UDC 635.36:631.563
DOI: 10.15587/1729-4061.2020.216431

STUDYING THE PRESERVATION OF BRUSSELS SPROUT DEPENDING ON ITS TREATMENT WITH ANTIMICROBIAL PREPARATIONS BEFORE STORAGE

The effect of antimicrobial preparations on the intensity of losses in the quality of Brussels sprout heads during storage has been scientifically substantiated. Brussels sprout heads were treated with antimicrobial solutions before storage. The following solutions were used: 0.05 % sorbic acid, 0.2 % benzoic, 0.5 % citric acid, Baikal EM-1, 0.5 % solution of ascorutin. The heads were stored in boxes lined with a 40 μm thick polyethylene film.

Treatment with antimicrobial preparations increases the shelf life of Brussels sprout to 50 days without significant weight loss. A solution of sorbic acid significantly reduces the natural mass loss by Brussels sprout after 10 days of storage. The effect of other preparations is observed only on day 30 of storage. Standard product output is 85.2–86.9 % depending on the features of the hybrid.

Antimicrobial preparations contribute to the preservation of chemical components in Brussels sprout heads. At the end of storage, the content of dry matter, dry soluble substances, total sugar, and ascorbic acid is 5–8 % higher than that in the control variant. A greater content of some components of the chemical composition is observed in produce treated with solutions of sorbic and benzoic acids before storage.

Solutions of sorbic and benzoic acids effectively hinder the development of harmful microorganisms on the heads of Brussels sprout.

The result of this study has established that a 0.05 % solution of sorbic acid and a 0.2 % solution of benzoic acid are more effective at contributing to the preservation of quality by Brussels sprout heads. Sorbic and benzoic acids do not affect the organoleptic properties of products and are safe for humans. This makes it possible to recommend to use their solutions as an effective and safe measure to preserve the quality of vegetable produce over its long-term storage

Keywords: Brussels sprout, sorbic acid, benzoic acid, citric acid, Baikal EM–1, ascorutin

L. Pusik
Doctor of Agricultural Sciences, Professor
Department of Optimization of Technological Systems named after T. Yevsiukov**
E-mail: Ludmilap@gmail.com

V. Pusik
Doctor of Agricultural Sciences, Professor, Head of Department*
E-mail: kysmish@gmail.com

V. Bondarenko
PhD, Senior Lecturer*
E-mail: zim-hot@rambler.ru

L. Gaevaya
PhD, Lecturer
Department of Fruit and Vegetable and Storage
Kharkiv National Agrarian University named after V. V. Dokuchaev
p/o “Dokuchaevske-2”, Kharkiv dist., Kharkiv reg., Ukraine, 62483
E-mail: Gaevaaludmila9@gmail.com

N. Kyruchina
PhD, Senior Researcher
Laboratory of Selection of Biennial and Rare Crops
Institute of Vegetable and Melon Growing of the National Academy of Agrarian Sciences of Ukraine
Institutska str., 1, Selektsionnoe vill., Kharkiv dist., Kharkiv reg., Ukraine, 62478
E-mail: kyruchinanatalja@ukr.net

H. Slobodyanyk
PhD, Associate Professor
Department of Vegetable Growing***
E-mail: sgy123@i.ua

S. Shchetyna
PhD, Associate Professor
Department of Vegetable Growing***
E-mail: sv_shetina@ukr.net

M. Shchetyna
PhD, Associate Professor
Department of Ecology and Life Safety***
E-mail: sv_shetina@ukr.net

L. Kononenko
PhD, Associate Professor
Department of Crop Production***
lidakononenko123@gmail.com

*Department of Agrotechnology and Ecology**
**Kharkiv Petro Vasylenko National Technical University of Agriculture
Alchevskykh str., 44, Kharkiv, Ukraine, 61002
***Uman National University of Horticulture
Institutska str., 1, Uman, Ukraine, 20305

Received date 15.09.2020
Accepted date 06.11.2020
Published date 21.12.2020

1. Introduction

The intense rhythm of modern human life requires nutrition that is rich in vitamins and other biologically active substances. This can be provided with fresh vegetables [1].

In terms of the content of chemical components, Brussels sprout can be attributed to valuable vegetable plants whose presence is extremely desirable in the diet of modern people. It is advised to be included in the menu for postoperative patients because it stimulates the healing process of wounds; for patients with cardiovascular system diseases and diabetes. The broth of sprout heads is not inferior in taste and nutrition to chicken broth. Riboflavin (vitamin B_2) is found almost as much as in milk and dairy products [2–4].

It is possible to prolong the period of consumption of fresh vegetables under conditions of refrigeration storage. At the same time, one of the ways to prolong the storing period, to reduce mass loss, as well as the loss of components of the chemical composition is to treat vegetables before storing with antimicrobial preparations. Antimicrobial preparations are both synthetically (mainly acids and their salts, vitamins) and organically derived (essential oils, bacteria, juice of some plants). Their use is an effective technique for inhibiting the pathogens of infectious diseases of vegetables during storage.

Consequently, the use of antimicrobial preparations to prolong the period of consumption of fresh vegetable products is relevant.

