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Influence of processing methods and storage on physico-chemical and antioxidant properties of guava jam

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Abstract

The present research was conducted to investigate the influence of different processing methods and ingredient mixing techniques to judge storage stability and consumer acceptability of guava jam. In the present study four treatments of guava jam were prepared at laboratory scale using two processing methods (open kettle, T_1 and T_2; double jacketed steam kettle, T_3 and T_4) and different ingredient mixing technique (dry mixing, T_1 and T_3; wet mixing or pre solution, T_2 and T_4). After preliminary analysis of guava fruit, all the four treatments were analyzed for physico-chemical, phytochemical and sensory analysis for an interval of 15 days during 2 month storage period. The results indicated that pH, water activity, color, firmness, ascorbic acid, non-reducing sugars, total phenolic contents, antioxidant activity and overall acceptability (sensory evaluation) showed a decreasing trend during storage. Opposite is the case with acidity, total soluble solids, total sugars as well as reducing sugars. Sensory analysis indicated that the order of preference for guava jam treatments was $T_4>T_3>T_2>T_1$. There was no significant effect of adding sugar and pectin in dry form or by making their pre solution for all the studied traits except for sensory parameters. As good sensory characteristics were shown by the treatments in which pectin and sugar was added by making their pre-solution, so it is recommended that for having superior sensory characteristics pectin and sugar should be added in pre-solution form. Study suggests that losses in fresh guava fruit can be curtailed by processing it into jam. It further suggests that losses in vitamin C, antioxidants and total phenolic contents during processing can be minimized by giving preference to double jacketed steam kettle over open kettle.

Introduction

Guava *(Psidium guajava)* is popular among the people of Pakistan owing to its relative low price than some other fruits, nutritional significance and fine taste. In Pakistan, it is grown on an area of 62.3 thousand hectare giving 512.3 thousand tons total annual production and 8223 kg per hectare yield (Hassan *et al.*, 2012). Due to inappropriate handling, processing and preservation 20-25% of this nutritious fruit is totally spoiled (Jain and Nema, 2007). These fatalities of the seasonal surplus of the guava fruit can be avoided by processing and preserving the fruit into different products like guava jam, jelly, juice, nectar and other products (Hossen *et al.*, 2009). The preservation of fruits particularly guava is the pre requisite for cost-effective and competent utilization of this perishable commodity in Pakistan. Consequently it will benefit both producer and consumer, therefore, judicious to develop products for household and public consumption.

Jam is one of the important fruit products in industries and is based upon the principle of having high solids-high acid contents. Not only are such fruit concentrates an important method of preserving fruits, but it is an important utilization of fruits. In addition to the pleasing taste of such preserved fruits, they possess substantial nutritive value also. Preserving fruits in the form of jam is relatively stable as compared to fruit juices, squashes, nectar and drinks because of the large amounts of sugar and relative low pH which make the environment relatively unpleasant for microbial growth.

The long cooking times and the dependence of heat transfer from hot surfaces of conventional jam production lead to undesirable changes in product flavor and color profile as well as responsible for the loss of some important bioactive components. The thermal treatment should be kept as short as it may negatively influence the quality of the jam. A milder thermal processing step could possibly solve these problems. Double jacketed steam kettle, rapidly heats the food internally and without the use of direct hot surfaces. Up till now possible processing methods

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used for preparation of jam by different researchers are high pressure processing (Igual *et al*., 2013), ohmic heating, microwave, osmotic dehydration (Avasoo and Johansson, 2011), common method i.e., using pre-cooked raw material, mild method (Renna *et al*., 2013), open kettle heating (Ajenifujah-Solebo and Aina, 2011) and heating in double jacketed steam kettle (Rababah *et al*., 2011b).

Guava jam is a product that is prepared from the processing of the edible portion of guava fruit mixed with water, sugar, pH adjusters, jellifying agents, and other additives. It is heat processed till reaching the desired consistency and packed for storage (Mori *et al*., 1998). During the processing and storage of food the bioactive compounds are vulnerable to oxidation reactions (Robards *et al*., 1999), since a few of these compounds are unstable during thermal processing (Samaniego-Sánchez *et al*., 2011) and cold storage (Cilla *et al*., 2011). Antioxidant capability and other quality parameters of fruit products can be influenced by processing ways conflicting in the numeral processing phases and practices and heating temperatures (Nicoli *et al*., 1999).

Up till now no research in the literature found on comparing the processing of fruit jam in open kettle versus double jacketed steam kettle. The present research was conducted to investigate the influence of different processing and ingredient mixing techniques to judge storage stability and consumer acceptability of prepared product.

