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Original Article

Effect of pre-cooling on the shelf-life and quality of formosa papaya

Efeito do pré-resfriamento na vida útil e na qualidade do mamão formosa

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Abstract

Papaya is a climacteric fruit, rapidly ripening after harvesting due to ethylene production and increased respiratory rate. This swift ripening results in softening of fruit tissues, shortening the fruit shelf life. Pre-cooling serves as an alternative to minimize fruit ripening and post-harvest losses by reducing metabolism. This study aimed to evaluate the effect of pre-cooling on the quality and conservation of Formosa 'Tainung I' papaya. Papayas at maturation stage II were obtained from a commercial orchard with conventional production. The experimental design was a completely randomized 4×6 split-plot scheme, with pre-cooling treatments (Control, without pre-cooling treatment; pre-cooling at 15 °C in a cold chamber; pre-cooling at 7 °C in a cold chamber; and forced-air cooling at 7 °C) in the plot, and days of storage (0, 7, 14, 21, 28, and 35 days) in the subplot. Pre-cooling effectively delayed the ripening and senescence of Formosa papaya, reducing the loss of green color and firmness. Regardless of the treatment used, chilling injury and incidence of fungi from the genus Fusarium and Alternaria limited the shelf life of Formosa 'Tainung I' papaya up to 21 days of storage. Additionally, the appearance of hardened regions in the pulp compromised the sensory quality of the fruits, necessitating further investigation into the causes of this disorder.

Keywords: *Carica papaya* L, forced-air, sensory analysis, postharvest.

Resumo

O mamão é uma fruta climatérica, amadurecendo rapidamente após a colheita devido à produção de etileno e aumento da taxa respiratória. Esse amadurecimento rápido resulta no amolecimento dos tecidos da fruta, reduzindo a vida útil. O pré-resfriamento serve como uma alternativa para minimizar o amadurecimento da fruta e as perdas pós-colheita, reduzindo o metabolismo. Este estudo teve como objetivo avaliar o efeito do pré-resfriamento na qualidade e conservação do mamão 'Tainung I' Formosa. Mamões no estágio de maturação II foram obtidos de um pomar comercial com produção convencional. O design experimental foi um esquema de parcelas divididas completamente aleatório 4×6, com tratamentos de pré-resfriamento (Controle, sem tratamento de pré-resfriamento; pré-resfriamento a 15 °C em uma câmara fria; pré-resfriamento a 7 °C em uma câmara fria; e resfriamento por ar forçado a 7 °C) na parcela, e dias de armazenamento (0, 7, 14, 21, 28 e 35 dias) na subparcela. O pré-resfriamento retardou efetivamente o amadurecimento e a senescência do mamão Formosa, reduzindo a perda de cor verde e firmeza. Independentemente do tratamento utilizado, lesões por frio e incidência de fungos do gênero Fusarium e Alternaria limitaram a vida útil do mamão 'Tainung I' Formosa até 21 dias de armazenamento. Além disso, o surgimento de regiões endurecidas na polpa comprometeu a qualidade sensorial das frutas, exigindo investigação adicional sobre as causas desse distúrbio.

Palavras-chave: *Carica papaya L.,* ar forçado, análises sensoriais, pós-colheita.

1. Introduction

Papaya (*Carica papaya* L.) is a tropical fruit of great economic importance worldwide. Although Brazil is considered the second largest producer in the world, it loses about 30% of production in the post-harvest (Oliveira and Meissner, 2021). In papaya fruits, high ethylene production and respiratory rates after harvest quickly trigger changes in the fruit, increasing susceptibility to mechanical damage and infections by pathogens. This significantly reduces shelf life and increases post-harvest losses (Gao et al., 2020; Fabi and Prado, 2019).

