IMPROVEMENT OF THE TECHNOLOGY FOR PRODUCING ECO-FRIENDLY BIOPLASTIC MATERIAL USING EGGSHELL WASTE AS A NATURAL MINERAL FILLER

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Abstract. This study focuses on improving the technology for producing eco-friendly bioplastic material using eggshell waste as a natural mineral filler. Eggshell powder was added to a biodegradable polymer matrix to enhance the strength, density, and structural stability of the material. The obtained bioplastic showed improved physical and technological properties, indicating that eggshell waste can be effectively used as a low-cost, available, and environmentally safe raw material for biodegradable material production.

Keywords: eggshell waste, eco-friendly bioplastic, mineral filler, biodegradable material, polymer matrix, waste recycling.

Annotatsiya. Ushbu tadqiqotda tuxum po'chog'i chiqindilaridan tabiiy mineral to'ldiruvchi sifatida foydalanib, ekologik bioplastik material olish texnologiyasini takomillashtirish masalasi o'rganildi. Tuxum po'chog'i kukuni biopolimer matritsaga qo'shilib, materialning zichligi, mustahkamligi va strukturaviy barqarorligini oshirishga xizmat qildi. Olingan natijalar tuxum po'chog'i chiqindilaridan arzon, mavjud va ekologik xavfsiz xom ashyo sifatida bioplastik material ishlab chiqarishda samarali foydalanish mumkinligini ko'rsatdi.

Kalit so'zlar: tuxum po'chog'i chiqindisi, ekologik bioplastik, tabiiy mineral to'ldiruvchi, bioparchalanuvchi material, biopolimer matritsa, chiqindilarni qayta ishlash.

Аннотация. В данном исследовании изучено совершенствование технологии получения экологически безопасного биопластического материала с использованием отходов яичной скорлупы в качестве природного минерального наполнителя. Порошок яичной скорлупы был введён в биополимерную матрицу, что способствовало повышению плотности, прочности и структурной устойчивости материала. Полученные результаты показывают, что отходы

яичной скорлупы могут эффективно использоваться как доступное, недорогое и экологически безопасное сырьё для производства биопластических материалов.

Ключевые слова: отходы яичной скорлупы, экологический биопластик, природный минеральный наполнитель, биоразлагаемый материал, биополимерная матрица, переработка отходов.

Introduction. The production of eco-friendly bioplastic materials from natural and renewable sources is one of the important directions in modern material science. eggshell waste is rich in calcium carbonate and can be used as a natural mineral filler to improve the properties of biodegradable materials.

The main problem is that large amounts of eggshell waste are usually discarded, causing environmental pollution and loss of valuable raw material. Previous studies have shown that natural fillers can improve the strength, density, and stability of bioplastic materials.

The aim of this study is to improve the technology for producing eco-friendly bioplastic material using eggshell waste as a natural mineral filler. The novelty of the research is the use of eggshell waste to enhance the physical and technological properties of biodegradable bioplastic material.

Materials and methods. the object of the study was an eco-friendly bioplastic material produced using eggshell waste as a natural mineral filler. eggshell powder, starch, glycerin, water, and a small amount of vinegar were used as the main raw materials and additives.

First, eggshell waste was washed, dried, ground into powder, and sieved. Then starch was mixed with water, glycerin, vinegar, and eggshell powder until a homogeneous mixture was obtained. The mixture was heated at 70–80 °C with continuous stirring until it became thick and gel-like.

The prepared mass was poured onto a flat surface and dried at room temperature or in a drying oven at 40–50 °C until a flexible bioplastic film was formed. The obtained samples were evaluated according to their appearance, thickness, flexibility, strength, density, and biodegradability. A balance, thermometer, drying oven, grinder, sieve, and measuring tools were used during the experiment.

Results. As a result of the experiment, an eco-friendly bioplastic material was obtained using eggshell powder as a natural mineral filler. the prepared samples had a smooth surface, light color, and film-like structure. the addition of eggshell powder improved the density and strength of the bioplastic material.

