Application of heat treatment, edible coating and chemical dip as postharvest treatments for the conservation of fresh-cut vegetables

Aplicación de tratamiento térmico, recubrimiento comestible y baño químico como tratamientos poscosecha para la conservación de hortalizas mínimamente procesadas

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Abstract

The fresh-cut vegetables consumption is increasing in worldwide since its foray in the early 90s. The international association of fresh cut products, reported sales in 2000 of 12 billion dollars. The interest in feed quickly and healthy, has stimulated the development of vegetable fourth range, however their high metabolic activity reduces its stability and shelf life. It has promoted the adoption of technologies for minimally processed products that give them longer life and ensure the reduction of postharvest losses. In this research evaluated the effect of 3 postharvest technologies on the respiration intensity and general sensory quality of six freshcut vegetables broccoli (*Brassica oleracea var. Italic*), cauliflower (*Brassica oleracea var. Botrytis*), zucchini (*Cucurbita pepo L.*), celery (*Apium graveolens*), carrot (*Daucus carota*) and chayote (*Sechium edule*). The experimental design was applied in a randomized complete block; blocks made by each of the vegetables and the response variables respiration rate and general sensory quality. For the edible coating was used low methoxyl pectin 2%, 1% of carnauba wax, 1,5% glycerol and 0,05% ascorbic acid; the heat treatment was 60 °C for 2 min, adding 0,25% ascorbic acid, 0,5% citric acid and calcium chloride 0,025%; the chemical dip was carried out with a solution of 0,5% citric acid, ascorbic acid 0,05% and calcium chloride 0,05% and one control. The rate production of CO_2 was measured by the static method, monitoring the gas composition of the headspace for 24 hours at 8 °C and relative humidity of 90%, the sensory evaluation of color, aroma, crispness objectionable taste were sensory characteristics taken into account in assessing the general quality of each vegetal, which was performed with a panel of seven trained judges. It was concluded that the heat treatment and edible coating, allowed the vegetables retain the sensory quality. Statistical analysis showed no significant differences from control ($p<0.05$). Respiration rate decreased for celery, broccoli, chayote, cabbage and carrot when applying heat treatment. The postharvest treatments were found to be a viable alternative for the conservation of fresh-cut vegetables.

Key words: Postharvest technologies, respiration, sensory properties, vegetables.

Resumen

El consumo creciente ha estimulado el desarrollo de los vegetales cuarta gama o mínimamente procesados. Actualmente, se promueve el uso de tecnologías aplicadas a estos productos que les brinden mayor duración y garanticen la reducción de pérdidas poscosecha. En esta investigación se evaluó el efecto de tres de estas tecnologías poscosecha sobre la intensidad de la respiración y la calidad sensorial general de las hortalizas mínimamente procesadas: brócoli (*Brassica oleracea* var. Itálica), coliflor (*Brassica oleracea* var. Botrytis), zucchini (*Cucurbita pepo* L.), apio (*Apium graveolens*), zanahoria (*Daucus carota*) y chayote (*Sechium edule*). Para el recubrimiento comestible se utilizó pectina de bajo metoxilo (2%), cera carnauba (1%), glicerol (1.5%) y ácido ascórbico (0.05%). El tratamiento térmico se hizo a 60 °C durante 2 min, con adición de ácido ascórbico (0.25%), ácido cítrico (0.5%) y cloruro de calcio (0.025%). El baño químico se realizó con una solución de ácido cítrico (0.5%), ácido ascórbico (0.05%) y cloruro de calcio (0.05%). La tasa de producción de CO_2 se midió por el método estático, monitoreando la composición de los gases del espacio de cabeza durante 24 h a 8 °C y humedad relativa de 90%. La evaluación sensorial de color, aroma, crujencia y sabor objetable fueron las características organolépticas tomadas en cuenta para evaluar la calidad general de cada vegetal, la cual fue realizada con un panel de siete jueces previamente entrenados. Se utilizó un diseño de bloques completos al azar, siendo los bloques cada uno de los vegetales y las variables de respuesta la tasa de respiración y la calidad sensorial general. Se encontró que el tratamiento térmico y el recubrimiento comestible permitieron que los vegetales conservaran la calidad sensorial. El análisis estadístico no mostró diferencias significativas respecto al control ($P > 0.05$). La celeridad de la respiración disminuyó en el apio, el brócoli, el chayote, la coliflor y la zanahoria, cuando se aplicó el tratamiento térmico. Los tratamientos poscosecha se mostraron como una alternativa posible para la conservación de hortalizas mínimamente procesadas.