2. Literature review and problem statement

Treatment with antimicrobial preparations prolongs the shelf life of vegetable produce, reduces the loss of components of the chemical composition of vegetables, decreases their diseases during storage, improves the output of commodity products.

Work [5] reports data on the use of antimicrobial preparations of organic origin. Researchers treated garlic bulbs, before laying to store, with the biopreparations Glyocladin (Russia, LLC AgroBioTechnology) and Phytosporin (Ukraine, LLC "NVP "BashIncom"). Glyocladin contains the fungal culture *Trichoderma harzianum,* strain VIZR-18; Phytosporin contains strains of *Bacillus subtilis* 26 D bacteria. It was established that the treatment of garlic bulbs with these biopreparations contributed to the release of commodity products after six months of storage at the level of 80–83 %. This is 10.2 % more than in a treatment-free variant [5].

One of the promising directions in the fight against the development of pathogenic microorganisms on fruit and vegetable produce during storage is to treat it with essential oils [6]. The use of essential oils of rosemary, oregano, and thyme makes it possible to halve the losses in crushed white cabbage and carrot, damaged by pathogenic organisms, over 6 days at a temperature of 8 °C. However, they burn the surface of produce, which spoils its physical appearance. Using fresh essential oil raw materials made it possible to achieve the same reduction in product losses from diseases and preserve its physical appearance [7]. Oregano essential oil, when applied to the inner side of the packaging film, hindered the development of pathogenic organisms on the salad made from crushed fresh carrots, red-headed cabbage, and lettuce. The effect was observed for four days at a storage temperature of 8 °C [8]. Essential oils of fennel and thyme at concentrations of 400 and 600 ml/l significantly inhibited the development of *Borytis cinerea* mycelium on grape berries over 60 days and contributed to the preservation of their mass and organoleptic indicators at a temperature of 4 °C [9]. Lemongrass essential oil as part of the protective coating contributed to a significant decrease in breathing intensity and reduced losses from diseases in fresh pineapple fruits. The oil was introduced to the coating at a concentration of 0.3 %. The effect was observed during 16 days of storage at a temperature of 10 °C. The organoleptic indicators were retained as well. While the concentration of oil of 0.5 % contributed to the preservation of mass and prevented losses from diseases, it worsened the organoleptic indicators of produce [10]. The convenience of using film-forming mixtures is that they can be supplemented with antiseptics and preservatives even though each type of raw material requires a specific formulation. In addition, such mixtures are poorly washed with water from the surface of fruits and vegetables. Therefore, they are more expedient to use on produce that can be used without a peel.

Researchers also emphasize the fungicide properties of extracts from plants such as borago (*Borago officinalis*), bean broomrape (*Orobanche crenata*), buck's-horn plantain (*Plantago coronopus*), ribwort plantain (*Plantago lanceolata*), salad burnet (*Sanguisorba minor*), bladder campion (*Silene vulgaris*), rough milk thistle (*Sonchus asper*), *sow thistle* (*Sonchus oleraceus*), and common dandelion (*Taraxacum officinale*). Extracts of these plants were used for treating before laying to storage table grapes, apricots, nectarine, and oranges. These herbal extracts significantly or completely inhibited the development of some pathogenic organisms of the genus *Penicillium, Aspergillus*, as well as *Botrytis cinerea*, *Monilinia laxa* [11].

The addition of *Aloe vera* juice to the protective coating on papaya fruits made it possible to increase their shelf life by three times – up to 15 days at a storage temperature of 30 °C, due to the decrease in the intensity of microorganism development [12, 13]. The use of *Aloe vera* juice as part of an edible protective coating on the fruits of table grapes significantly reduced the intensity of microorganisms' development over 15 days at a storage temperature of 4 °C [14]. It should be noted that the use of essential oils and plant extracts as antiseptics, as well as film-forming mixtures, has not been widely used by manufacturers. Essential oils in their pure form can leave burns on the surface when entering fresh produce. This spoils its physical appearance. An alternative is to use the stems and leaves of essential oil plants. They are laid out both from above and inside the products. However, most manufacturers do not have this possibility because the maximum preservation of essential oils in vegetable raw materials is possible provided they are fresh. And the import of enough essential oils or essential-oil raw materials is not economically justified. The same applies to the use of plant extracts.

Treating table grapes with lactic acid bacteria *Lactobacillus delbrueckii* subsp. *Bulgaricus,* strain F17, and *Leuconostoc lactis,* strain H52, significantly inhibited the development of mold and yeast on berries. This made it possible to preserve the organoleptic indicators of grapes for 20 days at a temperature of 8 °C. Chopped apples and lettuce leaves, which were treated with *Lactobacillus plantarum and Lactobacillus casei*, retained their organoleptic indicators at a temperature of 8 °C for 16 days. Treating lychee fruit with *Lactobacillus plantarum* ensured the preservation of mass and organoleptic indicators for 21 days at a temperature of 8 °C [15]. Lactic acid bacteria during their life activities emit carbon and fatty acids, ethanol, carbon dioxide, hydrogen peroxide, and other substances that demonstrate a bactericide effect [16].