To ensure fruits of good quality for consumers, several techniques for prolonging post-harvest shelf life have been studied. Therefore, pre-cooling has been shown to be effective in extending the post-harvest life of fruits and

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vegetables, especially in highly perishable fruits, such as papaya (Matouk et al., 2018). This method involves the rapid removal of field heat from the fruit after harvest, before storage, processing, and transportation, to quickly decrease the pulp temperature (Elansari and Mostafa, 2020). The rapid decrease in the temperature of the fruits before storage contributes to reducing production and sensitivity to ethylene, a phytohormone responsible for accelerating ripening and senescence (Soares et al., 2021). Consequently, it slows down the deterioration processes and increases the shelf life of the fruits.

There are different pre-cooling methods that vary in the efficacy of heat removal, cost, and effectiveness in maintaining the physicochemical quality of each fruit (Duan et al., 2020). The most used technique for fruits is cooling in conventional cold chambers—a slow system that involves exposing the product to cold in a chamber with uniform air distribution. Another method is forced air, a faster system in which a flow of cold air passes directly over the product (Zhou et al., 2019).

Pre-cooling has already shown positive results in other produce, such as tomatoes (Cherono et al., 2018), guava (Dhara et al., 2017), pear (Zhao et al., 2018), and mango (Li et al., 2019). However, there is limited information on the best pre-cooling technique for preserving and maintaining the postharvest quality of papaya.

Thus, the objective was to assess the effect of pre-cooling conditions on the quality and postharvest conservation of papaya fruits stored in a refrigerated environment.

2. Materials and methods

2.1. Experiment samples and installation

Formosa papayas (cv. 'Tainung I') were obtained from a commercial orchard of a fruit exporting company, located in the municipality of Icapuí, Ceará, Brazil (4°42'46" S and 37°21'18" W). The climate of the region is Aw according to the Köppen classification, that is tropical humid with average monthly temperatures above 18 °C and the driest month with precipitation below 60 mm (Beck et al., 2018).

Fruits were harvested at the maturation stage II (25% yellow peel), without apparent defects and free of diseases. Then, papayas were transported to packing house where they were washed with water and sanitized with sodium hypochlorite solution and Posfruit® fungicide.

Subsequently, treatments were applied, which consisted of subjecting the fruits to different pre-cooling conditions, being: I - Control (without pre-cooling treatment); II - pre-cooling in cold chamber at 15 °C and 88% relative humidity (RH) (15 °C-CC); III - pre-cooling in cold chamber at 7 °C and 83% RH (7 °C-CC); IV - forced-air cooling at 7 °C and 80% RH (7 °C-FA). The fruits were kept in these conditions until they reached a pulp temperature of 15 °C. Pulp temperature was monitored using a digital skewer thermometer (Incoterm®, 4 mm diameter tip), which was inserted into three fruits from each pre-cooling lot, at 60 min intervals. The fruits used to monitor pulp temperature were otherwise and, therefore, they were not further stored and analyzed.

Pre-cooling under forced air at 7 °C reduced pulp temperature to 15 °C in approximately 1 h, while in a cold chamber at 15 °C and 7 °C this temperature was reached after 2 and 4 h, respectively. Control fruits were stored with pulp temperature of approximately 28 °C.

Fruits from each treatment were then wrapped in microperforated plastic bags and stored in a cold chamber at 10 ± 1 °C and 70 ± 5% RH for 35 days. At harvest and every seven days, eight fruits per treatment were transported to the Post-harvest Physiology and Technology Laboratory at Federal Rural University of the Semiarid (UFERSA), Mossoró-RN, for quality evaluation.

2.2. Characteristics evaluated

Weight loss, expressed as a percentage, was obtained through the difference between the initial mass of the fruit and that obtained at the end of each storage period, using a precision analytical scale.

External and internal appearance of the fruits was determined using a visual scale of subjective notes adapted from Wills and Golding (2016) and Rocha et al. (2005), observing injuries caused by cold, depressions, spots, wilting, diseases (rot, pathogenic fungal structures). For the internal appearance, pulp watery softening, internal hardening caused by cold, and disease (rot, pathogenic fungal structures) were evaluated. When fungal structures were observed, the fungus was identified under an optical microscope.

