ХАРЧОВІ ТЕХНОЛОГІЇ

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O. P. Priss[1], Dr. Sci. Tech. ORCID: 0000-0002-6395-4202
P. O. Bulhakov[1], postgraduate ORCID: 0009-0002-9011-8151
T. O. Kolisnychenko[1], PhD ORCID: 0000-0003-0560-9520
L. V. Gazzavi-Rogozina[2], PhD ORCID: 0000-0002-8050-414X
[1]*Dmytro Motornyi Tavria State Agrotechnological University*
[2] *State Biotehnology University*
e-mail: olesia.priss@tsatu.edu.ua, tel.: +380675273110

USING PROTECTIVE COATING FOR REDUCTION OF LOSSES WHILE STORING ASPARAGUS

Summary. Asparagus is a highly valuable and perishable crop. It is advisable to use edible coating based on natural compounds to extend the shelf life of asparagus. Alginate is an effective natural polysaccharide used to form coating. At the same time, alginate coating is lacking in antioxidant properties. Therefore, the aim of the present research is to determine the effect of coating based on sodium alginate and some antioxidant substances on the preservation of asparagus. The article considers the effect of coating based on sodium alginate and rutin on the extension of shelf life, reduction of weight loss, marketability and organoleptic properties of the asparagus of two differently coloured varieties.

The green asparagus of the Prius F1variety and the green-purple Rosalie F1variety were researched. It has been found that the use of coating based on sodium alginate and rutin can extend the shelf life of asparagus by 3...7 days (depending on the composition of the coating). The combination of alginate and rutin can reduce weight loss 2.1...2.2 times, depending on the variety. The standard yield of asparagus treated with the composition of alginate and rutin after storage was 88.14...91.79 %, with a 7-day longer storage period. The amount of waste did not increase either. All the experimental samples showed higher organoleptic scores then the control samples. However, alginate and rutin-based coating did not have the desired effect in order to reduce the desiccation of bases.

Keywords. Storage, green asparagus, green-purple asparagus, edible coating, alginate, rutin, weight loss, marketability.

Problem statement. Food loss and waste are the manifestations of inefficient food systems [1]. Fruit and vegetables are at the top of the food waste and losses ranking (40-50% of their production), which leads to the use of non-renewable resources to produce food that will not be consumed (about 25% of all water used by agriculture each year and 23% of all arable land, producing about 8% of annual global greenhouse gas emissions) [2].

Reducing fruit and vegetable losses and waste can therefore be one of the leading global strategies for achieving sustainable food security and improving diets, reducing greenhouse gas emissions, reducing the pressure on water and land resources, as well as increasing productivity and economic growth.

Recent research and publications analysis. The main issue of high level of losses during storage of fruit and vegetable products is high moisture content (75-95%), intensive gas exchange, active metabolism, abiotic and biotic stresses, which leads to rapid spoilage and decay. The mechanisms of postharvest ageing and rapid quality loss are associated with the development of oxidative stress [3]. Preventing the natural ageing process and spoilage of fruit and vegetables in the process of storage is a fundamental challenge from a technical point of view. The main way to inhibit normal metabolism is by means of cooling and the use of coating that slows down the gas exchange and affects tissue oxidation. The application of edible coating on the surface of fruit and vegetable products has been actively used abroad since the early 2000s. However, in recent years, the increased attention of scientists has been paid to the environmental friendliness of the used substances, which explains the number of studies related to the use of edible coating based on natural compounds in order to extend the shelf life of fruit and vegetable products.