Treating eggplant fruits before storing with a 0.5 % citric acid solution and a 0.1 % solution of the preparation

Polydez (a mixture of salts of polyhexamethylene guanidine, 20 %) increased the shelf life at a temperature of 8±1 °C by 6–9 days. The output of standard produce increased to 94 % while in the control variant it was 90 % [17]. The use of a 1 % citric acid solution made it possible to preserve the organoleptic indicators of freshly cut early white cabbage and extend its shelf life to 22 days at a temperature of 0 °C [18].

Treating strawberries before freezing with a mixture of 0.4 % citric acid and 1 % calcium lactate contributed to the preservation of its texture and color during defrosting [19]. Effective was the use of a 0.5 % citric acid solution with starch to create a protective coating on fresh mango fruits for storing at a temperature of 5 °C. This contributed to the preservation of the organoleptic indicators of fruits, which affected their marketable physical appearance [20].

Synthetic preparations such as sorbic, benzoic, and citric acids, as well as vitamins, have become more widespread. They are characterized as food additives, are safe, they can be obtained in large quantities, they are cheap, and are conveniently used in the form of aqueous solutions.

Organic preparations that contain strains of microorganisms or products of their metabolism are gaining popularity among manufacturers. These preparations are also safe and their use does not harm the environment.

However, the scientific literature did not reveal data on the use of organic and synthetic preparations to extend the shelf life of Brussels sprout, as well as the application of water-soluble vitamins such as C and P, to preserve its quality during storage. Given today's wide range of vegetable products, this is an unresolved part of the scientific problem. Solving it is interesting from a scientific and practical point of view.

3. The aim and objectives of the study

The aim of this study is to investigate the preservation of Brussels sprout depending on the treatment with antimicrobial preparations before storage, which would prolong the duration of its consumption.

To accomplish the aim, the following tasks have been set:

– to determine the natural loss of mass by Brussels sprout heads during storage;

– to determine the mass loss during storage caused by diseases and physiological disorders;

– to investigate a change in the components of the Brussels sprout chemical composition during storage and to conduct a comparative assessment of the preservation of Brussels sprout depending on the type of antimicrobial preparation.

4. Materials and methods to study the preservation of broccoli quality; the chemical, organoleptic indicators

We studied the late-ripening hybrids of Brussels sprout (Abacus F_1 (Switzerland), Brilliant F_1 (the Netherlands)). A cultivation technique: transplanting (a 40-day-old Brussels sprout with 4–5 real leaves was planted in a field in the second decade of May). A plant arrangement technique: ribbon-type, with a placement scheme of (40+100)×50 cm. The area of the accounting plot in the experiment involving Brussels sprout is 20 m^2, the experiment was repeated three times. The arrangement of variants is systematic. The sprout was collected when the heads acquired the size and density characteristic of a particular hybrid. The diameter of the Brussels sprout head, according to the standard, was not less than 2 cm.

Abacus F_1 is a hybrid of the Brussels sprout with a ripening period of 110–115 days from transplanting. The diameter of the heads is 2.5–3 cm. The plants are very aligned and demonstrate high resistance to stress. The hybrid is meant for both freezing and fresh consumption.

Brilliant F_1 is a hybrid of the Brussels sprout with a growing period of 130 days from the moment of transplanting. The plant has a medium strength of growth, resistant to lying down. The heads are equal, densely and evenly placed on the stem, mostly large, with a diameter of about 3 cm, dark green. The hybrid has a strong resistance to disease and good taste properties. Meant for fresh consumption and freezing.

We determined the content of some components of the chemical composition in Brussels sprout heads in accordance with the acting state standards. The Brussels sprout heads were separated from the stem and treated with antimicrobial preparations before storage: a 0.05 % solution of sorbic acid (SA), a 0.2 % solution of benzoic acid (BA), a 0.5 % citric acid solution (CA), Baikal EM–1 (diluted working solution in water at 1:500), and a 0.5 % solution of ascorutin (C+P). The separated Brussels sprout heads were stored in boxes lined with a 40 µm thick polyethylene film. Control was the untreated sprout stored in a polyethylene film (PF). Sprout was stored at a temperature of 0±1 °C and relative air humidity of 90–95 %. Observations were conducted in dynamics after 10 days.

Underlying the working hypothesis is the assumption about the possibility of using antimicrobial preparations to increase the resistance of Brussels sprout during storage.

The data reported in this work is the average between three measurements. Statistical analysis was performed using Microsoft Excel 2007. The differences were considered statistically significant at the level of α=0.05.

5. Results of studying the preservation of brussels sprout

5. 1. Determining the natural mass loss by Brussels sprout heads during storage

It was established that the treatment of Brussels sprout with antimicrobial preparations before storage and subsequent packaging in polyethylene-lined boxes increased their preservation.

Thus, the treatment with antimicrobial preparations significantly reduced natural losses (HIP_{05}=0.2 %). The heads were stored no more after 50 days. During this time, the natural losses by Abacus F_1 amounted to 2.3–3.3 %, by Brilliant F_1 – 1.8–2.5 % depending on the treatment with the preparation (Fig. 1). Larger natural losses were demonstrated by variants involving the use of the preparation Baikal EM–1; smaller – involving the use of sorbic acid.

