EFFECTS OF FRYING TEMPERATURE AND TIME ON PHYSICOCHEMICAL CHANGES AND SHELF LIFE OF VACUUM FRIED JACKFRUIT CHIPS

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Abstract

The aim of the study was to optimize the vacuum fried jackfruit chips processing to produce quality jackfruit chips at suitable frying temperature and time. Jackfruit chips were prepared from matured khaja type jackfruit. The harvested matured jackfruit was cut into halves and separated the bulbs. The seed was removed and bulb was sliced into about 5 mm thickness and then packaged in high density polyethylene (HDPE) packet (~60 micron) and frozen at -18ºC for 24 - 48 hours. Then the frozen slices were fried instantly using BARI Vacuum Frying Machine at 100,110 and 120ºC for 5, 10, 15, 20 and 25 minutes, respectively. The fried chips were de-oiled using BARI De-oiling Machine at 1400 rpm for 3 minutes. Finally the de-oiled chips were packaged in metalex foil (~50 micron) packet without nitrogen gas and sealed for storage at ambient temperature (26±2^{o}C & 75±5%RH). Then the changes of physicochemical properties with different frying temperature and time at one month interval upto six months and consumer preference test was evaluated by expert sensory panelists. According to the sensory panelist, the best frying temperature and time combination was found 110ºC for 25 minutes, where sensory parameters scored 8.12. The study will generate the information to the food processors and product development sectors to find out proper ways and means of processing and production of good quality vacuum fried jackfruit chips and thus mitigate the postharvest losses by extending the shelf life and marketability.

Introduction

Jackfruit is dicotyledonous compound fruit of the jackfruit tree (*Artocarpus heterophyllus*) which belongs to the family Moraceae and grow commonly in the tropical countries of the Southeast Asia. Bangladesh, Thailand, Indonesia and Malaysia which are the top five producers of jackfruits in the world with a total production of approximately 3.11 million tons per year (Sidhu, 2012; Saxena *et al.,* 2013). Its interior consists of eye catching orange-yellow color edible bulbs and each bulb consists of sweet flesh (sheath) that encloses a smooth, oval, light, brown seed (Golden berg *et al.,* 2014). Jackfruits are tropical fruits rich in dietary fiber, protein, potassium, magnesium, iron, vitamin B complex, vitamin C and many phytochemicals including phenolics and carotenoids (Jagtap *et al.,* 2010). Due to a low yield of edible portion (around 35% of whole fruit), transportation and storage of raw jackfruit is not particularly economical (Saxena *et al.,* 2012). Different preservation/processing methods have been developed to preserve this multi-nutritional and perishable fruits. However, a large amount of jackfruits still get spoiled due to lack of proper preservation/processing technology, an integrated supply chain, and/or storage facilities during the peak season of harvest.

Through processing and preservation value addition has to be considered as an important alternative for reducing the postharvest losses of this nutritive fruit and to ensure its availability all the year round. In Bangladesh, air drying and atmospheric frying is a common method of food processing, where vacuum frying is an emerging and novel methods of food processing. Vacuum frying is an alternative frying technique where frying is done under reduced pressure and low temperature (Troncoso *et al.,* 2009). This frying condition rendered to produce superior quality of fried product with low oil content and retained the color (Song *et al.,* 2007). Degradation of important nutritional compounds and the generation of toxic molecules in the foodstuff due to high frying temperatures and exposure to oxygen have led to the development of healthy and low fat snack products (Fillion and Henry, 1999; Moreira *et.al.,* 1998). The conventional frying of jackfruit is not practicable due to its high sugar content (Selvaraj and Pal, 1989). Higher frying temperature causes charring of the fruit and negligible moisture removal from the fruit. Vacuum frying technique is more suitable for frying sugar rich materials such as jackfruit.

Hence, the objective of the present study was to study the effect of different frying conditions such as temperature and time on the quality of vacuum fried jackfruit chips. The developed value added vacuum fried (VF) jackfruit chips will be a revolution in the snacks items in Bangladesh as a low oil content, healthy and nutritious fruit chips. Remarkably, it will help to reduces postharvest losses and ensure quality fruit chips all the year round. The new product and technology also helps to generate income to the stockholders and entrepreneurs through processing, marketing and exporting. The market potential of jackfruit can be better exploited, if the fruits are made available to consumers in a ready-to-eat (RTE) or cooked (RTC) form throughout the year.

Materials and Methods

Collection of fruit, processing and frying conditions

Physiologically matured khaja type Jackfruit was collected from the Cotton Research, Training and Seed Multiplication Farm, Sreepur, Gazipur to the packhouse of Postharvest Technology Division, BARI, Gazipur. Jackfruits were sorted out from any harvesting and transportation injured and cleaned by washing with potable water. After peeling and decoring, the jackfruit bulbs were separated. The internal seed was removed by cutting into halves by sharp knives and then sliced at 5 mm thickness. After that jackfruit slices were sealed in HDPE packets and frozen at -18ºC in deep fridge for 24 - 48 hrs. (Figure 1). One batch/kilogram of processed jackfruit slices was placed in the vessel and fried in 15 L of vegetable oil below atmospheric pressure. After vacuum frying, the fried jackfruit chips were de-oiled for 2 minutes at 1400 rpm using BARI de-oiled machine to remove the excess frying oil. After de-oiling, the fried jackfruit chips were cooled then added spices and packed in HDPE packet with proper sealing and stored at ambient temperature (26±2^{o}C & 75±5%RH). The treatments studied in this work were: (1) Jackfruit chips were fried at three levels of frying temperature (100, 110 and 120ºC); (2) frying time at 5 minutes intervals (5, 10, 15, 20 and 25 minutes). Shelf life study with physicochemical properties changes were evaluated upto six (06) months at one month interval. The following steps were maintained to process the jackfruit for preparing quality VF jackfruit chips.

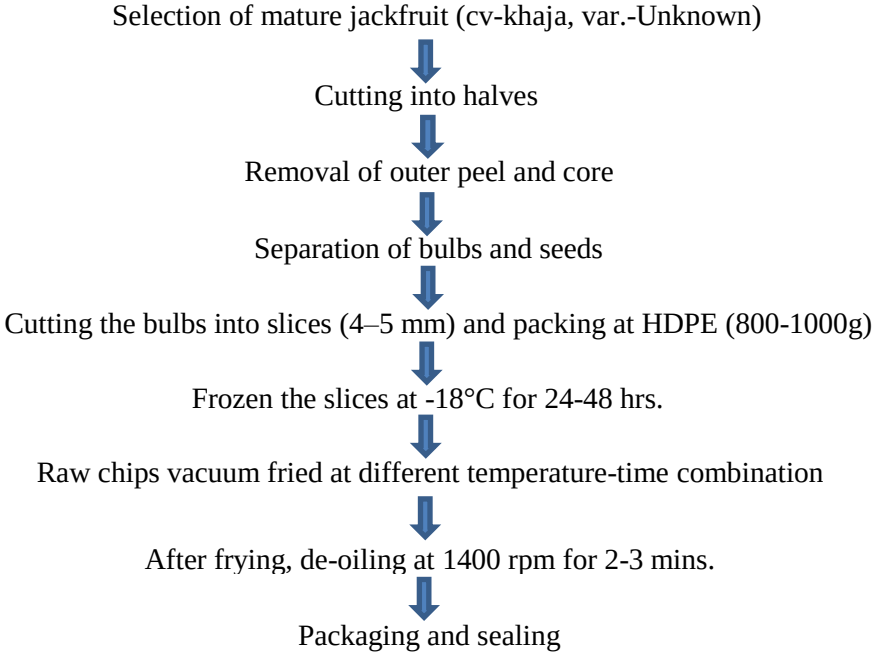

Figure 1. Diagram for the processing of vacuum fried jackfruit chips

Measurements of external appearance

On the basis of methods described by Dervisi *et al.* (2001), the external color of the chips was evaluated with a Chroma Meter (Model CR-400, Minolta Corp., Japan). CIE $L^*a^*b^*$ coordinates were recorded using D65 illuminants and a 10° standard observer as a reference system. L^* is lightness, a^* (-greenness to +redness) and b^* (-blueness to +yellowness) are the chromaticity coordinates. The a^* and b^* values were converted to chroma [$C^*=(a^{*2} + b^{*2})^{1/2}$] and hue angle [$H^*=\tan^{-1}(b^*/a^*)$]. Before measurement, the equipment was calibrated against a standard white tile. Then, it was assimilated to measure the values of L*, C*, and H* and was replicated three times for each treatment.

Measurements of moisture content

Moisture content was determined according to the method described by Ranganna (2007) with slight modification. Five gram of sample was taken in crucible and was placed in an oven dryer at 75°C for 72 hrs. until constant weight attained. Percent moister content was calculated using the following formula:

$$Moisture\ content\ (\%) = \frac{\text{Loss in weight}}{\text{Initial weight of sample}} \times 100$$

Measurements of total carotenoids content

Total carotenoids in the vaccum fried jackfruit chips were determined with slight modification of the method described by kuti (2004). At first extracted the total carotenoids from 5gm of sample with a solvent mixture containing 40 ml acetone (Fisher Scientific Ltd., UK) and 60ml petroleum ether the vacuum fried (VF) jackfruit chips residue turned to colorless. It was further purified with acetone, metabolic KOH and distilled water. The resulting solution was filtered with anhydrous sodium sulphate and read on a spectrophotometer (T-80, PG Instrument Ltd., UK) at 451 ηm against petroleum ether as blank. A standard graph was plotted using synthetic crystalline carotene (Fluka, Germany) dissolved in petroleum ether and its optical density measured at 451ηm.

Measurements of starch content

The amount of starch was determined by following the standard method and the value was expressed in percentage of starch on dry weight basis (Ranganna, 2007). About 5 g sample was homogenized with hot 80% ethanol. Centrifuge and retain the residue through repeated the extraction by washing with ethanol upto the removal of color with anthrone reagent. To the residue add perchloric acid. Again centrifuge and take the supernatant and made up the volume upto 100 ml. Add 4 ml anthrone reagent and boiling by heating. Rapidly cool and read the intensity of color at 630 ηm using UV-Spectrophotometer.

Sensory evaluation

For evaluating the changes of the sensory quality attributes of the VF jackfruit chips products of different frying temperature and time combination. Few panel tests were performed at one month interval during storage period. Based on a 0-9 hedonic scale the highest response was marked and comments of the expert persons were documented for quality improvement as per the procedure of Joshi (2006). A judgment panel was formed comprising of fifteen expert members from the BARI inter-divisional Scientists and different age grouped people to evaluate appearance, taste, aroma, crispiness and overall acceptability of the products.

Statistical analysis

All data was expressed in triplicate as means ± standard deviation. One-way ANOVA with posthoc by Tukey Multiple Comparison Test was used to evaluation of the recorded data. The connotation was stated at the 95% confidence level. Statistical analysis and data processing were performed using software SPSS 17.0 (IBM INC., New York).

Results and Discussion

Effects of appearance at different frying conditions during storage

The color values of VF jackfruit chips showed significant difference with various frying temperature and time combination. The Lightness (L*) values of VF jackfruit chips are shown in Table 1. The L* values of the VF jackfruit chips ranged from 54.17 to 67.48 when fried at different frying temperature and time. The L* values were seen to be inversely proportional to the frying temperature. A higher L* value was observed in VF jackfruit chips at frying condition of 100ºC and 20 min. The lower L* value of 54.17 was observed in the VF jackfruit chips at processing conditions of 100ºC and 5 min. When the frying time was further extended, the L* value decreased at all frying temperatures. Frying at 120°C and 25 minutes the lightness decreased to 57.89. During storage the lightness values decreased from 44.17 to 62.53 and the products became darker in color. The change in color was due to the interaction of an amine group with a reducing sugar, which is a non-oxidative browning reaction, pigment fragmentation and oxidation (Moriscal and Bouchon, 2008).

The $a*$ value of the VF jackfruit chips was found to increase with the progress of frying duration at all the frying temperatures (Table 2). The a* value ranged from 2.16 to 4.94. The increase was very rapid at 120°C compared to other frying temperatures. During storage a* values started to increase in all treatments. After six months storage, a* value ranged from 5.96 to 8.77. The major changes observed in lower temperatures 100°C and 110°C and lower frying time 5 and 10 minutes, respectively. Changes in $a*$ value indicated development of golden brown to dark brown color in jackfruit chips due to incomplete frying with higher moisture level that causes browning reactions, breakdown of the chemical compounds and fungal growth (Garayo and Moreira, 2002).

Moisture content changes at different frying conditions during storage

The moisture loss from the jackfruit bulbs under vacuum at different frying temperature and time is illustrated in Table 3. There were significant (P<0.05) differences observed in moisture content in the VF jackfruit chips. From the observation, the result indicated that at each temperature frying at 5 and 10 minutes produced incomplete fried chips due to less crispiness. The moisture content of the jackfruit chips were ranged from 40.38 to 1.83% at 100°C for 5 minutes and 120°C for 25 minutes, respectively. Since the frying is carried out under vacuum which decreases the boiling point of water, so moisture removal was instant without much warm-up. After 6 month of storage the moisture content increased in each treatment ranges 3.25% to 44.11% due to the absorbance of moisture with microspores of the packaging materials. Since the frying was carried out under vacuum which decreased the boiling point of water, moisture removal was instant from jackfruit slices without much warm-up phase. The phenomenon is in accordance with the findings for vacuum fried potato chips (Yagua and Moreira, 2011).

Starch content changes at different frying conditions during storage

There were significant differences observed in starch content in the jackfruit chips fried at different temperature and time. During frying starch became gelatinized due to heating and the products becomes crispy in nature. The starch content ranges from 15.91% to 17.88% after frying. Jackfruit bulbs fried at lower temperature for shorter time (100°C for 10 minutes) caused higher starch content 17.88% due to incomplete frying but it decayed drastically up to 13.24 % during six months storage. During storage, starch started broken down ranged from 10.15% to 13.25% by converting into sugar. The starch content in the jackfruit chips is illustrated in table 6. Starch content of potato tubers determined the texture of processed product and positively correlated with the dry matter (Uppal, 1999).

Total carotenoid content changes at different frying conditions during storage

The yellow color of jackfruit chips was due to the presence of carotenoids which were found to degrade during frying. After frying for 5, 10, 15, 20 and 25 minutes and total carotenoid content were degraded from initial value in chips fried at 100, 110, and 120°C, respectively. The carotenoids content ranged from 5.62 to 6.57 mg/100g after vaccum frying. Jackfruit bulbs fried at lower temperature for lower time caused higher starch content but it decayed drastically upto 4.08mg/100g during 6 months storage. The total carotenoids content in the jackfruit chips is illustrated in table 7. The carotenoid molecule has a characteristic conjugated polyene which is highly susceptible to degradation due to oxidation (Boon *et al.,* 2010). Further, carotenoid was reported to be deteriorated by several researchers during thermal processing depending on the type of raw material and the temperature involved in processing (Ahmed *et al.,* 2002; Koca *et al.,* 2007).

Sensory evaluation at different frying conditions during storage

Vacuum fried jackfruit chips were assessed for sensory acceptability in terms of appearance, taste, flavor, crispiness, oiliness and overall acceptability. The sensory score for jackfruit color was rated high during chips frying at higher temperature with time. It was observed that yellow flesh turned into golden yellow during vacuum frying. Jackfruit chips fried at higher temperature 120°C with longer frying time (over 25 min) resultant lowering the sensory score due to over frying and undesirable surface browning of the slices, which occurred caramelization of sugar. Higher frying temperature exhibited crispiness faster. In case of sensory evaluation, the highest overall acceptability 6.56 and 6.15 were observed in the treatments of 110°C for 25 min and 120°C for 20 min, respectively (Table 5). In the experimentation, temperatures 100°C, 110°C and 120°C for 5, 10 and 15 minutes were belonged to sensory score under 5 (Neither like or dislike) for the development of the VF jackfruit chips due to incomplete frying and less crispiness (Table 5).

Table 1. Effect of frying temperature-time combination on lightness (L*) value of VF jackfruit chips during 6 months of storage at ambient condition

Treatments		Lightness (L*) value			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	5	59.17±0.41f	47.69±0.49f	46.41±0.50f	44.77±0.47d
	10	62.63±0.65bc	55.23±0.94de	48.39±0.65f	45.23±0.03d
	15	64.98±0.26ab	63.19±0.34ab	57.81±0.41bcd	54.36±0.15bc
	20	67.48±0.95a	62.29±0.68ab	57.98±0.66bcd	54.07±0.13bc

Treatments		Lightness (L*) value			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	25	62.44±0.73ab	62.46±0.06ab	60.14±0.77abc	58.53±0.49ab
	5	56.76±0.51ef	52.34±0.42e	47.52±0.27f	44.14±1.57d
	10	62.52±0.57bc	52.26±0.82e	46.46±0.39f	48.27±1.17cd
110°C	15	63.96±0.32ab	61.19±0.68abc	56.83±0.54cd	55.55±0.56b
	20	63.34±0.06ab	60.49±0.48bc	58.11±0.20bcd	55.89±0.60b
	25	62.95±0.40bc	62.35±1.01ab	61.46±0.84ab	60.05±0.05ab
	5	60.37±0.87cd	57.96±0.21cd	52.56±0.62e	45.86±0.08d
	10	65.05±0.34ab	61.84±1.06ab	57.64±0.92cd	55.18±0.03b
120°C	15	66.23±0.50a	63.97±1.73a	62.40±0.10a	62.53±0.29a
	20	65.38±0.06ab	63.22±0.93ab	63.81±0.48a	59.56±0.40ab
	25	57.89±0.09de	56.62±0.54d	55.74±0.64de	54.85±0.15bc

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f indicates significant result (p<0.05).

Table 2. Effect of frying temperature-time combination on a* value of VF jackfruit chips during 6 months of storage at ambient condition

Treatments		a* value [($^{+}$ve) redness and ($^{-}$ve) greenness]			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	5	2.16±0.02g	5.14±0.08bc	7.41±0.11a	8.77±0.15a
	10	3.57±0.12ef	5.13±0.03bc	7.50±0.41a	8.64±0.13a
100°C	15	3.61±0.14ef	4.05±0.16g	5.59±0.46ef	5.95±0.03f
	20	4.38±0.24cd	4.85±0.04cd	5.58±0.05ef	5.96±0.02f
	25	4.76±0.29ab	5.08±0.04bc	5.66±0.02ef	5.85±0.22f
	5	3.43±0.41f	5.55±0.23a	7.21±0.03a	8.21±0.12a
	10	3.84±0.04ef	4.36±0.19efg	7.15±0.21a	8.84±0.05a
110°C	15	3.91±0.05ef	4.27±0.06fg	6.17±0.04cde	7.02±0.02b
	20	4.52±0.11abc	4.94±0.02bcd	6.24±0.03cd	6.47±0.07bc
	25	4.90±0.06a	5.07±0.02bc	5.64±0.13def	6.28±0.13de
	5	3.46±0.01f	4.51±0.07ef	6.16±0.14cde	7.74±0.17a
	10	3.54±0.11ef	5.19±0.08b	6.53±0.09bc	7.05±0.04a
120°C	15	4.03±0.03cde	5.10±0.09bc	6.12±0.08cd	6.66±0.36bcd
	20	4.37±0.09bcd	4.66±0.03de	5.17±0.36f	6.60±0.13cd
	25	4.94±0.05a	5.12±0.02bc	6.33±0.05c	6.73±0.04bc

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f, g indicates significant result (p<0.05).

Table 3. Effect of frying temperature-time combination on moisture content (%) of VF jackfruit chips during 6 months of storage at ambient condition

Treatments		Moisture (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	5	40.83±1.91a	41.18±0.18a	42.17±0.15a	44.11±0.10a
	10	8.11±0.59d	10.24±0.31d	10.60±0.24c	11.81±0.13d
100°C	15	3.61±0.23ef	4.34±0.18f	5.02±0.02e	5.96±0.06f
	20	2.69±0.03ef	2.84±0.02g	3.28±0.14f	3.73±0.06h
	25	2.60±0.08ef	2.87±0.01g	3.19±0.00fg	3.70±0.01h
	5	27.18±0.31b	27.15±0.94b	29.46±0.18b	29.78±0.18b
	10	6.39±0.37d	8.55±0.32e	8.62±0.05c	8.95±0.05e
110°C	15	3.09±0.09ef	4.59±0.13f	5.84±0.04d	5.96±0.03f
	20	2.73±0.10ef	2.92±0.03g	3.29±0.09f	3.71±0.02h
	25	1.88±0.06f	2.42±0.02g	2.92±0.03g	3.25±0.05i
	5	18.88±1.13c	21.51±0.43c	22.34±0.14b	22.71±0.16c
120°C	10	4.19±0.09e	4.70±0.25f	5.64±0.12d	6.04±0.28f
	15	3.08±0.13ef	4.20±0.02f	4.93±0.04e	5.32±0.02g

Treatments		Moisture (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	20	2.29±0.16f	2.64±0.04g	3.08±0.04fg	3.42±0.14i
	25	1.83±0.04f	2.32±0.05g	2.88±0.01g	3.41±0.07i

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f, g, h, i indicate significant result ($p<0.05$).

Table 4. Consumer preference test of VF jackfruit chips initially after frying

Treatments		Sensory attributes					
Temperature	Time (min)	Appearance	Taste	Flavor	Crispiness	Oiliness	Overall acceptability
100°C	5	3.60	2.80	3.00	1.40	1.40	2.44
	10	6.40	5.40	5.00	4.00	4.50	5.06
	15	7.10	6.70	6.60	7.20	7.60	7.04
	20	7.90	7.80	7.50	8.10	8.10	7.88
	25	7.80	7.10	7.80	8.00	8.00	7.74
110°C	5	5.80	3.60	3.20	2.20	2.80	3.52
	10	7.20	7.70	7.30	4.80	6.44	6.69
	15	6.80	5.80	6.40	5.40	7.10	6.30
	20	8.10	8.40	7.80	8.24	8.10	8.12
	25	7.30	8.20	8.00	8.20	8.10	7.96
120°C	5	6.40	3.20	4.40	2.20	4.60	4.16
	10	7.80	7.00	7.44	7.20	7.44	7.38
	15	7.50	7.20	7.30	7.50	7.80	7.46
	20	7.70	7.80	7.80	8.20	7.90	7.88
	25	6.90	7.44	7.04	8.20	7.90	7.50

Hedonic Scale: 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely.

