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EFFECTS OF THE COATING AND CALCIUM APPLICATION ON THE QUALITY AND SHELF LIFE OF RADISHES

EFEKAT APLIKACIJE KALCIJUMOVOG OMOTAČA NA ROK TRAJANJA ROTKVICE

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ABSTRACT

Local Kadirli radises were harvested and divided into four different groups. The crops were selected according to their uniformity, and then cut manually using a sharp knife. Treatments with 1 % calcium chloride, 1 % chitosan coating and 1 % calcium chloride + 1 % chitosan coating were applied to the fresh-cut radish slice samples and stored in a polypropylene box at 0 ° C in the 90 % relative humidity for 12 days. The treated fresh-cut radish samples were analyzed for mass loss, firmness, ethylene production, color (Chroma), sensory analysis, chemical (TSS, pH), microbiological and E.C. membrane integrity for 3-day intervals during storage. When the data obtained from the study were evaluated, it was determined that the calcium chloride application had significant effects on the mass loss (%) and firmness (N) of the samples examined, whereas $CaCI_2$ exerted a significant impact on the firmness and E.C. (%) membrane integrity of the samples examined. According to the results of microbiological analysis, the chitosan application was found to exert a notabe effect on the development of total aerobic bacteria.

Keywords*: calcium chloride, chitosan, firmness, fresh-cut, radish, storage.*

REZIME

Lokalne Kadirli rotkvice su podeljen je u četiri grupe, odmah nakon ubiranja. Rotkvice su podeljen je u odnosu na njihovu uniformnost, a potom su ručno rezane sa oštrim nožem. Tretmani sa 1% kalcijum hloridom, 1% hitozanom, i 1% kalcijum hloridom +1% hitozanom su primenjeni na sveže izrezane uzorke i skladištene u polipropilenske kutije na 0°C sa 90% relativne vlažnosti vazduha u trajanju od 12 dana. Tretirani sveže rezani uzorci su analizirani prema gubitku mase, čvrstini, proizvodnji etilena, boji (hromatičnosti), senzornim osobinama, hemijskom sastavu (TSS, pH), mikrobiološkim osobinama, i postojanosti membrane u trajanju od 3 dana tokom skladištenja. Procenom dobijenih podataka, definisan je značajan efekat tretmana kalcijum hloridom na maseni gubitak (%) i čvrstinu (N) uzorka, dok $CaCI_2$ pokazuje značajan učinak na čvrstoću i postojanost membrane uzorka. Prema razultatima mikrobiološke analize, upotreba hitozana ima primetan efekat na razvoj aerobnih bakterija.

Ključne reči*: kalcijum hlorid, hitozan, čvrstoća, zveže sečene rotkvice, skladištenje.*