Natural product losses depended by 51.7 % on the treatment with antimicrobial preparations, the influence of a hybrid was 32.0 %, the total effect of the preparation and the features of the hybrid accounted for 3.3 %, the rest of the impact was due to other factors. The natural losses per day fluctuated, for the hybrid Abacus F_1, within 0.05–0.07 %, for Brilliant F_1 – 0.04–0.05 %, depending on the preparation. They were substantially smaller (HIP_{05}=0.01 %) for the variants where acids and ascorutin were used. Dispersion analysis has found that the effect of the preparation on the daily mass losses by Brussels sprout is 51.3 %.

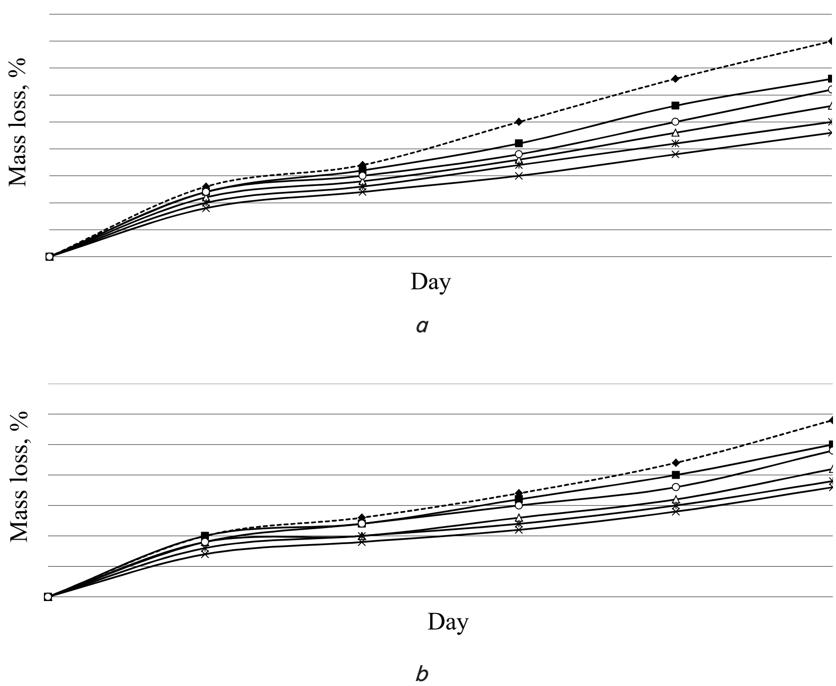

Fig. 1. The dynamics of natural losses by Brussels sprout depending on the treatment with antimicrobial preparations, %: *a* – Abacus F$_1$, *b* – Brilliant F$_1$; ···♦··· – PF; —■— – Baikal EM–1; —Δ— – CA; —x— – SA; —*— – BA; —○— – C+P
**Note: this figure indicates the possible shape of the dependence of natural mass losses on the treatment with antimicrobial preparations*

5. 2. Determining the mass losses by Brussels sprout heads during storage due to diseases and physiological disorders

The first signs of lesions of the Brussels sprout heads by diseases and physiological disorders (regardless of treatment with the preparation) appeared on day 30 of storage: the first mass losses by the hybrid Abacus F$_1$ amounted to 4.8–6.1 %, by Brilliant F$_1$ – 4.2–5.3 %, depending on the preparation (Fig. 2). They were larger for variants involving the use of Baikal EM–1, smaller – involving sorbic acid.

During the next 10 days of storage, the development of diseases and physiological disorders was not observed. On day 50, the loss of mass by the produce amounted to larger than 10 %. The affected rigid cover leaves of the heads were removed; the next ones are more delicate, so during the subsequent storage the produce was even more affected by diseases. On day 70, the losses due to diseases reached about 20 % or more.

It was found that the treatment of Brussels sprout with antimicrobial preparations affects the shelf life by 14.0 %, the feature of the hybrid – 3.0 %, the total effect of these factors is 14.0 %. The influence of other factors (weather conditions of the growing season, the degree of development of diseases and physiological disorders on the heads) accounts for 69.0 % (Table 3).

