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Effect of sucralose and biostimulant on pre-and postharvest of blueberries (*Vaccinium corymbosum* L. cv. Elliot) under organic and conventional production systems

Efecto de la sucralosa y un bioestimulante en pre-y poscosecha de arándanos (*Vaccinium corymbosum* L. cv. Elliot) en sistemas de producción organico y convencional

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Abstract

Blueberries (*Vaccinium corymbosum* L. cv. Elliot) from organic and conventional sources were subjected to either a pre-harvest application with an organic biostimulant or a post-harvest coverage with sucralose. Fruits were assessed in terms of firmness, dry matter, ascorbic acid, soluble solids, sensory attributes and color, during storage at 0 °C and RH of 90%, for a period of 21 days. Each trial with three treatments: T_0correspondingto the control, $T_1$to an application of biostimulant,22 days before harvest, and T_2 to a post-harvest coverage with sucralose. Fruits were evaluated in sensory aspect, with the participation of thirteen panelists, on day fifteen after being harvested and stored. Evaluations of both maturity and quality parameters were performed on days 1,7, 14and 21post-harvest.Pre-harvest treatment with the organic biostimulant showed a higher variation in dry matter and soluble solids, but these variations are not significant. The group with a coverage of Sucralose showed a significant increase in fruit firmness. The best sensory evaluation, was given by the panelists to the organic farming. Fruit measurements, such as color, ascorbic acid and colorimetry showed no significant differences in the results.

Keywords: Blueberries, organic farming, bio stimulating, sensory evaluation.

Resumen

En el estudio, frutos de arándanos (*Vaccinium corymbosum* L. cv. Elliot) provenientes de ensayos; cultivos orgánico y convencional, fueron sometidos a una aplicación en pre cosecha de un bioestimulante orgánico y una muestra similar fue sometida a una cobertura de sucralosa en postcosecha, con el objeto de evaluar la firmeza, el contenido de materia seca, ácido ascórbico, sólidos solubles y atributos sensoriales, además del color, durante un periodo de almacenamiento de 21 días a 0 °C y 90% de HR (humedad relativa). Cada ensayo consistió en tres tratamientos: T_0 correspondiente al testigo, T_1 con una aplicación de bioestimulante 22 días antes de cosecha, y T_2 con una cobertura de sucralosa en postcosecha. La evaluación de los efectos de los tratamientos en los frutos incluyeron las condiciones organolépticas después de 15 días de almacenamiento con la participación de 13 panelista. el grado de maduración y la calidad los días 1, 7, 14 y 21 después de la cosecha. La aplicación del bioestimulante orgánico en pre cosecha favoreció la producción de materia seca y la concentración de sólidos solubles, siendo estas variaciones no significativas. La aplicación de una cobertura de sucralosa mostró un aumento significativo en la firmeza de los frutos. La mayor valoración sensorial fue obtenida con la aplicación de los tratamientos orgánicos. El color y la concentración de ácido ascórbico no variaron por efecto de los tratamientos.

Palabras clave: Arándanos, cultivo orgánico, bio estimulante, evaluación sensorial.

Introduction

World production of blueberries is about 70 000 ha, of which 65% corresponds to wild blueberry production, which is geared entirely to the industry, mainly frozen. The organic blueberry market is large, motivated by a surcharge on the conventional product. Organic production in Chile started just a few years ago and is still underdeveloped. However, there is a comparative advantage of organic over conventional farming, creating great potential for strong growth in this sector (Berries of Chile, 2008). Between harvest and consumption, there are important losses in quantity and quality that affect berries commercialization. In this regard, it is recommended application of a rapid cooling treatment on blueberries immediately after harvested, in order to extend their post-harvest lifespan. Seaweed is used as the basis of various agricultural products, being most important those with biostimulant action. Biostimulants are biological molecules that work by enhancing specific metabolic and physiological expression in plants (Crounch and Vanstaden, 1993). Jones and Vanstaden (1997) pointed out, as benefits, the improvement of root growth and increase of fruits and seeds harvested (Zurawicz, Mazny and Basak, 2004). Furthermore, these compounds increase the degree of fruit ripening (Fornes, Almela, Abad and Agustí, 2002). Sucralose is extracted from sugar, with selective substitution of three hydroxyl groups by three atoms of chlorine in the molecule of sucrose, generating a very stable molecular structure and about 600 times sweeter than sugar (Navia, Dordick and Khan, 1995). Sucralose passes unchanged through the body, it is not metabolize and it is eliminated after consumption. When applied with a 1% solution on blueberries, it creates a protective layer, decreases gas exchange of the fruit, reducing respiratory rate and achieving higher post-harvest life.

