



Effect of sucralose, fungicide and modified atmosphere on sensory attributes of cherries (*Prunus cerasus*) cv. Lapins from an organic orchard

Efecto de la aplicación de fungicida, sucralosa y modificación de atmósfera en atributos sensoriales de cerezas (*Prunus cerasus*) cv. Lapins, provenientes de un huerto orgánico

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ARTICLE INFO

Article history:

Received 30.06.2014

Accepted 25.10.2015

Keywords:

Modified atmosphere

Sensory evaluation

Condition of the fruit

Post-harvest

Original Research Article,

Food Science

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ABSTRACT

The effect of using sucralose, fungicide and modified atmosphere on sensory attributes of cherries (*Prunus cerasus* L. cv. Lapins) was evaluated in this study. Plastic bags with 2.5 kg cherries were stored at 0 °C under modified atmosphere (40% CO₂ and 60% N₂) for a period of 56 days. The experimental design consisted of three treatments: T₀, storage only under modified atmosphere, T₁, addition of a fungicide and storage under modified atmosphere and T₂, addition of a fungicide with 1% sucralose and storage under modified atmosphere. The fruits were evaluated according to their physical, chemical and sensory conditions after 14, 32, 42 and 56 days of refrigerated storage. The performed sensory evaluation showed no significant differences among treatments. However, sucralose-based treatment showed a slight positive influence on appearance and acceptability of the cherries. Parameters that determined the condition of cherries, such as pedicel dehydration, pedicel absence, bruises and decay, continued their development during the 56 days of storage, showing that the treatments were not effective to slow down fruit deterioration.

RESUMEN

En este estudio se evaluó el efecto del uso de sucralosa, fungicida y atmósfera modificada en los atributos sensoriales de cerezas (*Prunus cerasus* L. cv. Lapins). Cerezas en bolsas plásticas de 2,5 kg fueron almacenadas a 0 °C bajo atmósfera modificada (40% CO₂ y 60% N₂) por un período de 56 días. El diseño experimental consistió en tres tratamientos: T₀, almacenaje solo con atmósfera modificada, T₁, adición de un fungicida y almacenaje en atmósfera modificada y T₂, adición de un fungicida con 1% sucralosa y almacenaje en atmósfera modificada. Los frutos fueron evaluados según parámetros físicos, químicos y sensoriales luego de 14, 32, 42 y 56 días de almacenamiento refrigerado. Los resultados de la evaluación sensorial no exhibieron diferencias significativas entre los tratamientos. Sin embargo, los tratamientos con sucralosa tuvieron una leve influencia positiva en la apariencia y aceptabilidad de las cerezas. Parámetros que determinaron la condición de las cerezas, tales como; deshidratación del pedicelo, caída del pedicelo, empardeamiento y podredumbre, continuo su desarrollo durante los 56 días de almacenamiento, exhibiendo por ello que los tratamientos no tuvieron efecto en disminuir el deterioro de la fruta.

Palabras clave: Atmósfera modificada, evaluación sensorial, condición de la fruta, post-cosecha.

INTRODUCTION

The cherry cultivar *Prunus cerzus* L. cv. Lapins, is originally from Canada and it is the product of the crossing of two cultivars, Van and Stella. It has an early flowering and dark red fruits that are medium size, firm and tasty with 17.3% soluble solids. During season 2007/08, a total of 30,443 ha were certified as organic orchards in Chile, from these, about 6 ha were cultiva-

ted with cherries and 4,161 ha with others fruits such us; apple, grapes, kiwis, among others (ODEPA, 2008).

A total of 12,468 ha of cherries have been cultivated in Chile until 2009. One of the major cherry producing areas is the region of Maule, with an approximate area of 3,184 ha in 2001 representing over 50% of the cherries plantation in the whole country. However, production has increased steadily, reaching 5,485 ha in 2007 (ODEPA, 2008).