INTRODUCTION

Fresh fruits and vegetables, which are important food sources, are rich in dietary fibers and phytochemicals, thus play an important role in human nutrition (*Mahajan, 2017*). Vegetables and fruits, especially those consumed fresh, help to prevent various diseases (*Jovanović et al., 2016*). Nowasdays, many consumers are aware of the importance of fresh vegetables, which are important sources of vitamins, minerals and fibers in their daily nutrition (*Jovanović et al., 2016*). For these reasons, an increase in the consumption of fresh products has led to the development of the sector related to these products (*Jovanović et al., 2016*). In addition, fruits and vegetables are rapidly degraded because they contain a high proportion of water and continue their metabolic activities after harvesting (*Mahajan 2017*). These deteriorations can be defined as browning, mass loss and microbial tissue spoilage (*Pushkala et al., 2013*). Efforts are being made to develop cheap and effective strategies to minimize these negative situations and to provide consumers with better quality and longer shelf-life products (*Pushkala et al., 2013*). These studies include chemical and natural preservatives (liquid chlorine, calcium, essential oils, citric acid, etc.), active packaging, edible coatings (chitosan, starch, cellulose, alginate, wax etc.), Modified Atmosphere Packaging (MAP) (*Corbo et al., 2010*). The radish (*Raphanus sativus* L.) belongs to the family of *Brassicaceae* (*Cruciferae*). It is a rich vegetable featuring a number of cultivars and devoted to wide production areas, especially in China, Japan and Asia, where radishes play an important role in the fresh vegetables requirement of consumers (*Akan et al., 2013*). The radish is a vegetable consumed especially by salting, as well as in the form of shredded garnish and salad (*Kaneko and Matsuzawa 1993*). While radishes are generally consumed fresh in Europe, radishes produced in Asian countries are generally consumed, cooked, pickled or dried (*Akan et al., 2013*). The root portion consumed in radishes can be of various sizes and colors (*Akan et al., 2013*). The total volume of the radish production in Turkey indicates a slightly increasing trend since 2010 (*TÜİK 2017a*). The white radish production in Turkey started in 2014. The annual per capita consumption of radishes in the country is 2.2 kg / year (*TÜİK 2017*). The annual amount of radish exports is 640 tons (TÜİK 2017a). Radishes are grown in almost every region of Turkey. However, the Turkish radish production is more intense in the provinces such as Osmaniye, Ankara, Kahramanmaras, Hatay, Mersin and Konya (*Akan et al., 2013*). The Kadirli district of Osmaniye generates 70-80 % of the total radish yield in Turkey (*TÜİK 2017b*). The radish is an important source of vitamin C (ascorbic acid), folic acid, potassium, B6, riboflavin and magnesium (*Akan et al., 2013*). Minimally processed fresh products have a number of advantages such as saving time and reducing solid waste problems. As they are partially prepared, no additional preparation is required for their use (*Pilizota et al., 2004*). Calcium is a metabolite that plays an important role in regulating the physiological functions of fruits and vegetables during and after harvest (*Aghdam et al.,2012*). Calcium is a potential regulator of the physiology of fruits and vegetables at the cellular level after harvest (*Aghdam et al.,2012*). It also plays an important role in the quality and preservation of fruit and vegetables by maintaining the integrity of the cell membrane of calcium fruits and vegetables and by reducing the membrane permeability (*Kou et al.,2015*). Different calcium salts such as calcium lactate, calcium chloride ($CaCI_2$), calcium phosphate, calcium propionate and calcium gluconate are used in pre-harvest and post-harvest treatments of fruits and vegetables to reduce their physiological disorders (*Naser, et al.,2018*). Among these salts, $CaCI_2$ is widely used to preserve the quality and texture of post-harvest fruits and vegetables (*Naser, et al.,2018*). $CaCI_2$ is used as a hardening additive in the canned tomatoe and cucumber pickle industry (*Guzman and Barrett 2000*). Other products that are protected and developed by $CaCI_2$ include all apples, whole hot peppers, whole or sliced strawberries, chopped tomatoes and whole peaches (*Guzman and Barrett 2000*). $CaCI_2$ provides texture protection, development enhancement, cell wall and middle lamella complexing pectins, calcium ions, stabilization of cell membrane with calcium ions, and the effect on cell turgor pressure (*Guzman and Barrett 2000*). Fruits and vegetables contain 80-90 % water and are highly degradable (*Dhall 2012*). If there was no cuticle layer on the surface of fruit and vegetables, the water in the product would evaporate rapidly, causing the shelf-life of the product to shorten (*Dhall 2012*). The main losses in fruits and vegetables occur from harvest to consumption (*Dhall 2012*). When fruit and vegetables are harvested, the gas balance between oxygen production and carbon dioxide production is changed (*Dhall 2012*). The prolongation of the post-harvest shelf life of food products depends on three critical factors: the reduction of water loss, the impediment of physiological processes (such as maturation and aging) and the reduction of initial microbial load and rate of increase (*Dhall 2012*). Techniques such as controlled atmosphere storage and modified atmosphere storage are used to reduce quality losses during storge (*Dhall 2012*). Edible films and coatings have become widespread nowadays and have been used in the fruit and vegetable industry (*Nawab et al., 2017*). Edible coatings form a barrier on the product surface, thus hindering water loss and oxidation rate (*Nawab et al., 2017*). Commercially used edible films and coatings are produced from waxes, polyesters, oils, resins, polysaccharides and proteins (*Hassan et al., 2018*). Starch is the storage polysaccharide of various legumes and tubers, and is a commonly used raw material for various industrial uses (*Dhall 2012*). Films and coatings made from starch are widely used because they are transparent, odourless and tasteless, and also have good oxygen and carbon dioxide barriers (*Hassan et al., 2018*). However, due to their hydrophilicity, starch-based films and coatings are soluble in water and act as a weak water barrier (*Hassan et al., 2018*). Starches, a source of high amylase, such as corn starch, are often used in the food industry because they provide a good film formulation (*Dhall 2012*). They are alternative edible coating methods which enhance the quality of minimally processed products (*Wong et al., 1994*). Fresh-cut products are gaining popularity for their convenience. The purpose of this paper is to examine the quality preservation of fresh-cut radishes and their quality loss during cold storage. Therefore, the effects of $CaCI_2$ and chitosan, separately and in a combination ($CaCI_2$+chitosan), on the quality and shelf life of fresh-cut radished were examined in the present study.

