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Physicochemical parameters and antioxidant capacity of Queen Purple pitahaya fruits in postharvest storage

Parámetros fisicoquímicos y capacidad antioxidante de frutos de pitahaya Queen Purple en almacenamiento poscosecha

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ABSTRACT

The pitahaya fruit (*Hylocereus* sp.) has an attractive color and flavor for the consumer. It also includes bioactive compounds, which are thought to offer several health benefits. However, it presents postharvest handling problems during storage, limiting its commercialization to distant markets. The objective of this research was to evaluate the physicochemical parameters and antioxidant capacity of Queen purple pitahaya fruits, stored at 13 ± 1 °C and 27 ± 1 °C. Queen purple pitahaya fruits were harvested in Compostela, Nayarit, Mexico and the variables of mass loss, firmness, color, pH, total soluble solids, titratable acidity, antioxidant capacity, and phenolic compounds were analyzed. Pitahaya fruits stored at 27 ± 1 °C had an average shelf life of 12 days, while those stored at 13 ± 1 °C extended up to 16 days. Likewise, the fruits stored at 13 ± 1 °C presented a lower weight loss (2.47 %), greater firmness (25.65 N), tone angle (31.6), and antioxidant capacity by the ferric ion reducing power method (FRAP) compared to those stored at 27 ± 1 °C. The phenolic content, total soluble solids, pH, and antioxidant capacity evaluated by DPPH and ABTS of pitahaya fruits were similar at both temperatures. The red color with a bright pink tone of the shell was accentuated, losing its brightness, until the last day of storage, presenting a red color with purple tones, at both temperatures. The conclusion was that the temperature of 13 ± 1 °C prolonged the postharvest life of Queen purple pitahaya fruits by four days, delaying the accumulation of phenolic compounds and antioxidant capacity up to eight days.

KEY WORDS: Quality, Phenolic compounds, Color, Temperature.

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ABSTRACT

The pitahaya fruit (*Hylocereus* sp.) has an attractive color and flavor for the consumer. It also includes bioactive compounds, which are thought to offer several health benefits. However, it presents postharvest handling problems during storage, limiting its commercialization to distant markets. The objective of this research was to evaluate the physicochemical parameters and antioxidant capacity of Queen purple pitahaya fruits, stored at 13 ± 1 °C and 27 ± 1 °C. Queen purple pitahaya fruits were harvested in Compostela, Nayarit, Mexico and the variables of mass loss, firmness, color, pH, total soluble solids, titratable acidity, antioxidant capacity, and phenolic compounds were analyzed. Pitahaya fruits stored at 27 ± 1 °C had an average shelf life of 12 days, while those stored at 13 ± 1 °C extended up to 16 days. Likewise, the fruits stored at 13 ± 1 °C presented a lower weight loss (2.47 %), greater firmness (25.65 N), tone angle (31.6), and antioxidant capacity by the ferric ion reducing power method (FRAP) compared to those stored at 27 ± 1 °C. The phenolic content, total soluble solids, pH, and antioxidant capacity evaluated by DPPH and ABTS of pitahaya fruits were similar at both temperatures. The red color with a bright pink tone of the shell was accentuated, losing its brightness, until the last day of storage, presenting a red color with purple tones, at both temperatures. The conclusion was that the temperature of 13 ± 1 °C prolonged the postharvest life of Queen purple pitahaya fruits by four days, delaying the accumulation of phenolic compounds and antioxidant capacity up to eight days.

KEY WORDS: Quality, Phenolic compounds, Color, Temperature.

Introduction

The pitahaya plant (*Hylocereus* sp.) is a perennial cactus that grows wild on rocks, trees, and bushes, with a climbing habit; under agronomic management conditions, stakes are used to support themselves (Montesinos-Cruz *et al.,* 2015). The pitahaya fruit has a globose ellipsoidal to oval shape with a diameter of 10 to 12 cm; the pulp is white, pink, red, and purple with numerous scattered black seeds, sweet or tasteless; while the color of the shell varies from red to red-purple, which is covered by triangular-shaped bracts arranged in a helical shape (Centurión *et al.,* 2008; Balois-Morales *et al.,* 2013). In terms of surface output and national performance, the main entities are Quintana Roo (67 %, 5687 t), Yucatán (23 %, 4360 t), and Puebla (7 %, 630 t) concentrating 98 % of the national production, only 2 % are concentrated in Campeche, Jalisco, Sinaloa, Sonora, Tabasco, Colima, and Nayarit. Pitahaya fruits are considered exotic due to their shape, color, and flavor, having demand in international markets, and favoring economic potential (Al-Mekhlafi *et al.,*

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2021; Oney Montalvo *et al.,* 2023). The fruit is a source of carotenoids, vitamins, minerals, proteins, fats, carbohydrates, and fiber, as well as phytoalbumins, flavonoids, phenolic compounds, and betacyanins, which are valued for their antioxidant potential (Ong *et al.,* 2014; Hua *et al.,* 2018), leading to an increase in its consumption (Sosa & Pérez-Orozco, 2022). Antioxidant, anticancer, antimicrobial, hepatoprotective, antihyperlipidemic, antidiabetic, and wound healing properties are attributed to these compounds (Ibrahim et al., 2018). However, postharvest handling problems arise during storage, affecting the organoleptic quality, which means that a large part of the production is not exported to distant markets (Verona-Ruiz et al., 2020).