Table 5. Consumer preference test of VF jackfruit chips after 6 months of storage at ambient condition

Treatments		Sensory evaluation (After 06 months)					
Temperature	Time (min)	Appearance	Taste	Flavor	Crispiness	Oiliness	Overall acceptability
100°C	5	1.00	1.00	1.00	1.00	1.00	1.00
	10	1.20	1.00	1.20	1.40	1.60	1.28
	15	4.40	3.50	3.40	5.60	5.60	4.50
	20	5.20	4.20	4.00	6.30	6.20	5.18
	25	5.60	5.50	5.20	7.04	6.90	6.05
110°C	5	1.20	1.00	1.20	1.00	1.00	1.08
	10	1.00	1.00	1.20	1.00	1.00	1.04
	15	4.70	4.00	3.50	5.40	6.00	4.72
	20	4.80	5.00	4.40	6.74	7.00	5.59
	25	6.20	6.00	5.70	7.50	7.40	6.56
120°C	5	1.40	1.00	1.00	1.00	1.00	1.08
	10	3.80	3.40	3.20	4.80	5.60	4.16
	15	4.80	4.00	3.80	5.90	6.20	4.94
	20	5.80	5.30	5.00	7.14	7.50	6.15
	25	4.60	4.50	4.10	6.50	6.70	5.28

Hedonic Scale: 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely.

Table-6. Effect of frying temperature-time combination on starch content (%) of VF jackfruit chips during 6 months of storage at ambient condition

Temperature	Time (min)	0 D	60 D	120 D	180 D
100°C	5	17.66±0.44a	15.95±1.50abc	12.59±0.37fg	11.10±0.02h
	10	17.88±2.06a	16.68±0.87ab	15.00±0.68ab	13.24±0.02abc
	15	16.57±0.63ab	15.21±0.76abc	13.23±0.03ef	13.12±0.09bcde
	20	17.25±1.01ab	15.23±0.03abc	14.59±0.59bc	13.24±0.02abc
	25	15.91±0.50b	15.21±0.03abc	13.67±0.54de	13.25±0.01ab
110°C	5	17.27±1.04ab	14.58±0.53c	12.20±0.18g	11.02±0.02h
	10	17.14±0.10ab	16.67±0.63ab	13.67±0.31de	13.08±0.04de
	15	17.88±0.52a	16.82±0.68a	14.05±0.21cd	13.04±0.04e
	20	16.66±0.55ab	15.07±0.11bc	14.15±0.29cd	13.09±0.03cde
	25	17.70±0.56a	15.16±0.33abc	14.17±0.03cd	12.77±0.11f
120°C	5	17.25±0.94ab	15.34±0.35abc	12.85±0.72fg	10.16±0.08i
	10	16.83±0.54ab	15.88±0.01abc	14.36±0.47bcd	12.04±0.04g
	15	16.26±0.96ab	16.01±1.98abc	14.34±0.03bcd	12.08±0.07g
	20	17.10±0.74ab	15.93±1.48abc	15.38±0.59a	13.22±0.20abcd
	25	16.23±0.01ab	15.09±0.69abc	14.14±0.16cd	13.29±0.13a

Values are mean ± standard deviation of 3 replicates. Different lowercase letters in same column are different at 5% level of significance

Table-7. Effect of frying temperature-time combination on on total carotenoids (mg/100g) content of VF jackfruit chips during 6 months of storage at ambient condition

Temperature	Time (min)	0 D	60 D	120 D	180 D
100°C	5	6.48±0.28a	5.07±0.05c	4.28±0.56e	4.08±0.02g
	10	6.57±0.56a	6.20±0.01a	5.68±0.66abc	5.09±0.05e
	15	6.37±0.13ab	6.11±0.09a	5.43±0.32abcd	4.87±0.10f
	20	6.25±0.47b	6.06±0.09a	5.87±0.16ab	5.48±0.07a
	25	6.26±0.44b	6.05±0.06a	5.97±0.05a	5.52±0.11a
110°C	5	6.30±0.08b	5.77±0.06b	4.28±0.06e	4.09±0.01g
	10	5.95±0.03bc	5.75±0.15b	5.17±0.56cd	5.13±0.07e
	15	5.67±0.05c	5.58±0.04b	5.37±0.13bcd	5.20±0.06cd
	20	5.65±0.06c	5.52±0.07b	5.42±0.07abcd	5.35±0.04b
	25	5.64±0.22c	5.60±0.34b	5.43±0.04abcd	5.27±0.04bc
120°C	5	6.22±0.02ab	5.53±0.15b	5.02±0.02d	4.05±0.05g
	10	5.92±0.05bc	5.57±0.25b	5.45±0.03abcd	5.28±0.02bc
	15	5.75±0.07c	5.70±0.09b	5.56±0.17abcd	5.30±0.08bc
	20	5.66±0.04c	5.57±0.25b	5.50±0.15abcd	5.31±0.02bc
	25	5.62±0.05c	5.59±0.10b	5.46±0.03abcd	5.32±0.03b

Values are mean ± standard deviation of 3 replicates. Different lowercase letters in same column are different at 5% level of significance

Conclusion

The main purpose of the experiment was to optimize the VF jackfruit chips processing protocol to produce export oriented jackfruit chips at suitable frying temperature and time combination with shelf life study for six months in metalex foil packet at ambient temperature. Proper processing and pretreatments are mandatory to develop quality products. Jackfruit bulbs are needed to slice at about 5 mm thickness to make it chips form with attractive slick shape. The jackfruit bulbs must be frozen at -18°C for 24-48 hours as a pre-treatment to get the crispy and crunchy products with longer shelf life. It can be concluded that suitable frying temperature-time combination is an important issue for quality VF chips products considering organoleptic properties. According to the sensory panelists on the basis of appearance, texture, flavor, crispiness, oiliness and overall acceptability, the suitable frying temperature-time combination was found 110ºC for 25 minutes or 120ºC for 20 minutes where sensory scored 8.12 and 7.88, respectively. Without suitable packaging materials, products quality attributes mainly texture and appearance were greatly affected. If nitrogen flash with foil pack is used for storing chips, the quality will be retained for longer time. This technology will add value in agro-processing industry for producing quality VF jackfruit chips and will assist to reduce postharvest loss of jackfruit of our country. The economic analysis will be conducted for further study.

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OPTIMIZATION OF PROCESSING PARAMETER FOR PRODUCING QUALITY VACUUM FRIED BANANA CHIPS

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Abstract

The aim of the study was to optimize the vacuum fried banana chips processing parameters to produce quality banana chips using BARI developed vacuum fryer at suitable frying temperature and time. Uniform size of BARI Kola-1 was collected from farmer's field and then peeled and thinly sliced by the slicer. To prevent turning into grayish black discoloration of banana during slicing due to catalase enzymatic action, 1% lemon extracted juice solution and 5% turmeric powder mixed water were prepared. Banana slices were soaked into mixed solutions for 3 hrs. to develop attractive natural color as well as to use as natural preservative. Enhancing spicy flavor and palatability spices combination comprising of salt powder (41.67%), sugar powder (47.67%), red chili powder (8.33%) and garlic powder (8.33%) were added to the banana chips after frying. The effects on physicochemical changes and quality attributes of three different frying temperature (110, 120 and 130ºC) and frying time (8, 10 and 12 minutes) combination were evaluated. The banana chips were de-oiled by centrifugation at 1400 rpm for 2 minutes and packaged in high density polyethylene (HDPE). Then the shelf life study at 1 month interval upto 6 months and consumer preference test were evaluated by expert sensory panelists. According to the sensory panelist's opinion, the best frying temperature and time combination was found at 120ºC for 12 minutes ranked higher sensory score (8.20) among the treatments. The study will generate the information to the food processors and product development sectors to find out proper ways and means of processing and production of good quality vacuum fried banana chips and thus will mitigate the postharvest losses by value addition and will extend the shelf life and marketability all the year round.

Introduction

Banana (*Musa sapientum* L) is one of the cheapest, delicious and most nourishing fruit crops in Bangladesh. The fruit is widely grown in sub-tropical Asia throughout the year and consumption rate is higher than any other fruit by people of all ages (BBS, 2019). Banana fruit deteriorates rapidly after harvest, due to high perishability. Around 26.63% gross postharvest losses occur from harvesting to consumption of banana (Molla *et al.*, 2012). The fruit can be consumed in both unripe and ripened form. Unripe banana is also called plantains which needs to process or cook before consumption (Durance and Scaman, 2002). Commonly, unripe banana is used in quality banana chips preparation to follow the processing steps. Bangladesh Agricultural Research Institute (BARI) developed Banana variety, BARI Kola-1 is high fruit yielding dessert variety with large sized fruit (average fruit weight 125gm) having bright yellow color, soft and sweet (TSS, 24%) pulp (Rahman *et al.*, 2019).

In Bangladesh, air drying and atmospheric frying is a common method of food processing, where vacuum frying is an emerging and novel methods of food processing. Due to lower frying temperature vacuum frying makes the products healthier as they taste better and crispier and contain minimum residual oil and retain more nutrients (Garayo and Moreira, 2002; Shyu and Hwang, 2001). Vacuum fried banana chips coated with edible coating and high speed post centrifugation step maintain good quality and low oil content chips products (Sothornivit, 2011). A vacuum frying system consisted of a gas-heated vacuum frying chamber, a water-cooled condenser and a liquid ring vacuum pump used in processing of bananas was reported by Yamsaengsung *et al.* (2011). Different processing methods affecting the oil uptake during the vacuum frying of foods have been covered in the review paper by Dueik and Bouchon (2011).

Fried chips products are appreciated by the people of all age groups. Healthy snacks products play an important role in consumer's diet due to appearance, good taste, texture and unique flavor. Vacuum fried banana chips may be one of the important potential banana products in Bangladesh. Fried banana chips may be also easily marketable snack food in the markets and will extend the marketable life all the year round. For longer shelf life, crispiness and chips quality moisture content is the most important factor as far as storage stability is concerned.

In Bangladesh, vacuum frying technology is not well known to the people and various parameters for optimization of the process have not been made available throughout the agro-processing industry. Keeping this in view, the study was undertaken to optimize the processing parameters such as frying temperature and time, physicochemical properties etc. for producing quality vacuum fried banana chips which will mitigate the postharvest losses and thus suggest proper ways and means for production of good quality vacuum fried banana chips.

Materials and Methods

Collection of fruit, processing and frying conditions

Physiologically matured BARI Kola-1 variety was harvested from farmer field of Dhamti village in Debidwar upazilla of Cumilla district. Green unripe bananas were washed and after peeling thinly sliced, dipped into 1% lemon solution and then soaked for 3 hrs. in 5% turmeric mixed solution for color development as well as use as natural preservatives (Figure 1). A low-cost small scale BARI vacuum frying machine was designed and fabricated by the PHTD, BARI, Gazipur was used in this experiment. A batch of 1 kg of processed banana slices was placed in the vessel and fried in 15 L of vegetable oil under atmospheric pressure. After vacuum frying, the fried banana chips were de-oiled for 2 minutes at 1400 rpm using small scale BARI de-oiling machine which was also designed and developed by PHTD, BARI, Gazipur. After de-oiling the fried banana chips were cooled, added spices and packed in HDPE (60 micron) packet with proper sealing and stored at ambient temperature. The treatments studied in this work were: (1) Banana chips were fried at three levels of frying oil temperature (110, 120 and 130ºC); (2) different frying time intervals (8, 10 and 12 minutes). Shelf life study with physicochemical properties changes were evaluated upto six (06) months at one month interval. The following steps were maintained to process the unripe banana to prepare vacuum fried (VF) banana chips product.

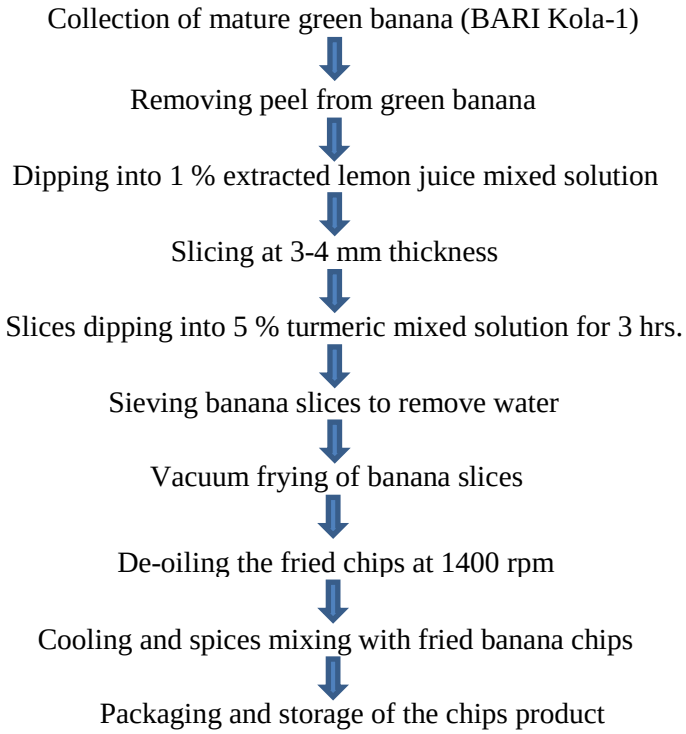

Figure 1. Diagram for the processing of vacuum fried banana chips

Spices preparation

For improving the palatability taste of the VF banana chips suitable spices was prepared with the combination of different spices ingredients. For spices combination mixed salt, sugar, garlic, red chili and garlic fine powder (Sieve size, 80 micron) were processed by drying, grinding and sieving. The garlic bulbs were blanched for 3 minutes and dried at 60-70°C in the cabinet dryer upto overnight. Red chili was not blanched but dried for overnight at the same temperature in the cabinet dryer. Salt powder (41.67%), sugar powder (47.67%), red chili powder (8.33%) and garlic powder (8.33%) were combined and mixed by blender properly (Table 1 & Table 2).

Measurements of external appearance

On the basis of methods described by Dervisi *et al.* (2001), the external color of the chips was evaluated with a Chroma Meter (Model CR-400, Minolta Corp., Japan). CIE $L^*a^*b^*$ coordinates were recorded using D65 illuminants and a 10° standard observer as a reference system. L^* is lightness, a^* (-greenness to +redness) and b^* (-blueness to +yellowness) are the chromaticity coordinates. The a^* and b^* values were converted to chroma [$C^*=(a^{*2} + b^{*2})^{1/2}$] and hue angle [$H^*=\tan^{-1}(b^*/a^*)$]. Before

the measurement, the equipment was calibrated against a standard white tile. Then, it was assimilated to measure the values of L*, C* and H* and was replicated three times for each treatment.

Measurements of moisture content

Moisture content was determined according to the method described by Ranganna (2007) with slight modification. Five gram of sample was taken in crucible and was placed in an oven dryer at 75°C for 72 hrs. until constant weight attained. Percent moister content was calculated using the following formula:

$$Moisture\ content\ (\%) = \frac{\text{Loss in weight}}{\text{Initial weight of sample}} \times 100$$

Measurements of texture

Textural properties of fried banana chips product were determined to estimate resistance by a texture analyzer (Stable Micro System, Godalming, UK). The analyzer prove (p-5) was directly inserted in the middle of the chips by the back extrusion method. The instrument working parameters were determined by the test mode compression with test speed at 1 mm/s and a distance of 2 cm. The analysis of the data was measured by Texture Exponent Lite version 6.1.14.0 software (Stable Micro System, Godalming, UK) to determine the rupture force and stated as Newton, N.

Measurements of vitamin-C content

Ascorbic acid (vitamin-C) content was determined according to Ranganna (2007) using 10 g samples blended for 2 minutes and homogenized with 50 mL of 3% cold meta-phosphoric (HPO_3) acid. Now, the samples were filtered through Whatman filter paper No#2. The clear supernatant samples were collected for assaying ascorbic acid and then 10 mL of aliquot samples was titrated with 0.1% 2,6-dichlorophenolindophenol solution until the filtrate changed to pink color persisted at least 15 seconds. The titer value was recorded for each aliquot sample. Prior to titration 2,6-dichlorophenolindophenol solution was calibrated by ascorbic acid standard solution. The results were expressed as mg/100g.

Measurements of fat content

The fat content was determined by the soxhlet extraction device and the method was followed as described by Ranganna (2007). The fat content was determined quantitatively by gravimetric method by extraction with a mixture of chloroform and methanol (2:1). Five grams of dried powder sample was taken in round joint flask and mixed with chloroform and methanol (2:1). Then, it was incubated at room temperature overnight. Then, the filtration was carried out until the color becomes clear (Color of the substance on the filter paper would be colorless). The filtrate sample was taken in a conical flask of known weight with boiling chips. Then the sample was heated in a chamber until the solvent was evaporated and dried in an oven at 105^{o}C for 3-4 hrs. Finally, weight of the conical flask was recorded.

Sensory evaluation

For evaluating the changes of the sensory quality attributes of the VF banana chips products of different frying temperature and time combination, few panel tests were performed at one month interval during storage period. Based on a 0-9 hedonic scale the highest response was marked and comments of the expert persons (15) were documented for quality improvement as per the procedure of Joshi (Joshi, 2006). A judgment panel was formed comprising of twenty expert members from the BARI inter-divisional scientists and different age grouped people to evaluate external appearance, taste, aroma, crispiness and overall acceptability of the finishd products.

Statistical analysis

All data was expressed in duplicate as means±standard deviation. One-way ANOVA with posthoc by Tukey Multiple Comparison Test was used to evaluation of the recorded data. The connotation was stated at the 95% confidence level. Statistical analysis and data processing were performed using software SPSS 17.0 (IBM INC., New York).

Results and Discussion

Effects on external appearance at different frying conditions during storage

Visual appearance of a product is a major quality criterion for determining the commercial quality with respect to consumers' preferences and marketability of the chips. Consumer perception of processed products depends mostly on the appearance and organoleptic characteristics. The products color may vary from process to process. To develop vacuum fried banana chips in the pretreatments,

dipping solution of lemon juice and turmeric power were performed to exhibit natural attractive yellow color and add natural preservative effects. In that case, white banana flesh turned into bright yellow color and after frying, it turned into deep yellow to shiny yellow color. In the study, it was observed that with the increasing of frying temperature and time VF banana chips color became lighter due to increasing glossiness of the products. The lowest lightness (L*) (65.96±0.76) was observed in treatment T_1 (110°C & 8 min) because of incomplete frying and oil absorption of fried banana chips and the highest lightness (L*) (76.43±0.85) was noticed in treatment T_9 (130°C & 12 min) (Table 1). It was occurred due to longer frying time with higher temperature so de-pigmentation was happened. Lightness value indicated the significant differences with different frying temperature and time. It was also stated that the lightness of fried chips became darker during product stored in HDPE packet where moisture was absorbed in the fried chips. The lightness values of all treatments became decreased from their initial value with storage (Table 3). The changes in color during frying were the results of starch gelatinization and non-enzymatic browning reactions (Richardson and Hyslop, 1985; Shyu and Hwang, 2001; Garayo and Moreira, 2002).

Chroma value is the departure degree of a color from the neutral color of the same value. Chroma, measured radially from the center of each slice, represents the "purity" of a color (related to saturation), with lower chroma being less pure. Therefore, the lowering of the chroma value indicated the lowering of the bright color into blemishes. There were significant changes in the chroma value for each treatment along with storage period also. In Table 4, treatment T_1 (110°C & 8 min) showed the more deviation from the initial chroma value (41.58±0.11) to (29.39±0.35) whereas treatment T_6 (120°C & 12 min) retained the more natural color after 6 months of storage. This variation might be due to the differences in the transmittance of light through the nano pores of the packages used in the experiment. Generally, polypropylene films are clear and more transparent than other polymer films. Hence, the light is able to enter into the package and influence the color of the packaged material (Kirwan and Strawbridge, 2003).

Hue (H*) value was statistically significant and increased when frying temperature and time increased but during storage it decreased day by day. At different frying temperature and time the hue angle ranged from 92.72 to 97.27. However, after 6 months of storage, the hue value (H*) of the stored banana chips of treatment T_1 (110°C & 8 min) and T_9 (130°C & 12 min) decreased as 85.55±1.19 to 84.13±0.51, respectively indicated that the products started to lose its initial bright yellow color (Table 5). The stored products finally turned into faded out in each treatments. This might be due to an increase in moisture content by perforation of packaging materials, reduction of carotenoid and the light penetration of the transparent HDPE packet. Rhim and Hong (2011) reported that the red color of the pepper became pale and tarnished black due to an increase in water activity, moisture content and storage temperature.

Moisture content changes at different frying conditions during storage

Initially, the moisture content of fresh banana was observed 86%. From the observation (Table 6), it was found that an increase in the oil temperature resultant in a significant reduction ($p<0.05$) of moisture retention of the fried banana chips with the same pressure. In Table 6, it was also noticed that the VF banana chips fried at lowest temperature in treatment T_1 (110°C for 8 min) contained the highest moisture content (8.69%) than chips fried at highest temperature in treatment T_9 (130°C for 8 min) (1.20%). During storage, as the fried banana chips were packaged in HDPE packet there was the absorption of moisture by penetration where the moisture content attained prominently from 4.02% to 9.88% among the treatments.

Firmness changes at different frying conditions during storage

In case of firmness, the maximum (0.54 N) was observed in treatment T_1 (110°C for 8 min) and the minimum (0.26 N) was found in treatment T_3 (110°C for 12 min) (Table 7). The increase in breaking force at the end of storage period was 0.93 N and 1.28 N in the treatments T_9 (130°C for 12 min) and T_1 (110°C for 8 min), respectively. The increase in moisture content and water activity during the storage period might have influenced the breaking force. Hence, the breaking force is directly influenced by water vapor transmission characteristics of film. Ammawath *et al.*, (2002) observed the increase in breaking force of banana chips which was stored in polypropylene film packet during storage.

