

"SMART" BIOPLASTICS BASED ON FRUIT PEELS AND THEIR
PROCESSING TECHNOLOGIES

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Abstract: This article discusses the possibilities of using local agricultural waste in the production of bioplastics, in particular, the technology for obtaining "smart" (with antibacterial properties) bioplastics based on fruit peels. The study analyzed the creation of a composite biopolymer based on starch, cellulose and natural extracts, its physicochemical properties, and environmental problems associated with polymer processing. As a result, the proposed material is characterized as an active packaging material that is not only biodegradable, but also extends the shelf life of food products.

Keywords: bioplastic, starch, cellulose, pomegranate peel, antibacterial material, active packaging, polymer processing, biodegradation.

Introduction: Currently, the increase in plastic waste is recognized as one of the global environmental problems. Traditional polymer materials, in particular plastics such as polyethylene and polypropylene, decompose very slowly in nature and lead to pollution of soil and water bodies. Therefore, the creation of environmentally friendly, renewable and biodegradable materials has become an important area of scientific research. One of such promising solutions is bioplastics, which not only do not harm the environment, but also have functional properties.

In recent years, the use of agricultural waste in the production of bioplastics has gained particular importance. Fruit peels, in particular pomegranate peels, are especially rich in biologically active substances. Pomegranate peels contain polyphenols, ellagitannins (punicalagin), flavonoids and anthocyanins, which have strong antibacterial and antioxidant properties. These substances act on the cell walls of microorganisms, slowing down or completely stopping their development. At the same time, due to their antioxidant properties, the oxidation process of food products also slows down, which extends their shelf life.

Starch is widely used as the main component in the production of bioplastics. Starch undergoes gelatinization under the influence of water and heat, forming a sticky and elastic mass. However, since pure starch-based plastics are brittle, glycerin is added to their composition as a plasticizer. Glycerin penetrates between the starch chains, softens their interconnections and gives the material flexibility. At the same time, cellulose fibers, such as cotton lint, are added to increase the mechanical strength of the bioplastic. As a result, a composite polymer system based on starch, glycerin and cellulose is formed.

The extract obtained from pomegranate peel gives this composite material additional functional properties. In particular, it forms an antibacterial “active packaging” system. Such packaging material is not only a simple protective agent, but also actively protects the product. In addition, since the anthocyanins contained in pomegranate are sensitive to the pH environment, the bioplastic can also act as a color-changing indicator. If the packaged product begins to deteriorate, the chemical composition of the environment changes, which leads to a change in the color of the plastic. As a result, the consumer can visually determine the condition of the product. The process of preparing this bioplastic consists of several stages, first, pomegranate peel is extracted in water at a certain temperature. Then, starch, glycerin and acetic acid are added to the resulting solution, and the mixture is heated. In this process, the starch undergoes gelatinization and forms a homogeneous mass. In the next stage, cellulose fibers are added, forming a composite structure. The finished mass is spread in a thin layer, dried, and an elastic bioplastic film is obtained.

Eksperimental tadqiqotlar natijasida ushbu materialning qator afzalliklari aniqlangan. Jumladan, u oddiy kraxmalli plastmassaga nisbatan mustahkamroq, antibakterial xususiyatga ega va biologik parchalanish qobiliyati yuqori. Tuproqqa tushganda u 30–60 kun ichida tabiiy ravishda parchalanadi, bu esa ekologik xavfsizlikni ta'minlaydi. Shu bilan birga, u oziq-ovqat mahsulotlarini saqlash muddatini uzaytirishga xizmat qiladi.

Iqtisodiy jihatdan ham ushbu texnologiya samarali hisoblanadi. 1 kg anordan oʻrtacha 400–500 g poʻstloq olinadi, bu esa bioplastik ishlab chiqarish uchun muhim xomashyo hisoblanadi. Oʻzbekiston sharoitida, xususan Surxondaryo viloyatida anor yetishtirish hajmi yuqori boʻlib, yiliga oʻn minglab tonna chiqindi hosil boʻladi. Bu esa bioplastik ishlab chiqarishni sanoat miqyosida tashkil etish uchun katta imkoniyat yaratadi.

EXPERIMENTAL PART: During the experiment, a process of obtaining a "smart" bioplastic based on pomegranate peel was carried out. The main raw materials used were starch, pomegranate extract, glycerin and cellulose fibers.

