ECOLOGY, BIOTECHNOLOGY, AGRICULTURE AND FORESTRY

IN THE 21ST CENTURY

PROBLEMS AND SOLUTIONS

EDITED BY
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The monograph is a collection of the results of scientists' achievements obtained directly in real conditions. The authors are recognized specialists in their fields, as well as young scientists and graduate students of Ukraine. The studies are conceptually grouped in sections: biotechnology, ecology, agriculture, forestry, sustainable development of the economy and the principles of effective agribusiness. The monograph will be of interest to specialists in biotechnology, ecology, breeding, plant protection, agrochemistry, soil science, forestry, agribusiness, etc., researchers, teachers, graduate students and students of specialized specialties of higher educational institutions, as well as everyone who is interested in sustainable development in the agricultural sphere and Green Deal Implementation strategies.

Keywords: sustainable development, modern technologies, agricultural production, biotechnology, ecology, plant protection, forestry, agribusiness.

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EFFECTIVENESS OF PROTECTIVE EDIBLE COATINGS TO EXTEND SHELF LIVES OF FRESH FRUITS AND VEGETABLES

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Synthetic films are an effective measure to preserve fresh fruits and vegetables, but such films pollute the environment. At the same time, extension of shelf lives of fresh fruit and vegetables is necessary to minimize food waste, which annually accounts for about a third of the manufactured products. Protective edible coatings allow one to solve these both problems. Edible coatings are based on natural polysaccharides, proteins, their mixtures, glycerol, pectin, and beeswax, which make them strong, but do not prevent them from biodegradation or composting. Since protective edible coatings can be supplemented with vitamins, flavorings, and dyes, these additionally allow for improvement of the qualities and nutritional values of fresh fruits and vegetables.

Key words: edible coating, vegetables, fruits, shelf life, microorganisms.

Extension of the shelf life is an important measure to minimize food waste. According to estimates by the Food and Agriculture Organization of the United Nations, a third of the foods produced worldwide is thrown away or lost every year. In addition, 60% of consumers worldwide never use expired products. Application of protective, but easily removable coatings

on fresh fruits and vegetables is an effective method of storage. A liquid is applied directly to the product or it is immersed in the liquid. Such coatings can be with or without an antimicrobial effect.

Edible films and coatings are thin layers of edible materials applied to food items, which play an important role in their preservation, distribution, and marketing. Protection of products against mechanical, physical, chemical, and microbiological damage are some of their functions. Their use is rationalized due to their specific properties such as cost, availability, functionality, mechanical properties (flexibility, tension), optical properties (brightness and opacity), barrier effect against gas flow, structural resistance to water and microorganisms, and sensory acceptability. They are used in combination with bioactive compounds, which provide foods with additional functions and extend their shelf lives (Falguera V., 2011).

For example, a beeswax-containing coating was developed for plums; it was applied immediately after harvest. Plums in a coating with 20, 40, or 60 g/100 g of beeswax were stored for four weeks at 1°C and then for 1–3 weeks at 20°C. It was found that beeswax reduced the mechanical strength of the coatings and worsened their barrier properties against oxygen, but improved the barrier properties against water vapor. In this study, it was demonstrated that plums were stored for the longest time without quality deterioration of their quality in a coating that contained wax in the amount of 20 g/100 g (Navarro-Tarazaga M.L., 2011).

In experiments with tangerines (Valencia-Chamorro S.A., 2011), scientists investigated consumer-oriented characteristics of coatings based on hydroxypropylmethylcellulose supplemented with hydrophobic components (beeswax and shellac) and food preservatives (sorbitol, Na benzoate, Na propionate, and their mixture) as antifungal components. Intact and artificially inoculated with Penicillium digitatum or P. italicum tangerines were stored for 30 days at 5°C and another seven days at 20°C. It was shown that the coatings with antifungal additives protected the refrigerated tangerines from spoilage well during storage.

