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Polymeric Blends Containing Different Carboxylic Acids

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Polymeric Blends Containing Different Carboxylic Acids

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Abstract: A single-screw extruder was used to produce polymeric blends comprising recycled high-density polyethylene (HDPE) and thermoplastic starch (TPS). Carboxylic acids with varying lengths of carbon chains were used as compatibilizing agents in the blends. While the mechanical properties did not show significant differences among the blends containing compatibilizing agents, all exhibited superior results compared to those without a compatibilizing agent. Therefore, opting for the more cost-effective acid is advisable.

Keywords: HDPE, TPS, Carboxylic Acid, Polymer Blend, Mechanical Properties

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Introduction

Synthetic thermoplastic/thermoplastic starch blends are formulated as a substitute material for disposable packaging to mitigate the adverse environmental effects of polymers [1]. Most synthetic polymers, such as polyethylene, are immiscible with starch at the molecular level, resulting in deficient mechanical properties in these blends [2]. One option to resolve this issue is to use compatibilizing agents. Maleic anhydride (MA) is extensively used as a compatibilizing agent in polymeric blends. However, MA is costly, difficult to produce, and non-biodegradable, similar to petroleum-based polymers [3]. One potential solution is to utilize carboxylic acids derived from renewable sources as a compatibilizing agent [4]. These acids have a compatible chemical structure, are available in the environment, and are biodegradable [5].

In this work, thermoplastic starch and recycled high-density polyethylene (HDPE) were mixed with carboxylic acids of different carbon chain lengths as compatibilizing agents to produce polymeric blends using a single-screw extruder.

Materials and Methods

Materials

The materials used were recycled HDPE, cornstarch commonly used in bakeries (Cornmill), glycerin PA (Synth), stearic acid (Synth), myristic acid (Dinâmica), and palmitic acid (Dinâmica).

The packaging thrown away for recycling by the cleaning department of the Universidade Federal de Pelotas was the source of the recycled HDPE. Based on ABNT NBR 13230:2008, all packages are code 2.

Preparation of the HDPE

The packages were separated, the labels removed, and then washed and dried at room temperature. Subsequently, the samples were cut manually and ground using a Marconi knife mill.

Preparation of the Starch/Glycerol Mixture

The starch and glycerol mixture (60/40 ratio by mass) was prepared in an industrial mortar mixer. The materials were mixed for 30 minutes until a homogeneous mixture was achieved. Subsequently, the mixture was dried in an oven at 50°C for 24 hours.

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Processing of the Blends

The blends were processed in a single-screw extruder ECO, at the following temperatures: 96°C (first zone), 177°C (second zone), 180°C (third zone), and 180°C (die), and with a rotation speed of 100 rpm. The blends were chopped using a shredder connected to the extruder.

Blends of 60% HDPE and 40% starch (along with glycerol, known as TPS) were produced. Within each blend, 10% of the total mass of HDPE consisted of various carboxylic acids, which were used as compatibilizing agents. The formulations and terminologies of the produced blends are detailed in Table 1

Injection of the Blends

The blends were injected using a Spazio reciprocal screw injector, model DW130 Plus, at the following temperatures: 100°C (first zone), 150°C (second zone), 190°C (third zone), 190°C (injection nozzle), and the mold at room temperature. Specimens were prepared for tensile tests following ASTM D638.

Tensile Properties Analysis

An Instron tensile test machine model 3369 was used for the tensile strength test with a displacement speed of 5mm/min.

Table 1. Formulations and nomenclatures of the produced blends.

Sample	HDPE (% mass)	TPS (% mass)	Compatibilizing agent		
			Myristic acid (M)	Palmitic acid (P)	Stearic acid (S)
HDPE	100	-	-	-	-
Zero	60	40	-	-	-
M	60	40	X	-	-
P	60	40	-	X	-
S	60	40	-	-	X

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Results and Discussion

The results of the tensile tests are shown in Figure 1.