Vitamin C content changes at different frying conditions during storage

Vitamin C (Ascorbic acid) is an important nutritional parameter for fried food products. Thermal degradation of total ascorbic acid increased with increasing frying temperature-time of fried banana chips. Reduction in ascorbic acid content is possible in the absence of oxygen and at relatively low frying temperatures as it can follow an anaerobic pathway of non-enzymatic browning reactions (Dueik and Bouchon, 2011). It was observed the similar results that vitamin C reduced significantly in all treatments of VF banana chips during storage period. The highest ascorbic acid (15.23±0.55 mg/100g) was obtained in treatment T_1 (110°C for 8 min) and the lowest (12.29±12.29 mg/100g) was found in treatment T_9 (130°C for 12 min). During 6 months of storage, the ascorbic acid content reduced drastically in all treatments (Table 8). It might be due to influence of light, oxidation and metabolic action. The loss of vitamin C was described a linear relationship with temperature in vacuum-fried gold kiwi fruit (Diamante *et al.,* 2013).

Fat content changes at different frying conditions during storage

From the economic point of view and quality aspect, oil content of chips should be as low as possible. So, determination of oil content of chips was essential. Oil uptake appeared to be related to moisture content, as the oil content directly proportional to moisture loss. But after de-oiling the oil content reduced significantly. Pandey and Moreira (2012) reported that the de-oiling mechanism removed more oil from the potato chip's surface when the samples were centrifuged at a higher speed for a longer time. In this study, the oil content of prepared chips from BARI Kola-1 for 2 minutes de-oiling at 1400 rpm speed oil contentment reduced significantly that ranged from 17.85% to 8.46% (Table 9). After 6 month of storage, the fat content quietly lowered due to drying and moisture absorbance by the VF banana chips products. Centrifugation, however, resulted in a reduced oil uptake up to 73% in atmospheric fried chips and upto 64% in VF banana chips using speeds of 140-1000 rpm for 2-10 minutes by Dueik *et al.* (2012).

Sensory evaluation at different frying conditions during storage

To find out the best frying temperature-frying time combination, a 9-points hedonic score based on appearance, taste, aroma, crispiness and overall acceptability were performed by the expert sensory panel members. In Table 10, it was observed that at initial stage the highest overall acceptability score 8.2 (Like very much) was observed in treatments T_6 (120°C & 12 min) and T_8 (130°C & 12 min) and the lowest (4.4) was found in treatment T_1 (110°C & 8 min). After 6 months of storage, the maximum overall acceptability (6.8) was noticed in treatment T_6 (120°C & 12 min), T_8 (130°C & 10 min) and T_9 (130°C & 12 min) by the expert panelists. After 6 months storage, treatment T_1 (110°C & 8 min) was found lowest score (2.87) (Dislike very much) due to higher moisture content, less crispiness and fungal growth inside the packets (Table 10).

Table 1. Spices combination of vaccum fried (VF) chips product

Name of ingredients	Ingredient of spices (%)				
	Type-A	Type-B	Type-C	Type-D	Type-E
Salt powder	Control treatment (without spices)	28.57	41.67	20.00	80.00
Sugar powder		47.62	47.67	40.00	-
Garlic powder		23.81	8.33	-	-
Chili powder		-	8.33	-	20.00
Capsicum powder		-	-	40.00	-

Table 2. Consumer preference test of mixed spices for vacuum fried banana chips

Spices combination	Sensory attributes				
	Appearance	Taste	Aroma	Crispiness	Overall acceptability
A	6.90±0.84b	6.90±0.89b	7.00±0.55a	7.50±0.45a	7.08±0.38b
B	7.20±0.84ab	7.30±0.84a	6.90±0.89b	7.30±0.84a	7.18±0.68a
C	7.50±1.10a	7.40±0.89a	7.20±0.89a	7.40±0.84a	7.38±0.84a
D	7.40±1.58a	7.40±1.30a	7.00±0.84a	7.50±0.84a	7.33±0.94a
E	7.10±0.84ab	6.40±0.89b	6.10±0.84b	6.60±1.00b	6.55±0.73c

Hedonic scale: 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely

Table 3. Effect of frying temperature-time combination on lightness (L*) value of vacuum fried banana chips during 6 months of storage at ambient condition

Treatments	Lightness (L*) value			
	Initial	2 months	4 months	6 months
T_1	65.96±0.76d	59.18±0.55c	54.46±1.14d	49.45±0.86c
T_2	70.18±1.42cd	61.46±0.35bc	56.09±143cd	52.02±0.38bc
T_3	72.92±.08bc	64.66±1.09b	62.45±0.82bc	64.88±0.53a
T_4	71.28±0.94bc	71.57±1.11a	68.49±0.78ab	55.11±0.93b
T_5	72.68±0.77bc	71.65±0.98a	67.57±0.61ab	65.02±0.35a
T_6	75.91±1.82a	72.23±1.02a	70.27±0.75a	64.88±0.64a
T_7	72.27±1.57abc	72.73±0.58a	69.52±0.26ab	63.87±1.62a
T_8	75.29±1.20ab	72.78±1.40a	72.86±0.81a	65.29±0.11a
T_9	76.43±0.85a	73.90±0.30a	69.52±0.98ab	69.44±1.17a

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6=Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time10 min, T_9= Temperature 130° C & time 12 min.All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicates significant result ($p<0.05$).

Table 4. Effect of frying temperature-time combination on chroma (C*) value of vacuum fried banana chips during 6 months of storage at ambient condition.

Treatments	Chroma (C*) value			
	Initial	2 months	4 months	6 months
T_1	41.58±0.11c	30.86±1.20b	33.35±0.07c	29.39±0.35b
T_2	42.98±1.31bc	41.22±1.14a	41.99±0.15a	34.00±0.62ab
T_3	43.72±1.01abc	35.31±0.84b	36.62±0.20bc	33.45±0.15ab
T_4	45.20±0.46abc	43.35±0.59a	40.83±1.23ab	33.46±0.88ab
T_5	45.11±0.76abc	45.59±0.70a	42.76±0.25a	35.32±0.50ab
T_6	45.71±0.72ab	44.49±0.46a	43.33±065a	38.57±0.25a
T_7	45.20±0.03abc	43.29±1.09a	40.70±055ab	33.27±1.01ab
T_8	46.98±1.21ab	41.43±1.24a	40.92±1.38ab	34.00±0.57ab
T_9	47.06±0.20a	43.23±0.9a	41.12±0.59ab	33.58±1.36ab

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6= Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time 10 min, T_9= Temperature 130° C & time 12 min. All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c indicate significant result ($p<0.05$).

Table 5. Effect of frying temperature-time combination on hue angle (H*) value of vacuum fried banana chips during 180 days of storage at ambient condition

Treatments	Hue angle (H*)			
	Initial	60 days	120 days	180 days
T_1	92.72±0.32b	88.90±0.74b	89.18±0.62a	85.55±1.19ab
T_2	95.45±0.59ab	94.40±1.26a	87.29±0.10ab	82.04±0.71abc
T_3	95.48±0.49ab	93.40±0.31a	83.98±0.89b	86.52±0.68a
T_4	95.68±0.03ab	93.28±0.54a	86.79±0.28ab	81.22±0.74bc
T_5	96.83±0.30a	93.53±0.97a	87.68±0.30ab	82.97±1.17abc
T_6	96.30±0.51a	94.70±0.63a	89.10±0.59a	83.64±0.49abc
T_7	95.05±0.45ab	95.06±0.59a	84.44±1.50b	80.25±1.12c
T_8	94.16±0.71ab	92.48±0.38b	87.47±0.50ab	85.75±0.39bc
T_9	97.27±0.27a	93.51±0.97a	84.29±1.08b	84.13±0.51abc

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6=Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time10 min, T_9= Temperature 130° C & time 12 min. All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicates significant result ($p<0.05$).

Table 6. Effect of frying temperature-time combination on moisture content (%) of vacuum fried banana chips during 6 months of storage at ambient condition

Treatments	Moisture (%)			
	Initial	2 months	4 months	6 months
T_1	8.69±0.05a	8.87±0.07a	9.87±0.05a	9.88±0.01a
T_2	5.40±0.02b	5.55±0.05b	5.83±0.02b	5.91±0.06b
T_3	3.96±0.03c	4.27±0.02c	4.33±0.03c	4.98±0.03c
T_4	4.06±0.05c	4.18±0.01c	4.60±0.02d	5.26±0.06b
T_5	2.54±0.08d	2.74±0.02d	3.55±0.01e	4.62±0.03e
T_6	2.31±0.1d	2.65±0.01d	3.46±0.02f	4.03±0.01f
T_7	2.49±0.18d	2.67±0.06d	3.27±0.05g	4.60±0.01e
T_8	1.24±0.07e	1.86±0.07e	3.27±0.01g	4.56±0.01e
T_9	1.20±0.03e	1.62±0.01f	3.25±0.02g	4.08±0.02f

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6=Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time10 min, T_9= Temperature 130° C & time 12 min. All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicates significant result ($p<0.05$).

Table 7. Effect of frying temperature-time combination on firmness (N) of vacuum fried banana chips during 6 months of storage at ambient condition

Treatments	Firmness (N)			
	Initial	2 months	4 months	6 months
T_1	0.54±0.03a	1.14±0.09a	1.16±0.12a	1.28±0.06a
T_2	0.28±0.03cd	0.64±0.02bc	1.10±0.11a	1.25±0.20a
T_3	0.26±0.04d	0.51±0.06cd	0.58±0.13c	0.84±0.01b
T_4	0.38±0.03b	0.59±0.04cd	0.70±0.03bc	0.95±0.03b
T_5	0.35±0.04bc	0.60±0.03bcd	0.70±0.03bc	0.82±0.03b
T_6	0.32±0.03bcd	0.48±0.05d	0.73±0.01bc	0.92±0.04b
T_7	0.33±0.02bc	0.75±0.05b	0.95±0.11b	0.98±0.05b
T_8	0.32±0.02bcd	0.52±0.03cd	0.76±0.09bc	0.95±0.01b
T_9	0.31±01bcd	0.62±0.04bcd	0.80±0.06bc	0.93±0.01b

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6= Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time 10 min, T_9= Temperature 130° C & time 12 min. All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicate significant result ($p<0.05$).

Table 8. Effect of frying temperature-time combination on vitamin C content (mg/100g) of vacuum fried banana chips during 6 months of storage at ambient condition

Treatments	Vitamin C (mg/100g)			
	Initial	2 months	4 months	6 months
T_1	15.23±0.55bc	8.03±0.50d	5.52±0.27d	2.27±0.25e
T_2	19.22±0.99a	14.67±0.64a	5.88±0.01d	2.02±0.12e
T_3	15.85±0.30b	15.22±1.42a	5.81±0.07d	3.46±0.44cd
T_4	15.21±0.50bc	12.09±0.32b	5.85±0.03d	3.39±0.18cd
T_5	13.75±0.49cd	12.25±0.05b	9.17±0.73b	4.38±0.44ab
T_6	14.97±0.50bc	12.87±0.32b	10.10±0.18a	4.83±0.08a
T_7	13.20±0.78d	11.30±0.14bc	9.09±0.52b	4.95±0.22a
T_8	12.59±0.25d	8.17±0.31d	5.82±0.05d	4.02±0.21bc
T_9	12.29±0.21d	9.57±0.56cd	6.90±0.12c	3.25±0.12d

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6= Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time 10 min, T_9= Temperature 130° C & time 12 min. All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicate significant result ($p<0.05$).

Table 9. Effect of frying temperature-time combination on fat content (%) of vacuum fried banana chips during 6 months of storage at ambient condition

Treatments	Fat (%)			
	Initial	60 days	120 days	180 days
T_1	17.85±0.27	14.16±0.12	12.26±0.18	11.12±0.10
T_2	13.81±0.05	11.97±0.07	10.31±0.11	11.00±0.36
T_3	10.37±0.36	10.54±0.00	9.64±0.05	9.65±0.50
T_4	11.75±0.05	10.43±0.15	10.01±0.02	9.74±0.30
T_5	8.27±0.15	8.28±0.06	7.49±0.02	6.95±0.03
T_6	8.26±0.16	8.24±0.05	7.04±0.09	6.87±0.03
T_7	8.61±0.14	8.52±0.07	6.85±0.22	6.32±0.12
T_8	8.58±0.03	8.25±0.01	7.28±0.06	7.85±0.01
T_9	8.46±0.18	8.62±0.16	7.71±0.23	7.82±0.02

Note: T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6= Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time 10 min, T_9= Temperature 130° C & time 12 min. Hedonic scale: 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely.

Table 10. Consumer preference test of the vacuum fried banana chips during 6 months of storage at ambient condition

Treatments	Initial					After 6 months				
	APR	Taste	Aroma	CRS	OAT	APR	Taste	Aroma	CRS	OAT
T_1	6.00±0.71d	3.60±1.95e	5.00±1.87e	2.80±1.30e	4.35±0.98d	Spoiled	Spoiled	Spoiled	Spoiled	Spoiled
T_2	7.00±0.71c	5.90±1.68d	6.60±0.89d	5.40±1.34d	6.23±0.58c	6.80±0.45b	5.00±1.00d	5.10±0.89e	4.30±0.45e	5.30±0.48d
T_3	7.40±0.55b	7.00±1.22c	7.60±0.55c	7.20±0.84c	7.30±0.41b	7.04±0.09a	5.40±0.55d	6.30±0.45b	4.90±0.22d	5.91±0.22c
T_4	7.40±0.55b	7.00±1.22c	7.60±1.14c	7.00±1.41c	7.25±0.98b	6.80±0.45b	6.40±0.55c	5.90±0.74d	6.00±0.01c	6.28±0.26b
T_5	7.20±0.45c	7.00±1.22c	7.60±1.14c	7.00±1.41c	7.20±0.89b	7.20±0.50	6.50±0.48bc	6.00±0.82c	6.10±0.25c	6.45±0.37b
T_6	8.00±0.71a	7.80±0.84b	8.20±1.30a	8.60±0.55a	8.15±0.72a	7.30±0.50a	6.90±0.63a	6.80±0.50a	6.30±0.50b	6.83±0.41a
T_7	7.60±0.55ab	7.80±0.45b	7.80±1.10b	8.20±0.45ab	7.85±0.49a	7.20±0.27a	6.30±0.45bc	6.40±0.42b	6.30±0.27b	6.55±0.23b
T_8	7.80±0.84a	8.20±0.45a	8.00±1.00a	8.40±0.55b	8.10±0.45a	7.20±045a	6.60±0.55b	6.80±0.45a	6.40±0.55a	6.75±0.40a
T_9	7.80±0.45a	8.20±0.84a	7.60±0.89c	8.60±0.55b	8.05±0.62a	7.00±0.71a	6.80±0.57a	6.80±0.45a	6.54±0.55a	6.79±0.42a

Note: APR=Appearance, CRS=Crispiness, OAT=Overall acceptability, T_1= Temperature 110° C & time 8 min, T_2= Temperature 110° C & time 10 min, T_3= Temperature 110° C & time 12 min, T_4= Temperature 120° C & time 8 min, T_5= Temperature 120° C & time 10 min, T_6= Temperature 120° C & time 12 min, T_7= Temperature 130° C & time 8 min, T_8= Temperature 130° C & time 10 min, T_9= Temperature 130° C & time 12 min. Hedonic scale: 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely.

Hedonic scale: 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely.

Conclusion

The main purpose of the experiment was to optimize the vacuum fried banana chips processing protocol for preparing quality banana chips at suitable frying temperature-time combination with shelf life study for six months storage in HDPE packet (60 micron) at ambient temperature (27±2°C, 75±5%RH). Without proper processing, banana turns into grayish black rapidly due to catalase enzymatic action that hampered the appearance of the VF banana chips products. That is why, the application of 1% lemon water solution and 5% turmeric powder mixed water dipping helps to develop attractive natural color as well as worked as natural preservatives. For increasing spicy and palatability taste, different spices combination was added with VF banana chips after frying. According to the sensory panelist on the basis of appearance, texture, flavor and overall acceptability score of the treatments T_6 (120° C & 12 min) performed better among treatments combinations. After six months of storage, VF banana chips stored in HDPE packet exhibited 'like slightly' by the consumer preference test. But, VF banana chips can be stored in laminated metalex foil packet with flashing nitrogen for longer storage and it will retain better quality for more than 8 months. These

findings will support the applicability of vacuum frying technology to provide good quality banana chips from BARI Kola-1 variety with appropriate processing. This technology will add value in agro-processing industry for producing quality banana chips and will assist to reduce postharvest loss of banana of our country. The economic analysis will be conducted for further study.

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EFFECT OF SUGAR CONCENTRATION ON PHYSICOCHEMICAL PROPERTIES, BIOACTIVE COMPOUNDS AND SHELF LIFE OF OSMOTICALLY DEHYDRATED MANGO SLICES

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Abstract

The objective of this study is to investigate the effects of different sugar concentration on the physicochemical properties, bioactive compounds and shelf-stability of osmotically dehydrated mango slices. Fresh and semi-ripe mango of Himsagor cultivar was collected from the farmers' orchard and peeled with stainless steel knife. For this, three different concentration of sugar solution (50, 60 and 70^{o} Brix) were used for osmotic dehydration followed by mechanical drying at 60^{o}C. Results revealed that sugar concentration significantly affect the physicochemical parameters and bioactive compounds during storage. The moisture content of osmotically dehydrated mango slices increased from the initial 8.63-9.66% to final 11.22-12.98% after 6th month of storage, while the ash content was recorded as 2.72-3.22% and 2.36-2.53% on the beginning and the end of the storage period, respectively. Results also showed that the acidity was increased throughout the storage period in all treatments. The total sugar content was decreased throughout the storage period while reducing sugar was increased in all treatments. All the dehydrated mango slices retained considerable amounts of different bioactive compounds such as ascorbic acid, total carotenoids and total phenolic compounds and showed significant antioxidant properties after 6th month of storage. However, 50^{o}Brix sugar concentration showed higher nutritional quality, retained maximum bioactive compounds and showed better antioxidant properties after 6th month of storage at ambient temperature (27±2^{o}C,75±5%RH). Therefore, it can be concluded that it is possible to prepare dehydrated mango slices from semi-ripe mango commercially using 50^{o}Brix sugar solution and can be preserved more than 6th month at normal temperature without appreciable nutrient loss.

Introduction

Mango (*Mangifera indica* L.) ranks second among tropical fruits in global market after banana (Altendorf, 2017). The mango is native from southern Asia, especially Bangladesh, Myanmar and eastern India (Torres *et al.,* 2006). The fruit is an important source of vitamin C and it is rich in various phytochemicals including carotenoids and phenolic compounds (Ribeiro *et al.,* 2010). Along with fresh mango's trade expansion, the global demand for minimally processed mango products has been increasing (Hanemann *et al.,* 2017). These mild treated products feature an extended shelf-life with fresh-like characteristics, while maintain a high nutritional and health promoting value (Ciurzynska *et al.,* 2016). Mangoes are used in the preparation of different value-added products such as Amchur, leather, dried products, pickles, jam and so on. Therefore, mango has the great potential for value-addition for minimizing postharvest losses and enhancing the non-seasonal availability. Dehydration is one of the ancient methods of food preservation used in agro-processing industry (Kamal *et al.,* 2019). It is the method of protecting food from deterioration by reducing the moisture to a safe level that is unavailable to the microorganism for their growth and metabolism (Kamal *et al.,* 2020). The shelf life of dehydrated products is almost unlimited and the cost of transportation, handling and storage are considerably lower than that of other methods of preservation (Shishir *et al.,* 2019). In the recent years, several dehydration techniques such as mechanical drying, use of osmotic agents are frequently applied to foodstuffs. The mango is commonly preserved in the dried form in Asia, but conventionally dried mangoes have an undesirable tough texture, poor color and non-fresh flavor with a loss of nutritive value, which reduce its economic importance (Durance *et al.,* 1999; Yadav and Singh, 2014). There has been and increasing interest in osmotic dehydration (OD) of foods due to the low temperature (minimal heat damage) and energy requirements in addition to better retention of the initial nutritional and sensory characteristics in the final product (Sulistyawati *et al.,* 2020; Ahmed *et al.,* 2016; Ciurzynska *et al.,* 2016; Ramya and Jain, 2017). Osmotic dehydration of foods involves the immersion of fruit in concentrated solutions where both partial dehydrations of the fruit and solid uptake are obtained (Tiwari 2005; Bakhara *et al.,* 2018). Though osmotic dehydration followed by convective drying is an advanced progressive technology, however, osmotically dehydrated mango is not available in the country. Therefore, the present study has been undertaken to investigate the effect of different sugar concentration on the nutritional quality and shelf life of osmotically dehydrated mango slices which can be available throughout the year.

Materials and Methods

Collection and preparation of raw materials

Fresh and semi-ripe mango of Himsagar cultivar was collected from the farmers' orchard of Rajshahi district of Bangladesh. The mangoes were washed with running tap water, peeled and cut into slices. The slices were dipped into 0.6% potassium metabisulphite (KMS) solution to avoid excessive browning. Sugar was procured from the local markets. Analytical grade chemicals and reagents were purchased from the Merck, Germany through the local traders.

Preparation of osmotically dehydrated mango slices

The mango slices were first blanched in boiling water for 2-3 minutes and cooled immediately in ice water. The blanched slices were dipped into different osmotic solutions (50, 60, and 70^{o} Brix sugar solution) and keep in rest overnight. On the following day, the slices with the solution were heated for 10 minutes and the solution was drained out from the slice. Then, the slices were dried at 55-60^{o} C until the moisture content reached to <12% (wet basis). After drying, the mango slices were packed in high density polyethylene (HDPE packet) and stored at room temperature (27±2^{o}C, 75±5%RH). The shelf life of osmotically dehydrated mango slices was evaluated over six (6) month at 2 months interval (Figure 1).