The technique of storing under modified atmosphere is commonly used as an alternative to prolong the post-harvest life of perishable products like fruits. Under normal conditions, fruits are affected and changed by atmospheric oxygen, aerobic microorganisms or a combination of those factors (Parry, 1995). Waxing or edible coatings is another technique currently being used in a complementary manner to the use of modified atmospheres. However, for an organically harvested fruit, the use of chemical synthetic waxes is somewhat limited, which can generate some degree of unfavorable interactions for the fruit. Therefore, in this paper, the hypothesis that sucralose application together with fungicide and storage under modified atmosphere would decrease the loss of sensory attributes of cherries cv. Lapins grown organically, promoting post-harvest conservation as a fresh fruit, was investigated. The percentage of damaged fruit due to pedicel dehydration, absence of pedicel, bruises and decay, as well as the sensory attributes such as taste, color, aroma, texture and acceptability of cherries for fresh consumption were evaluated.

MATERIALS AND METHODS

The study was conducted between December 2007 and January 2008 by Agribusiness Surfrut Ltda., located in the Quilvo sector, commune of Romeral, Province of Curicó, south-central Chile (34° 58'S, 71° 13'W). Temperature in the area ranges from a maximum temperature of 27.5 °C in January to a minimum of 4.1 °C in July (Santibañez and Uribe, 1993). Cherries cv. Lapins with a size between 22 to 24 mm donated by the company Santa Aurora Agrícola S.A., located in the town of Quilvo, commune of Romeral, were used. The bags "Fresh View" of 2.5 kg, with two micro holes and 45mm thickness for an optimum temperature of -1 to 0 °C were used. Also, a mixture of fungicide and bactericide, known commercially as "Pangermex", which is a yellow liquid, and sucralose (C₁₂H₁₉Cl₁₃O₈) 1%, as a fine white powder, were used. Cherries were harvested in the morning and taken to Surfrut Agro Ltda., being stored refrigerated at 0 °C and 95% RH. The fruits were treated with chlorinated water (50 ppm) at a temperature of 0 °C for 8 minutes. When the pulp temperature dropped to 4 °C, the fruit was stored in a chamber at a temperature of 0 °C and 95% RH in order to be processed and packed, removing pedicels and damaged fruits. The fruits were treated for the assays as follows: T₀: cherries without applying any product, were stored under modified atmosphere (40% CO₂, 60% N₂); T₁: application of a fungicide and organic bactericide, commercially known as "Pangermex" and storage under modified atmosphere (40% CO₂, 60% N₂); T₂: application of the same fungicide-bactericide preparation together with a layer of 1% sucralose, and storage under the modified atmosphere of 40% CO₂ and 60% N₂.

In order to create the modified atmosphere, a mixture of gases containing 40% CO₂ and 60% N₂ was injected into the "Fresh View" bag, using a packaging machine. The fungicide application was performed by preparing 54 mL of fungicide, diluted in 45 L of water in a plastic container, and immersing the fruits in the solution for 5 minutes.

To set the amount of sucralose to be applied, 15 kg of fruits were immersed in 45 L of water, with an added amount of 450 g of sucralose with the respective fungicide mixture. After the treatments were applied, the fruits were refrigerated for 56 days at Surfrut Agro Ltda., performing four measurements: on day 14 (December 18), day 32 (January 5), day 42 (January 15), and day 56 (January 29).

Condition parameters

One hundred fruits were randomly selected for the assays. They were separated according to visual damage, and every kind of damage found in the fruits was then expressed as a percentage of the total amount of sample.

Pedicel dehydration and pedicel absence

The evaluation of condition and absence of pedicel was performed visually, considering as dehydrated pedicel those with obvious changes from green to brown, including brown spots and redness along the pedicel.

Bruises and decay

The assessment of the degree of bruises and decay in the fruit was performed visually considering those fruits that were translucent, watery and had brown stains, as well as the presence of mycelium or odor on the surface.