Peel and pulp color were evaluated as luminosity (L), chromaticity (C) and hue angle (° hue) using a digital colorimeter (Konica Minolta, model CR400, CIELAB system, illuminant D65) positioned in two equidistant points on the peel and pulp.

Fruit and pulp firmness was determined using a digital texturometer (TA.XTExpress/TA.XT2icon, Stable Micro Systems) equipped with a cylindrical stainless steel 5 mm probe (model P / 5). The equipment was configured to insert the probe into 10 mm penetration depth at 1, 2, and, 10 mm s^{-1} pre-test, test, and post-test speeds, respectively, and 5 kg cell load. Two readings were performed at equidistant points in the equatorial region of the exocarp and mesocarp of the fruits sectioned. The results were expressed as Newton (N).

Then, the pulp fraction (mesocarp) was homogenized using a food processor (BL450BR, Nutri Ninja® Auto-IQ®) for further analysis. Soluble solids content (SSC) was directly evaluated in the pulp by digital refractometer (PR-100, Palette, Atago Co, LTD., Japan) (AOAC, 2002). Titratable acidity (TA) was determined by titration with 0.1 N NaOH (IAL, 2008), and results were expressed as % of citric acid. Pulp pH was directly determined using a phmeter (mPA-210, Tecnal®), according to the methodology proposed by AOAC (2002).

Total sugars were obtained using the Antrona reagent method, according to Yemm and Willis (1954), with results expressed in%. Vitamin C was determined by titration with Tilman's solution, as described by Strohecker and Henning (1967), the results were expressed as mg ascorbic acid 100 g^{-1} pulp.

β-carotene content in the pulp was determined spectrophotometrically according to Nagata and Yamashita (1992), and results were expressed as μg ml^{-1} pulp. Pectin methylesterase (PME) activity was determined using the methodology adapted from Jen and Robinson (1984), using, a mixture of 30 mL of 1% citrus pectin, diluted in NaCl at pH 7, with 5 mL of the enzymatic extract, and results was expressed in enzymatic unit (EU). min^{-1} g^{-1} of tissue.

Sensorial analysis was performed at 21 and 35 days of storage by ten trained tasters. The evaluated attributes were color, flavor, aroma, texture, and global acceptance using the 9-point hedonic scale: (1) dislike extremely, (2) dislike very much, (3) dislike moderately, (4) dislike slightly, (5) neither like nor dislike, (6) like slightly, (7) like moderately, (8) like very much, and (9) like extremely (Stone and Sidel, 2004). Purchase intent was assessed using the 5-point intention scale: (1) definitely would buy, (2) probably would buy, (3) might buy, (4) probably would not buy, and (5) definitely would not buy. For the development of sensory analysis within ethical standards, the research project was submitted to and approved by the Research Ethics Committee of the State University of Rio Grande do Norte (UERN), Mossoró, Rio Grande do Norte, Brazil, confirmed by the opinion No. 4,441,871.

2.3. Statistical analysis

The experimental design was completely randomized (DIC) in a 4 x 6 split-plot plot scheme, with pre-cooling treatments in the plot and days of storage in the subplot, with four replicates of two fruits each. Data were submitted to analysis of variance ($p < 0.05$) and means were grouped by Duncan's Multiple Range test ($p < 0.05$). For appearance and sensory analysis, data were analyzed by the Kruskal-Wallis test ($p < 0.05$) followed by the Bonferroni test ($p < 0.05$). Statistical analyzes were performed in R software version 3.5.2.

4. Results and discussion

A significant interaction between pre-cooling treatments and storage was observed for weight loss ($p < 0.01$), fruit firmness ($p < 0.01$), pulp firmness ($p < 0.01$), soluble solids content ($p < 0.01$), total soluble sugars ($p < 0.05$) and β-carotene content ($p < 0.01$). The main effects of pre-colling and storage were significant for titratable acidity ($p < 0.05$), pH ($p < 0.01$), and peel color indexes (luminosity, chromaticity, and Hue angle) ($p < 0.01$). Vitamin C content ($p < 0.01$) was influenced only by storage time.

