

Influence of the matrix type on the physical and mechanical parameters of the WPC

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Abstract. Natural fibers and biodegradable matrices are currently being considered as substitutes for synthetic fiber-reinforced polymer composites mainly in areas where high load-bearing capacity and high strength are not essential. This study compares a biodegradable wood-polymer composite (WPC) prepared by varying the weight of the base material PHB and a wood flour binder as reinforcement at a weight ratio of 50/50 and 60/40%, as well as a binder made of a high-density polyethylene with wood flour at identical ratios. The maximum flexural strength of 19.193 MPa was obtained using a 50/50 combination of PHB and wood flour. The maximum value of tensile strength was shown by composites of polyethylene with wood flour at a ratio of 60/40. The maximum values of impact strength were shown by composites with a lower filler content. The highest water absorption was shown by composites from the biodegradable PHB binder. Thus, the analysis of the results showed that not only the content of the filler, but also the matrix itself has the maximum effect on the strength characteristics. **Keywords:** biodegradability, wood-polymer composite, polyhydroxybutyrate, impact strength, tensile strength, flexural strength, water absorption.

1 Introduction

The modern packaging industry needs biodegradable materials. Traditional synthetic polymers and composites based on them, in particular, polyethylene, despite the successful combination of production technology, the possibility of varying physical and mechanical characteristics and prices, create significant problems for ecology and the environment. An analysis of the scientific literature indicates that the solution to this problem is seen in the use of biopolymers or their combination with environmentally friendly fillers [1–5].

For example, studies are known that consider biocomposites and bionanocomposites based on polyethylene/polyhydroxyalkanoates and summarize many recent advances in the field of biocomposites based on PE/PHA and bionanocomposites, as well as modern methods for their preparation [6]. There are also works where scientists have studied composites and mixtures of polyhydroxyalkanoates [7]. In this work, some of the properties of PHAs have been isolated and compound variations of their modulations have been studied. And it has also been shown that polyhydroxyalkanoate (PHA) composites have improved properties compared to the pure form of these polyethers. Depending on which polymer or material is

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added to PHA, different properties were enhanced. The following review article [8] also reviews polyhydroxyalkanoate (PHA) blends and composites and their applications, and provides a comprehensive view of PHA blending, which is more effective in improving its performance, resulting in improved production and increased quality-based usage.

The article [9] provides an overview of PHAs and their composites, their main properties, with particular emphasis on the potential application of PHBV in packaging. There is also an article [10] where the authors provide an overview of composites of polyhydroxyalkanoate (PHA) and plant fibers, as well as the influence of fiber type and production method on mechanical, thermal, barrier properties and biodegradability, which are relevant to bio-packaging. To learn about behavior and trends in biomaterial reinforcement, the researchers searched for issued patents on bio-packaging applications and gained insight into current developments and industry contributions.

The work of the authors [11] is devoted to studying the effect of natural weathering on the physical and mechanical properties of biodegradable composites based on poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) and wood flour (WF). In the research, the tensile strength of composites (all types of polymers) made with 50% WF gradually decreased. Thus, it was interpreted that this decrease is associated with the appearance of surface/volumetric defects caused by the degradation of wood particles as a result of fungal (mold) damage caused by moisture. And it turned out that in general, the wood content and the availability of wood particles within the matrix determine the resistance of composites to natural weathering.

Analyzing most of the literature, it can be noted that all these solutions, of course, have their limitations, such as, for example, optimization of physical and mechanical characteristics (with the acceleration of natural biodegradation) and limited degradability, depending on the biopolymer/filler ratio. In addition, the bulk of research is aimed at studying composites based on one type of polymer, and very few comparative studies of composites based on different binders have been considered. In order to eliminate these gaps, studies were carried out aimed at the fundamental possibility of forming biodegradable high-quality composites with satisfactory physical and mechanical properties that are not inferior in many respects to their synthetic counterparts.

2 Materials and methods

Biodegradable PHB polymer in the form of small granules and wood flour brand M160, as well as polymer granules of high density polyethylene (LDPE) brand 10803-020 were used as objects of study.