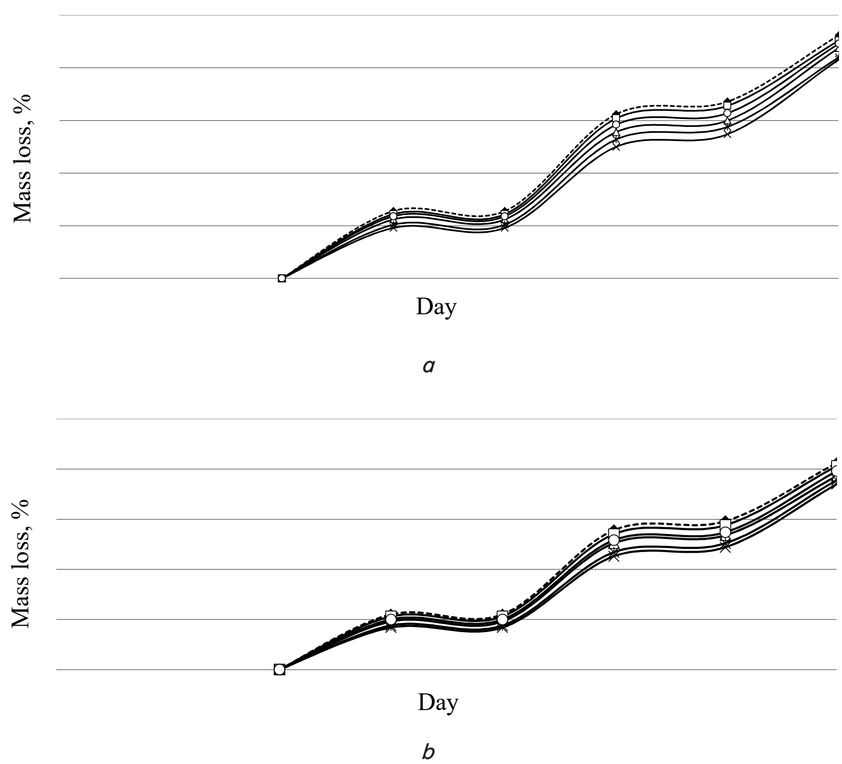

Fig. 2. The dynamics of mass losses by Brussels sprout due to diseases and physiological disorders depending on the treatment with antimicrobial preparations, %: *a* – Abacus F$_1$, *b* – Brilliant F$_1$; ···♦··· – PF; —■— – Baikal EM–1; —Δ— – CA; —x— – SA; —*— – BA; —○— – C+P
**Note: this figure indicates the possible shape of the dependence of mass losses due to diseases and physiological disorders on the treatment with antimicrobial preparations*

Losses due to diseases and physiological disorders were less in variants with the use of antimicrobial preparations; for Abacus F_1, 12.5–15.2 %; for Brilliant F_1, 11.3–13.5 % (Table 3). They were substantially smaller (HIP_{05}=0.7 %) for variants where citric, sorbic, and benzoic acids were used. Dispersion analysis has found that the effect of the preparation on losses due to diseases and physiological disorders was 47.7 %.

5. 3. Change in the components of the chemical composition and the assessment of Brussels sprout preservation during storage

It was found that the Brussels sprout variants, which used antimicrobial preparations, demonstrated the loss of mass, due to dry matter, that is 1.1–1.2 times less than that in the control variant depending on the preparation (Table 1). At the same time, the mass loss due to dry matter was significantly smaller (HIP_{05}=7.9 %) for the variants that used sorbic acid. The mass losses due to moisture evaporation for variants with antimicrobial preparations were greater, depending on the preparation, by 1.1–1.2 times than those in the control variant.

Table 1

The structure of the natural mass loss by Brussels sprout during storage depending on the treatment with antimicrobial preparations

Variant	Storage duration, day	Mass loss, %		
		total	due to the loss of dry matter	due to moisture evaporation
Abacus F_1				
1. PF	50	4.0	46.6	53.4
2. Baikal EM–1	50	3.3	43.3	56.7
3. CA	50	2.8	41.3	58.7
4. SA	50	2.3	38.5	61.5
5. BA	50	2.5	40.3	59.7
6. C+R	50	3.1	42.1	57.9
Brilliant F_1				
1. PF	50	2.9	42.8	57.2
2. Baikal EM–1	50	2.5	40.9	59.1
3. CA	50	2.1	38.1	61.9
4. SA	50	1.8	35.9	64.1
5. BA	50	1.9	36.9	63.1
6. C+P	50	2.4	39.9	60.1
HIP_{05}	3	0.2	7.9	8.0

Treating Brussels sprout heads with antimicrobial preparations contributed to the preservation of dry matter in them. It was found that during 50 days of storage, Abacus F_1 lost dry matter by less than 1.1–1.5 times compared to the control variant depending on the preparation. For variants with the hybrid Brilliant F_1, the loss of dry matter over 50 days of storage was less by than 1.1–1.3 times compared to control. The content of total sugar in Brussels sprout heads at the end of storage for variants using antimicrobial preparations was higher than that in control.

The content of ascorbic acid in Brussels sprout heads (Table 2) increased slightly under the influence of antimicrobial preparations in the middle of storage (day 20) compared to the control variant. For the hybrid Abacus F_1, the content of ascorbic acid increased by 16.4–17.5 %, for Brilliant F_1 – by 15.4–16.4 %, depending on the preparation. At the end of storage (50 days), the content of ascorbic acid in the variants using antimicrobial preparations was higher than that in control: Abacus F_1 – by 1.8–6.0 %, Brilliant F_1 – by 1.8–4.8 %.

Table 2

The dynamics of ascorbic acid content in Brussels sprout heads during storage depending on the treatment with antimicrobial preparations, mg/100 g (average for 2014–2016)

Variant	Storage duration		
	Start	20 days	50 days
Abacus F_1			
PF	124.5	148.4	116.9
Baikal EM–1	124.5	148.9	119.0
CA	124.5	149.5	121.6
SA	124.5	150.9	124.3
Ba	124.5	150.7	123.2
C+R	124.5	149.2	119.8
Brilliant F_1			
PF	140.6	165.8	137.2
Baikal EM–1	140.6	166.1	139.7
CA	140.6	166.7	141.4
SA	140.6	168.1	144.1
Ba	140.6	167.9	143.3
C+P	140.6	166.4	140.3
HIP_{05}	9.0	3.0	2.2

Significantly higher content of ascorbic acid was demonstrated by variants with the use of citric, sorbic, benzoic acids, and ascorutin.

