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Influence of Compounding Methods on Rheology and Morphology of Linear Low Density Polyethylene/Poly Lactic Acid

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Abstract:
Linear low density polyethylene (LLDPE)/poly lactic acid (PLA) blends were prepared via different melt mixing methods. The effects of various blend compositions and two mixing methods on morphological and rheological behavior of the blends were studied. Scanning electron microscope (SEM) was used to investigate morphology behavior of the blends. The rheological studies illustrated that all samples presented shear thinning behavior and the PLA-rich blends exhibited a Newtonian region. It was found from the rheological measurements that the LLDPE/PLA (75/25 w/w) prepared by batch mixer exhibited higher values of storage modulus and complex viscosity, which is in agreement with the morphology results. In addition, using the different mixing methods, significant differences in the morphological results for the LLDPE/PLA (50/50 w/w) blend were observed. Finally, the results showed that the blends prepared by batch mixer exhibited better morphology, higher storage modulus, and complex viscosity.

Key words:
Linear low density polyethylene, Poly (lactic acid), compounding method, morphology, rheology

1 INTRODUCTION

Thermoplastic polymers are blended to prepare engineering materials for specific end-uses. Engineering applications of polymer composites may be achieved through modification of the disadvantages of neat polymers. Cost saving can also be achieved by blending a high-performance polymer with a cheaper material [1–5]. On the other hand, environmental pollution caused by non-biodegradable plastic materials is now a serious and critical problem all over the world. In recent years, polymeric materials based on renewable resources have received significant attention from both academia and industry [6]. Total or partial substitution of synthetic plastics with biodegradable materials steadily increased and has been shown to be very useful as a solution to the plastic solid waste management problem. The major limitation for the far-reaching use of totally biodegradable polymers is their high cost. To overcome this limitation, partially biodegradable polymers have been developed as a compromise between cost and performance [7].

Polyethylene (PE) is one of the most consumed petrochemical-based polymers, and is mainly used in the packaging industry. It is non-biodegraded by the microorganisms present in the environment. It can be blended with biodegradable polymer in order to produce biodegradable plastic. Among the biodegradable plastics, poly (lactic acid) (PLA) is a suitable candidate due to several good mechanical properties such as high strength, high stiffness, and resistance to fats and oils so that it is readily prepared. Thus, PLA may be a promising polymer for various end-use applications. However it presents several disadvantages such as brittleness, low viscosity, low thermal stability, high moisture sensitivity, medium gas barrier properties, high cost (compared to PE, PP, PS, ...), and low solvent resistance, e.g. against water. Therefore, applications of neat PLA are limited [8, 9]. PLA blended with LDPE offers several benefits, including improved brittleness, ductility, and toughness of the PLA. On the other hand, the blends of LDPE with PLA lead to enhance degradability of LDPE [10–12]. Therefore, these types of blends may be a suitable choice as an alternative to petroleum-based commodity plastics and may be excellent as biodegradable packaging materials.

Several studies have investigated the mechanical, thermal, and morphological behavior of polyethylene and poly (lactic acid) [13–16]. In addition, the rheological properties of polymers have presented important implications in polymer research. They present an important

