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Effects of Processing Time and Temperature on the Quality Components of Cape Gooseberry and Sweet Lemon Juice

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ABSTRACT

Recently, processing of tropical fruits has started in many countries. This trend has caused an upswing in the fruit industries in the fruit-growing countries, which endeavor to promote and improve production, to be competitive in both domestic demand and export markets. However, limited studies are available regarding the processing of certain fruits viz. cape gooseberry and sweet lemon. Cape gooseberry and sweet lemon juice were processed at different temperatures (50, 60, 70 and 80 °C and different times (15, 30, 45 and 60 min), and evaluated for quality components and sensorial properties. The fruits were heated, and pressed; then the juice was cold stabilized, filtered and pasteurized. The samples showed an increase in pH and a decrease in titratable acidity. Total soluble solids increased until 70 °C then decreased when 80°C was reached. Significant differences were mostly observed between processing temperatures than between processing times. Increasing processing temperature enhances the total phenolics, total anthocyanin, and % radical scavenging activity of the juices until 70°C but declined when the temperature reached 80°C . Sensory evaluation showed that the preferred time–temperature combination for processing cape gooseberry and sweet lemon juice is between 60 and 70°C for 30–45 min.

INTRODUCTION

Today, the demand for high-quality and nutritious foods by the health conscious consumers is increasing, and so fruit juices nowadays have become very popular products. Fruit production worldwide is estimated to be over 360 million metric tons, the tropical countries producing less than half, and studies have shown that international markets exist for many of tropical fruits. During the last decades, the processing of tropical fruits started in many countries. This trend has caused an upswing in the fruit industries of the fruit-growing countries, which endeavor to promote production, to be competitive in both domestic demand and export markets (Askar 1998; Ramadan and Mörsel 2007). Cape gooseberry (*Physalis peruviana*) is one of the most promising tropical fruits. It has been grown in California, South Africa, India, New Zealand, Australia and Egypt. So far, however, it has nowhere become a major crop (McCain 1993). It is somewhat tomato-like in flavor and appearance, although the taste (sweet and sour) is much richer with a hint of tropical luxuriance. In addition to having a future as fresh fruit, the exotic fruit can be enjoyed in many ways as an interesting ingredient in salads, cooked dishes, dessert, juice, jam, natural snack, and preserves (Ramadan and Mörsel 2003; Ramadan *et al.,* 2008). Many medicinal properties have been attributed to the cape gooseberry, including antiasthmatic, diuretic, antiseptic, strengthener for the optic nerve, treatment of throat affections and elimination of intestinal parasites, amoebas as well as albumin from kidneys (McCain 1993; Ramadan and Mörsel 2003, 2009). Cape gooseberry can be a very interesting candidate for the processing of new functional foods and drinks. The yield of the juice is extremely high and the juice is a rich source of sugars as well as water- and fat-soluble bioactive. The preparation of new drinks based on the cape gooseberry could greatly extend the distribution and marketing of this delicious fruit.

Citrus fruits are an important part of the human diet because of their nutritional value, antioxidant activity, and high consumption. Citrus fruits including sweet lemon (*Citrus limetta*) are rich in vitamin C and also contain large amounts of phytochemicals such as carotenoids and phenolic compounds (Heber and Lu 2002; Vinson *et al*., 2002; Xu *et al.,* 2008). These bioactive compounds have antioxidant activities and are beneficial for human health. Dietary phenolic compounds of citrus fruits mainly include flavonoids and phenolic acids. Recent studies have shown that phenolic compounds are helpful in preventing chronic and degenerative diseases,

such as cardiovascular diseases, stroke and certain forms of cancer (Attaway 1994; Klimczak *et al*., 2007). It opens a new area for further studies on phenolic compounds of citrus fruits. However, limited studies on changes of phenolic components as well as other antioxidant parameters during processing of sweet lemon are available.

The aims of this study are to determine the effects of processing time and temperature on the properties of Cape gooseberry and sweet lemon juice and to optimize the processing time and temperature necessary to have high-quality juices from Cape gooseberry and sweet lemon fruits.

MATERIALS AND METHODS

Cape gooseberry and sweet lemon were obtained from a local market in Allahabad city for the production of juices. The fruits were destemmed, washed and crushed, and heated at different temperatures such as 50, 60, 70 and 80 °C for 15, 30, 45 and 60 min. The samples were then pressed while hot and filtered using cheesecloth. The juice samples were held overnight at -5 °C for cold stabilization. The juice samples after the cold stabilization process were then filtered using Whatman No. 2 filter paper, pasteurized and analyzed. The results of the analyses were expressed as means that correspond to the three analytical replicates.

Chemical Analyses

The pH of the processed Cape gooseberry and sweet lemon juice were measured using the pH meter (Metrohm, Switzerland). The Total Soluble Solids (°Brix) were measured using a hand refractometer (Erma, Japan). Titratable acidity was measured by adding 10 mL of juice samples to 100 mL of distilled water and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2 (Haight and Gump, 1995). The results were expressed as g citric acid/100 mL.