Polysaccharides such as chitosan, carboxymethyl cellulose and pectin demonstrate great perspective for preserving fruit quality and effectively delay weight loss, reduce the content of anthocyanins and secondary metabolites [4]. This edible coating provides a good antimicrobial effect yet has significant drawbacks, such as low water resistance and unsatisfactory mechanical properties. Other biopolymers including starches, lipids and proteins are used for improvement of the functional properties of chitosan coating [5]. Casein-based coating significantly effects the moisture and gas exchange, slows down metabolism, but does not have bactericidal properties. The coating of this type requires the inclusion of antioxidant and antimicrobial agents [6]. Essential oils and phenolic compounds are often used as antioxidants [7]. The inclusion of essential oils in polysaccharide matrices increases their antimicrobial effect as well as antioxidant properties. It has been found that the polysaccharide matrix adapts the release of essential oils and thus affects the shelf life of nutrition products [8]. However, these substances sometimes diffuse into nutrition products, imparting an undesirable taste and aroma due to the presence of a mixture of volatile and non-volatile components, which limits their use [9]. Another approach to processing fruit and vegetable products to reduce weight loss and extend shelf life is the use of bionanocomposite coating [10]. The authors point out the antioxidant and antibacterial properties of nanocomposite coating. Storage efficiency varies greatly, depending on the concentration of the treatment substances, storage conditions and the type of fruit and its characteristics [11]. Excessive concentrations of exogenous substances can be toxic to fruit cells due to their pro-oxidant effects or ability to utilize reactive oxygen species, which are necessary for cell functioning [12]. Despite the proven effectiveness of using various treatments to reduce the loss of fruit and vegetable products, the mechanism of influence of such coatings on the endogenous processes underlying fruit preservation is still poorly understood.

Asparagus is a highly valuable vegetable crop with a short shelf life. A number of coating types based on natural compounds are used to extend the shelf life of asparagus [13]. Some studies on the use of coatings containing alginate have been conducted [14]. Alginates are hydrophilic colloidal carbohydrates extracted from various species of brown seaweed belonging to the class Phaeophyceae [15]. Alginate is one of the most effective natural polysaccharides for coating formation. It has non-toxic and unique colloidal properties, such as thickening, stabilization, suspension, film formation, gel formation and emulsion stabilization. Films formed by alginate are uniform, transparent and represent good oxygen barriers, though they have low water resistance due to their hydrophilic nature. Tran, Y. T. N. et al. investigated the preservation of asparagus with a protective coating based on chitosan and alginate. They found that such coating reduces weight loss and extends shelf life by 3 days [16]. It can be assumed that the introduction of antioxidant substances, which affect the degree of tissue oxidation, into an alginate-based film will extend the shelf life of asparagus.

Purpose statement. The purpose of the article is to determine the effect of coating based on sodium alginate and antioxidant substances on the preservation of asparagus.

To achieve this purpose, the following tasks were solved:

- the effect of the applied coating on the natural weight loss in the process of asparagus storage was determined;
- the effect of the applied coating on the marketable condition of asparagus after storage was investigated;
- the effect of the applied coating on changes in the organoleptic characteristics of asparagus after storage was researched.

Materials and methods. The asparagus (Asparagus officinalis L.) of two differently coloured varieties was used for the research (the green Prius F1 variety and the green-purple Rosalie F1variety). The asparagus was grown in 2021 on the “Liubymivsky Saffron” farm in the Region of Kherson, Ukraine. After harvesting, the samples were quickly cooled and transported to the laboratory of Dmytro Motornyi Tavria State Agrotechnological University within 4 hours. The asparagus spears, used for the research, were intact, approximately the same length and diameter with closed bracts and met the requirements of CODEX STAN 225-2001 (the maximum allowable spear length for the green-purple and green varieties was 27 cm) (Fig.1).

a b

Fig. 1. Asparagus that was laid up for storage:
a – Rosalie F1; b – Prius F1

Coating application. An aqueous solution of 1% sodium alginate (A) was prepared by gradually dissolving the preparation in hot water (t=45°C). To prepare rutin solution, the dry preparation was dissolved in 96% ethyl alcohol (5% by weight) and then adjusted with water to obtain a concentration of 1% rutin (R). For the complex preparation of rutin with alginate (R+A), alginate was added to the heated 1% rutin solution and left to cool and gel uniformly for 20 minutes. The asparagus was completely immersed in the cooled solutions, then left to drain off the remaining solution and dry vertically for 1 hour. At the same time, a control sample was prepared without treatment.

Control samples and processed asparagus were stored in an industrial refrigerator at a temperature of 2°C ± 0.5 and relative humidity of 95%±1.

Determination of marketability. Asparagus marketability was assessed based on the requirements of CODEX STAN 225-2001. Waste included rotten produce and produce with signs of microbial damage. Non-standard produce included spears that had lost turgidity as well as spears with open bracts. Storage was considered complete when the amount of losses and waste reached 10%.