Palabras clave: Hortalizas, propiedades sensoriales, respiración, tecnologías poscosecha.

Introduction

The consumption of minimally processed vegetables is increasing since its incursion in the early 1990s. The countries responsible for leading the growth rate of the sector have been Italy, USA, and the UK (IFPA, 2000). Interest in healthy food and easy consumption has promoted the creation of new technologies such as minimally processed fresh products (Santos *et al*., 2012). However, the shelf life of these products is limited due to its perishability and for the physical, chemical and physiological changes that occur frequently (Arts and Allende, 2005). The main symptoms of deterioration include changes in texture, color, rapid loss of nutrients and microbial growth (Nguyen-the and Carlin, 1994). Reducing losses in processing requires the adoption of new technologies to provide greater stability of sensory and nutritional characteristics during storage time (Ragaert *et al*., 2004). In order to obtain healthy products, with high nutritional value and good organoleptic quality, alternatives have been generated to improve the utilization of the vegetables, with the minimum incidence of damage, at the level of markets for fresh consumption (Flores, 2000). For this technologies have been proposed aimed to know the techniques for postharvest conditioning of minimally processed vegetables, good agricultural practices (GAP) and good manufacturing practices in post-harvest (GPP) in order to ensure the reduction of losses during the production process (Aguayo *et al*., 2001; Teullado *et al*., 2005). In reply to the demand for this type of food, techniques have been developed for the minimal processing involving a series of unitary operations that allow extending the life of the vegetables without altering the nutritional and sensory characteristics (Cano, 2001).

Various techniques have been identified and studied to extend the life of these vegetables: cooling, disinfection, ethylene absorbers, radiation, edible coatings, immersion in chemical baths, modified and controlled atmospheres, mild heat treatment and ultraviolet radiation (UV-C). The positive reaction to one or more treatments depends on the vegetable matrix being employed, being necessary to carry out studies to identify what is the sequence of treatments necessary to obtain a synergistic effect and thus produce a barrier that allows extending the life of minimally processed fruits and vegetables (Arts and Allende, 2005; Bico *et al*., 2009;

Denoya *et al.*, 2012; Leistner and Gould, 2002).

In the above mentioned treatments the most widely used is the chemical bath, which comprises adding an aqueous solution of organic acids in combination with calcium, magnesium or sodium (Martin *et al.*, 2007). These compounds exert greater control of the pH in the food to limit the activity of microorganisms, which in combination with low temperatures can control growth and development, prolonging the shelf life of the plant material (Diaz *et al.*, 1999). In relation to calcium salts it has demonstrated its ability to restore the firmness of tissues at the level of the middle lamella of the cell wall and promote the formation of calcium pectates to strengthen the textural strength of fresh tissue (Luna-Guzmán and Barrett, 2000; Soto and Yahia, 2002).When organic acids and calcium salts are combined, results are obtained as the reduction of changes in color, flavor and texture while maintaining the organoleptic quality and freshness of minimally processed vegetable for up to seven days in refrigerator (Mendez, 2008; Quevedo *et al.*, 2005; Yahia and Ariza, 2001).

Mild heat treatment, in combination with organic acids and calcium salts are a technology that is currently being widely studied for use in minimally processed vegetables, thanks to its effect in reducing enzymatic browning and decreased loss of firmness (Arts and Allende, 2005, Alegria *et al.*, 2012).

