The influence of chitosan on the raspberry quality during the storage process

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ABSTRACT

Raspberry is a perishable berry raw material with a high capacity for mechanical and microbiological damage,andtherefore, after harvesting, it is necessary to use appropriate technologies to preserve its quality and extend the storage time. This work aimed to study the influence of different concentrations of chitosan solutions on the quality and duration of storage of raspberries under refrigerating conditions. Raspberries were picked at the consumer maturity stage in perforated plastic containers with a capacity of 500 grams. The berries were processed by spraying with 0.5%,1.0%,and 2.0% chitosan solution, thenremovingresidual moisture. The storage was carried out for twelve days in a refrigerating chamber at a temperature of 2 °C and relative humidity of 95%. The research was performed according to the physical, chemical, and organoleptic indicators, determining the changes in the mass fraction of ascorbic acid, themass fraction of sugars during storage, taste, aroma, colour, etc.consistency and appearance at the end of storage.It was found that the loss of ascorbic acid in the processed berrieswas1.5-3.9 times less than in the reference sample. A similar situation was observed with the mass fraction of sugars, which prevailed 0.9-2.5 times in the processed samples. According to the organoleptic indicators, the samples with a solution concentrationof 1.0% and 2.0% were recognized as the best.According to the results of experimental investigations, it was established that pre-processing of berries with chitosan solutions is a promising method to slow down unwanted metabolic processes that take place after harvesting.

Keywords:chitosan, storage time, raspberries, pre-processing, biopolymer

INTRODUCTION

Raspberry is a highly nutritious berry crop with a short storage time, high water content and thin cover tissues that mechanical and microbiologicalfactors may easily damage; this berry has a high nutritional value and a wide range of applications in the food industry[1]. Moreover,it can be used to make:‣jams, confitures and other preserves, which have a pleasant taste and aroma, as well as a high pectin content, which allows obtaining a stable gelatinous product;‣fruit juices, nectars and lemonades with a high content of vitamins and antioxidants;‣as an additive to ice cream and yoghurt;‣confectionery and dried fruits. Raspberries continuetheir metabolic activity after harvesting, gradually losingquality, decreased resistance to phytopathogenic damage, and increasedpercentage loss. Therefore, edible coatings made of biopolymers and their combinations extend the storage time of perishableberry products[2]. Chitosan is a biopolymer obtained from chitin, the main component of the skeleton of crustaceans and insects, which can form a thin layer around fresh products, which acts as a protective agent, extending the storage time, and also serves as an inhibitor of metabolic processes[3]. Chitosan has severaladvantages for processing berries, among which are the following:

‣berry storage, chitosan can be used as a preserving agent for berry storage as it is a natural antibacterial agent that helps to prevent the development of spoilage microorganisms[4];

‣the storage time extension, chitosan can increase the storage time of berries by creating a protective layer that helps to retain moisture and to prevent oxidation[5];

‣the improvement of the quality of berries, chitosan can improve the quality of berries by reducing moisture loss and increasing their viability and resistance to mechanical damage[6];

‣the environmental component, chitosan is a natural product that decomposes after use, so it is an environmentally compatible means for raspberry processing[7].

Diseases, improper transport,and storage techniques cost the world economy about $220 billion annually, reducingcrop productivity and quality and leading to higher food prices and global food insecurity. Reducing losses and scraps of fresh fruit and vegetables can help reduce pressure on food production systems, especially in the context of limited natural resources and climate change.

Edible coatings havebecome integralfor protecting fruits and vegetables from phytopathogenic damage. A wide range of studies demonstrated the antimicrobial activity of edible coatings against Botrytis cinerea, Colletotrichum spp., Penicillium spp.and Alternaria spp.[8]. Films formed on the surface of fruits can change the atmosphere's composition, creatinga barrier for gas exchange, such as oxygen, carbon dioxide and ethylene, which are involved in the process of respiration [9].