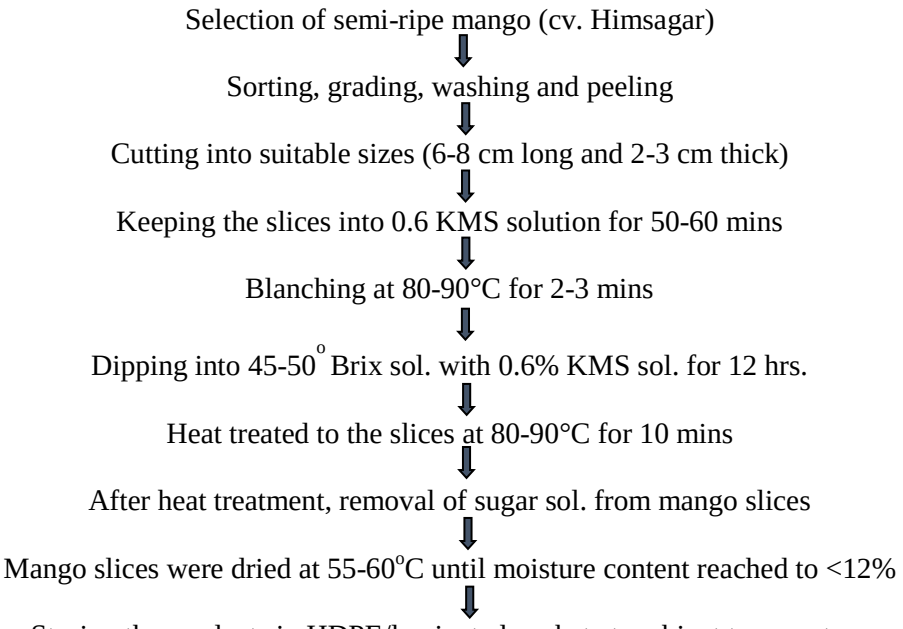

Figure 1. Preparation of osmotically dehydrated mango slices

Determination of physicochemical properties of mango slices

The moisture and ash content were determined based on the AOAC official methods (AOAC, 2005). Total soluble solids (TSS) was determined using digital refractometer. Total acidity was determined following the methods of Ranganna (2007). Firmness was measured using the texture analyzer (TX.PLUS, Stable Microsystem, Germany) and expressed as the newton (N). Total sugar content was determined following the procedure of Ranganna (2007). Color attributes were measured based on the CIELa*b* color coordinates using a Chroma meter (CR-104, Konica, Minolta, Japan), where L denotes the lightness, a* represents green/red, and b* implies blue/yellow.

Determination of bioactive compounds of mango slice

Ascorbic acid content was determined by 2, 6-dichlorophenolindophenol titrating methods following the description of Kamal *et al.* (2019) and the result was expressed as mg/100g. Total carotenoid was determined by the methods of Baria *et al.* (2019) with some modification. Total phenolic content was determined by spectrophotometer using Folin-Ciocalteu method following the procedure of Kamal *et al.* (2020) with slight modification using gallic acid as the standard, and the result was expressed as mg GAE/100g of sample.

Determination of antioxidant activity of mango slice

The antioxidant activity was evaluated in terms of DPPH free radical scavenging activity, which was expressed as percent inhibition (Kamal *et al.*, 2019). For this, 0.1 mL sample extract was mixed with 1.9 mL of 0.3 mM DPPH reagent and keep the mixture in dark place for 30 minute. After then the absorbance was measured at 517 ηm and the DPPH radical scavenging activity was determined following the equation below:

$$\%\ Inhibition = \frac{Absorbance_{Control} - Absorbance_{Sample}}{Absorbance_{Control}} \times 100$$

Statistical analysis

Statistical analysis was carried out using the software package SPSS (version 22.0, SPSS Inc., Chicago, IL) by using one-way analysis of variance (ANOVA). Duncan multiple range test (DMRT) at the significance level 5% ($P<0.05$) was used to determine significant differences among samples.

Results and Discussions

Changes in physicochemical properties of osmotically dehydrated mango slice

The changes in the physicochemical properties of osmotically dehydrated semi-ripe mango slices are presented in Table 1. It has been found that moisture become increased during the storage period and ranged between 9.66-12.97%, 8.63-12.06% and 8.98-11.22% for dehydrated mango slices obtained at 50^o, 60^o and 70^oBrix sugar solutions, respectively (Table 1). The results also showed a significant difference existent among the moisture content of different samples over the storage period. Initially, the highest moisture (9.66%) was recorded in dehydrated mango slices prepared using 50^oBrix sugar solution and the lowest (8.63) in 60^oBrix, while it was the maximum (12.97%) in 50^oBrix and minimum (11.22%) in 70^oBrix sugar solution after 6 months of storage. Table 1 also showed that moisture content significantly increased with the storage period increased, which might be due to absorption of moisture by the dried sample as a function of environmental issues e.g. differences in humidity over the storage period. The mineral substances present in any foodstuffs are reflected by its ash content. The values for ash content of osmotically dehydrated mango slices were showed in Table 1. The ash content of osmotically dehydrated mango slices were ranged from 2.72-3.22% and 2.36-2.53% on the beginning and the end of the storage period, respectively. The maximum and minimum ash was found in 50^oB (3.22%) and 60^oB (2.72%) sample at the beginning and it was the highest in 70^oB sample (2.53%) and the lowest in 60^oB sample (2.36%) at the end of storage period. It can be seen that ash content of 60^oB and 70^oB sample did not differ significantly, but differed with 50^oB samples at the initial stage of storage. However, 50^oB and 60^oB sample did not differ significantly, but differed with 70^oB sample. The total acidity of the dehydrated mango slices were summarized in Table 1, which showed that the prepared samples were very low in acid content and ranged between 0.42-1.03% on the processing day and 1.94-2.06% after 6^{th} month of storage. It was found that the values of the total acidity significantly differed among the samples irrespective of storage periods (Table 1). The maximum and minimum acidity was found in 50^oB sample (1.03%) and 70^oB sample (0.42%), at the beginning and it was the highest in 70^oB sample (2.06%) and the lowest in 60^oB sample (1.94%) at the end of storage period. It was found that the acidity of the prepared sample was increased in all samples with the storage period.

The sugar content in dehydrated mango slices obtained in this study is shown in Table 1. It was observed from Table 1 that the reducing sugar content was ranged between 8.01-8.47% on the processing day while it was recorded in the range of 13.71-14.81% after 6 months of storage. It is clearly demonstrated in Table 1 that the reducing sugar showed an increasing trend throughout the storage period (Table 1). On the other hand, the total sugar content followed decreasing trends during the storage period. It was observed from Table 1 that total sugar content of dehydrated mango slices varied between 38.05-41.08% and 31.81-34.75% initially and at 6 months of storage, respectively. Since the contained sugars in mango mostly are starch, it might be the degradation of starch and carbohydrate into simpler sugar molecules due to the action of heat and reactions with other component present in the sample (Rahman *et al.*, 2012). Furthermore, the increasing trends of reducing sugar in jackfruit leather might be conversion of total and non-reducing sugars by acid hydrolysis and thereby inversion of total and non-reducing sugars to reducing sugars (Rahman *et al.*, 2012; Meyer 1966 and Roy and Singh, 1979).

Another important property of dehydrated mango slices is its firmness with very hard or soft sample significantly influences the quality of the product. In the present study, the hardness of dehydrated mango slices are presented graphically in Figure 1 and found to range between 26.16-31.76 N and 41.08-56.10 N on the processing day and after 6 months of storage. It can be seen that the hardness value become increased with the storage period and were differed significantly at $p<0.05$ for all sample. However, with extension of storage period, it can be seen that sample prepared using 50^{o}Brix sugar solution represents more softness compared to other dehydrated mango slices. The variation in the firmness of dehydrated mango slices might be the extent of drying that significantly reduced the moisture from the sample than the others and created a slight hard (rubbery) texture, which increased the firmness value.

Color attributes

Color is considered as one of the key quality parameter that influences the consumer to decide whether purchase or not. The changes in the color properties of dehydrated mango slices in terms of lightness (L), green/redness (a*), and blue/yellowness (b*) are presented in Table 2. Results revealed that the brightness (L) of prepared dehydrated mango slices were ranged from 48.68-62.78 on the initial storage day and it was in the range of 37.49-49.25 after 6 months of storage. It was found that the L values of dehydrated mango slices were decreased with the storage period increased upto 6 months. It is also observed from Table 2 that the lightness value increased with the increased sugar concentration used for the preparation of the dehydrated mango slices. The lightness value of prepared the sample was also found to vary significantly among the treatments or samples irrespective of storage period.

From Table 2, it was observed that the values of a* (green/redness) was irregularly varied among the dehydrated mango slices prepared using different sugar concentration. It was recorded that the a* values were differed significantly ($p<0.05$) among the samples throughout the storage period and ranged from initial 4.09-5.66 to 3.92-6.37 after 6th month of storage, which showed a slight greenish red color of the dehydrated mango slices. This change might be due to the use of semi-ripe mango slices during the preparation of dehydrated mango slices. On the other hand, the b* (blue/yellowness) values were found to range between 33.73-43.23 and 28.89-36.96 on initially and after 6 months of storage, respectively (Table 2). These values are indicative of faint yellowness of the osmotically dehydrated mango slices. It is observed from the Table 2 that the yellowness of the dehydrated mango slices were reduced with the storage period, which might be due to the degradation of yellow pigmented substances due to reaction with sugar molecules and also during the drying process. Furthermore, previous study reported that the color changes in dehydrated products was evidenced due to different factors like heat, light, chemical reaction of the constituents and so on (Kamal *et al.,* 2020).

Bioactive compounds and antioxidant activity

The bioactivities of any products is comprised with its content of different compounds such as, ascorbic acid, phenolic compounds, carotenoids and so on (Molla *et al.,* 2021, Kamal *et al.,* 2019). These compounds also reflect their ability to fight against different degenerative diseases. Ascorbic acid is considered as one of the important bioactive compounds present in food matrix. The content of ascorbic acid present in dehydrated mango slices is represented in Figure 3. It is seen that ascorbic acid sharply decreased during the storage period and found to differ significantly ($p<0.05$). Initially, the ascorbic acid was ranged from 19.28-22.20 mg/100g to 11.86-13.93 mg/100g after 6 months of storage. The maximum ascorbic acid was recorded in sample prepared using 50^{o}Brix sugar solutions while the minimum in 70^{o}Brix. It is evidenced from the previous studies that the ascorbic acid is the most unstable molecule, which become lost due to the actions of heat, oxygen, light and the reaction with metal ions (Mondal *et al.,* 2017; Kamal *et al.,* 2019 and Molla *et al.,* 2021).

Previous researches demonstrated that the carotenoid has a crucial implication in the regulation of different functionalities in human body and regulate the health by reducing the risks of cancer and heart diseases because of the activity of pro-vitamin A (Chang *et al.,* 2002). The total carotenoid content in dehydrated mango slices obtained in this study is shown in Figure 4. It is observed in Figure 4 that the total carotenoids among the samples ranged between 8.01 to 9.47 mg/100g on the processing day while it was fluctuated within 2.08 to 3.01 mg/100g after the final storage period (6 months). Total carotenoids content followed a decreasing trends throughout the storage periods, being the maximum carotenoids were recorded sample prepared using 50^{o}Brix sugar

solution while the minimum in 70°Brix. It is clearly revealed in Figure 4 that the total carotenoids showed a significantly variation among the samples throughout the storage period. Previous studies reported that carotenoid pigments are heat and light sensitive elements, which degraded during the processing operations e.g., drying significantly alter the pigments in foodstuffs along with other factors like heat, light, and the presence of metallic substances (Mezzomo and Ferreira, 2016; Kamal *et al.*, 2019 and Molla *et al.*, 2021). Moreover, carotenoids in foodstuffs are swayed by numerous reasons such as, soil conditions, fruit maturity, enzymes, phenolic content, genomic features etc. (Molla *et al.*, 2021).

Polyphenols are considered as the major bioactive substance present in foodstuffs. Their content determines the biological functionality against chronic diseases like cancer, cardiovascular dysfunctions, inflammations etc. (Kamal *et al.*, 2019). Total polyphenols content recorded for dehydrated mango slices prepared are showed in Figure 5 and found to range from 1258 to 1435 mg GAE/100g on the processing day which was fluctuated between 728 to 814 mg GAE/100g after 6 months of storage. It was observed from Figure 5 that the total phenolic content became decreased with the storage period increased and found to vary significantly among the samples irrespective of storage period (Figure 5). Dehydrated mango slices prepared using 50°Brix sugar solution retained the maximum total phenolic compounds compared to the remaining sample which means less phenolic are degraded at lower concentration of sugar used for preparing dehydrated mango slices. It is evidenced that the liberation of polyphenolic substances is associated with chemical structure (bound to the plant matrix) that induced by the heat treatment (Tan *et al.*, 2019). The content of total phenolic also influenced by the conjugation of polyphenols with other components of food matrices including proteins, sugar, organic acids and so on (Xu *et al.*, 2007 and Kamal *et al.*, 2020).

The antioxidant ability of dehydrated mango products was evaluated by the DPPH free radical scavenging activity (DPPH-RSA) and expressed as the percent inhibition. The results obtained for DPPH-RSA of dehydrated mango products is presented in Fig. 6 and found to decrease continually with the storage period increased. Initially, the DPPH-RSA of dehydrated mango products ranged between 58.75-64.83%, which reduced to the range of 38.48-44.74% after 180 days of storage (Figure 6). However, all samples showed significant antioxidant activity, being the maximum was observed in samples prepared using 50°Brix sugar solution (Figure 6). It is reported in previous studies that antioxidant capacity of osmotically dehydrated mango products reflected by its content of different bioactive compounds, which is corroborated by the finding of this study. However, the decrease in antioxidant activity may occurred due to the reaction of different enzymes such as polyphenol oxidase along with the degradation of different bioactive compounds that the significantly reduced the antioxidant capacity of dehydrated mango products (Kulkarni & Aradhya, 2005).

Table 1. Changes in physicochemical properties of osmotically dehydrated semi-ripe mango slices during 6 months of storage at ambient condition

Parameters	Sample (°Brix)	Storage period			
		Initial	2 Months	4 Months	6 Months
Moisture (%)	50	9.66±0.23a	10.27±0.67a	11.22±0.38a	12.97±0.12a
	60	8.63±0.05cb	9.22±0.49a	9.57±0.15b	12.06±0.36ab
	70	8.98±0.30ab	9.27±0.37a	10.87±0.25a	11.22±0.38b
Ash (%)	50	3.22±0.08a	3.10±0.05a	2.85±0.14a	2.41±0.02b
	60	2.72±0.04b	2.75±0.04a	2.40±0.04b	2.36±0.01b
	70	2.78±0.11b	2.74±0.19a	2.29±0.07b	2.53±0.04a
Total acid (%)	50	1.03±0.01a	1.10±0.01a	1.19±0.01a	2.02±0.07a
	60	0.88±0.03b	0.98±0.01b	1.11±0.01a	1.94±0.07a
	70	0.42±0.01c	0.51±0.01c	0.98±0.06b	2.06±0.03a
Reducing sugar (%)	50	8.01±0.01ab	12.26±0.02a	14.21±0.33a	14.17±0.13b
	60	8.47±0.02a	12.76±0.26a	14.16±0.35a	14.81±0.04a
	70	8.17±0.08ab	12.51±0.33a	12.80±0.27b	13.71±0.27b
Total sugar (%)	50	41.08±0.80a	40.59±0.53a	33.91±0.20a	31.81±0.11c
	60	39.57±0.06ab	37.66±0.46b	34.29±0.11a	33.95±0.10b
	70	38.05±0.03b	36.77±0.43b	34.01±0.12a	34.75±0.18a

Values are mean ± standard error of mean (n=3). Means followed by different lowercase letters in each column are significantly different at P<0.05.

Table 2. Changes in color attributes of osmotically dehydrated semi-ripe mango slices during 6 months of storage at ambient condition

Parameters	Sample (°Brix)	Storage period			
		Initial	2 Months	4 Months	6 Months
L	50	48.68±0.36b	46.45±1.18b	40.60±0.64b	37.49±1.07b
	60	59.08±0.95a	52.16±1.70a	46.31±0.82a	40.42±0.25a
	70	62.78±3.01a	60.55±2.02a	55.92±0.05a	49.25±0.43a
a*	50	4.09±0.09b	3.92±0.83b	4.20±0.09c	4.46±0.28b
	60	5.33±0.23a	4.28±0.10ab	5.92±0.18b	3.92±0.48b
	70	5.66±0.04a	5.70±0.08a	7.92±0.03a	6.37±0.70a
b*	50	33.73±0.33c	29.97±1.54b	35.97±0.30b	28.89±1.37b
	60	43.23±0.53a	36.37±3.59ab	33.16±0.40c	34.55±1.48ab
	70	41.62±0.41b	41.81±0.74a	41.25±0.31a	36.96±2.12a

Values are mean ± standard error of mean (n=3)
Means followed by different lowercase letters in each column are significantly different at P<0.05.

Conclusion

In this study, the osmotically dehydrated mango products were prepared using three different concentrations (50, 60, and 70°Brix) of sugar solution. Results revealed that all samples contained significant amount of nutritional and bioactive compounds. However, the less nutrient and non-nutrient compounds were lost when lower concentration of sugar solutions was used. Overall, the sample prepared using 50°Brix sugar solution performed better and retained considerable amounts of nutrients and bioactive compounds with antioxidant properties during 6 months of storage at ambient condition.The economic analysis will be conducted & presented next year.

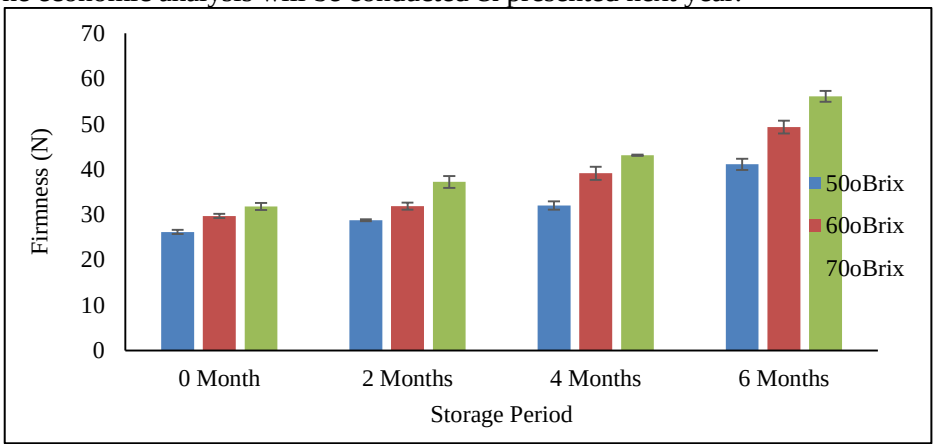

Figure 2. Changes in firmness (N) of dehydrated mango slices during 6 months of storage

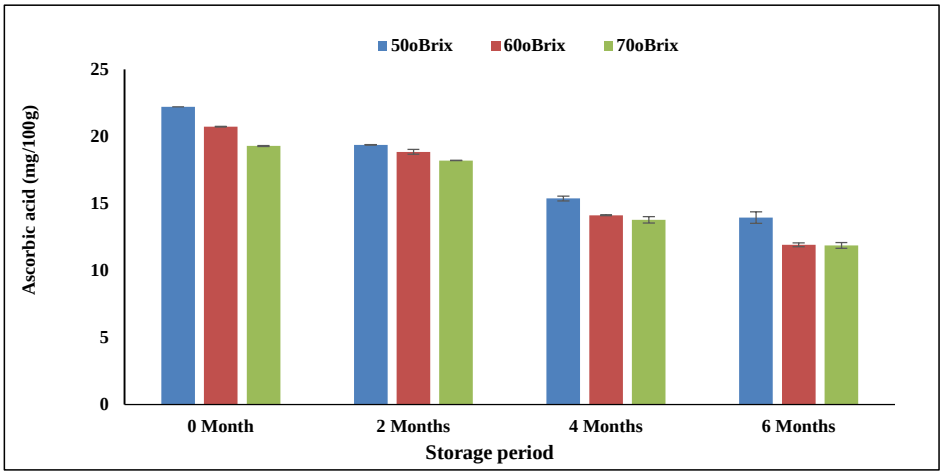

Figure 3. Changes in ascorbic acid (mg/100g) of dehydrated mango slices during storage

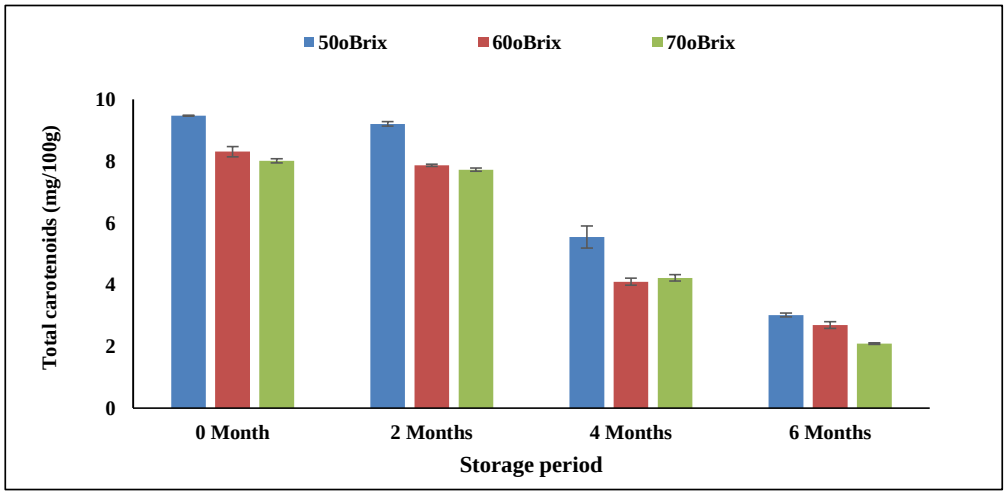

Figure 4. Changes in total carotenoids (mg/100g) of dehydrated mango slices during storage

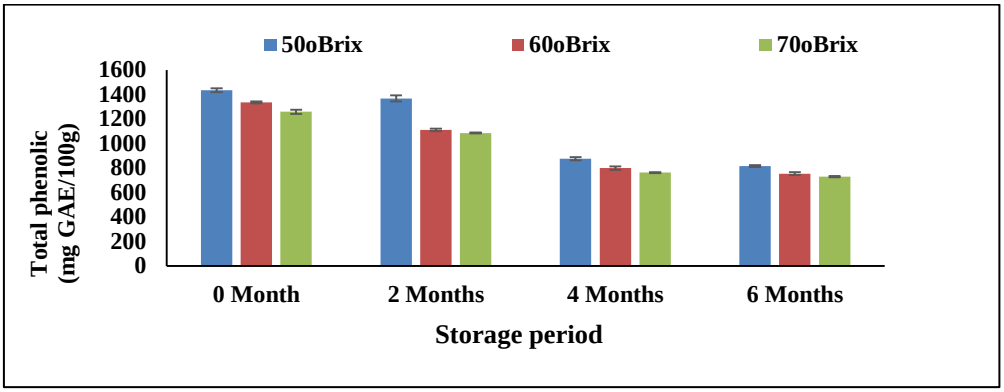

Figure 5. Changes in total phenols (mg GAE/100g) of dehydrated mango slices during storage

