The use of phytobiotics-based films as a condition of improving food quality and reducing waste

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Abstract. The study analyses the biodegradation degree of biodegradable phytobiotic-based films for packaging food products of animal origin. During the research the authors have completed the following tasks: studied the biodegradation degree of starch- and gelatin-based films, the structure of biodegradable natural polysaccharides-based polymers, water absorption of biodegradable edible films, the chemical stability of biodegradable natural polysaccharides-based polymers, pH and water activity. The study of the biodegradation parameters of phytobiotic edible films will allow the development of a new approach to the production process of edible packaging with an extended shelf life based on concentrated cranberry and lingonberry juice. The study has also evaluated the biodegradation parameters of edible protective coatings for products of animal origin. All the samples had almost complete biodegradation in one month's time. The biodegradation rate is directly proportional to the presence of plant polysaccharides. The article presents the product characteristics of boiled-smoked meat products in biodegradable packages and describes a production process of meat products with phytobiotic coatings, including additional operations for preparing coating compositions, their application to raw smoked products, as well as drying of coatings on product's surface. The research has shown that all studied firm samples are biodegradable.

1 Introduction

The deterioration of product quality is a consequence of a number of reactions (physical, chemical, fermentation, etc.) however, storage has to minimize the microbial growth that causes product spoilage. Therefore, the quality and safety of poultry meat products is directly related to their protection from microbial contamination. Implementing innovative technologies in processing and packaging will increase product stability during the storage [1].

The polymer packaging causes a number of serious problems [2, 3, 4]. According to the Ministry of Industry and Trade of the Russian Federation, about 3.5-5 million tons of

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synthetic polymer waste is generated in Russia annually, while only 7-12.5% of polymer waste gets recycled [5].

One of the promising ways to preserve the quality of poultry products and increase their shelf life is the use of biodegradable food packaging made of phytobiotics. As a rule, biodegradable packages in their composition contain a base (structure former) and various additives that provide the necessary properties to the coatings (preservatives, flavours, dye, etc.). Such polymers as chitosan, edible gelatin, starch, collagen, and milk and whey proteins are used as structure formers in protective coatings. As antimicrobial components, it is proposed to use biopolymers, phytoncides, spice extracts and other compounds of the natural immunity of plants and animals that are safe for humans. Myco- and bacteriostatic substances are used together with traditional types of packaging; they are applied to the surface or embedded in the structure of artificial films or in the composition of edible protective food film-forming coatings [1]. One of the areas of promising research is the creation of biodegradable packaging materials that will quickly degrade in the environment under the influence of physical, chemical and biological factors (light, heat, moisture, microorganisms, etc.), thereby excluding further waste accumulation and environmental degradation [6, 7].

Nowadays, it is important to create packaging materials based on natural biopolymers with characteristics that can replace synthetic polymeric packaging materials. In this regard, the purpose of the research is to evaluate the biodegradable properties of various compositions of edible films based on natural polymers (starch and gelatin) in combination with processed wild berries raw materials.

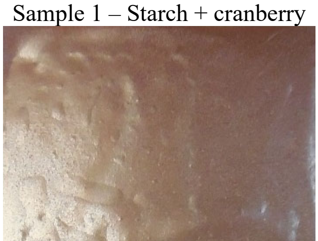
The authors have studied the degree of biodegradation of gelatin- and starch-based films, the structure of biodegradable natural polysaccharide-based polymers, the water absorption of biodegradable edible films, and the chemical stability of biodegradable natural polysaccharide-based polymers during the ongoing research.

2 Objects and methods of the research

The objects of the study are natural polysaccharide-based firms, obtained by pouring. The films contain polysaccharides of plant and animal origin in combination with concentrated juice of wild-growing cranberries and lingonberries (Figure 1).

Sample 1 – Starch + cranberry

Sample 2 – Starch + lingonberry



Sample 3 – Gelatin + cranberry

Sample 4 – Gelatin + lingonberry

Fig.1. Samples and composition of biodegradable films.

