Edible Films and Coatings for Food Products - Advantages and Disadvantages

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Abstract

Edible coatings and films are the thin layer of any material used for enrobing various foods that can be eaten together with food, with or without removal. The main purpose of the scientific article is to present the advantages and disadvantages of edible films and coatings for food products. The methods used in writing the scientific article are descriptive-analytical method, systematic approach, study of the works of authors, comparative analysis, method of observation, induction, deduction. Summarizing, systematizing and grouping of the advantages and disadvantages of edible films and coatings for various food products in present article will make it possible to better see the problems associated with the production and application of edible films and coatings.

Keywords: edible films and coatings, food.

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Introduction

Edible films and coatings, such as wax on various fruits, have been used for centuries to prevent loss of moisture and to create a shiny fruit surface for aesthetic purposes. These practices were accepted long before their associated chemistries were understood, and are still carried out in the present day. The term, edible film, has been related to food applications only in the past 50 years. One semi-sarcastic tale was that spies' instructions were written on edible films, so that in the off-chance they were captured, they could easily destroy their secrets by eating them. In most cases, the terms film and coating are used interchangeably to indicate that the surface of a food is covered by relatively thin layer of material of certain composition. However, a film is occasionally differentiated from a coating by the notion that it is a stand-alone wrapping material, whereas a coating is applied and formed directly on food surface itself. As recently as 1967, edible films had very little commercial use, and were limited mostly to wax layers on fruits. During intervening years, a significant business grew out of this concept (i.e., in 1986, there were little more than ten companies offering such products, while by 1996, numbers grew to 600 companies). Today, edible film use has expanded rapidly for retaining quality of a wide variety of foods (Pavlath & Orts, 2009).

Edible films and coatings have been considered as one of the potential technologies that can be used to increase the storability of foods and to improve the existent packaging technology, helping to ensure the microbial safety and the preservation of food from the influence of external factors. Innovations constantly appear in food packaging, always aiming at creating a more efficient quality preservation system while improving foods' attractiveness and marketability. The utilization of renewable sources for packaging materials, such as hydrocolloids and lipids from biological origin, is one the main trends of the industry. These films should have acceptable sensory characteristics, appropriate barrier properties (CO_2, O_2, water, oil), microbial, biochemical and physicochemical stability, they should be safe, and produced by simple technology in low cost. Also they can act as effective carrier for antioxidant, flavor, color and nutritional or anti-microbial additives. Nowadays, a great discussion exists about the potential applications of edible films/coatings on food products. The general trend is to find the correct combination between the food product and the edible film/coating, which will ensure the success of the technology (Maftoonazad, et al., 2013).

1. Edible films and coatings for food

Edible coatings and films are the thin layer of any material used for enrobing various foods that can be eaten together with food, with or without removal. The thickness of the edible and coatings is generally less than 0.3 mm. Edible coatings and films provide a replacement of the natural layers and act as semi permeable membrane. They prevent moisture losses, microbes of external source, extend shelf life, selectively allow controlled exchange of important gases like oxygen, carbon dioxide and ethylene which are involved in respiration process, it also ameliorates the appearance and maintains firmness of the food product. Edible coatings and films should not affect the sensory properties of food products negatively (Sachdeva, et al., 2021).

Edible films and coatings are classified into: (1) hydrocolloids (polysaccharides and proteins), (2) lipids and (3) composites. Among the most the materials studied to develop biodegradable packaging films and coatings are *polysaccharides* such as cellulose, chitosan, starch, pectin and alginate. These polysaccharides are able to form films and coatings with good barrier properties against the transport of gases such as oxygen and carbon dioxide. *Proteins* are essential organic polymers in the manufacture of edible films and coatings, as well as their abundance and their renewable nature. Proteins are distinguished because of their content of amino acids, which vary in their numbers (polar and non-polar) and the sequence of amino acids that play a role in the formation of bonds between molecules. There is an interest in the manufacturing of edible films from natural renewable protein polymers, such as plant proteins (wheat gluten, corn zein, and soy protein) and animal protein (casein, whey protein, gelatin, albumin of the egg). *Lipids* include many fatty compounds, such as plant fats, animal fats, and waxes (beeswax, carnauba wax, paraffin wax, and acetomonoglycerides) have been used in the preparation of edible films and coatings because of their high moisture retention capacity as hydrophobic substances and their good appearance. As a result, they prevent the water permeability from the foods, especially fresh foods e.g. fruits and vegetables. Composites films and coatings contain both hydrocolloids and lipids components. The selection of biopolymer and application type of edible films and coatings is strongly dependent on its desired function and applied food. Plasticizers, emulsifiers and solvents are added to the composition of edible films and coatings (Cazón, et al., 2017; Hammam, 2019; Kapetanakou, et al., 2014; Pashova, 2011).

