# Universal eco-friendly biodegradable packaging for storage and transportation of food and industrial goods based on shives of bast plants

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**Abstract**. Integrated processing of plant raw materials refers to the primary areas of use of natural resources and their rotection. During the primary processing of bast plants, a large amount of waste remains – a shives. Part of the shives is burned, the rest goes into the dump. Due to its chemical composition, high content of cellulose shives can be used in the production of eco-friendly packaging. Packaging can be obtained with the complete or partial replacement of waste paper in its composition. Thanks to this, the issue of the shortage of waste paper at the enterprises of recycling of secondary raw materials will also be resolved. The purpose of the work is the production of eco-friendly biodegradable packaging from flax shives in industrial conditions. The paper presents the results of samples of lumpy egg packaging obtained by vacuum casting with the use of flax production waste. In industrial conditions, it was possible to replace part of the waste paper on the fire. For more efficient use, the shives was pre-ground to the consistency of wood flour M-560. The following indicators were determined: humidity, strength, moisture absorption capacity, antibacterial properties. The obtained results showed the optimal ratio of the mixture components, processing modes. According to all indicators, the packaging with a bone is not inferior, and in the case of tensile strength and antibacterial properties exceeds the normalized values.

**Keywords:** Eco-friendly packaging • Vacuum casting • Flax Shives • Waste paper • Waste •Disposal.

## 1. Introduction

In the strategic policy of the development of food and processing industries of the Russian Federation, the priority direction is the introduction and use of energy-efficient, environmentally friendly, integrated, waste-free technologies [1-5].

Analysis of the work of food and processing industries has shown that today secondary resources are not used efficiently, often go to dumps, burned, dumped into reservoirs, which causes damage to the ecology of the region, and enterprises do not make a profit [6-10].

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Every year in the Udmurt Republic, flax processing enterprises accumulate about 25 tons of waste from flax production – shives. Half is burned in boiler rooms, despite the fact that the enterprises are fully gasified, and the other half goes to the dump. All this aggravates the ecological situation of the territories.

Shives is a large-tonnage waste of flax production, it makes up 70% of all raw materials (Fig.1).

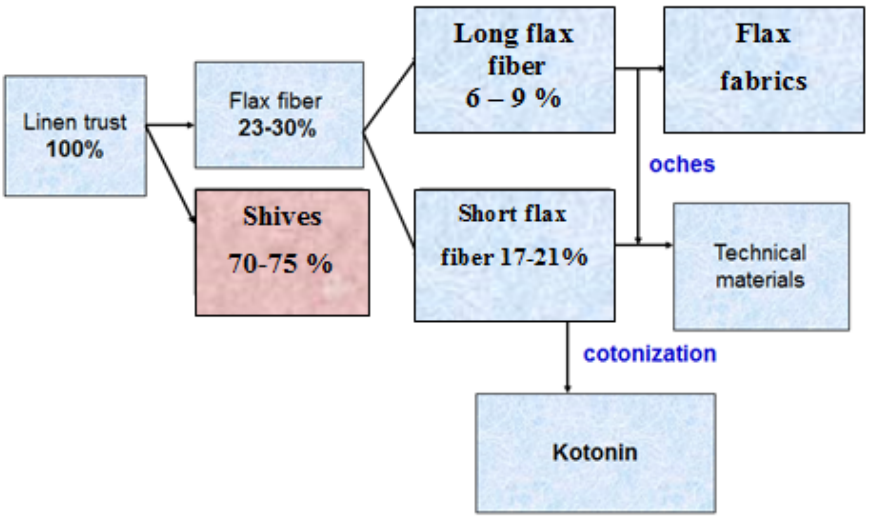


**Fig. 1.** Schematic diagram of flax retting processing ("Compiled by the authors").

The most important organic compounds are shives, by weight. %: cellulose up to 77.4; hemicellulose up to 16.2; soluble substances up to 3.4; resins, fats, wax up to 1.9 [11, 12]. From which it follows that due to the large amount of cellulose and hemicellulose, as well as the content of natural organic adhesives, shives can be used for the production of universal biodegradable packaging for food and industrial goods. What will make it possible to transfer the shives from the category of "Waste" to the category of "Valuable renewable raw materials".

