UDC 664:67.02

SCIENTIFIC BASES OF STANDARDIZATION OF REQUIREMENTS FOR ECOLOGICAL PACKAGING OF FOOD PRODUCTS

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https://doi.org/10.31073/foodresources2020-15-12

The subject of research *are food packaging processes using edible coatings and biodegradable packaging materials, in particular bioplastics, especially the barrier and other technological properties of these types of packaging for the implementation of packaging processes for meat, dairy, bakery and confectionery products.* ***The purpose of the study*** *is to prove the possibility and feasibility of using edible coatings and biodegradable packaging materials, in particular bioplastics, for packaging of various types of products of the meat, dairy, bakery and confectionery industries.* ***Methods****. During the research, a systematic approach was used to research factual materials, in particular scientific and scientific-practical literature, regulatory legal acts, regulatory documents and the like; abstract-logical approach to the synthesis of research results and the formulation of conclusions.* ***The results of the study.*** *Among the packaging materials used in the practice of the food industry, there are still several types of biological packaging. First of all, these are edible coating-packagings suitable for a number of food products of different groups. However, biodegradable plastics are more commonly used. Now domestic regulatory documents of various levels, which in detail regulate the general specifications or specifications for the production of food products, in particular their packaging, do not contain any norms that would establish the rules of ecological packaging (materials, technologies, etc.). To eliminate this incompliance, recommendations were drawn up for modifying regulatory documents of various levels, namely, adding rules and requirements for biological packaging of products of the meat, dairy, bakery and confectionery industries.* ***Scope of research results.*** *The results of the experiments will be used to improve the technologies for the production of various types of products in the meat, dairy, bakery and confectionery industries, to increase their food safety and quality, as well as to reduce the anthropogenic load on the environment due to ensuring the effective biodegradability of the packaging materials used and packages made from them.*

Key words: *biodegradable materials, edible coatings, biopolymers, meat products, dairy products, bakery products, confectionery, packaging*

НАУКОВІ ЗАСАДИ НОРМУВАННЯ ВИМОГ ДО ЕКОЛОГІЧНОГО ПАКУВАННЯ ХАРЧОВИХ ПРОДУКТІВ

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Предмет дослідження *– процеси пакування харчових продуктів з використанням їстівних покриттів і біорозкладних пакувальних матеріалів, зокрема біопластиків, особливості бар'єрних та інших технологічних властивостей зазначених видів паковань для реалізації процесів пакування продукції м'ясної, молочної, хлібопекарської та кондитерської промисловості.* ***Мета*** *– доведення можливості та доцільності використання їстівних покриттів і біорозкладних пакувальних матеріалів, зокрема біопластиків, для пакування різних видів продукції.* ***Методи.*** *Використовували системний підхід до досліджень фактологічних матеріалів, зокрема наукової та науково-практичної літератури, нормативно-правових актів, нормативних документів тощо; абстрактно-логічний підхід щодо узагальнення результатів та формулювання висновків.* ***Результати дослідження.*** *Серед пакувальних матеріалів, використовуваних у практиці харчової промисловості, наразі є декілька видів біологічних паковань. Насамперед, це їстівні покриття, придатні для низки харчових продуктів. Втім, частіше використовують біорозкладні пластмаси. Наразі вітчизняні нормативні документи різного рівня, які предметно регламентують загальні технічні умови або технічні умови щодо виробництва харчових продуктів, зокрема їх пакування, не містять жодних норм, які б встановлювали правила екологічного пакування (матеріалів, технологій та ін.). Для усунення зазначеної невідповідності складено рекомендації щодо модифікування нормативних документів різного рівня, а саме долучення правил і вимог щодо біологічного пакування продукції м'ясної, молочної, хлібопекарської та кондитерської промисловості.* ***Сфера застосування.*** *Результати використовуватимуться з метою вдосконалення технологій виробництва різних видів продукції м'ясної, молочної, хлібопекарської та кондитерської промисловості, підвищення її харчової безпечності та якості, а також зменшення антропогенного навантаження на довкілля завдяки забезпеченню ефективної біорозкладності застосовуваних пакувальних матеріалів та виготовлених із них паковань.*

Ключові слова: *біорозкладні матеріали, їстівні покриття, біополімери, м'ясні продукти, молочні продукти, хлібобулочні вироби, кондитерські вироби, пакування*