Sensory attributes measurement

Sensory analysis was performed using structured and non-structured score sheets, with measurements at 14, 32, 42 and 56 days of refrigerated storage. Thirteen panelists evaluated the intensity of perceived attributes, like flavor, color, aroma and texture, using a non-structured score sheet. For the evaluation of appearance and acceptability, a structured score sheet with numerical scale was used, where each panelist evaluated on a hedonic scale ranging from 1 to 9 the cherries typified under the different treatments.

Experimental design

A completely randomized design in factorial arrangement 3x4 at a confidence level of 95% was used,

considering as factors cherries treatments and storage time. Homogeneous groups for means were determined according to Tukey's multiple comparison test at a confidence level of 95%.

RESULTS AND DISCUSSION

Condition related parameters

Pedicle dehydration

The stem of the cherry is a green tissue product that as a consequence of its high surface/volume ratio, tends to become dehydrated very quickly turning brown and thin. This phenomenon generates an aged fruit and reduces its commercial value (Candan and Calvo, 2005). With respect to fruit pedicel dehydration, treatments T_0 , T_1 and T_2 showed just significant differences in dehydration rate ($p < 0.05$) (Figure 1). There was a progressive increase in fruit pedicel dehydration in each one of the treatments; however, treatment T_2 showed the lowest percentage of fruit pedicel dehydration throughout the test (Figure 1).

Results showed that sucralose together with the fungicide application caused some level of protection to the pedicel, by creating some sort of "plastic cover" on the fruits. It is worth mentioning that sucralose is accepted for use as edulcorant in foods and organic products (Codex Alimentarius, 2014). It is likely that under a modified atmosphere with lower O_2 levels, ranging from 2% to 10%, the addition of sucralose is responsible for the achieved significant differences. Moreover, the combination of CO_2 and sucralose in treatment T_2 could decrease the pedicel dehydration, which is considered as a quality criterion in fresh cherries on the export market.

Pedicle absence

There were no significant differences among treatments T_0 , T_1 and T_2 for pedicel absence. When analyzing the time evolution of this phenomenon, a slight tendency to increase the pedicel absence was observed; however up to 42 days of storage, difference was not significant. The high percentage of fruit showing absence of pedicel may be due to the level of dehydration in the fruit pedicel presented. High level pedicel dehydration makes fruits turn brown, and fall off from its base (Valenzuela, 1998).

Bruise

This condition parameter is due to the occurrence of mechanical damage during harvesting and packaging. It is observed as depressions on the surface of the fruit, usually dark, causing deterioration in the appearance of the fruit (Figure 2).

Despite existing differences in the presence of bruises on fruits belonging to each treatment, the differences were not significant among treatments (Figure 2). During the storage time differences among treatments remained non-significant, although the batches stored for longer periods contained lower percentages of fruits with bruises (Figure 2). Therefore there was no reduction of bruise damage over time, but rather more susceptibility of the products affected by this damage to fungal attack, that remained hidden behind the bruise.

Decay

In the cherry, one of the main causes of postharvest fruit deterioration is fungi, mainly the species *Penicillium*, *Botrytis* and *Monilia*, which are responsible for

