Blanching and antimicrobial mixture (potassium sorbate–sodium benzoate) impact on the stability of a tamarillo (*Cyphomandra betacea*) sweet product preserved by hurdle technology

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Abstract In a previous study, a stable tamarillo sweet product (TSP) was obtained by applying hurdle technology (low pH, reduction of water activity, sodium benzoate addition and stored at 4 °C, with oxygen and light protection). In order to improve the TSP shelf life, it was decided to employ a mixture of antimicrobial agents (sodium benzoate and potassium sorbate 50–50%) and fruit blanching. The phenolic compounds content, total monomeric anthocyanins of TSP, antioxidant capacity, microbial growth (aerobic mesophilic bacteria, molds and yeasts) and net color change were evaluated, during 63 days. The results showed that the use of blanched tamarillo and the addition of the antimicrobial mixture increased the TSP stability, in which the microbial counts were maintained below the limits established by the official food safety norms, without effects the antioxidant compounds and color.

Keywords Tamarillo · Antioxidant compounds · Blanching · Potassium sorbate–sodium benzoate

Introduction

Tamarillo (*Cyphomandra betacea*), also known as tree tomato, is a fruit that has been studied from different points of view by many researchers (Espin et al. 2016; Ghosal et al. 2013; Hurtado et al. 2009; Mwithiga et al. 2007; Ordoñez et al. 2010; Vasco et al. 2009; Villegas-Ruiz et al. 2012, 2013). It is a good source of antioxidant compounds (Ghosal et al. 2013), which are considered as potential reducers of risks in health problems, such as cancer and other chronic diseases. Tamarillo is a subtropical fruit, with high levels of production and consumption in South America. It is also cultivated and consumed in other regions, such as New Zealand, Spain, Mexico, India and Kenya, among others. The main way of consumption of tamarillo is as fresh fruit, but it is also used as an ingredient in the preparation of juice and desserts (Espin et al. 2016).

An alternative to preserve tropical fruits is the use of hurdle technology, which consists in the application of many factors at a moderate intensity level capable of delay the microorganisms growth (storage at refrigeration temperature, water activity reduction, low pH, antimicrobial agents addition, among others), in a way which gives an innocuous and stable product. This technique is able to preserve a great part of the nutrients available on fresh products, with minor modifications in sensory profile. Moreover, this technology has the benefit that can be applied with simple equipment and at a low cost (Leistner 1992).

Considering this, on a previous study, Villegas-Ruiz et al. (2013) employed tamarillo's natural low pH (3.7), combined with water activity reduction (0.9) through sucrose addition, and the use of sodium benzoate as antimicrobial agent. Also, the product was light protected by packing on black recipients and storage at 4 °C, to

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obtain a tamarillo sweet product (TSP), to be used as an ingredient to desserts, being able to be utilized disregarding the season of the year. This combination of preserving methods enabled the molds, yeasts and aerobic mesophilic bacteria counts of the product to endure 30, 42 and 57 days, respectively, within the specifications established by the Mexican Official norms for high-content sugar products (NOM-130-SSA1-1995). During storage, reduction in the antioxidant capacity, anthocyanins and phenolic compounds, has been partially attributed to the degradation caused by native enzymes activity (polyphenoloxidase and peroxidase) (Rossi et al. 2003; Sablani et al. 2010). In order to lessen the microbial growth, the addition of potassium sorbate (known as an antimicrobial agent with fungistatic capacity) in the TSP formulation, could delay molds growth and extend the TSP shelf life (Deuel et al. 1954).

Moreover, blanching is an efficient way to eliminate problems caused by enzymatic activity in fruits and vegetables. It consists on immersing in boiling water or on treating the vegetables with steam, during a few minutes, and after cooling them. Many studies have been developed evaluating the effect of blanching on antioxidant compounds. In this sense, it has been determined that it does not reduce the antioxidant content and even though, in some cases, it was increased. From this perspective, Srivastava et al. (2007) observed that heat treatment (85 °C, 2 min) applied on two types of cranberry did not affect neither the total content of anthocyanins and polyphenols nor the antioxidant activity. Meanwhile, Ziabakhsh Deylami et al. (2016) reported an anthocyanin retention near to 80% in mangosteen pericarp (*Garcinia mangostana*) blanched during 12 min at 90 °C. Likewise, Brownmiller et al. (2008) reported not change in the content of cranberry anthocyanins after blanching (95 °C, 3 min). On the other hand, Amendola et al. (2010) observed that the content of total phenolic compounds of red grape pomace in ethanol (pH 3–9), was increased after heating at 120 °C for 15 min. Additionally, Sablani et al. (2010) reported that blanching (95 °C, 2 min) of two varieties of blueberry (*Vaccinium corymbosum* L. vars. Duke and Reka) improved significantly the retention of anthocyanins, phenolic compounds and antioxidant activity of these fruits juices and purée. More recently, De Aguilar et al. (2015) noticed that anthocyanins and polyphenols of extracts of sweet potato pulp blanched during 10 min at 90 °C were notably increased.