There are manyedible coatings;among them, chitosan is the safest. Chitosan (β-(1,4)-2-amino-2-deoxy-D-glucose) is a natural biopolymer obtained by deacetylation of chitin, which is the second with ranking most important polysaccharide in nature after cellulose, and which enters into the composition of the exoskeleton structure of marine invertebrates, insects, as well as fungi, algae and yeast [10]. Chitosan is one of the most widely used edible coatings due to its biocompatibility, biodegradability, and bioactivity. When applied to fruits, vegetables andberries, chitosan creates a semi-permeable film that protects against the development of fungus diseases and slows down metabolic processes [11]. This edible coating is widely used for post-harvest fresh fruits and vegetables preservation. The scientific literature onedible coatings using chitosan has increased in recent years. This can be explained by the importance of chitosan for plant protection as a natural fungicide. In 2014, chitosan hydrochloride was approved as one of the first main plant protection substances by the European Union (EU Regulation 2014/563), and the second chitosan formulation was approved in 2022 (EU Regulation 2022/456) [12].Therefore, the use of raspberry in the food industry is a promising and relevant direction of research because its use will allow to expand of the assortment, increase the quality and nutritional value of products made on its basis, attract new consumers, and export can be a promising line for the development of the food industry of Ukraine.

Scientific Hypothesis

For further improvement of storing and processing raspberry technology, predictingthe storage time depending on various environmental influences may be considereda promising direction.

Therefore, the research aimed to developthe most effective method of storing raspberries to improve the prediction of the content of dry soluble substances, sugars and titrating acids in raspberries. By conducting experimental investigations, the expediency of predicting the content of the main components of the chemical composition in raspberries will be determined according to average values, and the factors that have the greatest influence on the accumulation of the studied indicators willbe identified.

MATERIAL AND METHODOLOGY

Samples

Raspberries of Patricia (Figure1 a), Polka (Figure1 b) and Chervona Koroleva (Figure1 c) varieties were picked in the fields of the academic and research department of the Uman National University of Horticulture at the consumer maturity stage according to DSTU 7179:2010[13].

Chemicals

Acetone, C_3H_6O (TD Energobudinvest, Ukraine).
Sodium hydroxide, NaOH (Khimlaborreaktiv TOV, Ukraine).
Ascorbic acid, vitamin C (Khimlaborreaktiv TOV, Ukraine).
Metaphosphoric acid, HPO_3(Khimlaborreaktiv TOV, Ukraine).
Pyrocatechin, $C_6H_4(OH)_2$(Khimlaborreaktiv TOV, Ukraine).
Chloroform, $CHCl_3$(CHEMICO GROUP, Great Britain).
Methanol, CH_3OH (CAS, the Netherlands).
Hexane, C_6H_{14}(Hammerite, the Netherlands).

Animals, Plants and Biological Materials

For experimental investigations, the following varieties were used: Patricia raspberry variety (produced by the academic and research department of the Uman National University of Horticulture, Cherkasy Oblast, Ukraine); Polka raspberry variety (produced by the academic and research department of the Uman National University of Horticulture, Cherkasy Oblast, Ukraine) and Chervona Koroleva raspberry variety (produced by the academic and research department of the Uman National University of Horticulture, Cherkasy Oblast, Ukraine).

Instruments

Drying oven SNOL 67/350 (ThermoEngineering TOV, Ukraine), a titrator (Labor-Technik TOV, Ukraine).Analytical electronic balance KERN ABS 120-4 (Khimtex, the State Enterprise, Ukraine).Refractometer IRF-454B2M (KOMZ VAT).pH meter ULAB MP 511 (ULAB, China).Gas chromatographKristallux-4000M (Meta-Chrom, the Research and Production Company).Refrigerator GGM Gastro (GGM Gastro, Germany).Refractometer (IRF-454 B2M, manufactured by Inter-Syntez TOV, Ukraine). Laboratory thermometer (TLS-200, manufactured by Inter-Syntez TOV, Ukraine). Photocolorimeter (KFK-3, manufactured by Inter-Syntez TOV, Ukraine). Flame spectrophotometer (Saturn-4, manufactured by Inter-Syntez TOV, Ukraine).