The organoleptic parameters were determined by the characteristics of turgidity (from fresh appearance to severe loss of turgidity), longitudinal striation (from the absence of stripes to strong striation), desiccation of bases (from no desiccation to intensive desiccation), colour change (from bright green or green-purple, typical for the variety, up to yellowing), the presence of off-odour (from no odour to noticeable odour) and the absence of microbial spoilage [17]. A four-point scale was used (4 – very good; 3 - good; 2 - acceptable; 1 - unacceptable). In addition, the importance coefficient of the indicators was taken into account: 0.3 - turgidity; 0.2 – presence of off-odours and absence of microbial spoilage; 0.1 – other indicators.

Natural weight loss was determined by weighing fixed samples during the entire storage period.

The research was carried out in the laboratory of crops primary processing and storage technology of Agrotechnology and Ecology RDC of Melitopol Tavria State Agrotechnological University.

All studies were performed in fivefold recurrence and the data obtained were presented as mean ± standard deviation. Data analysis was done by an analysis of variance, with mean separation by LSD at the 0.05 level.

Results and discussion. According to our data, control samples of asparagus of both varieties were stored under cooling conditions for no more than 14 days without significant loss of quality. During further storage, the sprouts quickly turned yellow, lost their elasticity and became woody. Under the same storage conditions, asparagus treated with protective coating and processing variants was stored for 18...21 days. The treatment with the R+A composition extended the shelf life as much as possible. With this treatment, the shelf life was 1 week longer compared to the control samples. Treatment with alginate or rutin alone extended the shelf life by 3 days.

One of the ways to reduce losses during storage of fruit and vegetable products is to reduce natural weight loss due to respiration and transpiration. The process of transpiration occurs due to the pressure gradient of water vapor between the shoots and the surrounding air. Transpiration usually depends on the thickness of the epidermal cell layer. Therefore, varietal differences in weight loss are quite possible. However, according to our results, the natural weight loss of the Prius and Rosalie varieties does not differ significantly (Table 1).

However, in previous studies it was found that the Prius F1 variety showed higher activity of respiratory processes compared to the Rosalie F1 variety [18]. It can be assumed that the varietal differences were leveled due to higher transpiration of the Rosalie F1 variety. The effect of the treatments used obviously reduces weight loss. A significant reduction (1.8 times regardless a variety in 14 days, when control samples were removed from storage) was observed when applying the alginate treatment.

Table 1

Dynamics of natural weight loss, (%). M±SD, n=5

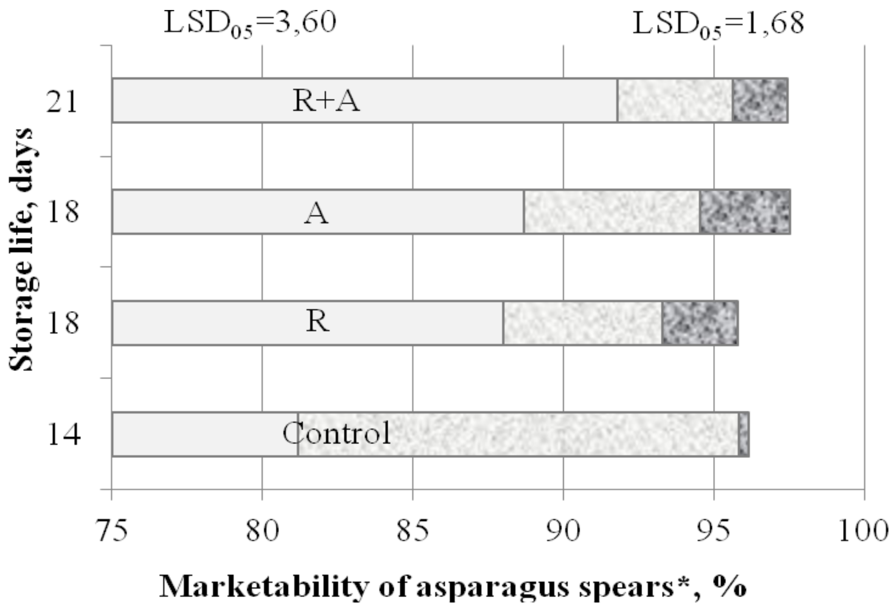
Variety	Shelf life, days	Control	R+A	R	A
Prius F1	0…7	2.20±0.17	1.10±0.16*	2.12±0.05	1.15±0.02*
	7…14	1.64±0.23	0.69±0.02*	1.19±0.04*	1.00±0.07*
	14…18	0.86±0.05	0.41±0.03*	0.91±0.05	0.35±0.04*
	18…21	0.74±0.09	0.35±0.02*	0.68±0.04	0.37±0.09*
	Total for 14 days	3.84±0.39	1.79±0.16*	3.32±0.06*	2.15±0.07*
	Total for 21 days	5.44±0.48	2.55±0.13*	4.90±0.08	2.86±0.16*
Rosalie F1	0…7	2.35±0.11	1.01±0.09*	2.32±0.08	1.28±0.17*
	7…14	1.65±0.11	0.83±0.12*	1.18±0.04*	0.96±0.04*
	14…18	1.29±0.07	0.55±0.07*	0.91±0.03*	0.73±0.03*
	18…21	0.78 ± 0.07	0.41±0.07*	0.79±0.05	0.41±0.07*
	Total for 14 days	4.00±0.21	1.84±0.20*	3.50±0.07*	2.24±0.18*
	Total for 21 days	6.07±0.32	2.80±0.32*	5.21±0.12*	3.38±0.26*