MATERIAL AND METHOD

Preparation of chitosan coating and % $CaCl_2$ solution

Chitosan (CH) solutions were made according to (*Alvarez et al., 2018*), and chitosan solution was dissoleved overnight at room temperature. $CaCl_2$ solutionwere dissolved in distilled water with magnetic stirring at 25 ∘C.

Plant materıal

Lcal Kadirli radishes were used as raw material. After harvest, radishes, which are suitable for storage, were separated into four groups. After washing with deionized water, the first group was not subjected to any application, whereas the control group was separated (no treatment) (I), the second group radishes were terated with $CaCl_2$ (1 % w/v) solution (II) (dipping for 2 min at 20^oC). The third group of radishes were treated only with chitosan (1% w/v) (III) material (dipping for 2 minutes). In the fourth, radishes were first dipped in $CaCl_2$ (1 % w/v) solution for 2 minutes, then the extra water was removed under room conditions and the crops were dipped in chitosan (1 % w/v) coating (IV) for 2 minutes. After the samples were treated with $CaCl_2$ plus chitosan and coated, they were placed on a metal grid at room temperature (25 °C) until the coating material was dry. Fresh-cut radishes were stored at 0°C for 12 days. To determine the effects of the treatments, ethylene production rate, quality parameters (firmness, mass loss, soluble solids, electrical conductivity (E.C.) and color (chroma) value were measured every three days of storage (as described below).

Determining Changes During Storage

1. Mass Loss

The mass loss of fresh-cut radishes was measured during storage by monitoring the mass changes of fresh-cut radishes. The mass loss was considered the difference between the initial and final mass of coated and uncoated fruits. The results are expressed as the percentage loss from the initial mass, according to the method described by *Meng et al.* (2008). The mass loss was expressed as a percentage of the initial mass.

2. Texture and SSC Measurements

The texture of the fresh-cut radishes (i.e. firmness) was detrmined using the CT3 model (Brookfield Engineering Labs Inc., Middleboro, MA, USA) (*Bao et al., 2016*). The samples were subjected to the following testing; compression, test distance; 4,00 mm, trigger load; 0.1 N and test speed; 1.00 mm/s and TA39 (TA General Probe KIT- Brookfield Engineering Labs Inc.). The total amount of dry matter dissolved in water was calcualted relative to the amount of dry matter present in the fruit juice and the refractometer (sensitivity ± 0.01) (Krüss brand) digital refractometer (*Cemeroğlu, 2010*).

3. Colour Measurements

The surface colour of the samples was determined using the Chroma Meter CR-400 (Konica Minolta, Tokyo, Japan) to assess the L (lightness), a (-green, +red) and b (-blue,+yellow) values. The chroma values (C) of the samples were calculated according to *McGuire (1992)*.

4. Determination of Ethylene Production Rate

The measurements of ethylene production were made using the Trace GC Ultra ThermoSCIENTIFIC brand Gas Chromatography (GC) device with a flame ionization detector (FID) and column (TG-624 30m x 0.32mm x1.80µm). The ethylene measurements were performed in 10 repetitions by taking 1 mL air sample of the jar head space with a plastic syringe evrey hour of measurement. Ethylene measurements were made at 20 ^oC and the results were expressed in µlC_2H_4 / kg / h.

5. Electrical Conductivity Measurements

The electrical conductivity of the samples was measured according to *Liu et al.* (2016), with minor modifications. Three pieces of fruit steel core probe (10 mm diameter, 1 mm thickness), shaken 3 times and immersed in 25 mL of distilled water at 25 °C for 2 hours, were used to determine the first electrical conductivity (E.C) (C.0) with the DDS-307A conductivity meter (Leici Inc., Shanghai, China). Then second measurement was made the next day, then the samples were frozen for 1 night and the total electrical conductivity (E.C)(C1) was monitored at room temperature.

6. Microbiological Analysis

Sterilized 90 mL of peptoned buffer dilution liquid is placed into a stomacher bag and 10 g of radishe slices were taken under sterile conditions and homogenized in the stomacher bag. After homogenization, the samples were diluted 1/10 with buffer pepton water and the appropriate medium were sown using the cast plate method. In the experiments, all microbial cultivations were performed in parallel with each dilution and count results were expressed as log.cob / g by taking the average of these two parallels (*Ulukanli and Karadag, 2010*).