4.1. Weight loss

Weight loss varied among treatments during storage. At 21 days, the lowest weight loss was observed in pre-cooled fruits at 7 °C-CC (1.74%). However, by the end of storage, lower weight loss was found in pre-cooled fruits in the cold chamber at 15 °C compared to the other treatments (Figure 1A).

Pre-cooling at 15 °C-CC in papaya was the most effective, blocking a 10.91% weight loss compared to pre-cooling at 7 °C in a cold chamber, forced-air cooling, and control. Pre-cooling reduces fruit respiration, decreasing water loss and, consequently, weight loss (Li et al., 2019). However, in this study, only pre-cooling at 15 °C-CC was effective in minimizing weight loss after 35 days of storage compared to the control. This may be attributed to the higher relative humidity inside the cold chamber, reducing weight loss. According to Tabassum and Khan (2020), such loss is due to water loss by transpiration and respiration. When elevated, these processes may compromise fruit appearance, causing a wrinkled surface. However, the weight loss of pre-cooled and control fruits at the end of storage was below that considered harmful to papaya, staying below 5%.

4.2. Fruit and pulp firmness and pectin methylesterase (PME) activity

Fruit firmness decreased during storage. However, the firmness of pre-cooled fruits remained consistent throughout storage and was higher than that of control fruits. After 14 days of storage, the firmness in pre-cooled fruits was around 81.36 N, similar to the initial storage period. In contrast, control fruits experienced a reduction in firmness to 61.87 N after 14 days, continuing to decrease until the end of storage (42.65 N). In pre-cooled fruits at 15 °C-CC, firmness was maintained until 21 days, while in fruits pre-cooled at 7 °C-CC and 7 °C-FA, it was sustained until 14 days (Figure 1B).

Pulp firmness significantly decreased after seven days of storage. However, pre-cooling at 7 °C-FA maintained pulp firmness at 15.51 N from the 7th to the 28th day of storage, while pre-cooling at 15 °C-CC led to a reduction in firmness during this storage period. In pre-cooled fruits at 7 °C-CC, the loss of firmness was similar to that of fruits without pre-cooling, decreasing throughout the entire storage period. The incidence of hardened regions in the fruit pulp significantly influenced firmness in pre-cooled at 7 °C-FA and 15 °C-CC, resulting in an increase in firmness after 28 days. At the end of storage, control fruits exhibited lower values of pulp firmness (4.33 N) compared to the other treatments (Figure 1C).

Firmness is a crucial quality attribute of fruits that influences consumer acceptability. Apart from palatability, various commercially significant factors, such as resistance to transport, handling, and disease incidence, depend on texture (Tan et al., 2022; Chen et al., 2021). In papaya, the ripening process is characterized by changes in texture related to cell wall carbohydrate metabolism, ultimately leading to softening (Zhu et al., 2022). The higher firmness values maintained in pre-cooled fruits can be justified by the effective action of the treatment in preserving firmness in papaya. Pre-cooling rapidly removes field heat from the fruits after harvest, reducing metabolism and pectin methylesterase (PME) activity—an enzyme that plays a role in cell wall degradation and softening of fruits during ripening (Sanchez et al., 2020; Prado et al., 2016). Similar results were observed by Li et al. (2019) when evaluating the effect of pre-cooling on the quality of mango and by Elansari and Mostafa (2020) in 'Navel' oranges, where a delay in firmness loss in pre-cooled fruits at the end of storage was observed compared to the control.