A rice starch-based coating with antioxidant and barrier properties against microorganisms was developed and its effect on tomatoes stored at room temperature was studied. Coconut oil and tea leaf extract were added to the rice starch-based coating for tomatoes. Biochemical changes in the tomatoes were studied during 20-day storage. It was revealed that addition of lipids and tea extract with antioxidant activity to the film-forming solution significantly improved its characteristics. At the end of storage, the tomatoes coated with starch–glycerol–lipids lost by 1,78% less weight and

those coated with starch–glycerol–lipids–antioxidants lost by 3,53% less weight than the uncoated tomatoes. It was found that coconut oil and tea extract in the coating slowed down the ripening process in the tomatoes during storage. In addition, these coatings had excellent barrier properties against microorganisms (Deba D., 2013).

It was possible to preserve ripe mangoes for two weeks without deterioration and with preservation of weight, color, flesh texture, and color due to an edible coating based on pectin, beeswax, sorbitol, and monoglyceride. The fruits were coated and stored at room temperature concurrently with uncoated control samples. The shelf life of the control sample was shorter than a week (Moalemiyan M., 2011).

An experiment was conducted to evaluate the effect of beeswax coating on physiological changes in 'Blood Red' sweet oranges at the Horticulture Department of the Arid Agriculture University (Rawalpindi, Pakistan) (Shahid M.N., 2011). Results showed that all wax coatings reduced weight loss and maintained turgidity, pH, solids content, titratable acidity, solids/acid ratio, reducing sugars, non-reducing sugars, total sugars, and ascorbic acid. In this study, beeswax performed better for citrus storage than all other treatments.

Such protection mostly does not present toxicological problems. However, an accidental transfer of components from a coating into a food item cannot be excluded. Breathable coatings slow down post-harvest ripening of fresh fruits and vegetables as well as further degradation and rotting. They are easier to use in packaging plants, require less investment and even outperform state-of-the-art packaging such as modified atmosphere packaging. It should be noted that coatings should be adapted to specific characteristics of products (Propozytsiia, 12.12.2021).

A Californian company, Apeel Sciences, presented its invention – an edible coating, which preserves fruits and vegetables fresh. To develop a coating, lipids are extracted from various organic wastes; then a powder is obtained from them. Lipids are natural fats and are completely safe to eat. They protect products against natural gases, which accelerate ripening, and keep moisture in to preserve freshness. To cover products with a lipid mixture, the powder is turned into a sticky mass. The company also offers Apeel Avocado and Apeel Citrus, special coatings for avocados and citruses, which are known to rot quickly. To form a film on the surface, fruits are either dipped in a mixture or it is sprayed over them (THE EPOCH TIMES. July 12, 2020).

Such coatings facilitate manufacturers' and transport companies' work. Crops can stay in the field longer, continue to ripen, and be harvested later because the risk of rotting during transportation and retail sales is reduced. In this way, the amount of waste during the entire agricultural production in general is reduced.

In Israel (startup Sufresca), an edible coating, which extends shelf lives of vegetables and fruits by several weeks without refrigeration, was developed. The edible skin on fruits and vegetables is designed to reduce the food waste amount at home. A layer with a GRAS chemical allows extending the shelf life and prevents spoilage of products.

This edible coating also eliminates the need to use plastic packaging, such as shrink wrap, to store products in the store. This coating is absolutely safe for consumers. Sufresca's technology uses liquid formulas, which, being applied onto fruits and vegetables, create a breathable coating. The company claims that the coating can extend the shelf life by several weeks while preserving the freshness and nutritional value of fruits.

Sufresca focused on fruits (bananas, pomegranates) and vegetables (cucumbers, tomatoes, onions, garlic, and peppers), for which there is currently no edible coating. Covering of fruits and vegetables is a way to minimize food waste and reduce spoilage of fruits and vegetables.

According to the United Nations, approximately one-third of the world's food supply goes to waste annually and 14% of this food is lost between harvest and retail distribution. The coating developed by Sufresca has been approved by the US government and is allowed to be used to extend shelf lives of food products (ENERGY CLUB, 01.05.2020).

Sufresca developed an edible biodegradable water-based emulsion composed of natural food ingredients with built-in improved characteristics of a modified atmosphere. The new edible coating was proven to perform very well with different tomato varieties, including cherry tomatoes, cucumbers, and even fruits such as mangoes.

So, due to edible coatings, retailers can now use biodegradable packaging without worrying about shelf lives. Coatings can extend the shelf life of a product to several weeks, saving plastic packaging and increasing shipping time.