6.1. Total Yeast and Mold

The dilutions were prepared to determined the total number of yeast and mold in the radishes planted in ther PCA medium (containing 50 mg / L chloramphenicol antibiotic and cast plaque method) (*Anonymous, 1989*; *Anonymous, 2001*). Following the sowing process, the radish samples were incubated for 120 hours at 25 ^oC, and the number of colonies was counted (log/cob / g).

7. Sensory Evulation

Sensory evulation was measured for the determined acceptable level of radishes using a nine-point hedonic scale as (1: extremely poor; 5: excellent) according to the method of *Santos et al. (2012*).

8. Statistical Analysis

Each result was expressed as the mean value ± standard deviation. All statistical analyses were performed using the SPSS version 13.0 (SPSS, Inc., Chicago, IL). One-way ANOVA and the least significant difference (LSD) tests were used to determine the significance of mean differences among the treatments and storage times. Differences at $P < 0.05$ were considered significant and are indicated using different letter designations.

RESULTS AND DISCUSSION

1. Mass Loss

In general, fresh fruits and vegetables continue to their respiration after harvest and storage. This causes the loss of

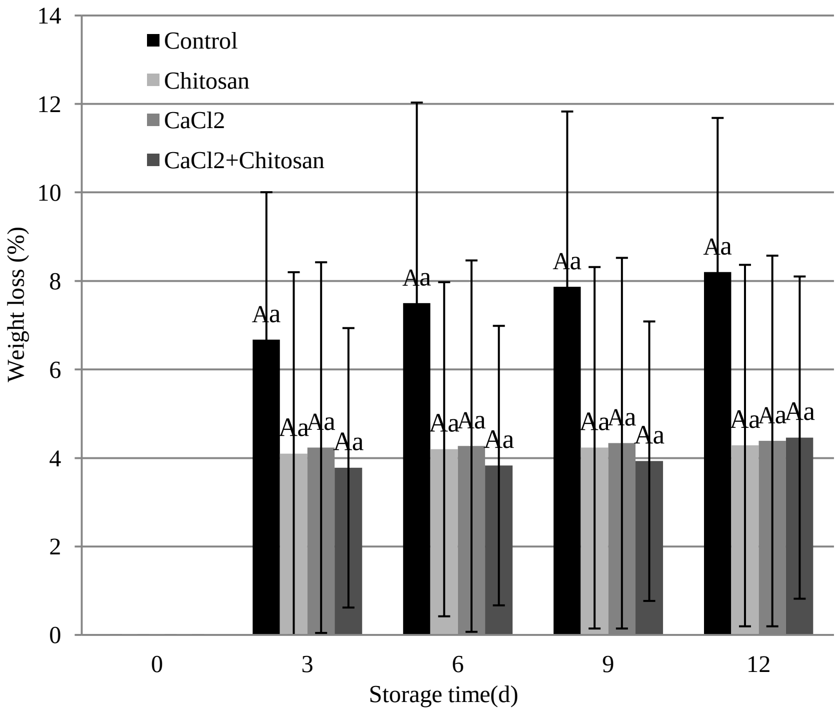

Fig. 1. Changes in the mass loss of fresh-cut radish slices

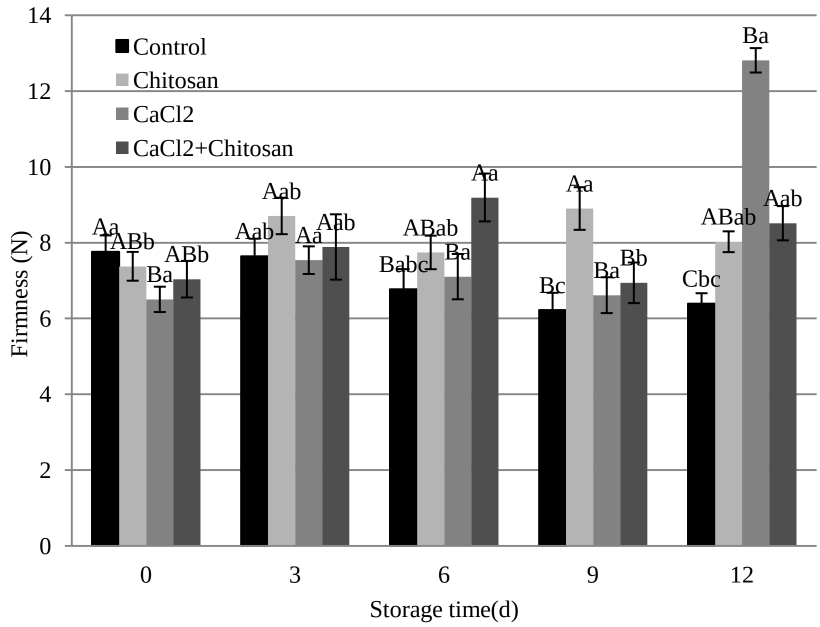