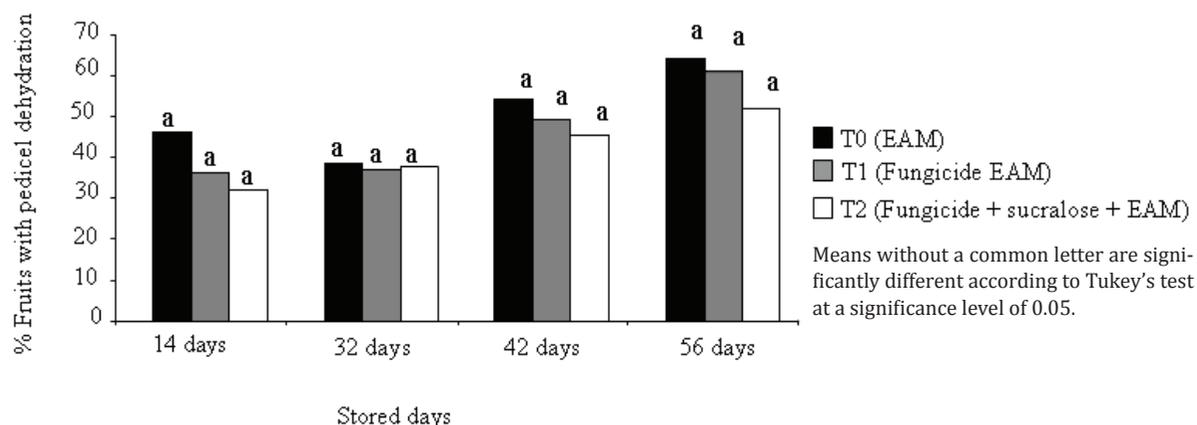


Figure 1. Evolution of cherry pedicel dehydration during 56 days of storage at 0 °C under modified atmosphere.

Figura 1. Evolución de la deshidratación pedicelar, en cerezas almacenadas durante 56 días a una temperatura de 0 °C bajo condiciones de atmósfera modificada.

the bluemold, gray mold and brown rot, respectively. This phenomenon can cause fermentation in the fruit and alter taste due to the presence of ethanol and acetaldehyde (Serrano *et al.*, 2005). Regarding the results obtained for the condition parameter, such as rot, there were no significant differences among measurements on the fruit for all the three treatment son days 42 and 56, respectively (Figure 3).

During storage, the onset of decay in treatments T₀, T₁ and T₂ was first observed after 42 days with values not exceeding 1% (Figure 3). The addition of CO₂ plus the addition of sucralose mainly in the treatment T₂ was enough to maintain the hygienic quality of the fresh cherries in this assay.

Parameters that determined the condition of the cherries, namely pedicel dehydration, absence of pedicel,

bruises and decay, did not stop the progression of decay during the 56 days of refrigerated storage. As a consequence, none of the treatments was completely effective in slowing down the deterioration of the fruit at this time.

According to Candan (2006), to reduce presence of pathogens it is crucial to wash with chlorinated water (100/150 ppm) and to apply preventive fungicides, which was the case for the fruits under treatments T₁ and T₂, where decay percentage was less than for the fruit subjected to treatment T₀, without application of fungicide "Pangermex".

The onset of decay was well controlled during the first 42 days of trial for the three treatments with the same degree of control. However, the appearance of fungi after 56 days of refrigerated storage could not be avoided in none of the treatments.

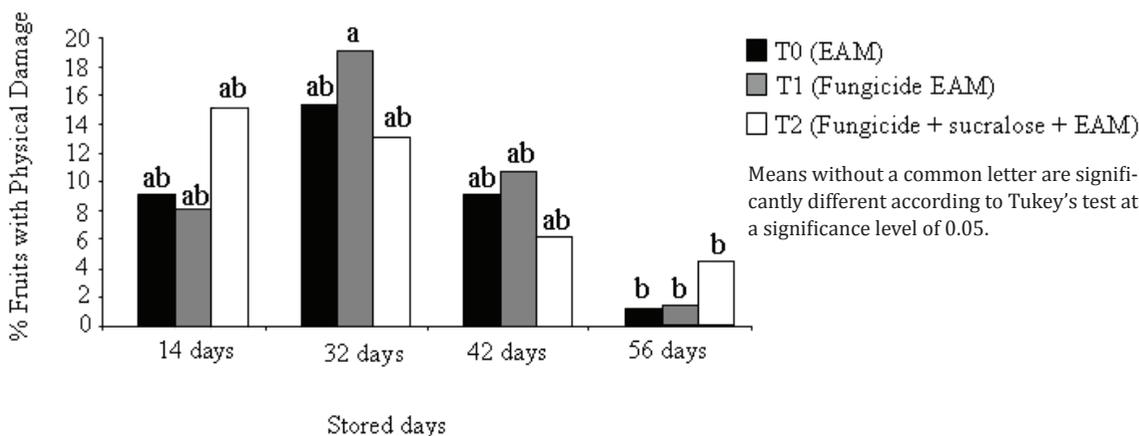


Figure 2. Evolution of parameter "machucón" in cherries during 56 days of storage at 0 °C under modified atmosphere.