Laboratory Methods

The selection and preparation of samples for analysis of fresh strawberries werecarried out according to DSTU (the State Standards of Ukraine) 7205:2009, and the products of its processing –according to DSTU 7244:2009.The quality assessment of fresh raspberries and preserves was carried out following the following regulatory documents:–fresh berries -according to DSTU 7205:2009 [14];–compotes -according to DSTU 8102:2015[15];–jams -according to DSTU 4900:2007[16];In the test samples, the following parameters were determined:–an average weight of strawberries byweighing;–a volume of strawberries bythe amount of displaced water when immersed in a measuring cylinder;–a hardness of berries by calculating the ratio of the mass of berries to their volume;–a density by piercing a fruit in the equatorial zone with aFT 02 penetrometer;–a respiration intensity by the amount of released carbon dioxide [17];–a weight loss of berries by the method of fixed samples weighing [18];–a shine -visually on a 5-point scale, where 1 –a dull surface of berries,no shine, and 5 -a shiny glossy surface;–a content of dry soluble substances according to DSTU 8402:2015 [19];–a content of sugars according to DSTU 4954:2008[20];–organic acids by titrating with alkali according to DSTU 4957:2008 [21];–pH –by the potentiometric method according to DSTU 6045:2008[22];–an acetaldehyde content –by the bichromatic and iodometric method [23];–an ethyl alcohol content –by the iodometric method [24];–an ascorbic acid content –by the iodometric method [25];–a content of nitrates –by the ionometric method according to DSTU 4948:2008[26];All investigations were performed in triplicate.

The results of the analysis led to the initial mass according to the formula(1):

X=!×(%&&'()%&&(1)

Where: X–the content of substances taking into account a mass loss, %;A–the content of substances at the end of storage, %;b–the mass loss during the storage period, %.

Microbiological studies were carried out by microscopy using a MICROmede XS –2610 microscope with a magnification of 50 times, taking samples from the surface of berries with an inoculating wireloop. Photomicrographs were taken using a photo camera.

Description of the Experiment

Sample preparation:

Bushes, typical for a certain variety, even-aged, with medium intensity of fruiting, were selected for the research. Raspberries of each variety were picked when the pulp of the berries wasstill dense enough, but the taste and color were appropriate for this variety. The harvesting datewas determined by the following characteristics of the quality of fresh berries: the appearance and the size of berries about the largest longitudinal diameter. The selected berries corresponded to the indicators of the first commercial variety:the shape and colour of the variety, berries with stalks, mechanical damage, vermin damage and fungal diseases. Fruits were picked from different bushes.

Experiment 1: Raspberries were processed with chitosan solutions of six concentrations (0.05%; 0.1%;0.2%; 0.3%; 0.4%; 0.5%) in two ways: spraying and immersion for 1 min. The processed berries were left to dry completely.

Experiment 2: Raspberries were processed with chitosan solutions of six concentrations: 0.05%; 0.1%; 0.2%; 0.3%; 0.4%; 0.5% and leftto dry completely.

Experiment 3: Raspberries were processed with a 0.5% chitosan solution and stored for seven days in a refrigerator with free access to air.

Number of analyzed samples: To determine the content of dry soluble substances, sugars and titrating acids, a sample of 100 berries of each pomological variety was taken from 6 bushes that had entered into a full fruiting period.

Number of repeated analyses: all instrument measurements and readings were performed 3 times.

Number of experiment replications: The number of repeats of each experiment to determine one value was also 3 times.

Design of the experiment:Experiment 1: Dry processed berries and the control were weighed and placed in perforated plastic (PET) containers with a capacity of 500 g, and stored at a temperature of 20 °C on racks in a ventilated location. Berries without processing were considered as the control.Experiment 2: Dry processed berries and the control were weighed and packaged in perforated plastic (PET) containers with a capacity of 500 g and in plastic bags with a thickness of 30 microns. The storage was carried out in two ways: with free access to air and in a modified gas environment at a temperature of 0±2°C with an atmosphere relative humidityof 90-95%. Berries without processing were considered as the control.Experiment 3: After storing, the preserveswere made from berries according to the manufacturing specifications: "Raspberry puree", "Raspberry jam", "Raspberry confiture", "Raspberry compote", and "Natural raspberry juice". The "Raspberry in own juice" preserves were produced according to the technology developed by our team. The preserves made from fresh unprocessed raw materials were considered as the control.

Statistical Analysis The results were evaluatedusing statistical software Statgraphics Centurion XVII (StatPoint, USA) –multifactor analysis of variance (MANOVA), LSD test. Statistical processing was performed in Microsoft Excel 2016 in combination with XLSTAT. Values were estimated using mean and standard deviations. The reliability of the research results was assessed according to the Student's test at a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

The study was conducted every second day of storage to assess the influence of pre-processing of raspberries with chitosan solutions.We have determinedweight loss,a mass fraction of dry soluble substances (a mass fraction of DSS),a respiration intensity,a mass fraction of organic acids,a mass fraction of sugars, an ascorbic acid content,pH level; a density,anda shine degree.