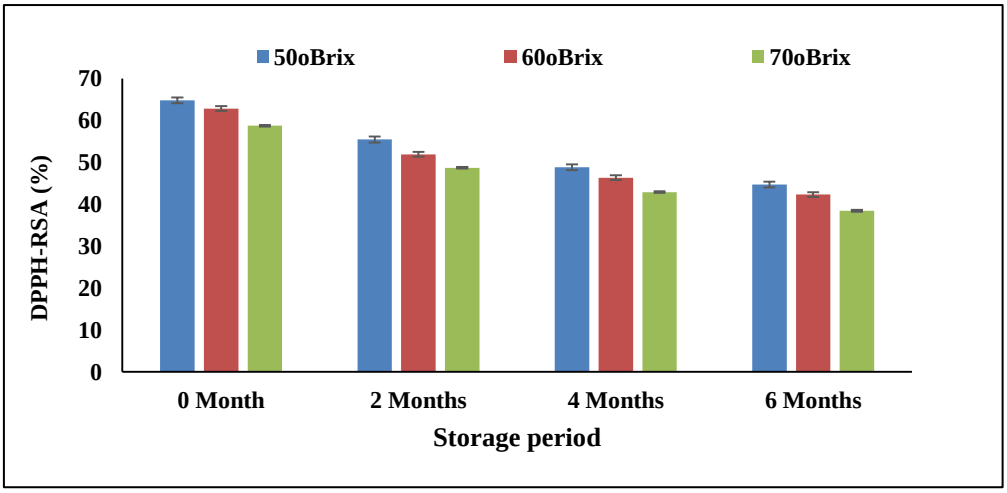

Figure 6. Changes in DPPH radical scavenging activity (% inhibition) of dehydrated mango slices during storage

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PHYSICOCHEMICAL PROPERTIES AND SHELF LIFE OF OSMOTICALLY DEHYDRATED JACKFRUIT SLICES

M.G.F. CHOWDHURY, M.H.H. KHAN, M. M. MOLLA, A.A. SABUZ, M.M. KAMAL

Abstract

The present study was carried out to preserve the jackfruit slices through osmotic dehydration techniques. Fully ripe jackfruit of khaja cultivar was collected from the farmer's orchard of Gazipur and then peeled and cut longitudinally to separate the bulb. For this study five different concentration of sugar solution (30, 40, 50, 60 and 70^{o}Brix) were used to squeeze out water from the jackfruit slices followed by drying in mechanical dryer. Results revealed that moisture content of osmotically dehydrated jackfruit slices increased slightly from the initial 5.87-7.42% to final 8.06-9.44% after 6th month of storage. The ash content was recorded by dehydrated jackfruit slices prepared using 30^{o}Brix (1.28%) sugar solution. Results also showed that the acidity was increased throughout the storage period in all samples. The total sugar content was decreased throughout the storage period while reducing sugar was increased in all the samples. All the dehydrated jackfruit slices contained significant amount of energy value (450.98 to 538.10 KCal/100g) after 6th month of storage; however, jackfruit slices prepared using 70^{o}Brix sugar showed the maximum calorific value. All the samples retained considerable amounts of different bioactive compounds such as ascorbic acid, total carotenoids, total phenols and showed significant antioxidant properties after 6th month of storage. The sensory evaluation revealed acceptable overall sensory qualities of dehydrated jackfruit, however, 60^{o}Brix sugar concentration showed higher acceptability than the other samples. Conclusively, the dehydrated jackfruit slice can be prepared commercially and preserved more than 6th month in high density polypropylene (HDPE packet) at ambient condition (26±2^{o}C, 75±5%RH) without appreciable nutrient loss.

Introduction

Among the tropical fruits, jackfruit is an important underutilized fruit and often called the poor man's fruit because of its affordability and availability in large quantities during the harvesting season. Jackfruit trees are mostly gown in the homestead garden without any management practices. It is the national fruit of Bangladesh which is grown almost in all districts. The annual production of jackfruit is about 10.02 lakh metric ton covering an area of 40.90 thousand acres during 2019-2020 (BBS, 2020). Jackfruit is nutritionally very rich and contains high amount of vitamins and minerals. The fruit is rich in carotene and carbohydrates and moderately rich in ascorbic acid. It also contains some minerals like calcium and potassium and vitamin B like thiamin, riboflavin, and niacin (Saxena *et al.*, 2009 and Swami *et al.*, 2012). Thus, jackfruit provides huge opportunity for livelihood as well as nutritional and food security of the rural communities of Bangladesh. Jackfruits can be processed into a variety of products such as canned fruit, dried fruit and pulp, jackfruit jam, dehydrated jackfruit, chips etc. (Swami *et al.* 2012; Swami and Kalse, 2019) Therefore, jackfruit has great potential for value addition for minimizing postharvest loses and enhancing the non-seasonal availability.

Dehydration is one of the ancient methods of food preservation used in agro-processing industry (Kamal *et al.*, 2019). It is the method of protecting food from deterioration by reducing the moisture to a safe level that is unavailable to the microorganism for their growth and metabolism (Kamal *et al.*, 2020). The shelf life of dehydrated products is almost unlimited and the cost of transportation, handling and storage are considerably lower than that of other methods of preservation (Shishir *et al.*, 2019). In the recent year, several dehydration techniques such as mechanical drying and use of osmotic agents are frequently applied to foodstuffs. Among the various techniques, osmotic dehydration is one of the low cost and sustainable methods of food preservation used in the food industry. In this process, different osmotic agents, e.g. salt and sugar are used to squeeze out the moisture from foodstuffs (Bakhara *et al.*, 2018). Osmotic dehydration is the phenomenon of removal of water from lower concentration of solute to higher concentration through semi permeable membrane results in the equilibrium condition in both sides of membrane (Tiwari 2005). Osmotic dehydration found wide application in the preservation of food-materials since it lowers the water activity of fruits and vegetables. This method is preferred over other methods due to their color, aroma, nutritional constituents and flavor compound retention value (Yadav and Singh, 2014). Application of osmotic treatment has been suggested for partial dehydration of foods usually as an upstream processing step prior to drying or freezing to reduce product water load with simultaneous improvement in final product quality of less heat damage, good blanching effect, less enzymatic browning, better retention of flavor (Yadav and Singh, 2014; Kaushal and Sharma, 2016 and Bakhara *et al.*, 2018). Though osmotic dehydration followed by convective drying is a well-advanced

progressive technology, however, osmotically dehydrated jackfruit is scanty in the country. Therefore, the present work has been undertaken to investigate the osmo-dehydration of jackfruit slices followed by hot air convective drying to obtain better quality dehydrated product which can be available throughout the year.

Materials and Methods

Collection and preparation of raw materials

Fresh and fully ripe jackfruit of Khaja cultivar was collected from the farmer's orchard of Gazipur, Bangladesh. Jackfruit was washed with running tap water and then cut longitudinally to separate the bulb. The bulbs were slices (approximately 2 cm × 2 cm) by cutting into halves and were dipped into 0.6% potassium metabisulphite (KMS) solution for 10 minutes and then dipped into 0.5% potassium sorbate solutions for 10 minutes to avoid excessive browning and fungal contamination. Analytical grade chemicals (Merck, Germany) and reagents were purchased from the local traders.

Preparation of osmotically dehydrated jackfruit slices

The jackfruit slices were first blanched in boiling water for 5 minutes and cooled immediately in ice water. The blanched slices were dipped into different osmotic solutions (30, 40, 50, 60 and 70^{o}Brix) and keep in rest overnight. On the following day, the slices in solution were heated for 20 minutes and the solution was removed from the slice. Then, the slices were dried at 60^{o}C until the moisture content reached to <12% (wet basis). After drying, the jackfruit slices were packed in HDPE (60 micron) packet and stored at room temperature (26±2^{o}C, 75±5%RH). The shelf life of osmotically dehydrated jackfruit slices were evaluated over six (6) month at 45 days' interval. The developed processing protocols are as follows (Figure 1 & Figure 2):

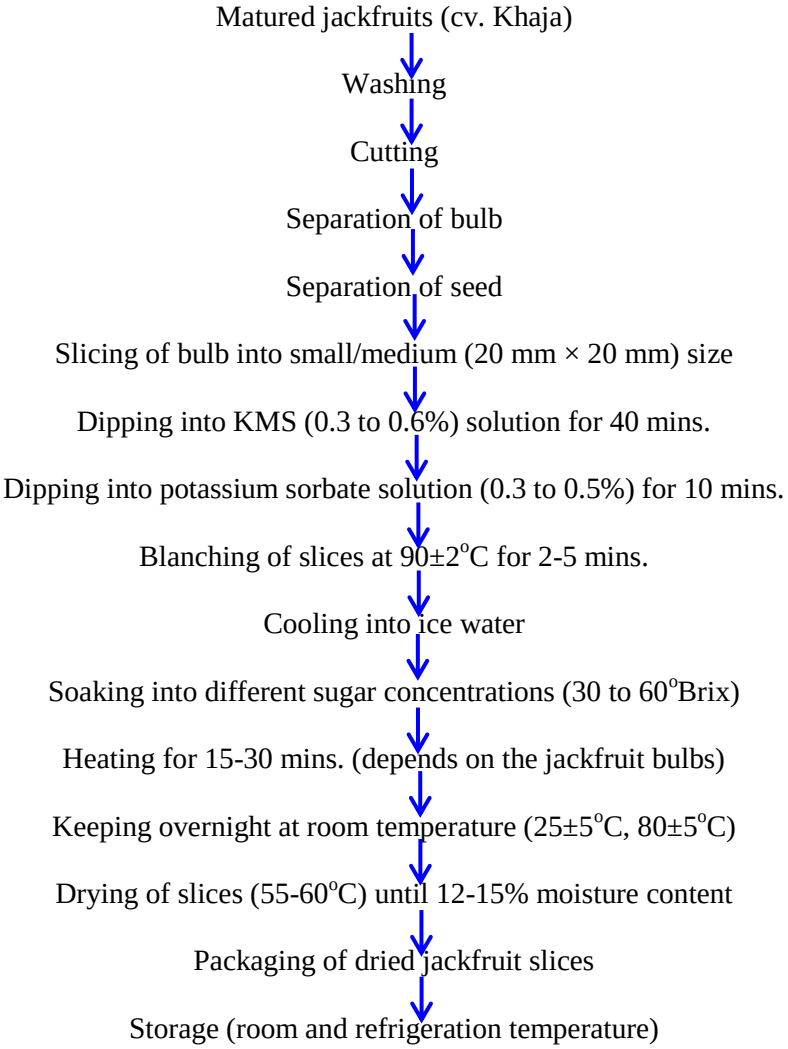

Figure 1. Process Flow Diagram for Osmotically Dehydrated Jackfruit Slices

Determination of physicochemical properties

The moisture and ash content was determined based on the AOAC official methods (AOAC, 2005). The total acidity was determined following the methods of Ranganna (2007). Firmness was measured using the texture analyzer (TX. PLUS, Stable Microsystem, Germany) and expressed as the newton (N). Total sugar content was determined following the procedure of Ranganna (2007). The calorific value was determined using the bomb calorimetric method. Color attributes were measured based on the CIELa*b* color coordinates using a Chroma meter (CR-104, Konica Minolta, Japan), where L denotes the lightness, a* represents green/red, and b* implies blue/yellow.

Determination of bioactive compounds and antioxidant activity of dehydrated jackfruit slices

Ascorbic acid content was determined by 2, 6-dichlorophenolindophenol titrating methods following the description of Kamal *et al.* (2019a) and the result was expressed as mg/100g. Total carotenoids were determined by the methods of Baria *et al*. (2019) with some modification. Total phenolic content was determined by spectrophotometer using Folin-Ciocalteu method following the procedure of Kamal *et al.* (2020) with slight modification using gallic acid as the standard, and the result was expressed as mg GAE/100g of sample. The antioxidant activity was evaluated in terms of DPPH free radical scavenging activity, which was expressed as percent inhibition (Kamal *et al.*, 2019b).

Sensory evaluation

The sensory properties such as, color, taste, flavor, texture, and overall acceptability of osmotically dehydrated jackfruit were evaluated twice over the storage period (initial and final storage day) by 10-expert panelists using 9-point hedonic scale.

Statistical analysis

Statistical analysis was carried out using the software package SPSS (version 22.0, SPSS Inc., Chicago, IL) by using one-way analysis of variance (ANOVA). Duncan Multiple Range Test (DMRT) at the significance level 5% ($P<0.05$) was used to determine significant differences among the samples and storage periods.

Results and Discussions

Physicochemical properties of dehydrated jackfruit slice

The moisture content of dehydrated jackfruit is presented in Table 1. It was found that moisture content ranged from 5.87 to 7.42% on the initial processing day while it was fluctuated between 8.06 to 9.44 % on the final storage periods (180 days). Table 1 also showed that the values for moisture content significantly differed among the samples and increased with the storage periods. The maximum and minimum moisture was found in sample T_2 (40^oB) and T_4 (60^oB) at the beginning and it was the highest in T_1 (30^oB) and the lowest in T_5 (70^oB) at the end of storage period. The variation in moisture content of dehydrated jackfruit slices depends on the extend of drying period and the perforation of packages along with the storage environment.

Ash content represent the total content of different mineral substances. The values for ash content of osmotically dehydrated jackfruit slices were showed in Table 1. It can be seen that ash content was significantly differed among the samples. Its content was ranged from 0.52 to 0.64% and 0.74 to 1.28 % on the beginning and end of the storage period, respectively. The maximum and minimum ash was found in sample T_1 (30^oB) and T_3 (50^oB) at the beginning and it was the highest in T_1 (30^oB) and the lowest in T_5 (70^oB) at the end of storage period.

The total acidity of the dehydrated jackfruit slices was summarized in Table 1 which showed that the prepared samples were very low in acid content and ranged between 0.10 to 0.15% on the processing day and 0.40 to 0.51% after final storage period. It was found that the values of total acidity significantly differed among the sample irrespective of storage periods (Table 1). The maximum and minimum acidity was found in sample T_1 (30^oB) and T_2 (40^oB), T_4 (60^oB) and T_5(70^oB) at the beginning and it was the highest in T_1 (30^oB) and the lowest in T_3 (50^oB) at the end of storage period. It was found that the acidity of the prepared sample was increased in all samples with the storage period.

The calorific value (energy content) of the dehydrated jackfruit slices was presented in Table 1. It is seen that all sample showed an excellent source of energy, which ranged from 395-425 KCal/100g at the beginning and 457 to 538 KCal/100g at the end of storage period (Table 1). These

values were found to differ significantly among the dehydrated jackfruit slices prepared using different sugar concentration and were increased slightly with the extension of storage period.

The sugar content in dehydrated jackfruit slice obtained in this study is shown in Table 1. It is observed from Table 1 that the reducing sugar content was ranged between 7.70 to 8.16% on the processing day while it was recorded in the range of 8.96 to 13.17% after 180 days of storage. It is clearly demonstrated in Table 1 that the reducing sugar showed a slightly increasing trend throughout the storage period and varied significantly among the samples (Table 1).

On the other hand, the total sugar content followed decreasing trends during the storage period. It observed from Table 1 that the total sugar content of dehydrated jackfruit slice varied between 30.59-31.17% and 17.14-19.78% after 0 day and 180 days of storage, respectively. Since the contained sugars in jackfruit mostly are starch, it might be the degradation of starch and carbohydrate in to different molecules due to the action of heat and reactions with other component present in the sample (Rahman *et al.*, 2012).

Color attributes

Color is an important quality parameter that determined the consumer's preference to a product. The changes in the color properties of dehydrated jackfruit slice in terms of lightness (L), green/redness (a*), and blue/yellowness (b*) are presented in Figure 3, Figure 4 and Figure 5, respectively. Figure 3 revealed that the brightness of studied dehydrated jackfruit slice was ranged from 60.54 to 66.18 on the initial storage day and it was in the range of 60.35 to 69.30 after 180 days of storage. It was found that the L values of dehydrated jackfruit slices were decreased slightly up to 90 days then were increased again still final storage (180 days). It is observed from the Figure 3 that the lightness increased with the increased sugar concentration used for the preparation of the dehydrated jackfruit slices. The lightness of prepared sample was also found to vary significantly among the sample irrespective of storage period.

From Figure 4, it is observed that the values of a* (green/redness) was decreased among the dehydrated samples prepared using different sugar concentration. It was recorded that the a* values were differed significantly ($p<0.05$) among the samples throughout the storage period and ranged from 4.10 to 5.26 on the processing day while it was found to range from 1.66 to 4.52 after 180 days of storage, which showed slight redness of the prepared samples.

On the other hand, the b* (blue/yellowness) values were found to range between 36.30 to 45.63 and 36.39 to 30.14 after 0 day and 180 days of storage (Figure 5). These values are indicative of bright yellowness of the osmotically dehydrated jackfruit slices. It is observed from the Figure 5 that the yellowness of the dehydrated sample was reduced with the storage period which might be due to the degradation of pigmented substances due to reaction with sugar molecules and also during the drying process. Furthermore, color changes in dehydrated products also pronounced due to different factors like heat, light, chemical reaction of the constituents and so on (Kamal *et al.*, 2020).

Bioactive compounds of dehydrated jackfruit slices

Ascorbic acid content

Natural antioxidants are widely reported to restrict oxidation-induced degenerative changes in cell physiology and ageing. Ascorbic acid has an important role as a phytochemical, due to its functionality as an antioxidant. The ascorbic acid content was recorded in Table 2. It was found in Table 2 that the ascorbic acid ranged from 8.26 to 11.79 mg/100g at processing day, which was found to varied significantly among the samples and ranged between 2.17 to 2.78 after 180 days of storage. In the present study, the ascorbic acid content followed a decreasing trend throughout the storage period for all dehydrated jackfruit sample (Table 2) and differed significantly ($p<0.05$). It is evidenced from the previous researches that ascorbic acid is highly unstable, readily decreased during the processing operations and highly susceptible to heat, light, air and directly affected by the reaction with metallic particles present in the food items (Kamal *et al.*, 2019).

Total carotenoids content

Carotenoids are the pigments present in food staffs have some beneficial health effects. The total carotenoid content in dehydrated jackfruit slices obtained in this study is shown in Table 2. It is observed from Table 2 that the total carotenoids among the samples ranged between 8.40 to 10.05 mg/100g on the processing day while it was fluctuated within 2.27 to 3.14 mg/100g after the final storage period (180 days). As like ascorbic acid, total carotenoids content also showed decreasing trends throughout the storage periods. After 180 days of storage study, the maximum carotenoids

were recorded in T_4 (60^{o}Brix) while the minimum in in T_1 (30^{o}Brix). It is clearly demonstrated in Table 2 that the total carotenoids showed a significantly variation among the samples throughout the storage period. However, a significant amount of total carotenoids has been retained in the samples. It is evidenced from the literature and previous studies that the carotenoid pigments are heat and light sensitive elements, which degraded during the processing operations (Mezzomo and Ferreira, 2016; Kamal *et al.,* 2019 and Molla *et al.,* 2021).

Total phenolic content

Phenolic compounds are considered as the most important group of phytochemicals that provide antioxidant properties against oxidative stress. The phenolic content of dehydrated jackfruit slices are presented in Table 2. It is observed from Table 2 that total phenolic content was ranged from 1132-1200 mg GAE/100g of sample at the beginning of the storage and it was found to varied between 385 to 577 mg GAE/100g of sample after 180 days of storage. It is also clear from Table 2 that the total phenolic content varied significantly ($p<0.05$) with the increase in concentration of sugar used as osmotic agent. Besides, phenolic content was also decreased with the increase in storage period (Table 2). However, the entire sample possessed significant amount of total phenols after the storage period. The changes in phenolic content influenced by the conjugation of polyphenols with other components of food matrices including proteins, sugar, organic acids, and so on (Xu *et al.,* 2007 and Kamal *et al*., 2020*).*

Antioxidant activity

Foodstuffs rich in antioxidative compounds can play a critical role in fight against the reactive oxygen species (ROS) induced diseases (Kamal *et al.,* 2019). In the present study, the antioxidant property of dehydrated jackfruit slices were evaluated in terms of DPPH radical scavenging activity and is given in Table 2. The DPPH value for dehydrated jackfruit slice prepared in this study varied between 40.19 to 54.96% on initial storage day (Table 2) which were found to range between 17.10 to 32.38% after 180 days of storage. It is clearly demonstrated in Table 2 that the values of DPPH differed significantly among the samples and were also found to decrease with the extension of storage period. The changes in antioxidant capacity of osmotically dehydrated jackfruit might be reflected by its content of different phenolic compounds present in the samples. However, the decrease in antioxidant activity may occur due to the reaction of different enzymes such as polyphenol oxidase along with the degradation of different bioactive compounds, which boosted the antioxidant capacity of products (Kamal *et al.,* 2019; Kulkarni & Aradhya, 2005).

Sensory attributes of osmotically dehydrated jackfruit slices

The sensory evaluation of the osmotically dehydrated jackfruit slices was conducted twice (at the initial day and final day) throughout the storage period. The results obtained for sensory attributes of dehydrated jackfruit slices were demonstrated graphically in Figure 6. Sensory evaluation is one of the determinants of consumer's choice of a product. Color is one of the most important quality parameters of dehydrated jackfruit products. It is closely related to the perception and reception of the product. It was observed that the color score for dehydrated jackfruit slices were ranged from 7.60 to 7.90 points at the initial day, which was ranged from 7.40 to 7.80 points after 180 days (Figure 6). The flavor attribute was ranged from 7.60 to 7.80 at the beginning and 7.50 to 7.70 points at the end of storage period. The texture was ranged from 7.10 to 7.80 at the beginning and 6.10 to 7.10 at the end of storage. The taste property ranged from 7.10 to 7.80 at the initial day and 6.50 to 7.60 points after 180 days of storage. While the overall accessibility of dehydrated jackfruit slices were ranged between 7.35 to 7.75 points at the beginning and 6.88 to 7.55 after 180 days of storage. It was observed that the sensory attributes were slightly decreased from the initial to final storage period. It is noticeable that all the sensory items were acceptable while the texture value was slightly lower, which might be due to over drying or cell degradation during drying that created a hard texture of the dehydrated jackfruit slices. It can be concluded from Figure 6 that the sample prepared using sugar concentration ranging from 40-60^{o}Brix provided the best sensory scores for all attributes and may be applied for industrial production of dehydrated jackfruit slices.