Edible coatings are one of the most studied technologies in the processes of conservation of minimally processed vegetables, and have been used successfully in pear, garlic, apple, papaya, carrot, strawberry, blackberry and loquat among others (Oms-Oliu *et al.*, 2008; Maia *et al.*, 2008; Baldwin *et al.*, 1996; Brazil *et al.*, 2012; Li and Barth, 1998; Restrepo, 2009; Ramirez, 2012; Márquez *et al.*, 2009). This technology aims to reduce the migration of moisture, oxygen, carbon dioxide, flavors and lipids, as well as serving as a carrier for additives such as antioxidants, antimicrobials, flavoring and coloring, which allows improving the mechanical integrity and promotes more suitable characteristics for the food.

Edible films and coatings are made from natural biopolymers of high molecular weight that provide a macromolecular matrix with high cohesive strength. The types of macromolecules that are used for this purpose are hydrocolloids, proteins, polysaccharides which, because of its hydrophilic nature, are very sensitive to water. Other major components in the formulation are lipids, plasticizers, emulsifiers, surfactants, agents for compounds of controlled release, antioxidants, etc., so it comes to multicomponent formulations (Gennadios, 1996).

The objective of the research was to evaluate different postharvest treatments for conservation of minimally processed vegetables, with the use of heat treatment, edible coating and chemical bath spray.

Materials and methods

Plant Material

The plant material was purchased in the Wholesale Central the department of Antioquia (Colombia). The vegetables used were: Broccoli (*Brassica oleracea* var Italica.), cauliflower (*Brassica oleracea* var botrytis.), zucchini (*Cucurbita pepo* L.), celery (*Apium graveolens*), carrot (*Daucus carota*) and chayote (*S. edule*). The treatments were applied in the Fruit and Vegetable Laboratory of the Universidad Nacional de Colombia at Medellin and the INTAL Foundation.

Thermal treatment solution

This solution contained calcium chloride (0.025%), citric acid (0.5%) and ascorbic acid (0.25%) previously dissolved in distilled water. Before immersing the vegetables, the solution was kept in a thermostatted water bath brand Memmert® model WNE 14 (USA) At 60 °C for 30 min (adapted from Loaiza *et al.*, 2003).

Edible coating

As a main matrix for the preparation of edible coating, low methoxyl pectin (2%), glycerol (1.5%) as plasticizer, carnauba wax (1%) as water vapor barrier (Restrepo, 2009), ascorbic acid (0.05%) as an antioxidant and distilled water were used. These components were dissolved in distilled water at 70 °C with magnetic stirring at 700 rpm on a heating plate brand IKA RCT BS1 model, a process that took 15 min to achieve homogeneity. This edible coating was stored refrigerated at 8 °C (adapted from Márquez *et al.* (2009).

Chemical bath

It was prepared in distilled water in which ascorbic acid (0.05%), citric acid (0.5%) and calcium chloride (0.05%) were dissolved. This solution was applied over the vegetables with a manual spray brand Swipe®, Motor Foam model (adapted from Garcia, 2008).

Methodologies

The vegetables were selected based on the similarities of shape, size and absence of external damage. Once washed and disinfected by dipping for 5 min in a solution containing dioxy-san 0.25% v/v, the vegetables were cut manually. The following treatments were separately applied for each type of vegetable, according to the preliminary tests: edible coating (RC), heat treatment (TT) or spray chemical bath (ASP), plus a control treatment. The edible coating was applied by immersing the vegetables for 2 min and in solution and drying in forced air circulation using a fan Samurai® with a flow rate of 140 m^3/min at a temperature of 18 ± 2 °C (adapted from Brazil *et al.*, 2012). For the application of the heat treatment, the vegetables were immersed in water at 60 °C for 2 min using a boiler thermostat bath DIES® brand, and then subjected to heat shock with water at 4 °C for 2 min. Vegetables were brought to a draining and drying process with air implementation similarly to as was done in the edible coating process, which was performed for 1 h before minimizing the water present on the surface of vegetables. The application of chemical bath was done by spraying the solution on the surface of each vegetable. The vegetables were taken to a drying process for 30 minutes using forced circulation air (adapted from Escobar *et al.*, 2014). Finally 100 g from each of the vegetables were packed in sealed glass containers (620 ml), using three replicates per treatment. Samples were stored at 8 ± 2 °C and 90 ± 5% relative humidity for 24 h, time at which the physicochemical and sensory analysis was conducted.