The ripening of fruit and vegetable products are genetically programmed phases, which are characterized by physiological and biochemical reactions that modify firmness, color, and flavor (Martínez-González *et al*., 2017), so these quality parameters change during the maturation process. One of the most used methods to extend the postharvest life of fruits is storage at temperatures below 15 °C. In this regard, it has been reported that cactus fruits are sensitive to cold damage and their optimal storage temperature is between 8 and 12 °C (Rosas-Benítez *et al*., 2016), since at lower temperatures, it has been reported that fruits can be sensitive to cold (Patel *et al*., 2016). According to Paull (2016), pitahaya fruits have a shelf life of up to 14 days at a storage temperature of 10 °C. On the other hand, Gularte *et al*. (2022) demonstrated that pitahaya fruits stored at 4 °C present cold damage, which causes changes in the physical structure of the shell, internal browning, oxidative stress, and loss of quality attributes. Therefore, it is advisable to use storage temperatures above 4 °C and below 15 °C. In this context, this has led to investigate on the physicochemical parameters involved in the ripening of Queen purple pitahaya fruits from the Compostela, Nayarit, Mexico. The objective of this investigation was to evaluate the physicochemical parameters of Queen purple pitahaya fruits, stored at 13 ± 1 °C and 27 ± 1 °C.

Material and methods

Plant material

Queen purple pitahaya fruits were harvested according to color (70 % red, 30 % green), size (10-15 cm), and at least 35 days after flowering from Rancho Las Pitahayas in Compostela, Nayarit (21°13’09.8’N, 104°53’56.9’W). The collected fruits were transported to the special analysis laboratory of the Food Technology Unit of the Autonomous University of Nayarit. Pitahaya fruits without physical damage and diseases were selected. Immediately, these fruits were washed with water and disinfected with 2 % sodium hypochlorite. Finally, the fruits were left to dry at room temperature. Out of a total of 76 fruits, 38 were stored at 27 ± 1 °C, and 38 fruits at 13 ± 1 °C for 16 days in a controlled temperature chamber (Clima Cell, Angelbachtal, Germany) with a relative humidity of 90 %. The variables evaluated were mass loss (%), color (CIE LCh system), firmness (N), total soluble solids (°Brix), titratable acidity (%) in relation to malic acid, pH and antioxidant capacity (DPPH, ABTS, and FRAP techniques) in mg of ascorbic acid (EAA)/100 g fresh weight and total phenols in mg equivalents of gallic acid (EAG)/100 g fresh weight. Physical analyses (weight loss, color, and firmness), were evaluated every four days, with the beginning of the

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storage period being day zero for each storage temperature. Likewise, the postharvest life of the pitahaya fruits was determined by visual and tactile inspection (darkening, presence of diseases, turgor).

Physicochemical analysis

Mass loss was determined by gravimetry using a digital scale (Ohaus Scout Pro) and reported as a percentage (% weight loss). Firmness was evaluated using a digital penetrometer (Force Gauge GY-4), with an 8 mm diameter punch. The measurements were made in a direction perpendicular to the surface of the fruit, the values were expressed in Newtons (N). The color was determined using a colorimeter (KONICA MINOLTA CR-400) measuring in the epidermis of the fruit in its equatorial areas. The readings directly showed the parameters: LCh, where L represents the luminosity reflected by the fruit (black to white), C is the chromaticity, and h is the tone angle. In terms of titratable acidity and total soluble solids (TSS), the pulp was milled, using 1 g of pulp with 10 mL of distilled water in a tissue homogenizer (IKA Ultra turrax T25). TSS was determined by placing a sample drop in a digital refractometer (HANNA HI9680). Titratable acidity was carried out by volumetric titration with 0.01 N of NaOH and phenolphthalein as an indicator, following the official technique of the AOAC (2005). The results were expressed as a percentage of malic acid, which is the major organic acid in the pitahaya fruit (Sheng *et al*., 2021).

Analysis of total phenols and antioxidant capacity

1 g of pulp in 10 mL of distilled water was homogenized in an Ultraturrax (T8 IKA® Staufen, Germany). Subsequently, it was centrifuged (Z326K Hermle, Wehingen, Germany) at 18,510 *g* for 15 min at 4 °C, recovering the supernatant, which was used as a sample for each of the antioxidant capacity and total phenolics methods.