Color Measurement

The color of the processed Camp bell grape juice was determined using an X-rite colorimeter. The values obtained were expressed as L^* (lightness), a^* (green to red) and b^* (blue to yellow) values. These values were used to calculate the total colour difference, which indicates the intensity or color saturation and hue angle (h = arctan[b/a]).

Sensory Evaluation

The sensory evaluation of the Cape gooseberry and sweet lemon juice samples was conducted at the Centre of Food Technology, University of Allahabad, Allahabad, India**.** The juice samples were presented in glasses with three-digit codes. The trained judges scored each attribute such as color, aroma, taste and overall acceptability on a 9-point hedonic scale in which 1 denotes dislike extremely and 9 denotes like extremely (Bergara-Almeida *et al.*, 2002).

Total Phenolics Analysis

The total phenolic content was determined by the Folin–Ciocalteu method (Singleton and Rossi, 1965) that was previously modified (Yildirim *et al.*, 2005) to reduce the assay volume. To 3.90 mL of H_2O, 0.1 mL of the sample (10% v/v grape juice) was added followed by 0.5 mL of Folin–Ciocalteu reagent. After 3–6 min, 0.5 mL of saturated sodium carbonate (20 g of Na_2CO_3 in 100 mL of H_2O; Merck) was added. After 30 min of vigorous mixing with a vortex mixer, a reading was taken at 725 nm (UVspectrophotometer, Thermoscientific, Japan). The results were expressed as gallic acid equivalents using a calibration curve with gallic acid (Sigma-Aldrich Chemical Co., Taufkirchen, Germany) as the standard (mg/L).

Free Radical Scavenging Method

The antioxidant activity of Campbell grape juice samples was measured in terms of hydrogen-donating or radical scavenging ability, using the stable radical, 1,1-diphenyl-2-picrylhydrazyl (DPPH) (Brand-Williams *et al.*, 1995). One mL diluted sample (10% v/v grape juice) was placed in a test tube and 4 mL of 6 x 10^{-5} mol/L ethanolic solution of DPPH (Sigma-Aldrich Chemical Co., Taufkirchen, Germany) was added. The mixture was shaken vigorously for 40 s and then absorbance measurements commenced immediately. The decrease in absorbance at 517 nm was determined with spectrophotometer (UV spectrophotometer, Thermoscientific, Japan). Ethanol was used to zero the spectrophotometer. The absorbance of the DPPH radical ethanolic solution was measured daily. All evaluations were made in triplicate. The % DPPH radical scavenging activity of the sample was calculated according to Blois (1958).

Total Flavonoid Analysis

Total flavonoid concentrations were determined using procedures outlined by Zhishen *et al.* (1999). One mL of diluted grape juice (1 mL juice/ 5 mL distilled H2O) was placed in a 10 mL flask. Four mL distilled water was added then 0.3 mL of NaNO2 (5 g/100 mL distilled water) was also added. After 5 min, 0.3 mL of $AlCl_3$ (10 g/ 100 mL distilled H2O) was added. After another 6 min, 2 mL of 1 N NaOH was added then the solution was diluted to a total volume of 10 mL with distilled water. The absorbance of the solution was measured at 510 nm and flavonoid concentration was determined by using a catechin calibration curve.

Statistical Analysis

Analysis of variance and Duncan's multiple range tests were performed using the SPSSS program to determine the differences among the processed Cape gooseberry and sweet lemon juice samples. The level of significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

The effects of processing time and temperature on physicochemical and color properties of Cape gooseberry and sweet lemon juice are shown in Tables 1 and 2. There is a significant difference in physicochemical properties of juice samples at different processing temperature and time.

Heating the cape gooseberries at a different time and temperature affected the physicochemical properties of the juice in all heating times. Mostly, significant differences are observed in juice samples heated for 30- 45 min at a higher temperature. There is an increasing trend in pH and a decreasing trend in titrable acidity in all processing times and temperatures. The total soluble solids increased until 70°C but decreased when the temperature was increased to 80°C in all heating times (Table 1). Heating tends to increase the total soluble solids of the cape gooseberry juice but at 80°C for 60 min total soluble solids declined, which suggest that very high processing time and temperature may have a detrimental effect on the total soluble solids of the cape gooseberry juice, which is line with the study made by Flora (1979), who found that high temperature tends to lower the total soluble solids of grape juice. Similarly in sweet lemon juice also pH showed an increasing trend whereas titrable acidity showed a decreasing trend in all processing times and temperatures. The TSS increased until 60°C at decreased when the

temperature was further increased to 70°C and 80°C in all heating times. The tannin content was significantly reduced in both the fruits with increasing time and temperature (Table 1).