Materials and Methods

Raw material procurement

Fully ripened guava fruits of variety "Gola" were harvested from a local farm located in vicinity of Faisalabad and brought to the laboratory of National Institute of Food Science and Technology, University of Agriculture Faisalabad.

Preparation

The guavas were washed in tap water to remove the dust and dirt adhered to surface. Leaves, stalks, blossom ends, defective ones and other undesirable portions were removed from guava fruit. The fruits were cut into small pieces with stainless steel knife.

Preliminary analysis of raw material

Initial analysis of guava were carried out for the determination of total soluble solids, titratable acidity, vitamin C, total phenolic content and antioxidant activity.

Blanching of guava fruit

Blanching of guava fruit was done to destroy enzymatic activity in fruit prior to further processing. The fruit pieces were blanched in hot water at temperatures ranging typically from 70°C to 80°C in double jacketed steam kettle.

Preparation of pulp

Guava pulp was extracted using fine pulper, pasteurized at 90°C for 1 min, preserved by adding Na-benzoate, citric acid and potassium metabisulphite (Durrani *et al.*, 2010) and was stored in PET-jars at temperature of 6±1°C (Jain *et al*., 2011) till preparation of guava jam.

Preparation of guava jam

The prepared and chemically preserved pulp was used for preparation of guava jam. The following processing methods were used for preparation of jam: by direct heating in an open kettle till reached at desired brix as described by Howard *et al.* (2010) and Poiana *et al.* (2012), and by heating in double jacketed steam kettle till reached at desired brix as described by Rababah *et al.* (2011b). Four treatments of guava jam were prepared at laboratory scale using two processing methods (open kettle, T_1 and T_2; double jacketed steam kettle, T_3 and T_4) and different method for addition of sugar and pectin (dry mixing, T_1 and T_3; wet mixing or pre solution, T_2 and T_4).

Packaging and storage

Guava jam was packed hot above in pre sterilized glass jars and was stored for a period of 2 months at room temperature. The product was studied for physico-chemical, antioxidant and sensory evaluation on 0, 15, 30, 45 and 60 days of storage period.

Physico-chemical attributes

The following physico-chemical analysis of jam was performed after every 15 days for storage interval of 2 months.

pH

The pH was measured using pH meter standardized by buffer solutions of pH 4 and 7 following the method as described in AOAC (2007).

Total soluble solids

The total soluble solids expressed as degree brix were analyzed using hand refractometer at room temperature following the procedure of Ranganna (2008).

Water activity

Water activity was determined using an electronic hygropalm water activity meter (model Aw-Win, Rotronic, equipped with a Karl-Fast probe) as described by Piga *et al*. (2005).

Acidity

Acidity was determined with 0.1 N NaOH solution and phenolphthalein indicator using the method of AOAC (2007).

Ascorbic acid

Ascorbic acid or vitamin C content were measured by titration with a 2,6-dichlorophenolindophenol sodium salt solution following the procedure of AOAC (2007).

Color

Color was determined according to the method of Rocha and Morais (2003) with the help of color meter (Colour Test-II; Neuhaus Neotec). The instrument was calibrated by using standards (54 CTn for dark and 151 CTn for light).

Firmness

Firmness of guava jam was determined according to Rababah *et al*. (2011b) with certain modifications by using a texture analyzer (Mod.TA-XT2 Stable Microsystems, Surrey, UK) with a 5 kg load cell. The firmness was determined with the test mode compression; to this purpose a flat cylindrical stainless steel probe was used. The probe speed during compression was 10 mm/sec.

Sugars

Reducing, non-reducing and total, sugars were determined by Lane and Eynon method as described by Ranganna (2008).

Phytochemical analysis:

Preparation of extracts

Extracts of fruit and jam were prepared using methanol (50%) following method as described by Yan *et al.* (2006). Ten to thirty gram of the fruit jam sample was blended for approximately 1 min to a paste. Homogenized sample was transferred into a 100 mL volumetric flask and volume was made up to the mark with 50% aqueous methanol. The flask was covered with aluminum foil and placed in orbital shaker at 120 rpm for 45 min at 60°C. The sample was filtered and solvent was removed from the sample with the help of rotary evaporator (Eyela, Japan) and was subsequently used for various analyses.

Total phenolic contents

Estimation of total phenolic contents was carried out using Folin-Ciocalteu reagent and absorbance was measured at 765 nm by help of spectrophotometer (CECIL CE7200) following method as described by Singleton *et al.* (1999).

Antioxidant activity

DPPH radical scavenging activity was evaluated by measuring absorbance at 517 nm using spectrophotometer (CECIL CE7200) according to the method of Brand-Williams *et al.* (1995).

