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Effect of Orange Peel Concentration on the Development of Sapota Marmalade in Terms of Proximate and Nutritional Composition and Consumer Preferences

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ABSTRACT

The study explored to find out the possible strategy for the processing of sapota into its value-added shelf-stable products. Therefore, an attempt was made to develop marmalade with different concentrations of orange peel viz. 0 %, 5 %, 10 %, 15 % and 20 % respectively. Sensory evaluation, proximate and nutritional composition was performed on the day of preparation and after storage. Marmalade treated with orange peel and without orange peel was rich source of proximate and nutritional composition. The final TSS of the developed marmalade maintained 65.30±02°B. ß-carotene (12.21±0.01 and 11.93±0.03 µg/100 g), pH (5.05±0.04 and 4.90±0.01), total sugar (21.15±0.04 % and 22.28±0.03 %) and reducing sugar (9.70±0.01 % and 10.15±0.05 %) was superior on the day of storage and after storage in without orange peel treated marmalade (T1). On the day of storage and after storage, the highest total carotenoid and vitamin-C content of the orange peel treated marmalade ranged from 31.92±0.02 to 49.21±0.51 mg/100 g and 23.26±0.02 to 43.39±0.05 mg/100 g, 4.68±0.02 to 5.84±0.03 mg/100 g and 2.36±0.01 to 3.62±0.06 mg/100 g respectively. According to the expert panelist, the highest overall acceptability score was secured by the combination of T_2 followed by others in terms of color, aroma, mouth feel and high spreadable capacity. The marketable life of the developed marmalade could be extended 6 months more without any excessive-quality deterioration. This technology could be utilized to fulfill the off-season nutritional requirement and increase the income of the farmers to enhance their productivity.

Keywords: Sapota fruit, vitamin-C content, total carotenoid content, ß-carotene content, marketable life, sensory evaluation.

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INTRODUCTION

Bangladesh is bestowed with varied agro-climatic conditions, so it can produce a wide variety of fruits and vegetables. It occupies a prominent place in the world as a producer of fruits and vegetables. The major fruits grown in Bangladesh include mango, banana, papaya, jackfruit, sapota, pineapple, sapota, ber, litchi, etc. Sapota or sapodilla (*Achras zapota or Manilkara zapota*) is a native of tropical America, having originated in Mexico of Central America. It is a delicious fruit also known as chiku, dilly, nispero, zapotte, sapota plum, sapodilla, or prickly pear. In Bangladesh, it is cultivated as minor fruits and major production is concentrated in the southern region especially in Jashore, Khulna, Barisal, Chattagram and Hill tracts. The fruit is a berry with a scurfy brown peel. It is well known for its sweetness and delicious taste when it's fully ripe. Nutritionally, it is a rich source of digestible sugars and possesses plenty of minerals, nutrients, bioactive compounds and an appreciable source of protein, fat, fibre and minerals like calcium, phosphorous and iron (Chadha, 2001). The principal constituents of the fruit are tannins and carbohydrates. Out of the carbohydrates, free sugars such as glucose, fructose and galactose form a major portion, whereas starch is found in small quantities or absent. The presence of fairly large quantities of tannins imparts an astringent flavour, but this astringency is masked by total sugars. The fruit also contains 1.13% sapotin, the principal bitter component.

The availability of fresh sapota fruit is very short throughout its production time. The fresh fruit cannot be stored for a long time due to its perishability nature. Therefore, a substantial amount of postharvest loss of sapota does occur due to lack of proper processing and storage techniques. The fruit is mostly eaten as fresh

fruit. According to Jadhav et al. (2018) various products like sapota nectar, sapota jam, sapota butter, sapota powder, sapota juice, sapota candy and sapota dried slices are available in the world. Pectin can be extracted from the peel of this fruit. Pectin and fruit pulp can be utilized to make sapodilla jam (Siddique et al., 2015).

Orange is a highly nutritious food, a source of phytochemical compounds like vitamin C, flavonoids, and carotenoids, which also give it its antioxidant property. It is commonly consumed fresh and in jams (Igual et al., 2016), juices (Spira et al., 2018), extracts for herbal medicines (Menichini et al., 2011), and dietary supplements (Restani, 2017). Its by-products (peel, membranes, and seeds) are generally disposed of in the environment, increasing the amount of organic waste in nature. The industry uses very little of the waste for the production of pectin, molasses, fibers, oils (Favela-Harnandez et al., 2017), and animal food (Ruvairo et al., 2019). Nevertheless, these by-products contain high levels of vitamin C (Sir-Elkhatim et al., 2018), thiamine, niacin, pyridoxine, phosphorus, calcium, iron, magnesium, and potassium (Ani and Abel, 2018), as well as soluble and insoluble dietary fibers (Tejada-Ortigoza et al., 2018).

