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EVALUATION OF COMPOSTING AND VERMICOMPOSTING IN THE DEGRADATION OF PLA/TPS BLEND FILMS

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Abstract - A sanitary landfill contains approximately 10% of polymers in its composition, such as polyethylene bags used for containing organic waste. These bags possess impermeability and mechanical strength characteristics, causing organic matter to become trapped within, hindering its degradation. Consequently, this reduces the landfill's lifespan. Furthermore, improper disposal of polyethylene bags is observed, leading to a significant environmental issue as they are not recycled but rather contribute to pollution. In an effort to mitigate these problems, the methods of composting and vermicomposting are intended to be evaluated for decomposing bags made from a biodegradable blend of polylactic acid with thermoplastic starch (PLA/TPS). In vermicomposting, annelids of the Eisenia fetida species were utilized to assess their efficiency in decomposing PLA/TPS. Biodegradation of PLA/TPS was determined through Fourier-transform infrared spectroscopy (FTIR), tensile mechanical testing, and optical microscopy. The results obtained revealed degradation of PLA/TPS, as well as enhanced efficiency in the vermicomposting environment compared to composting.

Keywords: *Biodegradation, Vermicomposting, Composting, Eisenia fetida, Polylactic acid.*

Introduction

Polymers derived from petroleum exhibit slow rates of degradation. This, coupled with their large-scale production and improper disposal, poses a severe environmental problem that can disrupt ecosystem balance [1-3]. It is estimated that globally, 0.5 to 1 trillion plastic bags are consumed annually [1]. In Brazil, about one and a half million plastic bags are estimated to be distributed every hour in commercial establishments. A small fraction of these is recycled, with the majority ending up in landfills [4]. Roughly 10% of all collected organic waste in cities comprises single-use synthetic plastic bags, often used to contain organic refuse [5]. These bags are sturdy and impermeable, impeding organic material degradation [6]. Therefore, it's pertinent to seek alternatives to mitigate the environmental impacts arising from the use of plastic bags as waste containers. Over the past two decades, biodegradable materials have been developed, such as thermoplastic starches (TPS), polylactic acid (PLA), and their blends. However, these polymers still have limitations in terms of cost, mechanical and chemical resistance when compared to synthetic polymers. Moreover, the recycling of biodegradable polymers, according to The European Waste Framework Directive, should be carried out through composting [7]. This enables their segregation in landfills. Thus, organic waste can be valorized through composting and vermicomposting methods, consequently extending landfill lifespans and diminishing environmental impacts [8]. Composting is defined as the exothermic aerobic biooxidation of a heterogeneous solid-state organic substrate. This process yields carbon dioxide, water, mineral substances, and organic matter stabilization [9]. Conversely, vermicomposting is an approach for treating and valorizing the organic fraction of waste, employing specific earthworm species [10]. These worms produce humus, which is decomposed organic matter and an excellent nutrient source for plant development

[11]. The research undertaken in this study aims to analyze the biodegradation and alteration of PLA/TPS plastic bags in vermicomposting and composting environments.

Experimental

Vermicomposting and composting structures

The composting and vermicomposting structures utilized were identical in design. Their dimensions measured 60 centimeters in length, 42 centimeters in width, and 78 centimeters in height. The structure has a capacity of 45 liters and comprises two digestion chambers and a leachate collection base, as shown in Fig 1. Within these containers, equal quantities of topsoil (without additives or fertilizers), fruits, vegetables, leafy greens, dried leaves, and cow manure were added. Temperature, pH, and soil moisture measurements were conducted using a measurement sensor from the Smart brand, model 4.1 Soil Survey Instrument, ISO 9001:2000.

