Mechanical Properties of PBAT/STARCH Films Submitted to Accelerated Weathering

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In this study, extruded plastic films of PBAT mixed with starch in proportions of 0, 30, and 40% were submitted to the accelerated weathering procedure at 0, 360, and 720 hours under UV radiation. Mechanical properties such as tensile strength, elongation at break, and Young's modulus of PBAT films under tension were evaluated before and after the accelerated weathering. The results pointed to a significant increase in the deformation values of the films with the highest starch concentration and an increase in stiffness after the degradation process.
Keywords: Accelerated Weathering. PBAT. Starch. Ultraviolet Radiation.

Introduction

Considering the problems caused by the accumulation of waste, mainly of polymeric materials, materials with favorable decomposition properties are a promising alternative for reducing the negative impacts on the environment [1]. Notably, food packagings, such as plastic bags and films, are a significant fraction of the waste discarded in the environment [2]. PBAT, poly (butylene adipate co-terephthalate), is one of the materials used in plastic bags and films and can also be blended with thermoplastic starch. TPS is a thermoplastic starch obtained from renewable sources that can be used as a filler, along with additives, such as glycerol and citric acid, to reduce the cost of PBAT films and improve their biodegradability [3-5]. Some recent studies on PBAT have been showing promising results when it comes to mechanical and biodegradable properties. However, there are still very few analyses involving accelerated weathering by UV radiation, including blends of PBAT and starch.

The study and analysis of the behavior of these materials after their disposal in the open environment, under the action of the sun and rain, requires a long time to show the effects of degradation. Chambers with unique lamps that constantly emit UVA and UVB radiation can be used to accelerate this degradation process and simulate a scenario in which the material was exposed for an enormous amount of time. This process is known as accelerated weathering [6,7]. The study aims to analyze the mechanical properties of PBAT films (such as tensile strength, elongation at break, and Young's modulus), the effect of blending different proportions of starch with it and comprehending its behavior before and after the accelerated weathering procedure.

Materials and Methods

Materials

PBAT was supplied by BASF (ECOFLEX® F Blend C1200), and Podium Alimentos supplied the cassava starch. The glycerol used was from the Neon brand, and the citric acid was from the Synth brand.

Preparation of Films

The samples were obtained using a flat-die twin-screw extruder, Brand AX-Plásticos, Model DR1640. First, the formulations were extruded to form pellets, then extruded to generate the films. All PBAT pellets and the flat film formulations were processed at 88 RPM with temperature profile 80/9

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0/110/120/130/130/130/120125°C. F1 (30% starch) had 8,55% glycerol and 0,45% citric acid, and F2 (40% starch) had 11.40% glycerol and 0.60% citric acid (Table 1).

Table 1. Formulations prepared for analysis.

Formulations	Composition
F0	PBAT
F1	70% PBAT + 30% STARCH
F2	60% PBAT + 40% STARCH

Accelerated Weathering

The accelerated weathering of the samples was carried out in a UV chamber for accelerated weathering tests, Model BASS UVV/2009, following the ASTM D 1435 standard for times of 360 and 720h (Table 2). In this process, the samples were only exposed to UV radiation, not containing moisture variation through the water spray. The process was defined after checking similar procedures [6-8].

Table 2. Accelerated weathering exposure time.

Reference	Exposure Time (h)
T0	0
T1	360
T2	720

TensileTest

The tensile test was performed on the samples with the Universal testing machine EMIC DL2000, according to the adapted ASTM D882 standard. (Test speed 25 mm/min, the distance between grips 100 mm, and sample width 25 mm. The software for data processing was TESC 2000. In the tensile test, eight specimens were tested, and five were selected for analysis of the results. The samples were removed longitudinally from the previously extruded film.