Fig. 2. Changes in the firmness of fresh-cut radish slices

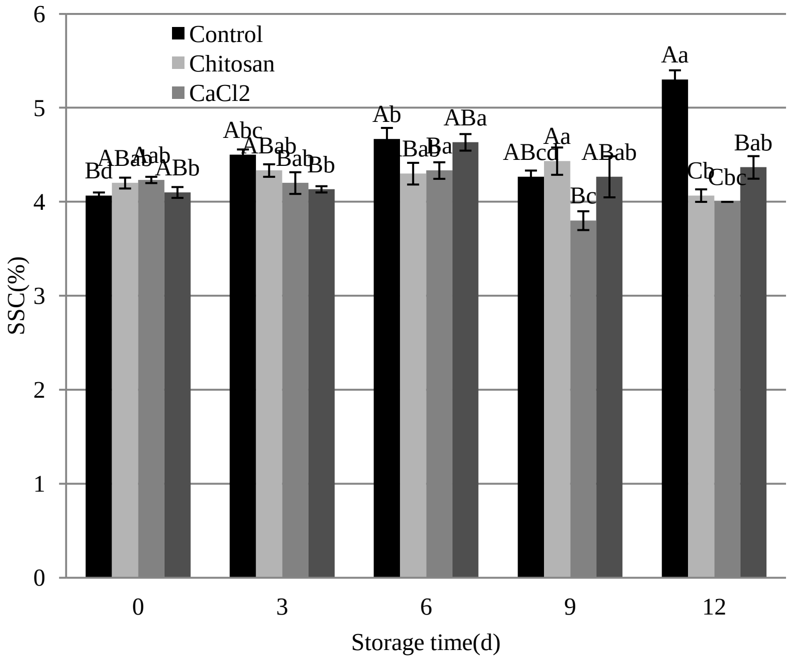

Fig. 3. Changes in SSC of fresh-cut radish slices

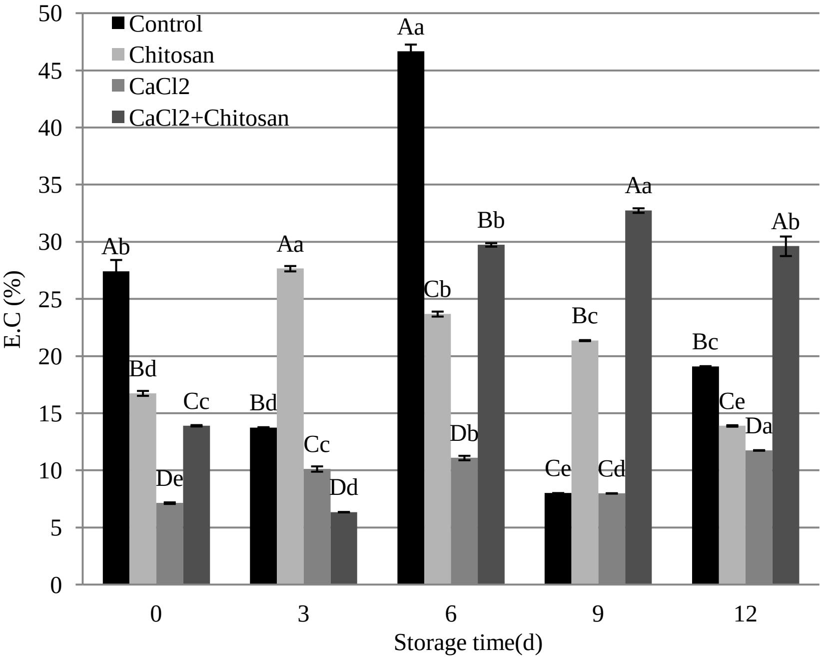

Fig. 4. Changes in the EC of fresh-cut radish slices

water in fresh commodities and naturally causes the loss of mass. Mass losses lead to tissue changes that negatively affect the shelf-life of vegetables (*Nawab et al., 2017*). The coatings provide a semi-permeable membrane to fresh crops to protect them from water loss and gas transfer. The mass loss of the control group was higher (7 %) at the end of storage, whereas the lowest mass loss was recorded in the chitosan coated samples (4.4 %) (Fig.1). Therefore, the coating application reduced the moisture transfer from the fresh-cut radish surface to the environment. The rate of mass loss increased with the storage time at 0 ºC. Coating treatments significantly decreased the mass loss percentage compared to the control radish samples. The mass loss decrease recorded may be attributed to the $CaCI_2$ and chitosan application which hindered the respiration rate of the radish samples. Previous studies have suggested that decreasing water losses may significantly affect radish appearance, i.e. prevent browning, wilting and shrivelling. However, the most significant changes in the appearance of radish slices were observed in the control samples.