During the storage period ends, the content of ethyl alcohol and acetaldehyde and the yield of commercial products were determined, and the organoleptic evaluation was carried out.

A series of similar scientific investigations, in which the influence of pre-processing with various solutions on various types of fruit and berry raw materials, is described in the following scientific papers:

–the influence of pre-processing of strawberry berries [27], [28];

–the influence of pre-processing of currant berries [29], [30];

–the influence of pre-processing of blackberry berries [31], [32];

–the influence of pre-processing of apple fruits with special solutions [33],[34];

–the influence of pre-processing of apricot fruits with solutions based on sulfites [35], [36];

–the influence of pre-processingof cape gooseberry fruits with special solutions [37], [38].

However, the use of sulfite can cause various types of allergic reactions, so its use is limited.Raspberries are characterized by a high moisture content, which is lost through thin cover tissues due to quick physiological changes. Berry mass losses during storage are caused by a rather high respiration intensity, a decrease in the content of nutritional substances, and a development of phytopathogenic damage [39].Pre-processing of raspberry with chitosan solutions made it possible to reduce the weight loss of berries during storage (Figure2).

The mass loss of raspberries increased with each day of storage,and on the second day,it ranged from 0.98 to 1.5% and from 1.0 to 1.3%,depending on the storage method. On the eighth day of the storage, the indicators ranged from 4.3 to 6.3% and from 3.8 to 5.7%. The lowest losses during the entire storage period were detected in the sample with a chitosan processing concentrationof 0.5%. During the storage period ends, the mass losses reached 9.6% and 10.9% in control, 6.2-10.4% and 5.2-8.9% in the preprocessed samples.

The analysis of the dynamics of raspberry's weight losses during the two-week storage period demonstrated thatthe processing with a chitosan solution contributes to weight loss reduction.

Carbohydrates, nitrogenous substances, acids, pectin, vitamins, enzymes, mineral salts and tanning substances represent dry solublesubstances. In raspberries, the mainpart of DSS is carbohydrates, mainly represented by sugars and acids. The change in the mass fraction of dry soluble substances during storage occurs due to the conduction of biochemical processes in raspberries.

The pre-processing of raspberries with chitosan revealed a positive effect on preservingdry soluble substances (Figure3).

The investigations have shown insignificant variations in the mass fraction of dry soluble substances among different methods of refrigerated storage of berries. However, the lowest loss of the mass fraction of dry soluble substances during refrigeratedstorage with free access to air for 14 days was observed when raspberries were processed with chitosan at a concentration of 0.5%, and the highest loss was in control and at a concentration of 0.05%. A similar dependence of the change in the mass fractionof dry soluble substances was revealed during refrigerated storage in a modified gas environment.

It was proved that the mass fraction of dry soluble substances decreased more slowly in the samples processed with chitosan.

On the second day, in the control, the accelerated loss rates of the mass fraction of dry soluble substances were observed, negatively affecting raspberries' preservation. On the sixth day of the storage of berries with free access to air, an equal value (8.0%) was detected in the sample with a processing concentration of 0.05% and in the sample without any processing. In the future, the difference in indicators between these two samples for both refrigerated storage methods was insignificant (0.2-0.4%), which may indicate the inexpediency of using this concentration. It was found that the lowest changes in the mass fraction of DSS were in samples with a processing concentration of 0.4% and 0.5%.

The respiration intensity is the main indicator of metabolic processes in berries. This is the dominant indicator, the slowing down of which allows for extending the storage time of fruits [40].Pre-processingraspberries before their placement in storage helps reduce their respiratory activity (Figure4). 66.577.588.599.51002468101214Mass Fraction of DSS, %Storage Time, daysControlConcentration of 0.05Concentration of 0.1Concentration of 0.2Concentration of 0.3Concentration of 0.4Concentration of 0.5HIP05= 0.55.

The physical effect of chitosan is that a thin transparent film forms on the surface of raspberries, which slows down a gas exchange.

The respiratory exchange of raspberries actively continues after their separation from a parent plant, negatively affecting the storage quality and duration.