Experimental design

The experimental design used was a randomized complete block with three replicates, and for independent schemes each vegetable (broccoli, cauliflower, zucchini, celery, carrot and chayote). As treatments were included: thermal, chemical bath and edible coating and as response variables respiration and sensory attributes.

Respiration rate

The respiration rate of the vegetables was determined in 100 g from each of the vegetables, which were introduced in an airtight container of 620 ml with a rubber septum on the top. The gas concentration was measured every hour for 24 h using a Dansensor® GDP equipment. The samples were stored in a mixed refrigerator brand Lassele® model LRF - 1382 PC, keeping the system at 8 ± 2 ° C and a relative humidity of 90 ± 5%. Three replicates per treatment were used for each vegetable and the experiment was replicated three times. The CO_2 production rate was expressed as average percentage of carbon dioxide (Fonseca *et al.*, 2012).

Sensory quality

To measure the intensity of sensory attributes an unstructured scale 10 cm long was employed, which included characteristics of color, aroma, crispiness objectionable flavor and overall quality of the vegetables. These tests were performed every 24 hours by a trained panel of seven judges (Anzaldúa, 1994; Loyola *et al.*, 2007; Morgado *et al.*, 2013).

Data analysis

Simple analysis of variance (Anova) was done. Where significant differences were found; a comparison of means was done by the multiple range test ($P < 0.05$) with the statistical package Statgraphics Centurion version 16.0.07; also for CO_2 production rate the Pearson correlation (Montgomery, 2005) was applied.

Results and discussion

Respiration rate

The rate of CO_2 production of the vegetables studied was reduced when the **heat treatment** was applied (Table 1), which shows that it affects the speed of respiration of minimally processed vegetables. This result is consistent with findings from Wiley (1997) and Alegría (2012) who found that such treatment reduces or eliminates the enzymatic activity, which affects the rate of breathing. It is likely that this treatment partially affected enzymes as ACC synthase and ACC oxidase, which are involved in ethylene biosynthesis which, in turn, trigger the cascade of events involved in the acceleration of the rate of CO_2 production and therefore those related to the loss of color and texture. Miyazaki and Yang (1987) found that heating not only inhibits the endogenous production of ethylene but also the response to exogenous implementation of this compound.

The response of each vegetable, in terms of CO_2 production rate expressed in %, showed significant differences when the treatments were applied, especially chayote, vegetable that showed significant difference among treatments and control. For the heat treatment it was found that the rate of CO_2 production significantly decreased in all vegetables, except zucchini (Table 1).

This effect was probably due to the presence of citric acid and calcium chloride in the solution, since the former is associated with inhibition of the phosphofructokinase enzyme activity that catalyzes the phosphorylation of fructose 6-phosphate in 1,6- bisphosphate in the glycolytic pathway of respiratory metabolism, which induces a decrease in the rate of CO_2 production in the vegetables (Kato and Watada, 1997); Similar results were found by Fontes *et al.* (2008) in minimally processed apples. Calcium chloride, in turn, aids in reducing metabolic activity, which apparently is related to tissue stiffness which causes a blockage in gas exchange and regulates the action of ethylene on plants (Saftner *et al.*, 1998); while minimizing the respiratory rate and improving the firmness of some minimally processed vegetables (Luna-Guzmán *et al.*, 1999).

The **edible coating** did not

Table 1. CO_2 production rate (%) during 24 h for six minimally processed vegetables

	Vegetables					
Treatment	**Celery**	**Broccoli**	**Chayote**	**Cauliflower**	**Carrot**	**Zucchini**
Chemical bath by spraying	0.243±0.005 a*	0.476±0.004 a	0.152±0.006 a	0.411±0.090 a	0.351±0.002 a	0.172±0.002 a
Edible coating	0.239±0.005 ab	0.565±0.072 ab	0.190±0.003 c	0.578±0.003 c	0.297±0.018 c	0.200±0.009 bc
Thermal treatment	0.076±0.020 c	0.379±0.064 c	0.107±0.003 d	0.295±0.032 d	0.189±0.009 d	0.187±0.013 ac
Control	0.232±0.001 ab	0.510±0.004 ab	0.167±0.010b	0.458±0.007 ab	0.333±0.027 ab	0.189 ±0.016 ab