2. Firmness (N) and SSC (%) Measurements

Tissue is an important factor in determining the sensory properties of fruits and vegetables. The tissue softening rate is closely related to the shelf-life of fruits and vegetables due to the depolymerization and dissolution of polysaccharides in the cell walls during the post-harvest storage (*Chong et al., 2015*). In general, fruits and vegetables are preserved during the post-harvest period due to the metabolic activies and the loss of water in the product and decrease in the hardness of the fresh produce with aging. However, in many studies (apple, apricot and persimmon etc.), calcium application has been found to slow down the rate of decrease in flesh hardness.The firmness of radishes is the most important quality parameter that affects the quality of fresh commodities during their shelf life. At the initial time of storage, the radish texture was about 8 N and decreased to nearly 6 N after the treatments (Fig. 2). However, the firmnes of $CaCI_2$ treated fresh-cut radishes was increased to approximately 13 N, followed by the chitosan and $CaCI_2$+chitosan treated radish samples (8 N), which idicated that the chitosan coating prevented firmness losses compared to the control radish samples during the 12 days of storage (Fig. 2). Statistically significant differences were found betweet the control radish samples and coated radish samples throughout the storage period. The total soluble solids value of fruits and vegetables is important for the taste of fresh commodities (*Ikeda et al., 2013*). Coating treatments cause the slowdown of of fruits and vegetable metabolic activity, leading to a reduction of degradation reactions of polysaccharides (*Liu et al., 2016*). At the begining of storage, SSC approximated to 4 % in all the treatment. However, the SSC of the treated fresh-cut radish remained invariant at the end of storage. The SSC of the control group increased up to 5.5 %, whereas significant differences between the treatments and SSC of control had the highest value at the end of storage (Fig.3.).

3. Electrical Conductivity (EC)

Tissue electrolyte leakage is a value that predicts the cell membrane damage of fresh produce, and there is a close relation with the cell membrane quality level of fresh-cut produce during the shelf life. The fresh-cut radish samples treated with $CaCI_2$ and chitosan coating showed low values of electrical conductivity (EC) and significant differences were found between the treatments conducted ($P < 0.05$) at the end of

