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Influence of maturity stage and storage duration on the physicochemical properties and eating quality of Barbados cherry *(Malpighia emarginata* D.C.)

Tam. T. T. Dang[1] and Ngoc. T. A. Tong[1*]

[1] Institute of Food and Biotechnology, Can Tho University, Vietnam
[*]Corresponding author: ttangoc@ctu.edu.vn

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Abstract

Barbados cherry (*Malpighia emarginata* D.C.) is notable for its rich vitamin C and phenolic content, both of which are significantly influenced by the fruit's maturity stage and tend to decline during storage. This study evaluated the physicochemical and bioactive attributes of Barbados cherry at different maturity stages—unripe, half-ripe, and ripe—and during the preservation period to determine changes in fruit quality. The results indicated that the highest amounts of vitamin C (100 mg/g) and total phenolic content (TPC, 90 mg GAE/g) were found in unripe fruit, while half-ripe and ripe fruits exhibited higher protein, carotenoid, and sugar contents. During storage, half-ripe Barbados cherry stored at 12 ± 2 °C maintained superior physical and nutritional quality, retaining vitamin C (57.15 mg/g), TPC (51.46 mg GAE/g), and antioxidant activity (DPPH, 29.45 mg TE/g) after six days. Correlation analysis revealed strong positive relationships among vitamin C, TPC, and DPPH, suggesting coordinated degradation of antioxidant compounds during preservation. These findings emphasize that harvesting Barbados cherry at the half-ripe stage and storing it under moderate refrigeration effectively maintains both nutritional and sensory qualities, providing practical recommendations for postharvest handling and short-term commercialization.

Keywords*:* Barbados cherry, Vitamin C, TPC, Quality, Storage time

1. Introduction

Barbados or Acerola (*Malpighia emarginata* D.C.) is a cherry-like tropical fruit that is a wild plant cultivated in tropical and subtropical climatic zones, originating from Southern Mexico. It is very popular in central America, the Caribbean countries, and Brazil [1]. The fruit is small, measuring between 1 and 4 cm in diameter and weighing 2–15 g. Its skin color changes from green during development to yellow and red tones as it ripens [2,3].

The increasing popularity of Barbados cherry is attributed to its high antioxidant activity and substantial amounts of ascorbic acid and other bioactive compounds, including amino acids, β-carotenoids, phenolic compounds, vitamins (B1, B2, B3, and A), and minerals (calcium, iron, potassium, magnesium, and phosphorus) [4]. Chang et al. [5] indicated that the antioxidant activity of Barbados cherry extract is significantly higher compared to phenolic-rich extracts from other fruits, such as cherry, grape, mango, and strawberry. Barbados cherry has become a valuable source for developing nutritional and functional foods due to its potent antioxidative, anti-inflammatory, anti-hyperglycemic, antitumor, antigenotoxic, and hepatoprotective properties [6]. Various commercial Barbados -based products are used as dietary supplements, including juice creams, jams, ices, gelatins, sweets, and liquors [2]. Over the past few decades, Brazil has emerged as the largest producer of Barbados cherry, cultivating 11,000 hectares and producing 3,000 kg/ha, totaling 32,990 tons/year, primarily for juice processing [7]. In 2016, North America accounted for 24% of the global Barbados market, which was estimated to grow at a compound annual growth rate (CAGR) of 9.7%. Similarly, Western Europe was forecasted to grow at an 8.7% CAGR. The global market for Barbados cherry consumption is projected to reach 17.5 billion US dollars by 2026, with an 8.5% growth rate [6].

Barbados cherry is rich in nutrients and offers numerous health benefits, making it primarily consumed fresh. However, the quality and shelf life of Barbados cherry depend significantly on the harvest maturity stage and

storage temperatures [8]. Consumption requirements and fruit quality are critical in determining the ideal maturity stage. Fruits harvested at the immature stage have a longer storage time and higher ascorbic acid content, but there are limitations in carbohydrate accumulation and aromatic volatile compounds [9]. Conversely, harvesting fruit at a more mature stage results in a shorter storage period but higher carbohydrate and volatile aroma content. Additionally, low storage temperatures are an effective method for maintaining fruit quality and prolonging postharvest life by reducing metabolic activities associated with respiration, softening, and decay incidence [10]. Due to the fruits' skin, moisture loss occurs rapidly when stored at high temperatures and low relative humidity, typically within 2 to 3 days after harvest [9,11]. However, tropical fruits preserved under chilled conditions may experience physiological disorders known as chilling injury, which alters cell membrane integrity, leading to cell disruption and death [12]. Symptoms of chilling injury include tissue darkening, translucent flesh, non-ripening, and a lack of color development, as well as loss of flavor and aroma. Therefore, depending on species, genotypes, and environmental growing conditions, the low-temperature tolerance of Barbados cherry may vary. The optimal temperatures recommended for preserving Barbados cherry range from 5–15 ^{o}C [13,14].