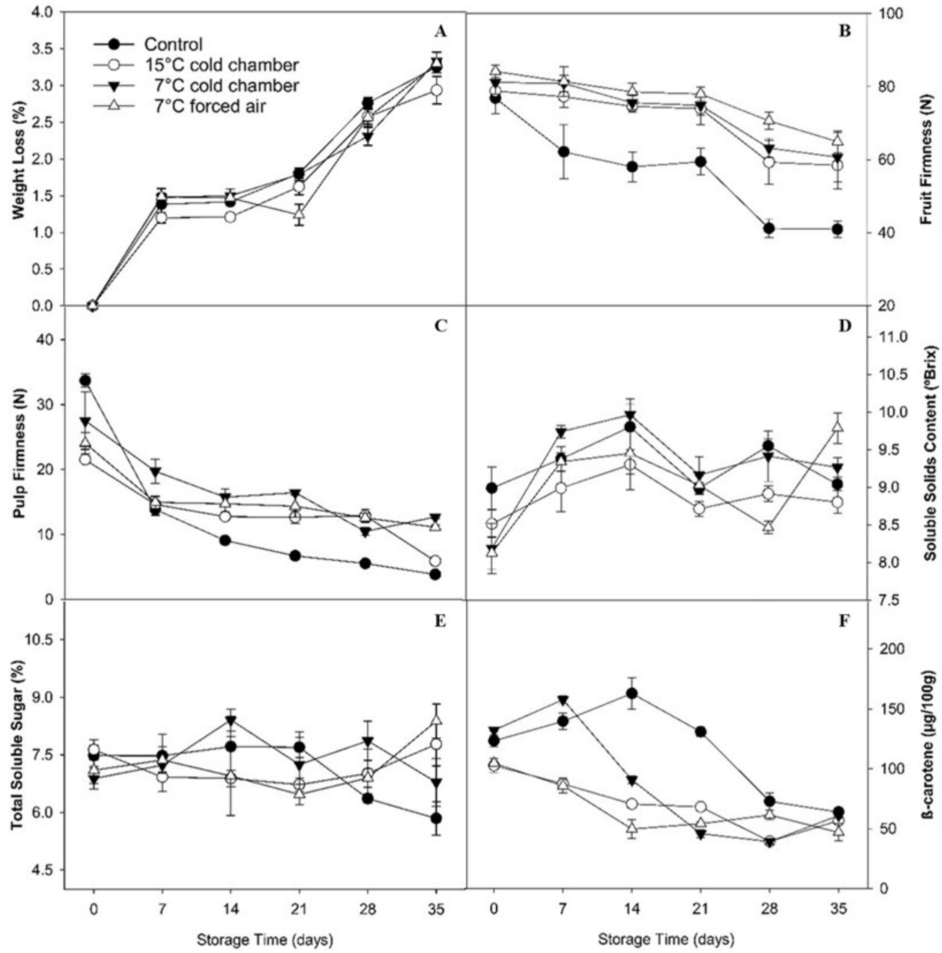

Figure 1. Weight loss (A), fruit firmness (B), pulp firmness (C), soluble solids content (D), total soluble sugars (E) and β-carotene content (F) in Formosa 'Tainung I' papaya subjected to different pre-cooling conditions, followed by cold storage (10 ± 1 ° C and 70 ± 5% RH).

Pre-cooling inhibited pectin methylesterase activity, as pre-cooled fruits exhibited lower enzyme activity compared to control fruits. Pre-cooling at 7 °C in a cold chamber induced less enzyme activity in papayas, and there was no significant difference from those pre-cooled at 15 °C (Table 1). This may be attributed to the slowing of fruit metabolism (Pan et al., 2017).

PME activity varied slightly over the 28 days (781.35 EU g-1 min-1), decreasing to 595.32 EU g-1 min-1 at the end of storage (Table 2). The lower activity of PME maintains the degree of esterification, making it challenging to demethylate the pectic polymer. Consequently, it reduces the subsequent action of the enzyme polygalacturonase, which plays a role in the degradation of pectic substances, thus affecting the solubilization of pectin and the softening of the fruit (Liu et al., 2020).

4.3. Titratable acidity and pH

Pre-cooled fruits exhibited equal or lower titratable acidity compared to control fruits. Similarly to titratable acidity, pulp pH was higher in pre-cooled fruits. However, the pH in pre-cooled fruits at 15 °C-CC did not differ from control fruits (Table 1). The higher acidity in control fruits is possibly linked to the degradation of pectin and the formation of galacturonic acid resulting from cell wall degradation during ripening. The rapid decline in metabolic activity provided by pre-cooling delayed the ripening processes that would lead to the accumulation of organic acids, thereby reducing acidity (Nunes et al., 2017).

