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ARTICLE

Carotenoids and Vitamin C during Handling and Distribution of Guava (*Psidium guajava* L.), Mango (*Mangifera indica* L.), and Papaya (*Carica papaya* L.) at Commercial Restaurants

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The content and stability of vitamin C (ascorbic acid, AA, and dehydroascorbic acid, DHA) and carotenoids (β-carotene, lycopene, and β-cryptoxanthin) were analyzed in papaya, mango, and guava after the reception, preparation (cleaning, peeling, and slicing), and distribution stages for consumption in a commercial restaurant. The analysis of carotenoids and vitamin C was carried out by high performance liquid chromatography (HPLC). The fruits analyzed were considered excellent sources of vitamin C and carotenoids. There were no significant differences in the vitamin C and carotenoids content during the different fruit handling stages at the commercial restaurant, which demonstrates the excellent stability of the components under the usual handling conditions employed. The results show that customers of the commercial restaurant are directly benefitted since the nutritional quality of the fruits was preserved during all of the handling and distribution periods.

KEYWORDS: Tropical fruits; handling stages; stability; ascorbic acid; dehydroascorbic acid; carotenoids

INTRODUCTION

Antioxidants present in foods protect the human body against free radicals such as reactive agent oxygen. Free radicals are known as the main cause of degenerative diseases related to age (*1*). Fruits and vegetables are good sources of natural antioxidants, such as vitamins, carotenoids, and phenolic compounds (*2*). Because of the detection of several bioactive compounds in fruits, there has been an increased interest in the relationship between antioxidants and the risk of diseases (*1*). Epidemiological studies have shown strong and consistent protective power of fruit and vegetable consumption against the risk of several diseases, such as cancer, cardiovascular diseases, cataracts, and macular degeneration (*2*, *3*).

Among the vitamins with antioxidant activity present in fruits and vegetables, vitamin C has shown exceptional qualities. Besides its antioxidant characteristic, it plays other important roles in maintaining the organism by helping in phenylalanine and tyrosine oxidation and in the folacin to tetrahydrofolic acid conversion. Furthermore, vitamin C is also involved with the biosynthesis of corticoids and catecholamines (*4*). It has high nutritional value in the human diet, preventing desquamations, maintaining healthy skin, bones, and teeth, and increasing the absorption and bioavailability of nonhemin iron 2.2 to 4 times. Ascorbic acid can prevent mutations in human DNA since high concentrations of the acid reduce mutations caused by stress in in vitro human cells (*5*).

Among the most important functions performed by carotenoids is their pro-vitamin A activity, represented by active carotenoids, such as α-carotene, β-carotene, and β-cryptoxanthin (*6*). However, other health benefits have been abundantly reported in the literature.

Epidemiological studies reveal that carotenoids, especially β-carotene, prevent cardiovascular diseases, reducing LDL-cholesterol oxidation and oxidative stress in the formation of atherosclerotic plaque. High levels of β-carotene are related to a reduced risk of lung cancer development (*7*).

Lycopene is considered the carotenoid with the greatest capacity to eliminate the singlet oxygen. Studies have demonstrated that lycopene protects lipid molecules, low-density lipoproteins, proteins, and DNA against free radical attack, playing an essential role in the protection against diseases (*8*, *9*).

β-cryptoxanthin, as well as other minority carotenoids found in fruits and vegetables, has been little explored in terms of antioxidant activity, but it presents promising potential and deserves further investigation. This is due to the fact that protection responses have shown not to be exclusively associated to a single factor but to the presence of multiple factors working synergistically (*10*).

Tropical fruits such as mango, papaya, and guava are good sources of vitamin C and carotenoids, frequently used in food services. However, before consumption, the fruits must go through

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different handling stages, such as reception, storage, cleaning, peeling, and slicing. These stages lead to changes in the fruits which may affect the content of vitamin C and carotenoids, decreasing their nutritional value. The removal of the peel and slicing causes intracell compartments in the plant tissue to rupture, promoting contact between enzymes and substrates such as oxidases and peroxidases, which may cause degradation. Cutting also promotes the synthesis of ethylene, accelerating the senescence processes. During the senescence processes, there are increases in oxidase activity, including lipoxygenase enzyme activity, causing the oxidation of fatty acids and carotenoids to be simultaneously degraded by co-oxidation (*11*). Furthermore, in commercial restaurants, fruits generally remain exposed for long time periods in order to be consumed. Consequently, carotenoids and vitamin C are directly exposed to the oxidative actions of light, oxygen, and room temperature (*12*).

Since an increasing number of individuals are using collective dining establishments, concerns also increase as to the quality of these meals in several aspects. Few studies have been carried out with the purpose of finding out the nutritional quality of these foods and to propose loss control measures for the food prepared in those places. Therefore, the quantification of vitamins and other important health components subject to losses during food handling may identify key stages in the incorporation of control measures and quality criteria of the meals provided to customers.