Sensory evaluation

Sensory evaluation of guava jam was conducted in the sensory evaluation laboratory, National Institute of Food Science and Technology, UAF. Bread was used as carrier for the evaluation of guava jam samples since jam is normally consumed with bread. All the samples were presented to 10 untrained panelist (but consumers of jam). For each sample, 10 g of jam was served in white disposable plate with a slice of white bread. On arrival at test venue, score sheet and method of evaluation were explained to the group using 9-point hedonic scale. The guava jam was evaluated for color, flavor, taste, mouth feel and overall acceptability by a panel of judges as described by Meilgaard *et al.* (2007) after a storage interval of 15 days for 2 months.

Statistical analysis

The obtained data for each parameter was subjected to statistical analysis to establish the level of significance (Steel *et al*., 1997).

Results and Discussion

Preliminary analysis of raw material

The results obtained for the preliminary analysis of guava fruit were as follows: tsoluble solids (°B) =8.8±0.32, titratable acidity (%) = 0.34±0.01, vitamin C (mg/100 g) =155.5±5.75, total phenolics content (mg GAE/100 g) = 185.46±7.97. and antioxidant activity (% inhibition) =87.4±3.41. The results obtained for TSS, acidity and vitamin C is in agreement with the findings of Adrees *et al.* (2010).

Effect of treatments and storage on physical characteristics of guava jam

Results regarding the physical characteristics of guava jam are presented in Table 1. Water activity provides valuable information about microbial spoilage and physico-chemical stability of food. The mean values of water activity for treatments were

Table 1. Effect of treatment and storage intervals on the physical properties of guava jam

Parameters	Storage (Days)	Treatments				
		T_1	T_2	T_3	T_4	Means
Color (CTn)	0	102.46±3.69	102.96±4.53	106.74±3.95	107.67±4.36	104.96^a
	15	101.56±4.27	101.89±3.87	105.38±4.22	106.09±4.35	103.73^b
	30	100.02±3.60	100.06±4.40	104.01±3.85	105.67±4.54	102.44^c
	45	99.20±4.17	99.34±3.77	103.59±4.14	104.94±4.30	101.77^d
	60	98.04±3.53	98.67±4.34	102.96±3.81	104.06±4.47	100.93^e
	Means	100.26^d	100.58^c	104.54^b	105.69^a	
Firmness (N)	0	0.56±0.02	0.54±0.02	0.68±0.03	0.69±0.03	0.62^a
	15	0.54±0.02	0.52±0.02	0.66±0.03	0.64±0.03	0.59^b
	30	0.52±0.02	0.51±0.02	0.62±0.02	0.63±0.02	0.57^c
	45	0.50±0.02	0.49±0.02	0.58±0.02	0.62±0.03	0.55^d
	60	0.48±0.02	0.47±0.02	0.62±0.03	0.59±0.03	0.52^e
	Means	0.52^d	0.51^c	0.62^b	0.63^a	
Water activity	0	0.842±0.03	0.804±0.04	0.768±0.03	0.742±0.03	
					0.789	
	15	0.841±0.04	0.802±0.03	0.766±0.03	0.740±0.03	0.7873
	30	0.839±0.03	0.801±0.03	0.765±0.03	0.738±0.03	0.7856
	45	0.837±0.04	0.798±0.03	0.763±0.03	0.735±0.03	0.7833
	60	0.834±0.03	0.796±0.04	0.760±0.03	0.733±0.03	0.7808
	Means	0.8386^a	0.8002^b	0.7644^c	0.7376^d	

Values are expressed as mean ± standard deviation. Different letters in same row and column against each parameter indicates significant differences ($p < 0.05$).

0.8386, 0.8002, 0.7644 and 0.7376 for T_1, T_2, T_3 and T_4, respectively as shown in Table 1. Statistical analysis depicted that the effect of treatments on water activity of guava jam is statistically significant among different treatments. However, there was a non-significant effect of different storage intervals on water activity of guava jam treatments. The results indicated that low water activity was shown by the treatments that were processed in double jacketed steam kettle as compared to the treatments that were processed in open kettle. This may be due to the reason that high temperature and short time heating of product in steam kettle quickly evaporates the moisture from it. It is apparent from the results that that there was a gradual decrease in water activity of guava jam treatments with increase in storage periods. This may be due to the loss of moisture during storage. The decrease in moisture content may also be due to increase in total soluble solids and total sugars that bind water resulting in decrease in water activity. Menezes *et al.* (2011) also established similar results in their studies that water activity value of guava preserves was not significantly influenced throughout storage. Color of any product is an imperative quality trait which attracts consumer reflecting the extent of consumer preference and ultimately acceptance. Statistical analysis of the data indicated that results are highly significant among different treatments and significant for storage. The mean color values for treatments were 100.26, 100.58, 104.54 and 105.69 CTn for T_1, T_2, T_3 and T_4, respectively. The maximum value was observed in case of T_4 (105.69 CTn) and minimum value was found for T_1 (100.26 CTn). The mean color values for storage period decreased from 104.96 at 0 day to 100.93 at 60 days. It is apparent from the results that darkness intensity significantly increased with increase in storage days. The change in color values may be due to non-enzymatic browning reactions. The results obtained in this study are supported by Damiani *et al.* (2012) who found a decrease in color of Brazilian guava jam during 12 months of storage. Besbes *et al.* (2009) indicated in their studies that color of date jam decreased from 0.75 to 0.64 after storage interval of 2 months. Firmness of jam is tested to estimate the gel structure and consistency or uniformity of jam samples. Statistical analysis depicted that results for firmness are significant for treatments. The results indicate that there was a gradual decrease in firmness with increase in storage days. However, there was a non-significant effect of storage on firmness of guava jam. It may be due to