Three sample variants were prepared and compared. Variant 1 contained a low amount of eggshell powder, Variant 2 contained an optimal amount, and Variant 3

contained a higher amount of eggshell powder. The best result was observed in Variant 2, which showed good flexibility, sufficient strength, and a uniform structure.

Table 1.

Physical and technological properties of bioplastic samples with eggshell powder

Sample variant	Eggshell powder amount	Appearance	Flexibility	Strength	Density
Variant 1	Low	Thin and soft	High	Low	Low
Variant 2	Optimal	Smooth and uniform	Good	Good	Medium
Variant 3	High	Dense and slightly rough	Low	High	High

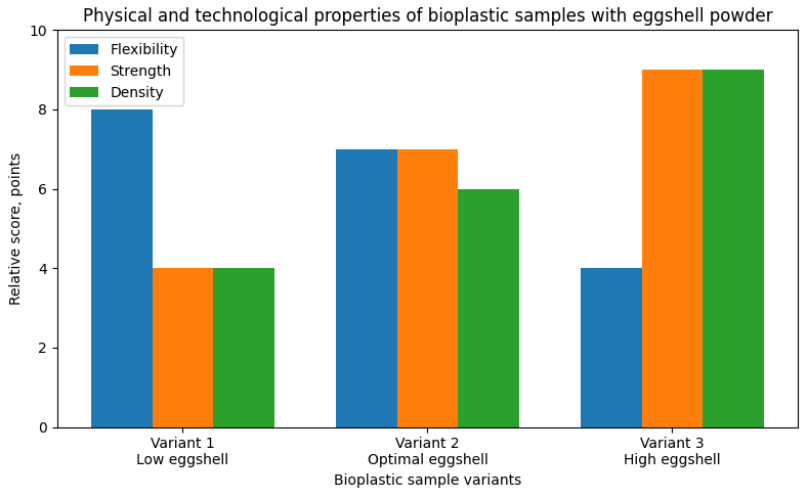

Figure 1. Effect of eggshell powder amount on the physical and technological properties of bioplastic samples.

The graph shows that Variant 2, containing an optimal amount of eggshell powder, demonstrated the best balance between flexibility, strength, and density. Variant 1 had higher flexibility but lower strength and density, while Variant 3 showed increased strength and density but reduced flexibility. Therefore, the optimal amount of eggshell powder is important for obtaining bioplastic material with balanced properties.

The results showed that excessive eggshell powder increased the density and hardness of the material but reduced its flexibility. Therefore, the optimal amount of eggshell powder is important for obtaining a bioplastic material with balanced physical and technological properties.

Discussion. The results show that eggshell powder can be effectively used as a natural mineral filler in bioplastic production. the calcium carbonate in eggshell powder improved the density, hardness, and structural stability of the material.

Variant 2 showed the best balance between flexibility and strength. This can be explained by the optimal ratio of starch, glycerin, and eggshell powder. Starch formed the main biopolymer matrix, glycerin increased flexibility, and eggshell powder strengthened the structure.

Compared with previous studies on natural fillers, the use of eggshell waste is more economical and environmentally friendly because it allows food waste to be reused. The main advantage of the obtained bioplastic is its low cost, availability of raw materials, and biodegradability. However, excessive eggshell powder may reduce flexibility and make the material more brittle.

The developed material can be used for simple packaging, disposable items, agricultural films, and other eco-friendly biodegradable products.

Conclusion. The study showed that eggshell waste can be effectively used as a natural mineral filler in the production of eco-friendly bioplastic material. The addition of eggshell powder improved the density, strength, and structural stability of the obtained material. The best result was observed in the sample with an optimal amount of eggshell powder, where flexibility and strength were well balanced. Excessive addition of eggshell powder increased hardness but reduced flexibility. Therefore, eggshell waste can be considered a cheap, available, and environmentally safe raw material for biodegradable bioplastic production.

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