In Vietnam, Barbados cherry is primarily cultivated in two provinces: Tien Giang and Ben Tre. The three popular cultivars are sweet (*Malpighia punicifolia* L.), traditional sour (*Malpighia glabra* L.), and imported sour variety (*Malpighia emarginata* D.C.) [15]. Most of the Barbados cherries produced are preserved at room temperature for sale as fresh fruit, resulting in quality and quantity losses. Few studies have focused on Barbados cherry, and there was not much information regarding its quality and preservation. Therefore, this study on the physicochemical and biological changes of Barbados cherry (*Malpighia emarginata* D.C.) at different maturity stages and during storage was conducted to compare the quality of fruit at three maturity stages and investigate quality changes of half-ripe Barbados during preservation, contributing to pivotal scientific knowledge aimed at improving and maintaining agricultural food quality for further applications.

2. Materials and methods

2.1 Barbados cherry materials

Barbados cherry was purchased in Go Cong town, Tien Giang province, Vietnam, in 2022. The cherries were washed with tap water to remove dust, dirt, and damaged fruit, then packed in PET (Polyethylene terephthalate) containers measuring 14.2 x 12.5 x 10.5 cm. The sealed boxes, each containing 500 g of Barbados cherry, were placed in a refrigerator (Sanaky, Vietnam) at 12 ± 2 ^{o}C for analysis and preservation over 12 days. Three independent storage experiments were conducted.

2.2 Determination of physical-chemical characteristics

The physical-chemical characteristics of Barbados cherry included color (L, a, b) measured on 10 Barbados fruits and each fruit assessed at three different positions using a colorimeter (FRU, China), following a description by Provesi et al. [16]. Weight and seed ratio were measured using a scale (Sartorius, Germany). Total soluble solids (TSS) were analyzed using an Atago refractometer (NM 2773, China) according to the AOAC method (2000), with results expressed in degrees Brix (°Bx). pH was measured using a pH electrode (Vemier, USA), moisture content was determined using the AOAC 934.06 method, which involved weighing 5 g of fresh-cut Barbados cherry and drying it at 105 ^{o}C until a constant weight was achieved. Total reducing sugar was analyzed using acid dinitrosalicylic (DNSA) (TCVN 4594:1988), total acid was determined by titration (TCVN 4589:1988) and those presented in dry matter, and total ash content was assessed using the AOAC No. 942.05 method. The Kjeldahl method (AOAC No. 920.87) was used to determine crude protein content, calculated from nitrogen content.

2.3 Bioactive compositions analysis

Vitamin C quantification was performed according to the AOAC method (1984). Five grams of samples were milled and immersed in 20 mL of 1% HCl for 5 minutes. Acid oxalic (1%) was added until the volume reached 100 mL, and the solution was shaken gently and placed for 15 min before filtering through filter paper. Then, 10 mL of the filtrate was mixed with 0.5 mL of 1% starch (using freshly prepared starch as an indicator) in a 125 mL Erlenmeyer flask and titrated with 0.01 N iodine. The results were expressed as mg ascorbic acid per g of dry matter (DM).

TPC was determined using Folin-Ciocalteu (FC) reagent, following the method described by Phuong et al. [17]. An aliquot of 0.5 g of the powdered sample was mixed with 15 mL of 80% methanol. The mixture was kept on ice for 15 minutes and centrifuged at 10,000 rpm for 15 minutes at 4 °C (Eppendorf, Germany). The supernatant was collected in a volumetric flask. The remaining pellet was re-extracted with 10 mL of 80% methanol using the same procedure. Both supernatants were combined and stored at -20 °C until analysis. One mL of sample extracts

was mixed with 0.5 mL of FC (10 times dilution) and left for 6 minutes before adding 1.5 mL of 20% Na_2CO_3 (w/v). After being kept in the dark for 2 hours, the mixtures were measured at 760 nm. The TPC content was expressed as mg gallic acid equivalent (GAE) per g DM, based on a standard curve of gallic acid in the range of 0-50 mg/L.

Antioxidant activity (DPPH – 2,2-Diphenyl-1-picrylhydrazyl) was assessed following the method of Nguyen et al. [18]. Two mL of DPPH solution was reacted with 100 µL of extracts in the dark for 30 minutes at room temperature. The absorbance was then read at 517 nm, and the results were expressed as mg trolox equivalent (TE) per g DM using a standard curve of trolox in the range of 0-0.1 mg/mL.