Total phenols

They were determined according to the method of Stintzing *et al*. (2005). 50 µL of the sample and 250 µL of the Folin-Ciocalteu reagent (1:10 v/v) were mixed and allowed to incubate for 5 min. Next, 200 µL of 7.5 % (w/v) sodium carbonate were added and incubated in the dark at room temperature for 30 min. Finally, the absorbance was measured at a wavelength of 760 nm. The total phenolic content was determined using a calibration curve with gallic acid (0-100 mg L^{-1}). The results were expressed in mg equivalents of gallic acid per gram of fresh weight (mg EAG/100 gFW).

2,2'-diphenyl-1-picrylhydrazyl (DPPH)

It was determined according to the methodology reported by Brand-Williams *et al*. (1995). A DPPH solution (7.4 mg/100 mL in 80 % ethanol) was made, stirring for 60 min. Next, the solution was adjusted to an absorbance of 0.70 (±0.02) at 520 nm using 80 % ethanol. 250 µL of the DPPH radical was mixed with 30 µL of the sample in a microplate. It was incubated for 30 min in the dark and the absorbance was subsequently read in a spectrophotometer (Thermo Scientific, Multiskan

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go) at a wavelength of 520 nm. The antioxidant capacity of the sample was determined using a standard curve with ascorbic acid (0 to 100 mg L^{-1}). The results were expressed in mg equivalent of ascorbic acid per gram of fresh weight (mg EAA/100 gFW).

2,2'azinobis-(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS•+)

It was quantified according to the methodology described by Re *et al.* (1999). The ABTS•+ radical was prepared by mixing 7 mM ABTS•+ solution (Sigma – Aldrich) and 2.45 mM potassium persulfate ($K_2S_2O_8$) in a 1:1 (v/v) ratio. The mixture (ABTS•+ radical) was incubated for 16 h at 23 ± 1 °C with constant shaking in the dark and was diluted with 20 % ethanol until reaching an absorbance value of 0.70 (±0.02) at 734 nm. 10 µL of the sample was mixed with 490 µL of the ABTS•+ radical and allowed to react for 7 min. Subsequently, the absorbance was quantified at a wavelength of 734 nm. The antioxidant capacity of the sample was determined using a standard curve with ascorbic acid (0 to 200 mg L^{-1}). The results were expressed in mg equivalent of ascorbic acid per gram of fresh weight (mg EAA/100 gFW).

Ferric ion-reducing power (FRAP)

It was determined by the method of Gow-Chin & Huin-yin (1995). In brief, 25 µL of sample, 63 µL of phosphate buffer (0.2 M, pH 6.6), and 63 µL of 1 % potassium hexacyanoferrate (K_3 Fe $(CN)_6$) were placed in a vortex. The mixture was incubated for 30 min at 50 °C and 63 µL of 10 % trichloroacetic acid was added. Next, they were placed in a vortex for one minute and 63 µL of the supernatant was taken, adding 63 µL of distilled water and 12.5 µL of 0.1 % ferric chloride ($FeCl_3$). Finally, the absorbance was read at a wavelength of 700 nm. The antioxidant capacity of the sample was determined using a standard curve with ascorbic acid (0 to 100 mg L^{-1}). The results were expressed in mg equivalent of ascorbic acid per gram of fresh weight (mg EAA/100 gFW).

Likewise, for each of the three methods, the percentage of radical scavenging from the samples was calculated using the following equation:

$$\%Radical\ scavenging = \left[\frac{Initial\ Absorbance - Final\ Absorbance}{Initial\ Absorbance}\right] x100$$

Experimental design

A completely randomized block design was used, using storage days as blocks. The data were analyzed using an ANOVA with a significance level of 5 %. A comparison test of means between temperatures was performed using the Tukey method ($p < 0.05$) when the ANOVA showed significant differences. Likewise, the Shapiro-Wilk tests were performed to check the normality of the data and the Bartlett test to verify their homogeneity. All statistical and graphical analyses were performed using the R language with the agricolae, ggpubr, and ggplot2 packages.

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Results and discussion

Pitahaya fruits stored at 27 ± 1 °C had an average postharvest life of 12 days, while those stored at 13 ± 1 °C had a postharvest life of up to 16 days.

Mass loss

Pitahaya fruits stored at 13 ± 1 °C presented less mass loss (2.47 %) compared to those stored at 27 ± 1 °C (6.98 %) (Figure 1A). Similar results were achieved by Magaña-Benítez *et al*. (2013) in red pitahaya fruits stored for six days (8.37 %) at 26 ± 2 °C and by Franco *et al.* (2022) in fruits stored for 21 days at 13 °C with 3.3 % losses. The mass loss can be attributed to the loss of water due to transpiration followed by respiration. In this regard, Lufu *et al.* (2019) reported that water loss due to respiration contributed up to 35 % (93 % relative humidity) of the total mass loss and the rest was due to transpiration in pomegranate fruits (cv. Wonderful). Temperature and relative humidity are two factors that affect the processes of transpiration and respiration, so mass loss is a function of these metabolic processes. In this sense, Araujo *et al*. (2022) showed that low temperatures decrease the respiration rate of dragon fruit. Likewise, Lentzou *et al.* (2021) reported in fig fruits (*Ficus carica L. var. Tsapela*) stored at 20 °C (relative humidity between 80.22 % and 98.65 %) a water loss of 4 % due to transpiration.