Hypothesis is that pre-harvest application of a biostimulant, and post-harvest bath solution of sucralose would allow to maintain for a period of 21 days at 0 °C with 85% R.H. freshness of blueberries cv. Elliot grown under two production systems, organic and conventional.

The objective of this research was to evaluate: (1) the effect of a biostimulant applied pre-harvestand a post-harvest bath solution of sucralose on blueberries from two forms of cultivation, organic and conventional, (2) the action of a biostimulant and addition of sucralose solution on quality indices (ascorbic acid content, dry matter and firmness of fresh fruit), (3) the contentof soluble solids in blueberries with the pre-harvest application of a bio-stimulant and the post-harvest addition of a solution of sucralose and (4) the sensory attributes, such as aroma, taste, texture and acceptability on blueberry fruits.

Materials and methods

This study was conducted in the province of Curico, south central Chile in the 2008-2009 season and lasted four months. The trial consisted of the evaluation of maturity parameters, indices of quality and sensory attributes of fruit of high bush blueberry (*Vaccinium corymbosum* L.) cv. Elliot, from two forms of cultivation, organic and conventional, after pre-harvest application of an organic biostimul ant and by adding a solution of sucralose to cover post-harvest fruits. Blueberries came from two commercial orchards located in the Los Ríos region, southern Chile, the first in a conventional culture located in the commune of Mafil, located inthe39°39' south latitude and 72°57'west longitude. The second organic garden, located in the commune of Lanco, located at 39°27 'south latitude and 72°43'west longitude. Both orchards have similar characteristics, 3 x 0.6 m planting distance, drip irrigation, date of establishment in 2005 and yield 8000 kg fruit/ha.

The blueberries were harvested in the early hours and selected for export in their own garden once full blue coverage, over 11°Brix, was achieved in the fruit. They were packed in175g buckets with perforated lid, immediately transferred to the storage facility and refrigerated. The storage facility and cold chamber were located at the Catholic University of Maule, Campus San Isidro, Los Niches road at 6 th km, province of Curico, Region del Maule, located at 35º01' South Latitude and 71° 11'west longitude. The fruit was stored at0 °C and relative humidity (RH) between 85% to 90% for 21 days. Formulation of biostimulant Bio Mar 15® withactive ingredients (AIs) seaweed extract (*Ascophy llumnodosum*) 3%, fulvic acids derived fromLeonardite 10% and humic acids derived from Leonardite 5%. This product was provided by the company OIKOS®, and applied 22 days before harvest of blueberries, with a 10 L pump back, using 100 mL of AIs mixed with water. The post-harvest addition of 1% solution sucralose was performed before entry into the refrigerated chamber by immersing the fruit in this solution for 20 seconds at 12 °C. After this time, the fruits were removed through a sieve and dried at room temperature for approximately 30minutes.

Treatments

T_0 was used as a control and two treatmentsT_1 and T_2, with three repetitions each was used for each form of cultivation, organic and conventional. T_1 treatment corresponded to the application of Bio Mar15®product with a dose of4 L/ha and

T_2 corresponded to the treatment of blueberries in solution of 1% sucralose.

Evaluations were performed on the day of harvest (day 0) and days 7, 14 and 21 after harvest, during cold storage. Each measurement was performed with three replicates, the experimental unit being 150 g of blueberries, using a total of 20 kg of conventionally grown fruit and 20kg of fruit grown organically, from 60 shrubs for every form of culture.

Methods and measurement parameters and sensory attributes

Measurement of soluble solids and color were made in Agrozzi agribusiness laboratory in the province of Curico. The sample was ground with a power grinder model Mini pimmer® and thenfilter through asieve of 0.02mmin order to extract whole blueberry pulp. Fruit soluble solids measurement, °Brix, was performed with an electronic refractometer model RX-5000 in which was applied a small amount of blueberry pulp sample. Ascorbic acid content and dry matter was analyzed by a ISO 9000 certified private laboratory as its own methodology.