In the Russian Federation, vacuum casting technology is used everywhere in the production of packaging for eggs, alveoli for fruits and other packaging materials. This technology is simple, and very well mastered. The main raw material for the production of packaging using this technology is waste paper of the following types: MS-5B, MS – 6B, MS – 7B, MS – 8B GOST 10700 – 97, technical water, and water-repellent additives of foreign production ("Compiled by the authors").

As a result of the economic crisis, the available waste paper has always increased significantly in price and volume, problems with its supply to production began to be observed. To solve this problem, scientists of the Udmurt State University have proposed a method for the production of packaging, with partial replacement of a part of waste paper, with pre-prepared raw materials produced from shives of bast plants (flax, hemp). All the necessary materials were prepared, laboratory samples of packaging material were manufactured and tested in laboratory conditions, which confirmed the hypothesis of the expediency of the decision taken. To introduce the technology into real production conditions, the composition of the raw material, its processing modes, and operating modes of the equipment are analyzed.

After that, industrial images of a lumpy substrate were made for storing and transporting eggs on the territory and equipment of the Beston vacuum casting line at the Izhevsk Sputnik Enterprise named after him. Isaenko E.M." the cities of Izhevsk of the Udmurt Republic.

## 2. Materials and Method

The purpose of the work is to create an industrial sample of lumpy packaging for transportation and storage of food and industrial goods.

Tasks: to evaluate the quality of the raw materials; to choose ways to refine the raw materials; to choose the optimal ratio of pulp components; to evaluate the quality of the products obtained.

The object of research is a lumpy packaging for storing and transporting eggs, made from waste paper and flax shives by vacuum casting on the "Beston" production line.

In the manufacture of images , the main raw material was:

- waste paper types MS-5B (corrugated cardboard, waste of its use, as well as its derivatives), MS –6B (cardboard with printed or patterned, as well as waste from its production), MS–7B (printing products: books, catalogs and brooches, notebooks, notebooks, and other products, made of white paper, but without bindings.) GOST 10700 – 97;
- shives of flax, ground to the state of wood flour brand M-560;
- technical water.

The waste paper was carefully sorted and inspected, and the MS-7B type waste paper did not exceed 25% of the total mass of waste paper.

The composition of bonfires was determined by instrumental method: dust - 2.8%, shives – 90.8%, meek fiber - 3.6%, flax seeds - 2.8% (Fig. 2).

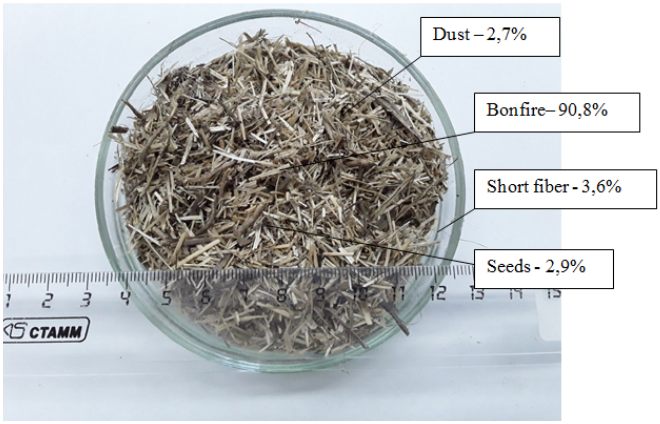


**Fig. 2.** Composition of the bonfire mixture: dust - 2.7%, shives – 90.8%, meek fiber - 3.6%, seeds - 2.9% ("Compiled by the authors").

The shives has been previously finalized. The refinement consists in grinding with whip mills to the state of wood flour M – 560 GOST 16361-87, the particle sizes of bonfires are 620 -560 microns, compressed into pallets for logistics efficiency (Fig.3).

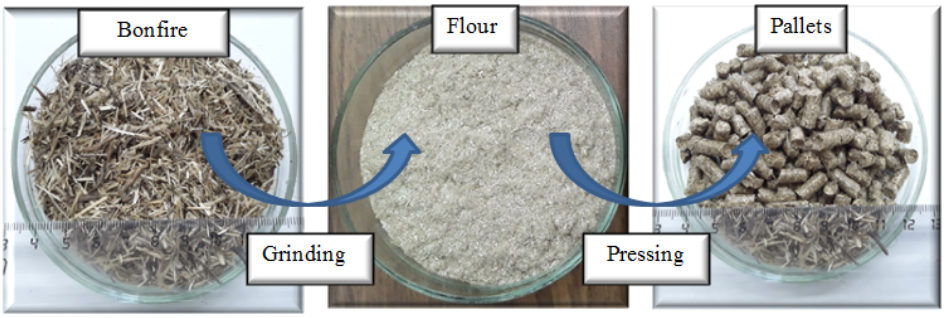


**Fig. 3.** The process of finalizing flax shives ("Compiled by the authors").

Pulp was prepared from flax shives, waste paper and industrial water by hydraulic fracturing, with a concentration of a fire-paper mixture of 2%.