*– difference is significant as compared to control samples at $p \leq 0.05$

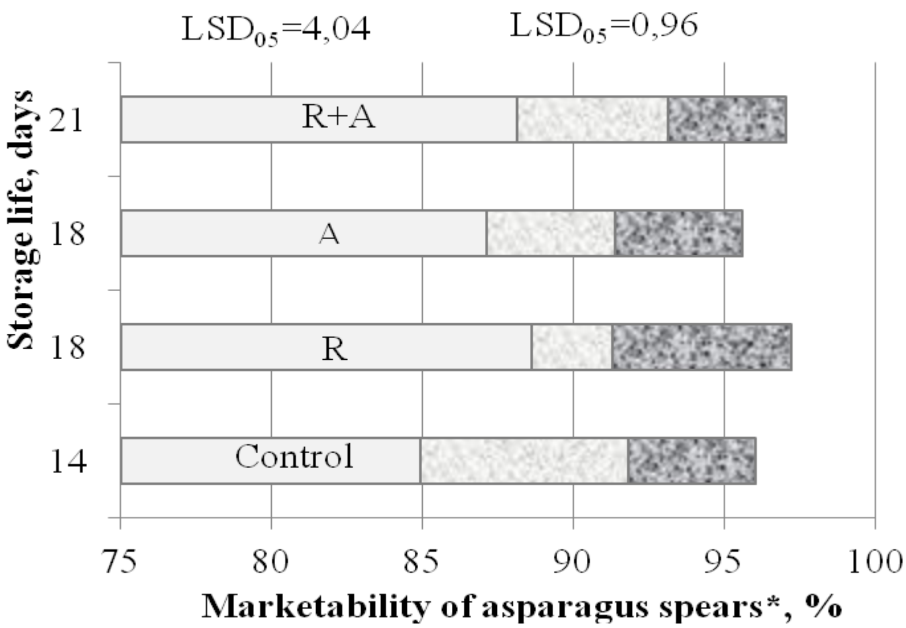
The applied coating acts as an additional layer that covers the stomata, which leads to a decrease in transpiration and, accordingly, a decrease in weight loss, which is considered the main effect of protective coating. A similar level of weight loss reduction was described by Spanish researchers when using alginate coatings for plum storage [19]. Even greater reduction in losses occurs when using the R+A composition: it makes 2.1 times for the Prius F1 variety and 2.2 times for the Rosalie F1 variety. It is generally accepted that weight losses are 75% due to moisture loss during transportation and 25% due to the consumption of dry matter during respiration. It has been proven that exogenous antioxidants can reduce the loss of dry matter by inhibiting the intensity of respiratory processes [20]. Therefore, it is quite logical that the coating containing antioxidant rutin helps to reduce weight loss.