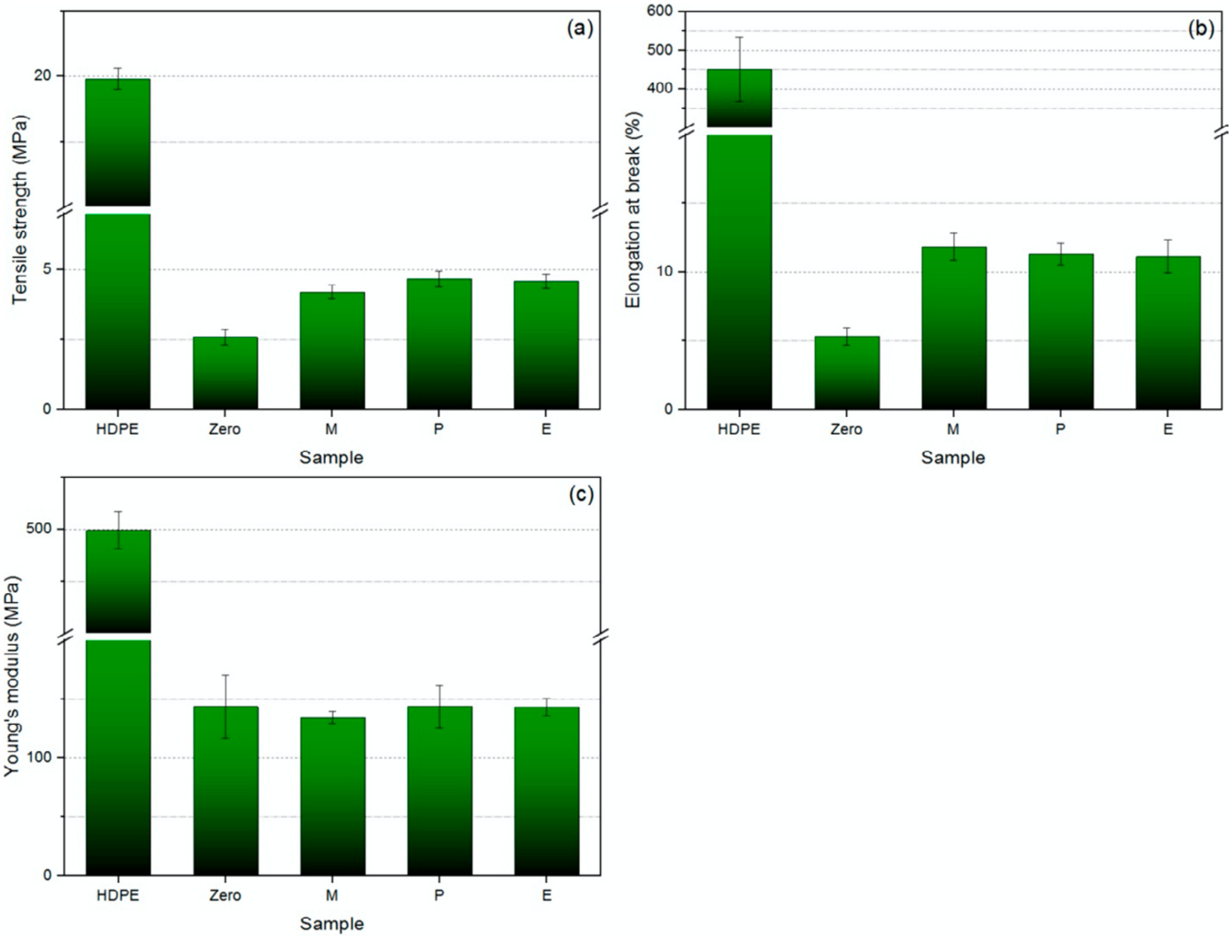

Figure 1. Tensile properties of the samples: (a) tensile strength, (b) elongation at break, and (c) Young's modulus.

In general, a reduction in the tensile properties of the Zero blend can be observed compared to the recycled HDPE. One potential reason for the decrease in tensile strength after adding starch to the HDPE is the inadequate interfacial interaction between the components of the blend, which may lead to mechanical rupture at the interface [6]. Moreover, the elongation at break is significantly influenced by the interfacial interaction between the blend phases [7]. Similar behavior was observed by Ning et al. [8] in glycerol/starch/linear low-density polyethylene (LLDPE) blends, which was attributed to the weak interfacial adhesion between two distinct polarity materials and unthermoplastic starch granules.

The blends containing compatibilizing agents exhibited higher tensile strength values and elongation at break. Elongation at break is a high-strain property influenced by interfacial interaction [1]. The results underscored the effectiveness of the compatibilizing agents employed. Conversely, Young's modulus values did not display significant variations across all blends.

No significant difference was observed among the blends containing compatibilizing agents (M, P, and E blends). In this case, opting for the less expensive acid is a more suitable choice.

Martins and Santana [1] produced polypropylene (PP)/TPS blends using the same compatibilizing agents employed in the current study and PP-grafted maleic anhydride (PPgMA). According to the researchers, compared to the PP/TPS blend, those containing stearic acid, PPgMA, and myristic acid exhibited enhancements of 25%, 22%, and 17% in tensile strength at break, and 180%, 194%, and 259% in elongation at break, respectively. Consequently, stearic acid displayed superior performance compared to PPgMA.

Conclusion

Recycled HDPE/TPS blends were produced in a single-screw extruder. Blends containing carboxylic acids exhibited superior tensile strength and elongation at break compared to those without a compatibilizing agent. However, the carbon chain length of the acids did not significantly influence the mechanical properties of the blends. The enhancement in the properties of the HDPE/TPS blends was attributed to the increased compatibility facilitated by the carboxylic acids.

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