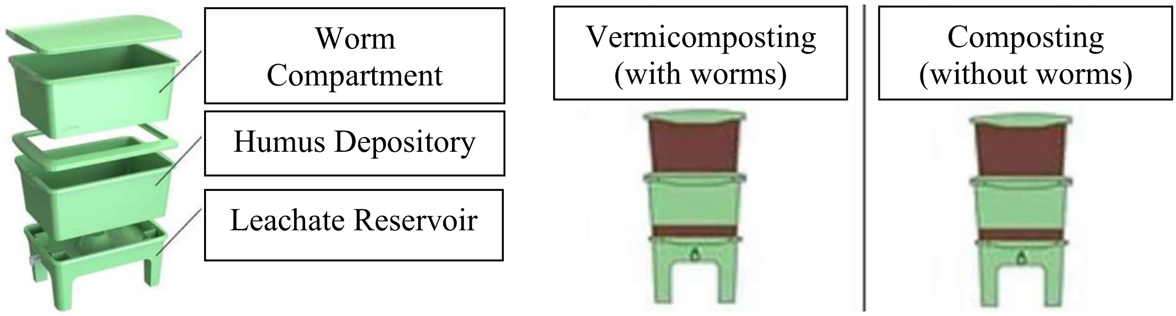

Figure 1 Structure Vermi/composting Humi. Source: https://composteirahumi.eco.br/

In the vermicomposting container, 942 adult worms of the species Eisenia fetida were added, Fig 2.

Figure 2 Earth worms Eisenia fetida.

Polymeric samples

The samples were cut into strips measuring 20 centimeters in length and 5 centimeters in width. The films are composed of PLA/TPS and were manufactured in Germany by the company Melitta Europa, certified under DIN EN 13432. The samples were collected in triplicate from both composting and vermicomposting structures at intervals of 30, 60, and 90 days.

Caracterization

The samples were analyzed using the following techniques: FTIR (Fourier Transform Infrared Spectroscopy) on a Perkin Elmer FT-IR spectrometer frontier with an attenuated total reflectance (ATR) accessory; DSC (Differential Scanning Calorimetry) on a Perkin Elmer DSC 6000 instrument; Universal Testing Machine for tensile mechanical testing, model Emic DL 20000; Optical Microscope (OM), model 400X Series Digital Microscope.

Results and Discussion

FTIR characterization was performed on the initial samples and after 30, 60, and 90 days of vermicomposting and composting. Fig 3 and Fig 4 display the FTIR spectra of the PLA/TPS samples subjected to vermicomposting and composting, respectively.

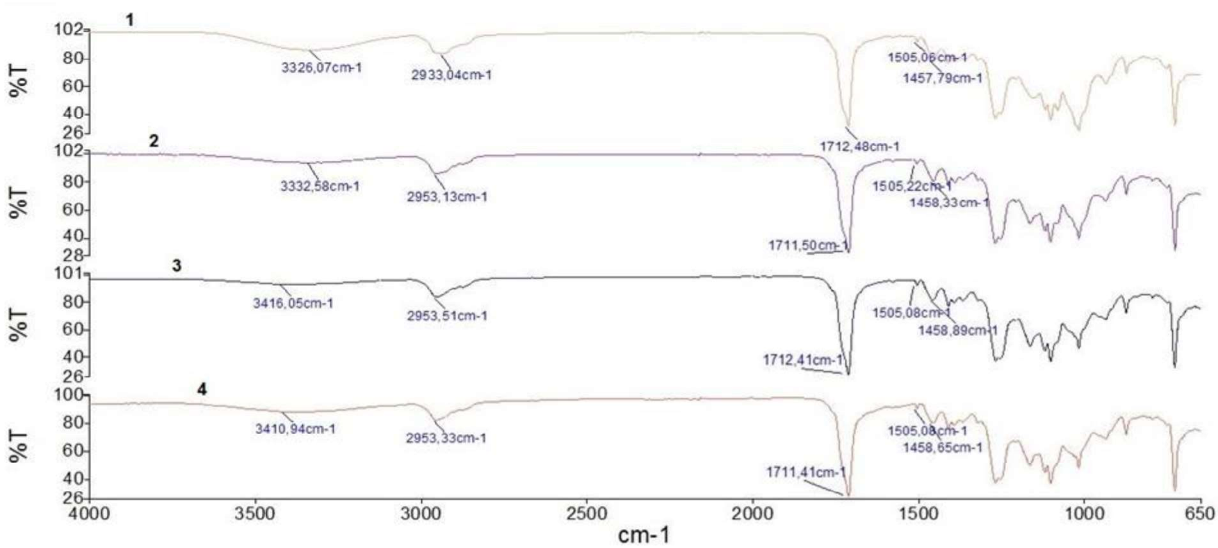

Figure 3 FTIR PLA/TPS vermicomposting (1=0, 2=30, 3=60 e 4=90 days).