* Values within the same column followed by the same letters do not difer significantly ($P > 0.05$), control represents the control treatment and the numerical value represents the mean ± standard deviation

significantly affect the rate of respiration in celery and broccoli vs. control, but it did in chayote and cauliflower (Table 1), consistent with the results of Ghidelli (2012) who used a coating based on soy protein and found an increase in respiration rate. In carrot the application of edible coating produced a significant reduction of the respiration intensity relative to control, probably due to the formation of semipermeable barriers which decrease the diffusion of gases and thereby controls respiration (Carrasco *et al.*, 2002), result in concordance with that obtained by Vargas *et al.* (2006) who applied a chitosan based film and oleic acid in this same minimally processed vegetable, with an increased life and preservation of organoleptic characteristics.

Sensory quality

Figure 1 presents the effects of treatments on the descriptor overall quality for the vegetables studied, according to the grades of the panel of evaluators for flavor, color, texture and aroma. **Chemical bath** treatment by spraying reduced the overall quality in celery, broccoli and zucchini, especially for the flavor characteristic that match the results of Dong *et al.* (2000) when they used a mixture of ascorbic acid (0.5%), calcium lactate (1%) and 4-hexylresorcinol (0.01%) for preserving minimally processed pears.

When **edible coating** was applied

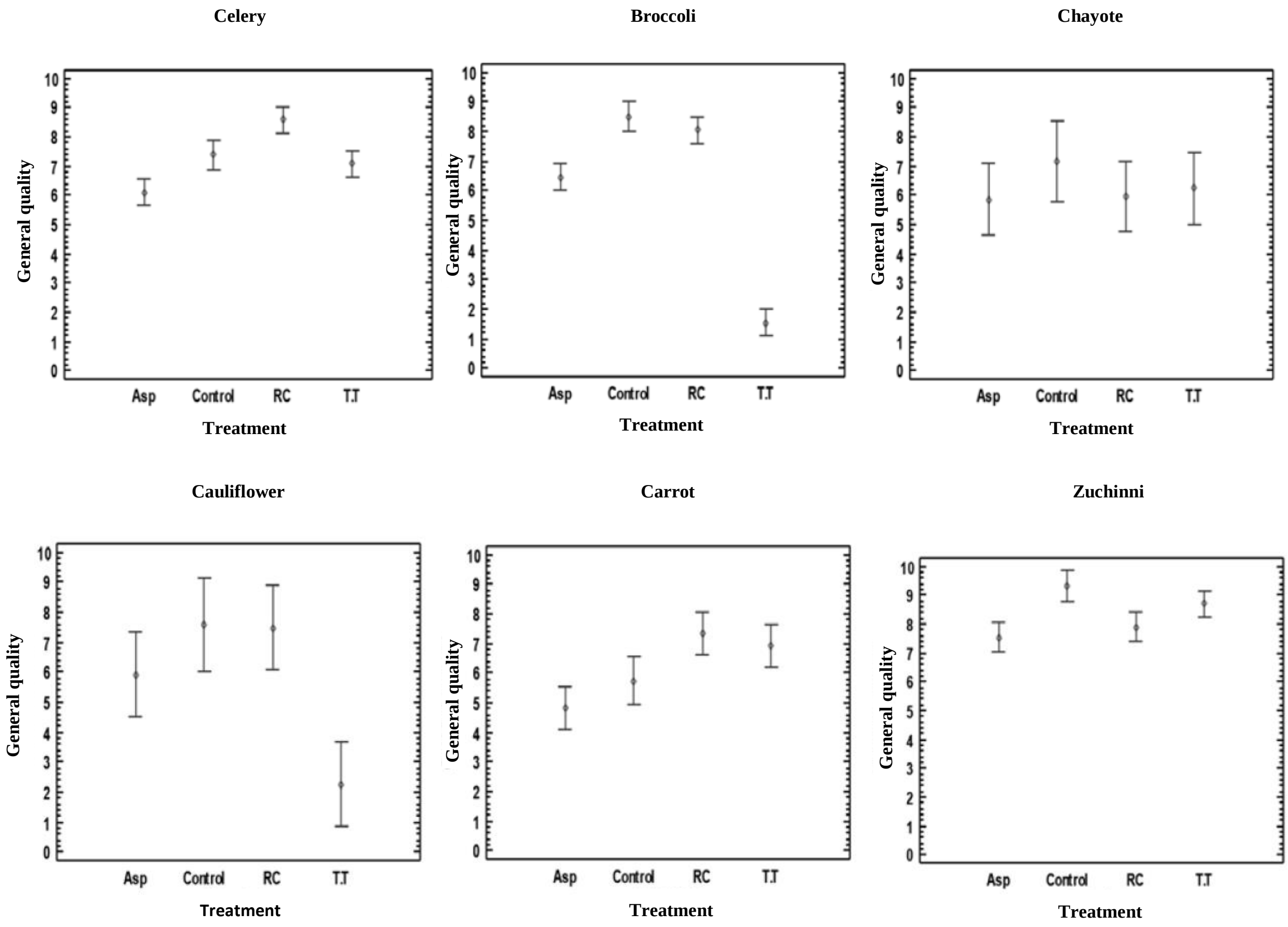

Figure 1. General sensory quality of minimally processed vegetables after 24 h of storage at 8 ° C ± 2 ° C and RH 90 ± 5%. The symbols represent the average value and the vertical bars represent ± standard deviation for a significance level of 95%.

Asp. = Chemical bath by spraying, RC = edible coating, TT = Thermal Treatment overall quality of celery and carrot was significantly better than the control ($P < 0.05$), being color and texture the sensory descriptors that presented the best characteristics, because this treatment reduced the water loss by transpiration in both vegetables (Baldwin *et al.*, 1995), which coincides with the findings of Howard and Dewi (1995) when they used Natural Seal © as surface coating of carrots. Avena *et al.* (1997) by applying an edible coating based on sunflower oil, corn starch, glycerol and sorbitol were able to maintain the color and reduce up to three times the loss of water vapor in minimally processed carrots, and similarly identified that the use of this type of coatings based on casein and acetyl monoglyceride increased the resistance to the passage of water vapor in minimally processed pieces of celery.

