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Research Article
Effects of Storage on the Quality Characteristics of Guava (*Psidium guajava* L.) Fruit Concentrates

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Abstract

Background and objective: White and red guava pulp concentrates produced in this study were stored at room temperature (25±5°C) for 13.5 months. The purpose of this research was to study the effects of storage on the quality characteristics of Guava (*Psidium guajava* L.) fruit concentrates with respect to their physicochemical, chemical and microbiological properties in comparison with their initial values before storage. **Materials and Methods:** After processing of the white and red guava pulp concentrates by evaporation under normal atmospheric pressure, changes in the physicochemical, chemical and microbial characteristics of white and red guava (*Psidium guajava* L.) fruit concentrates during storage were investigated using standard and official methods of analysis. **Results:** The results showed significant differences ($p \leq 0.05$) between the two concentrates before storage with respect to their total soluble solids (TSS), ascorbic acid and sugar contents. Then, the levels of TSS in both the white and red guava concentrates were gradually and significantly ($p \leq 0.05$), increased from 17.00-21.55% in the white guava concentrate and from 19.00-22.96% in the red guava concentrate at the start and end of the storage period, respectively. In contrast, the level of hydrogen ion concentration (pH) decreased from 4.60-3.00 and from 4.53-3.02 in the white and red guava concentrates, respectively, while the acidity of the two guava pulp concentrates (as citric acid) increased with increasing storage time from 0.30% at the initial period (zero time) to 0.90% at the end of the period. While, the levels of ascorbic acid and total, reducing and non-reducing sugars in the two guava pulp concentrates significantly ($p \leq 0.05$) decreased at the end of the storage period. The optical density (OD) values of the white and red guava concentrates remained constant at 0.13 and 0.14 OD, respectively, until the fifth month of the period. Afterwards, significant ($p \leq 0.05$) colour degradation was observed in the white guava concentrate (0.054 OD), while the OD value of the red guava concentrate slightly decreased from 0.13-0.11 by the end of the storage period. In addition, the results of the microbiological analysis revealed that the two guava concentrates remained free from any microorganisms for 12 months of storage. **Conclusion:** During the storage of the white and red guava pulp concentrates at room temperature (25±5°C) for 13.5 months, the two guava concentrates underwent similar changes in their TSS, pH and acidity. Colour degradation was very clear in the white guava pulp concentrate, especially at the end of the storage period. In addition, both the guava concentrates found to be free from any pathogenic microorganisms and with stable physical and chemical properties during storage period of up to 12 months.

Key words: Ascorbic acid, guava pulp, red guava, storage period, sugars, white guava

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The guava tree (*Psidium guajava* L.), which belongs to the *Myrtaceae* family, is considered one of the most important tropical fruit trees in the world with high palatability and pleasant flavour and odour[1]. The origin of the tree is tropical America and well grown in all warm areas of tropical and subtropical regions[2]. In Sudan, guava fruit is the most popular fruit after date, citrus, mango and banana. The most popular guava cultivars in Sudan are the pear- and apple-shaped fruit types with pink or white pulp. Both guava types are easily grown in the country with high productivity and usually harvested two to three times during the year. However, guava fruits are highly perishable; nearly 30% of their production are usually lost due to spoilage, mishandling, lack of transportation or cold storage facilities[3].

Guava fruit is very rich in tannins, phenols, terpenes flavonoids, essential oils, saponins, carotenoids, fibres and fatty acids. The fruit is also an excellent source of pectin, minerals (potassium, copper and magnesium) and vitamins such as ascorbic acid (vitamin C), vitamin A, thiamine (B1), riboflavin (B2), pantothenic acid, folic acid and niacin[4,5]. The fruit is eaten fresh or processed into juice, jam, concentrate or other food products[6,7]. Therefore, the preservation of guava pulp concentrates not only supports guava-based industries but also the financial loss associated with its importing can be avoided. No previous studies have been carried out to investigate the effects of storage on the quality characteristics of Guava (*Psidium guajava* L.) fruit concentrates. Thus, the present study was conducted to evaluate the effects of storage on the quality characteristics of Guava pulp concentrates with respect to their physicochemical, chemical and microbiological properties.

MATERIALS AND METHODS

The guava fruits (*Psidium guajava* L.) with white and red pulp colour were obtained from Alkadaro and Aljeraf farms, Khartoum, Sudan. All the chemicals and reagents used in this study were of analytical grades. This study was conducted during 2008-2012.