Previous research has shown the positive effects of adding *Citrus* fruit peel to several products such as crackers (Obafaye et al., 2018), meatballs (Nishad et al., 2018), marmalade (Sicari et al., 2018), jam (Chacko et al., 2013, Yunis et al., 2015), and yogurt (Arioui et al., 2016). In a study by Younis et al. (2015), the addition of sweet lemon peel in jam increased firmness and chewability, thus improving quality. This study aims to develop value-added marmalade from sapota using different concentrations of orange peel.

MATERIALS AND METHODS

Collection of sapota fruit

Physiologically matured sapota fruits (*Achras zapota or Manilkara zapota*) were collected from the local market of the Gazipur city, Bangladesh and shifted to Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Then the fruits were sorted out based on the pest and disease infestation and allowed for 2-3 days to naturally ripen.

Extraction of sapota pulp

The ripen sapota fruit was washed and then divided into two parts by hand. Then the tablespoon was used to collect the pulp and seeds removed. The collected fruit pulp was blended with laboratory-grade blender. Then the pulp was treated according to Table 1.

Processing of sapota marmalade

The measured pulp, sugar and water (Table 1) were taken in a cooking saucepan, and heated on a gas burner. When the total soluble solids (TSS) turned into 50±2°B, then the measured extracted fresh lemon juice (instead of citric acid) was added. Boiling until the TSS turned to 60±2°B. Meanwhile, the sliced and blanched orange peel was added to the saucepan. The pectin was mixed with an equal amount of sugar and then it was added into the saucepan. When the TSS reached up to 65°B then the cooking was stopped. The final consistency of the prepared marmalade was maintained at 65.30°B. No artificial color or flavoring agent was used. The finished product was poured into glass jars with the hot mass condition and immediately the lid was put on the jars. Then the filled jars were sterilized at 212ºF for 15 min. Then the jars were stored at ambient conditions for future studies.

Proximate and nutritional composition analysis

The proximate and nutritional analysis of moisture, ash, total sugar, reducing sugar and vitamin-C content was determined according to the method described by Ranganna (1995). pH data was recorded by a digital pH meter (Delta 320, Mettler, Shanghai). Total acidity (%) was measured using Auto Titrator (Metrohm 814, USB Sample Processor, Switzerland). Total soluble solid (°Brix) was recorded using a digital hand refractometer (Model NR151).

Analysis of total carotenoid

The analysis of total carotenoid content was performed according to the method described by Thaipong et al. (2006). The measured jelly was dissolved in n-hexane pro analysis. The ß-carotene solution in various concentrations was used as a standard of the carotenoid compound and as a standard curve. Absorbance was measured at 470 nm. The linear regression equation of the standard curve was used for calculating total carotenoid content. The results were stated as beta-carotene equivalent per 100 g of marmalade (mg/100 g).

Analysis of ß-carotene content

β-carotene content of the marmalade was analyzed according to the method described by Holden et al. (1999) and the value was noted as µg/100g of marmalade.

Color measurement

Sapota marmalade color was assessed with a Chroma Meter (Model CR-400, Minolta Corp. Japan). International Commission on Illumination (CIE) lightness (*L**), Chroma (*c**) and hue angle (*h**) values were documented using D65 illuminates and a 10E standard viewer as an orientation method. The equipment was calibrated on a standard white tile. Then it was assimilated to measure the value of *L*, c** and *h** and were replicated three times for each treatment.

Texture Analysis

Texture analysis was done based on our study of Molla et al. (2020) using probe p/5 by a Texture Analyzer TA.XT plus (Stable Micro System, Godalming, UK) by

Table 1: Formulation of Sapota marmalade.

Treatment	Ingredients						
	Sapota pulp (g)	Sugar (g)	Orange peel (g)	Lemon juice (mL)	Pectin (g)	Water (mL)	Sodium benzoate (g)
T_1	1000	400	0	100	15	750	1
T_2	1000	400	50	100	15	750	1
T_3	1000	400	100	100	15	750	1
T_4	1000	400	150	100	15	750	1
T_5	1000	400	200	100	15	750	1

Table 2: Proximate and nutritional composition of the fresh sapota pulp and orange peel.