Studies on fruits prepared at food services are not mentioned in the literature. Therefore, the objective of the present study was to evaluate the stability of vitamin C (ascorbic acid-AA and dehydroascorbic acid-DHA) and carotenoids (β-carotene, β-chryptoxanthin, and lycopene) in tropical fruits during the reception, preparation (cleaning, peeling, and slicing), and distribution for consumption stages in a commercial restaurant. Papaya, mango, and guava were chosen for this study because they are frequently used in commercial restaurants.

MATERIALS AND METHODS

Plant Material. Papaya (*Carica papaya* L. var. Formosa), mango (*Mangifera indica* L. var. Tommy Atkins), and red guava (*Psidium guaja* L. var. Paluma) were purchased at CEASA (Central Supply), Contagem, Minas Gerais, and at the market in Viçosa, Minas Gerais, Brazil. The fruits were acquired between January and April, 2008, and were visually ripe and ideal for immediate consumption. The average soluble solids content (SSC) ranged from 7.6 to 8.1 °Brix in the guava pulps; from 14.8 to 15.6 °Brix in the mango pulps; and from 11.7 to 12.15 °Brix in the papaya pulps.

Characterization, Handling, and Distribution Conditions of a Commercial Restaurant. A small commercial restaurant in the urban region of Viçosa, Minas Gerais, Brazil, participated in this study. The restaurant serves around 150 meals (lunch) every day offering menu options that include fruits in salads and desserts. It deals with a small establishment with 10 employees and a single work shift.

The purchase requests are done weekly, and the fruits are received in the restaurant daily, between 08 h 30 min and 09 h. The fruits begin to be manipulated about 10 h 30 min, starting with the sanitation stage. The peeling and slicing are manual, being cut in cubes of varied dimensions, in accordance with the type of fruit. The fruits are displayed for consumption, but if necessary, they are stored in a domestic refrigerator. The distribution of the meals begins at 11 h and ends at 14 h 30 min, having a distribution time of 3 h and 30 min.

It is important to note that these conditions are similar to those in small commercial restaurants in Brazil, which makes this study representative.

Sample Preparation. The samples were randomly collected after reception, preparation (cleaning, peeling, and slicing), during, and at the end of the distribution of the fruits for consumption at the commercial restaurant, evaluating real handling and consumption conditions.

The fruits were transported from the market to the commercial restaurant in plastic bags, approximately 150 m, and in approximately 5 min. The average transport temperature of the fruits to the restaurant was 25 °C with a ±2 °C variation. After being delivered to the commercial restaurant, about 10 min before the start of preparation, the fruits were prepared under usual routine conditions of the restaurant. Five repetitions were performed for each fruit with each day representing one repetition. Thus, for each fruit, the analyses were carried out over 5 days, totaling 15 days for the three fruits. The analyses of carotenoids and vitamin C were performed on different days, totaling 30 days of experimentation. From 3 to 10 units of each fruit (guava, 6 units, 2 kg; mango, 4 units, 1.5 kg; papaya, 3 units, 3.7 kg) were collected at the moment of reception without having gone through any preparation process and were considered the control sample. Following this, the fruits were washed in running water and cleaned (immersion in a sodium hypochlorite solution containing 200 ppm of active chloride at room temperature for 15 min). Next, the fruits were removed from the cleaning solution and rinsed in running water. Then, the peel was manually removed using a sharp knife (mango and papaya) or left intact (guava was prepared with the peel), the seeds were removed (mango and papaya), and the fruits were sliced. The slices of mango were approximately 7 cm in length, 5 cm in width, and 1 cm in thickness. Guava was cut in the form of approximately 1.5 cm cubes. Papaya was cut in approximately 5 cm cubes.

The time spent from the reception to the end of preparation of the fruits was approximately 1 h. During the preparation process of the fruits, the temperature of the preparation sector was an average of 25 °C, with a ±2 °C variation. After preparing, the fruits were packaged in an aluminum container with dimensions of 40 cm length, 29 cm width, and 4 inches depth, and were exposed for consumption on a distribution counter.

After the preparation process, around 0.5 kg of fruit was collected in different sections of the container. The fruits were left exposed on a distribution counter, during the entire distribution period (3.5 h). During distribution (after 1 h and 45 min of exposure) and at the end of distribution (after 3.5 h of distribution), about 0.5 kg of each fruit was collected in different sections of the container and were stored in properly identified plastic bags, protected by aluminum foil, stored in isothermic boxes, and transported to the Department of Nutrition and Health, Vitamin Analysis Laboratory, Federal University of Viçosa (UFV).

In the laboratory, the samples from the postpreparation stages, during and end distribution stages, were homogenized in a multiprocessor before analysis. Before the analysis, the control samples were peeled (papaya and mango), chopped, and also homogenized in a multiprocessor.

To control the variation of the components inherent to each fruit (experimental unit), the same unit was submitted to the different treatments in the commercial restaurant. Thus, each fruit was divided into 8 parts, and 4 parts were used as controls, while the others were submitted to the different handling stages (preparation and distribution). The control samples were subjected to the same conditions used in the restaurant and in the main experiment (size of pieces, water temperature, preparation temperature, and other conditions used in the commercial restaurant). The samples corresponding to each treatment were collected for the vitamin C and carotenoids analyses. This experiment was called the control experiment.