Figura 2. Evolución del parámetro "machucón", en cerezas almacenadas durante 56 días a una temperatura de 0 °C bajo condiciones de atmósfera modificada.

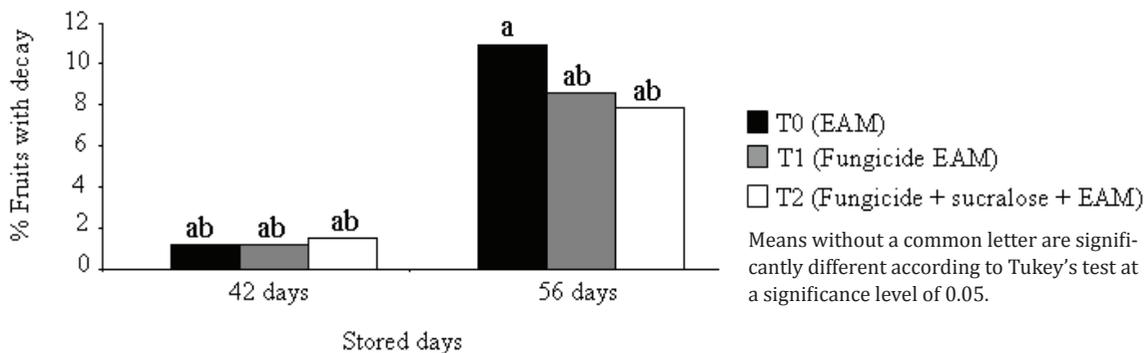


Figure 3. Evolution of cherry decay during 56 days of storage at 0 °C under modified atmosphere.

Figura 3. Evolución de pudrición, en cerezas almacenadas durante 56 días a una temperatura de 0 °C bajo condiciones de atmósfera modificada.

Assessments of sensory analysis

Taste

With respect to evaluation of taste, there were no significant differences between fruits of any of the three treatments and all the panelists gave a low evaluation regarding flavor of the fruit; a slightly bitter taste was perceived (Table 1).

During sensory evaluations on days 14, 32, 42 and 56 days of refrigerated storage, panelists noticed the addition of a sweetener in the treatment T₂. There were no significant differences in taste among the fruits of any of the treatments. However, panelists did not perceive any abnormality in taste, considering it as proper characteristic of the fruits. The amount of sucralose used in this assay was considered only for the protection of the fruits, acting as a physical barrier to diminish surface free water, which is a consequence of normal respiration. Sucralose in the added amount did not cause any change in the sensory attribute of taste, as reported by the panelists. Sucralose came from saccharose without the hydroxyl group which are replaced by chlorine in 4, 1' and 6' position. The chemical formula is 1,6-dichloro-1,6-di-deoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D-galacto piranoside (Linden and Lorient, 1996). Sucralose does not react chemically with other food component and could be stored for a year without any change in its flavor (Rodero *et al.*, 2009).

Good taste perceived by the panelists in the fruits of the three treatments can be related to low acidity, which in turn correlated with the decreasing content of organic compounds such as malic acid and ascorbic acid, responsible for acidic flavor of the cherries. During the course of maturation and the subsequent decrease of acids content, sugars increased, which caused the milder flavor and a proper balance of sweetness/acidity of the fruits (Torricella *et al.*, 2007).

Color

Color is an attribute that can be measured more easily than taste and smell, since the consumers do not need to taste or eat to compare quality, but rather judge by appearance (Lyon and Churchill, 1992). Sensory analysis of the attribute of color did not show any significant differences between the fruits of any of the treatments T₀, T₁ and T₂ (Table 2).