The achieved reduction of weight loss is positively reflected in the increase in the yield of standard production after storage (Fig. 2). The standard production (taking into account weight loss) was 87.14-88.69 % for the asparagus treated with rutin or alginate, depending on the variety and treatment option. The standard production was higher for the asparagus treated with R+A. This figure reached 91.79 % for the Prius F1variety and 88.14 % for the Rosalie F1variety, even with a 7-day longer storage period. Samples of the asparagus treated with protective coating also had a lower proportion of non-standard products.

However, extended storage leads to the increase in the amount of waste. It should be noted that according to our data, Rosalie F1 had more waste during storage. Treatment with protective coating allowed to minimize the amount of waste for this variety. The amount of waste when using the R+A composition did not significantly increase even with an extended shelf life.



a



b

*the results are shown taking into account weight loss

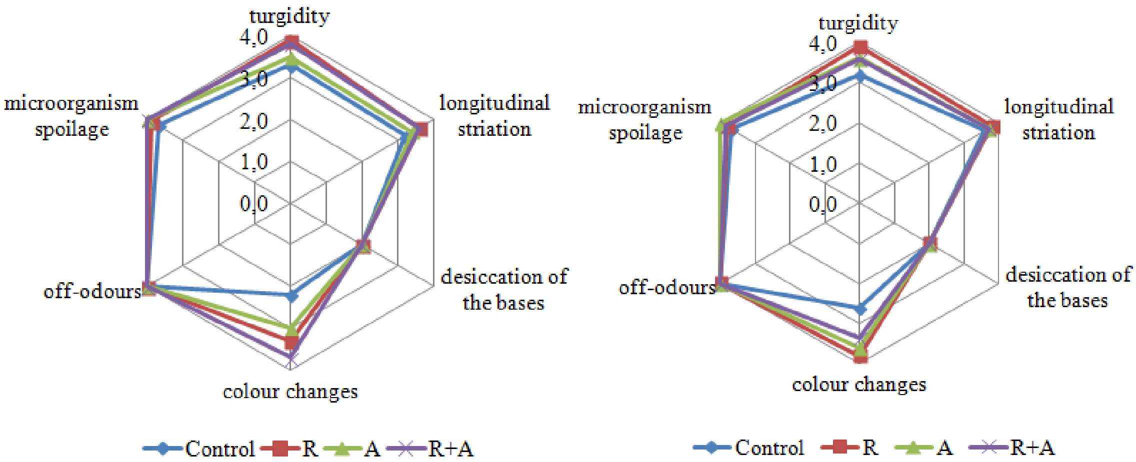
Fig. 2. Marketability of asparagus:

a – Prius F1; b – Rosalie F1;

□ – standard products; □ – non-standard products; ▨ – waste

The organoleptic evaluation was carried out after 14 days of storage of control samples, 18 days for samples treated with A and R, 21 days for the R+A variant. The organoleptic evaluation of asparagus is shown in Fig. 3.

In general, all the experimental samples showed a larger profilograph area in terms of organoleptic characteristics compared to the control samples. The most noticeable difference is in the colour change. While the control asparagus of the Prius F1 variety had 2.2 points, the R+A sample had 3.7 points. Slightly smaller colour changes were recorded for Rosalie F1 asparagus. Here, the control samples had 2.6 points. On the other hand, the R+A sample had only 3.3 points. This is less than R samples (3.8 points) and A samples (3.6 points). This, of course, can be explained by the longer shelf life of the R+A samples. At the same time, the R+A composition was more effective for the Prius F1 variety, even with a longer shelf life.



a b

Fig. 2. Organoleptic profilograph: a – Prius F1; b – Rosalie F1

Reduced turgidity is associated with natural mass loss through transpiration and respiration. Accordingly, a reduction in natural weight loss correlates with better turgidity of asparagus. Longitudinal striation is one of the important indicators that significantly reduce the marketability of asparagus. The Prius F1 variety is more susceptible to this defect. The applied treatment made it possible to virtually avoid the formation of longitudinal striation. None of the tested samples had differences in the odour inherent in fresh asparagus. The desiccation of the bases (the place of cut) decreased the overall organoleptic score the most. Unfortunately, the applied treatment did not have a positive effect on the desiccation of the bases. This is partly due to the oblique (slanted) cut made during harvesting. This obviously increases the area of moisture evaporation. Aligning the cuts could have a positive result. However, such an operation will increase the amount of waste. Therefore, it is necessary to perform an even cut when harvesting asparagus in the field. For this reason, further research is needed to find effective solutions to prevent this disadvantage.