During storage, titratable acidity values increased up to 28 days (0.137%), then decreased at 35 days (0.104%). Meanwhile, pH slightly decreased, ranging from 5.6 to 5.3 (Table 2). As the fruit ripens, acidity may increase, accompanied by a gradual decrease in pH, possibly resulting from the synthesis of organic acids from cell wall degradation. Therefore, a reduction in pH indicates the conversion of acids into sugars and their subsequent oxidation during respiration, as well as in other biochemical processes (Kuwar et al., 2015).

4.4. Soluble solids content and total soluble sugars

Soluble solids content (SSC) remained consistent throughout storage in fruits pre-cooled at 15 °C-CC, with values close to 8.87 °Brix. However, fruits pre-cooled at

Table 1. Mean of pectin methylesterase (PME) activity, titratable acidity (TA), pH, and peel color as luminosity (L), chromaticity (C) and Hue angle (° h) in Formosa 'Tainung I' papaya submitted to different pre-cooling conditions.

Pre-cooling conditions	PME (U min^{-1} g FW^{-1})	TA (% citric acid)	pH	Peel color		
				L	C	° h
Control	838.14a	0.126a	5.36b	45.44a	26.48a	109.20c
15 °C cold chamber	735.81bc	0.110b	5.38ab	44.62b	25.07b	112.85b
7°C cold chamber	663.57c	0.111b	5.42a	44.53b	24.59bc	114.37ab
7°C forced air	755.47b	0.110b	5.42a	43.44c	23.84c	115.34a

Means with same letter in column are not significantly different by Duncan's Multiple Range test ($p < 0.05$).

Table 2. Mean of pectin methylesterase (PME) activity, titratable acidity (TA), pH, peel color as luminosity (L), chromaticity (C) and Hue angle (° h), and vitamin C content (AA) in Formosa 'Tainung I' papaya during cold storage (10 ±1 °C and 70 ± 5% RH).

Storage time (days)	PME (U min^{-1} g FW^{-1})	TA (% citric acid)	pH	Peel			AA (mg 100g^{-1})
				L	C	° h	
0	863.65a	0.106cd	5.66a	43.06b	23.10c	117.45a	55.65bc
7	772.88ab	0.100d	5.39b	43.49b	23.84bc	115.61ab	58.98b
14	709.22b	0.114c	5.36b	44.22ab	25.15ab	113.41bc	69.96a
21	767.06ab	0.125b	5.41b	45.41a	26.46a	111.59cd	60.66b
28	781.35ab	0.137a	5.26c	45.20a	26.00a	110.61de	51.14cd
35	595.32c	0.104cd	5.28c	45.67a	25.41ab	108.98e	47.55d

Means with same letter in column are not significantly different by Duncan's Multiple Range test ($p < 0.05$).

7 °C-CC showed an increase in soluble solids content up to 14 days, followed by a slight reduction at 21 days, ranging from 9.7 to 8.9 °Brix, and maintaining this level up to 35 days of storage. Similar behavior was observed in fruits pre-cooled at 7 °C-FA and control, except that pre-cooled at 7 °C-FA showed a lower value at 28 days, differing significantly from the other treatments (Figure 1D). The increase in SSC under these pre-cooling conditions may be associated with the advancement of the ripening process, in addition to the loss of water, which increases the concentration of soluble solids. The low variation in SSC in fruits pre-cooled at 15 °C-CC may be due to the reduction in the metabolic rate of the fruits, with the retention of sugar molecules as polysaccharides (Fan et al., 2019).

For total soluble sugars, no significant differences were observed between pre-cooled and control fruits until 28 days of storage. However, at 35 days, pre-cooled fruits had a higher total sugar content than control fruits. In control fruits, total sugars tended to decrease during storage, while in pre-cooled fruits, the values remained constant (Figure 1E). Under pre-cooling conditions, the variation in sugar content was lower, likely due to the rapid removal of heat from fruits after harvest, which limits respiratory activity and reduces the use of sugars as a substrate for metabolism (Michailidis et al., 2017).