Table 1. Changes in physicochemical properties of osmotically dehydrated jackfruit slices during 180 days of storage

Sample (^{o}Brix)	Moisture (%)				
	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	7.13±0.01b	8.16±0.35a	8.53±0.32ab	9.15±0.02a	9.44±0.02a
T_2	7.42±0.03a	7.35±0.16b	9.13±0.30a	8.85±0.04a	9.21±0.08b
T_3	7.38±0.03a	7.25±0.11b	7.63±0.26bc	8.03±0.04bc	9.17±0.06b
T_4	5.87±0.13c	7.73±0.24ab	6.81±0.62c	8.13±0.03b	8.61±0.07c
T_5	7.36±0.02a	7.49±0.22ab	7.60±0.31bc	7.63±0.29c	8.06±0.02d
Sample (^{o}Brix)	Ash (%)				
	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	0.64±0.01a	0.61±0.01a	0.66±0.02a	0.66±0.02b	1.28±0.03a
T_2	0.56±0.03b	0.55±0.03ab	0.57±0.01b	0.64±0.01b	0.93±0.11b
T_3	0.52±0.02b	0.50±0.02b	0.59±0.01ab	0.74±0.01a	0.99±0.02b
T_4	0.56±0.01b	0.55±0.01ab	0.54±0.02b	0.72±0.01a	0.94±0.03b
T_5	0.59±0.01ab	0.57±0.01ab	0.56±0.03b	0.52±0.01c	0.74±0.01c
Sample (^{o}Brix)	Acidity (%)				
	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	0.15±0.02a	0.24±0.01ab	0.31±0.01b	0.37±0.01a	0.51±0.02a
T_2	0.10±0.01b	0.27±0.01a	0.31±0.01b	0.37±0.01a	0.45±0.03ab
T_3	0.11±0.01ab	0.24±0.01ab	0.33±0.01ab	0.36±0.01bc	0.40±0.02b
T_4	0.10±0.01b	0.24±0.01ab	0.34±0.01a	0.33±0.01d	0.45±0.01ab
T_5	0.10±0.01b	0.23±0.01b	0.32±0.01ab	0.35±0.01c	0.47±0.01ab
Sample (^{o}Brix)	Energy (KCal/100g)				
	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	413.65±7.95a	412.147±7.95a	422.27±4.02ab	450.09±2.17b	450.98±5.30c
T_2	395.64±5.70b	394.16±8.70b	407.29±6.12b	475.38±2.55a	481.67±1.70b
T_3	425.44±7.22a	424.06±5.22a	434.19±9.30a	472.59±5.41a	463.47±9.22c
T_4	424.28±6.53a	422.97±5.54a	433.10±8.02a	464.82±1.49ab	457.66±4.45c
T_5	415.74±6.68a	414.39±6.76a	424.52±7.68a	476.43±9.36a	538.10±2.47a
Sample (^{o}Brix)	Reducing sugar (%)				
	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	7.70±0.07b	7.94±0.17a	7.86±0.31a	12.20±0.17b	12.12±0.04b
T_2	8.16±0.04a	7.99±0.11a	8.12±0.28a	12.88±0.16a	12.83±0.18a
T_3	7.85±0.03b	8.04±0.05a	8.62±0.27a	9.53±0.05c	13.17±0.19a
T_4	8.16±0.04a	8.12±0.09a	8.39±0.39a	9.35±0.05c	8.96±0.07c
T_5	7.85±0.05b	8.14±0.02a	8.03±0.08a	12.20±0.17b	12.35±0.08b
Sample (^{o}Brix)	Total sugar (%)				
	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	31.17±0.47a	30.67±0.30a	30.10±0.91a	25.50±0.12b	17.61±0.14c
T_2	30.72±0.28a	30.42±0.42a	28.08±0.71a	26.06±0.14a	19.78±0.06b
T_3	30.90±0.16a	30.34±0.57a	30.14±0.17a	25.13±0.18bc	17.14±0.11c
T_4	31.17±0.28a	30.90±0.35a	29.69±1.02a	24.83±0.11c	17.45±0.22c
T_5	30.59±0.55a	31.53±0.27a	29.03±1.13a	25.35±0.26bc	20.25±0.11a

Note: Values are mean ± standard error of mean (n=3); Means followed by different lowercase letters in each column are significantly different at P<0.05.

T_1-30^{o}Brix; T_2-40^{o}Brix; T_3-50^{o}Brix; T_4-60^{o}Brix; T_5-70^{o}Brix.

Table 2. Changes in bioactive compounds and antioxidant activity of osmotically dehydrated jackfruit slices during 180 days of storage

Sample	Ascorbic acid (mg/100g)				
(^{o}Brix)	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	7.40±0.33e	5.84±0.01a	4.31±0.19ab	3.50±0.19a	2.78±0.05a
T_2	9.41±0.18c	5.69±0.01ab	4.50±0.20a	3.29±0.06a	2.35±0.12bc
T_3	8.26±0.02d	4.20±0.12c	3.66±0.14b	3.41±0.10a	2.17±0.01c
T_4	11.79±0.02a	5.62±0.04ab	3.90±0.20ab	3.21±0.21a	2.72±0.08ab
T_5	10.61±0.02b	5.41±0.16b	3.77±0.26b	3.39±0.02a	2.66±0.21ab
Sample	Total carotenoids (mg/100g)				
(^{o}Brix)	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	9.15±0.05b	8.30±0.66a	4.06±0.24c	3.33±0.20a	2.27±0.04c
T_2	8.89±0.03c	6.67±0.27a	4.80±0.07ab	3.38±0.18a	2.78±0.07ab
T_3	10.05±0.02a	7.45±0.95a	5.23±0.18a	2.04±0.27b	2.48±0.24bc
T_4	10.05±0.02a	6.39±0.43ab	4.72±0.10b	2.58±0.12b	3.14±0.10a
T_5	8.40±0.02d	4.74±0.23b	4.47±0.04bc	3.68±0.09a	2.80±0.08ab
Sample	Total phenol (mg GAE/100g)				
(^{o}Brix)	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	1200.22±34.29b	1166.70±55.36b	1078.92±56.39a	675.23±10.31bc	576.90±1.61a
T_2	1337.93±45.41a	1317.87±51.85a	982.53±54.15b	596.57±36.27d	386.15±8.61c
T_3	1306.85±65.36a	1238.70±40.80ab	1031.62±26.09a	712.87±3.64b	385.48±4.08c
T_4	1132.38±16.69b	1119.77±9.58b	1059.83±22.93a	616.78±9.11cd	390.30±5.44c
T_5	1179.73±11.51b	1143.50±20.42b	967.65±22.53b	852.72±42.02a	459.85±3.23b
Sample	% DPPH inhibition				
(^{o}Brix)	0 Day	45 Days	90 Days	135 Days	180 Day
T_1	54.96±1.11a	49.93±1.11a	43.14±1.11a	35.77±1.03a	31.87±1.11a
T_2	41.49±0.14b	36.46±0.15b	29.67±0.14b	22.30±0.69b	18.40±0.14b
T_3	40.19±0.07b	35.16±0.07b	28.37±0.07b	21.00±0.29b	17.10±0.07b
T_4	41.49±0.52b	36.46±0.43b	29.67±0.53b	22.30±1.06b	18.40±0.52b
T_5	55.47±1.99a	50.44±1.09a	43.65±0.59a	36.28±0.79a	32.38±0.99a

Note: Values are mean ± standard error of mean (n=3); Means followed by different lowercase letters in each column are significantly different at P<0.05.

T_1-30^{o}Brix; T_2-40^{o}Brix; T_3-50^{o}Brix; T_4-60^{o}Brix; T_5-70^{o}Brix

Conclusion

Results of this study revealed a good content of nutritional and bioactive compounds along with excellent sensory performance of the dehydrated jackfruit slices, which could be stored up to 180 days (six month). Based on the overall quality assessment for dehydrated jackfruit slices, it can be concluded that 50^{o}Brix sugar concentration was the best option for preparing the dehydrated jackfruit slices. This technology will add value in agro-processing industry to produce osmotically dehydrated jackfruit slices for domestic consumption and export purpose and will assist to reduce postharvest loss of jackfruit of our country. The economic analysis will be conducted for further study.

Figure 2. Photographic view of osmotically dehydrated jackfruit slices

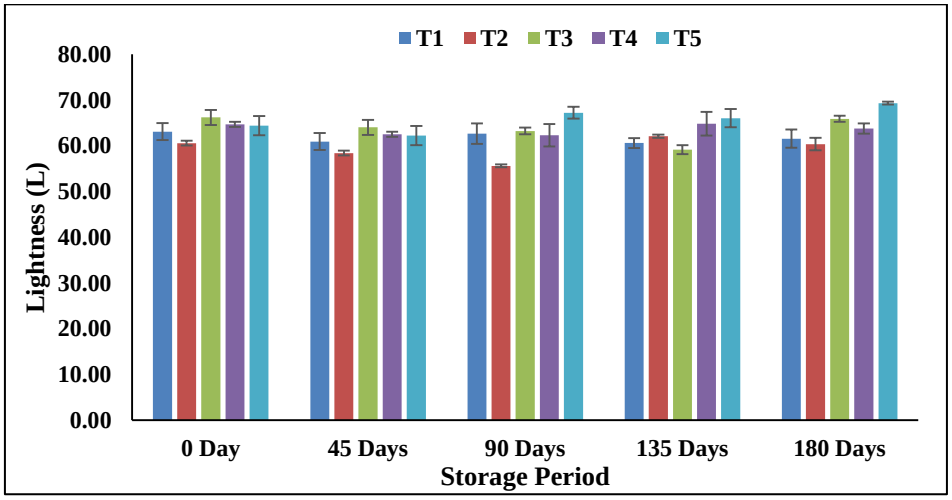

Figure 3. Lightness (L) values of osmotically dehydrated jackfruit slices (T_1-30°Brix; T_2-40°Brix; T_3-50°Brix; T_4-60°Brix; T_5-70°Brix)

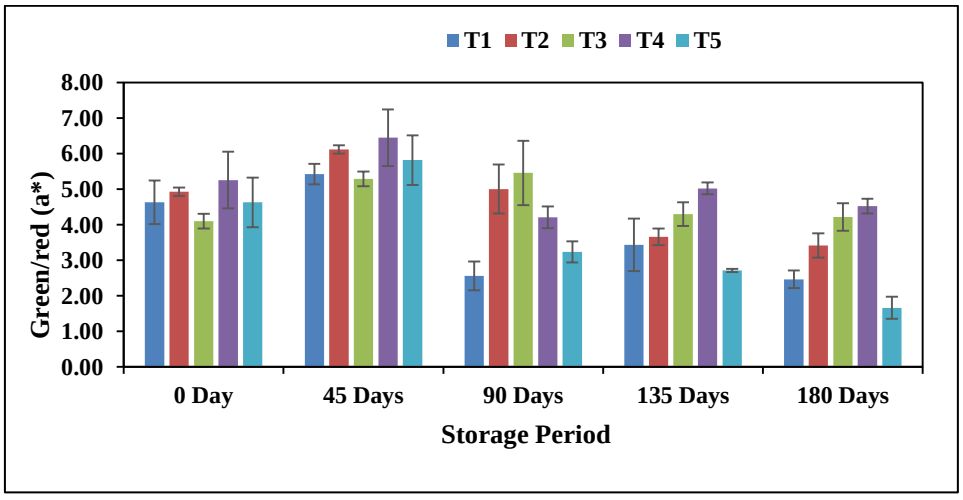

Figure 4. Red/greenness (a*) values of osmotically dehydrated jackfruit slices (T_1-30°Brix; T_2-40°Brix; T_3-50°Brix; T_4-60°Brix; T_5-70°Brix)

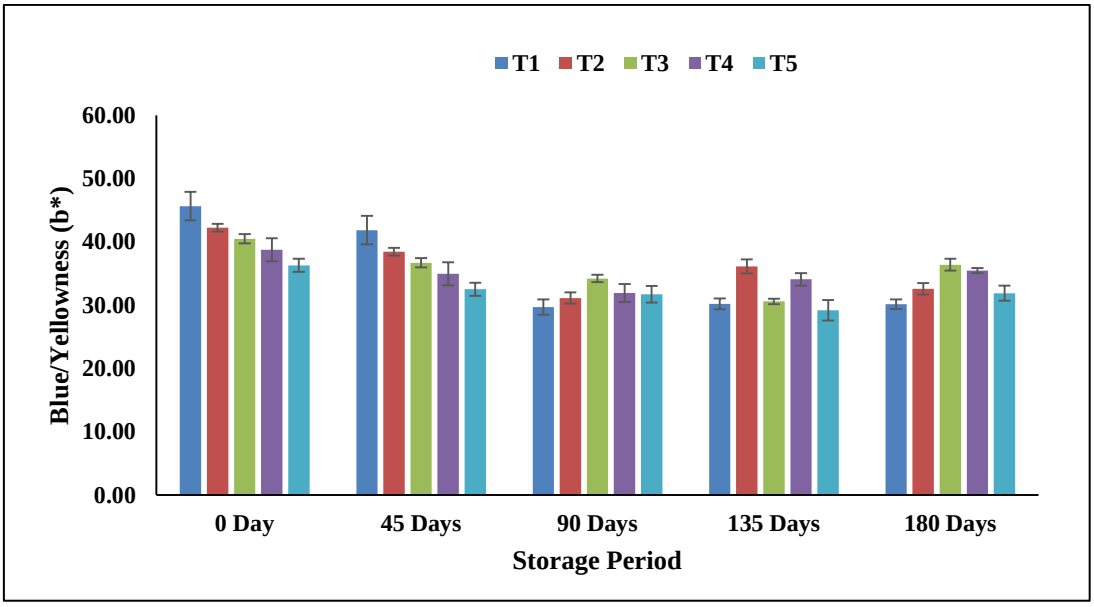

Figure 5. Blue/yellowness (b*) values of osmotically dehydrated jackfruit slices (T_1-30°Brix; T_2-40°Brix; T_3-50°Brix; T_4-60°Brix; T_5-70°Brix)

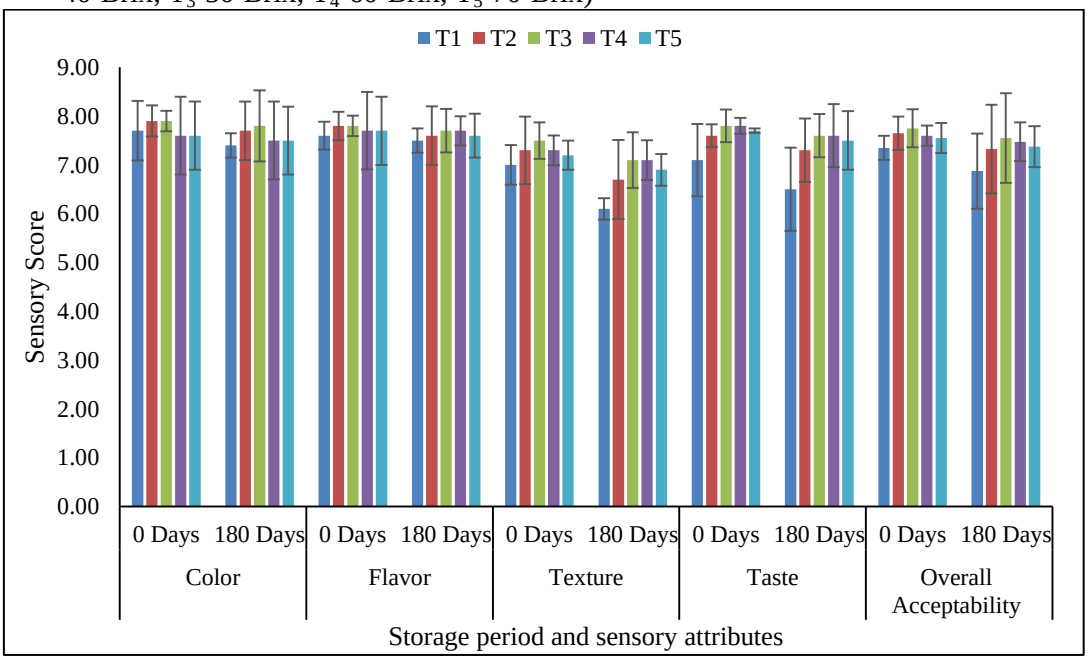

Figure 6. Sensory score of dehydrated jackfruit slices during storage (T_1-30°Brix; T_2-40°Brix; T_3-50°Brix; T_4-60°Brix; T_5-70°Brix)

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EFFECT OF DRYING ON PHYSICOCHEMICAL PROPERTIES, BIOACTIVE COMPOUNDS AND MICROSTRUCTURE OF JACKFRUIT SEED FLOUR

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Abstract

Jackfruit seed, a by-product of the fruit industry, is a potential raw material for the production of a number of valued-added products. In this study, physicochemical composition, minerals, bioactive compounds, antioxidant activity and functional properties of jackfruit seed flour were evaluated as a function of drying methods (hot air cabinet drying at 50-80^{o}C, freeze drying at-56^{o}C and sun drying). Results revealed that the drying methods significantly influenced the analyzed parameters, such as moisture (11.10~13.62%), protein (14.22~19.07%), fat (0.28~0.96%), carbohydrate (77.64~83.02%), starch (56.59~74.14%) and energy (470~490 KCal/100g) except ash (2.25~2.40%). Jackfruit seed flour was found to have significant amounts of different mineral constituents including sodium, potassium, calcium, magnesium, iron, phosphorus, zinc, sulphur. The antioxidant properties of jackfruit seed flour were reflected by its content of total carotenoids (31.86~72.20 mg/100g), ascorbic acid (42.41~65.05 mg/kg) and total phenolic content (704~1009 mg GAE/100g), which was evaluated by the DPPH radical scavenging activity (69.03~75.60%). Conclusively, it is expected that the jackfruit seed flour produced by different drying methods could be useful in formulating diverse food products including bakery in replace/adjunct to wheat flour.

Introduction

Tropical fruits are ample sources of both nutrients and health beneficial compounds for developing countries and are crucial from the commercial perspective. Due to the advancement of agro-industries, huge amounts of solid wastes are generating each year from fruits and vegetables either at the farm, processing industries and retails, most of which include peel, seed, hull, rind, core, kernel, stem, damaged fruits which are of serious concern to the environment (Kamal *et al.,* 2019). Generally, these fruit wastes are unwisely disposed to the environment, which is one of the major causes of pollution due to their susceptibility to enzymatic and microbiological degradation. Therefore, transformation of fruit waste into potential raw material for food, feed and pharmaceutical industries appears as the key challenges for the researchers in the past few decades. Recent studies evidenced that these fruit wastes are rich sources of different health beneficial components such as fiber, sugars, fat, proteins, pectin, organic acids, antioxidants, phenols, vitamins, minerals, flavors and other bioactive substances (Reis *et al.,* 2012).

Jackfruit (*Artocarpus heterophyllus*) is a popular tropical evergreen tree belongs to the *Moraceae* family and distributed widely including India, Bangladesh, Brazil, Thailand, Indonesia, Philippines, Srilanka, China, Africa, Australia, and Malaysia (Madruga *et al.*, 2014; Swami *et al.*, 2012; Sharma *et al.*, 2013). The fruit weight of jackfruit is typically 6-10 kg, and the ripe edible fruits contain strong sweet flavored golden yellow bulb comprising 30-35% of the fruit weight (Saxena *et al.*, 2012; Maity *et al.*, 2017). The residues remaining after processing of jackfruit can constitute upto 70% of the total weight of the fruit. A portion of such residues is the seeds, which may constitute from 8 to 15% of the total weight of the fruit (Swami *et al.,* 2012; Phrukwiwattanakul *et al.,* 2014; Swami and Kalse, 2019). Jackfruit seeds have been reported for its high content of carbohydrate and protein along with several compounds like minerals, vitamins, dietary fiber, phytonutrients, different bioactive polyphenols and antioxidative compounds (Swami *et al.,* 2012). Fresh jackfruit seeds are mostly discarded, steamed, roasted and eaten as a snack or used in several local dishes. Because of the higher moisture with starch and protein content and susceptibility to fungal growth, it is difficult to store fresh jackfruit seeds for longer time especially in the tropical regions. Therefore, it could be promising to process these seeds into dried and powdered form for longer storage as well as to be used in different food formulations.

Drying is one of the ancient methods for food preservation that extends shelf life of agro-products by removing a substantial amounts of moisture and prevent the growth of microorganisms (Kamal *et al,*. 2020) and different deterioration and biochemical reactions (Yap *et al.*, 2020). During drying, moisture removal occurs due to simultaneous heat and mass transfer between the sample and the adjacent environment caused by the vaporization of moisture through temperature and air convection forces (Younis *et al.*, 2018; Zahoor and Ali, 2019). It is evidenced that the weight and volume of agro-products become reduced due to drying that save the excess costs for packaging,

storage, and transportation (Shishir *et al.*, 2019). Moreover, dried products are more convenient in color and nutrient dense.

The drying process is a critical operation in food industry because it may induce undesirable changes in chemical composition, color, microstructure, functional properties and overall quality of the dehydrated products. Jackfruit seeds are generally dried under the normal sunlight, which is an easy and economical method but have some limitations such as long drying time, depends on weather conditions and potential risks for microbial contamination, which limits its commercial application. Conversely, hot air drying is a low cost technique that frequently used in most agro-processing industries for drying to preserve the nutritional quality with enhanced storability of agro-products. However, the quality of the dried products highly depends on the temperature, air flow rate and product internal composition (Kamal *et al.*, 2020; Shishir, 2019). In the recent year, freeze drying has gained popularity for its capability to preserve the color, nutritional quality and antioxidative properties of dried products.