Determination of the Content of Total Soluble Solids in Fruit Pulps. The soluble solids content (SSC) of the fruit pulps was determined using an optical refractometer (Analytic Jena, Germany), at a temperature of 22 °C. The sample was homogenized in a multiprocessor and an aliquot of 15 g was centrifuged at 4000 rpm (1789*g*) for 15 min to obtain the supernatant, and two drops were transferred to the refractometer. The results were expressed in ^{o}Brix.

Extraction and Analysis of Vitamin C. All the chemical analyses were carried out under dimmed lights, and tubes were wrapped in aluminum foil to exclude light.

The extraction method of AA was adapted from Campos et al. (*13*). A fruit sample and extraction solution (3% metaphosphoric acid, 8% acetic acid, 0.3 N sulfuric acid, and 1 mM EDTA) were mixed using a homogenizer (5 min), centrifuged at 4000 rpm (1789*g*) for 30 min, and the supernatant completed with 25 mL of ultrapure water. AA was determined as previously described (*13*) using high performance liquid chromatography (Shimadzu SCL, 10A VP) equipped with an RP-18 Lichrospher 100 chromatographic column, 250 mm × 4 mm, 5 μm. The mobile phase (1 mM NaH_2PO_4 and 1 mM EDTA, pH 3.00) was with a flow rate of 1.0 mL/min. The eluate was detected using a Shimadzu

SOD-M10 AVP photodiode-array detector set at 245 nm. AA was identified by comparing its UV spectrum and retention time with a standard. The quantification of AA was carried out using the external standard method.

The conversion of DHA into AA was carried out according to Campos et al. (*13*). DHA was reduced to AA with 40 mM α-dithiotreitol (DTT), thus determining total vitamin C. DHA quantification was performed by using the difference between the content of total AA (after the conversion of DHA into AA) and the content of AA (before the DHA conversion). Standards of L-ascorbate were purchased from Vetec (Rio de Janeiro, Brazil) and α-dithiotreitol (DTT) from Sigma-Aldrich (St. Louis, MO, USA).

Extraction and Analysis of Carotenoids. Carotenoids were extracted with acetone and petroleum ether, following the method of Rodriguez et al. (*14*). For the extraction of carotenoids from papaya, it was necessary to do the saponification of the extract with a solution of 10% KOH in methanol in an equal volume to that of the extract and approximately 0.3 g of butylated hydroxytoluene (BHT). The mixture was left in the dark for 16 h at room temperature (21−23 °C) and in an oxygen free atmosphere (*15*). This stage was carried out, with the intention of hydrolizing esters from carotenoids, encouraging the removal of lipids and destroying chlorophyll, making the subsequent separation, identification, and quantification of carotenoids of the papaya samples easy.

Carotenoids were determined as previously described (*16*) using high performance liquid chromatography (Shimadzu SCL-10A VP) equipped with an RP-18 Phenomenex C18 Chromatographic column, 250 × 4.6 mm. Mobile phase, methanol/ethyl acetate/acetonitrile (50:40:10) for mango and guava and (80:10:10) for papaya; flow rate, 2.0 mL/minute; run time, 5.5 min for mango and guava, and 18 min for papaya. The eluate was detected using a Shimadzu SOD-M10 AVP photodiode-array detector set at 450 nm. Carotenoids were identified by comparing their UV spectrum and retention time with standards.

Quantification was carried out by external standardization with calibrated standard solutions: β-carotene, lycopene, and β-cryptoxanthin were isolated from concentrated extracts of carrot, tomato, and papaya, respectively, by open column chromatography, according to the description of Rodriguez-Amaya (*17*).

The real concentration of the AA solutions and the real concentration of the carotenoids standards were determined by spectrophotometry and adequately corrected.

Validation Tests. For recovery tests, samples were mixed with standard solutions of AA and carotenoids before extraction. The extraction recovery for guava was 93.6%, 90.0%, and 89.5% ($n = 3$) for AA, lycopene, and β-carotene, respectively. For mango, the extraction recovery of AA, lycopene, and β-carotene was 120%, 89.3%, and 92% ($n = 3$), respectively. For papaya, the extraction recovery of AA, lycopene, β-carotene, and β-cryptoxanthin was 91.7%, 91%, 89%, and 90% ($n = 3$), respectively.

The determination of the linearity band was performed by the injection of increasing concentrations of the standard AA and carotenoids solutions in duplicate under the same chromatographic conditions used for the analysis of the samples. The data achieved for peak concentration areas used for each compound in the study were used for the linear regression analysis. The linearity evaluation was carried out by the coefficient determination (R^2). All of the components presented good linearity in the bands of concentrations used (injected weights: AA, 0.505−4.04 μg; lycopene, 0.022−11.48 μg; β-carotene, 0.1025−3.28 μg; β-cryptoxanthin, 1.19−3.57 μg). The linear correlation coefficient for AA was 0.996; for β-carotene, 0.992; for lycopene, 0.994; for β-cryptoxanthin, 0.990.

