Mechanical Properties of PLA-Jute Composites by using Natural Rubber and Epoxidized Natural Rubber as Impact Modifiers: Effect of Molding Technique

Yupaporn Ruksakulpiwat*,**, Patcharin Tonimit* and Jongrak Kluengsamrong*,**

*School of Polymer Engineering, Institute of Engineering, Suranaree University of Technology, Nakorn Ratchasima 30000, Thailand yupa@sut.ac.th

**Center of Excellent for Petroleum, Petrochemical and Advanced materials, Chulalongkorn University, Bangkok 10330, Thailand

ABSTRACT

Jute fiber was used as a reinforcing fiber in poly (lactic acid) (PLA) composites. Natural rubber (NR) and epoxidized natural rubber (ENR) were used as impact modifiers of PLA-jute composite. The composite specimens were prepared by either injection molding or compression molding. Comparisons between the mechanical properties of the composites prepared from injection molding and compression molding were made. Results indicated that compression molded PLA showed higher tensile strength, elongation at break and impact strength than injection molded PLA. Nevertheless, PLA-jute composites from injection molding showed higher tensile strength, Young's modulus and impact strength than the composites from compression molding. Moreover, tensile strength of injection molded PLA-jute composites was higher than that of injection molded PLA. In contrast, compression molded PLA-jute composites showed lower tensile strength than compression molded PLA. However, with the addition of NR or ENR, the mechanical properties of the composites seemed to be lower.

Keywords: PLA, jute fiber, mechanical properties, injection molding, compression molding

1 INTRODUCTION

Poly (lactic acid) (PLA) is one of the commercial biodegradable polymers which have been extensively used due to their environmental friendly plastics production. It is proven to be superior to the conventional petrochemical polymers in terms of the total energy consumption and CO_2 emission in the life cycle assessment. However, the major restriction of PLA applications is their inherent brittleness. It needs modifications for more practical applications. The improvement of the properties of PLA is an addition of fillers or reinforcing material [1]. Several fillers have been reported to use in PLA matrix such as talc, sodium stearate, calcium lactate [2], organoclay [3] and calcium metaphosphate [4]. Moreover, natural fibers such as kenaf [5], flax [6], bamboo [7], coir [8], jute [9] were also used as reinforcement materials in PLA composites. Due to the hydrophilic character of natural fibers, the modification to to decrease their hydrophilic of the lignocellulosic materials is needed. This may be done by chemical modification. It was reported in our previous study that by adding natural fiber in polypropylene (PP) matrix, the tensile strength of PP-natural fiber composite was higher than that of neat PP [10]. So PP-jute composite was used in this study in order to compare its mechanical properties with the mechanical properties of PLA-jute composite. Nevertheless, the use of natural fiber in polymer matrix normally increases the tensile strength of the composite but decreases their impact strength. From our previous work, the use of natural rubber (NR) in PP- natural fiber composites led to an increase in the impact strength of the composites [10]. So in this study the mechanical properties of PLA-jute composites by adding NR and ENR were reported. Compression molding and injection molding were used to prepare composite specimens. The mechanical properties of the composites prepared from injection molding and compression molding were compared. Furthermore, comparisons between the mechanical properties of jute- PLA composite and jute- PP composite were made.

2 EXPERIMENTAL

2.1 Materials

A commercial grade of PLA (PLA 2002D) from Natureworks, LLC. and a commercial grade of PP (PP 700J) from Thai Polypropylene Co. Ltd. were used in this study. Jute fibers (Hibiscus sabdariffa) were obtained from NEP Realty and Industry Public Company Limited., Thailand. Two types of rubber were used including NR and and epoxidized natural rubber (ENR). Epoxidized natural rubber (Epoxyprene 50) supplied by Muang Mai Guthrie Public Co., Ltd. and Natural rubber (STR 5 L) supplied by Thai Hua Rubber Co. Ltd. were used.

2.2 Composites preparation

Alkalization was used to treat jute fiber in this study. Jute fiber with aspect ratio of 12.15 was immersed in NaOH solution for 2 hours, then washed with water several time, and dried in an oven at 70°C for 24 h. PLA and NR or ENR with chemical substance were mixed by using an internal mixer (Haake Rheomix 3000P model 557-1306) for 3 min, then jute fiber was added and mixed together. The total mixing time is 10 min. Chemical substances used for dynamic vulcanization of natural rubber and EPDM were sulfur, tetramethylthiuramdisulphide (TMTD), zinc oxide (ZnO) and mercaptobenzothaizole (MBT). The internal mixer was performed at 150°C and rotor speed of 50 rpm. The ratio of jute fiber to PLA matrix was 20% (wt/wt). NR and ENR were used at content of 10% (wt). The composite was ground and dried before molding. Injection molding machine (Chuan Lih Fa Machine model CLF-80T) and compression molding machine (M scientific) with the melt temperature of 160 ^{o}C were used to prepare the composite specimens.