Total carotenoid content was investigated following the method described by Rojas et al. [19]. About 0.25 g of the sample was placed in a tightly capped glass tube covered with aluminum foil to prevent oxidation and light exposure. Then, 21 mL of solvent (4:3 ethanol:hexane) was added, and the mixture was homogenized for 1 min using an Ultra-Turrax (China). The homogenizer probe was rinsed with another 21 mL of solvent, and the wash solution was collected. The sample was centrifuged at 8000 rpm for 5 min (Eppendorf, Germany), and the supernatant was separated and protected from light. The wash solution was combined with the residue, centrifuged again under the same conditions, and the resulting supernatant was pooled with the first extract. Five milliliters of distilled water were added, and the mixture was allowed to separate into aqueous and hexane phases. The hexane layer containing carotenoids was collected, and 2.5 mL was transferred to a 1 cm quartz cuvette for absorbance measurement at 450 nm using spectroscopy (Eppendorf, Germany), with hexane used as a blank. Carotenoid content was calculated and expressed as mg/g dry matter equivalents.

2.4 Statistical analysis

Results are reported as mean ± standard deviation of three independent replicates. The data were compared using analysis of variance (ANOVA) with a significance level of 5%, as determined by the LSD (Least Significant Difference) test, using Statgraphics Centurion 18.1.12 (Statgraphics Technologies, Inc., The Plains, Virginia).

3. Results and discussion

3.1 Physiochemical and biological properties of fruits based on maturity indices

The physicochemical properties of Barbados cherry vary depending on maturity levels (Table 1). Unripe Barbados cherry had a lower pH value than half-ripe and ripe fruits ($p < 0.05$), while there was no significant difference in pH value between half-ripe and ripe fruits ($p > 0.05$). The unripe fruits are more acidic, as indicated by the total acid content, which was highest at 5.26%, nearly twice that of ripe Barbados cherry. This is due to the heightened synthesis and accumulation of organic acids in unripe Barbados cherry, leading to a higher total acid content. As the fruit progresses to the half-ripe and ripe stages, the metabolic processes that convert these acids to sugars or other compounds become predominant, which results in a considerable decrease in acidity [20].

Table 1 Physicochemical properties of fruits based on maturity indices

Attributes	Levels of maturity		
			
	Unripe	Half-ripe	Ripe
pH	4.20 ± 0.02^{b}	4.23 ± 0.01^{a}	4.24 ± 0.01^{a}
Total acid (%)	5.26 ± 0.22^{a}	4.15 ± 0.1^{b}	2.46 ± 0.02^{c}
TSS (%)	8.47 ± 0.05^{c}	8.64 ± 0.02^{b}	8.86 ± 0.04^{a}
Total reducing sugar (%)	85.02 ± 1.12^{b}	88.01 ± 1.62^{a}	88.79 ± 0.24^{a}
Weight (g)	4.61 ± 0.18^{a}	5.13 ± 0.44^{a}	4.84 ± 0.3^{a}
Seed ratio (%)	15.59 ± 0.55^{a}	12.40 ± 0.30^{b}	9.78 ± 0.39^{c}
L*	75.18 ± 0.89^{a}	75.48 ± 0.61^{a}	71.93 ± 0.24^{b}
a*	-2.28 ± 0.14^{c}	0.69 ± 0.14^{b}	5.90 ± 0.65^{a}
b*	10.51 ± 1.05^{a}	9.33 ± 0.47^{b}	7.29 ± 0.32^{c}
Moisture (%)	91.50 ± 0.62^{a}	90.93 ± 0.02^{a}	90.02 ± 0.26^{b}
Ash (%)	0.51 ± 0.02^{a}	0.48 ± 0.01^{ab}	0.46 ± 0.01^{b}

The results are expressed as mean ± standard deviation of three replicates. The different superscript letters in the same row indicate significant differences ($p < 0.05$). The color, weight, and seed ratio parameters are determined by average data from 10 Barbados fruits.

The observed results differ from those of Vendramini and Trugo [9], who reported an increase in titratable acid and constant pH values at various maturity stages of Barbados cherry. These differences could be attributed to variations in the cultivar used and the growth conditions. Additionally, TSS and total reducing sugar increased

significantly during maturity progress, which was from 8.47% to 8.86% for TSS and increased 3.77% for total reducing sugar ($p < 0.05$). The increase in TSS and reducing sugar with fruit maturity can be explained by starch hydrolysis into sugars, resulting in sweeter fruit and reduced acidity [21]. The percentage of ash decreased significantly during the ripening stage, from 0.51% to 0.46% ($p < 0.05$).