The detection limit, defined as the minimum concentration capable of giving a chromatographic signal three times higher than the back-ground noise (*17*), was 50 μg/L for AA; 60 μg/L for lycopene; 50 μg/L for β-carotene; and 55 μg/L for β-cryptoxanthin.

The quantification limit, defined as the minimum concentration capable of giving a chromatographic signal five times higher than the background noise (*17*), was 75 μg/L for AA; 85 μg/L for lycopene; 70 μg/L for β-carotene; and 75 μg/L for β-cryptoxanthin.

The repeatability test for AA and carotenoids was carried out after five extractions of a single sample with subsequent HPLC analysis in duplicate. The repeatability values were expressed as relative standard deviations (RSD), both for the retention time and peak area. For AA, the values were 1.28% and 1.30% for the retention time and peak area, respectively. For β-carotene, the values found for the retention time and peak area were 0.457% and 4.016%, respectively. For lycopene, the values were 0.46% and 5.29% for the retention time and peak area, respectively. And for β-cryptoxanthin, the values found for the retention time and peak area were 0.52% and 3.26%, respectively.

Statistical Analysis. All data (content of vitamin C and carotenoids) were reported as the means ± standard deviation of five independent samples. The Lilliefors test and the Cochran and Barttlet test were used to verify the normality and homogeneity of the data, and for those that presented normal distribution, the analysis of variance and Tukey's test at 5% probability were applied. For the data that did not present normal distribution, a nonparametric analysis through the Kruskal−Wallis test was used to check for the existence of the difference between the treatments. The statistical analyses were carried out using the SAS software (Statistical Analysis Systems), lincensed for UFV, 2008 (*18*).

RESULTS AND DISCUSSION

Qualitative Composition. Figure 1 shows the typical chromatographic profile of three samples analyzed in this work. AA, β-carotene, and lycopene were identified in all of the fruits analyzed. However, β-cryptoxanthin was found only in papaya. The retention time of AA in the three fruits analyzed was about 3.5 min. In the guava and mango samples, the retention time of lycopene and β-carotene was about 3.5 and 4.5 min, respectively. In the papaya samples, the retention time for β-cryptoxanthin, lycopene, and β-carotene was, approximately, 6.5, 13.5, and 17.0 min, respectively.

Soluble Solids Content. The soluble solids content in the guava, mango, and papaya pulps, referent to the samples intended for vitamin C and carotenoids analyses, are presented in **Table 1**.

There was no significant difference in the soluble solids content in the different stages of handling of the three fruits analyzed, indicating that in all stages the samples collected were in a similar stage of ripeness. This care taken in the procedure is important since the contents of carotenoids and vitamin C are different in fruits at different stages of ripeness (*19*).

The results achieved are comparable to those reported in other studies, with different varieties of mango, papaya, and guava (*19*, *20*).

Vitamin C and Carotenoids Contents. The average contents of AA, DHA, total vitamin C, β-carotene, and lycopene in the fruits during the handling and distribution stages at the commercial restaurant are presented in **Table 2**. β-cryptoxanthin was found only in papaya.

The AA values for guava varied from 58.8 to 71.4 mg/100 g and were lower than those reported by Padula and Rodriguez-Amaya (*21*) (142.6 mg/100 g). The DHA content in the fruits analyzed in the present study varied from 14.5 to 45.6 mg/100 g, which represents approximately 16.9 to 43.7% of the total vitamin C content (AA and DHA). According to Lee and Kader (*12*), AA is the main biologically active form, but DHA, a product of oxidation, also exhibits biological activity since it can easily be converted into AA in the human organism. Therefore, it is important to measure both AA and DHA in fruits and vegetables to find the true value of vitamin C.

Padula and Rodriguez-Amaya (*21*) found values lower than those of the present study for β-carotene (370 μg/100 g) and lycopene (620 μg/100 g) for guava. The higher values found in the guava analyzed in our study, mainly in relation to lycopene, which presented a content 10 times higher than that observed by Padula and Rodriguez-Amaya (*21*), demonstrates that customers of the commercial restaurant can be sure they are consuming considerable amounts of an important and powerful antioxidant compound since lycopene is considered the carotenoid with the greatest capacity to eliminate reactive oxygen species such as the oxygen singlet (*9*).