The L* and a* colour values of cape gooseberry juice gradually increased with time and temperature up to 70°C but on further heating to 80°C, the values decreased (Table 2). The b* colour values showed an increasing trend on heating up to 7°C for 15-45 min but on heating for 60 min the colour values showed a decline. The b* colour value was highest at a temperature of 70°C for 45 min. The total colour difference (ΔE) showed an increasing trend in all processing times and temperatures. It was found highest in Cape gooseberry samples heated at 80°C for 15 min (33.83±0.41). In sweet lemon juice samples the L* colour values showed an increasing trend whereas a* values or redness of the juice showed a decreasing trend in all processing times and temperatures. The b* colour values increased on heating up to 7°C for 45 min resulting in the gradual browning of the juice (Table 2). The total colour difference (ΔE) was highest on heating the sweet lemon samples at 8°C for 60 min (44.04±0.62). These observations are in line with the study made by Morris *et al.* (1986), as they reported that high extraction temperatures (99C) in Concord juice resulted in a better color initially than the juice extracted at 60°C . Furthermore, Flora (1979) observed that total heat input had a greater effect on color changes and processing, and storage time–temperature had the greatest influence on color deterioration. The result of this study emphasizes that higher processing temperature and longer processing time had an influence on the color changes of the cape gooseberry and sweet lemon juice samples.9*

Table 3 illustrates the changes in bioactive compound and % radical scavenging activity that occurred in cape gooseberry and sweet lemon juice samples processed at different temperatures and different times. This study showed that at the lower processing temperature (50°C) and processing time (15 min), there is a lower content of bioactive compound and a lower % radical scavenging activity.

Heating the fruits viz. cape gooseberry and sweet lemon until 70°C in all processing times before pressing increased the bioactive components and % radical scavenging activity of both the juice samples but declined when 80°C is reached. The result emphasizes that total phenolics, total flavonoids, and % radical scavenging activity showed the same increasing trend until 80°C but a decrease was observed in the values at 80°C in all processing times. The greatest decrease

in bioactive components was shown in juice samples heated at 80°C for 60 min. This result is in accordance with the study made by Su and Silva (2006) who reported that antioxidant activity is highly correlated to anthocyanin and total phenolics, and that free radical scavenging activity is greatly influenced by the phenolic composition of the sample; thus all the bioactive compounds of cape gooseberry and sweet lemon juice similarly increased at high temperatures and at high heating times, then similarly decreased at a very high processing time and temperature (8°C for 60 min). Total flavonoids were found higher when cape gooseberry and sweet lemon fruits were heated at 70 – 80°C for 15 to 45 min and declined on heating further for 60 min. These observations are in line with the study made by Morris *et al.* (1986), as they reported that high extraction temperatures (99°C) in Concord juice resulted in a better color initially than the juice extracted at 60°C. Furthermore, Flora (1979) observed that total heat input had a greater effect on color changes and processing, and storage time–temperature had the greatest influence on color deterioration. The result of this study emphasizes that higher processing temperature and longer processing time had an influence on the color changes of the juice samples.

The ascorbic acid content showed a gradually decreasing trend at all processing times and temperatures in both cape gooseberry and sweet lemon juice samples. The cape gooseberry juice samples heated at 70°C for 15 min contained the highest total phenolics and total flavonoids of 14.33±0.38 mg/100ml and 3.61±0.30 mg/100ml, respectively. Similarly, the sweet lemon juice samples heated at 70°C for 15 min contained the highest total phenolics and total flavonoids of 29.81±3.74 mg/100ml and 7.99±0.25 mg/100ml, respectively. The cape gooseberry and sweet lemon samples heated at 70°C for 60 min contained the highest % radical scavenging activity of 78.60±1.28% and 82.75±1.82%. The samples heated at 50, 60 and 70°C for 15 to 30 min showed higher levels of bioactive compounds than samples heated for 45 and 60 min. The results also demonstrated that there is a decrease in the total phenolics content and total flavonoid content at a higher temperature (80°C) while % radical scavenging activities showed a gradual decrease from 70 to 80°C at higher processing times (45 min–60 min), which suggest that heating the fruits at 50, 60 and 70°C for 15 - 30 min may enhance the extraction of the bioactive compounds from the fruits but prolonged heating time combined with a very high temperature had a harmful effect on the bioactive compounds of the juice.

In a study made by Flora (1977) and Sistrunk and Morris (1982) it was reported that increase in extraction temperature increases color, acidity and phenolic compounds in the juice as the color component that can be found in skins and phenols are higher in seeds and skins. Indeed, heating is necessary to obtain the bioactive compounds from fruits but very high heating temperatures for a long time may lead to detrimental effects on the quality of the juice. The results of the present study are related to the findings of Hamma and Nawar (1991) and Larrauri *et al.* (1997) who reported that there is a decomposition of phenolic compounds and loss of antioxidant activity at high temperatures. It was also observed that thermal treatments applied to peach, apple and pomegranate juice can affect the phenolic composition of these juices (Hernandez *et al.* 1997; Alper *et al.* 2005).

Table 4 illustrates the preferences of the panelists on the cape gooseberry and sweet lemon juice samples. Statistical tests indicated that all sensory attributes of the juice samples tended to be significantly influenced by processing time. The mean scores of cape gooseberry juice for overall acceptability revealed a significant difference in samples processed between 70 – 80°C at higher processing times. Ratings for colour (7.10-7.68), aroma (7.08-7.72) and taste (6.95-7.60) of cape gooseberry juice samples showed to be in the range of "moderately like" to "like very much" preferences category, respectively. The juice heated for at 70°C for 45 min showed the highest preference score for all sensory attributes. It was also found out that the juice heated at 50°C for 15 min received the lowest preference score in overall acceptability.