Table 2. Effect of treatment and storage intervals on the chemical properties (pH, titrateable acidity%, TSS, ascorbic acid) of guava jam

Parameters	Storage (Days)	Treatments				
		T_1	T_2	T_3	T_4	Means
pH	0	3.65±0.13	3.68±0.16	3.61±0.14	3.63±0.18	3.64^a
	15	3.63±0.16	3.65±0.15	3.58±0.17	3.57±0.12	3.61^b
	30	3.60±0.13	3.62±0.16	3.54±0.15	3.51±0.14	3.57^c
	45	3.56±0.14	3.59±0.13	3.50±0.15	3.48±0.14	3.53^d
	60	3.51±0.13	3.55±0.15	3.47±0.16	3.44±0.11	3.49^e
	Means	3.59	3.62	3.54	3.53	
Acidity (%)	0	0.650±0.02	0.647±0.03	0.656±0.03	0.654±0.02	0.652^e
	15	0.653±0.03	0.651±0.02	0.660±0.03	0.658±0.03	0.656^d
	30	0.657±0.02	0.654±0.03	0.665±0.02	0.661±0.04	0.659^c
	45	0.660±0.03	0.658±0.03	0.671±0.03	0.665±0.03	0.663^b
	60	0.664±0.02	0.661±0.01	0.677±0.04	0.668±0.03	0.668^a
Means		0.657	0.654	0.666	0.661	
TSS (°B)	0	68.00±2.45	68.21±3.00	67.93±2.51	68.14±2.93	68.07^e
	15	68.36±2.87	68.69±2.61	68.37±2.73	68.62±2.81	68.51^d
	30	68.81±2.48	69.16±3.04	68.85±2.55	68.96±2.97	68.95^c
	45	69.06±2.90	69.84±2.65	69.08±2.76	69.25±2.84	69.31^b
	60	69.48±2.50	70.09±3.08	69.42±2.57	69.74±3.00	69.68^a
	Means	68.74	68.20	68.73	68.94	
Ascorbic acid (mg/100 g)	0	29.43±1.06	29.67±1.31	33.12±1.23	33.96±1.46	31.55^a
	15	28.92±1.21	29.06±1.10	32.80±1.31	33.43±1.37	31.05^b
	30	28.44±1.02	28.68±1.26	32.35±1.20	33.14±1.34	30.65^c
	45	28.09±1.18	28.03±1.07	32.27±1.29	32.75±1.34	30.29^d
	60	27.71±1.00	27.64±1.22	31.62±1.17	32.23±1.39	29.8^e
	Means	28.52^d	28.62^c	32.43^b	33.10^a	

Values are expressed as mean ± standard deviation. Different letters in same row and column against each parameter indicates significant differences ($p < 0.05$).

cross linking among the carboxyl groups of adjoining chains of polyuronide via calcium ions resulting in the cell wall less reachable to the fruit enzymes which are ultimately a reason of softening and cell wall degradation. Decrease in firmness of jam may also be due to high temperatures allowing pectin to undergo either acid or base catalyzed depolymerization. The results obtained are in line with the findings of Rababah *et al.* (2011b) who found a decrease in firmness of strawberry jam from 0.69 to 0.55 N during storage period of 60 days. Damiani *et al.* (2012) observed that firmness of Brazilian guava jam was 0.83 N, which is linked to its continuity (pectin concentration) and rigidity (sugar and acid).