Fruit firmness was assessed using a Durofel instrument, which gave the values of firmness in the range of 0 to100, with 100 being the strongest value. Color blueberries pulp was measured with a Hunter Lab Color Flex CX1225® colorimeter, which yielded results on the Hunterlab scale for the parameters of brightness (L*), shades of red to green(a*) and shades of yellow to blue(b*).

Sensory attributes were measured every15 days after the fruit harvested by 13 trained panelists using a sensory evaluation, which consisted of a structured tasting primer. This primer measured the appearance and acceptability, on a scale from1 to 9. Also they were trained using a non-structured tasting primer where the panelist assessed the perception of sensory attributes of fruits such as: taste, aroma and texture (StoneandSidel,1990).

For sensory evaluation a comparison was made completely at random among all treatments. It was analyzed both cropping systems independently; organic and conventional (Table1).

The selected experimental unit corresponded to 150 g of blueberries. The experimental design of the trial corresponded to a completely randomized design. Both cropping systems were analyzed independently. Each of the three treatments consisted of three replications and 4 after harvest evaluation times. Data were evaluated with an analysis of variance and significant differences were found, it was performed Tukey's multiple range test at a significance level of 0.05.

Table 1. Treatments distribution and techniques of cultivation organic or conventional.

Treatments	Description
T_1O	Organic, control
T_2O	Organic, biostimulant pre-harvest
T_3O	Organic, coverage with sucralose
T_1C	Conventional, control
T_2C	Conventional, bioestimulant pre-harvest
T_3C	Conventional, coverage with sucralose

Result and discussion

Fruit firmness

The post-harvest addition of sucralose, coupled with refrigerated storage time, caused significant effects on fruit firmness and quality characteristics of blueberries both organic and conventionally grown. In both cultivation alternatives, highest firmness of fruit was found in those subjected to treatment T_2, in which fruits were treated with sucralose coverage, consistent with similar results presented by Allan, Forney, Carbyn, and Nichols (2001).

Higher firmness values for treatment T_2 were a consequence of the coverage of sucralose present in the epidermis of the fruits. Coverage provokes an alteration in gas exchange, providing the blueberries with less weight loss and higher firmness. Besides, in blueberries new tendencies in storage such us a sucralose cover allowed to retain moisture better, thus the firmness of the fruit improved (Artes y Hernandez, 2004).

Fruit from both organic and conventional farming, presents the lower firmness on the first day of measurement, which corresponded to the harvest day (Figure1). The former is explained by the stress provoked by harvesting a fruit such as blueberry, which is very small. Such a stress is due possibly to the gas exchange process of

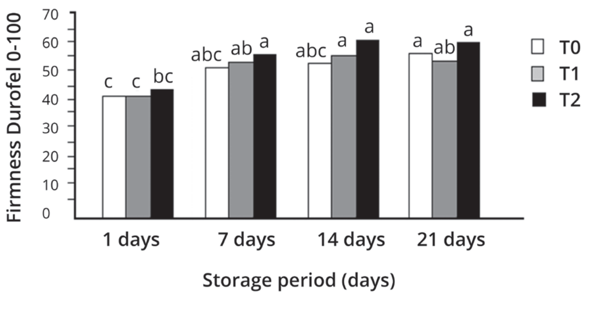

Figure 1. Postharvest treatment effect on blueberries firmness from organic production during storage period. Different letters on the values of each treatment represent significant differences.

respiration because of modified atmosphere and loss of water vapor.

Pre-harvest applications of organic biostimulant did not affect fruit firmness, regardless of the form of cultivation. The results of this study did not show significant differences between the fruit under the three treatments.

Dry matter content

Pre-harvest application of organic biostimulant and the post-harvest addition of sucralose, coupled with refrigerated storage time did not cause significant effects on dry matter (%) of organically cultivated blueberries. Fruit dry matter (%) increased significantly regardless of treatment applied from day 14 of stored. Under T_1treatment, fruit dry matter (%) reached higher values than those under going treatments T_0 and T_2. Pre-harvest application of organic biostimulant may increase dry matter (%) of fruits at harvest time, because they can increase the development, production and dry matter of fruits (Bietti and Orlando, 2003). Pre-harvest application of organic biostimulant, and the addition of sucralose during post-harvest, coupled with refrigerated storage time did not cause significant effects on(%) of dry matter in fruits of cultivated blueberries in a conventional manner (Figure2).