Values collected from panelist's responses were high. Fruits were predominantly dark red i.e. "dark", with values above average and scores around 7. Fruit color did not change significantly during storage, maintaining the dark red color highly valued by the panelists. It is likely that the addition of sucralose may have contributed to maintain the natural color of the cherries under an adequate control of relative humidity around the surface of the fruits. Sucralose does not affect the pulp of the fruits, since its protection is restricted only

Table 1. Scores of sensory analysis of taste for cherries stored at 0 °C under modified atmosphere.

Tabla 1. Puntuación de análisis sensorial del sabor en cerezas almacenadas a 0 °C bajo modificación de atmósfera.

Treatments	Storage periods							
	Day 14		Day 32		Day 42		Day 56	
T ₀	4.16	ab	1.44	ab	1.55	ab	3.52	ab
T ₁	4.39	a	2.52	ab	3.85	ab	2.71	ab
T ₂	1.86	ab	3.63	ab	0.65	b	1.92	ab

Different letters in the same row denote significant difference at a significance level of 0.05.

Table 2. Scores of sensory analysis of color for cherries stored at 0°C under modified atmosphere.

Tabla 2. Puntuación de análisis sensorial del color en cerezas almacenadas a 0°C bajo modificación de atmósfera.

Treatments	Storage periods			
	14 Days	32 Days	42 Days	56 Days
T ₀	10.00 a	8.44 a	9.74 a	8.52 a
T ₁	8.64 a	9.71 a	8.34 a	8.39 a
T ₂	8.93 a	7.95 a	9.89 a	7.44 a

Different letters in the same row denote significant difference at a significance level of 0.05.

to the surface and reducing the gas permeability of O₂ and CO₂, which are also responsible of the ripe fruits and together have influence in sensory attributes such as fruit color (Dinamarca *et al.*, 1989).

The panelists identified the attribute color, associated to a dark red color, with scores of 7, regardless of treatment applied and the time elapsed in the trial. This is consistent with the physical analysis of color, where both dark red tone and brightness loss in the fruits of all of the three treatments were determined. Loss of brightness detected only by instrumental color analysis caused a consequent darkening of the fruit.

Aroma

Compounds that contribute in defining the aroma of fruits are organic acids, sugars, bitter or astringent substances, and volatile aroma constituents (Gil and López, 2010). The latter, in greater or lesser amounts, form part of the volatile aroma compounds (Arthey and Ashurst, 1997).

Even though there were some noticeable differences among the fruits of the three treatments, aroma attribute values were statistically not significantly different. The panelist assigned relatively low values to this attribute, revealing a rather bland flavor of the fruit (Table 3).

As to the flavor attribute during storage changes were almost imperceptible during the first 42 days. A significant decrease in the value assigned by the pane-

lists is observed after 56 days for all treatment, confirming the poor aroma of the fruits.

Low fruit flavor perception by panelists is usually related to the presence of malic acid in the fruits. Throughout the trial, there was a decrease in malic acid content in the cherries of the three treatments. Malic acid in combination with other compounds such as sugars and volatile compounds, among others, are responsible for the aroma of the fruits, which would, in a certain way, explain the poor perception of the evaluated fruit aroma (Sancho *et al.*, 1999).

Texture

Texture of the fruit from treatments T₀, T₁ and T₂ were not significantly different. Panelists assigned similar scores to cherries texture of all three treatments, with an average score around 9.5 during the first 42 days of storage, indicating a marked trend towards crispy fruits, with a rating of 9-10 given by the judges (Meilgaard *et al.*, 1999) (Table 4). After 56 days of storage, degradation in texture was observed for all treatments.

In the final assessment, on day 56, the panelists detected deterioration in fruit texture and assigned a value below 7, which was significantly different compared to the rest of the measurements. Loss of fruit texture perceived by the panelists, coincided with physical measurements by pressure tests with value of 53 Durofel units.

Table 3. Scores of sensory analysis of aroma for cherries stored at 0 °C under modified atmosphere.

Tabla 3. Puntuación de análisis sensorial del aroma en cerezas almacenadas a 0 °C bajo modificación de atmósfera.