Table 3

Preservation of Brussels sprout depending on the treatment with antimicrobial preparations

Variant	Storage duration, days	Product loss, %			Output of standard produce, %
		natural		due to diseases and physiological disorders	
		total	24 hours		
Abacus F_1					
1. PF	50	4.0	0.08	15.6	80.4
2. Baikal EM–1	50	3.3	0.07	15.2	81.5
3. CA	50	2.8	0.05	13.9	83.3
4. SA	50	2.3	0.05	12.5	85.2
5. BA	50	2.5	0.05	13.2	84.3
6. C+R	50	3.1	0.06	14.6	82.3
Brilliant F_1					
1. PF	50	2.9	0.06	13.9	83.3
2. Baikal EM–1	50	2.5	0.05	13.5	84.0
3. CA	50	2.1	0.04	12.6	85.3
4. SA	50	1.8	0.04	11.3	86.9
5. BA	50	1.9	0.04	11.7	86.4
6. C+P	50	2.4	0.05	12.9	84.7
HIP_{05}	3	0.2	0.01	0.7	0.7

Note: PF – storage of untreated sprout; treated with: CA – citric acid, SA – sorbic acid, BC – benzoic acid; C+P – ascorutin

The output of standard produce was significantly higher (HIP_{05}=0.7 %) for variants using the antimicrobial preparations: Abacus F_1 – 81.5–85.2 %; Brilliant F_1 – 84.0–86.9 %. It was larger when using sorbic acid. It was found that the effect of the preparation on the output of standard produce was 47.3 %.

It was established that the natural mass losses by Brussels sprout over 50 days of storage were significantly smaller (HIP_{05}=0.2 %) for variants where antimicrobial preparations were used. Natural mass losses fluctuated, for Abacus F_1, within 2.3–3.3 %, Brilliant F_1 – 1.8–2.5 %, depending on hybrid (Table 3).

6. Discussion of results of studying the influence of antimicrobial preparations on the preservation of Brussels sprout quality

The quality of vegetable produce is a set of indicators that determine its consumer value. Among them, an attractive physical appearance and the content of chemical components occupy an important place. During storage, the appearance of juicy products can deteriorate due to moisture loss and damage by microorganisms. Consequently, the storage duration of produce is significantly reduced.

Using a polyethylene film, 40 μm thick, ensured the output of commodity produce after 50 days of storage at the level of 80–83 % (Table 3). The effectiveness of the use of packaging is due to the creation of a modified environment around the produce by changing the gas composition of the air. At the same time, the concentration of carbon dioxide gradually increases due to breathing, thereby inhibiting it. Increased carbon dioxide content in the air also adversely affects the development of harmful microorganisms.

The use of antimicrobial preparations enhances the effect of packaging. The efficacy of sorbic and benzoic acids is due to the ability to inhibit in microbial cells the activity of enzymes responsible for oxidative-reducing reactions. Citric acid reduces the pH of the environment and thus disrupts the flow of processes of metabolism of microorganisms. Rutin and ascorbic acid are powerful antioxidants that prevent oxidation processes and enhance each other's actions. The microorganisms included in the preparation Baikal EM–1 inhibit the life activities of pathogenic microflora on sprout. Thus, the use of antimicrobial preparations increased the output of commodity produce to 87 % (Table 3).

Natural sprout losses during storage are caused by moisture evaporation from the surface and breathing, during which the dry substance is consumed. The share of influence of the preparation on natural losses is 52 %. The antimicrobial preparations contributed to inhibition of breathing intensity, so dry matter consumption decreased by 1.5 times depending on the hybrid (Table 1). The significant effect (HIP_{05}=7.9) on the preservation of dry matter was exerted by the treatment with sorbic acid. The content of such a component of the chemical composition as ascorbic acid in Brussels sprout heads was significantly higher (HIP_{05}=2.2) at the end of storage for variants using antimicrobial preparations (Table 2).

Similar results were obtained when studying the effects of these same preparations on the preservation of broccoli quality. Baikal EM–1, a 0.5 % citric acid solution, a 0.2 % benzoic acid solution, a 0.05 % sorbic acid solution, a 0.5:0.5 % solution of ascorutin contributed to prolonging the storage duration of broccoli to 20 days and ensured the output of commodity produce at the level of 76.8–86.2 %. They also helped reduce the intensity of consumption of dry soluble substances, vitamin C, and sugars. The best results were obtained for variants with acids and ascorutin.

Ascorutin provided, over long-term storage, for the mass loss, due to diseases and physiological disorders, that was less by 0.8–2.2 %, as well as 4.1–7.6 % higher output of commodity produce [21].

Consequently, the effectiveness of the use of antimicrobial preparations depends on the species and varietal features of vegetable produce, the species composition of microflora on its surface, and other factors.

Antimicrobial preparations in the form of aqueous solutions do not affect water loss by reducing the intensity of produce breathing and its evaporation from its surface. These issues are solved using antimicrobial preparations together with packaging in polymeric films or paper, as well as in a mixture with film-forming compositions.