2.3 Mechanical testing

Tensile properties of composite specimens obtained from both injection molding and compression molding were tested according to ASTM D638 using the Instron universal testing machine (UTM, model 5565) with a load cell of 5 kN and crosshead speed of 10 mm/min. Izod impact test of the composites was performed according to ASTM D256 using an Atlas testing machine (model BPI) with a load cell of 2.7 J.

3 RESULT AND DISCUSSIONS

Figure 1 shows tensile strength of PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared by injection molding and compression molding. The tensile strength of PP-jute composite from injection molding was also given in this figure. It is interesting to point out that injection molded PLA showed lower tensile strength than compression molded PLA. Generally, shear rate in injection molding is much higher than shear rate in compression molding. The higher shear rate creates more viscous heating in polymer melt. PLA is very sensitive to heat. When it gets more heat, it could be possibly more degraded. This results in the lower tensile strength of injection molded PLA-jute composite compared to that of compression molded PLA-jute composite. Moreover, it was observed that by adding jute fiber in PLA matrix, the tensile strength of PLA-jute composite prepared by injection molding was higher than that of neat PLA prepared by the same molding technique. This is generally observed in other natural fiber reinforced composites. The injection molded natural fiber-PP composite also showed higher tensile strength than neat PP [10]. This is due to the higher tensile strength and the orientation of the fiber along the flow direction in injection molding machine. However, the compression molding showed the opposite result. Although the tensile strength of jute fiber is much higher than that of PLA [11] which should increase the tensile strength of PLA-jute composite compared to PLA, compression molded PLA-jute composite showed lower tensile strength than compression molded PLA. This might be due to the degradation of PLA during molding procedure. PLA-jute has been melted two times, first in the internal mixer and second in the molding machine. In contrast, PLA has been melted only once in the molding machine. This may lead to the more degradation of PLA-jute composite compared to that of PLA. Moreover, in compression molding the fiber has no preferred orientation. The orientation of fiber in the composite generally leads to the higher tensile strength in that orientation direction. This causes the higher tensile strength of PLA-jute composites from injection molding compared to compression molding. Furthermore, it was observed that the tensile strength of PLA-jute composites was higher than that of PP-jute composite. PLA-jute composite with the addition of NR and ENR presented a decrease in tensile strength compared to PLA-jute composite. This may be due to the incompatibility between PLA-jute composite and the rubbers.

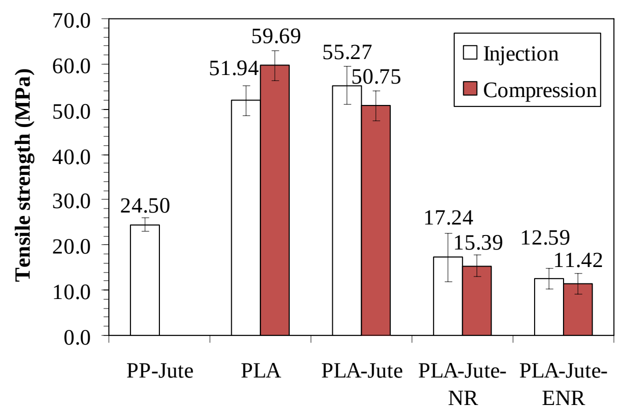

Figure 1 Tensile strength of PP-jute composite, PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared by injection molding and compression molding.

Figure 2 shows Young's modulus of PP-jute composite, PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared from injection molding and compression molding. Young's modulus of PLA composites from both injection molding and compression molding were higher than that of neat PLA from the same molding technique. This is in agreement with an increase in Young's modulus of PP with the addition of natural fibers [10]. This is due to the high modulus of jute fiber [11]. However, Young's modulus of

PLA-jute composite was lower than that of PP. In addition, it was shown that, Young's modulus of PLA composite prepared by injection molding was slightly higher than PLA composite prepared by compression molding. This may be attributed to the higher orientation of jute fiber in injection molding than in compression molding. The addition of NR and ENR slightly reduced Young's modulus of the composites.

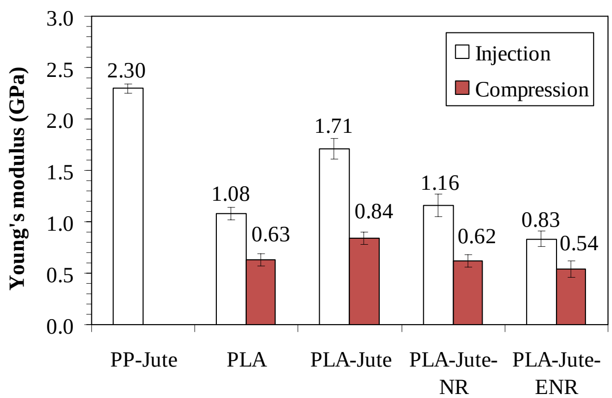

Figure 2 Young's modulus of PP-jute composite, PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared by from injection molding and compression molding.