Formulation of the problem. An important task for food specialists and scientists is to justify, taking into account economic and biological aspects, the needs of consumers in tasty, nutritious and healthy food products. Important, in this sense, is such a technological operation in the production of food products as their packaging, which guarantees the safety and quality of products during the shelf life determined by scientific research and introduced by the regulatory documents in force. The Law of Ukraine "On the basic principles and requirements for the safety and quality of food", introduced in accordance with [1], postulates that packaging is the placement of one or several primary packaged food products in another package (container), and primary packaging – these are food packaging in any wrapper or packaging (container), directly in contact with the food product. In [1], it is also specified that market operators when packaging food products, including primary packaging, must ensure that the following requirements are met: materials used for packaging, including primary packaging, shall not be a source of contamination; materials for primary packaging are stored in a manner that makes their contamination impossible; packaging, including primary packaging, is carried out in a manner that excludes contamination of products and the integrity of packages.

Now there is a steady upward trend in demand for high-quality ready-made food products with a long shelf life, which leads to an increase in anthropogenic pressure on the environment through an avalanche-like increase in the number of packages, the vast majority of which are made from non-biodegradable polymers. A significant step in solving this problem would be to replace, at least partially, the currently used packaging materials with edible packaging coatings and bioplastics – biodegradable materials, compostable, or those produced on the basis of renewable natural resources. However, until now it has not been possible to develop packaging methods using environmentally friendly materials that have found application in food enterprises – mainly due to inadequate sustainability and the high cost of introducing appropriate technologies. First of all, the above concerns products of animal origin, the technical and technological features of which determine special requirements for packaging and packaging materials [2-4].

Biodegradable packaging used in the food industry from materials such as wax, paper, natural fabrics has been used for several millennia. However, bioplastics, with the exception of some edible (food) coatings, have been involved in food manufacturing practices relatively recently. The term “bioplastics” refers to two distinct groups of materials. On the one hand, these are biodegradable materials subject to composting, on the other, bioplastics produced on the basis of renewable natural resources [5]. Bioplastics of the first group, regardless of the nature of the raw material for their manufacture (renewable or petrochemical), must meet all the criteria specified in the standards DSTU EN 13432:2015 [6] and ASTM D6400-12 [7]. At the same time, the widely used term “biodegradable” is not quite definite, since the time frame for biodegradation is not set by the regulatory framework. Biodegradation is evidenced by CO_2 emissions, which are the result of biological conversion processes. The definition of biodegradation through the emission of carbon dioxide clearly distinguishes it from the decomposition process initiated by special additives, which only cause fragmentation of a conventional polymer [8]. Bioplastics of the second group, which are produced on the basis of renewable resources, may contain up to 100% natural components, but not necessarily be biodegradable [5].

Biodegradable packaging materials used in industry are classified into the following three groups [9, 10]:

- plant polymers used alone or in a mixture with biodegradable synthetic polymers;
- microbial polymers obtained by fermentation of agricultural raw materials used as a substrate. Among these polymers, polyhydroxyalkanoates or PHA are also distinguished, the most well known of which is PHBV (polyhydroxybutyrate-co-valerate)
- monomers or oligomers, polymerized by conventional chemical processes and obtained by fermentation of agricultural raw materials used as a substrate. Among the materials in this category, the most well known one is polylactide (PLA).

In the classification proposed in [11], the fourth class is added to the three above mentioned:

- products obtained by synthesis from petrochemical raw materials. These are several polymers or subgroups: polycaprolactone (PCL) polyetheramides (PEA) aliphatic copolyester such as polybutylene succinate adipate (PBSA) aromatic copolyester such as polybutylene adipate coterephthalate (PBAT).

Biodegradable polymers PCL and PLA are the most widespread on the market, second only to starch derivatives [12]. The hierarchy of biodegradable polymers, as well as the raw materials used for their manufacture, are shown in Fig. 1.

Biodegradable materials used for food packaging are made from proteins – both of plant (soy, corn, wheat, peas, etc.) and animal (casein, collagen, whey, keratin, gelatin, etc.) origin [13, 14].