Firmness

The fruits stored at 13 ± 1 °C presented greater firmness (17.43 N) compared to the fruits stored at 27 ± 1 °C (14.87 N) (Figure 1B). This result is comparable to that of Freitas & Mitcham (2013), who reported a decrease in firmness from 11.6 N to 8.2 N in red pitahaya fruits stored at 10 °C. The loss of firmness of fruit and vegetable products is related to the degradation of the cell wall, since during softening the enzymes polygalacturonase, pectinmethylesterase, xylanase, and cellulase are activated, in addition to a weakening of intercellular adhesion (Mercado *et al*., 2019; Martínez- González *et al*., 2017; Balois-Morales *et al.,* 2013). In this sense, Gularte *et al.* (2022) evaluated the firmness in pitahaya fruits (*Hylocereus undatus*) stored at 23 °C, 9 °C and 4 °C. The authors found that fruits stored at 9 °C had greater firmness compared to those stored at 23 °C and 4 °C, attributing this to the fact that low temperatures decrease fruit metabolism and the activity of enzymes associated with cell wall degradation (pectinmethylesterase and polygalacturonase). Furthermore, Díaz-Pérez (2019) mentioned that fruit transpiration also causes a loss of cellular turgor, which is reflected in the softening and senescence of the fruits. According to this, it is possible that the temperature of 13 ± 1 °C may have reduced fruit transpiration and the activity of the enzymes pectinmethylesterase and polygalacturonase, resulting in firmer fruits than those stored at 27 ± 1 °C.

Color

The color parameter in fruit and vegetable products is an indicator of visual quality for the consumer. The pitahaya is a fruit that has an attractive color, hence, it is important to determine the color changes during postharvest storage. For this, the LCh evaluation system is used

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(L=luminosity, C= chromaticity, h=hue angle). Based on the data acquired, and according to the storage period and temperatures, the fruits exhibited the following characteristics: on day zero of storage the peel was red with a bright pink tone; on subsequent days the red color became more accentuated, losing its brightness, until the last day of storage when it presented a red color with purple tones at both temperatures evaluated (Table 1). Obenland *et al.* (2016) reported a decrease in the L parameter in four varieties of dragon fruit (*Hylocereus* spp.) stored at 10 °C for 14 days, mentioning that this darkening was caused by the storage conditions. On the other hand, Hernández-Ramos *et al.* (2023) evaluated pitahaya fruits (*Hylocereus ocamponis*) in a pre-consumption and consumption maturity at 6 °C and 22 °C, demonstrating that the C and h values in the epicarp of the fruit were affected by the temperature and time of storage. Likewise, the authors reported that the content of betacyanins (pigments that provide the red color to the pitahaya fruit) was higher in the fruits at consumption maturity (12.62 mg/100 g) than in the pre-consumption fruits (7.34 mg/100 g), as well as higher in fruits stored at 6 °C than in those stored at 22 °C. According to obtained data, it can be suggested that betacyanins appear to rise with ripening and are more stable at storage temperatures below 15 °C. The visual appearance of pitahaya fruits stored at 27 ± 1 °C changed from day 8 of storage, showing signs of dehydration (loss of turgor to the touch and darkening), as well as shrinkage and greening of the bracts (Figure 2). At the same temperature, on day 16 of storage, most of the fruits showed the presence of brown spots on both poles of the fruit, as well as yellow and/or browning bracts. On the other hand, all fruits stored at 13 ± 1 °C on day 16 only showed changes in the color of the bracts, which showed a green color with yellow tones (Figure 2B).