Parameter	Fresh sapota pulp	Fresh orange peel	LSD
TSS (°B)	15.25±0.24	10.47±0.06	*
Vitamin-C (mg/100 g)	72.42±1.01	179.35±1.05	*
ß-carotene (µg/100 g)	27.82±0.41	30.68±0.35	*
Total carotenoid (mg/100 g)	39.21±0.20	40.66±0.65	*
Total sugar (%)	18.57±0.56	8.55±0.04	*
Reducing sugar (%)	5.43±0.47	4.43±0.12	*
Acidity (%)	0.63±0.02	1.16±0.15	*
pH	5.25±0.24	5.51±0.10	NS
Ash (%)	2.33±0.02	1.20±0.10	*
Moisture (%)	70.01±0.10	67.56±0.45	*

back extrusion method. The test mode compression was used to determine the instrument working parameters with test speed at 1mm/s, distance 2.50 cm. The analysis of the data was performed by Texture Exponent Lite version 6.1.14.0 software (Stable Micro System, Godalming, UK) to determine the rupture force and it expressed as g/force.

Sensory evaluation

Sensory evaluation based on the 9-point hedonic scale of all the prepared marmalade was done by a taste panel. The tasting panel was consisting of 30 members. They were asked to evaluate the color, aroma, mouth feel, bitterness, spreadable, hardness and overall acceptability by a scoring rate, 9 means like extremely, 8 means like very much, 7 means like moderately, 6 means like slightly, 5 means neither like nor dislike, 4 means dislike slightly, 3 means dislike moderately, 2 means dislike very much and 1 means dislike extremely.

Statistical analysis

The data obtained were subjected to statistical analysis and all data was expressed in duplicate as means ± standard deviation. One-way ANOVA with posthoc using Turkey Multiple Comparison Test was performed to analyze the data. The connotation was defined at the 95% confidence level. Statistical analysis and data processing was performed using software SPSS 17.0 (IBM INC., New York).

RESULTS AND DISCUSSION

Proximate and nutritional composition of the fresh sapota pulp and orange peel

The proximate and nutritional composition of the fresh experimental sapota pulp and orange peel are shown in Table 2. All the proximate and nutritional compositions of the fresh sapota pulp and orange peel were statistically significant. The findings revealed that vitamin C, ßcarotene and total carotenoid were highly present in the fresh orange peel than the sapota pulp. The variation might be due to the cropping nature of the fruits and their orchard, classification, genus and family, soil type, and texture, etc.

Proximate and nutritional composition of sapota marmalade on the day of preparation and after storage

The proximate and nutritional composition analysis of the prepared marmalade was carried out by evaluation of different proximate and nutritional analysis, such as total soluble solid (TSS), titrable acidity, ash, moisture, pH, ß-carotene, total carotenoid, vitamin-C, total sugar and reducing sugar.

Total soluble solid (TSS)

TSS is primarily represented by sugars, with acids and minerals contributing. According to the Codex Alimentarius Standard (CODEXSTAN, 2009) normal fruit conserves or preserves must contain equal or greater than 60 % soluble solid. On the day of storage, the TSS content of our treated marmalades was recorded as 65.3±0.02°B whereas it was found 65.33±0.05°B after 6 months of storage, indicating that TSS slightly increased with the advancement of storage periods (Tables 3 and 4). The increase in TSS might be due to the conversion of monosaccharide's into sugar molecules and degradation of pectin resulting in an increase of total soluble solids (Er. Patil, 2013).

Table 3: Proximate and nutritional composition of sapota marmalade on the day of storage.

	Treatment					
Parameter	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**LSD**
TSS (°B)	65.30±0.02	65.30±0.02	65.30±0.02	65.30±0.02	65.30±0.02	NS
Vitamin-C (mg/100 g)	4.68±0.02	4.68±0.02	4.69±0.01	4.69±0.01	5.84±0.03	**
ß-carotene (µg/100 g)	12.21±0.01	11.77±0.02	10.68±0.01	10.29±0.01	9.37±0.02	*
Total carotenoid (mg/100 g)	22.53±0.02	31.92±0.02	42.45±0.02	43.62±0.05	49.21±0.51	*
Total sugar (%)	21.15±0.04	21.00±0.00	20.61±0.11	19.50±0.10	17.16±0.05	*
Reducing sugar (%)	9.70±0.01	9.38±0.31	9.07±0.06	9.03±0.02	8.05±0.04	*
Acidity (%)	0.12±0.01	0.21±0.01	0.22±0.01	0.31±0.01	0.41±0.01	*
pH	5.05±0.04	4.72±0.01	4.58±0.01	4.40±0.01	4.44±0.01	*
Ash (%)	0.31±0.01	0.41±0.00	0.49±0.01	0.51±0.01	0.67±0.02	*
Moisture (%)	31.46±0.01	31.42±0.00	31.42±0.00	31.43±0.03	31.43±0.02	*

All values are means of triplicate determinations ± SD. * indicate significant results at p<0.05 levels in the same row. NS means non-significant difference.

