

Growth of White Rot Fungi in Composites Produced from Urban Plastic Waste and Wood

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Summary: In the search for new biodegradable materials is found the combination of natural fibers with conventional polymeric materials or biodegradable polymers. The incorporation of natural fibers to thermoplastic polymer matrix is associated with improvement of their properties due to advantages such as the fact that the natural fibers are biodegradable and less abrasive when compared to synthetic fibers. The materials produced with conventional synthetic polymers are considered inert to immediate attack of microorganisms, as thermoplastic polymers used in this research, PP (polypropylene) and EVA (ethylene vinyl acetate). Thus, this study aims to evaluate the potential for biodegradation of wood plastic composites (WPC) obtained through the use of post-consumer bottle caps and wood flour. The monitoring was conducted through cultivation of different species of fungi (*basidiomycetes*) on different substrates, being made by gravimetric analysis and visual monitoring of the composites, in order to assess that species of fungus has increased growth kinetics and its relation with different kinds of wood and then have an estimate of the potential biotic degradation of these materials. Based on results presented here, it is concluded that the *Trametes villosa* (TV) fungi is that best interacted with the wood contained in the composite in both species of *Eucalyptus grandis* (Eu) as *Pinus elliottii* (Pi).

Keywords: basidiomycetes; biodegradation; recycling; wood plastic

Introduction

The evolution and needs of modern life lead people to seek new sources for research and, until recently, it was important to discover increasingly durable materials for everyday use, among which are the polymers.^[1] However the proliferation of petrochemical-based polymer materials brings a increase in the use of non-renewable resources and, in many cases, leads to society an accumulation of large amount of waste with long decomposition time, because they are

not biodegradable.^[2] So, in search for new biodegradable materials there is the combination of natural fibers with polymers. The natural fibers can give the characteristic of reinforcement to composite and, furthermore, the use of fiber originated from waste can minimize environmental pollution and reduce production cost of the material.^[3] It's important to emphasize that fibers may undergo chemical modifications to increase the fiber-matrix interaction, improving adhesion between the natural fiber and the polymeric matrix.^[4]

Like the conventional synthetic polymers are inert to immediate attack by microorganisms, they cause serious environmental problems, because after be discarded, depending on the polymer, they take 100 years or more to decompose, as most of the polyolefins,^[5] thus increasing

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the amount of polymeric waste discarded into the environment. The polymers are considered the major environmental villains because they may take centuries to degrade occupying much of the volume of landfills, interfering negatively with the processes of composting and biological stabilization.^[6] Furthermore, the polymeric waste, when discarded in inappropriate locations, as landfills, rivers, hillsides, causing an even greater impact on environment. Therefore, recycling is a systematic way of the most viable solutions to minimize the impact caused by polymers to the environment. Various aspects can motivate the recycling of polymeric wastes contained in municipal solid waste: energy saving; conservation of exhaustible sources of raw materials; cost reduction with final disposal of waste; the economy with the recovery of areas affected by improper waste disposal; increasing the useful life of the landfills; the reduction in costs of cleaning and public health and employment and income generation.^[6] In this context, the composite of natural fiber and polymer fit as a possibility to alleviate the problems related to the disposal waste. However, a more detailed study on the possible biodegradability of these materials is necessary. The deterioration of the polymer surface is an interfacial process. This degradation modifies the mechanical, physical and chemical properties of a given material. The biodegradation of polymers is caused by microorganisms that colonize its surface forming biofilms. These biofilms consist of cells embedded in a polymeric matrix of their own origin, containing polysaccharides and proteins.^[7] The biodegradation of a material occurs when this one is used as a nutrient for a given particular set of microorganisms (bacteria, fungi, algae), which must have suitable enzymes to break down some chemical bonds of the main chain of polymer and when favorable conditions (temperature, humidity, pH and oxygen) are available to the action of microorganisms.^[7,8] Fungi are probably one of the most common cause of degradation of wood. They are heterotrophic organisms that use

organic compounds as energy source.^[9] They feed by secreting enzymes that digest the extracellular substrate of the wood (food source) providing soluble nutrients capable of being absorbed by yeast cells. They consist of a vegetative body (thallus) composed of filaments (hyphae), which form a microscopic network within the substrate (mycelium) by which the nutrients are absorbed.^[9]

In this work, intend to evaluate the potential biodegradability of wood plastic composite through post-use bottle caps from PP-EVA and wood flour waste.

Among the variety of fungi that degrade the wood stand out from the “white-rot fungi”, to be most effective in biodegradation of lignocellulosic materials in nature, because the synthesis of oxidative enzymes capable of degrading the primary constituent of wood^[10] in relation to “brown rot fungi”.^[11,12] The degradation of wood by white rot fungi can occur in two ways: the most common involves the simultaneous removal of all components; other less common, involves the selective removal of lignin and polyoses while maintaining substantially intact cellulose. In this case, the lignocellulosic materials degraded by white rot fungi take on a whitish appearance and break down easily in the direction of the fibers.^[13,14]

Growth monitoring of different species of white rot fungi (basidiomycetes), on different substrates as a function of time, will be performed by gravimetric analysis and visual monitoring of the composites, in order to assess what species of fungus has greater growth kinetic and in what kind of wood and then have an estimate of the potential of biotic degradation of these materials.