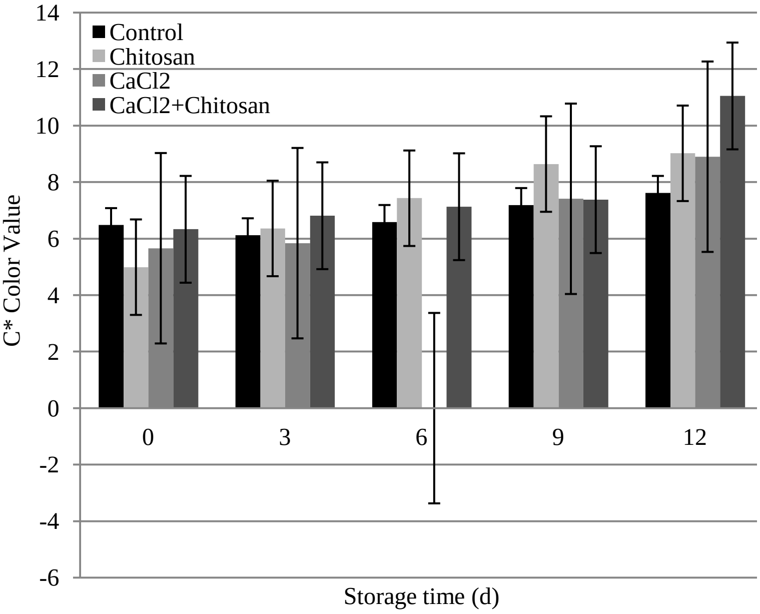

Fig. 5. Changes in the chroma color values of fresh-cut radish slices

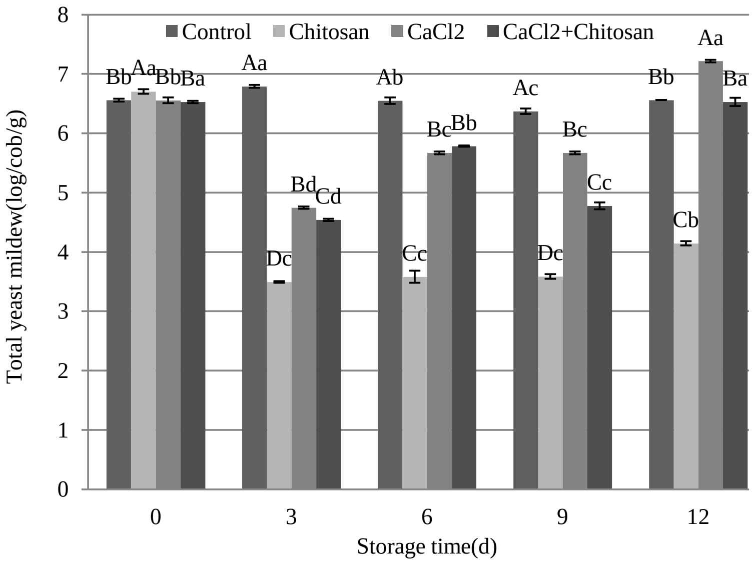

Fig. 7. Changes in the total yeast count in the mildew of fresh-cut radish slices

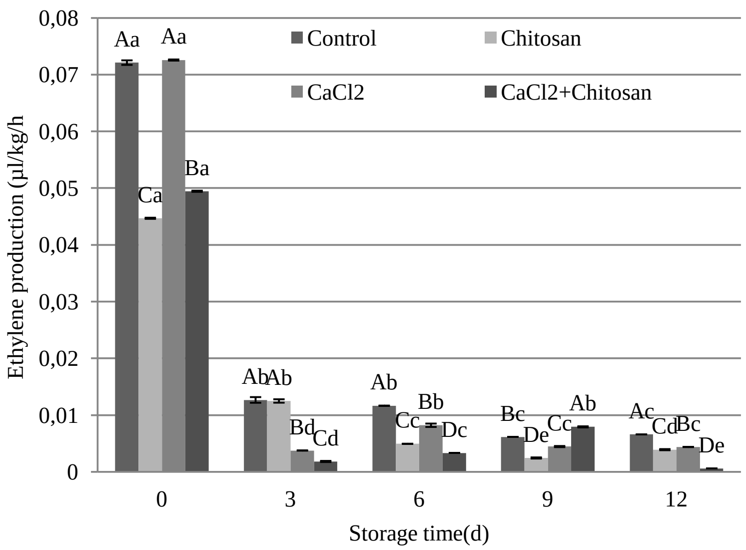

Fig. 6. Changes in the ethylene production rate of fresh-cut radish slices

levels at the end of storage.

4. Color Determination

The color of fruits and vegetables is the first quality parameter to be considered by consumers when buying, and is critical to the acceptance and purchase of the product. Therefore, different color indexes are used for a detailed description of this quality parameter. Chroma (C) values, which are color quality indices in this context, are characterized by internal and external color values of fruits and vegetables. As a result, these indexes are used as a parameter in the ripening, preservation and storage of fruits and vegetables (*Goyeneche et al., 2014*).The chroma color value of the fresh-cut radishes examined was around 6 at the begining of storage (Fig. 5). However, this value increased during storage and the $CaCI_2$+chitosan treated groups exhibited the highest C color value of 11 compared to the other groupd (Fig. 5).

5. Ethylene Production Rate

Ethylene production levels affect the shelf life of many fruits and vegetables. Even very low amounts of ethylene exerst effect on the maturation and aging of many fruits and vegetables. For this reason, ethylene is a critical factor in the shelf life of fruits and vegetables, and is largely caused by the ripening of fresh products and the loss of freshness. The prevention or suppression of ethylene production is necessary to extend the shelf life. Significant statistical differences were found in ethylene prodution rates between the control and treated radish slices during storage (Fig. 6). The ethylene production of fresh-cut radish samples approximated to 0.07 (µl/kg/h) at the begining of storage. However, the ethylene production decreased to approximatelz 0.01 (µl/kg/h) during storage storage. However, the lowest ethylene production value was recorded in the $CaCI_2$+chitosan treated samples at the end of storage.