Moreover, the current study recorded various statistical results for color characteristics among fruits at different maturity levels. Table 1 illustrates that the a^* value increased dramatically from -2.28 to 5.9, as the color of ripe Barbados cherry is orange or red. The increase in a^* value during ripening is primarily due to the degradation of chlorophyll, which reduces green coloration, and the accumulation of anthocyanins, enhancing red pigmentation [22,23]. Additionally, Table 1 shows the highest values of b^* and L^* in unripe fruit (10.51 and 75.18) compared to others, with these values significantly decreasing when the fruit ripens ($p < 0.05$). Vendramini and Trugo [9] also reported that the b^* value of Barbados cherry peaked (12.13) at the immature stage, while the a^* value reached its maximum (25.97) at the mature stage. Although the weight of fruits showed no significant differences across maturity levels, the seed ratio of unripe Barbados cherry was much higher than that of half-ripe and ripe fruits, at 15.59, 12.40, and 9.78%, respectively ($p < 0.05$). During the ripening process, the fleshy part of the fruit develops more rapidly than the seeds, and the pericarp expands, leading to an increase in fruit size and weight. Meanwhile, nutrient content in the flesh rises, resulting in a significant reduction in the seed ratio [24].

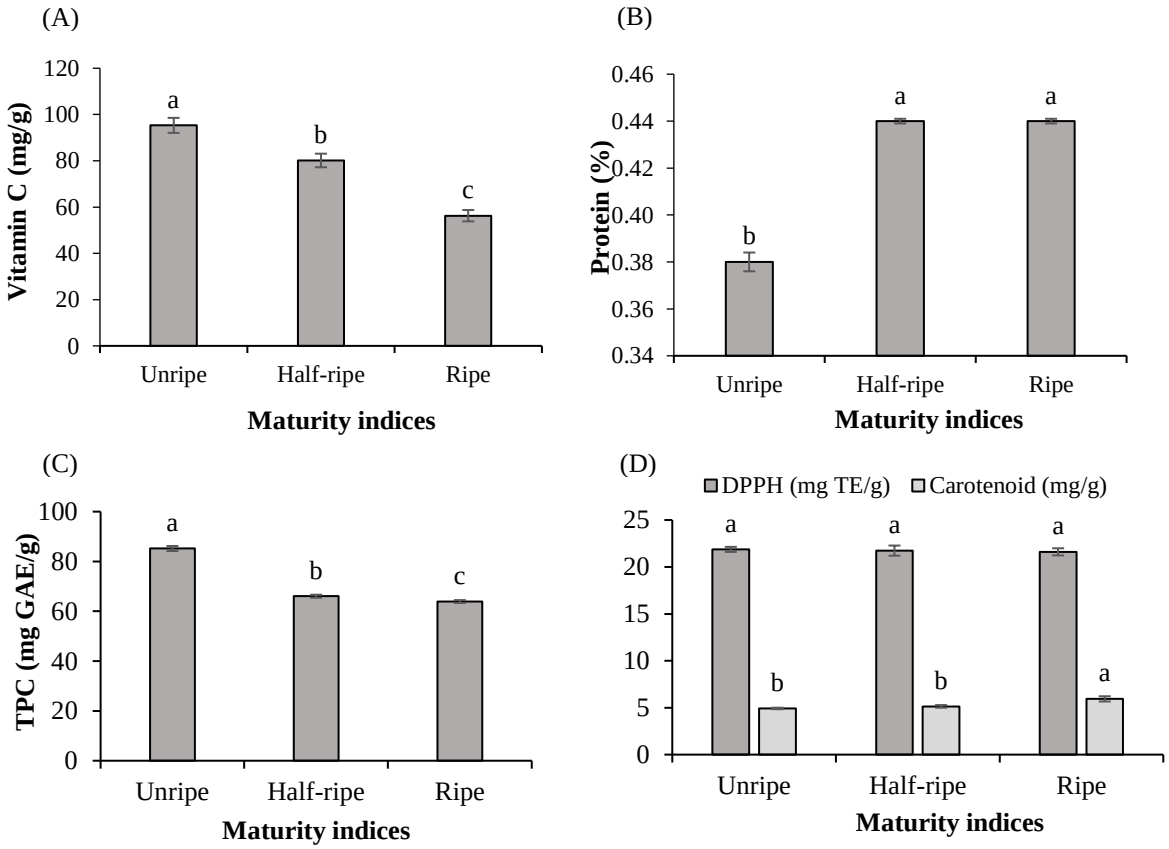

Figure 1. Chemical quality changes (vitamin C (A), protein (B), TPC (C), and DPPH and Carotenoid (D)) of Barbados cherry at different maturity stages

The results are expressed as mean ± standard deviation of three replicates. The different superscript letters are significantly different ($p < 0.05$).