Similarly, for sweet lemon juice the values for colour (6.85-7.41), aroma (7.05-7.90) and taste (6.42-7.33) showed to be in the range of "moderately like" to "like very much" preferences category, respectively. The juice heated for at 60°C for 30 min showed the highest preference score for all sensory attributes. It was also found out that the juice heated at 80°C for 60 min received the lowest preference score in overall acceptability. This study also demonstrated that the preferred time–temperature combination of processing cape gooseberry juice and sweet lemon juice is between 60 and 70°C for 30 to 45 min based on overall acceptability. The results suggest that the cape gooseberry and sweet lemon juices processed at low temperatures such as 60°C and at very high temperatures as 90°C in all heating times were the least preferred by the panelists. Huckleberry *et al.* (1990) reported that heat-processed juice was preferred especially in the red cultivar grapes but long heating periods at high temperatures impart an undesirable

cooked and astringent flavor (Joslyn *et al.*, 1929); thus, to preserve the quality of the juice, extensive extraction temperature must be avoided (Sistrunk and Morris 1982).

CONCLUSION

Processing time and temperature showed changes in quality components of the cape gooseberry and sweet lemon juice. Lower processing temperature and time is not enough to extract higher bioactive compounds and did not impart good sensory evaluation scores whereas very high processing temperatures and times were detrimental to the quality components of the juices. Thus, it can be concluded from this study that cape gooseberry and sweet lemon juice should be processed at 60-70°C for 30–45 min. At this time–temperature combination juice with higher bioactive compounds and better sensory attributes can be obtained.

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TABLE 1. THE PHYSICOCHEMICAL PROPERTIES OF CAPE GOOSEBERRY AND SWEET LEMON JUICE PROCESSED AT DIFFERENT TIMES AND TEMPERATURES

The results are expressed as the means ± standard deviation of the means (n=3).

	Temperature	pH				Acidity (as % citric acid)				TSS (^{0}Brix)				Tannins (%)			