Based on this, the aim of this study was to evaluate the effectiveness of adding blanching and potassium sorbate to the conservation factors employed in the study publish by Villegas-Ruiz et al. (2013) on the TSP physicochemical, microbial and antioxidant stability.

Materials and methods

Materials

Tamarillo fruits from Teziutlan, Puebla, Mexico (moisture 86.5%; soluble solids 10.5; pH 3.9; acidity 1.94% expressed as citric acid), sodium benzoate and potassium sorbate (Reactivos Meyer, Mexico City, Mexico) food grade, and standard commercial sucrose (Zafra S.A. de C.V., Mexico City, Mexico) were used.

Tamarillo properties

Humidity was determined by weight difference, after drying the sample in a vacuum oven, according to the method 920.151 of AOAC (2000). Water activity was measured using a hygrometer Aqualab Serie 3TE (Decagon Device Inc., USA). pH was measured by electrode direct immersion, employing a Orion 420A potentiometer (Orion Research Inc., USA), according to the method 981.12 of AOAC (2000). Acidity was determined by titration with NaOH 0.1 N and expressed as citric acid percentage, according to the method 942.15 of AOAC (2000). Soluble solids were determined using a manual refractometer (Atago Inc., USA), according to the method 932.12 of A.O.A.C. (2000) and were expressed as °Brix. Every determination was performed by triplicate.

Blanching

Tamarillo fruits (length 6.33 ± 0.52 cm; width 3.19 ± 0.42 cm) were immersed in boiling water (93 °C) and were drained after different treatment times (3, 6, 9 and 12 min). Later, the fruits were cooled with tap water, manually peeled and triturated.

Peroxidase activity

A 5 g blanched tamarillo sample was homogenized with 100 mL of cold phosphate buffer solution 1 M (pH 6.9). Then, supernatant was filtered and 10 mL were transferred to a test tube immersed on ice. At the same time, 2.9 mL of guayacol substrate (30 °C) were transferred to a spectrophotometer cell and using this substance as a reference, the equipment was calibrated at 470 nm. Immediately, 0.1 mL of the enzymatic extract was added. The test was carried out employing a spectrophotometer (UNICO, United Products and Instruments, Inc., USA), previously calibrated in kinetic mode, measuring every 10 s during 3 min. The obtained results were reported as enzymatic activity per milliliter of enzymatic extract, calculated according to the next equation:

$$\frac{EAU}{mL} = (m * 60 * d) / V \quad (1)$$

where m is the absorbance slope versus time curve (in absorbance/s units); V , enzymatic extract volume involved in the reaction (mL); d , dilution factor; EAU, enzymatic activity units.

TSP Elaboration

Four types of TSP were elaborated: tamarillo without blanching and without antimicrobial mixture (AM); tamarillo without blanching and with AM; blanched tamarillo and without AM; and blanched tamarillo and with AM. At every sample, tamarillo was triturated with an immersion blender (Ostermod 2616, Sunbean Mexicana, Mexico) and mixed with sucrose. Products without AM contained 48% of triturated tamarillo and 52% of sucrose; and sample formulations with AM were 47.9% tamarillo, 52% sucrose and 0.1% AM mixture (50% potassium sorbate and 50% sodium benzoate). TSP were distributed in 130 g portions, in polypropylene recipients with snap-on caps (diameter 9.525 cm, height 5.715 cm; Globe Scientific Inc.) which were covered with a black low density polyethylene film (thickness, 100 μ m; WVP 13 g/m²d) to protect the products from the light, and then stored them at 4 °C.

Microbiological analysis

To aerobic mesophilic bacteria (AMB), molds and yeasts determination, 10^{-1} , 10^{-2} and 10^{-3} samples dilutions were prepared, with sterile peptone water, according to the method established by NOM-110-SSA1-1994. For AMB determination, 1 mL of the correspondent dilution was transferred to a Petri plate and nutrient agar was added as growth medium. The plates were incubated at 35 °C during 48 h and, after enumerated (NOM-092-SSA1-1994). For molds and yeasts count, 1 mL of the correspondent dilution was poured in a Petri plate and potato dextrose agar was added (pH 3.5) as growth medium. The plates were incubated at 25 °C during 5 days (NOM-111-SSA1-1994). The obtained results were expressed as colony-forming units per sample gram (CFU/g). The analysis was determined by triplicate for every prepared dilution.