Effect of treatments and storage on chemical characteristics of guava jam

The results regarding the influence of treatment and storage on chemical characteristics of guava jam are presented in Table 2 and 3. The pH value of a food is a directly related to the free hydrogen ions in that food. The pH of jam is an important factor to obtain optimum gel condition. The pH of all jam samples was decreased during storage as shown in Table 2. Statistical analysis depicted pH of different treatments of guava jam indicated non-significant results among different treatments and significant for storage. The lowest pH score was observed for T_4 (3.53) and highest score was observed for T_2 (3.62). The mean values of pH for storage period decreased from 3.64 to 3.49. Change in pH is directly related to change in acidity of samples. During storage intervals pH decreases due to increase in acidity during storage. This may be due to the formation of acidic compounds. Similar results were reported by Hussain and Shakir (2010) who found that mean value for pH of apricot and apple jam during storage period at initial day was 3.75 which decreased at 60 days to 3.10. Muhammad *et al.* (2008) also observed a decrease in pH of diet apple jam from 4.34 to 3.01 during 90 days storage.

The acidity of a food product represents the stability and shelf life of that product. Acidity value of jam is because of the organic acids present naturally in fruits and those added while preparation of jam. The effect of treatments and storage on acidity of different treatments of guava jam is represented in Table 2. Acidity of all the four treatments of guava jam was increased during storage from 0.652 at initial day to 0.668 at 60 days. The mean values recorded for treatments were 0.657, 0.654, 0.666 and 0.661 for T_1, T_2, T_3 and T_4, respectively. Statistical analysis revealed that the effect of storage on titratable acidity of different treatments of guava jam were statistically significant for storage. Whereas, acidity of different guava jam treatments indicated non-significant results among treatments. The increase in acidity may be due to acid formation, degradation of polysaccharides and oxidation of reducing sugars or by break down of pectin in to pectenic acid. The rise in acidity may also be explained by the fact that the concentration of weekly-ionized acid and their salts increased during storage, resulting in increased acidity. These results are in accordance with the findings of Shakir *et al.* (2007) who found that the mean values of titratable acidity for different treatments of apple and pear mixed fruit jam increased significantly from 0.63 to 0.75 during storage interval of 90 days. Hussain and Shakir (2010) also showed in their studies that mean value for acidity of apricot and apple jam during storage period at initial day (0.650) which increased at 60 days (0.743).

Total Soluble Solids (TSS) of fruit and fruit products represents various chemical substances present in it in soluble form. TSS of all the jam samples were increased during storage as presented in Table 2. The mean values of TSS recorded for treatments were 68.74, 68.20, 68.73 and 68.94 for T_1, T_2, T_3 and T_4 respectively. The mean values for storage were 68.07, 68.51, 68.95, 69.31 and 69.68 having lowest TSS at 0 days and highest at 60 days. The analysis of variance in case of studying the effect of processing method and storage on TSS of different treatments of guava jam indicated significant results for storage and non-significant for treatments. Increase in TSS may be due to acid hydrolysis of polysaccharides especially pectin and gums. The increase in TSS contents of jam may also be due to solubilization of jam ingredients or components throughout storage. Similar results were found by Muhammad *et al.* (2008) who developed diet apple jam using different non-nutritive sweeteners and reported that TSS of diet jam significantly increased from 11.54 to 17.70 during 90 days storage. Likewise, Safdar *et al.* (2012) also found a gradual increase in total soluble solids content of mango jam throughout the storage period of 150 days.

Ascorbic acid is sensitive to heat, light and high temperature during cooking results in loss of vitamin C. The results in case of studying the influence of processing methods and storage on vitamin C content of guava jams are statistically highly significant among different treatments. Storage effect was found to be significant on vitamin C content of guava jam treatments. The mean values for treatments were 28.518, 28.616, 32.432 and 33.102 for T_1, T_2, T_3 and T_4, respectively. It is obvious from the data that maximum vitamin C content was observed in jam treatments that were processed in double jacketed steam kettle and minimum values were observed for treatments that were processed in open kettle. This may be due to reason that direct and long-time heating of pulp in open kettle during jams processing results in more loss of vitamin C in open kettle processing. The mean values of vitamin C for storage period decreased from 31.545 at 0 day to 29.8 at 60 day. This may be due to the reason that ascorbic acid is reduced in storage owing to the oxidation of ascorbic acid to dehydro ascorbic acid. Also, there is a significant effect of temperature on the speed of ascorbic acid loss. Increase in temperature increases the loss of vitamin C. Similar results were recorded by Jawaheer *et al*. (2003) who observed 37.5% retention of ascorbic acid in guava jam after processing. Likewise, Shakir *et al.* (2007) found that the mean values of ascorbic acid content of apple and pear mixed fruit jam significantly decreased from 12.38 at initial day to 14.86 at 90 days.