Figure 1 and figure 2 show the starch edible film and the pectin edible film, which were developed by the author of the present article.

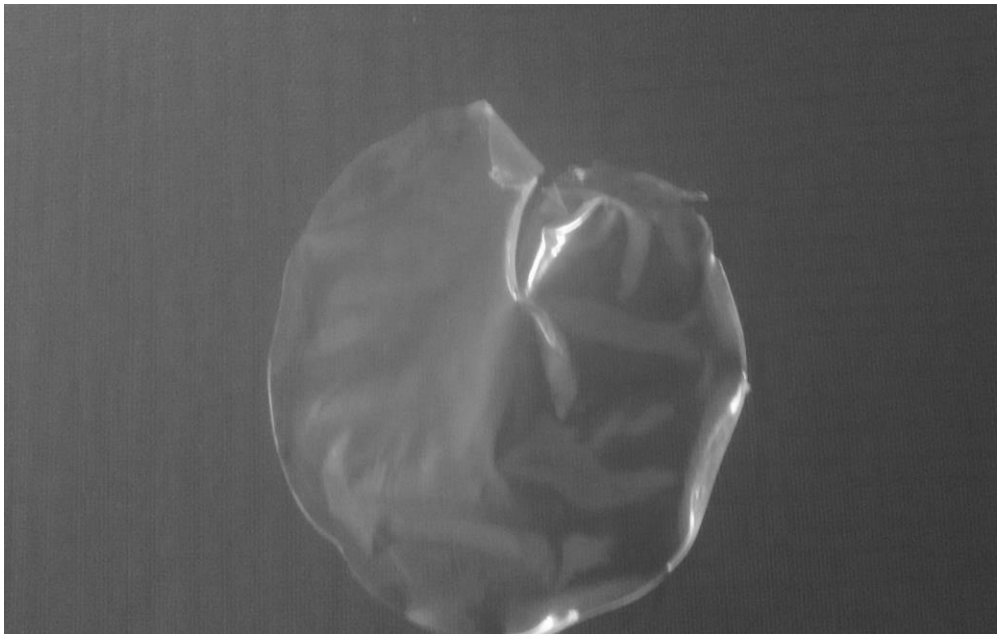

Figure 1. Starch edible film

Figure 2. Pectin edible film

Edible coating is formed directly on the food surface by spraying, dipping or spreading techniques, an edible film is first produced by solvent casting, compression molding or extrusion procedures and posteriorly implemented into the food products, being placed on or between food components (Ribeiro, et al., 2021).

Figure 3 shows the various work concepts in manufacturing, characterization and properties of edible films and coatings (Kamal, 2019).