The elongation at break of PP-jute composite, PLA, PLA-jute composite, PLA-jute-NR and PLA-jute-ENR composites are shown in Figure 3. The results showed that the elongation at break of PLA-jute composites was slightly lower than that of neat PLA prepared from both injection molding and compression molding. The addition of NR and ENR slightly reduced the elongation at break of the composites from injection molding. However, the elongation at break of the composites from compression molding showed no significantly difference when adding NR or ENR. Moreover, it was shown that elongation at break of injection molded PLA-jute composite was not different from injection molded PP-jute composite.

Figure 4 shows the impact strength of PP-jute composites, PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared by injection molding and compression molding. The impact strength of PLA decreased with the addition of jute fiber. This effect was more pronounced with the compression molded PLA than injection molded PLA. The lower impact strength with the addition of natural fiber in polymer matrix was normally observed [10]. This may be caused by the less surface adhesion between PLA matrix and jute fiber. However, with the addition of NR and ENR, the impact strength of the composites from both injection molding and compression molding was lower. This result was unexpected and was in contrast with our previous study [10]. It was found that the addition of rubber in natural fiber-PP composite can improve the impact strength of the composites [10]. Nevertheless, the addition of NR and ENR into PLA-jute composites may cause more phase separation due to the incompatibility between PLA-jute and NR or ENR. To obtain the polymer composite with better mechanical properties, the interaction between polymer, rubber and fiber need to be improved. Moreover, the impact strength of injection molded PP-jute composite was slightly lower than injection molded PLA-jute composites.

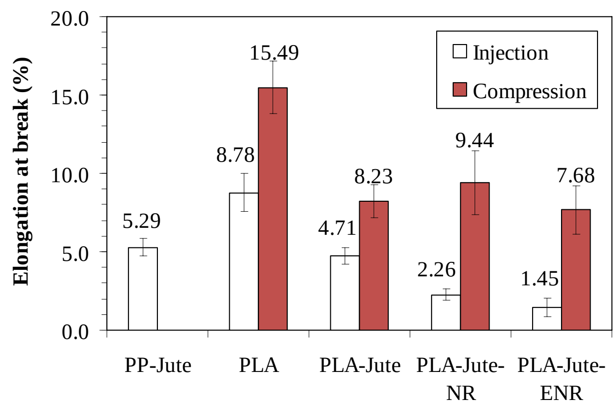

Figure 3 Elongation at break of of PP-jute composite, PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared by injection molding and compression molding.

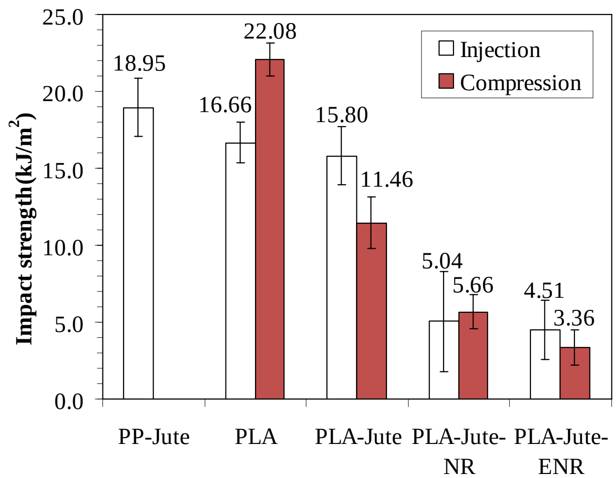

Figure 4 Impact strength of PP-jute composite, PLA, PLA-jute composites, PLA-jute composites with 10% (wt) NR, and PLA-jute composites with 10% (wt) ENR prepared by injection molding and compression molding.

4 CONCLUSIONS

Comparison between PLA and PLA composites from injection molding and those from compression molding was clearly made. The addition of jute fiber into PLA increased tensile strength and Young's modulus of PLA-jute composite prepared by injection molding. However, compression molded PLA-jute composites showed slightly lower tensile strength than compression molded PLA. Results indicated that compression molded PLA showed higher tensile strength, elongation at break and impact strength than injection molded PLA. Nevertheless, PLA-jute composites from injection molding showed higher tensile strength, Young's modulus and impact strength than the composites from compression molding. However, addition of NR and ENR led to lower impact strength of the composites.

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