Guava concentrate processing method: Freshly harvested fully ripened white and red guava fruits were quickly washed, sorted, weighed, graded, manually peeled, sliced and blanched. The fruit juice of the two samples was extracted by using a fruit pulpier (MDX-207823-HR, Reeves, USA), placed in a steam jacketed kettle (50 litre capacity, No. 1044-19-66, Gebrs-H.J Scheffers) and heated to 100°C until the total soluble solids (TSS) reached 19°Bx. Then the steam was turned off, and 0.03% sodium benzoate (CDH, England) was immediately added as a food preservative. Finally, the white and red guava concentrates were kept in cleaned tin containers (Cans: 3; Size: 700×404 inches; Capacity: 35.08 ounces), which were tightly closed, sterilized in boiled water (100°C) for 30 minutes, cooled to 30°C and stored at room temperature for further analysis.

Storage method and conditions: Both the white and red guava pulp concentrates produced in this study were stored at room temperature (25±5°C) for 13.5 months. During this period, representative samples from both guava pulp concentrates were taken every 45 days for analysis in order to determine the changes that occurred with respect to their physicochemical and chemical properties in comparison with their initial values before storage.

Physicochemical methods: TSS in the guava pulp concentrates was measured with a hand held refractometer (No. 002603, BS eclipse, UK) at 20°C as described by the AOAC[8], while the pH of the samples was measured by using a pH-meter with two buffer solutions (pH 4.01 and 7.0) at 20°C to the nearest 0.01 pH units.

Chemical methods: The concentrations of total, reducing and non-reducing sugars and ascorbic acid of the different guava pulp concentrates were determined according to the standard method of the AOAC[8]. The non-enzymatic browning optical density (OD) and Titratable acidity percentages were determined according to Ranganna[9].

Microbiological analysis methods: The microbiological quality and safety of the guava fruits concentrates before and during storage were assessed based on their total viable bacterial count (TVBC), total *Coliform* count (TCC), total *Staphylococcus aureus* count (TSAC), *Lactic* acid bacterial count (LABC), total *Salmonella* count (TSC), total yeast and mould count (TYMC), according to ICMSF[10].

Statistical analysis: All statistical analyses were performed using the Statistical Package for Social Science (SPSS) version 16.0 for windows (SPSS Inc., Chicago, IL, USA). While, the mean values were tested and separated using Duncan's Multiple Range Test (DMR) according to Steel *et al.*[11].

RESULTS AND DISCUSSION

Physicochemical and chemical characteristics of guava pulp concentrates before storage: After the processing of the white and red guava pulp concentrates by evaporation

under normal atmospheric pressure, the physicochemical and chemical characteristics of the two products were immediately investigated. The initial physicochemical and chemical characteristics of the white and red guava pulp concentrates was determined before storage as described by the AOAC[8] and presented in Table 1.

Results showed the significant differences between the TSS of the white guava pulp concentrate (17.0%) and red guava pulp concentrate (19.0%). This variation in TSS may be due to the thermal processing conditions or the initial pectin contents in the fruits[12,13]. In contrast, the hydrogen ion concentrations (pH) (4.60, 4.53) and titratable acidity percentages (0.30%, 0.30%), in the white and red guava concentrates respectively, were found to be different non-significantly. In the white guava concentrate, the vitamin C concentration (ascorbic acid) was significantly ($p \leq 0.05$) higher (134.9 mg/100 g) than that of the red-guava concentrate (124.0 mg/100 g). According to the literature, the degradation of vitamin C in fruit juice or fruit concentrate is usually influenced by the processing method and temperature[14]. On the other hand, the red guava concentrate had higher concentrations of total sugars (16.14%) and reducing sugars (10.95%) with no marked variations in its OD levels (0.13 and 0.14). Sabato *et al.*[15] reported that variations in sugar contents of different guava varieties is not only due to the physiological changes and polysaccharides metabolism that occur during the ripening process but also due to the effects of the thermal processing conditions during the production of guava concentrates.

Changes in the physicochemical and chemical characteristics of white and red pulp guava pulp concentrates during storage: One of the main objectives of this study was to determine the changes in the physicochemical and chemical properties of the white and red guava concentrates during storage. Therefore, representative samples from the two concentrates were taken every 45 days to evaluate the changes in their TSS (%), pH, acidity (%), ascorbic acid (mg/100 g), total sugars (%), reducing sugars (%), non-reducing sugars (%) and non-enzymatic browning optical density (OD).

Changes in physicochemical characteristics: Table 2 and 3 show changes in the TSS and pH of the white and red guava pulp concentrates, respectively, during storage. Table 2 indicates that the TSS increased gradually and significantly ($p \leq 0.05$) from 17.00-21.55% in white guava and from 19.00-22.96% in red guava by the end of the storage period. These results agree with the findings of Yang *et al.*[16] and Jain *et al.*[17]. The increasing trends in the TSS percentage may be due to the conversion of polysaccharides into soluble sugars during storage.