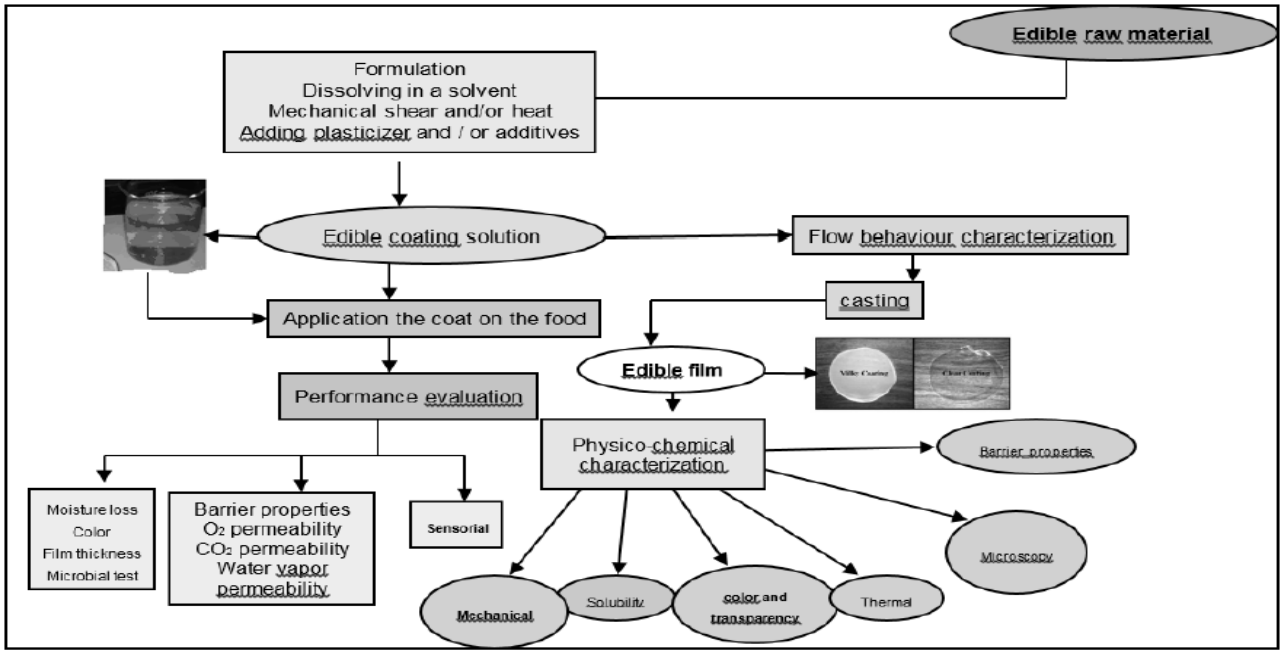

Figure 3. Flow chart showing the work concepts of edible films and coatings (Kamal, 2019)

Edible films and coatings with different compositions are used for various types of food, as preserve their quality and extend their shelf life: edible coatings elaborated with pectin and added with lemon essential oil and reuterin show great potential to be employed in *strawberries* preservation, because these coatings are able to avoid fungal spoilage without quality reduction. Coated samples showed a more intense, redder color than control samples (Hernández-Carrillo, et

al., 2021); application of edible films and coatings on *mango* fruits is an effective method to preserve their quality and safety (Tavassoli-Kafrani, et al., 2020); an oleo-proteic edible film can be successfully formed combining candelilla wax, whey protein, and glycerol. The addition of the F. cernua extract to the films did not significantly affect permeability and thickness. Films with extract presented a structure that was more smooth, continuous, homogeneous, and uniform. The edible coating applied to *tomato* reduced weight and firmness loss in storage for 10 days at 25 ◦C. The sensory evaluation proved that the product obtained is acceptable for consumers. The edible coating added with F. cernua extract was the most effective at inhibiting the growth of pathogenic fungi and the visual appearance at the end of storage confirmed the beneficial effect of the edible coating (Ruiz-Martínez, et al., 2020); to reduce the conservatives added in food, this study developed active edible films of potato starch, inverted sugar and sucrose to coat *mini panettones*. From 16 to 24 days, panettones without coating and without additives (potassium sorbate (1 g/kg), citric acid (10 g/kg)) (controls) showed growth of mold/yeast; while with both additives coating, fungal growth was observed from 40 days. When using potassium sorbate, mold/yeast was not detected until 48 days (Saraiva, 2016); the application of edible coatings carrying antifungal compounds on *cheese* was studied to reduce mass losses and control the fungal growth on the cheese surface during ripening. The effectiveness of 8 biopolymers and Aloe vera gel (AV) at controlling mass loss was analysed during the early stage of maturation, with and without lipids (Oleic acid and oleic acid-beeswax blend) and antifungal compounds (potassium sorbate (PS)), gallic tannin (GT) and Aloe vera gel. The gellan gum with both PS and GT exhibited the greatest efficacy at controlling the cheese water loss during the ripening period. The AV gel and its blend with gellan gum did not exert a good water vapour barrier capacity, although it did exhibit antifungal action against Penicillium roqueforti. The coating of gellan with PS resulted in an 84% inhibition of mycelial growth and could prevent fungal growth during cheese ripening, while controlling the cheese mass loss (Ordóñez, et al., 2021); irrespective of water content in the *sausages*, emulsion coatings (emulsions containing gelatine, kappacarrageenan, beeswax, lard, glycerol and water) effectively inhibited their weight loss during storage. The coating with lower content of carrageenan could be recommended. Instability of coatings colour during storage implies the need of adding a colorant to the composition of emulsion (Tyburcy, et al., 2010); the study is realize to determine the effects of whey protein isolate (5% w/v) based edible coatings (WPC) containing different concentrations (3, 6, 9% w/v) of acai powder extract (AE) and matcha extract (ME) on oxidative and microbial stability of cooked meatballs during storage (14 d at +4 °C or 60 d at −18 °C). This result showed that the use of AE and ME in WPC formulation inhibited lipid oxidation and microbial growth, and had the potential for extending shelf-life of meatballs by preserving the physicochemical properties (Şen & Kılıç, 2021); the goal of the research is to determine whether food-grade coatings on *eggs* may extend shelf-life under refrigerated storage. Four food-grade coatings are selected: paraffin wax, mineral oil, soy protein isolate, and whey protein isolate (WPI). These coatings are apply to fresh chicken eggs. The eggs were stored for 12 week in refrigerated storage at 7°C. Overall, oil-, wax-, and WPI-coated eggs maintained higher vitelline membrane strength (14%) than the uncoated eggs. Coating of chicken eggs with a food-grade film (oil, wax, WPI) will extend shelf-life beyond 6 week (Biladeau & Keener, 2009) and many other food products.