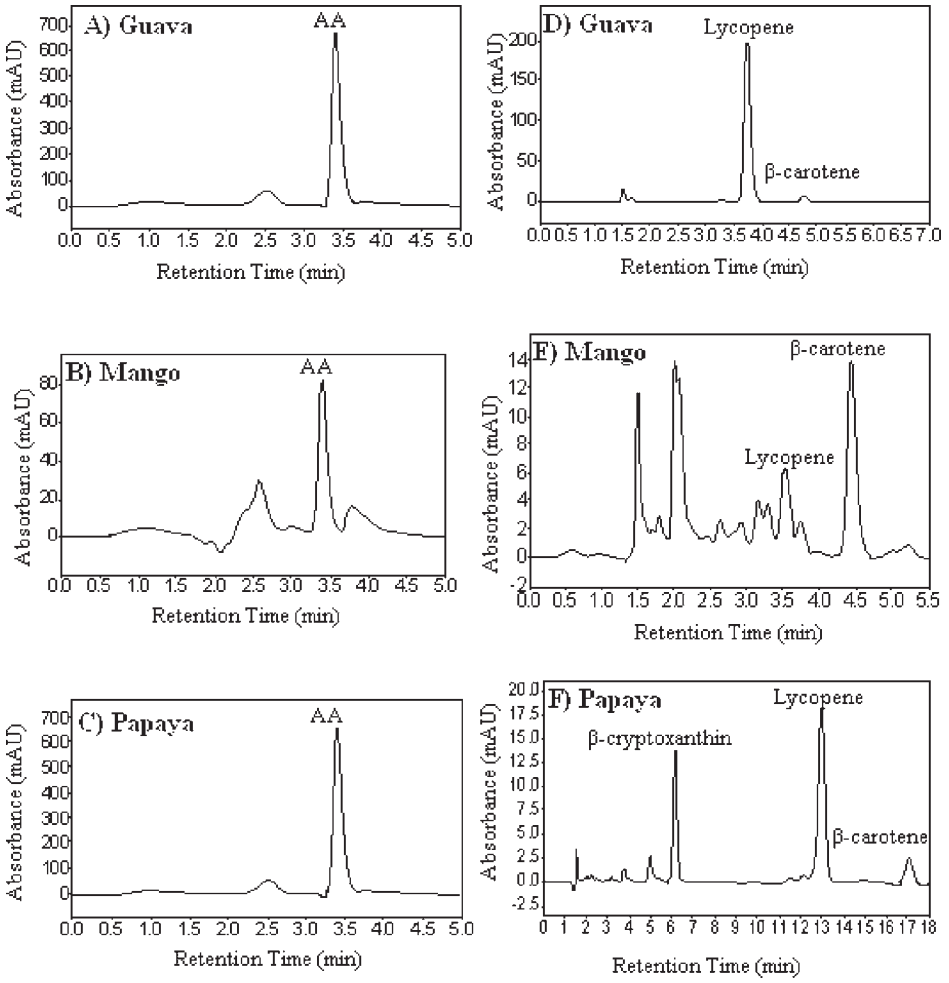

Figure 1. Analysis by HPLC of carotenoids and AA in guava, papaya, and mango. Chromatographic conditions for **A**, **B**, and **C**: mobile phase, ultrapure water containing 1 mM monobasic sodium phosphate and 1 mM EDTA pH adjusted for 3.0 with phosphoric acid; Lichrospher column, 100 RP-18 5 μm, 250 $\times$ 4 mm; photodiode-array detector (detection at 245 nm); flow, 1.0 mL/minute; volume of injection, 30 μL for guava and 20 μL for papaya; AA, ascorbic acid. Chromatographic conditions for **D** and **E**: mobile phase, methanol/ethyl acetate/acetonitrile (50:40:10); Phenomenex column, Gemini, C18, 5 μm, 250 $\times$ 4.6 mm; UV−visible detector (diode arrays, detection at 450 nm); flow, 2 mL/min; volume of injection, 30 μL. (**F**) Mobile phase, Methanol/ethyl acetate/acetonitrile (80:10:10); Gemini column c18 110 Å 5 μm, 250 $\times$ 4.6 mm; diode array detector (detection at 450 nm); flow, 2 mL/min; volume of injection, 30 μL.

Table 1. Average of Total Soluble Solids Contents[a] (°Brix) of Guava, Mango, and Papaya in the Samples Intended for the Analysis of Vitamin C and Carotenoids

	soluble solids content (°Brix)							
	handling stages[b]				handling stages[c]			
fruits	control[d]	after prepar.[e]	during distr.[f]	final distr.[g]	control	after prepar.	dur. distr.	final distr.
guava	7.8 ± 0.3	7.9 ± 0.5	7.8 ± 0.3	7.6 ± 0.2	8.2 ± 0.5	7.7 ± 0.3	8.1 ± 0.5	8.1 ± 0.7
mango	14.8 ± 1.3	15.5 ± 0.8	15.0 ± 0.7	15.5 ± 0.5	15.1 ± 1.2	15.6 ± 0.5	15.3 ± 0.7	15.6 ± 0.7
papaya	11.9 ± 0.6	11.9 ± 0.6	11.7 ± 0.9	11.9 ± 0.8	12.2 ± 0.5	12.1 ± 0.7	12.1 + 0.8	12.0 ± 0.5

[a] Average of 5 repetitions ± standard deviation. Averages in the lines per fruit do not differ statistically at 5% of probability by the variance analysis. [b] Average of total soluble solids contents in samples referent to the analysis of vitamin C. [c] Average of total soluble solids contents in samples referent to the analysis of carotenoids. [d] Control (reception) = fruit samples that did not undergo any preparation stage (*in natura*). [e] After prepar. = fruit samples that underwent the preparation process (cleaning and cutting, 1 h after reception). [f] During distr. = fruit samples that underwent all of the process stages and were collected and analyzed during the distribution period (3.5 h after the reception). [g] Final distr. = fruit samples that underwent all of the fruit preparation stages and distribution processes (4.5 h after the reception).