Over the past decades, jackfruit seeds mostly carried out on starch and protein isolates comprising their functionality with some information on product formulations. However, there is a dearth of literature on complete evaluation of chemical composition, mineral availability and bioactive compounds with antioxidant potentiality of the jackfruit seed flour as a function of drying. Therefore, the present study sought to investigate the effect of drying methods on the physicochemical properties, bioactive compounds, antioxidant properties and microstructure of jackfruit seed flour.

Materials and Methods

Chemicals and plant material

Fully matured and ripe jackfruit was collected from the farmer's orchard of Gazipur, Bangladesh. Fruits were cut and opened for collection of seeds. Analytical grade chemicals and reagents were procured from Merck, Germany or Sigma-Aldrich Co., USA through local traders.

Preparation of jackfruit seed flours

The jackfruit seeds were separated from the bulb and washed thoroughly with portable water and cut into small slices (approximately 3 mm) using sharp stainless steel knives. The sliced seeds were immediately soaked in 0.3% potassium metabisulphite (KMS) and 1% calcium chloride ($CaCl_2$) solution for 10 min. Thereafter, the slices were blanched in hot water at 95±2^{o}C for 5 min and immediately cooled in ice water for 5 min. The surface moisture of the slices was removed and the sample was ready for drying operations. The pretreated sliced jackfruit seeds were dried in convective cabinet type hot air dryer at four different temperatures (50, 60, 70 and 80^{o}C) and pilot scale freeze dryer (BIOBASE, BK-FD20S, China) at - 56^{o}C and 0.1 Pa constant pressure in the drying chamber. The drying operation was continued until the sample reached to a constant weight. Jackfruit seed slices were dried under natural sunlight which was used as the control sample. The dried seeds were pulverized to make powder using a laboratory grinder, sieved, packed in high density polyethylene pouch and stored at 4^{o}C until used for analysis. Overall processing methods is given in following figure (Figure-1).

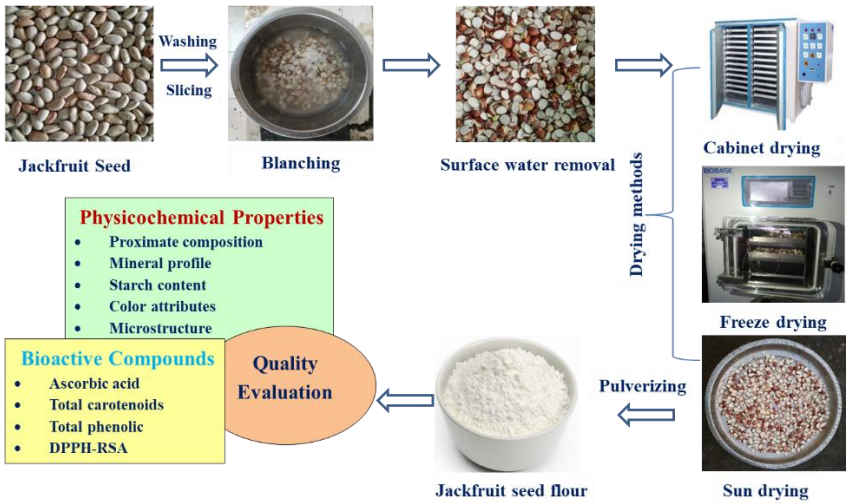

Figure-1: Overall process diagram of jackfruit seed powder preparation

Physicochemical properties

Moisture, crude protein ($N_{Kjeldahl}$×6.25), ash, and fat were determined following the methods of AOAC (2005) and expressed as the percentage on dry basis (db). The energy value of the flour samples was determined using bomb calorimeter and expressed as the KCal/100g of sample. The starch content was measured following the method described by Kamal et al. (2020). Color of the jackfruit seed flour was determined as L (lightness), a* (red/green) and b* (yellow/blue) values using the Chroma meter (CR-410, Konica Minolta, Inc., Japan). The hue angle (H) (Eq. 1) and Chroma (C) (Eq. 2) were calculated based on the following formula below:

$$H = \tan^{-1}\left(\frac{b^*}{a^*}\right) \qquad \text{(Eq. 1)}$$

$$C = \sqrt{b^{*2} + a^{*2}} \qquad \text{(Eq. 2)}$$

Here: L^*, a^*, and b^* were Hunter L^*, a^*, and b^* values.

Mineral profiling

The minerals analyzed in this study were: sodium, potassium, calcium, magnesium, phosphorus, sulphur, iron and zinc. Before quantification of their amounts, the flour was first ashed and then digested in nitric acid and parchloric acid solution (1:1) at 320^{o}C, cooled, diluted to an appropriate concentration, and filtered. This filtrate was considered as the stock solution for further analysis. Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Tokyo, Japan) (SpectrAA, 55B, Varian, USA) was used to assess the sodium, calcium, magnesium, iron and zinc. Potassium content was measured using flame photometry while phosphorous and sulphur content was assessed with the spectrophotometric method (Specord 205, Analytik Jena, Germany). Individual minerals were quantified by comparing the corresponding standard minerals procured from the Sigma Aldrich Co., USA.

Quantification of bioactive compounds and antioxidant property

Total carotenoid was determined following the methods of Baria *et al.* (2019) with minor modifications. Ascorbic acid content was determined based on the 2,6-dichlorophenol indophenol titration method as described by Kamal *et al.* (2019) with some modification and the result was expressed as mg ascorbic acid/kg of fresh sample. Total phenolic content (TPC) was determined using the Folin-Ciocalteu phenol reagent method as described by Kamal *et al.* (2019) with minor modification. The antioxidant activity of jackfruit seed flour was determined using DPPH free radical scavenging activity and was carried out following the protocol previously described by Kamal *et al.* (2019) with some modification.

Microstructural properties

The microstructures of the dried jackfruit seed flours were evaluated using an analytical scanning electron microscope (JEOL JSM-6490LA, JEOL Ltd., Japan)) at an accelerating voltage of 5 kV and the working distance was set at 20 mm. For this, the jackfruit seed flour was taken in the SEM stubs with double-sided adhesive carbon tape and platinum-coated using a sputtering coater (JFC-1600 Auto Fine Coater, JEOL Ltd., Japan). The microstructural images were taken at 100× magnification to observe the changes in the particle morphology of jackfruit seed flours that occurred as a function of drying.

Statistical analysis

All the analyses were carried out thrice and the obtained data were analyzed statistically using the IBM SPSS software (version 22.0, SPSS Inc., Chicago, IL). The results were reported as the mean ±standard error (SE) of three replicates. Statistically significant variations among the means were assessed by one-way analysis of variance at 95% confidence level.

Results and Discussions

Chemical composition

Table 1 represents the chemical composition of jackfruit seed flour obtained by applying different drying conditions. It is seen that a significant variation in the moisture, protein, fat, carbohydrate, starch content and energy values was observed among the jackfruit seed flour. However, ash content did not differ significantly at $P<0.05$. Moisture content is an important property of any food material that determines their storage quality and shelf life, and associated with the growth of microorganisms and their potential activities to deteriorate the products. In the present study, the moisture content of jackfruit seed flours obtained by different drying conditions was varied between 11.10 and 13.62%

(db) (Table 1), which lies within the safe limit for dried foodstuffs for longer storage. However, this range of moisture content is comparatively higher than the previous findings of jackfruit seed flour (Afroza, 2013; Lima *et al.,* 2014 and Kushwaha *et al.,* 2021). The variation of moisture content of jackfruit seed flour might be due to the drying conditions applied and extend of jackfruit seed left on the dryers.

Total ash content is another important component in foodstuffs that reflects the mineral availability. The ash content of jackfruit seed flours fluctuated between 2.25 to 2.40 % (db) (Table 1), and there was no statistically significant difference existent among the samples. It is well known that the minerals i.e. ash content of foodstuffs are less affected by the food processing operations which might cause the less variation of their content in the jackfruit seed flour. Moreover, the results obtained for ash content of jackfruit seed flour was also corroborated to the previous studies, for example, Maurya (2017) had reported the ash content of jackfruit seed flour was 3.78% while Ocloo, *et al.* (2010) and Eke-Ejiofor, *et al.* (2014) reported the ash content in the range of 2.46-2.76%; Lima *et al.* (2014) found 3.2%, and Kushwaha *et al.* (2021) stated 2.55-3.80%.

One of the most important properties of any food materials is its protein content, functions as the structural backbone of human and animal body. Table 1 shows that the protein content of jackfruit seed flour was fluctuated between 14.22 to 19.07 %, db and varied significantly ($P<0.05$) among the samples obtained at different drying conditions. The highest amount of protein was found in jackfruit seed flour obtained by applying freeze drying method while the lowest in the sun dried seed flour (Table 1). It is seen that the freeze dried jackfruit seed flour retained maximum amount of proteins than the mechanically and sun dried flours. These findings are analogous to the results reported previously by the authors, for instance, Kushwaha *et al.* (2021) had reported 12.15–18.56% protein for jackfruit seed flour based on different maturity stages while Ocloo *et al.* (2010) reported 13.50% and Lima *et al.* (2014) stated 20 %. It is evidenced that the protein content in the jackfruit seed flour may vary with the stage of maturity, food processing operations, and also due to the variation in the moisture content in the flour. Furthermore, different biochemical changes like, protein denaturation at different drying conditions, alteration of enzyme might also have contributed to changes in the protein (Kamal *et al.,* 2020 and Frenkel, 1968).

The fat content was ranged between 0.28 and 0.96% (Table 1), being the maximum in the sun dried (0.96%), cabinet dried at 60^{o}C (0.91%) and freeze dried (0.89%) jackfruit seed flour, and the lowest in the sample obtained by cabinet drying at 80^{o}C (0.28%). These findings are corroborated with the reports of Kushwaha *et al.* (2021), who obtained 0.58-0.73% fat for jackfruit seed flour based on maturity. However, Lima *et al.* (2014) reported 2.5 % fat in jackfruit seed flour, which is comparatively higher than our findings.

The total carbohydrate was found in the range of 77.64 to 83.02%, which mainly differed due to the compositional differences of others samples. Starch is the principle carbohydrate (polysaccharide) of jackfruit seeds and its flour.

In the present study, the total starch content of jackfruit seed flour was swayed between 72.99 and 78.06% and the drying methods significantly ($p<0.05$) affect the starch content (Table 1). This range of starch content is analogous to the reports available elsewhere (Kushwaha *et al*., 2021; Tulyathan *et al.,* 2002). However, higher content of starch (93.60%) in jackfruit seed was reported by Choy *et al.* (2017). The differences in the starch content of jackfruit seed flour might be the alteration of sugar molecules during drying at various conditions along with the modifications of starch granules due to the heat treatment (Kamal *et al.,* 2020).

A significant amount of energy has been recorded by the jackfruit seed flour. Total calorific or energy value was documented within the range of 470 to 490 KCal/100g which is corroborated with the previous findings. Ocloo *et al.* (2010) reported 383 KCal/100g calorific value for jackfruit seed flour. This energy value mainly due to the contribution of fats, protein, and carbohydrates present in the flour samples.

Mineral profile

The mineral content of jackfruit seed flour at different drying conditions have been summarized in Table 2. These values for different minerals were found to range between 2.52-3.45 g/100g for calcium; 0.84-1.15 g/100g for magnesium; 0.31-0.46 g/100g for potassium; 0.24-0.26 g/100g for phosphorus; 0.30-0.48 g/100g for sulphur; 71.76-106.20 mg/kg for iron; 10.26-14.64 mg/kg for zinc, and 0.12-0.14 mg/kg for sodium at different drying conditions (Table 2). It is seen that

jackfruit seed flour contained significant amount of mineral components, and differed significantly ($p<0.05$) at different drying conditions (Table 2). In most cases, with the increase in drying temperature (50-80^{o}C) during cabinet drying, the mineral content was increased, and freeze dried flour contained the maximum minerals among other sample. These variations might be due to the drying conditions used significantly reduced the moisture content that increases the solid mass of the sample (Kamal *et al.,* 2020 and Sanful *et al.,* 2013).

Color properties

Color is one of the crucial quality factors that determine the consumer's perception on buying the product and the most commonly measured parameter of dried products. The color properties and browning index of jackfruit seed flour obtained in this study as a function of drying methods are summarized in Table 3. The lightness (L) of jackfruit seed flour was ranged between 72.38-84.22, being the freeze dried flour was brighter than the other samples. It is noticeable that the brightness of cabinet dried jackfruit seed flour didn't differ significantly ($p<0.05$) except flour obtained at 50^{o}C. It implies that the less darkening of flour was observed at elevated temperature during cabinet drying of jackfruit seed (Kamal *et al.,* 2020). The changes in the whiteness of flour sample might be the pigment degradation triggered by the enzymatic and non-enzymatic reaction during drying that reduces the luminosity (García-Martínez *et al.,* 2013). Again the green/red components (a*) of flours were fluctuated between 3.20-4.27 and were significantly differed among the samples, while the yellow/blue (b*) was recorded in the range of 11.07-13.75 (Table 3). The drying conditions significantly reduced the a* and b*, which indicated less redness and yellowness of jackfruit seed flours that directly influenced the hue angle (ranged between 70.69-76.77^{o}) and the color saturation (chroma varied from 11.55 to 14.12) (Table 3). This might be attributed by the application of pretreatments (soaking in 0.3% KMS and 1% $CaCl_2$ solution for 10 mins followed by hot water blanching at 95±2^{o}C for 5 during drying operation resulted in reduced heat induced consequences related to the browning reactions and pigment degradation (Kamal *et al.,* 2020; Raja *et al.,* 2019; Ruttarattanamongkol *et al.,* 2016).

Bioactive compounds and antioxidant properties

Ascorbic acid content

Studies evidenced that the ascorbic acid is considered as the most powerful antioxidants in foodstuffs whose regular intake lowers the cancer risks in the human body (Kamal *et al.,* 2019; Almeida *et al.,* 2011). The nutrient loss in foodstuffs is evaluated through the containment of ascorbic acid (Ough and Amerine, 1988). Interestingly, the ascorbic acid content of jackfruit seed flour was ranged between 42.41- 65.05 mg/kg (Table 4) and found to varied significantly among the flour samples obtained at different drying conditions. Table 4 also shows that the ascorbic acid content of jackfruit seed flour decreased with the elevation of drying temperature from 50-80^{o}C at cabinet drying techniques, however, freeze drying method significantly retained the ascorbic acid compared to other drying methods applied. It evidenced by the preceding studies that ascorbic acid is considered as the most unstable compounds existing in foodstuffs and its content depends on various factors such as heat, pH, metal content, oxygen content etc. (Chang *et al.,* 2002). Therefore, the drying conditions used in this study has significant contributions to the changes in ascorbic acid content of jackfruit seed flour.

Total carotenoids

Previous researches demonstrated that carotenoid has a crucial implication in the regulation of different functionalities in human body and regulate the health by reducing the risks of cancer and heart diseases because of the activity of pro-vitamin A (Chang *et al.,* 2002). From Table 4, it can be seen that total carotenoids content of jackfruit seed flour was found in the range of 31.86-72.20 mg/100g and were significantly differed among the drying methods applied. Among the examined flour samples, freeze dried jackfruit seed flours recorded maximum carotenoids than the cabined and sun dried flours (Table 4). It is evidenced that processing conditions e.g. drying significantly alter the pigments in foodstuffs along with other factors like heat, light and the presence of metallic substances. Furthermore, carotenoids in foodstuffs are influenced by several factors such as, soil conditions, fruit maturity, enzymes, phenolic content, genomic features etc. (Molla *et al.,* 2021).

Total phenolic content

Polyphenols are considered as the major bioactive substance present in foodstuffs. Their content determines the biological functionality against chronic diseases like cancer, cardiovascular

dysfunctions, inflammations etc. Total polyphenols content (TPC) recorded for jackfruit seed flour obtained at different drying conditions are presented in Table 4, and found to range from 704 to 1000 mg GAE/100g. It is observed that total phenolic content didn't varied significantly ($p<0.05$) for cabinet dried flour obtained at 50-70^{o}C and sun dried flour, however, significant difference was found among the flours produced at 80^{o}C and by freeze drying methods (Table 4). The maximum TPC was recorded in freeze dried flours while minimum was in sun dried flour. The results obtained in this study is corroborated the finding of Zhang *et al.* (2017), who reported 971 mg GAE/100g. It is evidenced that liberation of polyphenolic substances is associated with chemical structure (bound to the plant matrix) that induced by the heat treatment (Tan *et al.*, 2019). Furthermore, the reduction in enzyme reaction i.e. polyphenoloxidase activity is also responsible for the release of phenolic compounds that may easily be influenced by drying temperature (Paul and Das, 2018). Moreover, the content of total phenolic also influenced by the conjugation of polyphenols with other components of food matrices including proteins, sugar, organic acids, and so on (Xu *et al.*, 2007; Kamal *et al.*, 2020).

Evaluation of antioxidant activity

Antioxidative properties of foodstuffs mainly boosted by the presence of different bioactive phytochemicals including polyphenols, anthocyanin, phenolic acids, flavonoids and so on, which facilitate the termination of free radicals and protect the body from various degenerative diseases. Besides, foodstuffs rich with antioxidative compounds can play a critical role in fight against the reactive oxygen species (ROS) induced diseases (Dutta and Ray, 2018). The antioxidant capacity of jackfruit seed flour was determined by the DPPH radical scavenging activity and expressed by the percent inhibition. The DPPH radical scavenging activity of the jackfruit seed flour shown in Table 4. The DPPH free radical activity of jackfruit seed flour was ranged from 69.03-75.60%. It is evidenced that maturity of jackfruit i.e. seed affected the scavenging activity of seed flour. The result showed that the antioxidant activity of DPPH was the lowest at 50^{o}C (cabinet drying temperature) and was the highest for freeze dried flour. Previous studies evidenced that freeze drying can preserve most of the components of foodstuffs.

Table 1. Chemical composition of jackfruit seed flour (dry basis, db)

Drying conditions	Moisture (g/100g)	Ash (g/100g)	Protein (g/100g)	Fat (g/100g)	Carbohydrate (g/100g)	Starch (g/100g)	Energy (kCal/100g)
CD at 50^{o}C	11.10 ± 0.11c	2.34 ± 0.11a	17.31 ± 0.29bc	0.64 ± 0.03b	79.71 ± 0.43c	77.98 ± 0.25ab	472.85 ± 4.13b
CD at 60^{o}C	12.81 ± 0.17b	2.27 ± 0.02a	14.77 ± 0.12c	0.91 ± 0.01a	82.05 ± 0.12b	72.99 ± 0.40d	477.02 ± 3.61ab
CD at 70^{o}C	12.75 ± 0.36b	2.25 ± 0.06a	14.29 ± 0.26c	0.45 ± 0.05c	83.02 ± 0.36a	78.06 ± 0.44a	471.71 ± 6.85b
CD at 80^{o}C	11.84 ± 0.19c	2.37 ± 0.04a	17.97 ± 0.24b	0.28 ± 0.03d	79.38 ± 0.29c	76.16 ± 0.30b	484.15 ± 7.19ab
Freeze drying	11.37 ± 0.22c	2.40 ± 0.05a	19.07 ± 0.10a	0.89 ± 0.03a	77.64 ± 0.18d	74.51 ± 0.15c	490.27 ± 3.92a
Sun drying	13.62 ± 0.40a	2.36 ± 0.07a	14.22 ± 0.14c	0.96 ± 0.01a	82.46 ± 0.14ab	77.13 ± 0.25ab	470.56 ± 3.10b

Note: CD-Cabinet Drying; Values are Mean ± standard error of mean; Means followed by different lowercase alphabets in each column are differed significantly at P<0.05.

Table 2. Mineral profiling of jackfruit seed flour

Drying conditions	Ca	Mg	K	P	S	Fe	Zn	Na
	g/100g					mg/kg		
CD at 50^{o}C	2.52 ± 0.01f	0.84 ± 0.01c	0.38 ± 0.01d	0.26 ± 0.01a	0.30 ± 0.01c	98.55 ± 0.45b	11.76 ± 0.01d	0.13 ± 0.01a
CD at 60^{o}C	2.66 ± 0.01e	0.89 ± 0.01c	0.31 ± 0.01e	0.25 ± 0.01a	0.32 ± 0.01c	94.20 ± 1.15c	11.40 ± 0.02e	0.14 ± 0.01a
CD at 70^{o}C	3.17 ± 0.01d	1.06 ± 0.01b	0.46 ± 0.01a	0.24 ± 0.01a	0.48 ± 0.01a	86.58 ± 0.57d	10.26 ± 0.04f	0.14 ± 0.01a
CD at 80^{o}C	3.31 ± 0.01c	1.07 ± 0.01b	0.39 ± 0.01cd	0.24 ± 0.01a	0.39 ± 0.01b	71.76 ± 1.18e	12.36 ± 0.01c	0.12 ± 0.01a

Drying conditions	Ca	Mg	K	P	S	Fe	Zn	Na
	g/100g					mg/kg		
Freeze drying	3.38 ± 0.01b	1.13 ± 0.01a	0.41 ± 0.01c	0.24 ± 0.01a	0.38 ± 0.02b	94.80 ± 0.63c	14.64 ± 0.02a	0.13 ± 0.01a
Sun drying	3.45± 0.01a	1.15 ± 0.01a	0.43 ± 0.01b	0.25 ± 0.01a	0.44 ± 0.02a	106.20 ± 0.57a	12.90 ± 0.02b	0.14 ± 0.01a

Note: CD-Cabinet Drying; Values are Mean ± standard error of mean; Means followed by different lowercase alphabets in each column are differed significantly at P<0.05.