Figure 1 illustrates the changes in the biological quality of fruits during development. Specifically, the amount of vitamin C present in Barbados cherry was highest at the immature stage, approximately 100 mg/g DM, and fell dramatically to nearly 40 mg/g DM when the fruit ripened. This decline is attributed to biochemical oxidation supported by the oxidative breakdown of ascorbic acid, with the only appearance of 3-hydroxy-2-pirone in ripe Barbados [9]. This result aligns with a report by Righetto et al. [25], which revealed that vitamin C content in Barbados fruits was high in immature fruits (1.9 g/100 g of juice) and experienced a significant decrease during ripening (0.97 g/100 g of juice in mature fruits). Similarly, TPC content was also highest when unripe, at about 85 mg GAE/g, and witnessed a notable decrease of approximately 20 mg GAE/g at the ripe stage. This decline may be explained by the activation of several browning enzymes during fruit development, that may utilize phenolic compounds as substrates, leading to a decrease in TPC. Furthermore, the biosynthesis of anthocyanin

structures also needs to use phenolic compounds [26]. Additionally, it was observed that Barbados cherry contained a high amount of protein during the half-ripe period, which remained unchanged until the ripe stage (0.44%) ($p > 0.05$), compared to unripe fruit at under 0.38% ($p < 0.05$). Although there were significant differences in TPC and vitamin C contents, the antioxidant activity of Barbados fruit remained constant during the maturity period at about 22 mg TE/g ($p > 0.05$). Furthermore, as the fruit ripened, the amount of carotenoid increased due to the color change to red ($p < 0.05$). This is a result of chlorophyll degradation, which is associated with an increase in carotenoids [27]. A similar result was published by Andersson et al. [28], showing a rise in carotenoids during the maturity of rose hips.

3.2 Physicochemical and biological characteristics of half-ripe fruit during storage

Half-ripe Barbados cherry was selected for the storage experiment due to its high bioactive and physicochemical characteristics. As shown in Table 2, most attributes exhibited a similar downward trend during storage time, except for pH, TSS, and weight loss. Specifically, the pH of the fruit increased by 0.36 after 12 days of storage ($p < 0.05$) due to a decrease in total acid from 4.28% on the initial day to 1.79% on the final day of the study. Total soluble solids in the fruit rose significantly from 9.20% to 11.20% after 12 days. Ribeiro and de Freitas [29] indicated that the titratable acid content in Barbados cultivars stored at 8 °C decreased considerably during ripening, while changes in soluble solids content were limited during preservation. Additionally, the increase in weight loss during the preservation process is notable due to spoilage and water loss. It was recorded that the weight loss of Barbados cherry was significantly different after 6 days compared to the third day, and this value continued to rise, peaking at 9.12% on the 12th day. The higher maturity of Barbados cherries correlates negatively with weight loss due to a much higher respiration rate and carbon loss during storage [29]. In contrast, the total reducing sugar value was highest at the start (102.17%) before dropping to 93.70% on the 6th day and remaining unchanged at the end of the period. Similarly, the lightness (L^*) and redness (a^*) of the fruit showed statistically significant differences after 9 days and remained stable until the last day, while no changes were noted in the yellowness (b^*) value during the storage period.

Table 2 Changes in physiochemical characteristics of half-ripe fruits during storage time

Attributes	Storage time (days)				
	0	3	6	9	12
pH	4.20 ± 0.02^{c}	4.24 ± 0.01^{c}	4.26 ± 0.04^{c}	4.36 ± 0.07^{b}	4.56 ± 0.06^{a}
Total acid (%)	4.28 ± 0.03^{a}	4.28 ± 0.16^{a}	3.87 ± 0.03^{b}	3.69 ± 0.08^{c}	1.79 ± 0.01^{d}
TSS (%)	9.20 ± 0.001^{d}	9.83 ± 0.05^{c}	10.67 ± 0.47^{b}	11.07 ± 0.17^{ab}	11.20 ± 0.001^{a}
Total reducing sugar (%)	102.17 ± 0.29^{a}	103.82 ± 1.43^{a}	93.70 ± 0.25^{b}	93.07 ± 1.55^{b}	89.95 ± 3.40^{b}
Weight loss (%)	0.00	3.25 ± 0.01^{d}	5.50 ± 0.2^{c}	6.51 ± 0.42^{b}	9.12 ± 0.2^{a}
L^*	75.41 ± 0.63^{a}	75.76 ± 0.79^{a}	74.74 ± 0.29^{a}	72.89 ± 1.34^{b}	72.43 ± 0.88^{b}
a^*	4.60 ± 0.63^{a}	0.79 ± 0.16^{c}	0.67 ± 0.05^{c}	1.31 ± 0.26^{b}	1.61 ± 0.25^{b}
b^*	8.72 ± 0.65^{c}	10.29 ± 0.61^{b}	11.70 ± 0.25^{a}	9.51 ± 0.87^{bc}	9.02 ± 0.61^{c}
Moisture (%)	90.91 ± 0.1^{a}	90.42 ± 1.66^{a}	89.28 ± 0.11^{b}	89.29 ± 0.62^{b}	88.37 ± 0.67^{b}

The results are expressed as mean ± standard deviation of three replicates. The different superscript letters in the same row indicate significant differences ($p < 0.05$).

