Evaluation of biocomposites' defectiveness, the effect of defectiveness on water absorption

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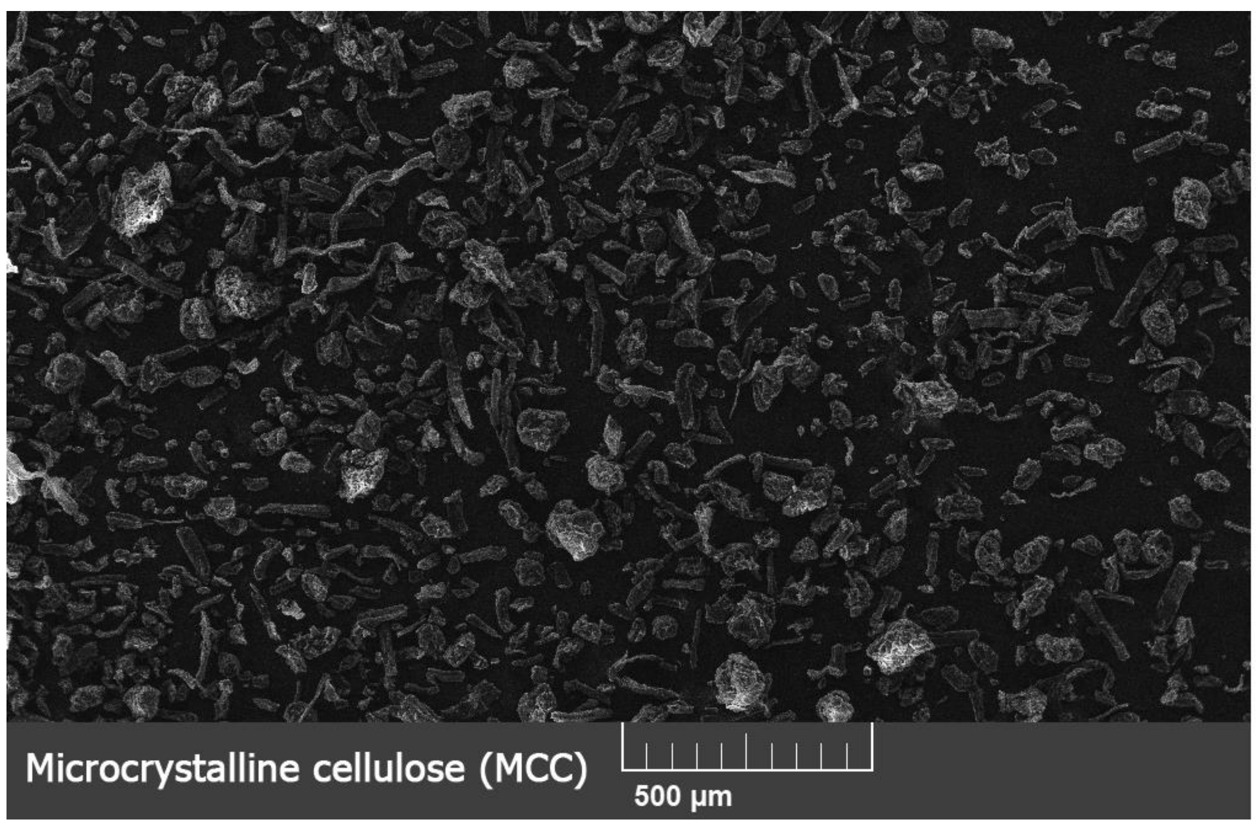
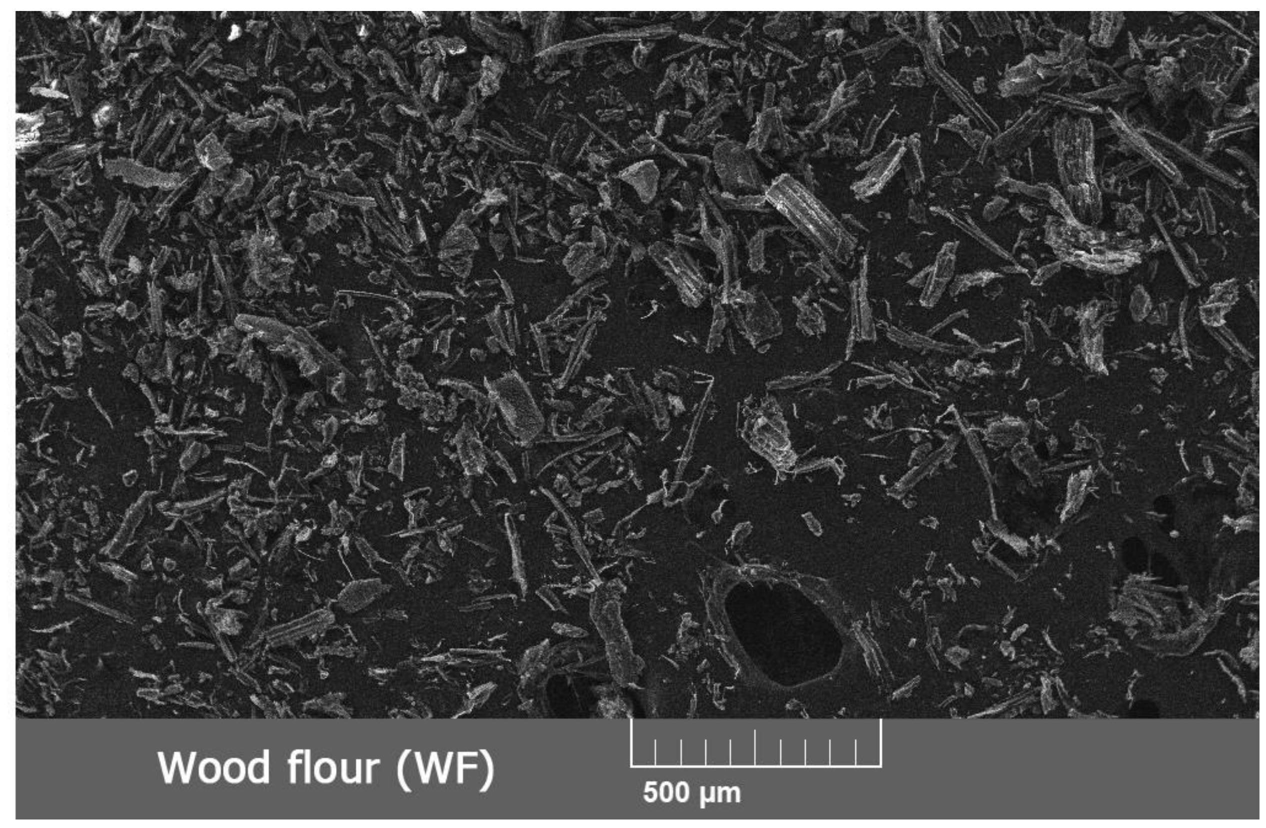
The production of biocomposite polymer materials increase every year. Manufacturers of packaging materials intend to be environmentally responsible because of their own ESG strategies and as a respond to the consumers' request. Biocomposites consist of synthetic polymer matrix and natural (vegetable or animal origin) fillers [1]. Different raw materials may be used as a filler. In most part of the works the cellulose or starch are being used. But these polysaccharides are very valuable and expensive. Plant waste are cheaper, and their application in biocomposites also solves the problem of their disposal. Wood flour (WF) is widespread and cheap material; however, the particles of WF have irregular shape. It may cause the defects in the structure of biocomposite, made of polymer matrix and WF. Earlier it was shown that complex fraction of the filler even after filtering through the sieve with 200 μm mesh have large aggregates and form defects in biocomposite [2]. For this study WF particles were filtered though 100 μm mesh. Microcrystalline cellulose (MCC) was chosen as a referent filler, it has more smooth particles. MCC was also filtered through 100 μm mesh. Photomicrographs of the fillers, prepared by scanning electron microscopy, are presented below.