Table 4: Proximate and nutritional composition of sapota marmalade after 6 months of storage.

	After 6 months					
	Treatment					
Parameter	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**LSD**
TSS (°B)	65.33±0.05	65.33±0.05	65.33±0.05	65.33±0.05	65.33±0.05	NS
Vitamin-C (mg/100 g)	2.36±0.01	2.36±0.01	2.38±0.01	3.51±0.01	3.62±0.06	*
ß-carotene (µg/100 g)	11.93±0.03	10.68±0.03	9.24±0.03	7.63±0.03	6.85±0.04	*
Total carotenoid (mg/100 g)	17.91±0.02	23.26±0.02	28.79±5.05	34.05±0.04	43.39±0.05	*
Total sugar (%)	22.28±0.03	21.55±0.45	21.14±0.04	20.68±0.03	20.11±0.01	*
Reducing sugar (%)	10.15±0.05	10.15±0.05	10.01±0.00	10.05±0.04	9.12±0.02	*
Acidity (%)	0.16±0.01	0.50±0.00	0.51±0.01	0.51±0.01	0.62±0.01	*
pH	4.90±0.01	4.62±0.01	4.36±0.01	4.31±0.01	4.26±0.01	*
Ash (%)	0.41±0.01	0.73±0.02	0.77±0.00	0.81±0.01	0.89±0.01	*
Moisture (%)	31.45±0.00	31.40±0.01	31.40±0.01	31.40±0.05	31.41±0.05	*

All values are means of triplicate determinations ± SD. * indicate significant results at p<0.05 levels in the same row. NS means non-significant difference.

Vitamin C

Vitamin-C content was significantly differed on the day of storage and after storage periods (Tables 3 and 4). On the day of storage, the vitamin-C content ranged from 4.68±0.02 to 5.84±0.03 mg/100 g whereas it ranged from 2.36±0.01 to 3.62±0.06 mg/100 g. The results indicate the vitamin-C content was decreased with the progression of storage periods. These findings are fully supported by the findings of El. Ashwash et al. (1980), who reported that the loss of vitamin C might be due to its oxidation during the long concentration steps at room temperature. On the day of storage and after storage, the highest vitamin C (5.84±0.03 mg/100 g and 3.62±0.06 mg/100 g) content was detected in the treated sample T_5 followed by others. This could be due to the use of a higher amount of orange peel (25 %) with the sapota pulp. Several researchers reported that orange peel is a rich source of antioxidant as well as vitamin-C content (Xu et al., 2006; Minichini et al., 2011; Sir Elkhatim et al., 2018). Thus the higher quantity of this peel might be contributed to achieving the highest vitamin C content in T_5.

ß-carotene

β-carotene is the major dietary precursor of vitamin A (Xu et al., 2006), becoming retinol inside the human body (Belitz and Grosch, 1997). Besides its function as pro-vitamin A, the functional significance of these carotenoids is also due to its antioxidant actions (Bushway, 1986). In this study the β-carotene content ranged from 12.21±0.01 to 9.37±0.02 µg/100 g on the day of storage and after 6months of storage, the β-carotene content varied from 11.93±0.03 to 6.85±0.04 µg/100 g (Tables 3 and 4). Although the sapota pulp treated treatment T_1 maintained greater β-carotene content but the orange peel contained sample T_5 greater losses β-carotene content with the advancement of storage periods. The loss of β-carotene might be attributed to the non-oxidative changes (cis-trans isomerization, epoxide formation or heat degradation of tissues) (Aruna et al., 1999) and temperature effect during the cooking process (Molla et al., 2017).