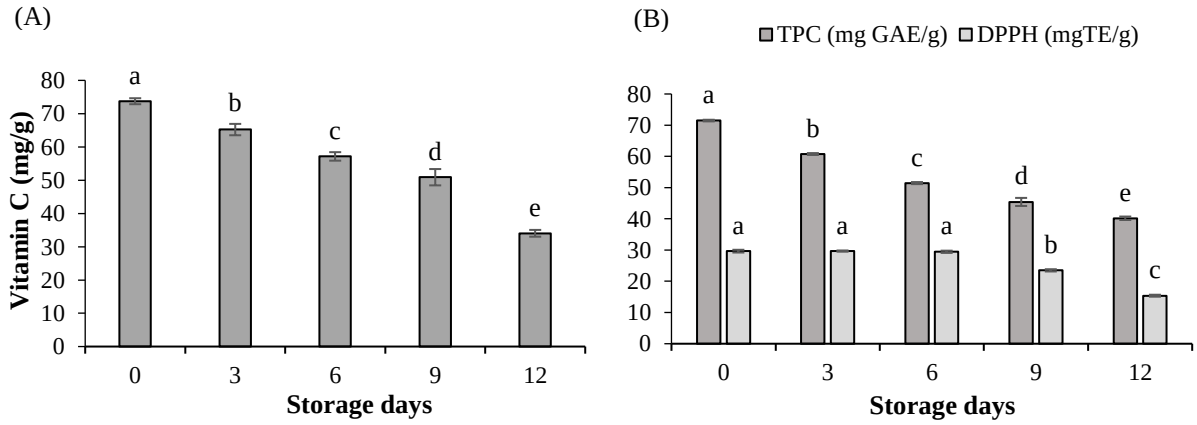

Figure 2 Changes in Vitamin C (A), TPC, and DPPH (B) during Barbados cherry storage times
The results are expressed as mean ± standard deviation of three replicates. The different superscript letters are significantly different ($p < 0.05$).

Moreover, the levels of oxidant compounds such as vitamin C, TPC, and DPPH in Barbados cherry decreased significantly over the preservation period (Figure 2). Specifically, the vitamin C content was over 70 mg/g at the start, which was twice as much as that on the 12th day (approximately 35 mg/g). Following the same trend, the TPC in the fruit was nearly 40 mg GAE/g on the 12th day, after experiencing a significant decline of approximately 32 mg GAE/g. A similar trend was observed in a report by Le et al. [15], which pointed out that vitamin C and TPC in Barbados during chilling storage (4 ± 2 ^{o}C) experienced notable decreases of over 77% and 26% after one month. Additionally, the DPPH value remained stable during the first 6 days of the study (nearly 30 mg TE/g) and decreased to the lowest point of about 15 mg TE/g on the last day.

Pearson's correlation analysis was performed on the physicochemical and biological characteristics of half-ripe Barbados during the preservation period. Positive correlations were observed among physicochemical attributes, including moisture, vitamin C, TPC, DPPH, and L*, while the remaining characteristics exhibited negative correlations with each other (Figure 3). Pearson's correlation analysis indicated that ripening of Barbados is governed by closely linked physicochemical changes. Declining acidity and pH were inversely related, while increasing sugars and color intensity reflected ongoing maturation. Strong positive correlations among vitamin C, phenolics, and antioxidant activity indicated coordinated biosynthesis of bioactive compounds. These relationships demonstrate that biochemical shifts during ripening directly influence the fruit's flavor quality and nutritional value. The obtained results align closely with a previous study by Davey et al. [30], which found that ascorbic acid loss during postharvest storage could be correlated with the loss of antioxidant activity.