Color parameters

It was determined by triplicate in function of Hunter parameters L_h (luminosity), a_h (green-red) and b_h (blue-yellow), using a Colorgard System/05 colorimeter (BYK Gardner, Germany), previously calibrated on reflectance

mode. To calculate the net color change (ΔE), Ec. 2 was used:

$$\Delta E = \sqrt{(\Delta L_h)^2 + (\Delta a_h)^2 + (\Delta b_h)^2} \quad (2)$$

where $\Delta L_h = L_h - L_{h1}$, $\Delta a_h = a_h - a_{h1}$, $\Delta b_h = b_h - b_{h1}$; L_{h1} , a_{h1} , b_{h1} corresponded to standard color data and L_h , a_h , and b_h to sample color data.

Anthocyanins, phenolic compounds and antioxidant capacity

Extract acquirement

To determine the bioactive compounds, sample extracts were excerpted. For this, 10 grams of each sample were weighed and then ethanol at 60% (Reactivos Meyer, Mexico) was added until completing 50 mL. The mixture was laid during 24 h, in the dark, at 4 °C. Later, it was vacuum filtered with Whatman paper No. 4; the filtration was heated in a rotary evaporator (Buchi RE 114, Switzerland), for 7 min at 53 °C, to separate the solvent present in the sample.

Total anthocyanin content

The total anthocyanin content was determined according to the pH-differential method (Giusti and Wrolstad 2001), using two buffer systems: sodium acetate 0.4 M (pH 4.5) and potassium chloride 0.025 M (pH 1). Absorbance was read at 500 and 700 nm with a UV–visible spectrophotometer (UNICO, United Products and Instruments, Inc., USA). Anthocyanin concentration was reported as milligrams cyanidin 3-glucoside per 100 g sample.

$$\begin{aligned} \text{Total anthocyanin content (mg/mL)} \\ = A \times MW \times DF / \varepsilon \times l \end{aligned} \quad (3)$$

where A is $(A_{517\text{nm}} - A_{700\text{nm}})_{\text{pH}1.0} - (A_{517\text{nm}} - A_{700\text{nm}})_{\text{pH}4.5}$. MW is cyanidin 3-glucoside molecular weight (449.2 g/mol), DF is dilution factor, ε is the cyanidin 3-glucoside molar absorptivity coefficient of (26,900 L/cm/mol), l is path length (1 cm).

Total phenols content

Total phenols content was determined colorimetrically using the Folin–Ciocalteu method (Singleton et al. 1999). An extract aliquot of 150 μ L was added to 3850 μ L of water, 250 μ L of Folin–Ciocalteu reagent, and 750 μ L of Na₂CO₃ solution (20%) and mixed. The absorbance was measured at 765 nm with a UV–visible spectrophotometer (UNICO, United Products and Instruments, Inc., USA) after incubation for 30 min at room temperature.

Quantification was based on the standard curve generated with gallic acid solutions.

Antioxidant activity

It was determined according to the method of Brand-Williams et al. (1995). A sample of 24 mg of DPPH was weighed and mixed with 100 mL of ethanol. The mixture was stirred until it was completely dissolved. The DPPH solution was obtained mixing 15 mL of stock solution with 75 mL of ethanol. This solution had to present an absorbance of 1.0 (initial absorbance, A_{initial}) at a wavelength of 515 nm. 50 μL of the extract and 2950 μL of the DPPH solution were added in a test tube to determine the antioxidant capacity. The mixture was stirred and after 60 min, the absorbance (final absorbance, A_{final}) was measured at a wavelength of 515 nm. The determination was made by triplicate. With the obtained data the radical inhibition percentage in every time of the analysis was calculated according to the Eq. 4:

$$\% \text{ inhibition} = \frac{A_{\text{initial}} - A_{\text{final}}}{A_{\text{initial}}} \times 100 \quad (4)$$

The obtained results were expressed as equivalents milligrams to Trolox/g of extract. The quantification was made with the use of a Trolox standard curve produced in every time of the analysis.