		15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min
Cape gooseberry Juice	50°C	3.47 ±0.04	3.57 ±0.26^{aB}	3.42 ±0.08^{aA}	3.44 ±0.14^{aA}	1.54 ±0.13^{aA}	1.61 ±0.16^{aB}	1.66 ±0.13^{bC}	1.77 ±0.09^{bD}	10.60 ±0.20^{aA}	11.37 ±0.25^{aC}	11.80 ±0.20^{abD}	10.83 ±0.21^{aB}	2.15 ±0.20^{dC}	2.17 ±0.07^{dD}	2.08 ±0.03^{cB}	2.04 ±0.04^{cA}
	60°C	3.65 ±0.05^{bA}	3.67 ±0.06^{aA}	3.61 ±0.07^{bA}	3.66 ±0.06^{bcA}	2.11 ±0.06^{bC}	1.68 ±0.17^{aB}	1.59 ±0.06^{abA}	1.59 ±0.06^{abA}	11.90 ±0.10^{bA}	12.63 ±0.15^{bB}	12.63 ± 0.15^{bB}	13.24 ±0.25^{cC}	2.02 ±0.01^{cC}	1.93 ±0.03^{cB}	1.86 ±0.03^{bA}	1.88 ±0.01^{bA}
	70°C	3.68 ±0.05^{bB}	3.67 ±0.05^{aB}	3.64 ±0.09^{bA}	3.64 ±0.05^{abA}	4.64 ±0.08^{cD}	2.49 ±0.43^{bC}	1.42 ±0.06^{aA}	1.54 ±0.09^{aB}	12.17 ±0.29^{bB}	12.27 ±0.35^{bC}	12.23 ±0.47^{abC}	12.00 ±0.53^{bA}	1.93 ±0.01^{bC}	1.91 ±0.01^{bC}	1.88 ±0.03^{bB}	1.84 ±0.03^{bA}
	80°C	3.68 ±0.06^{bA}	3.68 ±0.10^{aA}	3.68 ±0.06^{bA}	3.86 ±0.15^{cB}	7.80 ±0.09^{dA}	8.33 ±0.32^{cB}	9.49 ±0.16^{cC}	10.23 ±0.13^{cD}	10.97 ±0.31^{aB}	10.97 ±0.78^{aB}	11.40 ±1.10^{aC}	10.83 ±0.15^{aA}	0.74 ±0.04^{aD}	0.68 ±0.01^{aB}	0.62 ±0.03^{aA}	0.67 ±0.04^{aB}
Sweet lemon juice	50°C	4.14 ±0.07^{aB}	4.22 ±0.06^{bD}	4.20 ±0.10^{bC}	3.86 ±0.12^{aA}	0.64 ±0.13^{aA}	0.68 ±0.08^{aB}	1.02 ±0.13^{bC}	1.15 ±0.13^{cD}	7.12 ±0.08^{aA}	7.50 ±0.50^{aC}	7.54 ±0.50^{aC}	7.33 ±0.58^{aB}	2.31 ±0.33^{cC}	2.03 ±0.02^{cB}	2.01 ±0.01^{cB}	1.92 ±0.01^{cA}
	60°C	4.28 ±0.06^{abB}	4.21 ±0.05^{bA}	4.85 ±0.05^{cD}	4.31 ±0.05^{bC}	0.67 ±0.11^{bA}	0.70 ±0.07^{aB}	1.09 ±0.06^{bC}	1.87 ±0.11^{aD}	10.50 ±0.3° C^{B}	11.47 ±0.45^{dD}	10.73 ±0.25^{cC}	10.28 ±0.26^{cA}	2.03 ±0.03^{cC}	1.69 ±0.08^{bB}	1.63 ±0.02^{bA}	1.62 ±0.15^{bA}
	70°C	4.04 ±0.17^{abA}	4.06 ±0.05^{aA}	4.04 ±0.17^{bA}	4.32 ±0.05^{bB}	1.15 ±0.03^{aA}	2.77 ±0.01^{aC}	3.70 ±0.06^{aD}	2.41 ±0.10^{dB}	10.40 ±0.2° C^{B}	10.27 ±0.2° C^{A}	10.57 ±0.06^{cC}	11.20 ±0.2° C^{D}	1.85 ±0.1^{b} D	1.71 ±0.01^{bC}	1.66 ±0.04^{bB}	1.60 ±0.03^{bA}
	80°C	3.80 ±0.05^{aA}	4.18 ±0.11^{abB}	3.80 ±0.05^{aA}	4.29 ±0.06^{abC}	2.27 ±0.1° C^{A}	4.26 ±0.42^{bC}	5.62 ±0.22^{cD}	2.74 ±0.01^{aB}	8.87 ±0.15^{bA}	9.03 ±0.15^{bB}	9.20 ±0.26^{bC}	9.24 ±0.26^{bC}	0.8 0 ±0.04^{aC}	0.56 ±0.01^{aB}	0.52 ±0.03^{aB}	0.35 ±0.04^{aA}