Samples of lumpy packaging were produced on the production line of vacuum paper casting "Beston", in the production conditions of LLC "Izhevsk enterprise "Sputnik" named after Isaenko E.M." the cities of Izhevsk of the Udmurt Republic (fig. 4).


**Fig. 4.** Beston vacuum paper casting equipment ("Compiled by the authors").

To determine density, mass, humidity, automatic control methods were used – hydrometric (float) GOST 18481-81, laboratory scales GOSMETER series VLTE-150, humidity analyzer Sartorius MA 35, respectively. Control of the drying temperature and time was carried out using the dashboard of the Beston line (Fig.4). Organoleptic methods determined the condition of the surface and the appearance of the packaging images. The samples were tested for stretching and crumpling under laboratory conditions at the UIM-50 installation.

## 3. Results

The study of the influence of the ratio of waste paper and shives meal with the technological and technical capabilities of the "Beston" line allowed us to establish the optimal combination of technical and technological parameters.

A number of indicators are known, using which it is possible to give an objective assessment of the quality of samples of lumpy packaging for transportation and storage of eggs [13].

Industrial samples of a lumpy egg gasket were made of pulp of different composition. The composition of the shives was changed from 10-90%, relative to the mass of waste paper. During the production process, the following indicators were monitored: pulp density, filter condition, vacuum value of the system, drying speed, drying temperature, humidity and mass of finished products. After that, the samples were subjected to laboratory tests.

Figure 5 shows the dependence of the crushing load on the ratio of shives to waste paper. It can be seen from the graph that the greatest value, with a margin of safety of 16.6 times to the load carried, is the ratio of a mixture of 50% shives and 50% waste paper, which corresponds to the specified norms. With an increase in the content of shives in the pulp, packages become more fragile, dense, and the load on crumpling decreases.

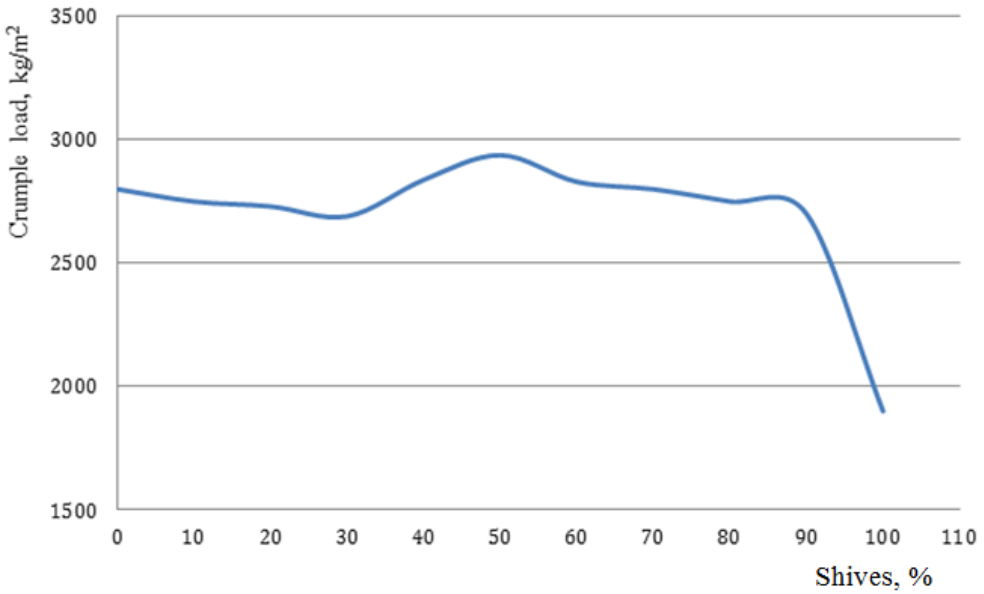


**Fig. 5.** Dependence of the crushing load on the pulp composition ("Compiled by the authors").

The results of the image rupture test are shown in Fig. 6. With an increase in the fires in the pulp and a decrease in the amount of waste paper, there is a decrease in the rupture load, but within the limits of the standards [4]. When the composition of the shives in the pulp is brought to 90-100%, the values drop sharply, which indicates a lack of connecting bonds between the shives particles and increased fragility of the packaging. The most acceptable composition that meets the requirements is the composition of pulp with a content of 10-60 % shives.