4.5. Vitamin C content

Vitamin C was not affected by pre-cooling treatments. However, vitamin C increased gradually until 14 days, reaching a maximum of 69.9 mg ascorbic acid per 100 g of fresh weight, then decreasing to 47.55 mg ascorbic acid per 100 g until the end of storage. The variation in ascorbic acid content may be related to the changes that occurred during fruit ripening throughout storage (Sanchez et al., 2020). Similar behavior was reported by Udomkun et al. (2016) and Gomes et al. (2018) in Formosa 'Tainung I' papaya, with mean values of 56.62 and 66.02 mg per 100 g, respectively.

4.6. Color and β-carotene content

As indicated in Table 1, for peel luminosity, the control fruits were lighter than the pre-cooled fruits, as evidenced by higher L values. Chroma (C) of the peel was significantly different between treatments, with higher values in the control fruits, indicating that these fruits had a greater intensity of color in the peel, tending toward brighter colors. Regarding hue angle (° h), the highest value was observed in papayas pre-cooled at 7 °C-FA, not differing from 7 °C-CC, indicating that the peel of these fruits was greener, while the peel in the control fruits was less green.

During ripening, a slight increase in luminosity and chromaticity was observed, resulting in fruits with intense color and brightness. The hue angle decreased during storage, shifting from green to a more yellow shade (Table 2). According to Paliyath et al. (2008), the peel changes to yellow due to the structural decomposition of chlorophyll molecules, involving the activity of chlorophyllase and carotenoid synthesis. However, these processes can be delayed by pre-cooling. Rapid fruit cooling after harvest reduces metabolism and the degradation of chlorophyll, as a consequence of the reduction in ethylene production. This, combined with the action of chlorophyllases and oxidative systems, as well as the reduction of pH due to the release of organic acids from the cellular vacuole, possibly contributes to a green appearance in pre-cooled fruits, especially those pre-cooled at 7º C under forced air (rapid cooling) (Rocha et al., 2005). Similar results were verified by Cherono et al. (2018) in pre-cooled tomatoes and Sena et al. (2019) in hydrocooled cashews (at 5 °C).

β-carotene content decreased in all treatments, presenting similar values at the end of storage. In non-pre-cooled fruits, β-carotene increased until 14 days (162.81 µg per 100 g), decreasing afterward. However, in fruits pre-cooled at 7 °C-CC, this increase occurred until the 7th day (157.71 µg per 100 g). On the other hand, in fruits pre-cooled at 15 °C-CC and 7 °C-FA, β-carotene slightly decreased at 14 days (from 102.80 to 70.60 µg per 100 g and from 104.61 to 49.70 µg per 100 g, respectively), maintaining this level up to 35 days (Figure 1F). β-carotene ranged from 40.20 to 162.81 µg per 100 g, and the control fruits displayed the highest values, consistent with results in other studies (Siriamornpun and Kaewseejan, 2017; Pritwani and Mathur, 2017).

Carotenoids are important compounds, acting as indicators of ripening. Factors such as radiation, temperature, variety, methods of determination, and postharvest handling can influence carotenoid content in the fruit (Zhou et al., 2019). Thus, the lower content of carotenoids in pre-cooled fruits indicates that this treatment, by reducing fruit metabolism, possibly reduced the biosynthesis of β-carotenes (Alara et al., 2022). Among the pre-cooling conditions, at 15 °C-CC and 7 °C-FA stand out due to the significantly lower average compared to other treatments up to 14 days of storage.