Total carotenoid

Statistically, significant differences were observed between sapota pulp (T_1) and sapota pulp with orange peel treated marmalades (T_2, T_3, T_4 and T_5) on the day of storage and after 6 months of storage (Tables 3 and 4). The highest total carotenoid content was exhibited in the orange peel treated marmalades (T_2, T_3, T_4 and T_5) than that of sapota pulp treated marmalade (T_1). The results indicate that total carotenoid content was increased with the advancement of storage periods. The

highest total carotenoid content obtained in the orange peel treated marmalades might be due to the combined mixture of sapota pulp and orange peel as well as the orange peel a rich source of antioxidants and phytochemicals (Favela-Hernandez et al., 2016). Carotenoids have been described as antioxidant compounds. Hence, the significant increase of the carotenoid in orange peel treated marmalade is due to its phytochemical and antioxidants action (Teixeira et al., 2020).

Total sugar

Total sugar content of the sapota marmalade is presented in Tables 1 and 2. On the day of storage, total sugar content of the treated samples ranged from 21.15±0.04 to 17.16±0.05 % (Table 3) whereas it ranged from 22.28±0.03 to 20.11±0.01 % after 6 months of storage (Table 4). The results indicate that total sugar content increased with the increase of storage periods. The increase in total sugar content is mainly due to the hydrolysis of starch. Similar results were also obtained by Iboyaima-Singh et al. (2000), Richard et al. (1963) and Rajanala et al. (1995) while working on the enzymatic liquefaction of mango, grapes and banana fruits respectively. They observed a significant increase in total sugar and reducing sugar content of grape juice and banana juice prepared using pectinolytic enzymes, and our results are also in agreement with these findings.

Reducing sugar

On the day of storage and after storage, the reducing sugar content was significantly differed (Tables 3 and 4). On the day of storage, the reducing sugar content ranged from 9.70±0.01 to 8.05±0.04 % whereas after storage, the sugar content ranged from 10.15±0.05 to 9.12±0.02 % respectively. The results shows that reducing sugar content increased with the advancement of storage periods. The highest reducing sugar content was observed only in sapota pulp treated (no peel was used) marmalade (T_1). The orange peel treated all samples gradually decreased the reducing sugar content than others and the higher amount of orange peel subsequently exhibited a lower amount of reducing sugar content (Tables 1, 2, 3 and 4). The reason might be due to the positive correlation among the total sugars, reducing sugars and acidity, which means that orange-produced peel has high acidity than the fresh pulp of sapota (Tables 3 and 4). The low acidity presented in the formulated sapota pulp may be contributed to achieving a higher amount of total and reducing sugar content (Tables 3 and 4). Moreover, it is assumed that the increased acidity present in the orange peel treated marmalade may have contributed to achieving a lower amount of total and reducing sugar content. These results are supported by the findings of Pallavi et al. (2015), Iboyaima-Singh et al. (2000), Rajanala et al. (1995) and Richard et al. (1963).

Acidity

On the day of storage, the acidity ranged from 0.12±0.01 to 0.41±0.01 % whereas it was from 0.16±0.01 to 0.62±0.01 % after storage. The acidity was increased with the progression of storage periods (Tables 3 and 4). Titrable acidity of the orange peel treated marmalades (T_2, T_3, T_4 and T_5) was higher than that of only sapota pulp treated marmalade (T_1). These results might be due to the enzymatic de-esterification and degradation of pectin increasing titrable acidity. Similarly, results were obtained by Iboyaima-Singh et al. (2000) while working on enzymatic liquefaction of mango pulp.

pH

pH of the sapota pulp (T_1) and sapota pulp with orange peel treated marmalade (T_2, T_3, T_4 and T_5) ranged from 5.05±0.04 to 4.44±0.01 whereas it was from 4.90±0.01 to 4.26±0.01 after storage. The pH was decreased with the progression of storage periods (Tables 3 and 4). pH of the orange peel treated marmalades (T_2, T_3, T_4 and T_5) was lower than that of only sapota pulp treated marmalade (T_1). These results might be due to the enzymatic de-esterification and degradation of pectin resulting in an increase of titrable acidity and hence decrease of pH values. Similar results were obtained by Iboyaima-Singh et al. (2000) while working on enzymatic liquefaction of mango pulp. Our results confirm that pH and acidity have an inverse relationship with each other which means that if the pH goes up, the acidity of the sample goes down.

Ash content

Ash content represents minerals like calcium, phosphorus and iron. The ash content of the differently treated samples was highly significant. On the day of storage, the ash content of the treated marmalade ranged 0.31±0.01%, to 0.67±0.02 % whereas it ranged from 0.41±0.01% to0.89±0.01 % after 6 months of storage (Tables 3 and 4) indicating that the ash content was increased with the advancement of storage periods. The increases in ash content also indicate that the products were stable during the entire storage period. The results are in agreement with the findings of Khan et al. (2016) and Khan et al. (2021).