There was an increasing trend shown by total sugars of all the jam samples during storage as presented in Table 3. Statistical analysis indicated that the results were non-significant for treatments as well as storage. The mean values of total sugars for storage periods increased from 63.395 to 63.56 at 0 and 60 days, respectively. The increase in TSS and total sugars would be attributed to the conversion of starch and other insoluble carbohydrates into sugars. The results found are in agreement with findings of Vidhya and Narain (2011) who recorded a gradual increase in total sugars of wood apple jam (0.02, 0.27 and 0.68%) on 30 , 60 and 90 days.

Reducing sugars of all treatments of guava jam were increased during storage as shown in Table 3. Statistical analysis revealed that results in case of studying the effect of treatments on reducing sugars of guava jam were statistically non-significant among different treatments. Likewise, there was a non-significant effect of different storage intervals on reducing sugars of guava jam. The mean values of reducing sugars for storage periods increased from 50.89 to 51.15 at 0 and 60 days, respectively. The increase in reducing sugars may be owing to

Table 3. Effect of treatment and storage intervals on the chemical properties (reducing, non-reducing and total sugars) of guava jam

Parameters	Storage (Days)	Treatments				
		T_1	T_2	T_3	T_4	Means
Total sugars (%)	0	63.25±2.28	63.48±2.79	63.31±2.34	63.54±2.73	63.40
	15	63.30±2.66	63.51±2.41	63.35±2.53	63.59±2.74	63.44
	30	63.36±2.25	63.54±2.80	63.39±2.35	63.62±2.74	63.48
	45	63.40±2.66	63.58±2.42	63.42±2.54	63.66±2.61	63.52
	60	63.46±2.28	63.61±2.80	63.47±2.35	63.70±2.74	63.56
	Means	63.35	63.54	63.39	63.62	
Reducing sugars (%)	0	50.90±1.83	50.94±2.24	50.84±1.88	50.88±2.19	50.89
	15	50.97±2.14	51.01±1.94	50.91±2.04	50.95±2.09	50.96
	30	51.06±1.84	51.07±2.25	50.97±1.89	51.01±2.19	51.03
	45	51.12±2.15	51.13±1.94	51.02±2.04	51.08±2.11	51.09
	60	51.20±1.84	51.18±2.25	51.09±1.89	51.13±2.20	51.15
	Means	51.05	51.07	50.97	51.01	
Non-reducing sugars (%)	0	12.35±0.44	12.54±0.56	12.47±0.47	12.66±0.54	12.51
	15	12.33±0.52	12.50±0.48	12.44±0.50	12.64±0.52	12.48
	30	12.30±0.44	12.47±0.56	12.42±0.48	12.61±0.53	12.45
	45	12.28±0.52	12.45±0.47	12.40±0.50	12.58±0.58	12.43
	60	12.26±0.41	12.43±0.53	12.38±0.49	12.57±0.51	12.41
	Means	12.30	12.48	12.42	12.61	

Values are expressed as mean ± standard deviation.

the inversion of non-reducing sugars i.e., sucrose to reducing sugars i.e., glucose and fructose in storage. The inversion of non-reducing sugar might be because of the presence of acids for instance citric and malic acids which together with elevated temperatures speed up the inversion process. Increase in reducing sugar may also be due to prolong storage and hydrolysis of sugars with increase in acidity and decrease in pH. Results interpreted from present research work are in agreement with the findings of Shakir *et al.* (2007) who found an increasing trend in reducing sugar of apple and pear mixed fruit jam during storage interval of 90 days. Likewise, Hussain and Shakir (2010) recorded that mean values for reducing sugar content of apricot jam increased from 28.37 to 29.41.

Non reducing sugars of all the jam samples were decreased during storage as presented in Table 3. The results in case of studying the effect of treatments on non-reducing sugars of guava jam were statistically non-significant among different treatments. Likewise there was a non-significant effect of different storage intervals on non-reducing sugars of guava jam treatments. The mean values of non-reducing sugars for storage periods decreased from 12.51 to 12.41 at 0 and 60 days, respectively. Decrease in non-reducing sugar may be because of the conversion of non-reducing sugar to reducing sugar. The results obtained are comparable with the findings of Hussain and Shakir (2010) who found a decrease in non-reducing sugar content from 43.20 at initial day to 19.46 at 60th day.

Effect of treatments and storage on phytochemical properties of guava jam

The effect of treatments and storage on total phenolic content of all treatments of guava jam is shown in Table 4. Statistical analysis depicted that the results in case of studying the influence of processing methods and storage on total phenolic content of guava jams are statistically highly significant among different treatments. Storage effect was also highly significant on total phenolic content of guava jam treatments. The mean values for treatments were 66.81, 67.39, 70.74 and 71.65 for T_1, T_2, T_3 and T_4, respectively. It is obvious from the data that maximum total phenolic content was observed in jam treatments that were processed in double jacketed steam kettle and minimum values were observed for treatments that were processed in open kettle. This may be due to reason that direct and long term heating of pulp in open kettle during processing of jam result in more loss of bioactive compounds in open kettle.