The following research methods were used in the work: mass fraction of moisture in raw materials and finished products was determined according to GOST R 51479 and GOST 28561-90; acidity index (pH) – by potentiometric method; water activity – according to the recommendations of Antipova; microbiological indicators: KMAFAnM – by GOST R 50396.1-10, GOST 10444.15-94; BGKP – by GOST R 52816-07; pathogenic microorganisms, including salmonella, L. monocytogenes – by GOST R 50455-92, GOST R 52814-07, GOST R 51921-02, MUK 4.2.1122-02; yeast and mold fungi – by GOST 10444.12-88. Microstructural studies were carried out using an AxioImager.A1 research microscope (ZEISS, Germany) in transmitted light; biological value of products was determined according to the recommendations of Rogov.

The research has studied various compositions of biodegradable films based on natural polysaccharides of starch and gelatin in combination with concentrated juices of cranberries and lingonberries in terms of rheological, deformation-strength properties, as well as in terms of resistance to water and chemical reagents.

3 Results and discussion

It is justified to use plant raw materials and products of their processing as well as biologically active plant compounds for creation of biodegradable packaging materials. In some cases, plant components form the basis of the film (carrageenans, starches, pectins), acting as a structure former, in others they are a functional component, giving the films antimicrobial, antioxidant activity, light-protective properties (essential oils, anthocyanins, polyphenols, organic acids, etc.). Many polymers obtained from plants and animals (chitin, chitosan, agar, carrageenan, alginate, cellulose, etc.) are promising raw materials for creating new packaging materials.

Films of k-carrageenan have antioxidant and antibacterial properties [8]. These polymers have surface-active functional groups (hydroxy groups, amino groups, carboxyl groups), which ensure the formation of intra- and intermolecular hydrogen bonds with the included materials [9, 10]. Thus, there is a method for the development of chitosan-based food film, adding chokeberry extracts with high barrier and antioxidant properties [11]. The films have a high antioxidant activity, as well as the ability to control the growth of microorganisms on the surface of a chilled meat product [12]. Starches, plasticizers and modifiers, fillers and cross-linking agents increase mechanical strength and impart thermoplasticity to starches. These components make it possible to obtain the best packaging materials with desired characteristics [1, 9].

Gelatin is a biogenic biopolymer used as a basis for food biodegradable and edible films. However, the native properties of gelatin films require addition in the composition of natural or synthetic components in order to increase thermal stability, elasticity, resistance to moisture, mechanical strength, and impart antimicrobial properties [3]. The addition of gelatin in films increases the thermal stability of films, in the same time it decreases their solubility in water, hardness and vapor permeability [13]. Active gelatin packaging film has antibacterial and antioxidant properties, it allows checking product freshness in real time [14] (Table 1).

Table 1. The degree of biodegradation of starch- and gelatin-based films.

Sample composition	Average proportion of weight loss of degraded samples, %				
	3 days	7 days	14 days	21 days	28 days
Starch+cranberry	78.0±0.3	79.0±0.2	80.0±0.3	82.0±0.7	86.0±0.1
Starch+lingonberry	63.0±0.1	64.0±0.3	66.0±0.3	71.0±0.3	74.0±0.5
Gelatin+cranberry	71.0±0.5	72.0±0.4	74.0±0.5	79.0±0.3	82.0±0.3
Gelatin +lingonberry	54.0±0.4	56.0±0.6	58.0±0.4	62.0±0.5	68.0±0.7

Starch-based samples with the addition of concentrated cranberry juice have the maximum degree of biodegradation (78.0% after 3 days and 86.0% after 28 days) (see Table 1). Cranberry is characterized by a higher content of polysaccharides. The minimum degree of biodegradation is typical for gelatin-based films in combination with lingonberries. Nevertheless, all the studied samples had almost complete biodegradation in one month's time. According to the results of the experiments, the biodegradation rate is directly proportional to the presence of plant polysaccharides. This is due to the peculiarity of the molecular structure of phytopolysaccharides, which are easier to hydrolyze under the biogenic and abiogenic external factors. As a result, we have observed the formation of low molecular weight complexes, which are easily assimilated by living organisms.