Moisture content

The shelf life of the products depends on the moisture content. Higher moisture content enhances higher water activity of the products. On the day of storage, the moisture content of the treated marmalade ranged from 31.46±0.00 % to 31.43±0.05 % whereas it exhibited 31.45±0.01 % to 31.41±0.02 % after 6 months of storage periods. Although the moisture content was statistically different however the decreasing changes were negligible. The decrease in moisture content might be due to the moisture loss by the process of evaporation, thus increasing the TSS of marmalade (Tables 3 and 4). The moisture content obtained in our marmalade is strongly supported by the findings of sapota jam by Ahmed et al. (2011) and Khan et al. (2016).

Color of the sapota marmalade

Color appearance by the consumer is to be a very

Table 5: Color changes of the sapota marmalade on the day of preparation and after storage.

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
Lightness (*L**)	42.66±2.06	39.08±0.82	38.14±1.46	37.34±0.67	36.71±2.23	*
Chroma (*C**)	14.40±2.79	18.61±2.83	19.47±1.69	20.40±3.98	23.87±2.05	*
Hue angle (*h**)	50.30±2.18	50.97±0.91	54.67±0.86	58.06±0.82	60.49±1.70	*
After 6 months of storage						
Lightness (*L**)	42.57±2.06	39.05±0.82	38.05±1.46	37.21±0.65	36.42±2.06	*
Chroma (*C**)	14.29±2.76	18.59±2.81	19.39±1.10	20.30±3.98	23.79±2.07	NS
Hue angle (*h**)	50.25±2.18	50.88±0.91	54.60±0.90	57.96±0.82	60.44±1.70	*

All values are means of triplicate determinations ± SD. * indicate significant results at p<0.05 levels in the same row. NS means non-significant difference.

Table 6: Sensory evaluation of sapota marmalade on the day of preparation.

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
Color	7.20±0.83	7.40±1.51	8.00±0.70	7.60±0.54	7.20±0.83	NS
Aroma	6.40±0.54	7.20±1.09	7.00±0.70	6.40±1.10	6.00±1.00	NS
Mouth feel	6.80±0.44	7.00±1.58	6.40±2.50	6.40±1.94	5.20±1.30	NS
Bitterness	5.60±1.14	6.80±1.09	5.00±1.22	6.60±1.14	6.60±1.14	NS
Spreadable	6.00±1.87	7.00±1.00	6.60±1.14	6.40±2.70	5.40±0.89	NS
Hardness	5.80±2.16	5.60±1.14	5.40±2.70	6.60±0.89	5.00±2.73	NS
Overall acceptability	6.30±0.72	6.83±0.65	6.39±0.99	6.66±0.86	5.90±0.51	NS

All values are means of triplicate determinations ± SD. NS means non-significant difference.

important criterion for the initial acceptability of the product. The color difference values (*L**, *c**, and *h** values) of the differently treated marmalade (T_1, T_2, T_3, T_4 and T_5) were measured (Table 5). The result obtained from the study shows that at the initial day of storage and after 6 months of storage, lightness (*L**) value for the sapota pulp treated marmalade T_1 was recorded higher than the other treated marmalades T_2, T_3, T_4 and T_5, which indicates that the marmalade T_1 had a little dark color than the other treated marmalades. In opposition, the lower lightness (*L**) value exhibited by the orange peel treated marmalade (T_2, T_3, T_4 and T_5) can be attributed to the bright color possessed by the orange peel treated marmalade. The C value of the orange peel treated marmalade (T_2, T_3, T_4 and T_5) was higher than the sapota pulp (without orange peel) treated marmalade, which shows that the color of the orange peel treated marmalade (T_2, T_3, T_4 and T_5) was more saturated than the treated marmalade T_1. At the initial day of storage (0 day), the hue angle (*h**)) of the orange peel treated marmalade (T_2, T_3, T_4 and T_5) ranged from 50.97±0.91 to 60.49±1.70 whereas the sapota pulp (without orange peel) treated marmalade showed 50.30±2.18, which indicates that orange peel treated marmalade (T_2, T_3, T_4 and T_5) was in the 0/360° region, which prove that orange peel treated marmalade (T_2, T_3, T_4 and T_5) turned to red color more than the sapota pulp (without orange peel) treated marmalade (T_1). After 6 months of storage, the hue angle (h*) value of the orange peel treated marmalade (T_2, T_3, T_4 and T_5) and without orange peel treated marmalade (T_1) gradually decreased. But the hue angle (*h**) value of the orange peel treated marmalade (T_2, T_3, T_4 and T_5) displayed higher than the without orange peel treated marmalade (T_1), which means that orange peel treated marmalade (T_2, T_3, T_4 and T_5) retained more red color than the without orange peel treated marmalade (T_1). The higher hue angle (*h**) value, as well as red color, persist by the orange peel treated marmalade (T_2, T_3, T_4 and T_5) probably due to the release of more carotenoids as a result of enzyme addition. These findings are in supported by the findings of Tung-Sun et al. (1995) for the plum juice.