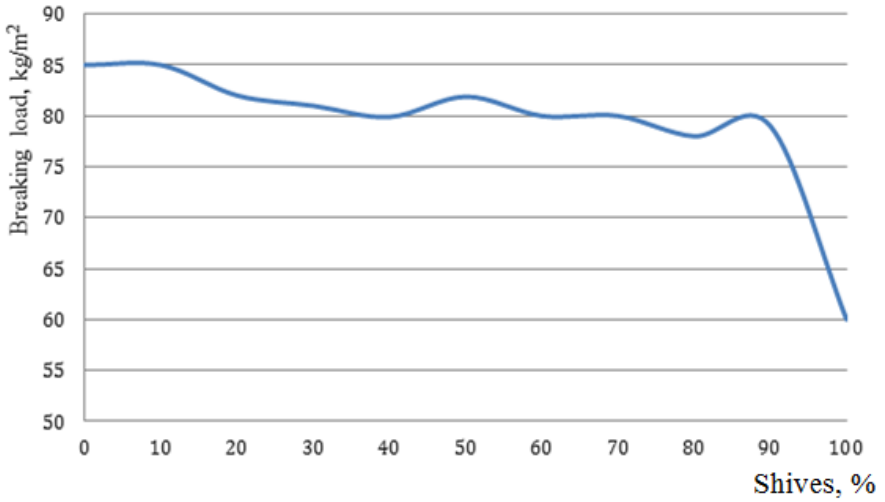


**Fig. 6.** Dependence of the rupture load on the pulp composition ("Compiled by the authors").

One of the most important indicators affecting the strength of the packaging, the ability to retain moisture and protect the product from moisture is the moisture absorption capacity. On the one hand, the packaging must absorb moisture, but within reasonable limits to avoid reducing its strength. Figure 7 shows the dependence reflecting the moisture absorption capacity of the packaging samples on the composition of the pulp. With an increase in the proportion of shives in the pulp, the moisture absorption capacity decreases from 76% to 40%. Studies have shown that the optimal result is a value of moisture absorption capacity equal to 65-60%, which corresponds to a pulp composition of 40-50%.

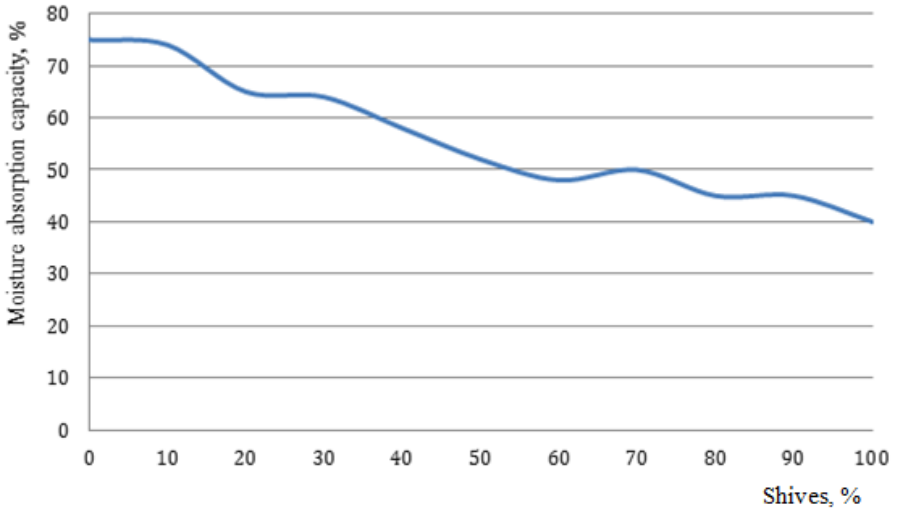


**Fig. 7.** The dependence of the moisture absorption capacity on the composition of the pulp ("Compiled by the authors").