Experimental Part

The materials used were post-consumer waste from bottle caps of PP and EVA, latter present in the internal “liner” of covers, provided in the “flakes form”, by the company Prisma Montelur Thermoplastics

and 2 types of wood flour: eucalyptus (Eu) and pine (Pi), from species *Eucalyptus grandis* and *Pinus elliottii* respectively, from state of Rio Grande do Sul, Brazil. The wood flour underwent size separation in a system of 32 and 16 mesh Tyler sieves, with selected particle size of >250 and <500 μm . The blends were processed on a single screw extruder (L/D: 22), the temperature profile of 170° to 190°C and screw speed of 65 rpm, and perforated in the “pellets form”.

After, the samples were weighed and placed in duplicate in Erlenmeyer flasks with 30 ml of distilled water and they were sterilized by autoclaving at 127°C , in a vertical autoclave CS-100 Primatec brand, with a capacity of 100 liters and variable working pressure between 1–1.5 kgf/cm^2 . The fungi chosen for the experiments were the species *Trametes villosa* (TV), *Pycnoporus sanguineus* (PS) and *Corioloopsis rigida* (CR), which were isolated in Petri dishes in culture agar malt extract (AEM) previously autoclaved and placed in an incubator at 25°C in the dark (Figure 1-a). After one week, the fungi were inoculated (from previous cultures) at each sample (substrate) and then placed in greenhouse at 25°C in the dark for 60 days to follow (Figure 1-b). The formulation and nomenclature of the samples are shown in Table 1.

Table 1.

Nomenclature and formulation of samples.

Samples	Formulation		Fungi		
	Matrix	Filler	TV	PS	CR
PP-EVA	100%	0	•	•	•
Pi	0	100%	•	•	•
Eu	0	100%	•	•	•
PP-EVA-Pi	70%	30%	•	•	•
PP-EVA-Eu	70%	30%	•	•	•

Results and Discussion

In the sample of wood from *Pinus elliottii* (Pi) (Figure 2-a) it was observed, weekly by gravimetric monitoring, that the higher mass loss occurred in samples submitted to the *Trametes villosa* (TV) fungi followed by *Pycnoporus sanguineus* (PS), indicating the greatest degradation of this wood species by these two fungus, which can be displayed by the images of Figure 4-a and 4-b. In the samples of *Eucalyptus grandis* (Eu) in Figure 2-b, the largest mass loss occurred among those submitted to the *Pycnoporus sanguineus* (PS) fungi. Such variations in the mass loss are explained by differences in the structural and chemical constitution of the woods, which occur even among trees same species,^[15,16] causing changes in the ownership of natural durability of the same.

a)



b)

**Figure 1.**

Trametes villosa (TV), *Pycnoporus sanguineus* (PS) and *Corioloopsis rigida* (CR), fungi isolated in Petri dishes agar cultivation malt extract (AEM) (a) and samples in an greenhouse at 25°C in the dark for 60 days (b).

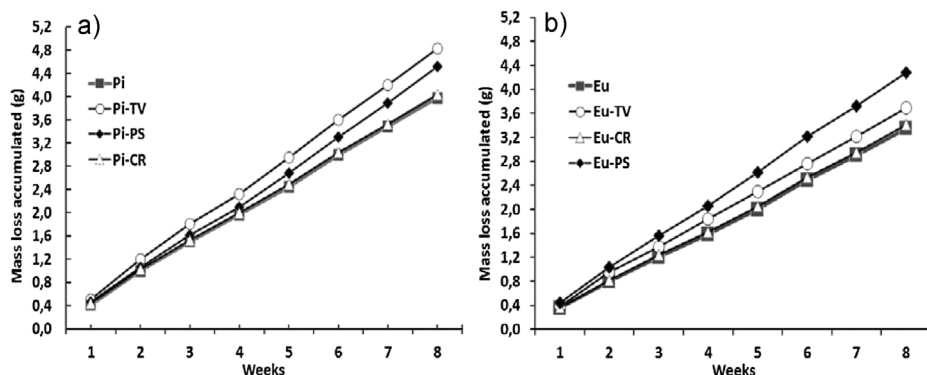


Figure 2.

Monitoring the mass loss of pine (a) and eucalyptus (b) samples for eight weeks.

Thus, the same species may occupy the same level of resistance to deterioration, especially when different types of degrading fungi are used.^[17]

The Figure 3-a and 3-b show mass loss of PP/EVA/Pi and PP/EVA/Eu composites.