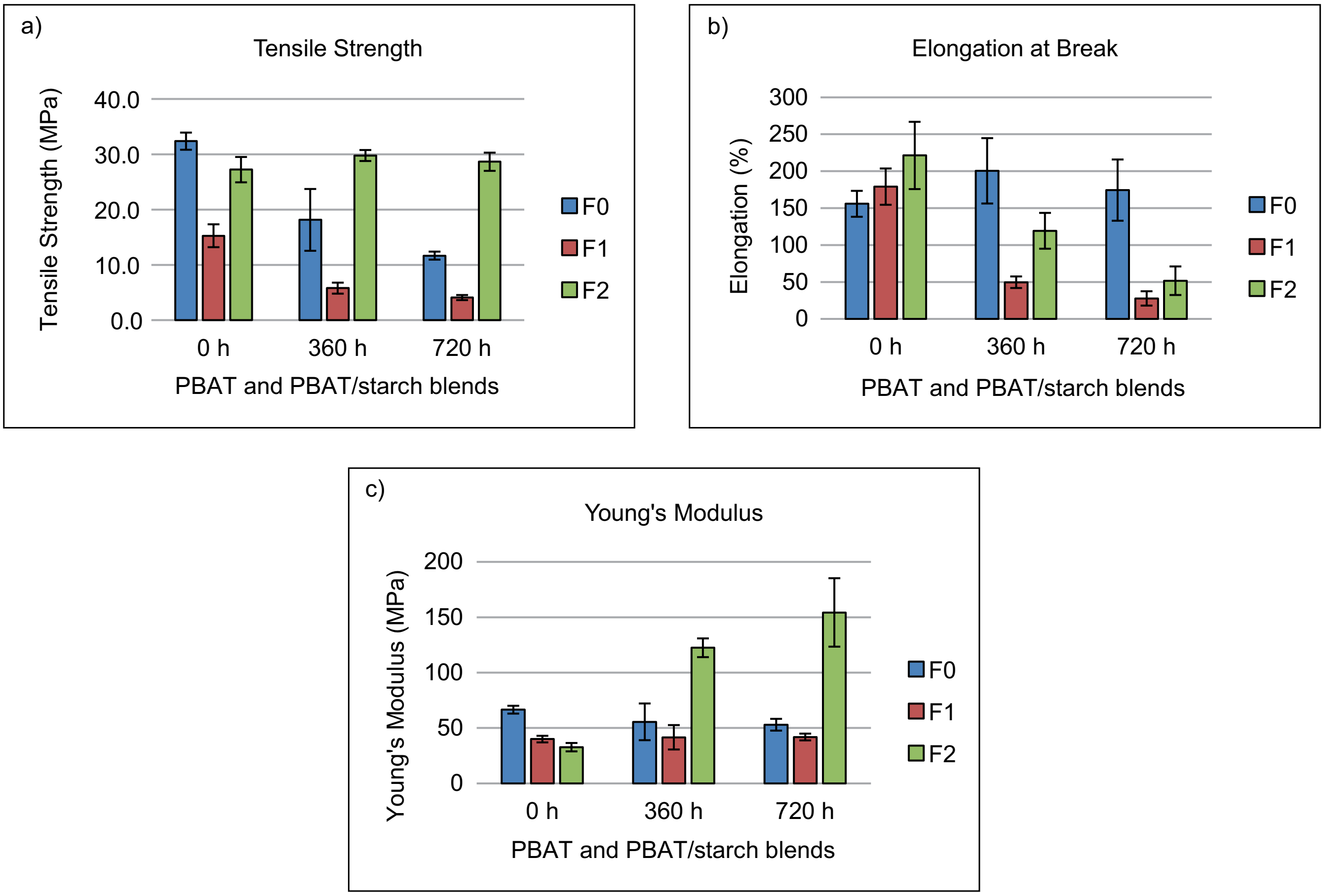
Results and Discussion

After performing the mechanical tests of the PBAT and PBAT/starch blends films, we compared the behavior of the formulations over the exposure time (Figure 1).

Figure 1A presents that F1 showed a drop in the tensile strength value with the addition of starch. According to Pellicano and colleagues [9], the addition of starch promotes the formation of a less resistant compound. Furthermore, according to the authors, the incorporation of starch reduces the mechanical properties caused by the matrix/filler interface with low compatibility and the non-occurrence of the wetting mechanism. In addition, starch acts as a stress concentrator, causing fissures and reducing tensile strength [5,9,10]. However, the 60/40 PBAT formulation showed higher tensile strength when compared to 70/30, where there may have been a better interaction between the carbonyl group of the matrix and the starch favored by the higher amount of glycerol added, about 25% more than the F1[10]. This behavior was also constant with the accelerated weathering time. After the degradation process, PBAT 60/40 samples did not lose their tensile strength, which did not occur with F0 and F1. F2, with higher starch content, appeared to be, visually, with a higher opacity. One hypothesis that could be brought up is that the whitish surface may have acted as a physical barrier to the transposition of UV light, which helped to preserve the tensile strength of the F2 samples throughout the exposure.

