Evaluation of properties of biodegradable wood-polymer composite based on ozonized wood filler and polyhydroxybutyrate for application in agricultural industry

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Abstract. The aim of this work is to develop a biodegradable planting container based on a wood-polymer composite made from polyhydroxybutyrate (PHB) and modified wood flour. To obtain a product with a given biodegradation rate, a filler is introduced into the polymer matrix in a ratio that provides the required mechanical strength. In the work were conducted experimental studies to determine the tensile strength and bending strength, impact toughness and a study to determine the rate of biodegradation of samples. The results of the studies showed that preliminary ozonization of wood flour allows to introduce into the composite up to 50% of wood filler from the total mass of the composition without loss of its mechanical properties.

1 Introduction

At present, the agricultural industry is actively developing the technology of growing plants with a closed root system, for which disposable plastic containers are used. At the same time, there is a growing public concern about the environmental situation, which is constantly deteriorating due to the pollution of the environment by a large amount of solid domestic waste made of plastic. As a consequence, there is a tendency to replace traditional plastic containers with biodegradable ones. In this case, the use of biodegradable container allows not only to reduce the environmental load, but also to ensure the possibility of planting the plant on the main place directly in the biocontainer, ensuring the complete safety of the root system [1]. For this purpose it is necessary to create a material with a given rate of biodegradation and sufficient strength, in addition, the cost of production should not exceed the cost of production of classical non-degradable plastic containers from petroleum products.

In order to solve the problem, it is proposed to create biodegradable containers for planting crops based on wood-polymer composite made of polyhydroxybutyrate and modified wood flour.

Polyhydroxybutyrate is a polymer belonging to the class of complex polyesters, biologically produced and biodegradable. To obtain a product with a given rate of

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biodegradation, as well as the cost comparable to the cost of products made of polyethylene and polypropylene, wood filler is introduced into the polymer matrix in a ratio that provides the necessary mechanical strength. It is known that wood flour having low adhesion to the polymer matrix, it is advisable to subject it to modification, in particular, ozone treatment, which allows increasing the adhesion between the polymer and wood filler.

In particular, this was revealed in the work of Safiullina A.H. and colleagues [2], who analyzed the effect of ozonation of the surface of natural and thermo-modified wood on the change in adhesive properties during bonding. It was found that ozone pretreatment increases the wettability of wood, promoting increased adhesion between wood and binder, which also ultimately leads to economical adhesive consumption and reduced emission of harmful volatile substances into the environment. *

MasahikoKobayashi et al [3] investigated the effect of ozone treatment of wood filler on the yield strength of polymer melt. They found that the formulation with wood treated with ozone in the gas phase had better flowability. In addition, the authors concluded that pretreatment with ozone can increase the filler content in the composite without significant damage to the technological parameters.

According to the presented analysis of domestic and foreign sources, it can be concluded that ozonation of wood filler before its introduction into WPC composition improves adhesion properties, increases compatibility of wood filler with polymer. At the same time, increasing the content of wood filler, as well as its deep compatibility with the polymer matrix allows to change the rate of biodegradation of the final product. In this regard, in this work we set the task to study the rate of biodegradation and strength characteristics of biocomposite based on polyhydroxybutyrate and wood filler in order to use in the production of biodegradable containers for growing seedlings with a closed root system.

2 Methods and Materials

Samples for the study of basic properties of biodegradable wood-polymer composite were made on the basis of wood flour and polyhydroxybutyrate. Studies were conducted with samples to which 2 types of flour were added: untreated and ozonized.

Ozonation was carried out in an ozone chamber GOTECH, this unit allows to evaluate ozone aging of polymeric materials under static and dynamic conditions in the presence of a given ozone concentration [4-6]. Flour was placed on a gauze cloth, flattened with a thin layer and placed in the ozone chamber.

Mechanical tests to determine the tensile strength were performed on samples with dimensions according to GOST 11262-2017, for statistical bending with dimensions according to GOST 4648-2014. Tests were carried out on a universal 2-column testing machine Gotech Testing Machine UAl - 7000M, at a temperature of 23+2 ° C and strain rate of 5.0 mm/min, with the possibility of determining the modulus of elasticity (GOST 9550-81) yield strength in tension (GOST 11262-80) [7-11].