Statistical analysis

Four types of TSP were elaborated: tamarillo without blanching and without antimicrobial mixture (AM); tamarillo without blanching and with AM; blanched tamarillo and without AM; and blanched tamarillo and with AM. Samples were stored at 4 °C and evaluated at days 0, 14, 28, 35, 42, 49, 56 and 63. ANOVA test was carried out at $P < 0.05$, with Tukey's test. Further, the interaction between AM and blanching effect on the antioxidants and color during samples storage was evaluated. The statistical analysis was done using Minitab 16 software (Minitab Inc., USA).

Results and discussion

Effect of blanching time on tamarillo peroxidase activity and antioxidant properties

To determine the blanching time that could reduce tamarillo enzymatic activity to its minimum, entire fruits were blanched in boiling water at different times and peroxidase activity was determined. Due to peroxidase high thermal stability and the easiness to determine its activity, this

enzyme has been commonly used as an enzymatic inactivation indicator in many fruits and vegetables (Anthon et al. 2002). Additionally, the effect of blanching time on tamarillo's antioxidant capacity, phenolic compounds and total monomeric anthocyanins was determined (Table 1).

After blanching for 12 min, the peroxidase activity decreased to 0.028% of the initial value. On the other hand, the phenolic compounds content corresponds to 85.4% of the initial value and the anthocyanins and the antioxidant capacity did not present significant differences ($P < 0.05$) compared to non-blanching fruit. The tamarillo antioxidant stability after blanching presented concordance with the results obtained in other studies (Brownmiller et al. 2008; Srivastava et al. 2007; Ziabakhsh Deylami et al. 2016). Considering the previous results, the following studies on TSP quality and stability were developed employing blanching tamarillo for 12 min.

Blanching effect and antimicrobials (AM) addition on TSP quality and stability

Microbiological analysis

TSP stability was determined as a function of the aerobic mesophilic bacteria (AMB), molds and yeasts growth (Table 2). It can be observed that TSP with tamarillo without blanching and with AM and the one produced without preservatives and with blanched fruit presented an AMB count lower than 10 CFU/g, during 42 days of storage. On the other hand, TSP with blanched tamarillo containing AM maintained low AMB growth during 49 days. It was also observed that, during the 63 days of storage, the AMB counts on TSP with blanched tamarillo was lower than 50 CFU/g, which is the maximum limit of these microorganisms, established by the Mexican official norms (NOM-130-SSA1-1995). TSP with non-blanching tamarillo, with and without AM, remained below this limit (50 CFU/g) during 42 and 56 days, respectively. After comparing the obtained results in the present study with those reported by Villegas-Ruiz et al. (2013), similar behavior was detected on TSP sample with non-blanching tamarillo and without AM.

Regarding to molds and yeasts growth, it can be observed that TSP with blanched tamarillo presented for longer time a low count than 10 CFU/g, compared to those elaborated with non-blanching tamarillo. In the case of those samples added with AM compared to those without, the same behavior was detected, presenting longer times in the Mexican Official Norm limits. In contrast, TSP molds and yeasts counts in the study published by Villegas-Ruiz et al. (2013), were maintained no more than 30 days below the maximum limit specified by the Mexican norms.

Table 1 Blanching^a effect on peroxidase activity and compounds with antioxidant properties^b

Time (min)	Peroxidase activity ^c	Total phenolic compounds ^d	Antioxidant capacity ^e	Anthocyanins ^f
0	13.020 ± 0.02 ^a	482.11 ± 1.25 ^a	309.09 ± 1.67 ^c	1.89 ± 0.35 ^a
3	2.940 ± 0.03 ^b	370.60 ± 2.16 ^c	317.16 ± 0.37 ^a	1.85 ± 0.19 ^a
6	0.600 ± 0.02 ^c	367.22 ± 1.08 ^d	314.81 ± 0.74 ^{ab}	1.87 ± 0.04 ^a
9	0.012 ± 0.00 ^d	384.24 ± 1.87 ^c	315.45 ± 0.74 ^a	1.84 ± 0.02 ^a
12	0.004 ± 0.00 ^d	411.83 ± 2.16 ^b	311.34 ± 2.21 ^{bc}	1.91 ± 0.02 ^a

^aBlanching in boiling water (93 °C)^bMean ± SD. Distinct letters on the same column show significant difference ($P < 0.05$)^cExpressed as units of enzymatic activity/mL of enzymatic extract^dmg equivalents of galic acid/100 g pulp and seeds^emg equivalents of Trolox/100 g pulp and seeds^fmg of cyanidin-3-glucoside/g pulp and seeds**Table 2** Effect of storage time on aerobic mesophilic bacteria (AMB), molds and yeasts in the tamarillo sweet products (TSP)^a