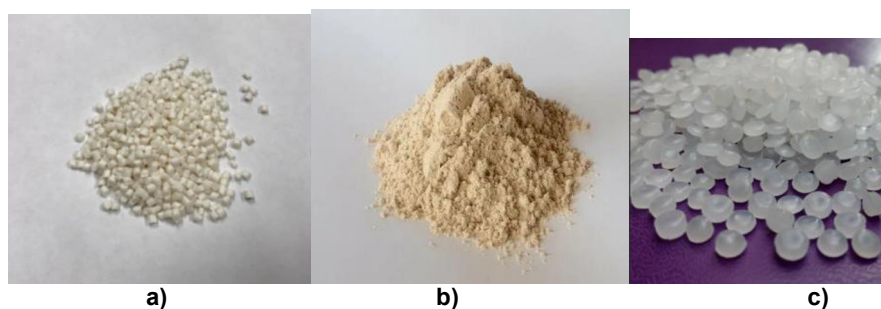


Fig. 1. Composite material components: a) biopolymer-polyhydroxybutyrate b) M160 wood flour c) LDPE brand 10803-020

3 Sample preparation

For experiments, a series of samples of biodegradable composites based on PHB was obtained by introducing a natural filler in the form of wood flour.

The preparation of a composite material based on polyhydroxybutyrate and wood flour was carried out by mixing in the “Measuring Mixer 350 E” chamber of the Brabender “PLAsti-Corder”® Lab-Station” mixing equipment at a temperature of 175 °C and a rotor speed of 30 rpm for 5 minutes. The resulting mixture was subjected to rolling through laboratory UBL-6175 A rollers with a gap of 3 mm [18].

An injection molding machine was used to obtain samples for further testing (Fig. 2).

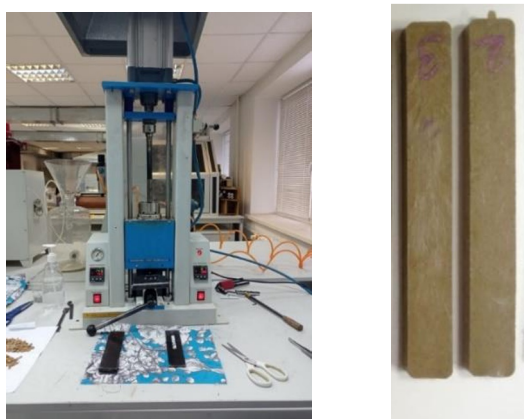


Fig. 2. Determination of the contact angle 1 – universal testing machine UAI-7000 M; 2 – test samples

To study samples for tensile strength, a universal testing machine UAI-7000 M was used.

The water absorption of the composites was determined by immersing the test samples in a container with distilled water, in which they were kept for a certain amount of a fixed time, while being periodically removed from the water and weighed on an analytical balance.

4 Results

As a result of the studies of biocomposite samples, the following data on tensile strength were obtained (Fig. 2). As can be seen from the tensile results obtained, samples from the PE matrix have higher tensile strength values compared to the biopolymer matrix. An increase in the amount of filler reduces the tensile strength both in samples with a PE matrix and with a PHB matrix (Fig. 3).

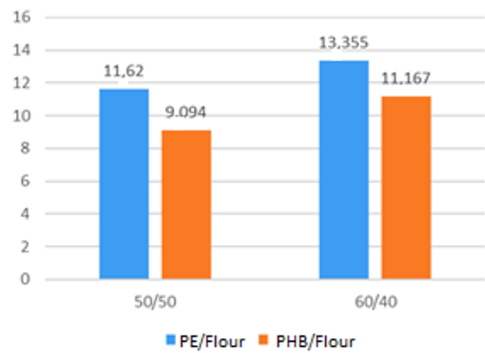


Fig. 3. Tensile strength of composite materials

As studies of the bending strength have shown, fillers also have a different effect on these indicators. However, in this case, an increase in the amount of filler in both cases leads to an increase in the ultimate bending strength (Fig. 4). At the same time, the PHB matrix in both ratios showed the highest performance compared to the PE matrix. Charpy impact strength graphs are similar to the bending strength (Fig. 5).