Conclusions. In summary, the use of coating based on sodium alginate and rutin can extend the shelf life of asparagus by 3...7 days (depending on the composition of the coating) compared to untreated versions. Alginate coating can significantly reduce weight loss. For example, the combination of alginate and rutin reduces weight loss 2.1 times for the Prius F1 variety and 2.2 times for the Rosalie F1 variety. The standard production of the asparagus treated with the composition of alginate and rutin after storage was 91.79% for Prius F1 and 88.14% for Rosalie F1, even with a longer storage period of 7 days. The amount of waste did not increase with the extended storage period. The samples of asparagus treated with protective coating also had a lower proportion of substandard produce.

It was found that all the experimental samples showed a larger profilograph area in terms of organoleptic characteristics compared to the control samples. The desiccation of the sections was the biggest problem during storage. In fact, alginate and rutin coating did not have the desired effect on this indicator. Therefore, further developments should be aimed at finding effective solutions to eliminate this drawback during asparagus storage.

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О. Прісс[1], П. Булгаков[1], Т.Колісниченко[1], Л. Газзаві-Рогозіна[2]
[1] Таврійський державний агротехнологічний університет імені Дмитра Моторного
[2] Державний біотехнологічний університет

СКОРОЧЕННЯ ВТРАТ ПРИ ЗБЕРІГАННІ СПАРЖІ ЗІ ЗАХИСНИМ ПОКРИТТЯМ

Анотація

Фрукти та овочі займають перше місце у кількості харчових відходів і втрат. При їх вирощуванні, використовується 25% усієї води, що використовується сільським господарством щороку і 23% усіх орних угідь, продукуючи приблизно 8% щорічних глобальних викидів парникових газів. Це призводить до використання невідновлюваних ресурсів для отримання харчових продуктів, які не будуть спожиті. Тому скорочення втрат і відходів плодоовочевої продукції може бути однією з провідних глобальних стратегій досягнення сталої продовольчої безпеки та покращення раціонів харчування, скорочення викидів парникових газів, зменшення навантаження на водні та земельні ресурси, а також підвищення продуктивності та забезпечення економічного зростання. Спаржа є високоцінною і швидкопсувною овочевою культурою. Для подовження термінів зберігання спаржі доцільно використовувати їстівні покриття на основі природних сполук. Альгінат є одним з найцікавіших природних полісахаридів для формування покриттів. Однак альгінатні плівки не володіють антиоксидантними властивостями. Тож, метою роботи було встановлення впливу покриттів на основі альгінату натрію та речовин антиоксидантної дії на збереженість спаржі. У роботі розглянуто вплив покриттів на основі альгінату натрію та рутину на подовження термінів зберігання, скорочення втрат маси, вихід товарної продукції та органолептичні характеристики спаржі двох сортів різного забарвлення. Досліджували зелену спаржу сорту Prius F1 та зелено-фіолетову сорту Rosalie F1. Встановлено, що використання покриттів на основі альгінату натрію та рутину дозволяє подовжити термін зберігання спаржі на 3…7 діб (залежно від складу покриття). Поєднання альгінату та рутину дозволяє скоротити втрати маси в 2,1-2,2 рази залежно від сорту. Стандартна продукція у спаржі обробленої композицією альгінату і рутину після зберігання становила 88,14-91,79 %, при довшому на 7 днів терміні зберіганні. Кількість відходів також не збільшилась. Всі дослідні зразки за органолептичними показниками показали вищу оцінку, ніж контрольні варіанти. Проте, покриття на основі альгінату та рутину не дали бажаного ефекту для зменшення висихання зрізів. Тож подальші розробки мають бути направлені на пошук ефективних рішень для усунення цього недоліку при зберіганні спаржі.

Ключові слова. зберігання, зелена спаржа, зелено-фіолетова спаржа, харчові покриття, альгінат, рутин, втрати маси, товарна продукція.