Malaysian scientists are developing protective coatings for fruits and vegetables that are believed to be safe and transparent, odorless and tasteless. They are made from gum arabic, a natural product from acacia trees of Sudan (Africa). These new coatings are water soluble, biodegradable, non-toxic, and eco-friendly. They are considered as

complying with the Global Recycling Standard (GRS), which is generally recognized as safe by the FAO, FDA, and several other food agencies. These coatings delay ripening, enhance aesthetic and sensory characteristics, slow down gas exchange by providing a semi-permeable barrier, and prevent mechanical injuries. The coatings were proven to preserve vital chemicals and antioxidants in fruits by controlling the exchange of CO_2 and oxygen (McKinney L., 2023).

In India, an edible vegetable coating was applied to store cucumbers. It included corn starch, mint (Mint viridis L.) extract, citric acid solution, and glycerol as a plasticizer. The cucumbers were stored at 25°C or 10°C. The protective coating made it possible to extend the shelf life of the fresh cucumbers at these temperatures up to 12 days without significant changes in taste, firmness, and appearance (Pramod R., 2018).

Indonesian scientists suggested storing strawberries in Ecogel, consisting of aloe gel (Aloe barbadensis Mill.) supplemented with ascorbic acid. The strawberries in ecogel were stored for up to nine days at 7±1°C without significant loss of weight or worsening of organoleptic parameters (Suriati L., 2021).

However, a formulation developed for peppers was not expected to perform well for avocados because the chemical compositions, physical structures of their cuticles, and other physiological features, such as respiration rate and water content, differ. The consumer wants to use environmentally friendly materials, not synthetic chemicals that pollute nature. In addition, extensive application of pesticides on fruits can result in pesticide resistance of some strains of fungi.

Ready-made mixtures of emulsifiers and additives can be of great practical importance, allowing both to improve the main parameters of emulsions and to impart special properties that take into account the specifics of an application area. Further development of technologies for manufacturing of wax emulsions and improvement of their properties, which are demanded by the market at the moment and in the future, determines the relevance and necessity of research in this area (Hong X., 2023).

The purpose of our study was to justify some components of a post-harvest processing technology for winter garlic, which will allow for improvement of garlic storability and extension of garlic consumption length. The working hypothesis was based on the assumption that it is possible to use a modified paraffin-containing coating, which is able to increase the stability of garlic bulbs during storage. Covering of bulbs with a mixture of 90% shellac + 10% aloe vera gel ensured the storage length of

145 days with the daily weight loss of 0,036%. 20% sunflower wax prolonged the storage time up to 142 days with the daily weight loss of 0,036%, while paraffin treatment resulted in 100 days and 0.10%, respectively.

A rise in the relative air humidity during storage reduced the weight loss of garlic bulbs to 8,2%, which means a 2,5-fold reduction. Covering of garlic bulbs with the protective film ensured a 4,6- to 5-fold reduction in the weight loss at the relative humidity of 60–70%. An increase in the relative air humidity to 75–85% and 90–95% reduced the weight loss by 4,7–5,3 and 2,9–3,1 times, respectively. The contribution of the protective coating to the bulb weight loss reduction was 76,0%; the contribution of the relative humidity was 12,0%; and the interaction between the studied factors accounted for 12,0%. Therefore, the coatings of garlic bulbs extended their storage by 25–45 days, depending on the coating variant. The longest storage was 142–145 days (Puzik L., 2023).

Conclusions

1. Edible coatings and films are of great value for extending shelf lives of fruits and vegetables and also an environmentally friendly approach to food packaging.

2. Edible coatings, like synthetic films and packaging, control the ingress and egress of water and gases. At the same time, they are made of natural biopolymers (polysaccharides, proteins, and their mixtures), and therefore are biodegradable and suitable for composting.

3. Protein films have good mechanical strength; polysaccharide films and coatings show effective gas-blocking properties, but both types are not waterproof. These disadvantages can be overcome by combining these polymers with lipids and/or some suitable hydrocolloids.

4. Supplemented with antimicrobial agents, antioxidants, nutraceuticals, and flavorings, edible coatings can be a useful tool to protect fruits and vegetables against microbiological spoilage while increasing their nutritional value and quality.

5. Since the cuticles of different fruits and vegetables are not the same in structure, it is advisable to develop various edible coatings for different groups of fruit and vegetable products.

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