This study reports the results of using sorbic, benzoic, and citric acids on Brussels sprout, as well as the results of applying ascorutin and Baikal EM–1 on this crop. The use of these preparations to prolong the shelf life and preserve the quality of Brussels sprout produce has a positive effect. The accuracy of our results has been confirmed by statistical analysis.

However, this study focused on synthetic preparations and was limited to only one of the organic origin. In further studies, it would be appropriate to investigate the antimicrobial effect of more preparations of organic origin. This is due to that the cultivation of organic products is gaining popularity. These products are also laid down for storage; prolonging its duration implies the use of organic antimicrobial preparations.

In addition, a promising direction is a search for measures that could increase the effectiveness of the use of antimicrobial preparations. As well as studying their impact on changes in the content of macro- and microelements in vegetable produce during storage.

7. Conclusions

1. Treating Brussels sprout heads with antimicrobial preparations significantly (HIP_{05}=0.2) reduces natural mass loss. The smallest natural losses at the end of storage (50 days) were demonstrated by variants involving a sorbic acid treatment – 1.8–2.3 %, depending on the features of the hybrid; for the control variant, it was 4.0 After 30 days of storage, the number of heads damaged by disease and physiological disorders was, for the hybrid Abacus F_1, 4.8–6.4 %; for Brilliant F_1, 4.2–5.5 %. The development of pathogenic microorganisms was more efficiently restrained by the use of solutions of sorbic and benzoic acids.

2. After 30 days of storage, the number of heads damaged with disease and physiological disorders was, for the hybrid Abacus F_1, 4.8–6.4 %; for Brilliant F_1, 4.2–5.5 %. The development of pathogenic microorganisms was more efficiently restrained by the use of solutions of sorbic and benzoic acids.

3. Antimicrobial preparations contribute to the preservation of chemical components in Brussels sprout heads. At the end of storage, the content of dry matter and total sugar was 1.5 times larger than that in the control variant. The content of ascorbic acid in variants with the antimicrobial preparations was higher than that in control: Abacus F_1 – by 1.8–6.0 %, Brilliant F_1 – by 1.8–4.8 %. Better preservation

of ascorbic acid in produce was contributed to by the treatment with citric, sorbic, benzoic acids, and ascorutin.

4. The output of standard produce at the end of storage was greater when using benzoic acid, 84.3–86.4 %, and sorbic acid, 85.2–86.9 %, depending on the features of the hybrid. Dispersion analysis has found that the antimicrobial preparation significantly (HIP_{05}=0.7) increases the output of standard produce; its share of influence is 47.3 %.

Acknowledgments

This study was carried out in accordance with the thematic plans of research work at the Department of Fruit and Vegetable Production and Storage, Kharkiv National Agrarian University named after V. V. Dokuchaev, "Development of energy-saving elements of technologies for production and storage of vegetables and fruits " (DR No. 0112U003730).