Treatments	Storage periods							
	14 Days		32 Days		42 Days		56 Days	
T ₀	2.94	ab	2.63	ab	2.95	ab	1.73	b
T ₁	4.58	ab	2.51	ab	2.35	ab	2.05	b
T ₂	6.19	a	2.65	ab	3.72	ab	1.55	b

Different letters in the same row denote significant difference at a significance level of 0.05.

Table 4. Scores of sensory analysis of texture for cherries stored at 0 °C under modified atmosphere.

Tabla 4. Puntuación de análisis sensorial de la textura en cerezas almacenadas a 0 °C bajo modificación de atmósfera.

Treatments	Storage Time							
	14 Days		32 Days		42 Days		56 Days	
T ₀	9.79	a	9.49	a	10.43	a	6.33	b
T ₁	9.37	a	9.45	a	9.50	a	6.35	b
T ₂	9.56	a	9.61	a	9.89	a	6.46	b

Different letters in the same row denote significant difference at a significance level of 0.05.

Appearance

Appearance evaluation of the cherries was conducted using a score sheet with a structured hedonic scale from 1 to 9 (Meilgaard *et al.*, 1999). There were generally no significant differences among treatments during the first 42 days of storage. Changes occurred after 56 days of storage (Figure 4), where the fruit from treatment T_0 was evaluated by the panelists with a score of 5 (“I do not like or dislike”), which was statistically lower than the score 7 (“like moderately”) assigned to the fruit of treatment T_2 .

During the time of the experiment, for all of the treatments applied, no significant differences in appearance were observed. There was a tendency to lower values assigned by the panelists, with an exception for the fruit from treatment T_2 that kept a more or less constant value throughout the trial (Figure 4).

Although there were no significant differences among treatments regarding fruit appearance, the panelists identified the best fruits in treatment T_2 , at all storage times studied, i.e. 14, 32, 42 and 56 days of storage.

Acceptability

The assessment of acceptability by the panelists, according to data expressed in the score sheet of a structured sensory evaluation with a hedonic scale from 1 to 9, showed no significant differences among the fruits for all treatments. Values fluctuated throughout the trial between 5 and 7, corresponding to “I do not like or dislike and like moderately” (Figure 5). The acceptability of the fruit of any treatment did not change significantly during storage. However, it could be observed that the fruit of treatments T_0 and T_1 showed during storage greater decrease in the acceptability value as-

signed by the panelists. On the contrary, the fruits subjected to treatment T_2 maintained the same assessment, 7 “like moderately”. This was supported by the addition of the sucralose, considered by the panelists to enhance the sensory attribute of taste. In general, it was observed that the panelists assigned a favorable evaluation to fruits belonging to treatment T_2 , in which sucralose was applied, achieving a higher acceptance in all assessments, when compared to fruits from the other two treatments. However, the above observations did not correlate with the attributes of the fruits evaluated by both physical and chemical methods, where measured characteristics remained unchanged in all treatments, showing no significant changes attributable to the use of sucralose with fungicide (Figure 5).

Panelists did not find differences in taste, color, aroma and texture in all treatments after 56 days of storage. The texture of the cherries was negatively evaluated on day 56 of refrigerated storage, regardless of treatment applied. The fruits were found to be soft and not crispy enough. Although statistically no significant differences were determined, the treatment with sucralose plus both fungicide and modified atmosphere, was considered by the panelists as the one that most positively influenced appearance and acceptability of cherries throughout the duration of the trial.

CONCLUSIONS

The use of sucralose as edible coating did not have a significant effect that would support its use in a complementary way to modified atmosphere packaging for post-harvest conservation of cherries cv. Lapins, since they could not slow down fruit aging.