The biodegradation rate is affected by the thickness and density of biodegradable films. Gelatin-based firm with concentrated lingonberry juice has the maximum thickness (1.518 mm). The minimum thickness (0.593 mm) is a characteristic of a starch-based film in combination with concentrated cranberry juice. These films stretch better and have maximum strength. Gelatin-based films in combination with concentrated cranberry juice (1.3857 g/cm) have maximum density (Table 2).

Table 2. Structure of biodegradable polymers based on natural polysaccharides.

Sample	Thickness, mm	Density, g/cm
Starch + cranberry	0.593±0.030	1.2879±0.0644
Starch + lingonberry	1.270±0.064	1.3455±0.0673
Gelatin + cranberry	0.711±0.036	1.3857±0.0693
Gelatin + lingonberry	1.518±0.076	1.3086±0.0654

Since the proposed composites of polysaccharide films are supposed to be used to create packaging materials, it is important to determine the water absorption of the created biodegradable materials. Under the influence of moisture, serious changes can occur in polymeric materials. The penetration of moisture into the polymer is followed by a decrease of intermolecular interaction in it. However, up to a certain level, this process can be useful in terms of strength properties.

Table 3. Water absorption of biodegradable polysaccharide films.

Sample	Mass fraction of water absorption, %	Mass of water absorbed by the sample, mg
Starch + cranberry	3.0±0.6	0.0071±0.0015
Starch + lingonberry	19.0±0.8	0.0913±0.0036
Gelatin + cranberry	1.5±0.7	0.0157±0.0052
Gelatin + lingonberry	24.7±0.4	0.2043±0.0090

Gelatin-based film samples have the maximum water absorption (19.0% and 24.7%) (Table 3).

In addition to being biodegradable, polymers must also have chemical resistance. This is one of the main criteria for the protective characteristics of packages that make it possible to withstand the effects of chemical agents of the environment, including mineral and organic acids, solutions of their salts, alkalis, etc. The experiment has studied the chemical resistance of biodegradable films towards acids (sulphuric, hydrochloric) and alkalis (sodium hydroxide) (Table 4).

Table 4. Chemical stability of natural polysaccharides-based biodegradable polymers.

<table>
<tr><th rowspan="2">Sample</th><th colspan="3">Solvent (sample dissolution time)</th></tr>
<tr><th>Sulfuric acid</th><th>Chlorohydric acid</th><th>Sodium hydrate</th></tr>
<tr><td>Starch + cranberry</td><td>3 min</td><td rowspan="4">22 hours</td><td rowspan="2">Films swollen, but not disintegrated</td></tr>
<tr><td>Starch + lingonberry</td><td>17 min</td></tr>
<tr><td>Gelatin + cranberry</td><td>55 min</td><td rowspan="2">Films have not been degraded</td></tr>
<tr><td>Gelatin + lingonberry</td><td>72 min</td></tr>
</table>

The high solubility of films in acids (sulfuric acid) is inherent in samples based on starch phytopolymer. This is due to the aggressiveness of the environment towards starch. Gelatin is more resistant to acids. Polysaccharide films do not undergo hydrolysis in an alkaline environment. All studied film samples have shown a high degree of biodegradation.

During storage, it is occurred the enrichment of protein degradation products, it leads to an increasing pH of the studied samples of raw smoked poultry products covered with film and without it. This contributes to the development of pathogenic microorganisms in products. The pH of the control sample increases significantly on the 40th day of storage, the medium becomes neutral. The pH value of the prototypes changes linearly over 50 days. The shift of pH to neutral is noted on the 66th day of storage. Thus, edible protective coatings in comparison with the traditional one help to increase the resistance of covered product to microbiological deterioration. Microstructural analysis of processed meat products with different structure formers in edible protective films and without them has shown that the appearance of finished products covered with edible films corresponds to high customer requirements and has an attractive look (Figure 2).