Sensory evaluation of the developed sapota marmalade

The sensory evaluation of the developed marmalade was performed on the basis of the grade score obtained by the expert product sensory evaluator. The sensory attributes in terms of color, aroma, mouth feel, bitterness, spreadable, hardness and overall acceptability presented in Tables 6 and 7 show that all the attributes were not statistically different on the day of storage and after storage. On the day of storage, the maximum overall acceptability score (6.83±0.65) was obtained by the orange peel treated marmalade T_2 (5 % orange peel) followed by other orange peel and without orange peel treated marmalade. After 6 months of storage, the maximum overall acceptability score was also gained by the evaluator for the orange peel treated marmalade T_2. The lowest score was obtained by the evaluator for other orange peel-treated marmalade (T_3, T_4 and T_5). The evaluator opined that marmalade formulated using 10 % above orange peel ascended little bitterness than the marmalade formulated of below 10 % orange peel. The lower score obtained by the treatment T_5 might be due to its excessive use of orange peel pieces that sometimes changed the sense of the evaluator. But nutritional it was superior followed by others. Only sapota pulp treated

Table 7: Sensory evaluation of sapota marmalade after 6 months of storage.

Parameter	After 6 months					
	Treatment					
	T_1	T_2	T_3	T_4	T_5	LSD
Color	5.60±2.30	8.20±0.44	6.20±2.94	7.00±2.34	7.20±1.92	NS
Aroma	7.20±0.83	7.00±1.41	7.40±1.14	7.00±1.87	6.00±2.64	NS
Mouth feel	7.60±1.14	7.40±0.89	6.80±1.78	6.60±1.51	6.40±1.51	NS
Bitterness	6.20±1.78	7.20±1.78	6.00±1.58	6.60±1.51	5.80±1.30	NS
Spreadable	5.60±2.07	5.60±2.07	5.80±2.16	5.80±1.30	6.40±1.14	NS
Hardness	6.80±1.48	6.80±0.83	6.00±2.64	7.00±2.34	7.00±1.22	NS
Overall acceptability	6.50±1.06	7.03±0.73	6.36±1.72	6.66±1.41	6.46±1.30	NS

All values are means of triplicate determinations ± SD. NS means non-significant difference.

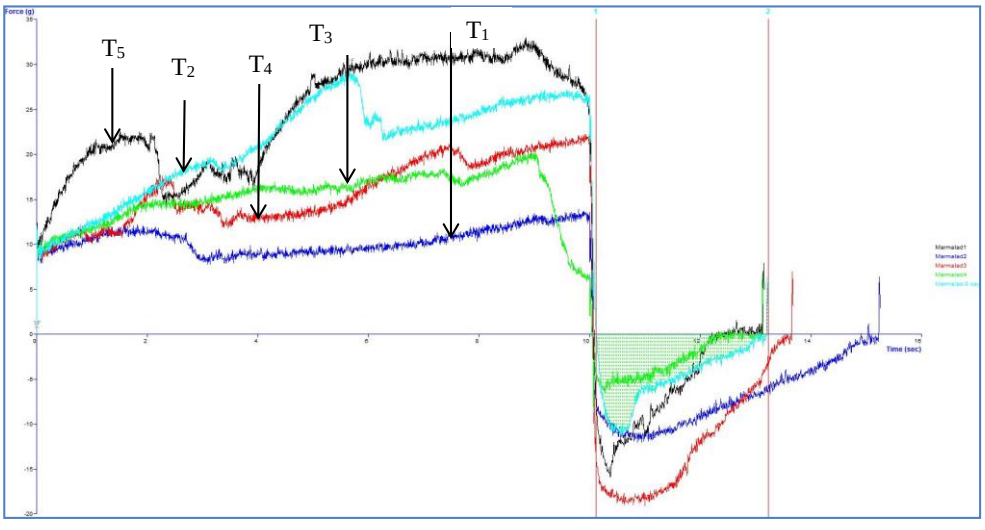

Figure 1: Texture of the sapota marmalade on the day of storage.