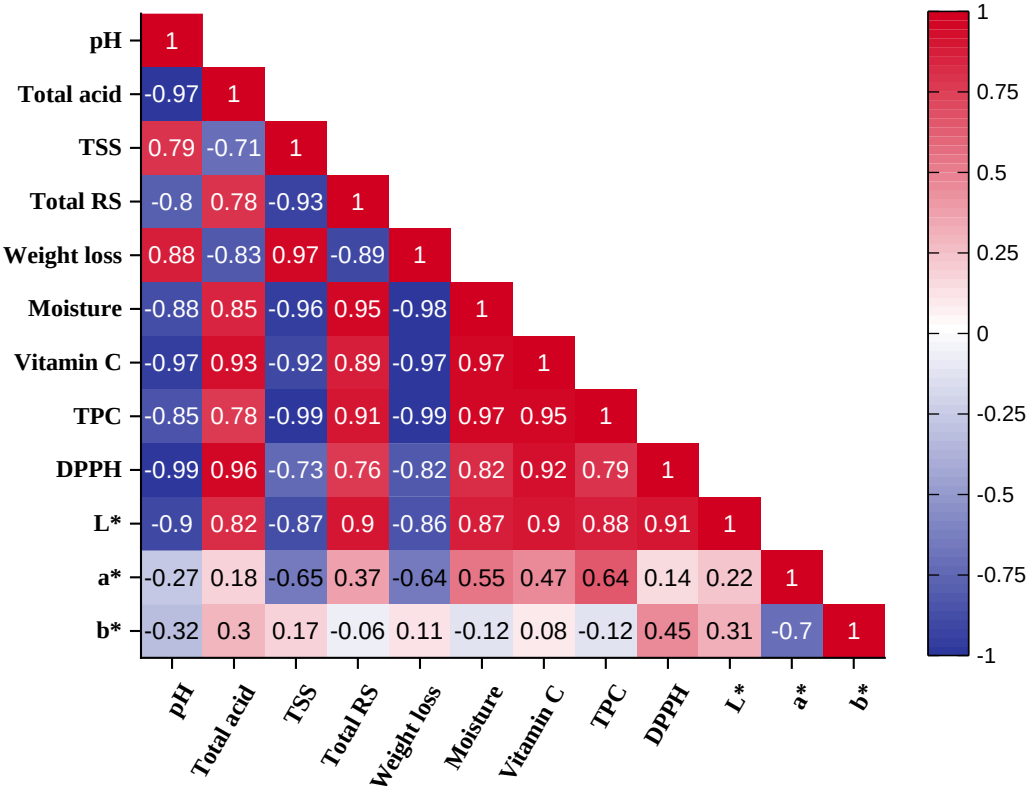

Figure 3 Pearson's correlation analysis of Barbados' physicochemical properties during the preservation period

4. Conclusion

The physicochemical and biological attributes of Barbados cherry vary significantly depending on maturity stages and storage duration. Specifically, unripe fruit had high amounts of vitamin C (100 mg/g DM) and TPC (90 mg GAE/g), while ripe fruit exhibited higher protein, carotenoid, and sugar contents. Additionally, Barbados cherry stored at 12 ± 2 ^{o}C for 6 days maintained high physicochemical and biological quality characteristics, namely vitamin C (57.15 mg/g), TPC (51.46 mg GAE/g), and DPPH (29.45 mg TE/g). These results provide vital evidence supporting the efficiency of normal fruit consumption and commercialization.

5. Acknowledgements

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6. Conflicts of interest

The authors declare that there is no conflict of interest.

7. Author contributions

Ngoc, TTA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing; Tâm ĐTT Data analysis, Writing – original draft, Writing – review & editing.

8. References

[1] Delva L, Schneider RG. Acerola (*Malpighia emarginata* DC): Production, postharvest handling, nutrition, and biological activity. Food Rev Int. 2013;29(2):107-126.

[2] Mezadri T, Fernández-Pachón MS, Villano D, García-Parrilla MC, Troncoso AM. The acerola fruit: composition, productive characteristics, and economic importance. Arch Latinoam Nutr. 2006;56(2):101-109.

[3] Prakash A, Baskaran R. Acerola, an untapped functional superfruit: a review on latest frontiers. J Food Sci Technol. 2018;55(9):3373-3384.

[4] Moura CF, Oliveira LD, de Souza KO, da Franca LG, Ribeiro LB, de Souza PA, de Miranda MR. Acerola-Malpighia emarginata. In Exotic Fruits. Academic Press; 2018.

[5] Chang SK, Alasalvar C, Shahidi F. Superfruits: Phytochemicals, antioxidant efficacies, and health effects–A comprehensive review. Crit Rev Food Sci Nutr. 2019;59(10):1580-1604.

[6] Belwal T, Devkota HP, Hassan HA, Ahluwalia S, Ramadan MF, Mocan A, Atanasov AG. Phytopharmacology of Acerola (*Malpighia* spp.) and its potential as functional food. Trends Food Sci Technol. 2018;74:99-106.

[7] Pommer CV, Barbosa W. The impact of breeding on fruit production in warm climates of Brazil. Rev Bras Frutic. 2009;31(2):612-634.

[8] Braman K, Ahmad S, Siddiqui MW. Factors affecting the quality of fruits and vegetables. In Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance. Academic Press; 2015.

[9] Vendramini AL, Trugo LC. Chemical composition of acerola fruit (*Malpighia punicifolia* L.) at three stages of maturity. Food Chem. 2000;71(2):195-198.

[10] Siddiqui MW, editor. Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance. CRC Press; 2015.