It is observed that in composites with pine specie (Figure 3-a) the TV fungi was the only one that caused the greatest mass loss, proving that this fungi is the most suitable among the three tested for biodegradation of these composites.^[18] In the composites with eucalyptus specie, the TV and PS fungi showed similar results, with best results in the mass loss accumulated during the eight weeks, viewed in Figure 4-c and 4-d.

It is important to note that in this kind of composite, different types of wood and

characteristics of the preparation and processing can influence the results of the fungal attack to the material. Manufacturing processes and more specifically binary mixture of solid components in the material can cause an greater number of voids in the composite, which act as channels for the movement fungal through the material, associate with the effect of encapsulation of the fibers by the polymer.^[19]

Table 2 shows the values of the “a” parameter of the $y = ax + b$ equation from graphs of cumulative mass loss of the samples.

This parameter “a” refers to the slope of the line, which shows the growth kinetic of fungi in different ways, with the lines that showed the highest slope those with greater

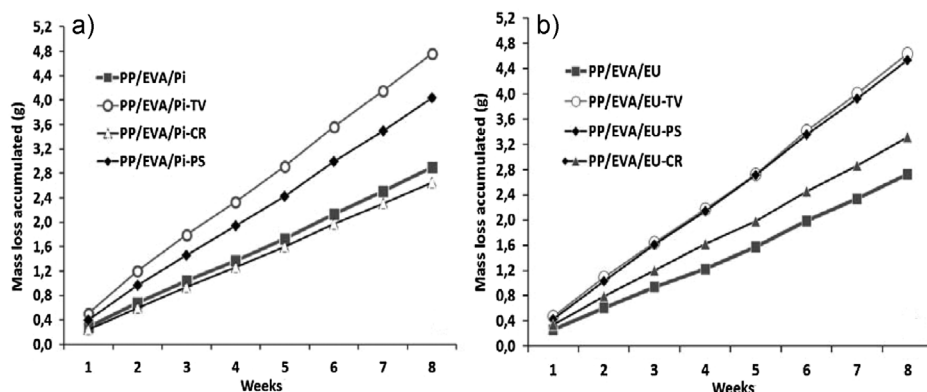


Figure 3.

Monitoring the mass loss of PP/EVA/Pi (a) and PP/EVA/Eu (b) composites for eight weeks.

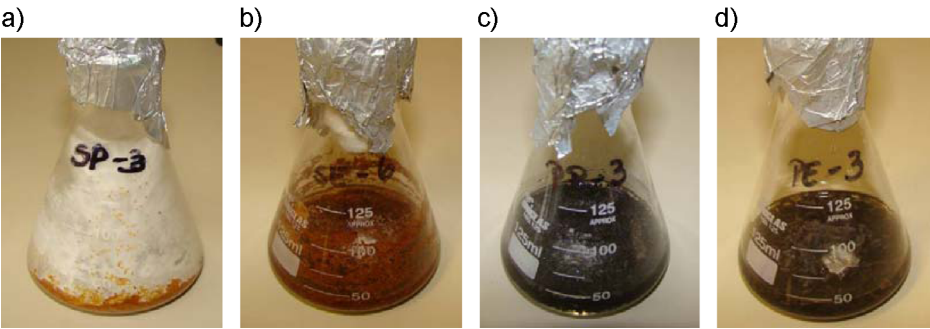


Figure 4. Images of fungal growth after 8 weeks: (a) TV in pine sample, (b) PS in the eucalyptus sample, (c) TV in the PP/EVA/Pi composite and (d) PS in the PP/EVA/Eu composite.

Table 2. Comparison between the “a” parameter of the equations of the lines monitoring the cumulative mass loss of each species exposed to fungal samples.

Fungi	Samples - Parameter a ($y = ax + b$)			
	Pi	Eu	PP-EVA-Pi	PP-EVA-Eu
Control	0,5042	0,4257	0,3699	0,3498
TV	0,6102	0,4655	0,6005	0,5901
PS	0,5737	0,5454	0,5133	0,5839
CR	0,5094	0,4323	0,344	0,42

kinetic growth of fungi and effectiveness in the mass loss of the samples. It can thus prove that, in general, the samples exposed to the *Trametes villosa* (TV) fungi showed the most growth kinetics (mass loss in the time period analyzed), with the exception of wood specie from *Eucalyptus grandis* (Eu), where the fungus *Pycnoporus sanguineus* (PS) was more effective.

Conclusion

Based on the results presented in this study, it is concluded that the *Trametes villosa* (TV) fungi was that better interacted with the wood contained in the composites, both in species of *Eucalyptus grandis* (Eu) and *Pinus elliottii* (Pi), and the *Pycnoporus sanguineus* fungi also showed interesting results. Thus, this preliminary study served as an initial assessment of the fungus species that have better ability to interact with the wood fibers used in this research. So, new perspectives for future studies in this area

have emerged to study the biodegradation of these materials.

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