According to the previous works, ethylene vinyl acetate (EVA) matrix was chosen as the most appropriate polymer matrix [3], [4]. In this study EVA grade with 15% of vinylacetate and MFI = 6 g/10 min was chosen as a matrix. Biocomposites were mixed in melt condition by heated rolls at a temperature of 130-150 °C. After they were crushed and molded by hydraulic press with plates heated to 140 °C. As a result, white flat sheets were obtained from biocomposites with MCC, and brown ones from biocomposites with WF. Different content of the fillers was added to EVA: 50, 60, 70 wt.%. Visually it was obvious that the composite with 70 wt.% of WF had a lot of voids and defects. In contrast, the same composite with 70wt. % of MCC was homogenous with well dispersed filler's particles. For evaluation of the defectiveness of biocomposites the defect ratio was calculated as the difference between theoretical density of biocomposite and its real density. Theoretical density was calculated as a sum of densities of matrix and filler. Real density was measured by hydrostatic weighting in liquid media. The obtained results on the defect ratio are presented in Table 1. It can be seen that there is a large defect rate gap between 60 and 70% of WF. It means that WF_70 composite is very defective and cannot be used for the manufacture of products as it is.

Table 1. Defect ratio, calculated as the difference between theoretical and real densities of biocomposites

Filler \ Filler content	50 wt.%	60 wt.%	70 wt.%
Microcrystalline cellulose (MCC)	5	6	6
Wood flour (WF)	3	4	**9**

The defectiveness of composites effect on the water absorption index (Table 2). With an increase in the concentration of the filler, water absorption increased. It was expected since only polar cellulose-containing filler can absorb water. The difference in water absorption between MCC_60 and MCC_70 was just 4.2%. At the same time, the difference between WF_60 and WF_70 was 10.0%. Probably, water penetrates into the defective areas of the biocomposite and remains there even after removing the sample from the water. The water absorption index quite accurately characterizes the defectiveness of biocomposites. The difference between two fillers is also obvious – 70% composites with WF had twice higher water absorption that the same ones with MCC. It can be explained by irregular shape and wide size distribution of WF particles that can be seen from photomicrographs in Figure.

Table 2. Water absorption of biocomposites

Filler \ Filler content	50 wt.%	60 wt.%	70 wt.%
Microcrystalline cellulose (MCC)	11.6	13.5	17.7
Wood flour (WF)	14.1	20.1	**30.1**

Melt flow index also proves the defectiveness of WF_70 biocomposites. For example, biocomposites based on EVA (LG 19150) had a weak flow for biocomposites filled by 70% of MCC, and no flow for 70% of WF. The data on MFI are presented in Table 3.

Table 3. Melt flow index of biocomposites (Load = 10 kg, T = 190 ◦C)

Filler \ Filler content	50 wt.%	60 wt.%	70 wt.%
Microcrystalline cellulose (MCC)	92.0	22.0	0.4
Wood flour (WF)	16.5	0.8	**No flow**

Conclusion: The method for determining the defectiveness of biocomposites by the difference between the real and theoretical density makes it possible to accurately identify both the most perfect and the most defective biocomposites. Early rejection of unsuccessful composites by this parameter saves time and resources of the researchers.

Acknowledgement: This work was supported by Plekhanov Russian University of Economics.

References:

[1] M. Brebu, Polymers 12 (2020) 166
[2] A.K. Zykova, P.V. Pantyukhov, N.N. Kolesnikova, et al., J Polym Environ 26 (2018) 1343–1354
[3] P.G. Shelenkov, P.V. Pantyukhov, A.A. Popov, IOP Conf. Ser.: Mat. Sci.Eng., 369-1 (2018) 012043
[4] P.G. Shelenkov, P.V. Pantyukhov, A.A. Popov, Mat. Sci. Forum, 992 (2020) 306–310

The whole study was recently published:

Shelenkov P.G., Pantyukhov P.V., Poletto M., Popov A.A. Influence of Vinyl Acetate Content and Melt Flow Index of Ethylene-Vinyl Acetate Copolymer on Physico-Mechanical and Physico-Chemical Properties of Highly Filled Biocomposites. Polymers, 2023, 15, 2639. https://doi.org/10.3390/polym15122639