[11] Mohammed M. Acerola (*Malpighia emarginata* DC.). In Postharvest biology and technology of tropical and subtropical fruits. Woodhead Publishing; 2011.

[12] Aghdam MS, Naderi R, Jannatizadeh A, Sarcheshmeh MA, Babalar M. Enhancement of postharvest chilling tolerance of anthurium cut flowers by γ-aminobutyric acid (GABA) treatments. Sci Hortic. 2016;198:52-60.

[13] Crisosto CH, Gordon Mitchell F, Ju Z. Susceptibility to chilling injury of peach, nectarine, and plum cultivars grown in California. HortScience. 1999;34(6):1116-1118.

[14] Maciel MI, Lima VL, Santos ES, Lima MD. Effects of biofilm and refrigeration on acerola postharvest conservation. Rev Bras Frutic. 2004;26(1):168-170.

[15] Le TT, Luong HQ, Angeli DC, Le QT, Katleen R. Changes of total polyphenolics and vitamin C in acerola during storage and spray drying process. J Agric Dev. 2018;17(3):69-76.

[16] Provesi JG, Dias CO, de Mello Castanho Amboni RD, Amante ER. Characterization and stability of quality indices on storage of pumpkin (*Cucurbita moschata* and *Cucurbita maxima*) purees. Int J Food Sci Technol. 2012;47(1):67-74.

[17] Phuong NN, Le TT, Dang MQ, Van Camp J, Raes K. Selection of extraction conditions of phenolic compounds from rambutan (*Nephelium lappaceum* L.) peel. Food Bioprod Process. 2020;122:222-229.

[18] Nguyen NM, Le TT, Vissenaekens H, Gonzales GB, Van Camp J, Smagghe G, Raes K. In vitro antioxidant activity and phenolic profiles of tropical fruit by-products. Int J Food Sci Technol. 2019;54(4):1169-1178.

[19] Rojas ML, Silveira I, Augusto PED. Ultrasound and ethanol pre-treatments to improve convective drying: Drying, rehydration, and carotenoid content of pumpkin. Food Bioprod Process. 2020;119:20-30.

[20] Ozturk B, Celik SM, Karakaya M, Karakaya O, Islam A, Yarilgac T. Storage temperature affects phenolic content, antioxidant activity, and fruit quality parameters of cherry laurel (*Prunus laurocerasus* L.). J Food Process Preserv. 2017;41(1):e12774.

[21] Jia C, Han F, Miao X, Yan A, Wu P, Sun Y. Study on the changes of sugar and acid in fermentation process of different varieties of cherry wine. J Food Sci Nutr. 2019;2(1):15-19.

[22] Samim AK, Shivakumar BS, Ganapathi M. Effect of IBA, NAA and their combination on rooting and biochemical parameters of stem cuttings in Barbados cherry. Int J Res Appl Sci Biotechnol. 2021;8(5):147-150.

[23] Düsman E, Berti AP, Mariucci RG, Lopes NB, Tonin LTD, Vicentini VEP. Radioprotective effect of the Barbados cherry (*Malpighia glabra* L.) against radiopharmaceutical iodine-131 in Wistar rats in vivo. BMC Complement Altern Med. 2014;14:41.

[24] Gouthu S, Deluc LG. Timing of ripening initiation in grape berries and its relationship to seed content and pericarp auxin levels. BMC Plant Biol. 2015;15(1):1-14.

[25] Righetto AM, Netto FM, Carraro F. Chemical composition and antioxidant activity of juices from mature and immature acerola (*Malpighia emarginata* DC). Food Sci Technol Int. 2005;11(4):315-321.

[26] Kulkarni AP, Aradhya SM. Chemical changes and antioxidant activity in pomegranate arils during fruit development. Food Chem. 2005;93(2):319-324.

[27] Lima VL, Mélo EA, Maciel MI, Prazeres FG, Musser RS, Lima DE. Total phenolic and carotenoid contents in acerola genotypes harvested at three ripening stages. Food Chem. 2005;90(4):565-568.

[28] Andersson SC, Rumpunen K, Johansson E, Olsson ME. Carotenoid content and composition in rose hips (*Rosa* spp.) during ripening, determination of suitable maturity marker and implications for health-promoting food products. Food Chem. 2011;128(3):689-696.

[29] Ribeiro BS, de Freitas ST. Maturity stage at harvest and storage temperature to maintain postharvest quality of acerola fruit. Sci Hortic. 2020;260:108901.

[30] Davey MW, Montagu MV, Inze D, Sanmartin M, Kanellis A, Smirnoff N, Benzie IJ, Strain JJ, Favell D, Fletcher J. Plant L-ascorbic acid: chemistry, function, metabolism, bioavailability and effects of processing. J Sci Food Agric. 2000;80(7):825-860.