Time (days)	AMB (CFU/g)				Molds and yeasts (CFU/g)			
	Non-blanching		Blanching		Non-blanching		Blanching	
	Without AM ^b	With AM ^b	Without AM ^b	With AM ^b	Without AM ^b	With AM ^b	Without AM ^b	With AM ^b
0	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
14	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
28	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
35	22	< 10	< 10	< 10	25	< 10	< 10	< 10
42	30	< 10	< 10	< 10	50	< 10	< 10 ^c	< 10
49	52	30	31	< 10	64	22	< 10	< 10
56	93	45	33	21	120	24	23	< 10
63	> 250	62	43	26	> 250	31	27	24

^a50 CFU/g and 10 CFU/g are the maximum limits authorized for AMB and for molds and yeasts, respectively, according to the Official Mexican Norm (NOM-130-SSA1-1995)^bAM: antimicrobials makes reference to a mixture 50% potassium sorbate, 50% sodium benzoate (in weight)

< 10 = Estimated value under 10 CFU/g

> 250 = uncountable

These results showed that including blanching and the addition of potassium sorbate, in the conservation methods applied by Villegas-Ruiz et al. (2013) (tamarillo's natural low pH, combined with water activity reduction through sucrose addition, and the use of sodium benzoate as antimicrobial agent), permitted to increase the TSP stability in terms of the microbial growth and, in consequence, a shelf life extension was achieved.

Color

Table 3 presents the values of ΔE of different TSP samples, analyzed during storage. The corresponding values for initial time of every product were used as a reference to evaluate this parameter. It can be observed that ΔE tended to increase over storage time. However, not significant

differences were observed in all cases ($P < 0.05$). On this sense, Ochoa et al. (1999) report that ΔE of a raspberry pulp (37° Brix) stored at 4 °C was maintained practically stable during 40 days. Meanwhile, Qu et al. (2012) did not find notable changes on ΔE of pomegranate peel (pH 3.5) stored at 4 °C. Similarly, Amendola et al. (2010) observed that the color index of red grape pomace extracts retained with minor changes during 120 days of storage at 4 °C.

On the other hand, addition of AM had no significant effect on ΔE ($P < 0.05$). In return, ΔE values of TSP with blanching tamarillo were lower than those elaborated with non-blanching tamarillo, in which, observed differences were statistically significant ($P < 0.05$). This could be explained due to responsible enzymes inactivation that catalyzed color change reactions, which was triggered by blanching.

Table 3 Effect of storage time on color change (ΔE)^a of tamarillo sweet products (TSP)^b

Time (days)	Non-blanching tamarillo		Blanched tamarillo	
	Without antimicrobials ^c	With antimicrobials ^c	Without antimicrobials ^c	With antimicrobials ^c
14	9.72 ± 0.59 ^{abA1}	9.54 ± 0.90 ^{dA1}	4.04 ± 0.33 ^{cB1}	3.83 ± 0.18 ^{bB1}
28	8.98 ± 0.10 ^{bA1}	10.02 ± 0.51 ^{cdA1}	5.49 ± 1.09 ^{abcB1}	6.06 ± 2.45 ^{aA1}
35	8.26 ± 0.51 ^{Ab1}	10.21 ± 0.69 ^{bcdA1}	6.42 ± 1.09 ^{abB1}	5.58 ± 2.88 ^{abB1}
42	9.79 ± 0.51 ^{abA1}	11.94 ± 0.14 ^{abcA1}	6.78 ± 0.16 ^{abB1}	6.30 ± 2.96 ^{abB1}
49	10.68 ± 1.60 ^{abA1}	12.35 ± 0.80 ^{abA1}	6.68 ± 0.85 ^{abB1}	7.96 ± 1.48 ^{abB1}
56	11.95 ± 1.12 ^{aA1}	12.52 ± 0.91 ^{aA1}	4.87 ± 0.51 ^{bcB1}	7.31 ± 0.33 ^{abB1}
63	12.23 ± 1.61 ^{aA1}	12.97 ± 1.27 ^{aA1}	6.77 ± 1.00 ^{abB1}	8.20 ± 1.50 ^{abB1}

^aAs reference for color change calculation, values of time zero were taken

^bMean ± SD. Distinct small letters on the same column show significant difference ($P < 0.05$) due to storage time. Distinct capital letters between rows show significant difference ($P < 0.05$) due to blanching. Distinct numbers in the same row show significant difference ($P < 0.05$) due to the use of the antimicrobials

^cAntimicrobials makes reference to a mixture 50% potassium sorbate, 50% sodium benzoate (in weight)