4.7. External and internal appearance

Appearance assessment is one of the main criteria used by consumers when judging quality. Characteristics such as color and the absence of mechanical, physiological, and pathological injuries allow for estimating shelf-life on the market. Products must reach consumers with acceptable visual quality for commercialization (Zillo et al., 2018). Scores for external and internal appearance were reduced during storage, regardless of pre-cooling conditions (Figure 2). For external appearance, fruits lost quality after seven days of storage due to the appearance of cold injury and rind stains, in addition to the delay and unevenness in fruit ripening at 28 days. During the same period, there was an incidence of pathogenic fungi in the peduncular region and in small areas of the fruit epidermis, limiting the shelf-life of the fruits. These fungi were identified as being of the genus Fusarium and Alternaria. However, at the end of storage, the fruits had characteristics suitable for consumption, with scores above 3.0, classifying them as good-looking fruits.

Regarding internal appearance, quality was maintained until 21 days of storage with maximum scores (5.0), indicating fruits with pulp without defects (Figure 2). After 28 days of storage, slight defects in the pulp were observed, related to chilling injury characterized by the inhibition of ripening and the presence of hardened regions. Due to these defects, fruits were classified as unfit for consumption, with characteristics unsuitable for commercialization.

4.8. Sensory analysis

It was found that the control samples pre-cooled at 15 ° C-CC and 7 ° C-FA did not differ significantly for the evaluated attributes. Higher scores for the desirable attributes in this produce were presented among the hedonic terms “like slightly” and “like very much” (Figure 2A).

At 35 days of storage, all the evaluated attributes were significantly different among treatments. It was observed that quality was less affected in control fruits and fruits pre-cooled at 7 ° C-CC compared to the other treatments, with higher scores in the test. Purchase intention proved to have the best acceptability at the end of storage, obtaining scores above 5 (“like slightly” to “like moderately”). Fruits pre-cooled at 15 ° C-CC and 7 °C-FA showed lower scores, varying between “neither like nor dislike” and “moderately dislike”, presenting undesirable characteristics such

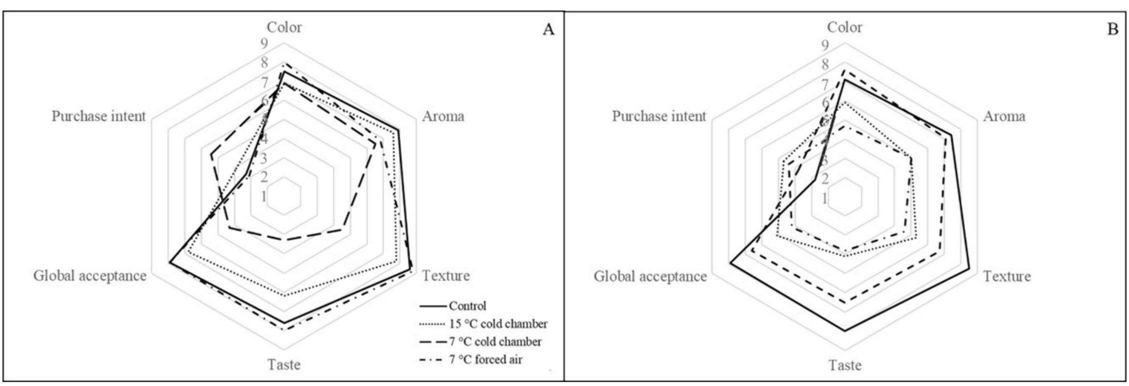

Figure 2. Sensory profile of Formosa ‘Tainung I’ papaya samples submitted to different pre-cooling conditions performed at 21 (A) and 35 (B) days of storage.

as pale color, bitter taste, without sweetness, without a characteristic aroma, and with hard texture. These characteristics can be attributed to the appearance of hardened regions in the fruit pulp observed at 28 and 35 days, according to internal appearance evaluation, favoring the development of undesirable characteristics, especially in the samples treated in these pre-cooling conditions (Figure 2B).

5. Conclusion

Pre-cooling delayed ripening and senescence of Formosa papaya, reducing the loss of green color and firmness. The appearance of cold injury and the incidence of fungi from the genus Fusarium and Alternaria limited the shelf-life of Formosa 'Tainung I' papaya up to 21 days of storage, regardless of treatment. Additionally, the appearance of hardened regions in the fruit pulp compromised the sensory quality of the fruits, warranting further investigation into the causes of this disorder.

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