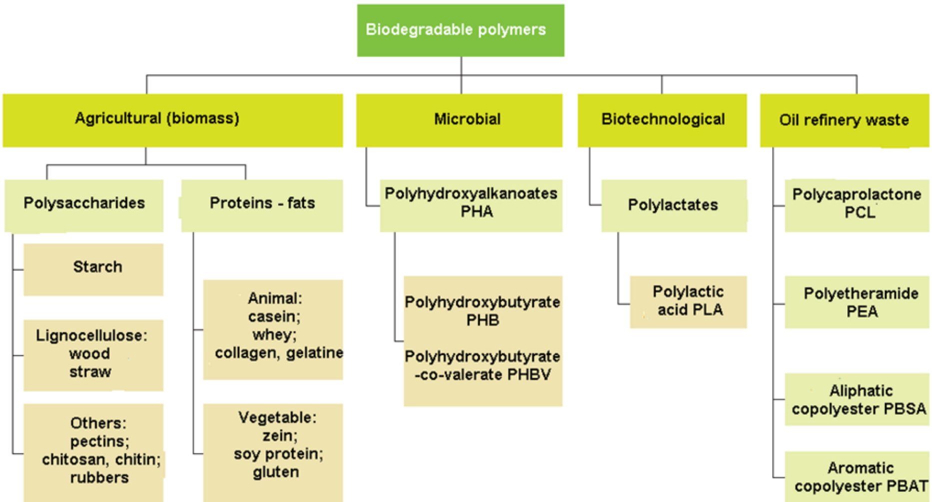

Fig. 1. Nomenclature of biodegradable polymers – adopted from [2, 11, 12]

The coatings act as barriers to water loss and gas exchange while controlling the transfer of moisture, oxygen, lipids and flavor components (Fig. 2) with an effect similar to the effect contributing to the preservation of properties under controlled conditions or in a modified atmosphere [15, 16].

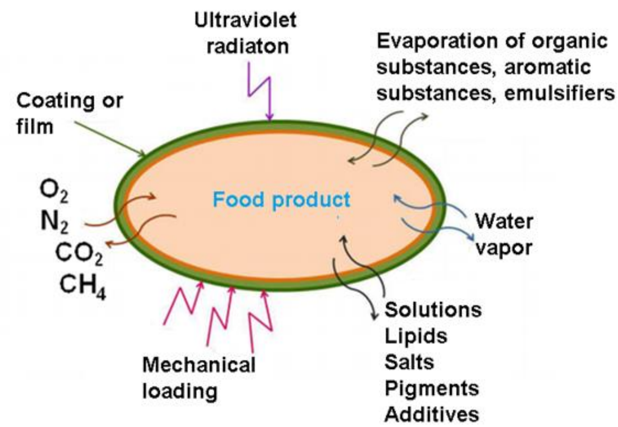

Fig. 2. Factors by which biodegradable films used for food packaging must have barrier properties – adopted from [15-18]

The relevance of the solution to the issues outlined above prompts the search for materials that are effectively laid out in the natural environment after use, and the proper regulatory registration of the use of food packages that are produced from these materials.

Materials and methods. The subject of this article is the assessment of the environmental and technical and technological feasibility of using biodegradable materials for packaging food products of four main groups: meat, dairy, bakery and confectionery. During the research, we used a systematic approach to researching factual materials, in particular scientific and scientific-practical literature, regulatory legal acts, regulatory documents, and the like; abstract-logical approach to generalization of research results and formulation of conclusions.

Results and discussion. A promising technology for maintaining the quality and extending the shelf life of perishable and / or minimally processed food products is the use of edible films and coatings [3, 19]. The mechanical and barrier properties of these coatings depend on the properties of all components [20], and their composition can include various polymers, for example, proteins (gelatin, casein, wheat gluten, zein), polysaccharides (starch, pectin, cellulose, alginate, carrageenan) and lipids (stearic acid, waxes and fatty acid esters).

They can be used alone or in various combinations [20-22].

The main role of edible coatings is to maintain the high quality of the food product [23, 24]. Since the coating is consumed with the product, its properties and composition must meet the requirements established for food products, requiring the introduction of new rules to regulate their safety and impact on the environment.