In contrast, at the end of the storage period the pH values significantly ($p \leq 0.05$) decreased from 4.60-3.00 in the white guava concentrates and from 4.53-3.02 in the red guava concentrates. The decline in the pH values of the two guava concentrates during storage may be due to the conversion of soluble sugars into organic acids. It was observed that, the processing methods and increase in storage temperature and period decreased the pH levels and viscosity in fruit beverages and concentrates[18-20].

Changes in chemical characteristics

Changes in acidity and ascorbic acid: Table 4 and 5 show changes in acidity and ascorbic acid concentration in the white and red guava concentrates during storage, respectively. The acidity of the two guava concentrates (as citric acid) increased with increasing storage time from 0.3% at the initial storage time (zero time) to 0.9% by the end of the storage time (Table 4).

In contrast, the levels of ascorbic acid (Table 5) in the white and red guava concentrates significantly ($p \leq 0.05$) decreased from 134.9 and 125.0 at the initial time of storage to 16.20 and 10.91 mg/100 g by the end of the storage period,

Table 1: Physicochemical and chemical characteristics of white and red guava pulp concentrates before storage

	Guava pulp concentrates			
Parameters	White variety	Red variety	$LSD_{0.05}$	SE±
TSS (%)	17.00±1.38^{b}	19.00±2.09^{a}	1.7253*	0.063
pH value	4.60±0.07^{a}	4.53±0.06^{a}	0.036$^{n.s}$	0.009
Acidity (%)	0.30±0.01^{a}	0.30±0.01^{a}	0.007$^{n.s}$	0.001
Ascorbic acid (mg/100 g)	134.90±0.03^{a}	125.40±0.01^{b}	8.541**	0.064
Total sugars (%)	15.32±0.01^{b}	16.14±0.07^{a}	1.539*	0.009
Reducing sugars (%)	9.09±0.02^{b}	10.95±0.05^{a}	1.632*	0.087
Non-reducing sugars (%)	6.23±0.04^{a}	5.19±0.03^{b}	0.854*	0.065
Non-enzymatic browning (OD)	0.13±0.00^{a}	0.14±0.00^{a}	0.008$^{n.s}$	0.002

Mean±S.D value(s) bearing same superscript letters within each row are non-significantly ($p \leq 0.05$) different. n.s: Non-significant, *Significant at ($p \leq 0.05$), **Highly significant

Table 2: Changes in total soluble solids of white and red-guava pulp concentrates during storage (13.5 months)

Storage period (months)	TSS (%) of guava pulp concentrates	
	White variety	Red variety
0.0	17.00±1.00^{e}	19.00±1.01^{def}
1.5	19.00±1.01^{def}	19.00±1.01^{def}
3.0	19.00±1.01^{def}	19.75±1.03^{d}
4.5	19.00±1.01^{def}	20.00±1.04^{cde}
6.0	19.00±1.01^{def}	20.00±1.04^{cde}
7.5	19.50±1.02^{de}	20.55±1.05^{cd}
9.0	19.50±1.02^{de}	20.76±1.06^{c}
10.5	20.70±1.07^{c}	21.50±1.07^{b}
12.0	21.19±1.07^{bc}	22.09±1.08^{ab}
13.5	21.55±0.00^{b}	22.96±1.13^{a}
$LSD_{0.05}$	0.2756*	
SE±	0.0381	

Mean±S.D values bearing same superscript letters within columns and rows are non-significantly ($p \leq 0.05$) different. *Significant at $p \leq 0.05$

Table 3: Changes in pH of white and red-guava pulp concentrates during storage (13.5 months)

Storage period (months)	pH of guava pulp concentrates	
	White variety	Red variety
0.0	4.60±0.07^{a}	4.53±0.06^{ab}
1.5	4.20±0.05^{b}	4.25±0.05^{b}
3.0	4.00±0.04^{c}	4.10±0.04^{bc}
4.5	3.80±0.03^{cd}	3.70±0.03^{d}
6.0	3.57±0.02^{de}	3.41±0.02^{e}
7.5	3.38±0.01^{ef}	3.31±0.01^{f}
9.0	3.31±0.01^{f}	3.16±0.01^{fg}
10.5	3.09±0.01^{gh}	3.11±0.01^{g}
12.0	3.05±0.01^{h}	3.08±0.01^{gh}
13.5	3.00±0.01^{hi}	3.02±0.01^{hi}
$LSD_{0.05}$	0.0019*	
SE±	0.00063	