Color parameters a_h and b_h decreased during 63 days storage in four TSP samples. TSP sample without blanching and without AM, showed reduction in a_h from 22.0 to 10.2 and of b_h from 6.7 to 3.9. TSP without blanching and with AM, showed that a_h diminished from 23.2 to 11.1 and b_h from 7.3 to 4.3. Minor diminutions were observed in TSP blanched, being from 14.8 to 8.4 for a_h and from 4.0 to 2.6 for b_h . Finally, TSP without AM showed reduction from 16.6 to 9.4 for a_h and 5.0 to 2.9 for b_h for the TSP with AM. Additionally, in all TSP samples, the combined effect of blanching and AM addition presented significant differences ($P < 0.05$).

Anthocyanins, phenolic compounds and antioxidant capacity

Tables 4, 5 and 6 present the results obtained on the total monomeric anthocyanins, total phenolic compounds and antioxidant capacity of TSP samples. Analyzing the AM addition effect, it was found that, even though among samples there were statistically significant differences ($P < 0.05$) in the anthocyanins content and in the antioxidant capacity, none of these parameters showed a defined tendency. With regard to phenolic compounds, there was no significant effect of AM addition. Regarding storage time effect on anthocyanins content (Table 4), there were no significant changes. The only exception was TSP with non-blanching and with AM, in which a tendency to decrease was observed, with a retention of 70% at day 63 of storage. The behavior of this sample was similar to that reported by Villegas-Ruiz et al. (2013).

In relation to phenolic compounds (Table 5), in general, there were no significant changes caused by storage time in TSP elaborated with non-blanching tamarillo. These results

were contrary to those presented by Villegas-Ruiz et al. (2013), who reported a decrease from 121.3 to 81.6 mg gallic acid equivalents/100 g of TSP, between the fresh elaborated TSP and the one stored at refrigeration during 60 days. Meanwhile, TSP elaborated with blanched tamarillo behaved in a different way, because remained without significant changes during the first 35 days of storage. However, at day 42, they presented a significant increase ($P < 0.05$) on its total phenolic compounds content.

TSP with non-blanching tamarillo and without AM, did not show significant in antioxidant capacity during the first 28 days of storage; at day 35 it showed a significant decrease and, later, it remained constant. At the end of the storage, the parameter decrease corresponded to 6% of the initial one. The rest of the TSP samples did not present significant differences during the first weeks of storage (56, 42 and 49 days), for TSP with non-blanching tamarillo and with AM, and with blanched tamarillo with and without AM, respectively. After this, the antioxidant capacity increased. Once again, these results contrasted with the work presented by Villegas-Ruiz et al. (2013), in which a continuous decrease of the antioxidant capacity during 60 days of storage was reported.

In other studies with fruit products, phenolic compounds, anthocyanins and antioxidant capacity were reported to be slightly affected during storage at refrigeration temperature. For instance, a slow decrease of anthocyanins retention percentage during 50 days of storage of raspberry pulp at 4 °C was observed (Ochoa et al. 1999). Further, in blackberries (*Rubus* spp.) coated with a chitosan film and storage at 10 °C, the anthocyanins content remained without changes (Menezes et al. 2014). Similarly, Augustine et al. (2013) observed 49.8% retention of anthocyanins in marc from Bangalore blue grapes, added with 0.1% of sodium benzoate

Table 4 Effect of storage time on total monomeric anthocyanins^a of tamarillo sweet products (TSP)^b

Time (days)	Non-blanching tamarillo		Blanched tamarillo	
	Without antimicrobials ^c	With antimicrobials ^c	Without antimicrobials ^c	With antimicrobials ^c
0	1.18 ± 0.17 ^{aA1}	1.19 ± 0.05 ^{aA1}	1.31 ± 0.03 ^{aA1}	1.23 ± 0.07 ^{aA1}
14	1.17 ± 0.06 ^{aB1}	0.98 ± 0.03 ^{bB2}	1.25 ± 0.06 ^{aA1}	1.14 ± 0.05 ^{aA2}
28	1.12 ± 0.06 ^{aB1}	0.95 ± 0.04 ^{bcB2}	1.21 ± 0.08 ^{aA1}	1.16 ± 0.05 ^{aA2}
35	1.03 ± 0.08 ^{aA1}	0.94 ± 0.02 ^{bcB1}	1.11 ± 0.17 ^{aA1}	1.09 ± 0.05 ^{aA1}
42	1.18 ± 0.19 ^{aA1}	0.91 ± 0.05 ^{bcB2}	1.19 ± 0.05 ^{aA1}	1.15 ± 0.05 ^{aA2}
49	1.02 ± 0.08 ^{aB1}	0.89 ± 0.05 ^{bcB1}	1.26 ± 0.02 ^{aA1}	1.21 ± 0.13 ^{aA1}
56	0.94 ± 0.18 ^{aB1}	0.91 ± 0.07 ^{bcB1}	1.18 ± 0.08 ^{aA1}	1.10 ± 0.01 ^{aA1}
63	1.04 ± 0.20 ^{aB1}	0.83 ± 0.08 ^{cbB1}	1.12 ± 0.03 ^{aA1}	1.14 ± 0.03 ^{aA1}