Fig. 8. shows samples of a lumpy gasket of various pulp compositions. The most 50%. Packaging with a composition of 30/70 - has a reduced weight, thin walls. Composition 60/40 - gives us increased mass and humidity, which indicates the irrationality of its use in logistics processes, samples with composition 90/10 have a violation of integrity.

Thus, we can identify the optimal modes and formulation of the final product (Tables 1-3).

**Table 1.** Optimal ratio of components.

| № n/a | Basic raw materials | Quantity in % by dry matter |
|---|---|---|
| 1 | Flaxseed flour M - 560 | 50% |
| 2 | Waste paper | 50% |
| 3 | Water | other |

Source: "Compiled by the authors".

**Table 2.** Optimal technological modes.

| № n/a | Parameter | Unit of measurement | Meaning |
|---|---|---|---|
| 1 | Pulp viscosity | $kg/m^3$ | 1250 |
| 2 | Pulp mixing time | min | 25…40 |
| 3 | Drying time | min | 14 |
| 4 | Drying temperature | ˚C | 170-200 |
| 5 | Drying speed | m/sec | 0, 027 |
| 6 | Vacuum | $Kgt/cm^3$ | 0,7 |

Source: "Compiled by the authors".

**Table 3.** Optimal indicators characterizing the quality of the tuberous gasket

| № n/a | Parameter | Unit of measurement | Meaning | Note |
|---|---|---|---|---|
| 1 | Gasket weight (average weight of 10 gaskets) | gram | 60-70 | TU 5481 – 002 -131593340 – 07 (Norm 60-75) |
| 2 | The weight of the gasket before drying | gram | 240 | Norm (240-260g ) |
| 3 | Final humidity | % | 8-12 | Corresponds to the TU 5481 – 002 -131593340 – 07 (norm, up to 12%) |
| 4 | Defect | % | 0,01 | Corresponds to the TU 5481 – 002 -131593340 - 07 |
| 5 | Crumple load | $kg/m^2$ | 2838 | Safety margin 15,5 |
| 6 | Breaking load | $kg/m^2$ | 79 ,9 | Safety margin 5 |

Source: "Compiled by the authors".

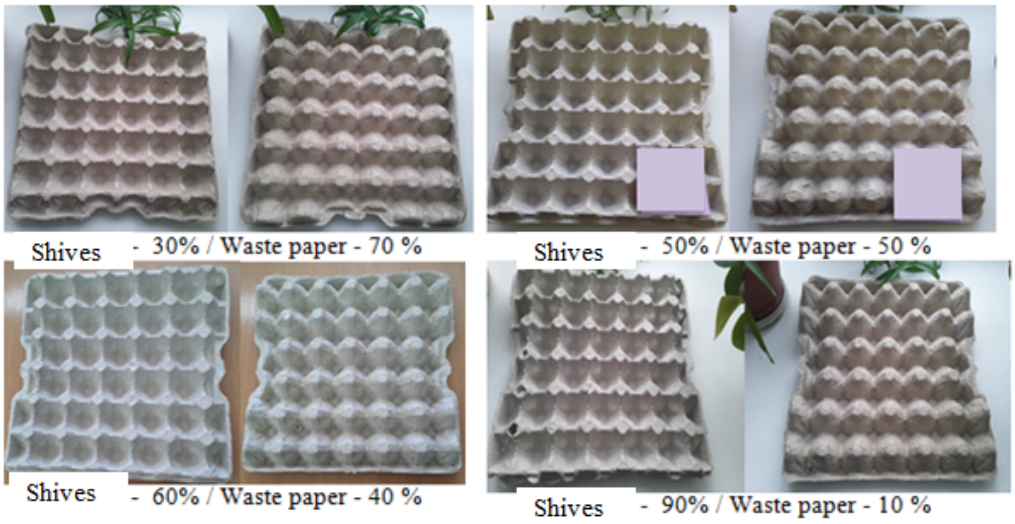


**Fig. 8.** Samples of lumpy egg pads with different pulp composition. ("Compiled by the authors").

Due to its unique composition, flax shives has antibacterial properties [14, 15]. Accordingly, the packaging of shives should have similar antibacterial properties, prolonging the shelf life of products, preventing its spoilage.

