mixers.

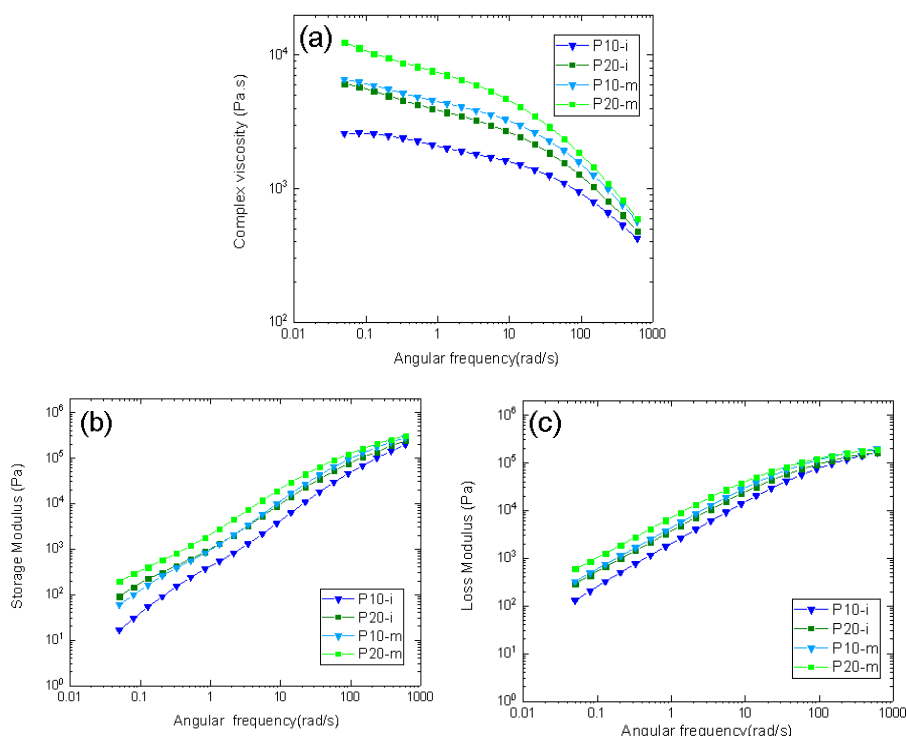


Fig. 5. Comparison of (a) complex viscosity (η^*), (b) storage modulus (G') and (c) loss modulus (G'') as a function of frequency for PLA/POE blends prepared by minicompounder and internal mixer

In general, the blends which were prepared by minicompounder due to higher interfacial area in their microstructure show richer rheological behavior. In another words, the enhancement of the rheological properties of the prepared blends with minicompounder may be due to change in the total interfacial area and relaxation process of the dispersed phase droplets during the oscillatory shear flow.

4. CONCLUSION

The effect of two compounding methods and the polyolefin elastomer (POE) content on the microstructure and rheological properties of polylactic acid (PLA)/POE blends were investigated. The blends exhibited a different microstructure and rheological behavior depending on their compounding method and the POE content.

The FESEM analysis for both compounding methods revealed the homogeneous dispersion of POE particles in the PLA matrix. Based on the microscopy images of the blends, it was observed that the PLA/POE blends prepared by internal mixer have presented the larger droplet size than that prepared by the minicompounder. Thus, the morphological changes may be explained by the mixing process conditions such as distribution of temperature, shear rate and residence time in the mixer. In both compounding methods, a change in the POE composition results in various structures of the blend. So, the 20wt% of POE reduces the interfacial tension and decreases the drop size of the dispersed phase.

Regardless of the mixing method, the incorporation of POE into PLA significantly improves the storage modulus and the melts complex viscosity of the blends. the rheological behavior of all blends presented a higher elasticity than the neat PLA and this behavior was observed with both compounding methods. The PLA/POE blend containing 20wt% of POE exhibit significant increase in the rheological properties compared to neat PLA. Also, the PLA/POE blends prepared by minicompounder showed higher elastic properties and melt viscosity. In conclusion, the results showed that it is

possible to improve the performance of a polylactic acid blends by a suitable choice of the compounding method and composition of POE.

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