Edible coatings containing polysaccharides (cellulose and its derivatives, starch and its derivatives, resins) or proteins (gelatin, zein, milk proteins, gluten) have the necessary mechanical and optical properties (which lose stability at high humidity), and are also characterized by low barrier properties for water and steam. On the other hand, coatings consisting of lipids (wax, oil and derivatives) or polyesters also have satisfactory barrier properties, but usually produce matt surfaces of relatively low elasticity. Starch is the most commonly used polymer in coatings, mainly due to its low cost, wide availability, and relative ease of use [9]. Protein coatings are essentially hydrophilic, and their barrier properties are determined by the amount of plasticizer and moisture [25].

Edible coatings can contain one or more components in dry, wet, single or multi-layer form. Before using in the production process, the components should be analyzed taking into account their chemical, physical and biochemical properties, such as: water content, pH, chemical composition, storage requirements, etc. [26].

In order to perform their function, edible coatings must be applied to the article and remain on it during storage, but must disintegrate or dissolve during the preparation or consumption of food with the specified coating. With respect to protein coatings, the degradation process can be determined by the specific properties of the proteins used (e.g. thermoplastic properties or solubility), as well as external factors such as pH value, manufacturing conditions, protein denaturation level, coating thickness or processing temperature. Based on research data, whey-coated proteins are readily degraded when heated [27].

Edible coatings must meet a number of functional requirements. The most important functions are: satisfactory barrier properties for water, other substances and gases, solubility in water and fat, adequate color and appearance, acceptable mechanical and rheological properties, non-toxicity. These properties are determined by the type of material used, the production method and the method of application to the food product. At the same time, certain types of plasticizers and substances, additives to inhibit the growth of microorganisms, and other functional substances can alter the properties of edible coatings [28].

At the same time, a number of traits are also inherent in the edible coating, to one degree or another, limit their intended use. Milk protein-based food coatings have acceptable mechanical properties and oxygen, lipid and odor barrier properties, but inadequate moisture barrier properties. A number of edible coatings can unnecessarily compromise the sensorial properties of a product. The influence of other natural polymers, such as wax, fats, and fatty acids, can also change the properties of protein coatings [29].

In the meat industry, along with casings made of natural intestinal raw materials and collagen materials, polymer film materials are widely used for the manufacture of casings for sausages and frankfurters. These polymer casings are distinguished by excellent technological properties, but they do not decompose in natural conditions, increasing the anthropogenic load on the environment. For this reason, it is advisable to introduce the production and use of biodegradable sausage casings from bacterial cellulose produced by various microorganisms. Due to the fact that bacterial cellulose consists of a glucose monomer, it has special properties: significant water-holding capacity, high degree of polymerization, excellent mechanical strength, high crystallinity, etc. [30]. This promises broad prospects for the use of this material in the medical, electronic and food industries [31, 32]. It is believed that bacterial cellulose is a versatile material of the future, since it significantly surpasses its plant analogue in useful properties due to its high purity, nanostructures, high degree of polymerization and crystallinity. It is a chemically pure, non-toxic polymer that does not contain lignin, resins, fats, hemicellulose and undergoes biodegradation [33, 34].

Both vegetable cellulose and cellulose of bacterial origin are biodegradable polymers that can be used to make semipermeable casings. Bacterial cellulose can be made from waste products of agricultural raw materials, which contain a large amount of sugars [35]. The studies, the results of which are described in [35], have shown that sausage casings made from bacterial cellulose have sufficient thermal stability and greater permeability compared to collagen casings. At the same time, the final product had two drawbacks: insufficient adhesion between the casing and the content, and the unpleasant resemblance of the cellulose casing to paper when consuming the sausages. Evaluation of the properties of sausages in a casing made of a combined material, which included bacterial cellulose and polylysine, in particular the microbial resistance of the finished product, showed [32] that expressive antimicrobial activity was inherent in it even after autoclaving at 121 °C for 30 min. And the permeability of the shells to air was much lower than the permeability of the shells made of polyethylene and polyvinyl alcohol. The tensile strength of the material was 51.8 MPa.

The necessary nutrient medium for the synthesis of bacterial cellulose must have a sufficient content of glucose and other nutrients. Nutrient media available for domestic practice are such wastes from the food industry as distillery stillage, milk whey [36], molasses [33], etc. In [37], the possibility of using grape peel, curd whey and acidic hydrolyzate of wheat straw, in [36] – the lignocellulosic material of oat hulls are shown.