The application of edible films and coatings on the surface of various types of food products helps to better preserve of quality and its sensory, physicochemical and microbiological parameters for a longer storage period.

There is scarce information in the scientific literature on the advantages and disadvantages of edible films and coatings, which is the reason for the present study.

The main purpose of the scientific article is to present the advantages and disadvantages of edible films and coatings for food products.

The methods used in writing the scientific article are descriptive-analytical method, systematic approach, study of the works of authors, comparative analysis, method of observation, induction, deduction.

2. Advantages of edible films and coatings for food products

The point presents the positive aspects of edible films coatings for food in the following sequence (Raghav, et al., 2016; Šuput, et al, 2015; Shukla, et al., 2019):

- ✓ edible films and coatings (EFC) improve retention of composition of food products - preserving food composition is important for producers, traders and consumers;
- ✓ components of the composition of (EFC) supplement the nutritional values of the different type of food - some components of the composition of (EFC) improve the nutritional and biological value of food products;
- ✓ maintain quality of food products during storage - EFC can retard surface dehydration, moisture absorption, oxidation of ingredients, aroma loss, frying oil absorption, ripening/aging, and microbial deterioration of food products. Preservation of the sensory, physico-chemical and microbiological parameters of food products with applied edible films and coatings is important for all participants in commodity market relations - producers, traders and consumers;
- ✓ enhance the sensory properties of packaged food by incorporating flavorings, colorings and sweeteners. They also contribute to visual quality and surface smoothness of food. In modern conditions, food products with good sensory properties are preferred by consumers to enjoy their receptors when consuming food. Improving the sensory properties of food can be achieved by including flavors, colors and sweeteners in the composition of edible films and coatings;
- ✓ carry antimicrobial and antioxidant agents – some EFC contain various antimicrobial and antioxidant agents. Oxygen has a deleterious effect on the quality of a wide variety of food products. The application of edible films and coatings to food products represents a new approach to solve this problem. Edible films and coatings can include antioxidant agents in their formulation and at the same time, they represent a barrier to oxygen, which results in a better preservation of quality to prolong period of time (Bonilla, et al., 2012). Microbiological studies are important for the quality of various food products (Stefanova & Pashova, 2018) and therefore antimicrobial agents are sometimes used in the composition of edible films and coatings to preserve food from certain types of microorganisms, thereby extending the shelf life;
- ✓ shelf-life extension and safety enhancement - an increased protective function of food products extends shelf life and reduces the possibility of contamination by foreign matter;
- ✓ reduce weight loss and firmness loss - EFC with a certain composition slow down the loss of water from food (mainly fresh fruits and vegetables) and firmness loss, and the food products are fresh for a longer period of time;
- ✓ individual packaging of small of foods - the individual packaging of small foods can be done with edible films (figure 1 and figure 2) with different composition, carefully analyzing the specifics of the food product;
- ✓ reduces environmental pollution through decrease use polymer packaging and waste decrease use polymer packaging and waste - EFC are biodegradable and can therefore be used as substitutes for some synthetic packaging that pollutes the environment, which can achieve an environmental effect from the use of edible films and coatings;
- ✓ edibility and biodegradability - to main-tain their edibility and biodegradability, all film components should be food-grade in-gredients and biodegradable (environ-mentally safe). Edible films and coatings can be consumed along with food products. In order to be edible, each of the components included in the composition of edible films and coatings must be safe, be able to be used in contact with food set by the requirements of bulgarian and european legislation;
- ✓ EFC can contain health beneficial nutrients - the composition of edible films and coatings may contain various useful components (most often vitamins, plant extracts, etc.) that have a positive effect on the health of the human. From this point of view, edible films and coatings can be used to enrich food products with useful nutrients;
- ✓ physical and mechanical protection - mechanical properties should be optimized regarding tensile strength, elongation-at-break, elastic modulus, compression strength, puncture strength,