Figure 1B showed that the elongation at the broken property of the samples without weathering increased. This fact may probably be linked to the presence of glycerol, which was used as a plasticizer and may have interfered with the mobility of polymeric chains, causing in some cases the elongation at the break of the films to increase significantly, as shown in the work by Shanshan Lv and colleagues [10]. It can also be observed that at the time of 360h, the deformation of F2 decreased concerning time 0. It may have occurred because possibly the incidence of UV radiation

Figure 1. A.Tensile strength, B. Elongation at Break, C. Young's Modulus of PBAT formulations and their blends over exposure time.



caused the glycerol to migrate to a more external region, weakening the plasticizing effect that it had previously caused, leading the PBAT films with starch to a decrease in ductility and consequently an increase in stiffness as verified in Young's modulus (Figure 1C). This behavior was also addressed in the literature by Shanshan Lv and colleagues [10]. In 720h of accelerated weathering, it is verified that the fragile behavior intensifies. The exposure may also have caused the formation of micro-fissures and reduced deformation.

In the unaged state, it is possible to observe that the material becomes more ductile with the addition of starch, in which Young's modulus decreases and the elongation at break increases. However, in the literature, it is possible to find many studies that point out that adding starch increases the stiffness of the blend since the starch has rigid characteristics, thus increasing Young's modulus of the studied samples [3,4,9,10].

Conclusion

From the results obtained, the presence of starch tends to decrease the tensile strength compared to pure PBAT. However, it is also possible to observe that the concentration with the highest presence of starch helped the films maintain their tensile strength during accelerated weathering. It was also evaluated that glycerol in the samples with starch may have increased deformation, acting as a plasticizer. However, after exposure to UV radiation, the elongation behavior at rupture was significantly altered, with the sample with higher starch content having a fragile behavior and not deforming as before due to the possible migration of glycerol to outer layers in the films.

References

1. Müller J, González-Martínez C, Chiralt A. Combination of poly(lactic) acid and starch for biodegradable food packaging. Materials. [S.l.]: MDPI AG., August 2017.
2. Djukic-Vukovic A et al. Towards sustainability of lactic acid and poly-lactic acid polymers production. Renewable and Sustainable Energy Reviews 2019;108:238–252.
3. Nayak SK. Biodegradable PBAT/Starch nanocomposites. Polymer - Plastics Technology and Engineering 2010;49(14):1406–1418.
4. González Seligra P et al. Influence of incorporation of starch nanoparticles in PBAT/TPS composite films. Polymer International 2016;65(8):938–945.
5. Ferreira FV et al. An overview on properties and applications of poly(butylene adipate-co-terephthalate)–PBAT based composites. Polymer Engineering and Science 2019;59,(2):E7–E15.
6. González-López ME et al. Accelerated weathering of poly(lactic acid) and its biocomposites: A review. Polymer Degradation and Stability. [S.l.]: Elsevier Ltd., Set 2020.
7. Copinet A et al. Effects of ultraviolet light (315 nm), temperature and relative humidity on the degradation of polylactic acid plastic films. Chemosphere 2004;55(5):763–773.
8. Coelho FA et al. Engenharia Moderna: Soluções para Problemas da Sociedade e da Indústria. Ponta Grossa - Paraná - Brasil: Atena, 2020. Doi 10.22533/at.ed.467202809. Available at: <https://www.researchgate.net/publication/344658356_AVALIACAO_DA_BIODEGRADACAO_E_ENVELHECIMENTO_ACELERADO_POR_RADIACAO_ULTRAVIOLETA_NA_BLENDA_PBATTPS>. Accessed on Jun 22, 2022.
9. Pellicano M, Pachekoski W, Agnelli JAM. Influência da Adição de Amido de Mandioca na Biodegradação da Blenda Polimérica PHBV/Ecoflex®. Polímeros: Ciência e Tecnologia 2009;19(3):212-217.
10. Amass W et al. Starch based biodegradable PBAT nanocomposites: Effect of starch morphological thermal morphological and biodegradability behavior. Journal of Polymers and the Environment 2016;19(1):736–745.
11. Shanshan LV et al. Effect of glycerol introduced into PLA based composites on the UV weathering behavior. Construction and Building Materials 2017;144:525–531.