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smooth fracture surface so that the dispersed phase is distributed more uniformly than the other blends. Figure 6c also shows that for the LLDPE/PLA (25/75 w/w) blend, when the PLA acts as a matrix phase, the droplet sizes of the LLDPE dispersed phase is larger than the PLA droplets in the LLDPE/PLA (75/25 w/w) blend. Moreover, the large droplet dispersed phase with non-uniform distribution is observed for LLDPE/PLA (50/50 w/w) blend, and the change in its structure is considerable as compared to the other samples. To compare the role of mixing methods, Figures 7 to 9 show the morphology of the LLDPE/PLA blends with the various compositions that were prepared by the two types of mixers. As can be demonstrated by these figures, a good agreement is observed between the morphological images and the corresponding rheological behaviors of these blends. For the LLDPE-rich blends which were prepared by batch mixer, some fibers are linking the droplets of the dispersed and matrix phases, which results in improving adhesion between droplet and matrix phases and leading to the higher values of the moduli for the LLDPE/PLA (75/25 w/w) blends. The LLDPE/PLA (75/25 w/w) blend prepared by twin screw extruder has presented the larger droplet size than that prepared by the batch mixer. As seen, the morphology structure of the LLDPE/PLA (50/50 w/w) blend prepared by the twin screw extruder is different from the other samples, and indicates poor adhesion between its matrix and dispersed phases. This structure confirms its rheological behavior with the lowest storage modulus. Thus, the morphological changes may be explained by the mixing process conditions such as temperature profile and screw shear rate in the twin screw extruder. As can be seen from Figure 9, the presence of some partial adhesions in the interface between the two phases in the blends, which are prepared by the batch mixer, are observed. Thus, the mixing type provided by batch mixer can reduce the size of the dispersed phase and allow the formation of a stable morphology for these polymer blends. Comparing the SEM images of the LLDPE/PLA (25/75 w/w) blends, one can conclude that the type of mixer presents no significant effect on the structure of the blend. But the structures of the other samples, particularly for LLDPE/PLA (50/50 w/w), do depend on the mixing method.

4 SUMMARY AND CONCLUSION

In this work, the rheological and morphological properties of the viscoelastic behavior of the LLDPE/PLA blends with different weight percentages, prepared by a batch mixer and twin screw extruder, were studied. The rheological responses were that the reflections of the different morphologies that took place in the blends through the various mixing methods. The results from Han plots showed that these blends exhibit an immiscible structure. These results are in agreement with those obtained through morphological observations. The linear viscoelastic results showed that the incorporation of 25 wt% of PLA into LLDPE led to an enhancement in complex viscosity and storage modulus in the low frequencies in comparison to neat LLDPE that is the presence of the interpenetrated structure in this blend. The shear thinning behavior was observed for neat LLDPE and their blends, except that neat PLA and LLDPE/PLA (50/50 w/w) blend that exhibited a Newtonian region. The storage modulus of all of the blends prepared by batch mixer is higher than that of blends prepared by twin screw extruder. The LLDPE/PLA (50/50 w/w) blend prepared by twin screw extruder showed a lower storage modulus than the other blends and also showed a layered-structure with poor adhesion. Moreover, it can be concluded from the SEM results that the blends prepared by batch mixer provided the well-dispersed phase. As a result, one can conclude that the immiscible blend morphology is influenced by the components compositions and mixing method.

REFERENCES

[1] Utracki LA: Polymer blends handbook, Kluwer Academic Publishers, London (2002).
[2] Paul DR, Bucknall CB: Polymer blends. John & Wiley and Sons, New York (2000).
[3] Lunt J: Large-scale production, properties and commercial applications of polylactic acid polymers, Polym. Degrad. Stab. 59 (1998) 145 – 152.
[4] Maiti S, Jana T: Biodegradable polymers: Polymer recycle and waste management, Anusandhan Prakashan, Midnapore, India (2005).
[5] Hashmi SAR, Kitano T: Effects of state change of liquid crystalline polymer on dynamic visco-elasticity of its blends with polyethylene-terephthalate, Appl. Rheol. 17 (2007) 64510.
[6] Abdolrasouli MH, Nazockdast H, Sadeghi GMM, Kaschta J: Morphology development, melt linear viscoelastic properties and crystallinity of polylactide/polyethylene/organoclay blend nanocomposites, J. Appl. Polym. Sci. 131 (2014) 41300.
[7] Singh G, Bhunia H, Rajor A, Jana RN, Choudhary V: Mechanical properties and morphology of polylactide, linear low-density polyethylene, and their blends, J. Appl. Polym. Sci. 118 (2010) 496 – 502.
[8] Petersson L, Oksman K: Biopolymer based nanocomposites: comparing layered silicates and microcrystalline cellulose as nanoreinforcement, Comp. Sci. Tech. 66 (2006) 2187 – 2196.
[9] Hamad K, Kaseem M, Deri F: Melt rheology of poly (lactic Acid)/low density polyethylene polymer blends, Adv. Chem. Eng. Sci. 1 (2011) 208 – 214.