stiffness, tea-ring strength, burst strength, abrasion re-sistance, adhesion force, folding endurance, etc. There is an appropriate methodology and equipment for studying the physico-mechanical properties of edible films and coatings, and the results obtained provide the necessary information about the properties of the particular edible film or edible coating intended for the surface of food products;

- ✓ migration, permeation, and barrier functions - All barrier properties are affected by film composition and environmental conditions (relative humidity and temperature). By optimizing the composition of edible films and coatings and finding suitable storage conditions (temperature and relative humidity) for EFC and food products, EFC can have very good barrier properties that preserve quality of food products for a longer period of time;
- ✓ active substance carriers and controlled release - edible films and coatings can be utilized for food ingredients, pharmaceuticals, nutraceuticals, and agrochemicals in the form of capsules, microcapsules, soluble strips, flexible pouches, and coatings on hard particles.

3. Disadvantages of edible films and coatings for food products

The point presents the negative aspects of edible films coatings for food in the following sequence (Okcu, et al., 2018; Raghav, et al., 2016):

- ✓ Thick coating can prohibit oxygen exchange, causes off-flavour development. The surface of the food product and the chosen method of applying the edible coatings can form a thick layer of the coating, which reduces the functionality and efficiency of the edible coatings;
- ✓ Some edible film and coatings are hygroscopic in nature, which helps to increase the possible growth of microbes, which prevents the EFC from fulfilling its main purpose. For this reason, you need to know and choose the right components (including antimicrobial agents if necessary) for the composition of edible films and coatings;
- ✓ allergic reactions - some of the components (for example: beeswax) in the composition of edible films and coatings can cause allergic reactions in consumers;
- ✓ the high cost of the components (natural bipolymers) included in the composition of edible films and coatings increases the cost and reduces the economic efficiency of the use of edible films and coatings. In most cases, edible films and coatings are more expensive than synthetic packaging. This is one of the reasons for the difficult application of edible films and coatings in food production;
- ✓ lack of sufficient information for the use of machinery and equipment for the production of edible films and coatings with different compositions, different application methods, and EFC must have appropriate physical and mechanical properties to fulfill their main purpose;
- ✓ need for a second packing material because EFC have lesser physical and chemical resistance compared to synthetic packaging. These facts lead to serious consideration of the possibilities of edible films and coatings to replace synthetic packaging, as well as to look for opportunities to improve the physico-chemical and mechanical properties of the produced EFC.

Based on the scientific experience of the author of the present article in the field of EFC, some additional suggestions are given regarding the negative aspects of edible films and coatings for food:

- ✓ high cost of some physico-mechanical laboratory tests for the properties of edible films and coatings create difficulties related to the financing of the development of EFC;
- ✓ there are difficulties in applying edible films and coatings on the surface of food products - the viscosity and specificity of the composition of edible films and coatings, as well as the type and surface of food and the chosen method of applying create these difficulties in application of EFC;
- ✓ there are no separate regulatory requirements for the use of edible films and coatings, which makes it difficult to determine the composition of the EFC. Sometimes in the scientific literature there are very good scientific results of specific edible films and coatings, but some of the components are not allowed for use in food. This is another reason for the difficult application

of edible films and coatings in food production.

4. Advantages and disadvantages of edible films and coatings for food products

The advantages and disadvantages of edible films and coatings, which are obtained on the basis of the scientific literature review, are presented in a summarized form (Table 1).