References

1. Pereira, P. M. de C. C., Vicente, A. F. dos R. B. (2013). Meat nutritional composition and nutritive role in the human diet. Meat Science, 93 (3), 586–592. doi: https://doi.org/10.1016/j.meatsci.2012.09.018
2. Chiavaro, E., Mazzeo, T., Visconti, A., Manzi, C., Fogliano, V., Pellegrini, N. (2012). Nutritional Quality of Sous Vide Cooked Carrots and Brussels Sprouts. Journal of Agricultural and Food Chemistry, 60(23), 6019–6025. doi: https://doi.org/10.1021/jf300692a
3. Kim, J. K., Shin, E.-C., Kim, C. R., Park, G. G., Choi, S. J., Park, C.-S., Shin, D.-H. (2013). Effects of Brussels Sprouts and Their Phytochemical Components on Oxidative Stress–Induced Neuronal Damages in PC12 Cells and ICR Mice. Journal of Medicinal Food, 16 (11), 1057–1061. doi: https://doi.org/10.1089/jmf.2012.0280
4. Manchali, S., Chidambara Murthy, K. N., Patil, B. S. (2012). Crucial facts about health benefits of popular cruciferous vegetables. Journal of Functional Foods, 4 (1), 94–106. doi: https://doi.org/10.1016/j.jff.2011.08.004
5. Pusik, L., Pusik, V., Postnova, O., Safronska, I., Chervonyi, V., Mohutova, V., Kaluzhnij, A. (2020). Preservation of winter garlic depending on the elements of postharvest treatment. Eastern-European Journal of Enterprise Technologies, 2 (11 (104)), 24–32. doi: https://doi.org/10.15587/1729-4061.2020.200842
6. Patrignani, F., Siroli, L., Serrazanetti, D. I., Gardini, F., Lanciotti, R. (2015). Innovative strategies based on the use of essential oils and their components to improve safety, shelf-life and quality of minimally processed fruits and vegetables. Trends in Food Science & Technology, 46 (2), 311–319. doi: https://doi.org/10.1016/j.tifs.2015.03.009
7. Scollard, J., Francis, G. A., O'Beirne, D. (2013). Some conventional and latent anti-listerial effects of essential oils, herbs, carrot and cabbage in fresh-cut vegetable systems. Postharvest Biology and Technology, 77, 87–93. doi: https://doi.org/10.1016/j.postharvbio.2012.11.011
8. Muriel-Galet, V., Cerisuelo, J. P., López-Carballo, G., Aucejo, S., Gavara, R., Hernández-Muñoz, P. (2013). Evaluation of EVOH-coated PP films with oregano essential oil and citral to improve the shelf-life of packaged salad. Food Control, 30 (1), 137–143. doi: https://doi.org/10.1016/j.foodcont.2012.06.032
9. Abdolahi, A., Hassani, A., Ghosta, Y., Bernousi, I., Meshkatalsadat, M. (2010). Study on the Potential Use of Essential Oils for Decay Control and Quality Preservation of Tabarzeh Table Grape. Journal of Plant Protection Research, 50 (1). doi: https://doi.org/10.2478/v10045-010-0008-2
10. Azarakhsh, N., Osman, A., Ghazali, H. M., Tan, C. P., Mohd Adzahan, N. (2014). Lemongrass essential oil incorporated into alginate-based edible coating for shelf-life extension and quality retention of fresh-cut pineapple. Postharvest Biology and Technology, 88, 1–7. doi: https://doi.org/10.1016/j.postharvbio.2013.09.004
11. Gatto, M. A., Ippolito, A., Linsalata, V., Cascarano, N. A., Nigro, F., Vanadia, S., Di Venere, D. (2011). Activity of extracts from wild edible herbs against postharvest fungal diseases of fruit and vegetables. Postharvest Biology and Technology, 61 (1), 72–82. doi: https://doi.org/10.1016/j.postharvbio.2011.02.005
12. Marpudi, S. L., Abirami, L. S. S., Pushkala, R., Srividya, N. (2011). Enhancement of storage life and quality maintenance of papaya fruits using Aloe vera based antimicrobial coating. Indian Journal of Biotechnology, 10, 83–89. Available at: http://nopr.niscair.res.in/handle/123456789/10956
13. Monzón-Ortega, K., Salvador-Figueroa, M., Gálvez-López, D., Rosas-Quijano, R., Ovando-Medina, I., Vázquez-Ovando, A. (2018). Characterization of Aloe vera-chitosan composite films and their use for reducing the disease caused by fungi in papaya Maradol. Journal of Food Science and Technology, 55 (12), 4747–4757. doi: https://doi.org/10.1007/s13197-018-3397-2
14. Alberio, G. R. A., Muratore, G., Licciardello, F., Giardina, G., Spagna, G. (2015). Aloe vera extract as a promising treatment for the quality maintenance of minimally-processed table grapes. Food Science and Technology (Campinas), 35 (2), 299–306. doi: https://doi.org/10.1590/1678-457x.6471
15. Agriopoulou, S., Stamatelopoulou, E., Sachadyn-Kr l, M., Varzakas, T. (2020). Lactic Acid Bacteria as Antibacterial Agents to Extend the Shelf Life of Fresh and Minimally Processed Fruits and Vegetables: Quality and Safety Aspects. Microorganisms, 8 (6), 952. doi: https://doi.org/10.3390/microorganisms8060952
16. Pawlowska, A. M., Zannini, E., Coffey, A., Arendt, E. K. (2012). "Green Preservatives": Combating Fungi in the Food and Feed Industry by Applying Antifungal Lactic Acid Bacteria. Advances in Food and Nutrition Research, 66, 217–238. doi: https://doi.org/10.1016/b978-0-12-394597-6.00005-7

17. Myronyuk, S. (2015). The effect of antimicrobic treatment on the quality and storage duration of aubergine fruits. Zbirnyk naukovykh prats Vinnytskoho natsionalnoho ahrarnoho universytetu. Seriya: Tekhnichni nauky, 1 (1 (89)), 111–116. Available at: http://lib.udau.edu.ua/handle/123456789/5556
18. Manolopoulou, E., Varzakas, T. (2011). Effect of Storage Conditions on the Sensory Quality, Colour and Texture of Fresh-Cut Minimally Processed Cabbage with the Addition of Ascorbic Acid, Citric Acid and Calcium Chloride. Food and Nutrition Sciences, 02 (09), 956–963. doi: https://doi.org/10.4236/fns.2011.29130
19. Abd-Elhady, M. (2014). Effect of citric acid, calcium lactate and low temperature prefreezing treatment on the quality of frozen strawberry. Annals of Agricultural Sciences, 59 (1), 69–75. doi: https://doi.org/10.1016/j.aoas.2014.06.010
20. Chiumarelli, M., Pereira, L. M., Ferrari, C. C., Sarantópoulos, C. I. G. L., Hubinger, M. D. (2010). Cassava Starch Coating and Citric Acid to Preserve Quality Parameters of Fresh-Cut "Tommy Atkins" Mango. Journal of Food Science, 75 (5), E297–E304. doi: https://doi.org/10.1111/j.1750-3841.2010.01636.x
21. Pusik, L., Pusik, V., Lyubymova, N., Bondarenko, V., Gaevaya, L. (2018). Research into preservation of broccoli depending on the treatment with antimicrobic preparations before storage. Eastern-European Journal of Enterprise Technologies, 4 (11 (94)), 20–28. doi: https://doi.org/10.15587/1729-4061.2018.140064