The average contents of AA, DHA, and total vitamin C in mango varied from 10.4 to 16.6 mg/100 g, 1.3 to 10.9 mg/100 g, and 17.5 to 23.6 mg/100 g, respectively. Ribeiro et al. (*20*) found inferior values in the Tommy mango (8.78 mg of AA/100 g; 1.01 mg of DHA/100 g; and 9.79 mg of total vitamin C/100 g). A different work reported the AA content value of 80 mg/100 g in Ataulfo mango (*22*). In our study, 7.42% to 46.02% of the value of the total vitamin C value observed in the mango was in the DHA form. Such a result differed from the findings of Hernández et al. (*19*), who observed that for both mango and papaya, the DHA content was not higher than 10% of the total vitamin C.

The average contents of β-carotene and lycopene in mango varied from 1490.0 to 1748.0 μg/100 g, and 57.4 to 81.1 μg/100 g, respectively. Ribeiro et al. (*20*) found lower values for β-carotene (608,39 μg/100 g) in the Tommy mango. Mercadante et al. (*23*) also reported content varying from 200 to 690 μg/100 g.

The papaya presented average contents of AA, DHA, and total vitamin C varying from 75.6 to 80.8 mg/100 g, 1.1 to 4.9 mg/100 g,

Table 2. Average Content[a] of Vitamin C and Carotenoids in Samples of Guava Paluma, Mango Tommy Atkins, and Papaya Formosa, Randomly Collected, during the Stages of Handling and Distribution in a Commercial Restaurant

		fruits		
antioxidant compounds	handling stages	guava	mango	papaya
AA (mg/100 g FM[f])	control[b]	71.4 ± 11.4 a	16.2 ± 7.7 a	79.1 ± 5.0 a
	after preparation[c]	64.0 ± 7.2 a	10.4 ± 5.4 a	77.7 ± 13.1 a
	during-distr.[d]	36.7 ± 6.8 a	15.2 ± 8.9 a	75.6 ± 17.3 a
	final-distr.[e]	58.8 ± 8.9 a	16.6 ± 9.5 a	80.8 ± 12.0 a
DHA[a] (mg/100 g FM)	control	14.5 ± 3.6 a	1.3 ± 1.0 a	1.1 ± 1.2 a
	after preparation	31.7 ± 21.0 ab	10.9 ± 16.3 a	1.4 ± 1.0 a
	during-distr.	37.2 ± 35.2 ab	3.7 ± 2.4 a	5.0 ± 3.0 a
	final-distr.	45.6 ± 31.4 b	7.0 ± 9.3 a	1.3 ± 0.8 a
total vitamin C[a] (mg/100 g FM)	control	85.9 ± 10.9 a	17.5 ± 7.1 a	79.2 ± 5.7 a
	after preparation	96.3 ± 23.0 a	21.3 ± 15.1 a	56.1 ± 31.1 a
	during-distr.	100.9 ± 32.0 a	18.9 ± 11.0 a	80.6 ± 15.0 a
	final-distr.	104.5 ± 30.9 a	23.6 ± 18.2 a	82.2 ± 12.8 a
β-carotene (μg/100 g FM)	control	366.3 ± 64.0 a	1557.1 ± 180.2 a	548.6 ± 175.1 a
	after preparation	432.4 ± 81.0 a	1748.2 ± 249.4 a	468.1 ± 224.3 a
	during-distr.	364.2 ± 121.7 a	1747.5 ± 178.9 a	598.0 ± 103.4 a
	final-distr.	351.3 ± 84.6 a	1490.1 ± 284.4 a	513.9 ± 256.9 a
lycopene (μg/100 g FM)	control	6999.3 ± 2420.5a	77.2 ± 58.0 a	3137.5 ± 596.3 a
	after preparation	7649.9 ± 1599.2 a	81.2 ± 69.2 a	3131.4 ± 1485.8 a
	during-distr.	7023.8 ± 1739.3 a	74.4 ± 60.7 a	4281.0 ± 635.6 a
	final-distr.	5503.4 ± 1668.8 a	57.4 ± 37.4 a	3105.4 ± 1482.7 a
β-cryptoxanthin (μg/100 g FM)	control			3798.6 ± 278.0 a
	after preparation			3477.0 ± 1043.7 a
	during-distr.			4097.3 ± 596.9 a
	final-distr.			3435.0 ± 1723.2 a

[a] Average of 5 repetitions ± standard deviation. DHA and total vitamin C of guava; lycopene, DHA, AA, and total vitamin C of mango; and lycopene and total vitamin C of papaya were analyzed by parametric test of Kruskal−Wallis and other variables by ANOVA. Averages in columns by the fruit, followed by the same letter did not differ at 5% probability by Tukey's test or by the Kruskal−Wallis test. [b] Control (reception) = samples of the fruits that did not undergo any stage of the preparation (*in natura*). [c] After preparation = fruit samples that underwent the fruit preparation process (cleaning and cutting; 1 h after the reception). [d] During-distr. = fruit samples that underwent all of the processing stages and were collected and analyzed during the distribution period (3.5 h after the beginning of the distribution). [e] Final-distr. = fruit samples that underwent all of the fruit preparation stages and distribution processes (after 4.5 h of distribution). [f] FM = fresh matter.