Mean±S.D values bearing same superscript letter(s) within columns and rows are non-significantly ($p \leq 0.05$) different. *Significant at $p \leq 0.05$

Table 4: Changes in acidity percentage in white and red-guava pulp concentrates during storage (13.5 months)

Storage period (months)	Acidity (%) of guava pulp concentrates	
	White variety	Red variety
0.0	0.30±0.01^{cd}	0.30±0.01^{cd}
1.5	0.50±0.01^{c}	0.50±0.01^{c}
3.0	0.50±0.01^{c}	0.50±0.01^{c}
4.5	0.50±0.01^{c}	0.50±0.01^{c}
6.0	0.50±0.01^{c}	0.50±0.01^{c}
7.5	0.60±0.01^{bc}	0.70±0.01^{bc}
9.0	0.70±0.01^{b}	0.70±0.01^{b}
10.5	0.80±0.02^{ab}	0.80±0.02^{ab}
12.0	0.80±0.02^{ab}	0.80±0.02^{ab}
13.5	0.90±0.02^{a}	0.90±0.02^{a}
$LSD_{0.05}$	0.00034*	
SE±	0.000062	

Mean±S.D values bearing same superscript letter(s) within columns and rows are non-significantly ($p \leq 0.05$) different. *Significant at $p \leq 0.05$

respectively. These results agree with the previous studies[17,21]. The decrease in vitamin C was due to many factors, such as, oxygen, heat, light, storage conditions and type of containers[22].

Table 5: Changes in ascorbic acid in white and red guava pulp concentrates during storage (13.5 months)

Storage period (months)	Ascorbic acid in guava pulp concentrate (mg/100 g)	
	White variety	Red variety
0.0	134.9±0.03^{a}	125.4±0.01^{b}
1.5	125.2±0.02^{b}	117.5±0.01^{d}
3.0	120.2±0.02^{c}	110.1±0.02^{f}
4.5	112.2±0.01^{e}	97.10±0.01^{g}
6.0	80.43±0.01^{h}	65.90±0.01^{j}
7.5	71.52±0.01^{i}	52.35±0.05^{k}
9.0	50.14±0.01^{l}	38.24±0.02^{n}
10.5	46.55±0.03^{m}	30.85±0.01^{o}
12.0	26.48±0.26^{p}	17.18±0.83^{q}
13.5	16.02±0.01^{r}	10.91±0.02^{s}
$LSD_{0.05}$	0.3217**	
SE±	0.1125	

Mean±S.D values bearing same superscript letters within columns and rows are non-significantly ($p \leq 0.05$) different. **Highly significant at $p \leq 0.01$

Changes in sugars: Changes in total, reducing and non-reducing sugars of the white and red concentrates during storage are shown in Table 6. The levels of total sugars in the white and red guava concentrates decreased significantly ($p \leq 0.05$) from 15.32 and 16.14% at the beginning of the storage period to 13.15 and 13.7% by the end of the storage period. In addition, the concentration of non-reducing sugars in the white and red guava concentrates decreased significantly ($p \leq 0.05$) from 6.20 and 5.19% at the initial time to 0.04 and 0.06% by the end of the storage period. Similar results were reported in previous studies[20,23].

Changes in non-enzymatic browning optical density (OD): Changes in OD during storage of the white and red guava concentrates are shown in Table 7. Until the fifth month of the storage period, the OD values of the white and red guava concentrates remained constant at 0.13 and 0.14 OD. Afterwards, significant ($p \leq 0.05$) and gradual colour degradation was noticed in white guava concentrate until the end of the storage period, while the optical density value of the red guava concentrates slightly decreased from 0.13 to 0.11 OD by the end of the storage period. Zhao *et al.*[24] stated that, during storage, the OD values of fruit juices and concentrates is influenced by the Millard reaction and the polymerization of polyphenols, not by the degradation of ascorbic acid.