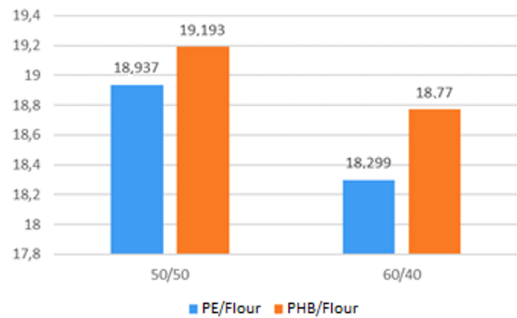


Fig.4. Bending strength of composite materials

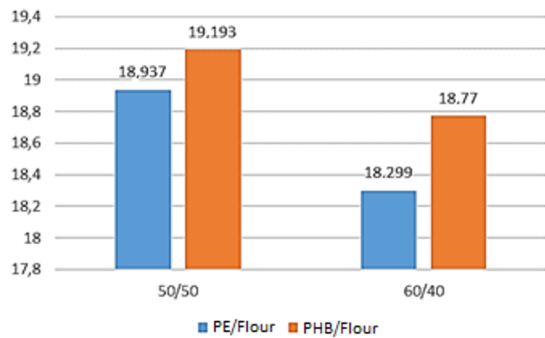


Fig.5. Charpy impact strength of composite materials

The results of the Shore D hardness test are presented in (Fig. 6).

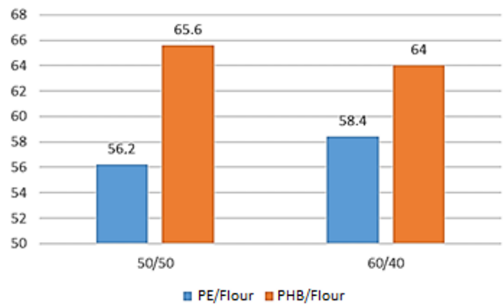


Fig.6. Shore D hardness of composite materials

As can be seen from the data obtained, the hardness of the composites differs slightly depending on the type of matrix. Nevertheless, the PHB matrix has a higher hardness than the samples made of PE matrixes.

Below are the results of studies to determine water absorption (Fig. 7). Analysis of the obtained data shows that samples of composites based on biodegradable PHB underwent the highest water absorption, which once again proves the ability of these samples to quickly degrade in natural conditions. Composites based on PE suffered little water absorption. Moreover, the quantitative content of the filler did not have a significant role in the research results, and the nature of the graphs for both contents is similar. With an increase in the amount of filler in the composites, their water absorption increases.

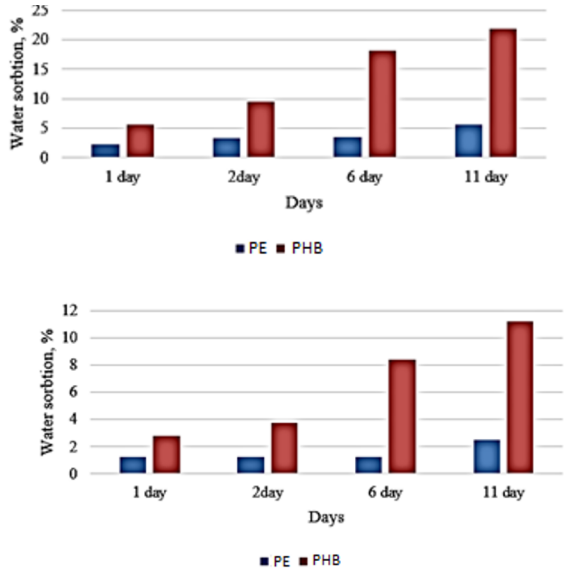


Fig.7. Water absorption of composite materials

5 Conclusions

As a result of the studies performed, samples of composite materials with PE and PHB matrices, as well as with different quantitative content of wood flour, were obtained.

For the obtained samples of composites, the physical and mechanical properties were determined, and the experimental dependences of their parameters on the type of polymer

and the quantitative content of wood flour were established. It has been established that the PE binder has higher tensile strength, but the lowest binding strength and impact strength. In addition, the hardness indices of PE composites turned out to be lower than those of the biocomposite.

An increase in the percentage of wood flour, regardless of the type of polymer, leads to a decrease in the elastic modulus. However, it also leads to higher values of tensile strength and impact strength. The water absorption of the PHB-based composites was found to be significantly higher than that of the PE-based composites.

Thus, we can conclude that the use of biodegradable polymers together with wood flour makes it possible not only to significantly reduce the polymer content in the composite by adding fillers to the composition (which, in turn, makes it possible to reduce the cost of the biocomposite), but also to increase its certain physical and mechanical properties and obtain stronger composites, in comparison with composites with PE matrix.

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