Values followed by different letters within the same column are significantly different at $P < 0.05$.

Within a row, numbers followed by different uppercase letter(s) are significantly different at $P < 0.05$.

TABLE 2. THE COLOUR PROPERTIES OF CAPE GOOSEBERRY AND SWEET LEMON JUICE PROCESSED AT DIFFERENT TIMES AND TEMPERATURES

	Temp	L*				a*				b*				Tan^{-1} b/a				ΔE			
		15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min
Cape gooseberry juice	5°C	27.05 ±0.25^{a} C	26.11 ±0.35 aB	27.2 ±0.39^{bD}	25.39 ±0.74^{a} A	5.02 ±0.31^{a} A	5.91 ±0.14^{a} B	7.21 ±0.15^{a} C	7.78 ±0.25^{a} D	7.93 ±0.21 aA	8.49 ±0.26 aB	9.29 ±0.22 aD	9.17 ±0.18 aC	1.01 ±0.13 bD	0.97 ±0.11^{b} C	0.93 ±0.11^{c} B	0.87 ±0.14 bA	28.08 ±0.85 aA	28.63 ±0.32^{a} B	29.64 ±0.63^{a} C	28.09 ±0.17 aA
	60 C	28.98 ±0.35 bC	28.57 ±0.14 bB	26.83 ±0.18^{aA}	28.95 ±0.34^{c} C	8.61 ±0.08^{c} A	9.0 ±0.66^{c} B	9.2 ±0.26^{c} C	9.36 ±0.74^{b} D	10.18 ±0.74 bC	10.08 ±0.32 bB	10.23 ±0.45 bD	9.71 ±0.25 bA	0.85 ±0.02 aB	0.84 ±0.35^{a} A	0.85 ±0.09 bB	0.83 ±0.21 aA	31.8 ±0.45 bC	31.63 ±0.68^{b} B	30.15 ±0.47^{b} A	31.96 ±0.19 cD
	70 C	29.9 ±0.21^{c} D	29.42 ±0.14 cB	27.71 ±0.33^{cA}	29.51 ±0.18^{d} C	9.3 ±0.24^{d} A	9.4 ±0.51^{d} A	9.9 ±0.41^{d} B	10.35 ±0.16^{c} C	10.51 ±0.81 dB	10.81 ±0.63 dC	11.25 ±0.51 dD	9.81 ±0.65 cA	0.85 ±0.08 aB	0.83 ±0.05^{a} A	0.81 ±0.04^{a} A	0.83 ±0.05 aA	33.03 ±0.24 cC	32.72 ±0.88^{c} B	31.50 ±0.51^{c} A	32.77 ±0.25 dB
	80 C	31.60 ±0.18 dC	30.31 ±0.21 dB	30.50 ±0.61^{dB}	28.70 ±0.24^{b} A	6.24 ±0.15^{b} A	7.73 ±0.24^{b} B	7.76 ±0.25^{b} B	7.76 ±0.33^{a} B	10.33 ±0.28 cB	10.79 ±0.55 cD	10.62 ±0.82 cC	10.13 ±0.29 dA	1.03 ±0.12 bC	0.95 ±0.01^{b} B	0.94 ±0.02^{c} B	0.92 ±0.08 cA	33.83 ±0.41 dD	33.09 ±0.74^{d} B	33.22 ±0.62^{d} C	31.41 ±0.32 bA
Sweet lemon juice	50 C	26.54 ± 0.32^{aA}	27.29 ± 0.66^{aB}	28.80 ± 0.22^{aC}	31.36 ±0.34^{a} D	2.4 ±0.12^{d} D	1.74 ±0.15^{d} C	1.57 ±0.56^{d} B	1.41 ±0.44^{d} A	5.60 ±0.12 bA	5.92 ±0.25 aC	6.09 ±0.14 aD	5.85 ±0.19 bB	1.16 ±0.15 aA	1.28 ±0.06^{aB}	1.32 ±0.17 bC	1.34 ±0.24 bC	27.23 ±0.25 aA	27.97 ±0.33^{a} C	29.47 ±0.18^{a} B	31.93 ± 0.25^{a} D
	60 C	34.21 ± 0.35^{bA}	38.47 ± 0.54^{bB}	39.22 ± 0.53^{bD}	38.81 ±0.11^{b} C	0.77 ±0.11^{c} B	0.5 ±0.06^{c} A	0.92 ±0.25^{c} C	1.38 ±0.14^{c} D	5.65 ±0.28 bA	6.10 ±0.64 bB	6.98 ±0.24 cC	5.64 ±0.29 aA	1.43 ±0.12 bB	1.48 ±0.32^{b} C	1.44 ±0.04^{c} B	1.33 ±0.18 bA	34.68 ±0.62 bA	38.95 ±0.58^{b} B	39.85 ±0.61^{b} D	39.23 ±0.18 bC
	70 C	35.21 ± 0.25^{cA}	38.52 ± 0.61^{bB}	40.21 ± 0.14^{cD}	39.81 ±0.23^{c} C	0.66 ±0.06^{b} C	0.17 ±0.08^{b} A	0.82 ±0.13^{b} D	0.59 ±0.04^{b} B	6.56 ±0.34 cA	7.64 ±0.28 dC	7.89 ±0.15 dD	6.86 ±0.51 dB	1.47 ±0.25 cA	1.55 ±0.11^{cB}	1.47 ±0.23^{c} A	1.48 ±0.17 cA	35.82 ±0.41 cA	39.27 ±0.43^{c} B	40.99 ±0.48^{c} D	40.40 ±0.37 cC
	80 C	38.85 ± 0.12^{dA}	42.13 ± 0.12^{cB}	42.99 ± 0.41^{dD}	43.63 ±0.41^{d} C	0.05 ±0.04^{a} C	0.16 ±0.06^{a} D	-0.312 ±0.06^{a} B	-0.38 ±0.07^{a} A	5.57 ±0.31 aA	6.22 ±0.34 cD	6.13 ±0.54 bC	6.02 ±0.47 cB	1.56 ±0.31 dB	1.54 ±0.26^{cB}	-1.52 ±0.05^{a} A	-1.50 ±0.08 aA	39.25 ±0.34 dA	42.58 ±0.28^{d} C	42.44 ±0.27^{d} B	44.04 ±0.62 dD

The results are expressed as the means ± standard deviation of the means (n=3).

Values followed by different letters within the same column are significantly different at $P < 0.05$.

Within a row, numbers followed by different uppercase letter(s) are significantly different at $P < 0.05$.

TABLE 3. THE ANTIOXIDANT ACTIVITY PARAMETERS OF CAPE GOOSEBERRY AND SWEET LEMON JUICE PROCESSED AT DIFFERENT TIMES AND TEMPERATURES