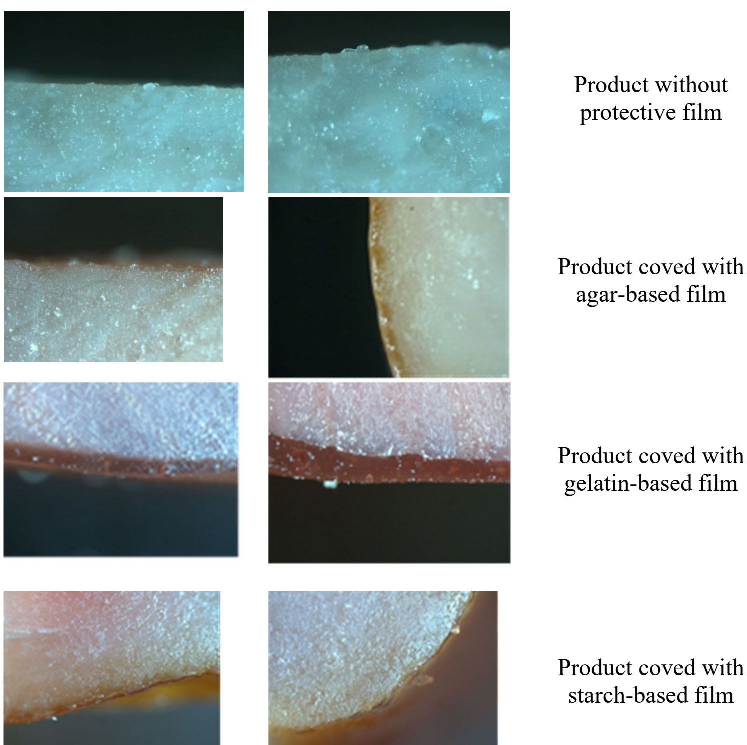


Fig.2. Samples of smoked pork loin covered with biodegradable films.

The experiments allow to recommend cranberry and lingonberry juice obtained by high-temperature evaporation under atmospheric pressure as a structural additive in the composition of edible protective films. The technological process for food products with an extended shelf life includes additional operations for preparing coating compositions, their application to raw smoked products, as well as drying of coatings on product's surface.

4 Conclusion

Producers use various preservation agents to protect meat products, these additives are injected directly into the product. An alternative way to preserve the quality of meat products and increase their shelf life is to form food protective coating directly on the product surface.

Protective systems based on phytobiotics and their derivatives can be in demand by the meat industry. They can prevent the impact of unfavourable environmental factors on the product for a long time, and minimize microbial degradation at the cover-product interface [10]. Moreover, they can be used both individually and in various combinations. Such compounds are capable of perfect modification, which makes it possible to include various food additives (preservatives, antioxidants, flavours, dyes, plasticizers, tanning agents, etc.) in their structure. The additives give the coating individual multifunctional properties, including those that contribute to maximum food preservation [6].

Along with the listed advantages, most coatings have a number of disadvantages that limit their use. These include insufficient strength and deformation characteristics, low resistance to bio corrosion, high humidity, high vapor permeability, etc.

The study of the biodegradation parameters of phytobiotic edible films will allow the development of a new approach to the production process of edible packaging with an extended shelf life based on concentrated cranberry and lingonberry juice. As a part of the study, the authors have experimentally substantiated and developed the possibility of obtaining edible phytobiotics-based packages with a high biodegradation coefficient. The study has also evaluated the biodegradation parameters of edible protective coatings for products of animal origin. A patent has been obtained for a proposed method for producing an edible protective coating for meat products [15].

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