For the packaging of dairy products, in particular, biodegradable materials are used, such as cellulose-based paper materials for liquid and dry dairy products, parchment wrappers for butter, curd products, etc. Biodegradable plastics used for packaging of almost all types of dairy products, as well as bio-based materials derived from renewable resources that can be used for dairy products with a limited shelf life [17, 18, 38].

As with all packaging materials, the above materials must protect the dairy product from environmental influences and ensure the preservation of quality during transport and storage. Critical aspects are mechanical and barrier properties for oxygen, carbon dioxide, water, light and odors. In addition, when choosing packaging materials for dairy products, safety aspects (migration, microbial growth), resistance (heat resistance and chemical), technological requirements (suitability for welding and forming), convenience and compliance with marketing principles (communication, printing options) should be considered [39].

The mechanical properties are of decisive importance and must be adapted in such a way that the dairy product is protected even during long-term storage and transport. The polymers can be adapted to some extent to suit certain mechanical properties, for example, by choosing raw materials or mixing with other polymers or fillers, by adding fibers, plasticizing, and the like. Adequate mechanical properties are typical for PLA in semi-crystalline form. There are various processing parameters that can be varied to obtain certain mechanical properties of biopolymers, mimicking the properties of conventional oil-based polymers, such as rigid (polyethylene terephthalate, PET) and flexible materials (eg polyethylene, PE) [39, 40]. Comparative tests showed that the tensile strength, elongation and tensile strength of PLA and starch-PCL films were lower than in low-density polyethylene (LDPE) and high-density polyethylene (HDPE) films, compression of cups based on starch, PLA and polyhydroxybutyrate (PHB) was in the same range as for polypropylene (PP), polystyrene (PS) and polyethylene (PE) cups [41]. At the same time, natural starch does not meet the requirements for food packaging because its mechanical strength and stability are too low.

When analyzing the heat resistance of bioplastics, it should be noted that the usage temperature for most dairy products is between 0 °C and 40 °C. However, hot filling and sterilization can be used for liquid dairy products with a long shelf life. In addition, when processing packaging materials (shaping, sealing), they are exposed to high temperatures. The field of thermal application of biological packaging materials will be relatively limited, since stability decreases with increasing temperature, as was observed for PLA [39, 40], especially when exposed to high humidity. Containers made of PLA remain stable only up to 55 °C, while materials based on starch-PCL mixtures – between 60 and 90 °C.

The barrier properties to water vapor depend on the type of product. For example, expressive water vapor barrier properties are critical in the packaging of dairy products such as butter and cheese, where preventing moisture loss and surface drying is key. On the other hand, packaging for products with a short shelf life is less critical as the temperature is low and the shelf life is less than 10 days.

It is necessary to modify national standards in order to attract the requirements of ecological packaging of food products by developing amendments to national standards, or reviewing national standards. Modifications to the national standard of the type of specifications or general specifications for food products are carried out in accordance with its specific scope. In general, it can be recommended to amend the regulations of these standards in the manner and to the extent set out below.

The component "Terms and definitions" should, if necessary, be supplemented with terms and definitions of concepts in order to modify the national standard in the sense of adding to it the requirements for ecological packaging of food products:

x.1 ecological packaging. Packaging food products in a manner that makes it impossible or at least minimizes the harmful effects of the packaging used and the materials used for packaging on the environment, in particular from the disposal and / or destruction of used packaging.

x.2 ecological packages. Products and materials used for food packaging that meet the conditions of ecological packaging.

x.3 degradation. Changes in initial properties due to chemical decomposition of macromolecules that form a polymer element, regardless of the decomposition mechanism.

x.4 biodegradation. Changing the initial properties of a polymer element using a cell-mediated phenomenon.

x.5 biodegradable packages. Materials that are fully biodegradable or packaging products made from such materials.

x.6 food (edible) coating. A layer of edible material applied to the surface of a food product for technological purposes that can be consumed with the processed product.

In addition to the above, other terms and definitions may be given in accordance with the objectives and content of the standards, and are being modified.