The mean values of total phenolic content for storage period decreased from 78.92 at 0 day to 59.66 at 60 day. Keeping in view the amount of TPC in fresh fruit (185.46±7.97 mg GAE/100 g) it was observed that guava fruit has significantly

Table 4. Effect of treatment and storage intervals on the phytochemical analyses of guava jam

Parameters	Storage (Days)	Treatments				
		T_1	T_2	T_3	T_4	Means
Total phenolic contents (mg GAE/100 g)	0	76.84±2.77	76.27±3.36	81.13±3.00	81.45±3.56	78.92^a
	15	74.09±3.11	73.58±2.80	75.16±3.01	76.64±3.14	74.87^b
	30	66.89±2.41	67.13±2.95	70.06±2.58	71.98±2.71	69.02^c
	45	60.07±2.52	61.06±2.32	65.88±2.64	66.13±2.71	63.29^d
	60	56.18±2.02	58.91±2.54	61.48±2.27	62.06±2.61	59.66^e
	Means	66.81^d	67.39^c	67.39^c	71.65^a	
Antioxidant activity (% DPPH assay)	0	39.50±1.42	40.08±1.76	43.89±1.62	44.09±1.90	41.89^a
	15	37.55±1.58	36.04±1.37	41.87±1.66	42.03±1.72	39.37^b
	30	35.02±1.26	34.82±1.53	39.25±1.45	39.04±1.68	37.03^c
	45	32.80±1.38	31.56±1.20	36.57±1.46	37.56±1.54	34.62^d
	60	30.05±1.08	29.13±1.27	33.84±1.23	34.59±1.49	31.09^e
	Means	34.98^c	34.33^d	39.08^b	39.46^a	

Values are expressed as mean ± standard deviation. Different letters in same row and column against each parameter indicates significant differences ($p < 0.05$).

higher amount of TPC as compared to guava jam. The reduction of total phenolics during jam cooking might be due to disruption of cell structure during fruits processing. Also, jam processing changes the amount of imperative bioactive components present in fresh fruit. The results obtained are in accordance with Rababah *et al.* (2011b) who found that strawberry fruits had significantly the maximum quantity of total phenolics (1693.55 mg GAE/100 g) followed by strawberry jam after processing (848.86 mg GAE/100 g) and strawberry jam stored for 60 days 77.285 mg GAE/100g.

DPPH is a free stable radical that adopt an electron or hydrogen ion to transfer in a stable free radical in methanol or aqueous solution and accepts an electron or hydrogen radical to turn into stable atom or molecule. The effect of treatments and storage on antioxidant activity of all treatments of guava jam is shown in Table 4. Statistical analysis indicated that results are highly significant among different treatments as well as for storage. The mean values for treatments were 28.518, 28.616, 32.432 and 33.102 for T_1, T_2, T_3 and T_4, respectively. It is obvious from the data that maximum antioxidant activity was observed in jam treatments that were processed in double jacketed steam kettle and minimum values were observed for treatments that were processed in open kettle. This may be due to reason that direct and long-time heating of pulp and high temperatures reached to the point 105 to 106°C in open kettle during processing of jam results in more loss of antioxidants in open kettle processing. The mean values of antioxidant activity for storage period decreased from 31.55 at 0 day to 29.8 at 60 day. Keeping in view antioxidant activity of fresh guava fruit (87.4±3.41% inhibition) it was observed that guava fruit has significantly more antioxidant activity as compared to guava jam. Temperature has a main influence on the antioxidants loss rate after processing and all through storage. Loss of antioxidant activity might be at least partly clarified by development of antioxidant Millard products all through jam preparation. Also, jam processing changes the amount of imperative bioactive components present in fresh fruit. The results obtained in this study are in accordance with the findings of Rababah *et al.* (2011a, 2011b) who recorded that the antioxidant activity of the strawberry fruit as showed by inhibition percent was the highest (84.91%) followed by strawberry jam after processing (59.38%), and jams stored for 15 days at 25°C (55.13%), 35°C (32.05%), 45°C (29.82%), and 55°C (16.95%). Likewise, Scibisz and Mitek (2009) showed that 13-19% of antioxidant capacity in fruits was lost during jam making.