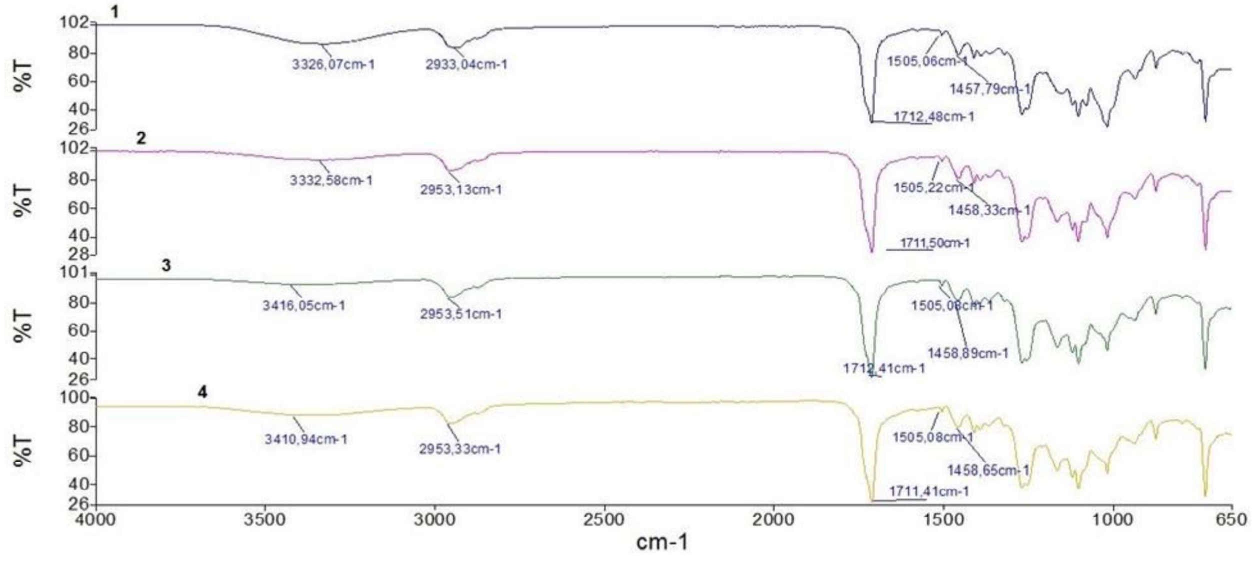

Figure 4 FTIR PLA/TPS composting (1=0, 2=30, 3=60 e 4=90 days).

Upon analyzing the spectra of PLA/TPS, changes were observed in the region of 3400 cm-1, where it can be seen that the initial sample had a more pronounced peak compared to the 30, 60, and 90-day samples. It can be concluded that degradation occurs through the disappearance of hydroxyl groups from the polymer chain, as indicated in the aforementioned region. This was observed in both the composting and vermicomposting samples. Fig 5 presents the results of the tensile tests conducted on the samples subjected to composting and vermicomposting.