To determine the Charpy impact toughness, a pendulum copter UGT-7045-MDL was used, with impact energy 5.5 J, pendulum speed 3.46 m/s, angle of incidence 150°, resolution 0.01J. Mechanical tests to determine the impact toughness were performed on specimens with dimensions according to GOST 4648-2014.

To test the wood-polymer composite for the rate of biodegradation, compost was made according to GOST R 57219 - 2016: wood chips were mixed with cattle excrement, 65% water, sea sand and vermiculite. Samples were weighed, placed in a container with compost for 90 days, after which the material was weighed again and the biodegradation rate was calculated.

3 Results

During the experiments on the samples it was revealed that the properties of composites depend on the amount of filler and the type of its modification. The tensile strength of the obtained composites was studied, as well as the influence of dosage and modification of wood filler, the obtained results are presented in Figure 1.

Fig. 1. Tensile strength of wood-polymer composite with different ratio of components in the mixture.

From the data obtained in the study of tensile strength of wood-polymer composites, it was observed that ozone treatment of common flour increases the tensile strength of the specimens.

The flexural tensile strength was investigated. Figure 2 shows the results of flexural strength of composites at different ratio of wood filler and polymer.

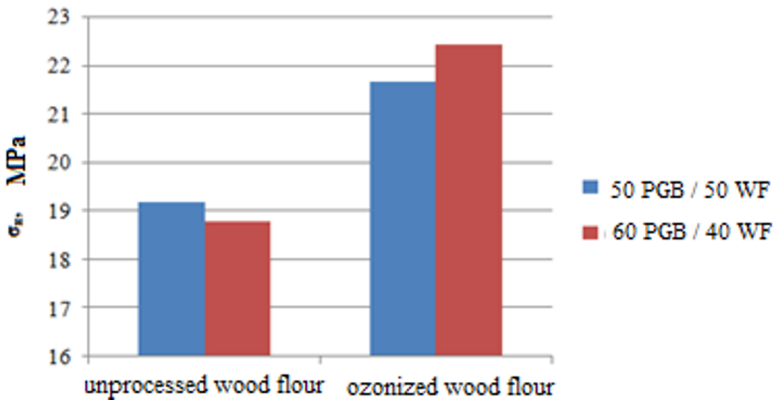

Fig. 2. Flexural strength of wood-polymer composite with different ratio of components in the mixture.

The data obtained during the experiment indicate that ozone treatment of conventional flour does not give a significant increase in flexural strength. When the amount of wood flour is reduced, the strength characteristics decrease.

The impact viscosity of the specimens depending on the ratio of wood filler to polymer matrix was determined and the results are shown in Figure 3.

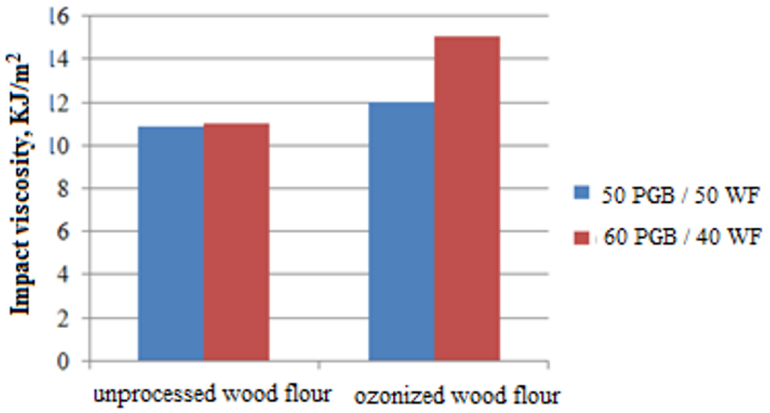

Fig. 3. Impact viscosity of wood-polymer composite with different ratio of components in the mixture.

Impact toughness increases with ozone treatment and when the amount of wood filler is reduced. It depends on the plasticity of the polymer: the more polymer, the more plastic the material, and the impact toughness depends on the plasticity and toughness of the material.

An important characteristic of composites that affects the performance properties is their density. Figure 4 shows the results of the study of the density index of the obtained composites depending on the content and type of wood filler processing.