The average respiration intensity of fresh raspberries was 34.6 mg CO2.kg/h. On the second day of the storage, the indicator decreased sharply regardless of the processing concentration and the storage method and ranged from 8.9 to 10.5 and from 8.5 to 11.3 mg CO2.kg/h. This was facilitated by a significant decrease in temperature to 0±2°C. During further storage, the indicators have continued to decrease gradually. In the sample processed with a 0.5% chitosan solution, the respiration intensity was the lowest and on the eighth day was 5.3 CO2.kg/h when stored with free access for air and 4.6 CO2.kg/h in a modified gas environment, that by 2.4 and 1.4 less than the control.

Organic acids in raspberries are represented by citric, malic, quinine, salicylic, phosphoric, succinic, shikimic and glycolic acids [41].

During the storage of raspberries, there is a tendency to lose organic acids, which are most involved in respiration. Pre-processing of raspberries with chitosan reduced the respiration intensity, thereby slowing the loss of organic acids by 0.15-0.19% of the counter (Figure5).On the second day, the highest percentage of organic acids (0.88%) was found in the sample with a processing concentration of 0.5% for both storage methods.

On the fourth day of the storage, a significant decrease in the content of organic acids was observed in raspberries that were stored with free access to air. However, the samples in a modified gas environment noted a stabilization of the dynamics of losses.

On the eighth day of the storage of berries in a refrigerator with free access to air, the lowest content of organic acids (0.50) was detected in the sample with a chitosan processing concentration of 0.1%.0510152025303502468101214 Respiration Intensity, mg CO2 kg/h Storage Time, days Control Concentration of 0.05Concentration of 0.1Concentration of 0.2Concentration of 0.3Concentration of 0.4Concentration of 0.5HIP05= 2.2.

At the beginning and until the end of the storage period, the best result was observed in the sample with the highest processing concentration, proving its application's effectiveness.

The processing of berries with chitosan solutions significantly reduces the decomposition rateof organic acids.

It is commonly known that sugars in raspberries are represented by glucose, fructose and sucrose. In combination with organic acids, sugars participate in oxidation processes, so their loss is partly caused by the respiration intensity [42].

Our researchestablished that pre-processing of raspberries with a chitosan solution significantly affects the changes in the content of sugars that occur during the storage period. This is explained by the fact that chitosan slows down the respiratory processes in berries, which causes significant losses of sugars

.It is found that the average sugar content in freshly harvested raspberries was 6.0%. During the entire storage period, significant losses of sugars were detected in the control samples.

The authors of scientific papers [43],[44]found that the average sugar content in freshly harvested raspberries was 6.0-10%, but raspberry varieties and places where these researches have been conducted, were not indicated. Thus, such statements cause doubts about the obtained research results.

On the second day of the storage, a sharp decrease in the mass fraction of sugars was observed in the control samples (5.2%) and (4.9%) and in samples with a chitosan processing concentration of 0.05% (5.0%) and (5.2%). When raspberries were stored in a modified gas environment (MGE) from the beginning to the eighth day, the value for the control and the sample with the minimum processing concentration was equal to one.

By the end of the storage period, the sugar content in berries gradually decreased and,on the fourteenth day,ranged from 2.7 to 4.3% in samples with free access to air and from 2.5 to 3.6% in a modified gas environment.

The intensity of the use of sugars in the physiological and biochemical processes that occurred during the storage of processed raspberries was significantly lower compared to the control due to the slowing down of respiratory activity.

The content of ascorbic acid usually determines the vitamin value of raspberries. The content of vitamin C depends mainly on the variety and soil and climatic conditions. 0.40.450.50.550.60.650.70.750.80.850.902468101214Mass Fraction of Organic Acids, % Storage Time, daysControlConcentration of 0.05Concentration of 0.1Concentration of 0.2Concentration of 0.3Concentration of 0.4Concentration of 0.5HIP05=0.02.

Ascorbic acid is an unstable compound that is easily oxidized during storage [45]. Many factors affect its decomposition; the main of which are light, temperature and pre-processing.

Over the years of investigations, it has been established that the average ascorbic acid content in the Dukat variety raspberriesis 65.1 mg/100 g. Depending on the refrigerated storage period, it decreased as well as with free access to air (Figure6).