and 79.1 to 82.2 mg/100 g, respectively. Hernández et al. (*19*) found higher values of AA, DHA, and total vitamin C for the ripe papaya variety Baixinho do Santa Amália (149.0, 5.32, and 154.0 mg/100 g, respectively). Of all the three fruits analyzed, papaya presented the lowest percentage of DHA (from 1.41 to 6.04%), in relation to the content of total vitamin C, but even so, it should be quantified because it presents a nutritional value of vitamin C, which is transformed into AA in humans.

Besides lycopene and β-carotene, β-cryptoxanthin was also found in significant amounts in papaya. This carotenoid also presents a nutritional value of vitamin A. The average contents achieved were higher than those found in other studies, varying from 468 to 597 μg/100 g for β-carotene, from 3105 to 4280 μg/100 g for lycopene, and from 3777 to 4097 μg/100 g for β-cryptoxanthin. Souza et al. (*24*) found values for β-carotene in the ripe papaya Formosa, varying from 290 to 293 μg/100 g. The contents of carotenoids in papaya Formosa reported by Sentenin and Rodriguez-Amaya (*25*) were 2300; 920 and 120 μg/100 g for lycopene, β-cryptoxanthin and β-carotene, respectively.

The results achieved demonstrate the importance of β-cryptoxanthin quantification in papaya since it is the main pro-vitamin A carotenoid present in this fruit, although most works have not determined that. In this study, the content of β-cryptoxanthin represented approximately 45% of the carotenoids analyzed in papaya, reinforcing that studies that do not include the value of this carotene underestimate the pro-vitamin A content in papaya.

It must be pointed out that the variations in the vitamin C and carotenoids content observed in the different studies may be attributed to factors such as the stage of ripeness, cultivation location and practices, weather conditions, different varieties of the same fruit, parts of the fruits analyzed, as well as the techniques applied (*26*). Thus, the studies must completely describe and detail sampling characterizations to facilitate comparisons between them.

Stability of Vitamin C and Carotenoids. Different from that expected, the content of carotenoids and vitamin C did not differ statistically in the handling stages for any of the fruits studied with the exception of the DHA in guava, which differed statistically between the control stage and the final-distribution stage (**Table 2**).

Insignificant unexpected fluctuations in the content of all of the components analyzed were observed between the handling stages of the fruit samples tested. These fluctuations may be associated with the variations in the content of the compounds analyzed inherent to each experimental unit (each fruit). In order to evaluate the real conditions of consumption by the population, during the experiment different experimental units were used. Then, a *pool* of each fruit was used simulating the real handling and distribution conditions between repetitions and between handling and distribution stages, which did not allow for a greater sample control. The results of the control experiment, where one single experimental unit (the same fruit) went through all of the handling and distribution stages, also demonstrated fluctuations

Table 3. Average Content[a] of Vitamin C and Carotenoids in Fixed Samples[b] of Guava Paluma, Mango Tommy Atkins, and Papaya Formosa, during the Stages of Handling and Distribution in Commercial Restaurants (Control Experiment)

		fruits		
antioxidant compounds	handling stages	guava	mango	papaya
AA (mg/100 g FM[f])	control[c]	63.0 ± 11.8	9.8 ± 2.8	36.1 ± 19.9
	during-distr.[d]	54.8 ± 8.6	10.6 ± 2.8	43.0 ± 2.9
	final-distr.[e]	50.2 ± 9.1	9.8 ± 1.4	42.2 ± 5.9
DHA (mg/100 g MF)	control	13.5 ± 3.3	4.4 ± 3.2	2.5 ± 1.9
	during-distr.	20.4 ± 6.5	3.4 ± 1.12	2.1 ± 0.9
	final-distr.	20.1 ± 12.6	3.5 ± 2.1	1.9 ± 0.9
total vitamin C (mg/100 g FM)	control	76.4 ± 11.7	14.2 ± 2.0	32.4 ± 18.4
	during-distr.	75.2 ± 11.7	14.0 ± 2.2	40.9 ± 2.1
	final-distr.	69.8 ± 16.9	13.3 ± 2.7	44.3 ± 2.8
β-carotene (μg/100 g FM)	control	828.1 ± 399.2	1864.1 ± 857.1	262.0 ± 88.9
	during-distr.	696.4 ± 399.2	1813.9 ± 910.6	303.5 ± 129.2
	final-distr.	818.2 ± 456.2	1760.2 ± 989.3	330.9 ± 141.2
lycopene (μg/100 g FM)	control	7117.0 ± 2321.7	8.2 ± 2.9	2504.9 ± 948.3
	during-distr.	5570.1 ± 997.0	10.2 ± 4.1	3252.7 ± 705.2
	final-distr.	7432.3 ± 2591.7	5.8 ± 2.8	3323.0 ± 745.6
β-cryptoxanthin (μg/100 g FM)	control			2921.2 ± 396.2
	during-distr.			3031.4 ± 501.2
	final-distr.			3138.2 ± 358.2