Microbial features of white and red guava concentrates during storage: Finally, the results of the microbiological analysis revealed that both the guava concentrates produced in this study were free from total viable yeasts, moulds and *coliform*, *Staphylococcus* sp., *Salmonella*, lactic acid bacteria and *anaerobic* spore-forming bacteria up to the end of the

Table 6: Changes in sugars of white and red guava concentrates during storage (13.5 months)

Storage period (months)	Guava pulp concentrate					
	Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
	Variety					
	White	Red	White	Red	White	Red
0.0	15.32±1.07^{bc}	16.14±1.12^{a}	9.09±0.46^{m}	10.95±0.54^{k}	6.23±0.18^{a}	5.19±0.16^{b}
1.5	15.32±1.07^{bc}	16.14±1.12^{a}	9.09±0.46^{h}	10.95±0.54^{g}	6.23±0.18^{a}	5.19±0.16^{b}
3.0	14.32±1.02^{d}	15.80±1.10^{ab}	10.56±0.51^{gh}	11.81±0.59^{e}	3.76±0.12^{cd}	3.99±0.14^{c}
4.5	14.23±1.01^{de}	15.49±1.08^{b}	11.13±0.57^{ef}	12.19±0.61^{de}	3.19±0.08^{d}	3.30±0.09^{d}
6.0	14.22±1.01^{de}	15.20±1.06^{c}	11.96±0.61^{e}	12.43±0.65^{d}	2.26±0.05^{g}	2.77±0.07^{e}
7.5	14.12±0.98^{e}	15.17±1.05^{c}	12.33±0.63^{d}	12.65±0.68^{cd}	1.79±0.04^{h}	2.52±0.06^{ef}
9.0	14.12±0.98^{e}	15.12±1.04^{c}	12.89±0.72^{c}	12.84±0.71^{c}	1.23±0.02^{j}	2.28±0.05^{g}
10.5	13.82±0.95^{fg}	14.80±1.03^{cd}	13.10±0.73^{bc}	13.35±0.79^{b}	0.75±0.01^{h}	1.45±0.03^{hi}
12.0	13.53±0.91^{g}	13.92±0.96^{f}	13.25±0.75^{b}	13.62±0.81^{ab}	0.28±0.00^{hi}	0.30±0.00^{hi}
13.5	13.15±0.85^{g}	13.75±0.92^{fg}	13.11±0.73^{bc}	13.69±0.87^{a}	0.04±0.00^{i}	0.06±0.00^{i}
$LSD_{0.05}$	0.2861*		0.0795*		0.0268*	
SE±	0.0367		0.0282		0.0031	

Mean±S.D values bearing same superscript letter(s) within columns and rows are non-significantly ($p \leq 0.05$) different. *Significant at $p \leq 0.05$

Table 7: Changes in non-enzymatic browning in white and red guava pulp concentrates during storage (13.5 months)

Storage period (months)	Guava pulp concentrates (O.D)	
	White variety	Red variety
0.0	0.13±0.00^{a}	0.14±0.00^{a}
1.5	0.13±0.00^{a}	0.14±0.00^{a}
3.0	0.13±0.00^{a}	0.14±0.00^{a}
4.5	0.13±0.001^{a}	0.14±0.002^{a}
6.0	0.11±0.001^{ab}	0.13±0.002^{a}
7.5	0.10±0.002^{ab}	0.13±0.00^{a}
9.0	0.07±0.001^{b}	0.12±0.002^{a}
10.5	0.07±0.001^{b}	0.11±0.002^{ab}
12.0	0.054±0.001^{c}	0.11±0.002^{ab}
13.5	0.054±0.001^{c}	0.11±0.002^{ab}
$LSD_{0.05}$	0.0362*	
SE±	0.0015	

Mean±S.D values bearing same superscript letters within columns and rows are non-significantly ($p \leq 0.05$) different. *Significant at $p \leq 0.05$

storage period (13.5 months). By the end of the storage period, the white and red guava concentrates showed very low counts of aerobic spore-forming bacteria (3×10^2 and 6.5×10^2 CFU g^{-1}), respectively. Abadias *et al.*[25] stated that, the good microbiological qualities of guava concentrates can be attributed to the good manufacturing practices that are followed during the processing steps. Overall, the two guava concentrates produced in this study were found to be safe and with acceptable levels of microorganisms after storage.

CONCLUSION

During the storage of the white and red guava concentrates at room temperature (25±5°C) for 13.5 months, the two guava concentrates underwent similar changes in their TSS, pH and acidity. In addition, a significant decrease in vitamin C, a minor decrease in total sugars and a minor increase in reducing sugars was observed in both guava fruit concentrates. Colour degradation was very clear in the white guava pulp concentrate, especially at the end of the storage period. In addition, both the guava concentrates found to be free from any pathogenic microorganisms and with stable physical and chemical properties for a storage period of up to 12 months.

SIGNIFICANCE STATEMENT

This study discovered the possible industrial utilisation of guava cultivars for the production of guava concentrates with high processing and storage qualities. This study will also support the local guava-based industries by reducing guava fruit losses during the harvesting season. Moreover, the present study will greatly help researchers to uncover critical areas in fruit product preservation, especially in underdeveloped countries.

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