(without orange peel) marmalade secured a lower score due to its lower color value and more softness and hence it does not fulfill the requirement of marmalade. None of the expert members of the sensory evaluation like very hardness and softness of the marmalade.

Texture profile of the sapota marmalade

The texture of the developed product depends on the amount of final moisture content and duration of storage. On the day of storage and after storage, the values of rupture force (FR) were measured in order to evaluate the consistency and quality of the orange peel treated marmalade (T_2, T_3, T_4 and T_5) and without orange peel treated marmalade (T_1) (Figures 1 and 2). The lowest peak was recorded in only sapota pulp treated (without orange peel) marmalade (T_1) whereas the highest peak was verified by the orange peel treated marmalade (T_2, T_3, T_4 and T_5) both on the day of storage and after storage. The maximum peak as well as hardness obtained by the orange peel treated marmalade (T_2, T_3, T_4 and T_5) might be due to the presence of lower moisture content than without orange peel treated marmalade both on the day of storage and after storage (Tables 2 and 3). Another significant reason might be due to the use of orange peel pieces in orange peel-treated marmalade (T_2, T_3, T_4 and T_5) that might be interrupted by the textured probe (p/5) to easily penetrate the probe into the bottom of the marmalade jars. This hindrance may be contributed to achieving maximum hardness by the orange peel treated marmalade (T_2, T_3, T_4 and T_5) followed by without orange peel treated marmalade (T_1).

CONCLUSION

The sapota marmalade formulated using different proportions of orange peel and without orange peel exhibited a rich source of proximate and nutritional composition. According to the expert panel opinion, the best formulation was found in treatment T_2 (5 % orange peel treated marmalade) followed by others in terms of its color, aroma, mouth feel and high spreadable capacity. But nutritionally the maximum total carotenoid and vitamin-C content were found in the sample T_5 followed by others. The marketable life of the developed marmalade could be extended 6 months more without any excessive-quality deterioration. This developed technology could contribute to the proper use of sapota fruit by minimizing its postharvest losses during glut season in the southern region of Bangladesh. As the fresh fruit shelf life is very short, therefore the technology may be helpful to fulfill the off-season nutritional

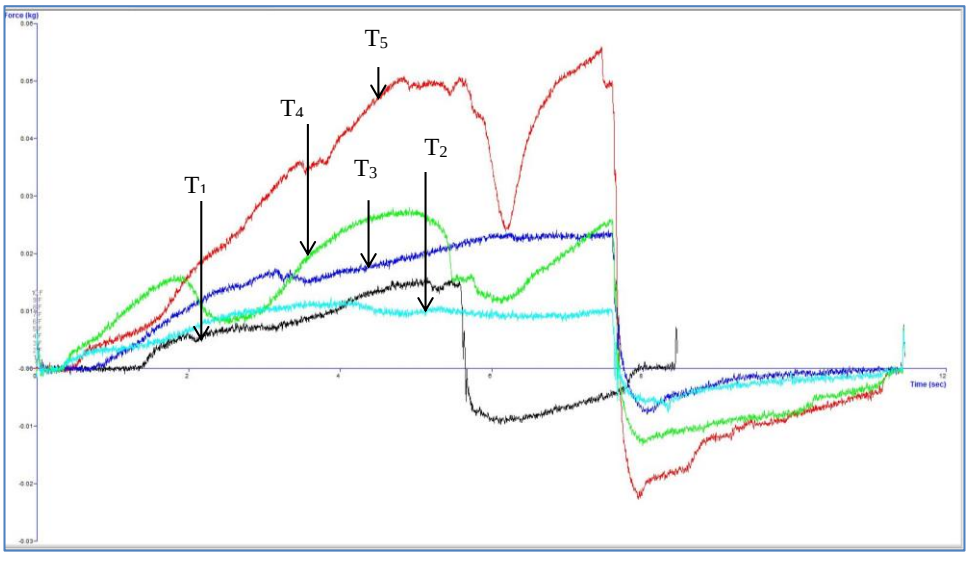

Figure 2: Texture of the sapota marmalade after 6 months of storage.

requirement through its processing into marmalade. Further research may be conducted to develop mini pack marmalade or ready to serve (RTS) drink powder for schooling nutrition programs to uplift the nutritional status of the school-going children.

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