The component **"Requirements / provisions for the object of standardization"**, in the sense of compliance with the requirements of ecological packaging, should be supplemented with requirements and provisions for:

- a specific nomenclature of food products that can / should be packed using ecological packaging;
- physical, chemical, structural and mechanical and other relevant parameters of food products, which are subject to the standards for environmental packaging;
- terms, temperature and humidity and other relevant parameters of storage of food products, packaged with the use of ecological packaging;
- conditions for the transportation and sale of food products packed with the use of ecological packaging;
- other relevant parameters.

These requirements, in addition to the structural element **"Requirements / provisions for the object of standardization"**, are also noted in the structural elements **"Packaging"**, **"Transportation and storage rules"**, **"Control methods"** and **"Acceptance rules"**.

The structural element **"Packaging"** shall be supplemented with provisions on the procedure for packaging a food product using ecological packaging and contain the following norms: a nomenclature of possible ways of ecological packaging; the range of materials and packaging products used for ecological packaging; technical and technological requirements for the process of ecological packaging; other relevant parameters.

Conclusion. The performed analysis of scientific and technical information confirms the possibility and feasibility of using biodegradable materials, in particular bioplastics as innovative packaging materials for use in the food industry. These materials, primarily PLA, do not differ significantly, in terms of mechanical and other technological properties, from traditional plastics from hydrocarbons.

Modifications of regulatory documents of various levels on specifications for food products, in the sense of adding provisions governing the procedure and rules for their ecological packaging, will allow in a sufficient and expedient way to update domestic regulatory documents, as well as harmonize them with the regulatory documents of the European Union in force.

References

1. Zakon Ukrainy "Pro vnesennia zmin o deiakykh zakonodavchykh aktiv Ukrainy shchodo kharchovykh produktiv" [Law of Ukraine "On amending certain law documents of Ukraine on food products"] № 1602-VII of 22 July 2014. (2014). Vidomosti Verkhovnoi Rady – Gerald of Verkhovna Rada, 41-42, 20-24 [In Ukrainian].

2. Verbytskyi S., Kopylova K., Kozachnko O., Verbova O., Kos T. (2019). Ekolohichna upakovka kharchovykh produktiv (vid teorii do praktyky) [Ecological packaging of food products (from theory to practice)]. Upakovka [Packaging], 4 (131), 30-34 [In Ukrainian].

3. Kopylova K., Verbytskyi S., Kos T., Verbova O., Kozachenko O. (2018). Otsiniuvannia mozhlyvosti ta dotsilnosti vykorystannia ekilohichnykh plastmas dlia pakuvannia kharchovykh produktiv [Evaluating possibility and expediency of bioplastics to be used for packaging foods]. Zbirnyk naukovykh prats za materialamy 11th Mizhnarodnoi naukovo-practychnoi konferentsii "Problemy ta perspektyvy rozvytku akademichnoi ta universytetskoi nauky" 20-21 December 2018, Poltava: PolNTU, 140-145 [In Ukrainian].

4. Patsera N., Kopylova K., Verbytskyi S., Kozachenko O. (2020). Normuvannia vymoh shchodo ekolohichnoho pakuvannia produktsii khlibopekarskoi ta kondyterskoi promyslovosti [Standardization of the requirements on the requirements for the ecological packaging of bakery and confectionary products]. Zbirnyk materialiv 6-ho Mizhnarodnoho konhresu «Stalyi rozvytok: zakhyst navkolyshnoho seredovyshcha. Enerhooshchadnist. Zbalansovane pryrodokorystuvannia» Natsionalnyi universytet «Lvivska politekhnika» 23-25 September 2020, Lviv: Zakhidno-Ukrainskyi Konsaltynyi Tsentr (ZUKTs), TzOV, 158 [In Ukrainian].

5. Engels D., Marta D., Lor S., Tsimmermann P. (2012). Plastmassy, sozdannye prirodoi: ot mechty do realnosti [Plastics, created by nature: from a dream to reality]. Upakovka [Packaging], 6, 14-15 [In Ukrainian].

6. DSTU EN 13432:2015 Upakovka. Vymohy do upakovky, utylizovanoi sposobom kompostuvannia i biodehradatsii. Testovi skhemy ta kryterii otsiniuvannia dlia ostatochnoho pryiniattia upakovky [Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging] (EN 13432:2000, IDT). (2015). Chynnyi vid 2016–01–01. Kyiv: DP "UkrNDNTs" [In Ukrainian].

7. ASTM D6400 – 12. Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities. ASTM International. (2012). In force from 2012, 3.