It was investigated that the ascorbic acid content in raspberries decreased rapidly,and on the fourth day, itranged from 50.6 to 58.7 mg/100 g and from 49.5 to 60.2 mg/100 g,depending on the storage method. During the storage period ends, the highest ascorbic acid contentwas detected in samples with a processing concentration of 0.5% (35.4 mg/100 g) and (37.8 mg/100 g), which is 11.6 and 11.4 more than the control.

The active acidity of berries is animportant characteristic of them, as it impactsthe microflora's vital activity. The acid taste of fruit and vegetable products is provided by hydrogen ions, which are formed as a result of the electrolytic dissociation of acids and acid salts. The activity of hydrogen ions is characterized by the pH indicator [46].

It was established that the average pH level in fresh raspberries is 3.2. During storage, the active acidity decreasesdepending on the time and method of storage (Figure7). Depending on the storage method, the indicator increased by 0.2-

0.4 and 0.1-0.3 on the second day. On the eighth day of the storage, the lowest pH level was observed in the sample with a chitosan processing concentration of 0.5% (3.8) and (3.6), 0.5 and 0.4 less than the control.

During the storage period ends, the acidity of raspberries ranged from 4.2 to 4.8 in samples stored with free access to airand from 4.0 to 4.5 in a modified gas environment.

The analysis of research results proves that chitosan can slow down the pH level increase.

The tissue density indicatesthe consumer ripeness (degree of maturity) of fruits. It depends on the variety, fruit size and weather conditions during cultivation. The high density contributes to better storing and transportingof fruit and berry raw materials [47].

During storage, the tissue density decreased significantly, and in the middle of the storage period (the 6th day) it ranged from 0.24 to 0.28 kg/cm2in processed berries that were under conditions of free access to air, and from 0.25 to 0.28 kg/cm2in a modified gas environment.During ripening, the berry tissue gradually softens, and in the case of frequent rains, it becomes thin and sensitive to mechanical damage.

It was studied that the average density of fresh raspberries after harvesting was 0.30 kg/cm2.

In berries without any processing, the indicator was 0.21 and 0.24 kg/cm2. At the raspberry storage period end, the density of processed berries was in the range of 0.14-0.20 kg/cm2and 0.17-0.24 kg/cm2, depending on the storage method, which is 0.01-0.07 and 0.02-0.09 kg/cm2more than in control. The analysis of the research results showed that pre-processing of raspberries with chitosan solutions significantly affects tissue density preservation. As the concentration of the solution increased, the indicator decreased more slowly.

Ethyl alcohol is a strong solvent, and due to that, all biochemical processes are accelerated. Its formation in raspberries during storage occurs due to insufficientoxygen when the berries start anaerobic respiration [48].The highest content of ethyl alcohol was observed in samples stored in a modified gas environment, 0.68-0.85% in processed berries, and 0.88% in the control (Figure8). In the samples that were stored with free access to air, the content of ethyl alcohol did not exceed 0.05-0.18%.

It was established that after fourteen days of storage, the accumulation of acetaldehyde was in raspberries (Figure9). This indicates the creation of anaerobic conditions in the storage environment.

It was found that the mass fraction of acetaldehyde was higher in samples stored in a modified gas environment. The indicator ranged from 0.11 to 0.15 mg/100 g when berries were stored with free access to air, and from 0.16 to 0.28 in MGE.It was established that pre-processing of raspberries with chitosan solutions improved organoleptic properties (Figure10), better-preservingcolour, tissue density and taste.

An organoleptic assessment is one of the most important indicators of product quality.The potential buyer, first of all, pays attention to the appearance of the product, its color, aroma and consistency. The maintenance of the natural attraction of berries is a complex process, because during storage, a change in color, loss of elasticity and aroma is inevitable.

The accelerated rates of quality loss of raspberries were detected in the control sample. The sample with a 0.5% chitosan processing concentration was recognized as the most relevant for maintaining the organoleptic properties of raspberries.

Shine is a characteristic feature of the freshness of berry products. Its loss leads to the deterioration of the commercial qualities of the product, resulting in adecrease in the selling price

.Scientific papers [52]and [53]describea wide range of organoleptic examinations of different types of berries immediately after harvesting, and also indicate the storage periods without the use of special solutions, but any studies of physical and chemical features were not conducted; it is unclear how the qualitative composition of raw materials changed during storage. During the storage of raspberries, quick rates of shine loss were detected, particularlyin the control sample (Table 1).