6. Microbiological Analysis

The outer surfaces of fruits and vegetables may be contaminated with various mesophilic microorganisms and coliform bacteria, as they come into contact with soil, irrigation water, packaging facilities and many different places during the growth period (*Jovanović et al., 2016*). Yeast and molds act as hidden or strong parasites, depending on plant resistance, ambient conditions and competing microflora (*Goyeneche et al., 2015*). When plant resistance decreases after harvesting, they show an extreme development and lead to a rapid deterioration of the plant (*Goyeneche et al., 2015*). $CaCl_2$ and chitosan strengthen the structure of the cell wall and prevent the deterioration of fruits and vegetables after harvest and thus provide a protective barrier for fruits and vegetables (*Liu et al., 2016*).

7. Sensory Analysis

The coating and $CaCI_2$ treatments showed better taste and aroma sensory quality than other treatments. The panelists did not taste any off -odors in the fresh-cut radish samples presented (Fig. 8).

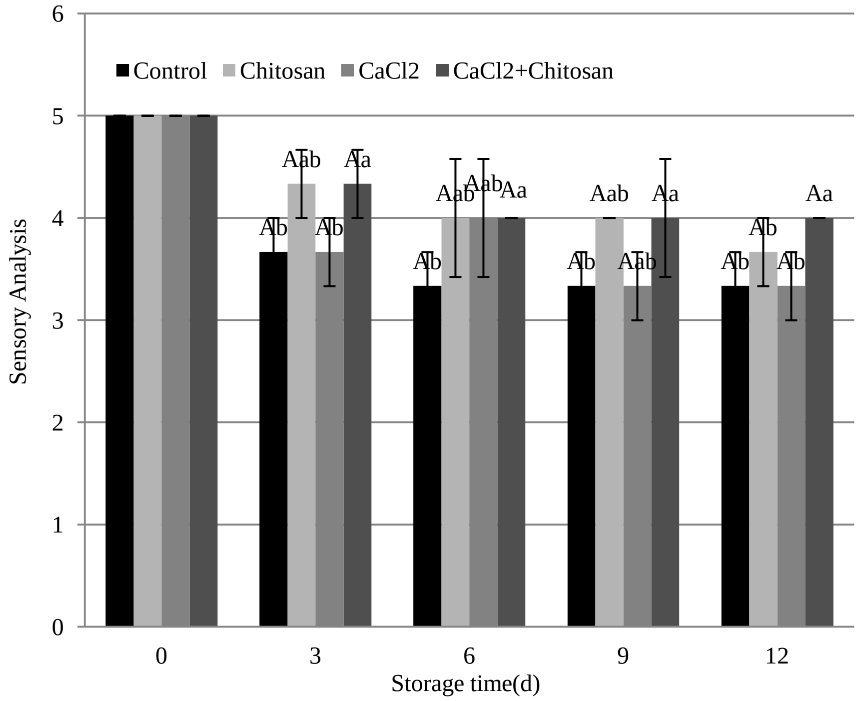

Fig.8. Changes in the sensory parameters of fresh-cut radish slices

CONCLUSION

The shelf-life of fresh-cut radishes can be prolonged with $CaCI_2$ and chitosan treatments. There are several studies that include postharvest coating treatments that can be applied to enhance the quality, storage and shelf life of radishes in the literature. The present investigation showed the use of chitosan coating and $CaCI_2$ treatments on fresh-cut radishes. Chitosan coating treatments and $CaCI_2$ were found to improve the shelf life of radisdhes. Coatings provide a semi-permeable barrier on the coated product, which decreases the O_2 and CO_2 exchange between the coated product and the environment and suppresses the ethylene production rate and mass loss decline in fresh-cut radishes during storage. $CaCI_2$ exerted a significant impact on the firmness and EC membrane integrity. Chitosan coating and $CaCI_2$ treatments prevented the loss of quality by preventing water and fimness loss. To conclude, we suggest that chitosan and $CaCI_2$ treatments do not only favor the quality of minimally processed fresh-cut radishes, but also reduce the microbial growth and fruit tissue decay. Furthermore, these treatments can be applied to freshly harvested radishes when required. The effect on the other quality parameters of the fruit needs to be assessed in future research. On balance, it was found that calcium chloride + chitosan applications contribute significantly to the preservation of the physical properties of fresh-cut radishes (mass loss and tissue). The quality losses of radishes, caused by mass and firmness losses, were hindered for a longer period due to the application of calcium chloride. The application of calcium chloride and chitosan is low-cost, thus can be easily applied by fruit and vegetable producers in practice.

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