8. Narayan R. Misleading claims and misuse. (2010). Proliferate in the Nascent Bioplastics Magazine. 5 (1), 38-41.

9. Vilpoux O., Averous L. (2004). Starch-based plastics In: Technology, use and potentialities of Latin American starchy tubers, 521-553.

10. Guilbert S. (2000). Potential of the protein based biomaterials for the food industry. The Food Biopack Conference, Copenhagen (Denmark), 27-29 Aug, KVL.

11. Averous L. (2002). Etude de système polymers multiphasés: approche des relations matériaux-procédés-propriétés. Dans: Habilitation à diriger des recherches, Université de Reims Champagne-Ardenne, 46.

12. Weber C. (2000). Biobased packaging materials for the food industry: status and perspectives, a European concerted action, KVL.

13. Bunea M. (2017). Studiul materialelor plastice biodegrsdabile pentru ambalarea produselor alimentare. Conferința științifică internațională "Perspectivele şi Problemele Integrării în Spațiul European al Cercetării și Educației", Universitatea de Stat "B.P. Hasdeu" din Cahul, 7 iunie, I, 317-321.

14. de Moraes Crizel T., Haas Costa T. M., de Oliveira Rios A., Hickmann Flores S. (2016). Valorization of food-grade industrial waste in the obtaining active biodegradable films for packaging, Industrial Crops and Products, 87, 218-228.

15. Santiago Santiago, M. (2015). Elaboración y caracterización de películas biodegradables obtenidas con almidón nanoestructurado. Universidad Veracruzana. Xalapa de Enríquez, Veracruz, México, 119.

16. Debeaufort, F., Voilley, A. (1995). Effect of surfactants and drying rate on barrier properties of emulsified edible films. International Journal of Food Science Technology, 30(2), 183-190.

17. Kopylova K., Verbytskyi S., Kozachenko O., Verbova O., Kos T. (2019). Innovatsiini biorozkladni materialy dlia pakuvannia produktsii molochnoi promyslovosti [Innovative biodegradable materials for packing products of dairy industry]. Materialy 8th Miznarodnoi spetsializovanoi naukovo-praktychnoi konferentsii “Resurso- ta energooshchadni tekhnologii vyrobnytstva i pakuvannia kharchovoi produktsii – osnovni zasady ii konkurentozdatnosti”, 12 September 2019, Kyiv, NUFT, 150-152.

18. Kopylova K., Verbytskyi S., Kozachenko O., Verbova O. (2019). Osnovni zasady ekolohichnoho pakuvannia molochnykh produktiv [Principal bases of ecological packaging of milk products]. Prodovolchi resursy [Food Resources], 13, 69-86 [In Ukrainian].

19. Kopylova K., Verbytskyi S., Kos T., Verbova O., Kozachenko O. (2018). Yistivni plivky na bazi kazeinu ta dotsilni sposoby vyznachannia yikhnikh mekhanichnykh kharakterystyk [Edible films based on casein and expedient ways to determine their mechanical characteristics]. Materialy VII Mizhnarodnoi spetsializovanoi naukovo-praktychnoi konferentsii «Resurso- ta enerhooshchadni tekhnolohii vyrobnytstva i pakuvannia kharchovoi produktsii – osnovni zasady yii konkurentnozdatnosti», 13 September 2018, Kyiv, NUKhT, 116,117 [In Ukrainian].

20. Rooney M. (Ed.). (1995). Active food packaging. Ed. Springer Science+Business Media, Australia. 255 p.

21. Bravin B., Peressini D., Sensidoni A. (2004). Influence of emulsifier type and content of functional properties of polysaccharide lipid-based edible films. Journal of Agricultural and Food Chemistry, 52:6448-6455.

22. Chiumarelli M., Hubinger M. (2014). Evaluation of edible films and coatings formulated with cassava starch, glycerol, carnauba wax and stearic acid. Food Hydrocolloids, 38:20-27.

23. Suhag, R., Kumar, N., Petkoska, A. T., Upadhyay, A. (2020). Film formation and deposition methods of edible coating on food products: A review. Food Research International, 136, 109582.

24. Longares A., Monahan E., O’Riordan E. D., O’Sullivan M. (2004). Physical properties and sensory evaluation of WPI films of varying thickness. Lebensm. Wiss. Technol., 37, 545–550.