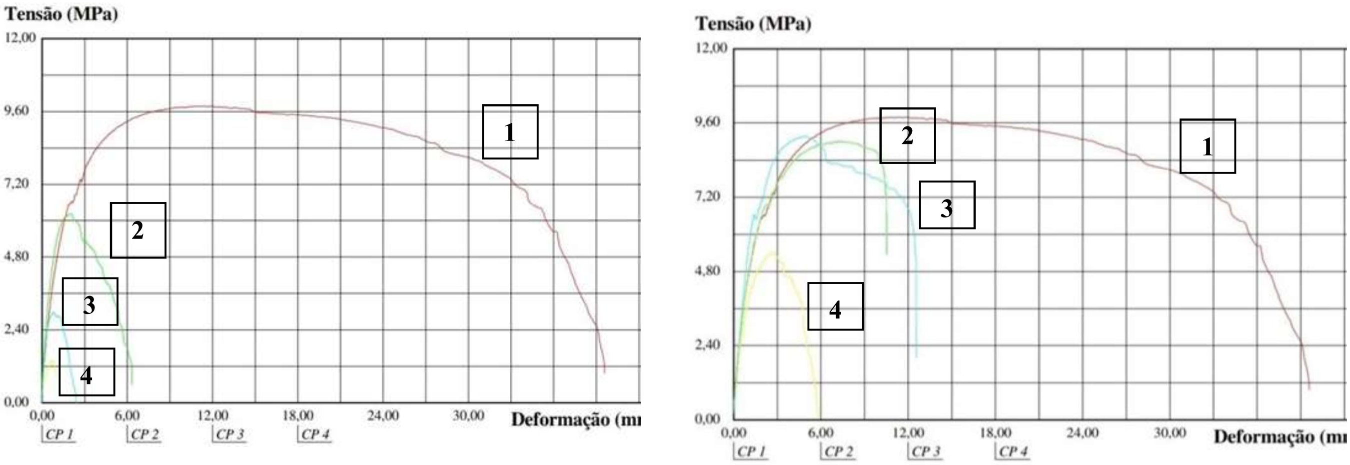

Figure 5 Tensile Testing of PLA/TPS Samples: Vermicomposting (left) and Composting (right) (1=0, 2=30, 3=60, and 4=90 days).

It can be inferred that the duration of exposure made the samples more fragile, resulting in a lower modulus of elasticity. By analyzing the graphs of the tensile tests, a loss of mechanical properties in the samples can be observed, with this effect being more pronounced in the vermicomposting samples. The PLA/TPS showed significant reductions in maximum stress (85.9%) and strain (97%) in the vermicomposting process. In composting, the PLA/TPS exhibited reductions in maximum stress (44.6%) and strain (76%). Based on these results, it can be concluded that significant changes occur in the mechanical properties of the materials after the vermicomposting process. The images obtained by the optical microscope, shown in Fig 6, clearly demonstrate the change in the material's surface over time. It is evident that there were more surface changes in the samples subjected to vermicomposting. The tear in sample d from the vermicomposting process is due to the passage of the annelid.

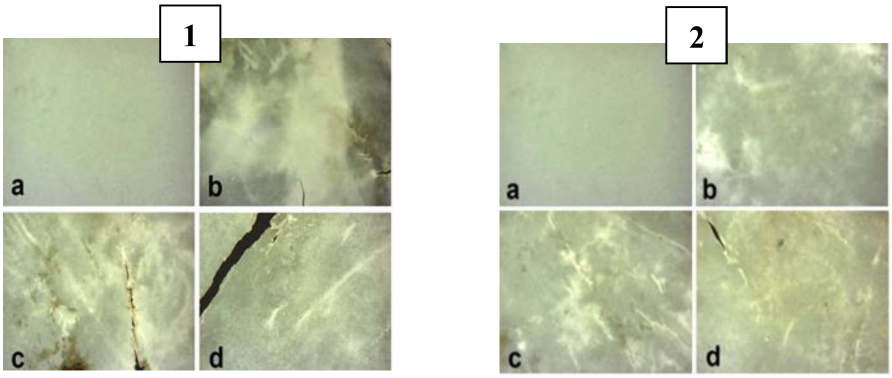

Figure 6 Optical Microscopy (OM) of PLA/TPS: Vermicomposting (1), Composting (2); after (a=0 days, b=30 days, c=60 days, d=90 days). Magnification scale 50X.

Conclusions

Based on the conducted tests, it can be stated that degradation occurred in the polymer films, with a notable emphasis on the vermicomposting process. In the case of PLA/TPS samples, after 90 days of vermicomposting, there was a decrease in maximum stress from 9.79 to 1.38 MPa and a reduction in elastic deformation from 39.5 to 1.2 mm. In composting, after 90 days, there was a decrease in maximum stress from 9.79 to 9.01 MPa and a reduction in elastic deformation from 39.5 to 9.5 mm. Through FTIR analysis, it was observed that hydroxyl groups in the polymer chain disappeared, indicating material degradation in both vermicomposting and composting samples. However, it can be affirmed that vermicomposting demonstrated higher efficiency in terms of biodegradation.

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