^aExpressed as mg of cyanidin-3-glucoside/g of TSP^bMean ± SD. Distinct small letters on the same column show significant difference ($P < 0.05$) due to storage time. Distinct capital letters between rows show significant difference ($P < 0.05$) due to blanching. Distinct numbers in the same row show significant difference ($P < 0.05$) due to the use of the antimicrobials^cAntimicrobials makes reference to a mixture 50% potassium sorbate, 50% sodium benzoate (in weight)**Table 5** Effect of storage time on phenolic compounds^a of tamarillo sweet products (TSP)^b

Time (days)	Non-blanching tamarillo		Blanched tamarillo	
	Without antimicrobials ^c	With antimicrobials ^c	Without antimicrobials ^c	With antimicrobials ^c
0	360.53 ± 14.76 ^{bA1}	379.10 ± 22.13 ^{abA1}	345.22 ± 9.92 ^{cA1}	347.96 ± 16.00 ^{bA1}
14	350.69 ± 8.25 ^{bA1}	345.77 ± 11.72 ^{abA1}	344.40 ± 6.57 ^{cA1}	348.50 ± 14.44 ^{bA1}
28	352.33 ± 9.21 ^{bA1}	330.74 ± 37.03 ^{bA1}	343.04 ± 17.98 ^{cA1}	350.69 ± 11.16 ^{bA1}
35	321.45 ± 34.00 ^{bB1}	320.36 ± 5.33 ^{bB1}	360.25 ± 4.50 ^{cA1}	370.09 ± 11.91 ^{bA1}
42	365.72 ± 12.44 ^{bB1}	357.79 ± 5.74 ^{abB1}	404.24 ± 13.97 ^{abA1}	424.46 ± 5.01 ^{aA1}
49	418.18 ± 9.85 ^{aA1}	412.17 ± 12.28 ^{aA1}	367.36 ± 21.83 ^{bcB1}	407.52 ± 11.89 ^{abB1}
56	345.22 ± 22.96 ^{bB1}	369.54 ± 16.73 ^{abB2}	392.51 ± 4.80 ^{bA1}	414.90 ± 11.63 ^{aA2}
63	369.00 ± 22.09 ^{bB1}	380.06 ± 22.15 ^{abB1}	420.09 ± 15.70 ^{aA1}	420.91 ± 8.67 ^{aA1}

^aExpressed as mg equivalents of galic acid/g of TSP^bMean ± SD. Distinct small letters on the same column show significant difference ($P < 0.05$) due to storage time. Distinct capital letters between rows show significant difference ($P < 0.05$) due to blanching. Distinct numbers in the same row show significant difference ($P < 0.05$) due to the use of the antimicrobials^cAntimicrobials makes reference to a mixture 50% potassium sorbate, 50% sodium benzoate (in weight)

and packed in low density polyethylene and store at 4 °C. Likewise, in a study with pomegranate peel (pH 3.5), reductions of total phenolic compounds and antioxidant capacity of 19 and 23%, respectively, were observed after 60 days storage at 4 °C (Qu et al. 2012). In another study performed with red grape pomace extracts (pH 3), phenolic compounds and antioxidant activity showed constant values during one-year storage at 4 °C (Amendola et al. 2010). In addition, in a study performed with blanched cranberry extracts (3 min in boiling water) and stored at 6 °C, the antioxidant capacity retention was higher than 90% at day 60 of storage (Srivastava et al. 2007). Meanwhile, Kujala et al. (2000) in a study with beetroot skin (*Beta vulgaris*, var. Little Ball), observed that the total phenolic compounds amount

changed from 15.5 to 13.1 mg GAE/g after 196 days of storage at 5 °C. Besides, it is important to mention that these authors found that antioxidant compounds like isobetanin and β -D-fructofuranosyl- α -D-(6-O-(E)-feruloyl)glucopyranosidase, ferulic acid main ester, were increased during storage, and that betanin decreased after day 140, just to increase later.