	Temperature	ASCORBIC ACID				TPC				DPPH				FLAVONOIDS			
		15min	30min	45min	60min	15min	30min	45min	60min	15min	30min	45min	60min	15min	30min	45min	60min
Capegooseberry juice	50°C	29.16 ±0.57^{dD}	27.53 ±1.15^{dC}	25.84 ±0.91^{dB}	21.48 ±0.51^{cA}	11.87 ±0.68^{bD}	10.81 ±0.45^{aC}	9.57 ±0.23^{aB}	8.78 ±0.05^{bA}	19.16 ±0.30^{aA}	24.56 ±1.57^{aB}	38.15 ±2.08^{bD}	35.14 ±0.62^{bC}	0.69 ±0.53^{aA}	1.09 ±0.24^{aB}	3.29 ±0.11^{cC}	3.36 ±1.60^{dC}
	60°C	26.62 ± 0.52^{cD}	24.87 ±0.8°C^{cC}	22.57 ±1.83^{cB}	20.9 ±0.97^{bA}	11.98 ±0.27^{bC}	10.12 ±0.79^{aB}	9.51 ±0.90^{aB}	8.85 ±0.24^{bA}	39.9 ±0.59^{bA}	41.19 ±0.56^{bB}	41.90 ±3.01^{cB}	38.87 ±0.42^{cA}	2.06 ±0.28^{bA}	2.18 ±0.14^{bB}	2.45 ±0.23^{aC}	2.27 ±0.28^{aB}
	70°C	21.25 ±0.99^{bB}	20.57 ±0.38^{bA}	20.18 ±1.16^{bA}	19.05 ±0.16^{bA}	14.33 ±0.38^{cC}	13.56 ±0.75^{cB}	13.12 ±0.45^{bB}	12.69 ±0.46^{cA}	65.47 ±0.51^{dA}	78.60 ±0.25^{dD}	75.62 ±1.28^{dC}	72.1 ±1.82^{dB}	3.61 ±0.30^{dB}	3.11 ±0.36^{cA}	3.05 ±0.27^{bA}	2.99 ±0.3°C^{cA}
	80°C	13.42 ±1.04^{aC}	11.15 ±1.94^{aB}	10.02 ±1.76^{aA}	9.58 ±0.39^{aA}	11.56 ±0.46^{aC}	11.47 ±0.31^{bC}	9.81 ±0.31^{aB}	8.62 ±0.98^{aA}	47.81 ±7.86^{cD}	45.06 ±1.56^{cC}	31.69 ±1.79^{aB}	29.78 ±1.72^{aA}	3.15 ±0.15^{cC}	3.05 ±0.41^{cB}	2.98 ±1.15^{bB}	2.46 ±0.81^{bA}
Sweet lemon juice	50°C	49.27 ±1.03^{cC}	47.44 ±1.73^{dB}	45.51 ±0.73^{dA}	45.30 ±0.95^{dA}	20.76 ±2.79^{bC}	20.12 ±2.54^{bC}	19.75 ±0.87^{bB}	18.82 ±0.91^{bA}	51.84 ±1.8^{aB}	57.81 ±2.55^{aC}	58.24 ±1.90^{aC}	45.26 ±1.45^{aA}	0.48 ±0.11^{aA}	0.97 ±0.09^{aB}	1.54 ±0.20^{aC}	1.67 ±0.22^{aC}
	60°C	35.67 ± 6.15^{bC}	32.47 ±1.44^{cB}	32.15 ±1.08^{cB}	29.95 ±1.02^{cA}	19.66 ±1.96^{aC}	18.24 ±0.57^{aB}	15.45 ±0.73^{aA}	14.56 ±1.23^{aA}	65.81 ±1.3^{dA}	79.20 ±0.68^{cC}	78.99 ±0.98^{cC}	71.25 ±0.42^{cB}	1.83 ±0.24^{bA}	2.42 ±0.26^{bB}	3.56 ±0.2°C^{cC}	2.71 ±0.51^{bB}
	70°C	29.81 ±3.71^{aC}	27.84 ±0.70^{bB}	27.57 ±2.41^{bB}	25.61 ±2.77^{bA}	29.81 ±1.74^{cC}	27.84 ±2.7°C^{bB}	27.57 ±2.41^{cB}	25.60 ±2.77^{cA}	62.75 ±0.72^{cA}	80.51 ±0.96^{cC}	82.35 ±1.59^{dD}	69.25 ±1.82^{cB}	3.53 ±0.25^{dA}	4.52 ±0.39^{dC}	4.10 ±0.45^{dB}	3.51 ±0.6°C^{cA}
	80°C	29.23 ±0.90^{aC}	22.78 ±1.57^{aB}	19.48 ±1.43^{aA}	19.25 ±1.55^{aA}	21.53 ±0.93^{bB}	21.04 ±0.93^{bB}	20.82 ±1.06^{bB}	18.45 ±1.11^{bA}	55.07 ±1.27^{bA}	65.24 ±1.45^{bD}	61.14 ±1.88^{bC}	58.45 ±0.28^{bB}	2.18 ±2.24^{cB}	3.61 ±1.87^{cD}	2.92 ±1.27^{bC}	1.86 ±0.32^{aA}

The results are expressed as the means ± standard deviation of the means (n=3).

Values followed by different letters within the same column are significantly different at P < 0.05.

Within a row, numbers followed by different uppercase letter(s) are significantly different at P < 0.05.

TABLE 4. AVERAGE SCORES OF SENSORY EVALUATION OF CAPE GOOSEBERRY AND SWEET LEMON JUICE PROCESSED AT DIFFERENT TIMES AND TEMPERATURES