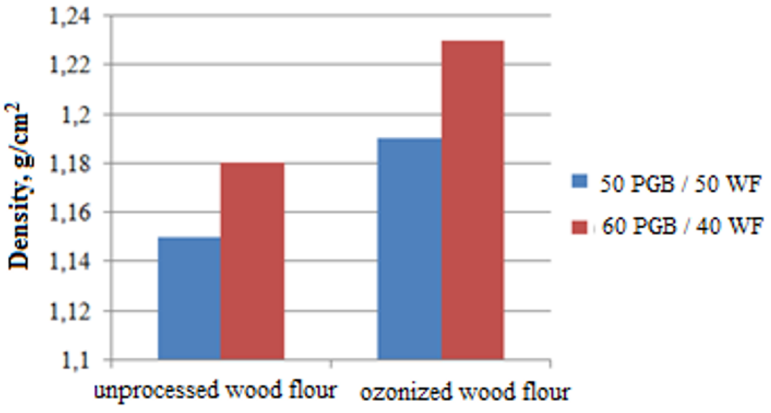

Fig. 4. Density of wood-polymer composite with different ratio of components in the mixture.

When treated with ozone, the density of the samples changes insignificantly. When the dosage of wood filler in the composition decreases, the density increases.

During the experiment to determine the biodegradation rate of the material, the data shown in Table 1 were obtained.

Table 1. Results of the experiment to determine the rate of biodegradation of wood-polymer composite based on polyhydroxybutyrate.

Composition	**60 PGB / 40 wood flour**		**50 PGB / 50 wood flour**	
Type of processing	**unprocessed wood flour**	**ozonized wood flour**	**unprocessed wood flour**	**ozonized wood flour**
Weight before the experiment, g	3.31	3.4	3.23	3.36
Weight after the experiment, g	1.02	0.65	0.91	0.52
Volume of decomposed material, %	69.19	80.89	71.83	84.53

The results of the study showed that ozonation of wood filler contributes to a significant increase in the rate of decomposition of the material, also the rate of biodegradation depends on the amount of wood flour in the composite, the composition with 50% flour decomposed faster than the composition containing 40% filler.

4 Discussion

The development of biodegradable containers for growing plants with a closed root system implies the development of a material with the required mechanical characteristics, with a given rate of biodegradation, as well as the cost comparable to the cost of a product made of plastic. The solution to the problem of reducing the cost of a product made of biodegradable plastic - polyhydroxybutyrate - is traditionally solved by introducing plant filler into the polymer matrix. However, when wood filler is added to the polymer matrix, the strength characteristics of the material are significantly reduced. In this regard, experimental studies were carried out, in which wood filler was treated with ozone, which allowed to increase up to 50% of the polymer filling with wood flour without loss of mechanical strength. At the same time, it was found that the decomposition period of the product depends on the amount of filler. Thus, by pre-ozonation of the filler it is possible to solve not only the problem of cost reduction without loss of properties, but also to predict the duration of biodegradation. In particular, the introduction of 50% ozonized filler allows to decompose more than 84% of the product in 90 days, while the decomposition of pure polyhydroxybutyrate requires more than half a year. The results showed the expediency of the filler modification before its introduction into the composite.

5 Conclusion

The key to the health and full development of a plant is a good root system, which is why the trend of planting plants with a closed root system has recently become popular in the agricultural industry. However, the question arises as to which containers should be used for planting using this method. Plastic and peat containers are materials that lose their relevance due to a large number of disadvantages and the feasibility of their use is reduced to zero. This paper presents the development of biodegradable pots for planting crops, which will allow planting plants with preservation of the root system and subsequent decomposition of the container in the soil.

Since the addition of wood filler to the polymer matrix reduces the mechanical properties of the material, it is proposed to ozonize the wood flour introduced into the composition.

Tensile and bending strengths were studied, and results were obtained on the impact toughness of the material and biodegradation rate depending on the content of wood filler. It was found that modification of the filler with ozone has a positive effect on the basic properties of the composite, and also allows to regulate the rate of biodegradation of the material by introducing the necessary amount of flour.

In the course of the work an innovative wood-polymer composite based on polyhydroxybutyrate and modified wood flour for the manufacture of biodegradable containers was developed.

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