Fruits on which treatments T_1 and T_2 were applied, reached higher dry matter (%) withaverage values exceeding 17%, which would be more favorable to achieve higher post-harvest life of fruit and reach more distant markets (Valenzuela, 1999). This results are similar to that described by Redemacher (2004) for blueberries and plum fruits, after apre-harvest application of an organic biostimulant.

Soluble solids content

Pre-harvest application of organic biostimulant, and post-harvest addition of sucralose, coupled with refrigerated storage time did not cause significant effects on the soluble solids content, in fruits of blueberries cultivated in both organic and conventional manner. Blueberries evaluated with T_1 treatment showed higher values of soluble solids throughout the storage period, seemingly caused by the pre-harvest application of a biostimulant, which, by increasing the calcium content in the middle lamella, would homogenize sugars in the fruit. Additionally, this would allow the fruit to achieve a greater post-harvest life. [4]Blueberries from conventional farming and evaluated for treatment T_2 showed higher soluble solids values throughout all the storage period. However, it is important to consider that concentration effect of soluble solids due to water loss was not considered in this study.

Blueberries under all the three treatments increased the soluble solids content throughout the storage period (Collins, Clark and Magee, 1994). Fruit soluble solids obtained from this trial of 13.2°Brix, are associated with a better aptitude for conservation, which would translate into a better post-harvest life of fruits. In this way blueberries with °Brix values lower than eleven, are too immature and without sweetness, due to inadequate harvest of the fruit which has not reached addecuated physiologic maturity. This situation did not occur with fruit son this study (Figure 3).

Ascorbic acid content

Pre-harvest application of organic biostimulant, and post-harvest addition of sucralose, coupled with refrigerated storage time did not cause significant effects on the ascorbic acid content of blueberries organically cultivated.

Ascorbic acid is found in all plant cells, mainly in free form and probably bound to proteins. It is able to decrease the pH, besides it has a strong reducing power, without risk to health. Blueberries evaluated with T_1 treatment had higher ascorbic acid content than the other three treatments, but such an increment was not significant.

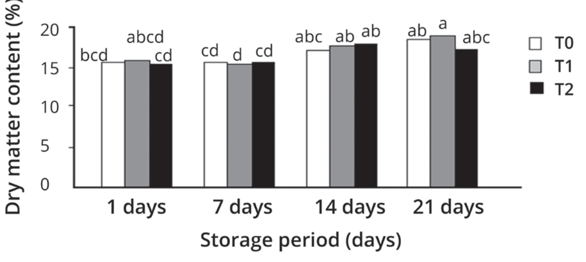

Figure 2. Postharvest treatments effect over blueberries dry matter content (%) from organic production during storage period. Different letters on the values of each treatment represent significant differences.

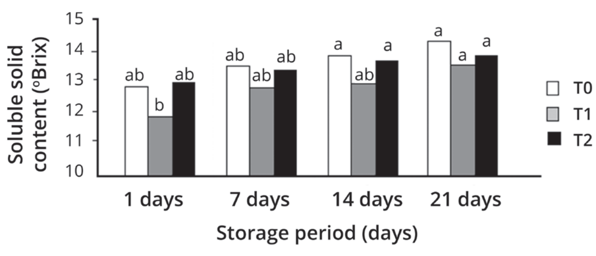

Figure 3. Postharvest treatments effect over blueberries soluble solid content (°Brix) from conventional production during storage period. Different letters on the values of each treatment represent significant differences.

The application of organic biostimulant based on seaweeds, fulvic acids and humic acids, would increase the vitamin C in blueberries, which is a nutritional advantage, due to the food antioxidant content. Blueberries evaluated with T_1 treatment had higher ascorbic acid contents, being the pre-harvest application of organic biostimulant the cause of this increment of vitamin C as a source of antioxidants and also an indicator of quality characteristic of blueberries (Allan *et al.*, 2001). The results obtained in this study regarding the ascorbic acid composition are similar to that found by Senser and Scherz(1999), who obtained a value of 18mg/100g (Figure 4).

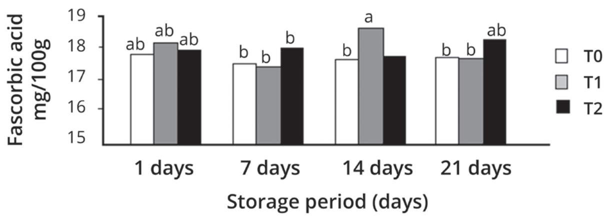

Figure 4. Postharvest treatments effect over blueberries ascorbic acid mg/100g content from organic production during storage period. Different letters on the values of each treatment represent significant differences.