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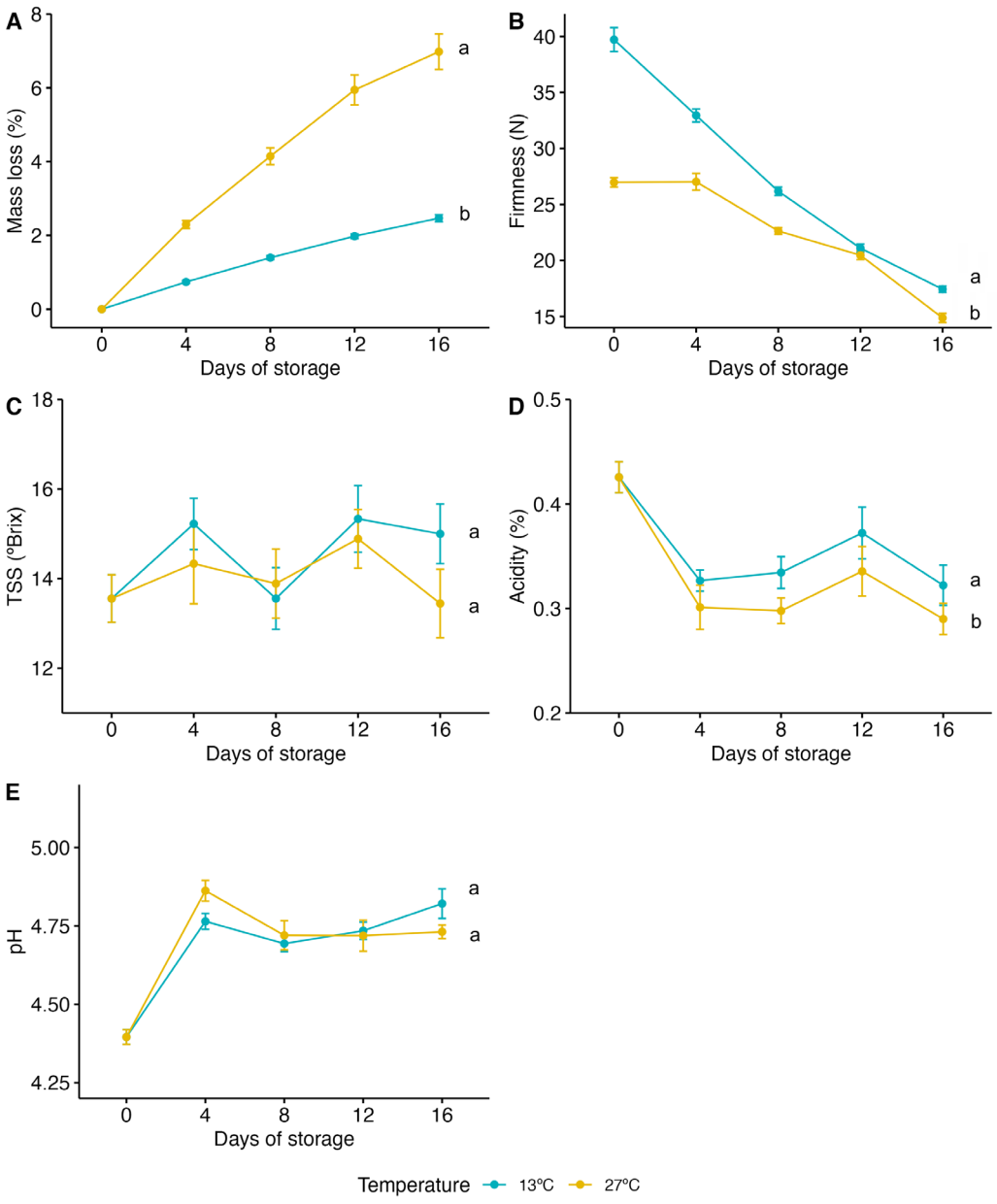

Figure 1. Pitahaya fruits stored at 27 ± 1 °C (yellow color) and 13 ± 1 °C (blue color) for 16 days. A) Weight loss. B) Firmness. C) Total Soluble Solids. D) Acidity. E) pH. Different letters mean a statistically significant difference between storage temperatures according to the Tukey test ($p < 0.05$). The vertical lines indicate the standard error. Each point is equivalent to n=10.

Source: Own elaboration based on data from this investigation.

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Table 1. Color of pitahaya fruits stored at 27 ± 1 °C and 13 ± 1 °C for 16 days, luminosity (L), chromaticity (C) and tone angle (h).

Days	L		C		h	
	27 ± 1 °C [a]	13 ± 1 °C [a]	27 ± 1 °C [a]	13 ± 1 °C [a]	27 ± 1 °C [a]	13 ± 1 °C [b]
0	51.15	50.16	33.86	34.03	47.48	41.67
4	48.35	48.28	39.2	36.5	31.55	37.95
8	46.63	46.4	39.32	38.96	28.35	34.24
12	46.6	46.56	38.15	40.44	27.08	33.83
16	46.47	45.9	35.34	40.8	28.19	31.6

Different letters indicate significant differences between storage temperatures according to the Tukey test ($p < 0.05$).

Source. Own elaboration

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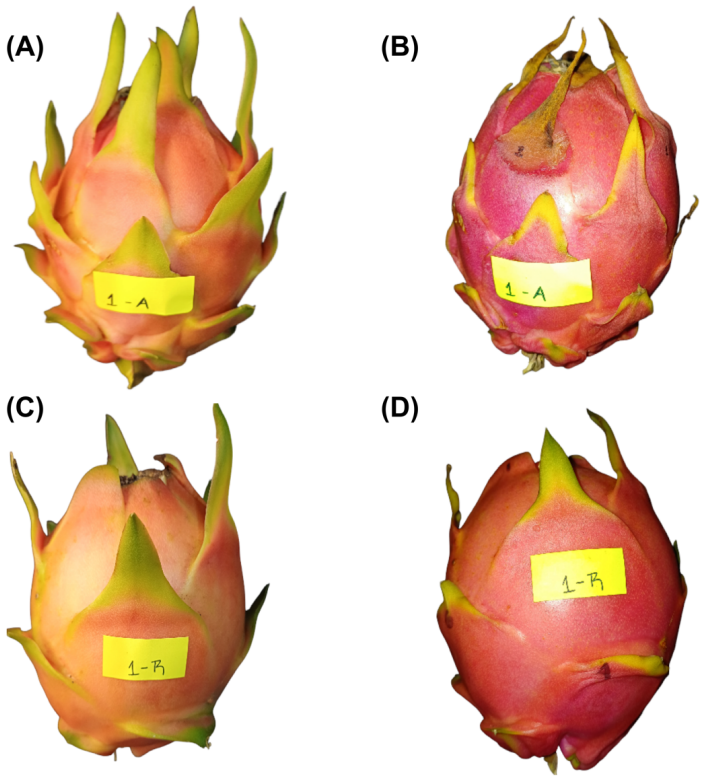