Effect of treatments and storage on sensory parameters of guava jam

All the observed sensory parameters were decreased during storage. The mean values for effect of treatments on all monitored sensory parameters of guava jam are presented in Table 5. Statistical analysis depicted that the influence of processing method on guava jam treatments was found to be statistically highly significant among different treatments for all the observed sensory parameters. However, storage effect was found to be significant. The mean values for the effect of storage on all the monitored sensory parameters are shown in Table 5. The results

Table 5. Effect of treatment and storage intervals on the sensory parameters of guava jam

Parameter	Storage (Days)	Treatments				
		T_1	T_2	T_3	T_4	Means
Color	0	6.16±0.22	6.2±0.27	7.33±0.29	7.45±0.32	6.79^{a}
	15	6.04±0.25	6.11±0.23	7.27±0.29	7.34±0.30	6.69^{b}
	30	5.93±0.21	6.01±0.26	7.11±0.28	7.23±0.31	6.57^{c}
	45	5.84±0.25	5.95±0.23	7.01±0.28	7.12±0.29	6.48^{d}
	60	5.77±0.21	5.85±0.28	6.92±0.23	7.03±0.27	6.39^{e}
	Means	5.95^{d}	6.02^{c}	7.13^{b}	7.23^{a}	
Flavor	0	6.07±0.23	6.25±0.27	7.47±0.29	7.64±0.32	6.86^{a}
	15	5.93±0.25	6.19±0.23	7.30±0.29	7.53±0.30	6.74^{b}
	30	5.82±0.31	6.04±0.25	7.21±0.26	7.44±0.23	6.63^{c}
	45	5.76±0.24	5.98±0.27	7.11±0.25	7.29±0.29	6.54^{d}
	60	5.70±0.29	5.88±0.26	6.93±0.24	7.16±0.28	6.42e
	Means	5.86^{d}	6.07^{c}	7.20^{b}	7.41^{a}	
Texture	0	6.22±0.25	6.36±0.27	7.42±0.28	7.58±0.33	6.90^{a}
	15	6.1±0.26	6.24±0.24	7.31±0.29	7.49±0.31	6.79^{b}
	30	6.03±0.22	6.18±0.25	7.23±0.29	7.40±0.32	6.71^{c}
	45	5.96±0.25	6.10±0.23	7.12±0.28	7.33±0.27	6.63^{d}
	60	5.87±0.21	6.02±0.27	7.06±0.32	7.26±0.28	6.55^{e}
	Means	6.04^{d}	6.18^{c}	7.23^{b}	7.41^{a}	
Spreadability	0	6.08±0.22	6.10±0.27	7.20±0.31	7.27±0.28	6.66^{a}
	15	6.00±0.25	6.05±0.29	7.15±0.23	7.21±0.30	6.60^{b}
	30	5.95±0.21	5.96±0.26	7.07±0.32	7.14±0.28	6.53^{c}
	45	5.84±0.25	5.89±0.22	7.03±0.28	7.08±0.29	6.46^{d}
	60	5.78±0.21	5.82±0.30	6.97±0.26	7.00±0.24	6.39^{e}
	Means	5.93^{d}	5.96^{c}	7.08^{b}	7.14^{a}	
Overall acceptability	0	6.36±0.33	6.40±0.28	7.45±0.25	7.56±0.24	6.94^{a}
	15	6.27±0.31	6.34±0.30	7.38±0.24	7.47±0.26	6.87^{b}
	30	6.20±0.32	6.26±0.27	7.30±0.22	7.35±0.28	6.78^{c}
	45	6.15±0.30	6.20±0.29	7.23±0.24	7.26±0.26	6.71^{d}
	60	6.09±0.31	6.16±0.28	7.17±0.27	7.20±0.22	6.66^{e}
	Means	6.21^{d}	6.27^{c}	7.31^{b}	7.37^{a}	

Values are expressed as mean ± standard deviation. Different letters in same row and column against each parameter indicates significant differences ($p < 0.05$).

indicated that the treatments that were processed in double jacketed steam kettle indicated overall more sensory acceptance for all observed parameters as compared to the treatments that were processed in open kettle. The results obtained for all the monitored sensory parameters are in agreement with findings of Muhammad *et al.* (2009). Moreover best texture was observed in treatments in which pectin and sugar were added by making its pre solution in water.

Conclusion

The development of different treatments of guava jam at laboratory scale indicated that guava fruit can be best preserved by its processing into jam. The results indicated that fresh guava fruit contain considerably higher amounts of total phenolics and antioxidant activity as compared to after its processing into guava jam. This study also highlighted that losses of phytochemical components and vitamin C can be minimized by processing of guava into jam using double jacketed steam kettle as compared to open kettle processing. Sensory analysis of jam stated that best sensory characteristics were observed in the treatments that were processed in double jacketed steam kettle i.e., T_4 and T_3. However, all the treatments remained acceptable after 60 days of storage at room temperature.

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