Coloration of thefruit

Pre-harvest application of organic biostimulant and post-harvest addition of sucralose, coupled with refrigerated storage time did not cause significant effects on the color, a*red tones, on blueberries grown inorganic form (Figure 5). Color evaluation is crucial because it is performed before other sensory attributes, therefore maybe exclusive. The evaluation of color, a* value red tones, of the pulp subjected to all treatments showed a color as expected.

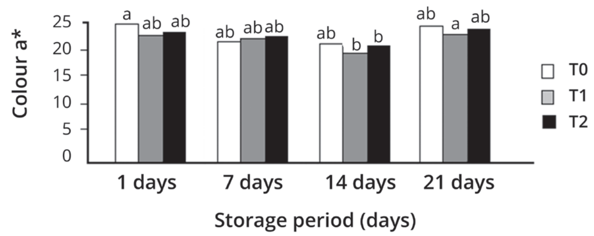

Figure 5. Postharvest treatments effect over blueberries a* red colour from organic production during storage period. Different letters on the values of each treatment represent significant differences.

Color is an important factor in assessing the quality of blueberries. This property is linked to maturation, presence of impurities, poor storage condition and early alteration by microorganisms. The pulp of blueberries showed values of a* red tones of 22 with a colorimeter, which is consistent with that described by (Sapers, Burgher, Phillips, and Jones, 1984). Blueberry color is given by the presence of anthocyanins that give the fruit its pigmentation. Blueberries for all treatments tested values for flesh tones a*23.1 on average. In this regard. This phenomenon occurs due to the stability, at low pH values, such as that of the fruits, of flavylium cation, which is present in the molecule. However, the change to dark reddish color could demonstrate the pulp color change, mainly non-enzymatic browning due to sugars and amino acids affected by the heat from the grinding of the sample (Somogy, Ramaswamy and Hui, 1996).

Sensory evaluation

Panelists evaluated sensory attributes such as taste, aroma and texture at 15 post-harvest days of the fruit. A comparison was made completely at random between all treatments and both farming systems, organic and conventional, were independently analyzed (Table2).

Table 2. Summary of organoleptic attributes in organic and conventional cultivation.

Treatments	Taste	Aroma	Texture
Organic farming			
T_1O	5.6 b*	7.1 a	5.9 a
T_2O	5.9 ab	7.6 a	7.2 ab
T_3O	6.3 a	8.1 a	6.6 a
Conventional farming			
T_1C	5.3 b	6.9 a	7.2 ab
T_2C	5.5 b	7.3 a	8.1 a
T_3C	6.8 a	6.8 a	7.6 a

* Average of sensorial evaluation at fifteen post-harvest days and storage of the fruit. Different letters next to the values represent significant differences (Tukey: 0.05).

Taste

This sensory attribute, measured 15 days after the trial, is associated with the feeling of human experiences when it is consumed a particular food or fruit. Acceptability of the fruit by consumers relies on this attribute (Stone and Sidel, 1993). With regard to measurements of the attribute taste during the sensory evaluation, in every form of culture, the panelists attribute greater value to the fruit subjected to treatments T_3O and T_3C, both based on a coverage with sucralose (Figure 6).

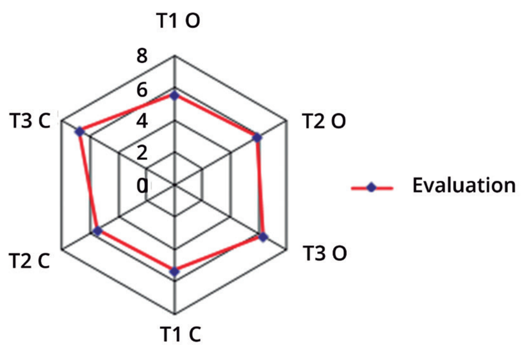

Figure 6. Average of taste attribute of blueberries according to the sensory evaluation realized at fifteen post-harvest days and storage at 0 ºC and 90% RH.

It was obtained significant differences (Table 2) between fruits from treatments with post-harvest application of sucralose for both forms of cultivation. This could be perceived by the panelists because they assessed as best the organically grown fruit.