To confirm the hypothesis about the antibacterial properties of packaging using shovels, we conducted an experiment by placing pieces of a loaf of "Podmoskovny" on a substrate of waste paper and a substrate of flax and waste paper bonfires in a ratio of 50% / 50% (Fig.9). After seven days, traces of mold fungi appeared on a piece of a loaf located on a substrate of waste paper, and no traces of fungal spores were found on a piece of a loaf located on a substrate of waste paper and flax shives.

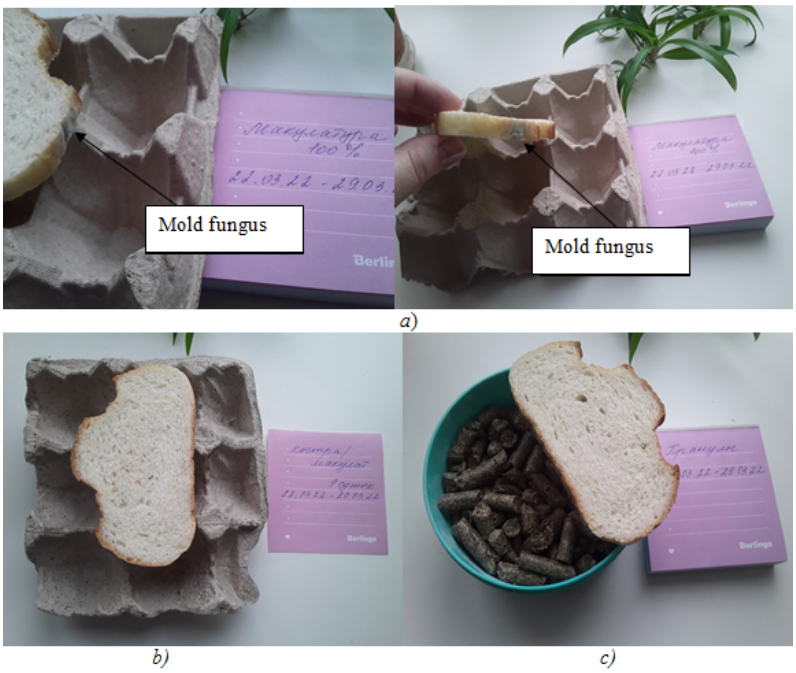


**Fig. 9.** The development of mold fungi on a loaf of "Podmoskovny", stored on substrates of different composition: a) on a lumpy egg pad made of 100% waste paper; b) - on a lumpy egg pad made of 50% waste paper and 50% flax shives; c) - on pallets of shives flax flour M – 560 ("Compiled by the authors").

## 4. Discussion

Observing the recommended operating modes of the equipment, the requirements for the raw materials, the ratio of pulp components, it is possible to obtain a universal, biodegradable packaging for storage and transportation of food and industrial goods. When finalizing the technical capabilities of the "Beston" vacuum paper casting line and additional processing of shives flour, we consider it possible to increase the percentage of shives in pulp to 90%.

## 5. Conclusion

As a result of the work done, it was possible to achieve the goal. We have created industrial samples of lumpy packaging for transportation and storage of food and industrial goods from shives of flax and waste paper.

In the process of work, the tasks were solved. The quality of the raw materials was evaluated. The most acceptable types of waste paper were selected, the features of flax shives were taken into account, measures were taken to refine it – grinding and palletizing. The optimal formulation and technological modes of operation of the "Beston" vacuum casting line have been selected. The qualitative characteristics of the obtained samples are evaluated, their properties are proved, and the possibility of their intended use is proved.

The practical significance of the study lies in the use of an alternative source of raw materials, previously considered a waste of linen production. As a result, two problems are being solved: the shortage of waste paper in the secondary raw materials market and the

disposal of flax production waste by introducing it into the production process of eco-friendly, biodegradable packaging.

In the future, it is planned to increase the share of shives in the pulp to 90-100%, having previously subjected the shives flour to high-temperature treatment at reduced pressure.

We are convinced that this method can produce eco-friendly, biodegradable packaging of a large consumer spectrum.

The authors of the article express their gratitude to the Izhevsk Enterprise "Sputnik" LLC. Isaenko E.M." the city of Izhevsk of the Udmurt Republic, represented by General Director Kolbina Nadezhda Sagidzyanovna and technologist Osmolovsky Oleg Nikolaevich for assistance in conducting experiments, Honored Worker of Agriculture of the Udmurt Republic Ovsyannikov Nikolai Vladimirovich for the raw materials provided and advice.

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