Regarding to tamarillo blanching effect, it was found out that, during the first 28 days of storage, there were no significant differences ($P < 0.05$) between the phenolic content compounds of TSP with blanched tamarillo and non-blanching tamarillo. However, anthocyanins content was higher in TSP with blanched tamarillo and its antioxidant capacity was lower. On the other hand, after

Table 6 Effect of storage time on antioxidant capacity (DPPH)^a of tamarillo sweet products (TSP)^b

Time (days)	Non-blanching tamarillo		Blanching tamarillo	
	Without antimicrobials ^c	With antimicrobials ^c	Without antimicrobials ^c	With antimicrobials ^c
0	307.36 ± 1.66 ^{aA1}	290.17 ± 5.49 ^{bA1}	278.85 ± 17.62 ^{cB1}	272.98 ± 15.10 ^{dB1}
14	305.47 ± 0.63 ^{aA1}	286.18 ± 1.58 ^{bcA2}	270.07 ± 1.92 ^{cB1}	274.03 ± 7.25 ^{dB2}
28	304.21 ± 5.59 ^{aA1}	284.09 ± 5.03 ^{bcA1}	277.17 ± 4.36 ^{cB1}	288.91 ± 2.02 ^{bcdA1}
35	264.38 ± 4.04 ^{bB1}	277.38 ± 4.09 ^{bcB2}	274.24 ± 1.31 ^{cA2}	283.88 ± 5.04 ^{cdA1}
42	273.40 ± 1.09 ^{bA1}	276.12 ± 3.69 ^{cB2}	269.83 ± 4.19 ^{cA1}	286.39 ± 3.84 ^{cdA2}
49	270.04 ± 4.55 ^{bB1}	279.48 ± 5.84 ^{bcB1}	291.22 ± 18.91 ^{bA1}	300.86 ± 2.21 ^{cA1}
56	275.70 ± 25.66 ^{bB1}	284.30 ± 4.88 ^{bcB1}	313.23 ± 2.21 ^{bA1}	311.97 ± 1.58 ^{bA1}
63	289.75 ± 3.50 ^{abB1}	305.26 ± 5.24 ^{abB2}	341.12 ± 12.30 ^{aA1}	362.50 ± 14.94 ^{aA2}

^aExpressed as mg equivalents of Trolox/g of TSP^bMean ± SD. Distinct small letters on the same column show significant difference ($P < 0.05$) due to storage time. Distinct capital letters between rows show significant difference ($P < 0.05$) due to blanching. Distinct numbers in the same row show significant difference ($P < 0.05$) due to the use of the antimicrobials^cAntimicrobials makes reference to a mixture 50% potassium sorbate, 50% sodium benzoate (in weight)

day 35 of storage, in most of the cases, the phenolic compounds, anthocyanins and antioxidant capacity presented higher values in TSP with blanched tamarillo than in those elaborated with non-blanching tamarillo, being the differences statistically significant ($P < 0.05$), in most of the cases. These results are similar to those observed in blueberry juice/purée (*Vaccinium corymbosum* L.), in which it was detected that anthocyanins retention, phenolic compounds and antioxidant activity during storage (5 months at 23 °C), was improved by fruit blanching (2 min at 95 °C) (Syamaladevi et al. 2012). The favorable blanching effect on antioxidant compounds may be caused by the inactivation of fruit native enzymes, decreasing the anthocyanins and phenolic compounds degradation and stabilizing the antioxidant activity. Moreover, blanching causes structural changes in vegetal tissue, increasing the cell wall porosity and improving the antioxidant compounds extraction (Brownmiller et al. 2008; De Aguilar et al. 2015; Rossi et al. 2003).

Finally, it is important to remark the combined effect of tamarillo blanching and AM addition on the anthocyanins, phenolic and antioxidant capacity, which was significant ($P < 0.05$) in all evaluated treatments.

Conclusion

Antimicrobial mixture and blanched tamarillo (12 min in boiling water) were beneficial for TSP, since the stability in terms of microbial growth was reduced and the net color change decreased during storage, without reducing the anthocyanins, antioxidant capacity and phenolic

compounds content. Additionally, values of these two last parameters in TSP with blanched tamarillo increased during the last weeks of storage, being higher than the values presented on TSP elaborated with non-blanching tamarillo. Besides, it would be interesting to perform more detailed studies about the changes experimented by specific antioxidant compounds of TSP as a consequence of blanching and of storage time, aiming to explain the mechanisms involved in these changes.

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