Elliot cultivar has higher acidity than other blueberry cultivars, thus from the sensory point of view, citric acid is detected very rapidly in the tasting, provoking a strong impression (Anzaldúa and Morales, 1994). This acidity is masked by the sucralose coverage causing a greater pleasure by the panelists when eating the fruit.

Aroma

The fruit from each cultivation system subjected to different treatments, show no significant differences as to aroma attribute. However, higher values were reached for blueberries from an organic farming system (Table 2). Blueberry aroma comes from a variety of chemical compounds from the family of volatile aromatics. These components are quite soluble in water so it is difficult to separate them from the pulp (Prior *et al.*, 2001).

Texture

Texture is one of the most important sensory attributes for the possible product acceptance by consumers. Consequently, the best assessment of the texture can be done through the sensations experienced in the mouth (Stone and Sidel, 1993). The panelists rated better the texture of fruits subjected to treatmentsT_2 O and T_2C, both treatments had a pre-harvest application of organic biostimulant, and fruits from treatments T_3O and T_3C, both with post-harvest coverage with sucralose were rated as better as well. This result applies for fruits from both organic and conventional cultivation.

Panelists perceived more textured fruits in treatments T_1C,T_2C and T_3C,which were conventionally grown, however, these values are not significant (Table 2).

It could be delayed the softening of blueberries using covers. These provoke an alteration of gas exchange, which is reflected in a lower weight loss and fruit firmness (Mainland, 2002). Other author sindicate that use of coverage in small fruits such as blueberries, decrease drespiratory rate, reducing loss of water inside the fruit and thus the firmness (Rodriguez, Ramos, Pistonesi, Del Blanco y Agullo, 1998), so that, in this test, panelists found a more crispy fruit for those samples with these treatments.

Appearance

Fruit appearance, as evaluated by the panelists, considers all that is visually perceived from food, such as size, color, consistency and the presence of defects. Panelists described a better appearance to the conventionally grown blueberries. Within this system of production, fruits subjected to treatment T_2C reached the highest values of appearance. This treatment is a pre-harvest biostimulant application, the obtained values were not significant (Table 3). Regarding appearance, panelists did not find significantly differences between the fruits under the three treatments, both pre and postharvest, derived from both organic and conventional farming (Table 3).

Table 3. Appearance and acceptability in organic and conventional cultivation.

Treatments	Appearance	Acceptability
Organic cultivation		
T_1O	6.8 a	7.1 ab
T_2O	6.9 a	7.7 a
T_3O	6.9 a	8.1 a
Conventional cultivation		
T_1C	7.1 a	6.9 b
T_2C	7.5 a	7.3 ab
T_3C	7.4 a	8.3 a

* Average of sensorial evaluation at fifteen post-harvest days and storage of the fruit. Different letters next to the values represent significant differences (Tukey: 0.05).

Acceptability

The analysis of acceptability is used to determine whether the product will be rejected or accepted by its potential consumers. This assessment delivers the quantification of the magnitude of the acceptability of a product. During the sensory evaluation, panelists gave the same degree of acceptability to the fruits from the organic farming system, independent of the treatment applied in pre and postharvest.

The panelists gave the highest values of acceptability to blueberries under T_3C treatment from a conventional culture system, with an addition of coverage of sucralose. This result was statistically significant between the other treatments (Table3). These data correlate with those found in the taste evaluation where blueberries under T_3C treatment had higher values than the rest.

The cover age with sucralose retained better the properties of blueberries, thus reducing the alterations produced by the action of cold storage, temperature, relative humidity or even the food's biological activity itself (Catalá and Gavara, 2001). Similar results were found byWeber (2009), who mentioned that edible coatings provide a barrier to moisture and aromas, which can improve their sensory or nutritional properties for trading.

Fruit firmness from both types of cultivation, organic and conventional, showed significant increases with post-harvest coverage with sucralose (T_2 treatment). Fruit soluble content from both conventional and organic farming showed a positive trend during the 21days of refrigerated storage, reaching higher values (13.2°Brix) when the application of biostimulant was done during the pre-harvest period. Panelists identified better taste, aroma and acceptability of the fruit from organic sources under all treatments. Regarding appearance and texture, panelists gave a higher score to those fruits from the conventional culture system.

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