Sucralose based treatment was considered by the panelists as the one that most positively influenced

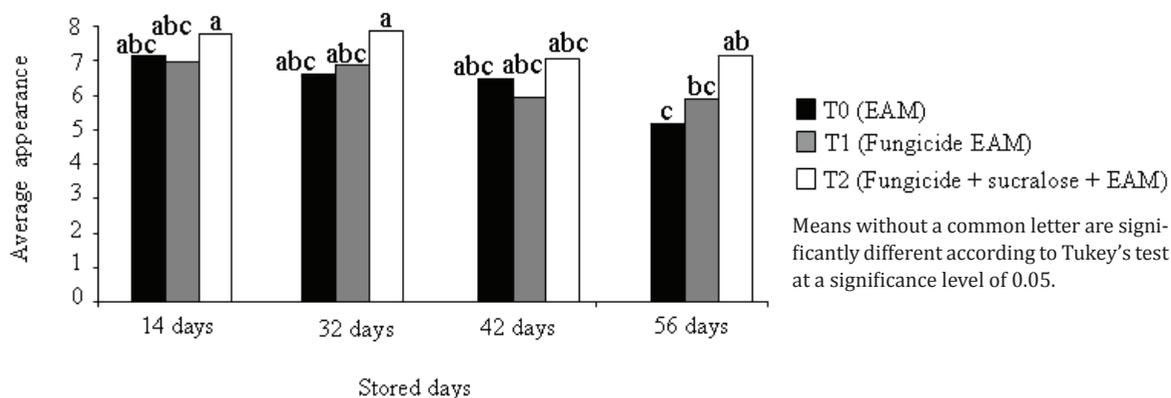


Figure 4. Evolution of cherry appearance during 56 days of storage at 0 °C under modified atmosphere.

Figura 4. Evolución del parámetro apariencia, en cerezas almacenadas durante 56 días a una temperatura de 0 °C bajo condiciones de atmósfera modificada.

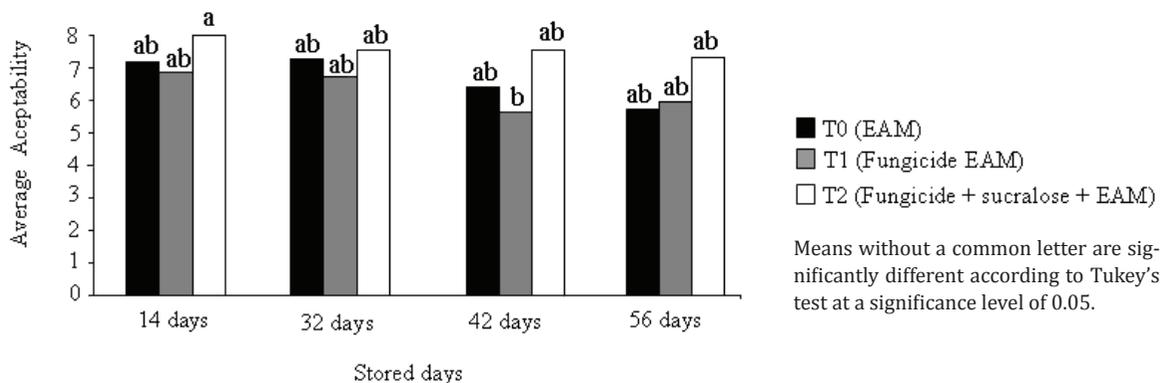


Figure 5. Evolution of cherry acceptability during 56 days of storage at 0 °C under modified atmosphere.

Figura 5. Evolución del parámetro aceptabilidad, en cerezas almacenadas durante 56 días a una temperatura de 0 °C bajo condiciones de atmósfera modificada.

appearance and acceptability of cherries. Parameters that determined the condition of the cherries such as pedicel dehydration, pedicel absence, bruises and decay, continued their development during the 56 days of storage, showing therefore no effective treatment in slowing down the fruit deterioration.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge the financial support from project "Programas de Innovación Territorial (PTI): Alternativas de manejo para mejorar la vida post cosecha de frutas y hortalizas orgánicas para el mercado fresco de la VII Región del Maule", PYT-2007-168, under the sponsorship of the Fundación para la Innovación Agraria" (FIA).

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