This coating treatment negatively affected zucchini quality due to the syneresis presented by the film, favoring the presence of a tacky texture. This effect is possibly due to the lack of use of lubricants and controlled release agents in the formulation (Baldwin *et al.*, 1995).

Heat treatment mainly affected the texture in broccoli and cauliflower because of the effect it has on the cell wall, especially on pectic substances, causing disruption of the structure and generates changes in permeability and flexibility of tissues (Aguilar *et al.*, 1999), Monzini *et al.* (1975) showed the softening of vegetables thermally processed by scalding and identified the deterioration in the color of vegetables, particularly the green hue, which is due to the change of chlorophyll pigments to pheophytins by heat and presence of organic acids originated by the structural breakdown generated by heat (and Marangoni Heaton, 1996; Kidmose *et al.*, 2002, Market and Aquino, 2005).

Conclusions

- The heat treatment decreased the speed of respiration in: celery 68%, carrot 44%, cauliflower 26%, pear vegetable 26%, broccoli 16%, compared with the respective control treatment. This treatment also affected sensory descriptors as the aroma and texture in broccoli and cauliflower, contributing to the overall loss of sensory quality of both vegetables: Other vegetables showed no significant differences regarding the control sample during the storage period and they retained their overall quality.
- The chemical bath by spraying did not affect the characteristics of minimally processed pear vegetable, decreasing by 9% its breathing intensity and maintaining a general sensory quality behavior similar to the control sample.
- The edible coating reduced by 11% the intensity of respiration for minimally processed carrots, also allowed to retain its overall sensory quality during storage time; On the contrary, in this treatment, celery showed better overall sensory quality that the respective control.
- Post-harvest treatments: thermal, edible coating and spraying with chemical baths proved alternative for the conservation of minimally processed vegetables, relatively simple, practical and economical.

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