Figure 2. Color of pitahaya fruits at 0 and 16 days of storage. A) day 0 at 27± 1°C, B) day 16 at 27± 1°C, C) day 0 at 13± 1°C, D) day 16 at 13± 1°C.

Source: Own elaboration based on data from this investigation.

Total Soluble Solids (TSS)

Pitahaya fruits have been described as tasteless, indicating a low sugar content. This parameter can be influenced by environmental conditions (light, temperature, relative humidity), genetics and storage time. Hernández-Ramos *et al*. (2020) mentions that acidity and TSS are the main components of the pitahaya fruit flavor. In this regard, Queen purple pitahaya fruits stored at 13 ± 1 °C and 27 ± 1 °C presented TSS of 13 to 15 °Brix, with no differences observed between both treatments (Figure 1 C). Franco *et al.* (2022) stored pitahaya (*Hylocereus undatus*) fruits at 5 °C and 13 °C, demonstrating that the TSS of the fruits did not change significantly (12-13°Bx). Based on this information, it is possible that a difference in the TSS was not determined in the fruits stored at both temperatures due to their non-climacteric nature, because the biochemical processes are slower, so the TSS values remain consistent during postharvest storage. On the other hand, Obenland *et al.* (2016) reported a sugar reduction in pitahaya fruits (*Hylocereus* spp.) stored at 5 °C and 10 °C.

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Titratable acidity

Fruits stored at 27 ± 1 °C presented lower acidity values ($p < 0.05$) (Figure 1D). This behavior is similar to that reported by Quiroz-González *et al*. (2017), in pitahaya fruits (*Stenocereus* spp) stored at 24 ± 4 °C, where these had lower acidity than those stored at 2 ± 1 °C and 7 ± 1 °C. According to Žnidarčič & Požrl (2006) and Álvarez-Herrera *et al.* (2009), organic acids are used in the respiration of fruits or are converted into sugars, so there is a decrease in acidity. In this study, we found that the temperature of 13 ± 1 °C reduced fruit respiration, resulting in less usage of organic acids as a substrate and greater acidity levels. Furthermore, fruit acidity decreased from 0.42 % to 0.28 % between days 0 and 16 of storage at 27 ± 1 °C. This behavior was similar to that reported by Magaña-Benítez *et al.* (2013), where pitahaya fruits (*Hylocereus undatus*) stored at 26 ± 2 °C presented a decrease in acidity from 1.71 % to 0.88 % on day 6. Similarly, Franco *et al.* (2022) reported that the percentage of titratable acidity decreased from values between 0.41-0.74 % to 0.17 % malic acid in pitahaya fruits (*Hylocereus undatus*) stored at 13 °C for 21 days.

pH

The fruits presented similar pH values at the two temperatures evaluated ($p > 0.05$) (Figure 2C). However, this increased with respect to time, displaying values of 4.39 on day 0 and 4.82 on day 16 for fruits stored at 13 ± 1 °C, probably as a consequence of the decrease in acidity of the fruits.

Antioxidant Capacity

The antioxidant capacity of pitahaya fruits (Figure 3) was similar at the two temperatures evaluated by the DPPH and ABTS methods ($p > 0.05$). The FRAP method presented significant differences between temperatures as seen in Figure 3B ($p < 0.05$). In this regard, Obenland *et al.* (2016) reported that the antioxidant activity evaluated in six varieties of dragon fruit remains without significant changes for 2 weeks at 10 °C. According to this author, this may be due to the stability that betacyanins present at low temperatures. The results of this investigation coincide with the reported by the author mentioned since the temperature of 13 ± 1 °C did not affect the antioxidant capacity, color (tone angle), and appearance of the fruit. The antioxidant capacity increases from day 12, presenting a maximum value on day 16 (Figure 3). The increase in the antioxidant capacity of the extracts may be due to the synthesis of new components with high antioxidant capacity, such as anthocyanins and/or betalains (betacyanins). In this sense, Manzanarez-Tenorio *et al.* (2022) found a positive correlation between the antioxidant capacity of DPPH (r = 0.889) and FRAP (r = 0.818) and the betacyanins content in purple cactus. Esquivel *et al.* (2007) suggest that betalains are the compounds that contribute most to the antioxidant activity in fruits of *Hylocereus* sp. since these were found in a greater proportion than phenolic acids such as gallic acid and acetylcoumarin. It is important to highlight that the highest and lowest values of antioxidant capacity of pitahaya fruits were detected with the FRAP and ABTS methods, respectively. Jiménez-García *et al.* (2022) mentioned that the sensitivity of the method is associated with the type of components in the sample.