25. Wan V., Kim Ch., Lee S. (2005). Water vapor permeability and mechanical properties of soy protein isolate edible films composed of different plasticizer combinations. J. Food Sci., 70, 387–391.

26. Kokoszka S., Lenart A. (2007). Edible coatings-formation, characteristics and use-a review. Polish journal of food and nutrition sciences, 57(4), 399-404.

27. Fang Y., Tung M., Britt I., Yada S., Dalgleish D. (2002). Tensile and barrier properties of edible films made from whey proteins. J. Food Sci., 2002, 67, 188–193.

28. Gontard N., Guilbert S., Cuq J. (1993). Water and glycerol as plasticizers affect mechanical and water vapour barrier properties of an edible wheat gluten film. J. Food Sci., 58, 206–211.

29. Rhim J., Lee J., Hong S. (2006). Water resistance and mechanical properties of biopolymer (alginate and soy protein) coated paperboards. Lebensm. Wiss. Technol., 39, 806–813.

30. Kopylova K., Verbytskyi S., Cherniak O. (2017). Vykorystannia bakterialnoi tseliulozy, yak syrovyny dlia vyhotovlennia obolonok kovbasnykh vyrobiv [Use of bacterial cellulose as a raw material for the manufacture of sausage casings.]. Materialy VI Mizhnarodnoi spetsializovanoi naukovo-praktychnoi konferentsii «Resurso- ta enerhooshchadni tekhnolohii vyrobnytstva i pakuvannia kharchovoi produktsii – osnovni zasady yii konkurentnozdatnosti», 12 September 2018, Kyiv, NUKhT, 76,77 [In Ukrainian].

31. Esa F., Tasirin S., Rahman N. (2014). Overview of bacterial cellulose production and application. Agriculture and Agricultural Science Procedia, 2, 113-119.

32. Zhu H., Jia S., Yang H., Tang W., Jia Y., Tan Z. (2010). Characterization of bacteriostatic sausage casing: A composite of bacterial cellulose embedded with ε-polylysine. Food Science and Biotechnology, 19(6), 1479-1484.

33. Sapunova N., Bogatyreva A., Shchankin M., Liyaskina E., Revin V. (2016). Poluchenie bakterial'noj cellyulozy na srede s melassoj [Obtaining bacterial cellulose on a medium with molasses]. Vestnik Kazanskogo tekhnologicheskogo universiteta [Messenger of Kazan Technological University], 19(24), 154-156 [In Russian].

34. Blanco Parte F., Santoso S., Chou C, Verm, V., Wang H., Ismadji S., Cheng K. (2020). Current progress on the production, modification, and applications of bacterial cellulose. Critical Reviews in Biotechnology, 40(3), 397-414.

35. Álvarez C., Gallego D., Córdoba C., Castro C. (2011). Elaboración de una funda para chorizo a partir de celulosa bacterial. Bioresource technology.

36. Revin V., Liyaskina E., Pestov N. (2014). Poluchenie bakterialnoj cellyulozy i nanokompozicionnykh materialov [Obtaining bacterial cellulose and nanocomposite materials]. Izdatel'stvo Mordovskogo universiteta, Saransk, 128 s. [In Russian].

37. Carreira P., Mendes J., Trovatti E., Serafim L., Freire C., Silvestre A. (2011). Utilization of residues from agro–forest industries in the production of high value bacterial cellulose. Bioresource technology, 102, 7354–7360.

38. Verbytskyi S., Kopylova K., Kozachenko O., Verbova O., Kos T. (2019). Biopakovannia dlia molochnykh produktiv (realno ta praktychno) [Bio packaging for dairy products (real and practical)]. Upakovka [Packaging], 6 (133), 30-33 [In Ukrainian].

39. Jakobsen M., Holm V., Mortensen G. (2008). Biobased packaging of dairy products. In “Environmentally compatible food packaging” (Chiellini E. ed.). Elsevier.

40. Södergård A., Stolt M. (2002). Properties of lactic acid based polymers and their correlation with composition. Prog Polym Sci,. 27, 1123-1163.

41. Petersen K., Nielsen P., Olsen M. (2001). Physical and mechanical properties of biobased materials. Starch/Starke, 53, 356-361.