It was established that thanks to the film-forming properties of chitosan, the berries had a shiny glossy surface, significantly improving the raspberry's appearance. The obtained research results make it possible to recommend pre-processingraspberry with 0.4% and 0.5% concentration chitosan solutions.

Rapidlosses of quality accompany the storage of berries in the conditions of trade transactions. This occurs due to increased physiological activity, particularly the high respiration intensity, whichleads to the loss of nutritional substances [49].

During the storage of berries at a temperature of 20-22 °C, the quick deterioration of raspberry quality was observed. The criterion for the end of storage was the appearance of phytopathogenic damage on the surface of the berries. The berries were assessed according to the physical parameters. The investigations were conducted every day. It was found that the weight loss depended on both the storage period and the berry processing concentration. Scientific papers [50]and [51]describe the process of storing raspberries at temperatures above 22 °C, and the authors do not state the deterioration of quality indicators.

Thus, thequestion arises about what preparation was used for the berries pre-processing; this information is not specified.Thus, on the second day of non-refrigerated storage of berries, the mass loss ranged from 6.2 to 8.2% and from 6.4 to 8.4%, depending on theprocessing concentration, and from 8.3% to 8.6% in control. During the following days of the storage, the indicator increased and at the end,was 15.4-19.2% in the berries processed by the spraying method and 21.0% in control, and 15.1-19.0% in the samples processed by the immersion method and 20.9% in control.

The density of the berry tissues also decreased with the loss of mass. Thus, on the second day of the storage, the indicator decreased by 0.06-0.11 kg/cm2for both processing methods (Figure11and Figure12).

On the third day of storage, the density of berry tissues ranged from0.15 to 0.20 kg/cm2. By the end of storage, the indicator decreased rapidly, and on the fifth day, it was 0.12 kg/cm2in samples with processing concentrations of 0.4 and 0.5% and 0.10 kg/cm2in the remaining samples.

The pH level of raspberries changed very quickly during storage in the conditions of trade transactions. The active acidity has decreased, which led to the deterioration of the quality of berries and the development of fungal diseases. Figure 12The change in the density of raspberries during non-refrigerated storage with the immersion processing method (2018-2020).

On the second day of the storage, the indicator ranged from 3.2 to 3.5 for both processing methods. On the third day of storage, the pH level decreased to 3.6-4.4 for the spraying method and 3.8-4.2 for the immersion method. At the end of the storage period of the berries, the pH level ranged from 4.3 to 4.9 and from 4.4 to 4.8 in the processed samples and 5.0 in the control.

CONCLUSIONI

t was established that the chitosan coating positively affects the maintenance of raspberries' quality indicators. It was detected that the processed berries had a loss of ascorbic acid of 1.5-3.9 times less than the control sample. A similar situation was observed with the mass fraction of sugars, which prevailed 0.9-2.5 times in the processed samples. According to the organoleptic indicators, raspberries without processing had an unattractive appearance, a softened consistency and a less pronounced aroma.

It was established that the mass loss of strawberries has increased daily regardless of the storage method. The strawberries'weight loss has a high inverse correlation dependence on the processing concentration. The mass loss has decreased with the increase of the chitosan percentage in the solution. The strawberries stored at a temperature of 20-22 °Cfor more than five days, both processed and unprocessed, are not advisable due to a significant loss of mass (15.4-21.0%). The ascorbic acid content accumulated during the vegetation quickly decreasedon the second day of storage in all studied samples. The strawberries processed with chitosan solutions had lower vitamin C losses thanthe control high inverse correlation dependence between the change in the ascorbic acid content and the chitosan solution concentration was established.

It was found that the change in the pH level of strawberries depends on the chitosan processing concentration, regardless of the storage and processing methods.

The tissue density decreasedduring the entire storage period and reached the value of 10 kg/cm2. It was investigated that strawberries processedwith a chitosan solution of different concentrations had a higher density, contributingto long-term preservation.

The content of ethyl alcohol at the end of storage depended on the storage method. The highest values were detected when strawberries werestored in a modified gas environment. It was found that the strawberries pre-processed with a chitosan solution were suitable for preservationafter seven days ofstorage. According to the physical, chemical,and organoleptic indicators, the preserves made from pre-processed berries fully complied with the requirements.

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