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Likewise, DPPH and FRAP are related to the presence of phenolic acids and water-soluble compounds, while the ABTS method has been associated with the presence of flavonoids and fatty acids, due to their ability to absorb lipophilic compounds. According to the above, it is likely that these latter compounds are found in a lower proportion in the analyzed pitahaya samples, indicating a weaker capacity to inhibit the ABTS absorption.

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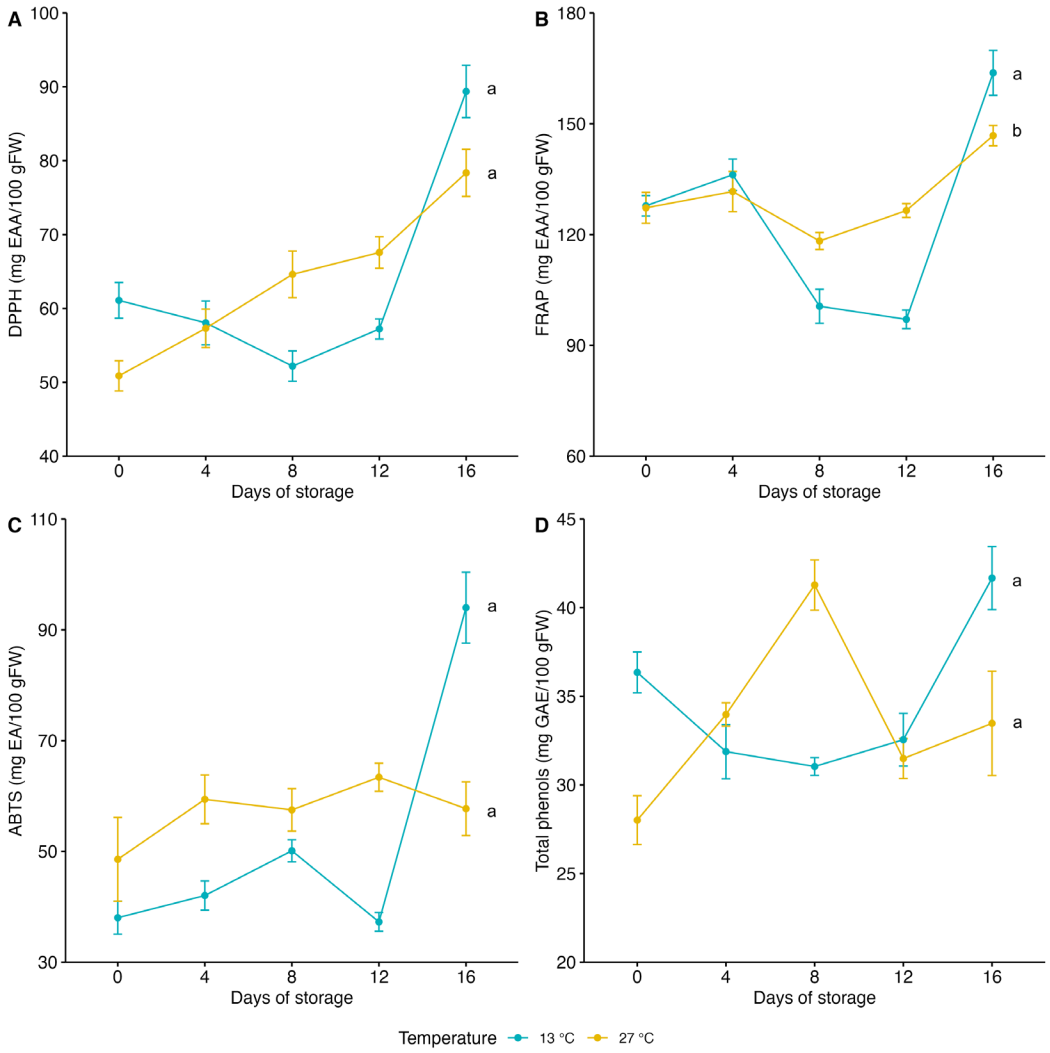

Figure 3. Antioxidant capacity of pitahaya fruits stored at 27 ± 1 °C (yellow color) and 13 ± 1 °C (blue color) for 16 days. A) DPPH, B) ABTS C) FRAP, D) Phenol Content. Different letters indicate significant differences between storage temperatures according to the Tukey test ($p < 0.05$).

Source. Own elaboration based on data from this investigation.