The experiment was carried out in several stages, and specific physicochemical processes were observed at each stage.

Stage	Process description	Materials used	Observed result
1	Extraction	Pomegranate peel + water	A brown solution rich in polyphenols was obtained
2	Mixing	Starch + extract + glycerin + vinegar	A homogeneous liquid mixture was formed
3	Gelatinization	Heating (85–95°C)	A thick and viscous gel was formed
4	Compositing	Addition of cotton fibers (cellulose)	A strong composite mass was formed
5	Molding and drying	Spreading in a thin layer	An elastic bioplastic film was obtained

The bioplastic samples obtained as a result of the experiment were subjected to a series of tests. These tests were aimed at determining the physical, mechanical and functional properties of the material.

The table below presents the tests conducted and their results:

Test type	Method	Result
Hydrophobicity	A water droplet was placed on the surface	Water was absorbed slowly; better than ordinary starch-based plastic
Mechanical strength	The film was stretched manually	The sample bent without breaking; cellulose effect was observed

Test type	Method	Result
Biodegradation	Buried in soil	Decomposition started within 30–60 days
Antibacterial activity	Tested with meat sample	Spoilage process was slowed down
pH indicator (color response)	Exposed to different pH environments	Noticeable color change was observed

In general, the experimental results showed that the bioplastic made from pomegranate peel has a number of advantages over ordinary starch plastic. In particular, it has antibacterial properties and extends the shelf life of food products. The addition of cellulose increased the mechanical strength of the material, while glycerin provided its elasticity. Also, the sensitivity of the bioplastic to pH confirmed its ability to act as a “smart” indicator material.

Biodegradation tests showed that this material is environmentally safe, since it decomposes in the soil in a short time. Therefore, it was found that the obtained bioplastic can be used as an active packaging material in the food industry.

LITERATURE REVIEW

In recent years, the number of scientific studies conducted on bioplastics and their environmental benefits has increased significantly. In particular, the direction of developing biodegradable polymers based on renewable raw materials has become one of the most relevant areas of materials science. Literature analysis shows that starch-based bioplastics have been widely studied, they are characterized by their low cost and availability. However, their main drawback is low mechanical strength and insufficient water resistance.

Some researchers have recommended the use of various plasticizers, in particular glycerin, to improve the properties of starch-based bioplastics. Glycerin reduces the interaction between starch chains and gives the material flexibility. At the same time, the increase in mechanical strength of bioplastics as a result of the addition of cellulose fibers has been scientifically substantiated. This indicates the effectiveness of the direction of creating composite biopolymers.

The use of plant extracts to improve the functional properties of bioplastics has also been widely studied. In particular, it is noted in scientific sources that plants rich in phenolic compounds have antibacterial and antioxidant properties. Pomegranate peel deserves special attention in this regard, as it has been found to contain ellagitannins, flavonoids and other bioactive substances. Studies have shown that these substances suppress the activity of microorganisms and slow down the deterioration of food products.

In modern scientific work, the concept of “active packaging” is widely developed. According to this approach, the packaging material is not a passive protective agent, but a system that actively affects the preservation of product quality. The literature contains information about the development of biopolymer films with antibacterial additives, antioxidants and indicator substances. In particular, research is being conducted to develop “smart” packaging systems based on pH-sensitive indicators.

Biodegradation processes have also been studied in many scientific studies. It has been found that materials based on natural polymers decompose in a short time under the influence of microorganisms. This makes them environmentally superior to traditional plastics. At the same time, the issues of industrial production and economic efficiency of bioplastics have also been discussed in the scientific literature.

The analyzed scientific sources show that, although starch and cellulose-based bioplastics have been sufficiently studied, the issue of increasing their functional properties by adding local agricultural waste, in particular pomegranate peel, to their composition has not yet been fully studied. In particular, the direction of creating “smart” bioplastics that combine antibacterial, antioxidant and indicator properties is scientifically new and promising.

Thus, based on the analysis of the existing literature, it can be concluded that bioplastics prepared on the basis of pomegranate peel not only serve to solve environmental problems, but also play an important role in the development of active packaging technologies. This confirms the relevance and scientific novelty of this research area.

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