	Temperature	Cape gooseberry juice				Sweet lemon juice			
		15 min	30 min	45 min	60 min	15 min	30 min	45 min	60 min
Colour	50°C	7.10 ± 0.85^{aA}	7.15 ± 0.22^{aB}	7.23 ± 0.21^{bC}	7.20 ± 0.25^{bC}	7.20 ± 0.65^{aB}	7.27 ± 0.23^{bC}	7.20 ± 0.24^{bB}	7.08 ± 0.24^{bA}
	60°C	7.25 ± 0.45^{bA}	7.28 ± 0.74^{bB}	7.39 ± 0.54^{cC}	7.37 ± 0.69^{cC}	7.41 ± 0.75^{cC}	7.41 ± 0.15^{dC}	7.38 ± 0.39^{dB}	7.18 ± 0.19^{cA}
	70°C	7.48 ± 0.52^{cA}	7.59 ± 0.45^{cB}	7.68 ± 0.45^{dC}	7.59 ± 0.26^{dB}	7.34 ± 0.26^{bB}	7.35 ± 0.91^{cB}	7.32 ± 0.75^{cA}	7.38 ± 0.52^{dC}
	80°C	7.12 ± 0.23^{Aa}	7.14 ± 0.25^{aB}	7.15 ± 0.74^{aB}	7.11 ± 0.54^{aA}	7.23 ± 0.15^{aD}	7.18 ± 0.42^{aC}	7.04 ± 0.92^{aB}	6.85 ± 0.94^{aA}
Aroma	50°C	7.08 ± 0.25^{aA}	7.19 ± 0.13^{aB}	7.33 ± 0.89^{aD}	7.28 ± 0.39^{aC}	7.52 ± 0.78^{cB}	7.62 ± 0.66^{cC}	7.65 ± 0.78^{cC}	7.34 ± 0.35^{cA}
	60°C	7.24 ± 0.12^{cA}	7.34 ± 0.18^{cB}	7.45 ± 0.41^{cD}	7.38 ± 0.16^{bC}	7.56 ± 0.25^{cB}	7.90 ± 0.29^{dD}	7.84 ± 0.25^{dC}	7.45 ± 0.12^{dA}
	70°C	7.53 ± 0.26^{dA}	7.63 ± 0.96^{dB}	7.72 ± 0.85^{dC}	7.56 ± 0.24^{cA}	7.44 ± 0.84^{bC}	7.35 ± 016^{bB}	7.46 ± 0.69^{bC}	7.12 ± 0.35^{bA}
	80°C	7.18 ± 0.14^{bA}	7.21 ± 0.65^{bB}	7.38 ± 0.26^{bC}	7.25 ± 0.77^{aB}	7.21 ± 0.96^{aC}	7.18 ± 0.24^{aB}	7.08 ± 0.41^{aA}	7.05 ± 0.42^{aA}
Taste	50°C	6.95 ± 0.67^{aA}	7.05 ± 0.24^{aB}	7.17 ± 0.13^{aC}	7.16 ± 0.59^{aC}	7.20 ± 0.42^{cD}	7.14 ± 0.46^{bC}	7.11 ± 0.39^{cB}	6.86 ± 0.36^{cA}
	60°C	7.18 ± 0.48^{bA}	7.23 ± 0.25^{bB}	7.32 ± 0.41^{bC}	7.30 ± 0.67^{cC}	7.18 ± 0.71^{cB}	7.33 ± 0.18^{dC}	7.31 ± 0.18^{dC}	9.95 ± 0.64^{dA}
	70°C	7.44 ± 0.41^{dA}	7.56 ± 0.61^{dB}	7.60 ± 0.75^{dC}	7.54 ± 0.61^{dB}	7.11 ± 0.36^{bC}	7.20 ± 0.82^{cD}	6.87 ± 0.26^{bB}	6.56 ± 0.19^{bA}
	80°C	7.23 ± 0.21^{cA}	7.31 ± 0.81^{cB}	7.45 ± 0.86^{cC}	7.24 ± 0.19^{bA}	6.88 ± 0.56^{aD}	6.7 ± 0.12^{aC}	6.61 ± 0.31^{aB}	6.42 ± 0.82^{aA}
Overall acceptability	50°C	7.05 ± 0.53^{aA}	7.08 ± 0.44^{aA}	7.28 ± 0.36^{aC}	7.15 ± 0.31^{aB}	7.36 ± 0.19^{cC}	7.48 ± 0.35^{cD}	7.27 ± 0.46^{bB}	7.00 ± 0.26^{bA}
	60°C	7.19 ± 0.54^{bA}	7.30 ± 0.84^{cB}	7.38 ± 0.64^{bC}	7.32 ± 0.51^{cB}	7.45 ± 0.86^{dB}	7.64 ± 0.28^{dC}	7.72 ± 0.51^{dD}	7.28 ± 0.18^{dA}
	70°C	7.48 ± 0.84^{cA}	761 ± 0.52^{dC}	7.67 ± 0.24^{cD}	7.55 ± 0.98^{dB}	7.21 ± 0.35^{bB}	7.25 ± 0.16^{bB}	7.42 ± 0.94^{cC}	7.15 ± 0.54^{cA}
	80°C	7.20 ± 0.81^{bA}	7.28 ± 0.29^{bB}	7.35 ± 0.89^{bC}	7.26 ± 0.26^{bB}	6.94 ± 0.81^{aB}	6.88 ± 0.57^{aA}	7.11 ± 0.11^{aC}	6.87 ± 0.26^{aA}

The results are expressed as the means ± standard deviation of the means (n=3).

Values followed by different letters within the same column are significantly different at $P < 0.05$.

Within a row, numbers followed by a different uppercase letter(s) are significantly different at $P < 0.05$.