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[10] Anderson KS, Lim SH, Hillmyer MA: Toughening of polylactide by melt blending with linear low density polyethylene, J. Appl. Polym. Sci. 89 (2003) 3757 – 3768.
[11] Rezgui F, G'Sell C, Dahoun A, Hiver JM, Sadoun T: Plastic deformation of low-density polyethylene reinforced with biodegradable polylactide, Part 1: Microstructural analysis and tensile behavior at constant true strain-rate, Polym. Eng. Sci. 5 (2011) 117 – 125.
[12] Kim F, Choi CN, Kim YD, Lee KY, Lee MS: Compatibilization of immiscible poly(l-lactide) and low density polyethylene blends, Fiber Polym. 5 (2004) 270 – 274.
[13] Wang Y, Hillmyer MA: Polyethylene-poly(l-lactide) diblock copolymers: synthesis and compatibilization of poly(l-lactide)/polyethylene blends, J. Polym. Sci. Part A 39 (2001) 2755 – 2766.
[14] Balakrishnan H, Hassan A, Wahit MU: Mechanical, thermal, and morphological properties of polylactic acid/linear low density polyethylene blends, J. Elastom. Plast. 42 (2010) 223 – 239.
[15] Djellali S, Haddaoui N, Sadoun T, Bergeret A, Grohens Y: Structural, morphological and mechanical characteristics of polyethylene, poly (lactic acid) and poly (ethylene-co-glycidyl methacrylate) blends, Iran. Polym. J. 22 (2013) 245 – 257.
[16] Singh G, Kaur N, Bhunia H, Bajpai PK, Mandal UK: Degradation behaviors of linear low-density polyethylene and poly (L-lactic acid) blends, J. Appl. Polym. Sci. 124 (2012) 1993 – 1998.
[17] Gahleitner M: Melt rheology of polyolefins, Prog. Polym. Sci. 26 (2001) 895 – 944.
[18] Yomogida Y, Tsukada H Li Y, Shimizu H: Reactive blending of polyethylene and poly (L-lactic acid) using a high-shear extruder, The 18th International Conference on Composite Materials, Jeju Island, South Korea (2011).
[19] Jiang G, Huang HX, Chen ZK: Rheological responses and morphology of polylactide/linear low density polyethylene blends prepared by different mixing type, Polym. Plast. Technol. Eng. 50 (2011) 1035 – 1039.
[20] As'habi L, Jafari SH, Khonakdar HA, Boldt R, Wagenknecht U, Heinrich G: Tuning the processability, morphology and biodegradability of clay incorporated PLA/LLDPE blends via selective localization of nanoclay induced by melt mixing sequence, Express Polym. Lett. 7 (2013) 21 – 39.
[21] Pastor JM, Gallego R, Basurto FC, Nunez K, Garcıa-Lopez D, Merino JC: Study of different mixing sequences in polymer blends reinforced with nano-clays, Macromol. Symp. 32 (2012) 140 – 144.
[22] Wagner JR: Multilayer flexible packaging, Elsevier (2009).
[23] Mahallati P, MahiHassanabadi H, Wilhelm M, Rodrigue D: Rheological characterization of thermoplastic elastomers (TPE) based on PP and recycled EPDM, Appl. Rheol. 26 (2016) 33503.
[24] Lacoste C, Choplin L, Cassagnau P, Michel A: Rheology innovation in the study of mixing conditions of polymer blends during chemical reaction, Appl. Rheol. 15 (2005) 314 – 325.
[25] Chuang HK, Han CD, Rheological behavior of polymer blends, J. Appl. Polym. Sci. 29 (1984) 2205 – 2229.

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