Table 1. Summary of the advantages and disadvantages of edible films and coatings

№	Advantages (+)	Disadvantages (-)
1	preserve the composition of food products	sometimes the formed edible coating has a thick layer
2	EFC can improve the nutritional value of food	some edible film and coatings are hygroscopic in nature, which helps to increase the possible growth of microbes
3	maintain quality of food products during storage	some of the components of edible films and coatings can cause allergic reactions in consumers
4	enhance the sensory properties of food	high cost of the components and reduce the economic efficiency
5	EFC may include in the composition antimicrobial and antioxidant agents	lack of sufficient information for the use of machinery and equipment for the production of EFC
6	shelf-life extension and safety enhancement	need for a second packing material because more of EFC have lesser physical and chemical resistance compared to synthetic packaging
7	reduce weight loss and firmness loss	high cost of some physico-mechanical laboratory tests for the properties of EFC
8	can use for individual packaging of small of foods	there are difficulties in applying edible films and coatings on the surface of food products
9	reduces environmental pollution through decrease use polymer packaging	there are no separate regulatory requirements for the use of edible films and coatings, which makes it difficult to determine the composition of the EFC
10	edibility and biodegradability	
11	EFC can contain health beneficial nutrients	
12	EFC have a good physical and mechanical protection	
13	EFC have a good barrier properties	
14	EFC can be active substance carriers and controlled release	

The summarized results of figure 1 show that the advantages of edible films and coatings are fourteen and their disadvantages are nine.

The advantages of edible coatings can be systematized into several main groups:

- ✓ advantages of using EFC about food quality - 1. preserve the composition of food products; 2. EFC can improve the nutritional value of food; 3. maintain quality of food products during storage; 4. enhance the sensory properties of food; 7. reduce weight loss and firmness loss; 11. EFC can contain health beneficial nutrients;
- ✓ advantages of using EFC about shelf-life extension and safety enhancement - 5. EFC may include in the composition antimicrobial and antioxidant agents; 6. shelf-life extension and safety enhancement; 14. EFC can be active substance carriers and controlled release;
- ✓ advantages of using EFC about environmental pollution - 9. reduces environmental pollution through decrease use polymer packaging; 10. edibility and biodegradability;
- ✓ advantages in the production of EFC - 8. production of individual packaging of small of foods; 12. EFC have a good physical and mechanical protection; 13. EFC have a good barrier properties.

The disadvantages of edible coatings can be systematized into four main groups:

- ✓ disadvantages about the composition of EFC (2. some edible film and coatings are

hygroscopic in nature, which helps to increase the possible growth of microbes; 3. some of the components of edible films and coatings can cause allergic reactions in consumers);

- ✓ disadvantages about the production and applying of EFC (1. sometimes the formed edible coating has a thick layer; 5. lack of sufficient information for the use of machinery and equipment for the production of EFC; 6. need for a second packing material because more of EFC have lesser physical and chemical resistance compared to synthetic packaging; 8. there are difficulties in applying edible films and coatings on the surface of food products);
- ✓ disadvantages about the price and the economic efficiency about application of EFC (4. high cost of the components and reduce the economic efficiency; 7. high cost of some physico-mechanical laboratory tests for the properties of EFC);
- ✓ disadvantages about the regulatory requirements of the EFC (9. there are no separate regulatory requirements for the use of edible films and coatings, which makes it difficult to determine the composition of the EFC).

The summarized results and the grouping by groups of the advantages and disadvantages of edible films and coatings are important for the development of research on EFC. The *advantages* of EFC that authors should use and deepen their work are regarding the fact that: EFC preserve food quality; EFC extend the shelf life of food; the use of EFC may limit the use of synthetic packaging; in the production of EFC, they have good physico-mechanical and barrier properties. The *disadvantages* of the EFC about that the scientific community must work on is to create appropriate strategies, opportunities and conditions to minimize the negative effects about: the composition of the EFC; the production and application of EFC; the price and the economic efficiency about the application of EFC; the regulatory requirements of the EFC.

Conclusion

The scientific article summarizes, systematizes and groups the advantages and disadvantages of edible films and coatings for various food products. The scientific literature is dominated by authors focused on the advantages of edible films and coatings, but nevertheless their disadvantages are also presented. Summarizing, systematizing and grouping of the disadvantages of edible films and coatings in present article will make it possible to better see the problems associated with the production and application of edible films and coatings. Research on the advantages and disadvantages of edible films and coatings could provoke further research by researchers in the field of edible films and coatings.

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