[a] Average of 5 repetitions ± standard deviation. [b] Fixed sample = one unit of each fruit that went through the handling and distribution stages. β-Carotene and DHA of guava were analyzed by the parametric test of Kruskal−Wallis and other variables by ANOVA. Averages in the columns by fruits did not differ at 5% probability by ANOVA or by the Kruskal−Wallis test. [c] Control (reception) = fruit samples that did not undergo any preparation stage (*in natura*). [d] During-distr. = fruit samples that underwent all of the processing stages and were collected during the distribution period (3.5 h after the reception). [e] Final-distr. = fruit samples that underwent all of the preparation stages and distribution processes (4.5 h after the reception). [f] FM = fresh matter.

in the contents of the analyzed components in the handling stages, although such differences have not been statistically significant (**Table 3**). Different stages of ripeness of the fruits analyzed inside one single repetition or between repetitions of the same fruit could also lead to fluctuations in the content of the compounds analyzed in the four handling and distribution stages since the degree of ripeness influences the content of vitamin C and carotenoids (*19*). Nevertheless, the soluble solids content of the samples did not differ significantly between the handling and distribution stages (**Table 1**). The differences for the analyzed components in three fruits (with the exception of the DHA of the guava) were not significant, which suggests excellent stability of the compounds due to preparation and distribution conditions that are ordinarily employed at commercial restaurants.

Only for the content of a single component of the fruit was a statistical difference observed during the preparation and serving for consumption. The DHA content of the guava in the control stage was statistically inferior to that found at the end of the distribution.

The AA stability during the stages of preparation and exposure of the fruits for consumption is in accordance with the results achieved in a study with papaya Formosa, submitted to different kinds of processing and stored for up to seven days, at different temperatures (3, 6, and 9 °C), which demonstrated that the content of AA was not affected by the processing type, nor different temperatures. In other words, the contents remained from 65.0 to 70.0 mg/100 g (*24*).

Donadan et al. (*27*), in a study on changes in the content of AA in oranges Pêra-Rio, evaluated the influence of the kind of peeling (manual, mechanical and enzymatic) and storage at 5 and 10 °C and at room temperature (21−23 °C) for 3 days. They discovered that the content of AA was not affected by the different peeling processes and storage at different temperatures. Similar to the results of the present study, that work did not observe significant losses of vitamin C and carotenoids at room temperature.

A comparative study with whole and chopped fruits, stored for 9 days at 5 °C, found distinct changes in the antioxidant components of each fruit analyzed. Vitamin C losses at 5 °C were around 5% in the pieces of mango, strawberry, and watermelon, 10% in the pieces of pineapple, and 12% in the slices of kiwifruit. Carotenoid losses were not verified in the kiwifruit slices and watermelon cubes, but losses of 25% were observed in the pineapple pieces and of 10−15% in the mango and strawberry pieces after six days of storage at 5 °C. In this work, the effect of the exposure of the chopped fruits to light was evaluated, and in general, this exposure had no diminishing effect on the quality and nutrient content. The authors concluded that the results obtained were different from those expected, and it was clear that minimum processing had a very reduced effect on the main antioxidant components since the changes in the antioxidant nutrients observed during nine days at 5 °C did not significantly affect the nutritional quality of the chopped fruits (*22*).

Studies that evaluate the content of vitamin C and carotenoids under conditions similar to those in the present study were not found, which hindered the comparison and discussion of the results.

Although the fruits in this study remained exposed at room temperature (21−23 °C) during distribution, the handling stages were carried out in sequence (reception, preparation, and exposure for consumption) without time intervals between the stages, shortly before the distribution period which may have contributed to the failure of the mechanisms that operate in the degradation of antioxidant compounds.

New studies that evaluate the stability of vitamins and carotenoids during the handling process of tropical fruits, vegetables, and tubercles are needed to confirm the findings of the present

study, contributing to the evaluation of the nutritional quality of meals.

Unexpectedly, the fruits analyzed do not present statistically significant differences in the content of vitamin C and carotenoids, during the preparation and serving for consumption (the period of 4.5 h from reception until the end of distribution), which demonstrates the excellent stability of the components under the handling conditions commonly used by the commercial restaurant.

Only for the content of one component of a single fruit was a statistical difference observed during the preparation and exhibition for consumption. The DHA content of the guava in the control stage was statistically inferior to that found in the guava at the end of the distribution.

The results achieved demonstrate that commercial restaurant customers are directly benefited since the nutritional quality of the fruits was preserved during all of the preparation and distribution stages, also allowing for more flexibility in choosing a meal time.

ABBREVIATIONS USED

AA, ascorbic acid; DHA, dehydroascorbic acid; HPLC, high performance liquid chromatography; FM, fresh matter.

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