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Moreover, the radical elimination percentage obtained by the DDPH method during storage (Table 2) was 40.5 % and 46.84 % in fruits stored at 27 ± 1 °C and 13 ± 1 °C, respectively. These values are higher than those reported by Sudha et al. (2017), who found a radical removal percentage of 18.5 to 30 % from aqueous extracts of white pitahaya by the DPPH method. In the present study, a radical scavenging percentage of 18.48 % and 11.50 % by ABTS was obtained for fruits stored at 27 ± 1 ºC and 13 ± 1 °C, respectively (Table 2). Jiménez-García *et al.* (2022) in *Hylocereus polyrhizus* and *Selenicerus undatus* reported values of 24.88 % and 23.81 % radical scavenging by the DPPH method, 51.22 % and 50.92 % by the ABTS method, respectively, which is greater than the obtained results.

Table 2. Percentage of radical scavenging (%) of DPPH radicals, ABTS and FRAP ion by samples of pitahaya fruits stored at 27 ± 1 °C and 13 ± 1 °C.

Days	DPPH (%)		ABTS (%)		FRAP (%)	
	27 ± 1 °C	13 ± 1 °C	27 ± 1 °C	13 ± 1 °C	27 ± 1 °C	13 ± 1 °C
0	29.89	38.06	18.29	8.32	52.47	52.83
4	32.06	39.85	13.18	9.51	53.59	54.09
8	38.57	44.57	13.08	10.79	54.5	43.67
12	46.1	47	19.28	8.12	54.99	40.99
16	55.94	64.75	18.57	20.78	58	61.53
Average	40.51	46.84	18.48	11.50	54.71	50.62

Source. Own elaboration.

Total Phenols

The phenolic content of the fruits stored at both temperatures was similar ($p > 0.05$), presenting average values at 27 ± 1 ºC of 32.79 mg EAG/100 gFW and 32.58 mg EAG/100 gFW in the fruits stored at 13 ± 1 °C. Different authors report contents of phenolic compounds that range between 19.72- 48.30 mg EAG/100 gFW for pitahaya fruit (Ochoa-Velasco *et al.*, 2012, Jalgaonkar *et al*., 2020, Huang *et al*., 2021, Jiménez-García *et al.*, 2022, Franco *et al*., 2022). Franco *et al.* (2022) evaluated the antioxidant capacity and phenolic content in pitahaya fruits (*Hylocereus undatus*) under different storage conditions, finding that fruits harvested on day 31 and stored at 13 °C, decreased their antioxidant capacity from 83.0 % to 72.17 % in two weeks of

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storage and at non-detectable levels in week 5 of storage. In that same study, the phenol content decreased from 31.3 to 27.26 mg EAG/100 gFW and non-detectable levels in weeks 2 and 5 of storage, respectively.

Figure 3D demonstrates that after 8 days of storage at 27 ± 1 °C, the phenolic component concentration of fruits decreases. Similar results were reported by Hernández-Ramos *et al.* (2023) in pitahaya fruits (*Hylocereus ocamponis*), where the concentrations of phenolic compounds decreased after 12 days of storage, attributing it to the oxidative metabolism caused by the increase in the enzymatic activity of polyphenol oxidase and peroxidase, which are involved in the degradation of phenolic compounds due to stress conditions. Based on this, it is likely that the temperature of 13 ± 1 °C slows oxidative metabolism, with the decrease in these compounds occurring after day 16. The maximum peak of antioxidant capacity and phenolic compounds occurred on day 16 of storage. In this regard, Chen *et al.* (2021) found a positive correlation (r = 0.982) between the total phenolic content and the antioxidant capacity evaluated by the FRAP method, attributing the reducing capacity of the pitahaya fruit to the phenolic content of the extracts. In the same investigation, phenolic compounds were identified in pitahaya fruits (*H. undatus* and *H. polyrhizus*) including phenolic acids (25), flavonoids (38), lignans (6), stilbene (3), and other polyphenols (8). Based on the above, the highest antioxidant activity in the examined fruits is likely due to phenolic compounds generated on day 16 at 13 ± 1 °C, coinciding with a red color.

Conclusions

The temperature of 13 ± 1 °C prolonged the postharvest life of Queen purple pitahaya fruits by four days, delaying the accumulation of phenolic compounds and antioxidant capacity up to eight days. Likewise, fruits stored at 13 ± 1 °C presented less weight loss, greater firmness, tone angle, and antioxidant capacity by the FRAP method than fruits stored at 27 ± 1 °C. The fruits stored at 13 ± 1 °C visually presented an intense red color on day 16 with green bracts, without the presence of diseases and/or enzymatic darkening. In future research, it is suggested to evaluate the transpiration and respiration rate of pitahaya fruits, as well as perform a sensory analysis on the last day of storage.

Authors' contribution

Conceptualization of work, B-V. G.; methodology development, C-R. V.; software management, B-V. G., C-R. V.; experimental validation, O-J. GOES. B-L. J.E.; analysis of results, B-V. G., C-R. V.; Data Management, B-M. R.; writing and preparation of the manuscript, C-R. V.; writing, review, and editing, B-M. R., B-L. J.E., O-J. GOES.; project manager, B-M. R.; acquisition of funds, B-V. G.

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Conflict of interest

The authors declare that they have no conflict of interest.

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