Table 3. Color attributes of jackfruit seed flour

Drying conditions	L	a*	b*	Chroma (C*)	Hue angle (H^o)
CD at 50^{o}C	77.40 ± 1.49c	3.75 ± 0.10b	13.14 ± 0.37a	13.67 ± 0.34a	74.01 ± 0.80b
CD at 60^{o}C	80.68 ± 0.61b	3.20 ± 0.15c	11.46 ± 0.12b	11.90 ± 0.14b	74.41 ± 0.57ab
CD at 70^{o}C	80.22 ± 0.49b	3.79 ± 0.12b	12.57 ± 0.17ab	13.14 ± 0.19ab	73.03 ± 0.99bc
CD at 80^{o}C	79.21 ± 0.30bc	4.27 ± 0.26a	12.21 ± 0.28ab	12.94 ± 0.27ab	70.69 ± 1.21c
Freeze drying	84.22 ± 0.83a	3.31 ± 0.07bc	11.07 ± 0.21b	11.55 ± 0.22b	73.36 ± 0.42b
Sun drying	72.38 ± 0.70d	3.23 ± 0.14c	13.75 ± 0.15a	14.12 ± 0.18a	76.77 ± 0.44a

Note: CD- Cabinet Drying; L-Lightness; a-red/green; b*-yellow/blue; Values are Mean ± standard error of mean; Means followed by different lowercase alphabets in each column are differed significantly at P<0.05.*

Table 4. Bioactive compounds and antioxidant activity of jackfruit seed flour

Drying conditions	Total carotenoids (mg/100g)	Ascorbic acid (mg/kg)	Total phenol (mg GAE/100g)	DPPH-RSA (% Inhibition)
CD at 50^{o}C	58.99 ± 0.63b	51.17 ± 0.09c	750.98 ± 18.66c	69.03 ± 0.73de
CD at 60^{o}C	42.01 ± 0.97c	54.67 ± 0.82bc	743.75 ± 11.01c	70.42 ± 0.64d
CD at 70^{o}C	39.67 ± 1.10c	51.68 ± 0.42bc	744.81 ± 13.41c	70.83 ± 0.46d
CD at 80^{o}C	36.97 ± 0.44d	42.41 ± 0.65d	909.20 ± 10.51b	74.06 ± 0.53b
Freeze drying	72.20 ± 0.30a	65.05 ± 0.45a	1009.13 ± 28.94a	75.60 ± 0.06a
Sun drying	31.86 ± 0.93e	53.25 ± 0.95b	704.30 ± 13.76c	71.72 ± 0.83cd

Note: CD-Cabinet Drying; Values are Mean ± standard error of mean; Means followed by different lowercase alphabets in each column are differed significantly at P<0.05.

Microstructural properties

To investigate the impact of drying methods and conditions on the flour particle microstructure, the SEM images of jackfruit seed flours were captured and shown in figure 2. The SEM images were captured at 100× magnifications. It can be seen that the jackfruit seed flour particles were of round to bell shapes, which are comparable to the published reports (Madruga et al., 2014; Rengsutthi & Charoenrein, 2011). Most of the cabinet-dried and freeze-dried flour particles had a smooth surface with an average particle size of around 50-100 µm that could be considered as an acceptable feature of flour used for baking products (reference if any). While the sun-dried flour particles had a rough surface with irregular shape and aggregated structure. The rough surface and aggregated structure of sun-dried flour could be correlated to the function of drying and the presence of higher moisture content, respectively (reference if any). However, the present study suggests that the satisfactory microstructural properties of jackfruit flour could be attainable by hot air cabinet drying and freeze drying in comparison with sun drying.

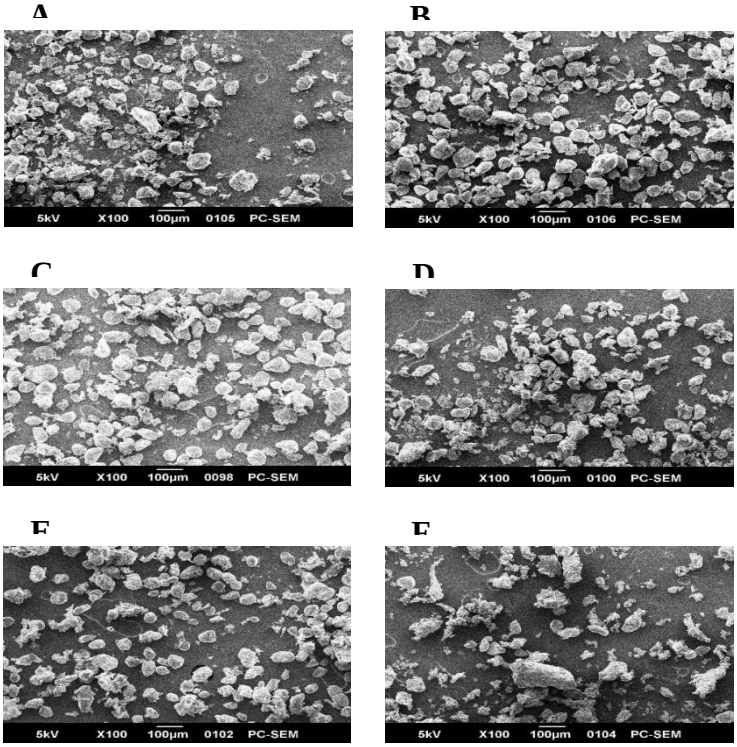

Figure 2. Scanning electron micrographs of jackfruit seed flours: A. cabinet-dried at 50°C, B. cabinet-dried at 60°C, C. cabinet-dried at 70°C, D. cabinet-dried at 80°C, E. freeze-dried, and F. sun-dried. Magnification = 100x and bar = 100 µm.

Conclusion

This study was conducted to investigate the physicochemical properties, bioactive compounds and antioxidant and microstructural properties of jackfruit seed flour. To execute these, cabinet drying at different temperatures (50-80^{o}C), freeze drying and natural sun drying techniques were used for producing jackfruit seed flour. It is revealed that the jackfruit seed flour contained significant amount of protein, ash, fat, and starch along with different mineral constituents. It is also found that the jackfruit seed flour is an ample source of different bioactive compounds and has posed huge antioxidant potential. Overall, the jackfruit seed flour obtained would get its potential applications in different food formulations and other fields such in pharmaceuticals.

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EFFECT OF COOKING METHODS AND OIL ON PHYSICOCHEMICAL, NUTRITIONAL, MINERALS AND BIOACTIVE COMPOUNDS OF LEAFY VEGETABLES

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Abstract

Bioactive compounds especially ascorbic acid is changed soon after harvest particularly drastically changed by thermal process. The research explored to determine the nutritional, physicochemical, minerals and phytochemical compounds of leaf of the BARI cultivar Radish-2, locally called BARI Mula-2. Its green leaf is mainly consumed as frying by soybean oil in traditional cooking process. Recently extra virgin olive oil is recommended by the dietician becase it provives various health benefits. But the information is insufficient regarding the proximate and nutritional composition, minerals and phytochemical constituents using extra virgin olive oil and soybean oil. Results indicate that BARI radish-2 is the rich source of ascorbic acid, anthocyanin, total carotenoid, total phenolic, ß-carotene and energy content. It does contain amusing amount of Ca (1.25±0.02 %), K (3.31±0.01 %), Fe (286.33±0.23 ppm) and Zn (49.23±0.02 ppm), which is essential for adults (especially women) and child. Most of the minerals and bioactive compounds enriched after cooking and steam blanching by extra virgin olive oil as compared to soybean oil. The highest ß-carotene (84.54±0.09 µg/100gm) and energy content (7486.29±0.28 cal/gm) possessed by the steam blanching using extra virgin olive oil whereas the control sample contained 29.08±0.07 µg/100gm ß-carotene and 4528.72±0.48 cal/gm of energy content. Moreover, the leafy vegetables blanched by steam blancher using extra virgin olive oil is the superior source of minerals and bioactive compounds and lower source of carbohydrate and crude fat content. Hence, the steam blanching process and extra virgin olive oil may be helpful for the dietary people to reduce their overweight by intake of low fat and carbohydrate food through fat adaptation and metabolism process.

Introduction

Vitamins, minerals, fibers, and disease-fighting phytochemicals found superior in fruits and vegetables where the human body needs to maintain good health. Although consumption of fresh unprocessed plant food is widely advocated, evidence is emerging that bioavailability of many protective compounds is enhanced when vegetables are cooked (Bongoni et al., 2014). The type of processing affects the extent to which a vegetable food is a good source of a nutrient (Hui et al., 2014). The processing needs to be designed and controlled to give the product qualities identified and wanted by the consumers (Earle and Earle, 2003).

Recent studies shown that selection of proper cooking methods can enhance the availability of healthy nutrients. Steaming, roasting, boiling, frying, sauteing, and microwave and pressure cooking are found to be the most common methods for cooking vegetables (Dos Reis et al., 2015). Moreover, the researchers also considered in their work, factors related to the preparation phase of common domestic processing, including washing, peeling, cutting, chopping, and soaking (Tiwari and Cumins, 2013). Such information has been studied in detail for broccoli (Bongoni et al., 2014). Understanding how and why nutrient losses are therefore helpful for the consumer, chef, and food processor to limit such losses and enhance the nutritional quality of leafy vegetables.

Bangladesh Agricultural Research Institute (BARI) up to now developed few leafy vegetable varieties that are being tentatively introduced and disseminated to all over the country. They are grown almost all over the country and are renowned for their emblematic taste, yield and highly adaptation to different regions in Bangladesh. These varieties have a great demand throughout the Bangladesh.

Limited works have been carried out on the physicochemical, proximate composition, minerals and bioactive compounds of leafy vegetables. Acidity, pH and vitamin-C of the fresh (uncooked) leafy vegetables have been done in somewhere but they are still incomplete. Research on different cooking methods and their effect on loss of nutritional and bioactive compounds are meager in the country. Minimization of this loss might make the consumer more aware on how to optimize the nutrients obtained during a meal. Thus, the aim of this study was to evaluate the effect of the two cooking methods and edible oils on the composition of nutritional, minerals and phytochemicals of the selected green leafy vegetable.

Materials and methods

Well-known and abundantly consumed BARI Radish-2 was collected from the Research Field of Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI). Soon after harvest, the leafy vegetable was precooled to remove field heat and then it was treated according to the following treatments.

Treatments

T_1= Leafy vegetable cooking with soybean oil using traditional oven

T_2= Leafy vegetable cooking with soybean oil using steam blancher

T_3= Leafy vegetable cooking with olive oil using traditional oven

T_4= Leafy vegetable cooking with olive oil using steam blancher

T_5= Control (uncooked)

Nutritional and physicochemical studies

The nutritional and physicochemical analysis of acidity, crude fat, moisture, ash, moisture and ascorbic acid was determined according to the method described by Ranganna (1995).

Color measurement

The color of the cooked leafy vegetables 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 of the steam blanched and traditionally cooked vegetables were done based on our previous paper Khan et al. (2021) with minor modification. A cylindrical prove by a Texture Analyzer TA.XT plus (Stable Micro System, Godalming, UK) by 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^{-1}force.

Analysis of Minerals

The minerals analyzed in this study were: sodium, potassium, calcium, magnesium, phosphorus, sulphur, boron, copper, manganese, iron, and zinc. Before quantification of their amounts, the fruits were first wet ashed and then digested in nitric and parchloric acid solution at 320^{o}C, cooled, diluted to an appropriate concentration, and filtered. This filtrate was considered as the stock solution for further analysis. Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Tokyo, Japan) was used to assess the sodium, iron, copper, zinc, boron, manganese, calcium and magnesium. Potassium content was measured using flame photometry while phosphorous and sulphur content was assessed with the spectrophotometric method. Individual minerals were quantified by comparing the corresponding standard mineral procured from the Sigma Chemical Co., USA.

Determination of phytochemicals

Total phenolic content (TPC) of the cooked leafy vegetables were measured following the protocols used by Ough and Amerine (1988) with some modification. Briefly, 1 mL extract and 0.2 mL 10% Folin-Ciocalteau reagent were taken in glass tubes and vortexed for 3 min. Thereafter, 0.8 mL Na_2CO_3 (7.5%, w/v) was added, mixed properly, and kept in dark condition for 1h. Then, the absorbance was measured at 760 nm using a UV-Vis spectrophotometer (T80 UV/VIS Spectrometer, PG Instruments LTD.) against the blank. Gallic acid was used as the standard and TPC was expressed as mg GAE/g of the sample.

Ascorbic acid was determined according to the method described by Ranganna (1995). The ascorbic acid content was expressed in mg/100 g in fresh weight basis.

ß-carotene content was determined based on the method described by Molla et al. (2017) with minor modification. A 3 g of freeze dried powder was diluted with acetone (Fisher Scientific Ltd.,

UK) and petroleum ether. It was further purified with acetone, metabolic potassium hydroxide (KOH) and distilled water. The subsequent solution was filtered with anhydrous sodium sulphate and the absorbance was measured by UV-Vis Double Beam Spectrophotometer at 765 nm against petroleum ether as a blank.

The anthocyanin content was measured following our previous paper (Molla et al., 2021) and the result was expressed as mg/100g of the sample.

Sensory evaluation

The sensory attributes were performed following the procedure of Joshi (2006). It was performed using a 9-point hedonic scale, i.e. 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely. A judgment panel was formed by the thirty expert members from the BARI inter-divisional Scientists to evaluate their color, flavor, texture, mouth feel, spreadable capacity and overall acceptability. The score obtained by the panelist was analyzed by statistical analysis.

Statistical analysis

All data was expressed in duplicate as means ± standard deviation. One-way ANOVA with post-hoc using Turkey Multiple Comparison Test were 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

Titrable Acidity

The titrable acidity of the leafy vegetables significantly differed as than others. The highest acidity was calculated as 3.87±0.09% in uncooked fresh leafy vegetables than the treated leafy vegetables. The lowest acidity recorded as 1.03±0.01% and 1.04±0.02% in the extra virgin olive oil cooked by traditional and steam blanching process (Table 1). The results obtained from this study indicate that cooking methods significantly affect the acidity content of the leafy vegetables.

pH

There was highly significant differences of pH among the uncooked (fresh), traditionally cooked and steam blanched leafy vegetables using extra virgin olive oil and soybean oil. Lowe pH was recorded as 5.64±0.13% in highly acidity uncooked fresh leafy vegetables and higher pH was noted as 6.06±6.05 % and 6.02±0.02% for the lower acid value containing extra virgin olive oil under traditional and steam blanched process (Table 1). Results indicating that the pH of the steam blanched vegetables using extra virgin olive oil increased as compared to traditional process using soybean oil. Degradation of heat liable and soluble acid during steaming may be contributed to the rise in pH (Kaushal et al., 2013; Quarcoo and Wireko-Manu, 2016). The rises in pH might also be attributed to the decrease of obtainable carboxylic groups of proteins, but also the proclamation of calcium and magnesium ions from proteins (Ergezer and Gokce, 2011). The results also confirm that there is a negative relation between the pH and acidity (Table2).

ß-carotene content

Table 1 shows, the highly significant difference between the cooked and uncooked leafy vegetables. The highest amount of ß-carotene content (84.54±0.09 µg/100gm) noted in steam blanched vegetables using extra virgin olive than the vegetables cooked using soybean oil under domestic process. The showing less amount of ß-carotene content by the traditional cooking process might be owing to the effect of heating process as the ß-carotene content are more susceptible to heat damage (Mazzeo et al., 2011). Less amount of ß-carotene content (12.80±0.20 µg/100gm) shown in the fresh (uncooked) mixed vegetables might be due to partial diluted in the soluble that may be hampered the better extraction of ß-carotene content.

Crude fat content

The fat content for both uncooked, cooked and steam blanched vegetables were varied significantly. The variation of fat content might be due to conversion of higher amount of carbohydrate into sugar and in later the sugar might be accumulated into fat content by fat adoption and metabolism process. The higher amount of fat content 27.46±0.01% and 17.18±0.01% was noted in leafy vegetables cooked using soybean oil under domestic cooking process whereas the lower was recoded as 12.49±0.01% and 15.81±0.48% using extra virgin olive oil by steam blanching. It is notable that the

lowest fat content (9.46±0.01%) was found in uncooked fresh leafy vegetables than the vegetables cooked by domestic and steam blanching process using both oil (soybean and extra virgin olive oil). The higher amount of fat content obtained by the soybean oil might be due to hydrolysis of fat under domestic cooking process that may be enhanced the acid value of the oil for the production of free fatty acids from triglycerides (Kumar et al., 2017). The higher acidity may be donated to advance higher fat content in the soybean oil.

Energy content

Table 1 shows, energy content were significantly affected by the cooking and uncooking process. The higher energy value recorded as 7486.29±0.28 and 7306±0.52 cal/gm for the steam blanching process using extra virgin olive oil and soybean oil whereas the lower energy value 6674.75±0.35 and 6770.17±0.16 cal/gm was found using soybean oil both domestic and steam blanching process. Uncooked fresh leafy vegetables shown 4528.72±0.48 cal/gm energy value followed by cooking and steam blanching process, indicating that leafy vegetables cooked using both soybean and extra virgin olive oil enhanced to obtain higher energy value.

Ash content

The ash content was significantly varied among the uncooked, cooked and steam blanched process (Table 1). The highest ash content observed in soybean oil cooked both domestic and steam blanching. The lowest ash content was recorded in uncooked fresh leafy vegetables. The higher ash content obtained by the domestic cooking process might be owing to the declined of cell membrane (Ferracane et al., 2008) in vegetable tissues due to the over heat and thus few minerals might have been accumulated through this process instead of leaked out.

Moisture content

Moisture content of the steam blanched leafy vegetables using extra virgin olive oil and traditional cooking process using soybean oil varied significantly. The highest moisture content (86.80±1.75 %) was found in uncooked fresh leafy vegetables followed by cooking and steam blanching process. In case of cooking, the highest moisture content was found in steam blanching process (75.09±1.04 % and 72.46±1.62 %) than the domestic cooking process.The highest moisture content found in uncooked (fresh) vegetables might be due to non-disruption of cell walls and membrane whereas the cooked samples might be influenced by the heating process to interference of cell walls and membranes allowing water to fill spaces.

Table 1. Physicochemical properties & energy content of the leafy vegetables under different cooking conditions

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
Acidity (%)	1.14±0.01	1.58±0.07	1.03±0.01	1.04±0.02	3.87±0.09	**
pH	5.80±0.10	5.68±0.10	6.06±0.05	6.02±0.02	5.64±0.13	**
ß-carotene µg/100g)	21.15± 0.12	22.22±0.18	34.81±0.10	84.54±0.09	29.08±0.07	**
Crude fat (%)	27.46± 0.01	17.18±0.01	15.81±0.48	12.49±0.01	9.46±0.01	**
Energy (Cal/g)	6674.75± 0.35	6774.17±0.16	73060±0.52	7486.29± 0.28	4528.72± 0.48	**
Ash (%)	7.64±0.05	2.29±0.28	6.72±0.86	3.43±0.82	1.89±0.14	**
Moisture (%)	52.54± 1.26	75.09±1.04	61.48±0.64	73.46±1.62	86.80±1.75	**

*All values are means of triplicate determinations ± SD. ** indicate significant results at p<0.01levels.*

Minerals profile

Minerals are the inorganic components present in foodstuff as ash when food is cremated. Generally, two forms of minerals are present in foodstuffs – macro and micro minerals both play important metabolic roles in our body functioning (Reilly, 2002) and contribute to our daily diet. In our study, eleven (11) minerals were assessed, whose results are presented in Table 2. It can be seen that the leafy vegetables cooked using extra virgin olive oil both domestic and steam blanching process contained higher amounts of macro minerals such sodium (3.18±0.01 and 3.14±0.01 mg %), potassium (3.15±0.04 and 3.22±0.01 mg %), calcium (1.39±0.00 and 1.37±0.01 mg %), magnesium

(0.73±0.00 and 0.72±0.01 mg %), and phosphorus (0.32±0.00 and 0.38±0.00 mg %) with considerable amounts of micro minerals such as boron (21.00±0.00 and 15.01±15.01 ppm), copper (23.31±0.05 and 23.04±0.03 ppm), iron (310.64±0.03 and 312.59±0.01 ppm) and manganese (164.36±0.01 and 165.20±0.19 ppm). Zn (50.39±0.01 and 51.57±0.02 ppm) is highly presented in soybean oil both domestic and steam blanching process. The results indicating that among the different minerals identified in leafy vegetables cooked using extra virgin olive under domestic and steam blanching process was the rich sources of minerals than others.

Table 2. Minerals of the leafy vegetables under different cooking conditions

Minerals	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
Ca (%)	1.27±0.01	1.24±0.01	1.39±0.00	1.37±0.01	1.25±0.02	**
Mg (%)	0.66±0.01	0.64±0.01	0.73±0.00	0.72±0.01	0.75±0.00	**
K (%)	3.16±0.03	3.04±0.03	3.15±0.04	3.22±0.01	3.31±0.01	**
P (%)	0.21±0.00	0.31±0.00	0.32±0.00	0.38±0.00	0.33±0.01	**
Na (%)	0.85±0.00	0.81±0.01	3.18±0.01	3.14±0.00	0.88±0.01	**
S (%)	0.29±0.00	0.18±0.01	0.20±0.00	0.21±0.01	0.28±0.00	**
Cu (ppm)	21.31±0.01	20.87±0.00	23.31±0.05	23.04±0.03	21.13±0.03	**
Fe (ppm)	290.39±0.00	273.55±0.04	310.64±0.03	312.59±0.01	286.33±0.23	**
Mn (ppm)	153.60±0.04	144.71±0.04	164.36±0.01	165.20±0.19	151.44±0.18	**
Zn (ppm)	50.39±0.01	51.57±0.02	38.87±0.01	40.19±0.01	49.23±0.02	**
B (ppm)	13.79±0.01	12.59±0.01	21.00±0.00	15.01±0.01	22.17±0.03	**

*All values are means of triplicate determinations ± SD. ** indicate significant results at p<0.01levels.*

Phytochemical compositions of the cooked and uncooked leafy vegetables

Ascorbic acid

There were highly significant among the different treatment of the sample (Table 3). The ascorbic acid content of the fresh leafy vegetables were higher (31.73±0.02 mg/100 g)) followed by treated samples. The leafy vegetables cooked using steam blancher using soybean and extra virgin olive oil were not statistically differed. But the leafy vegetables cooked with soybean oil under traditional process retained more ascorbic acid content (12.91±0.01 mg/100 gm) than the vegetables blanched by steam blancher using olive oil (5.05±0.02 mg/100 gm). The reduction in ascorbic acid content by steam blancher might be due to its water soluble and labile. Consequently it is easily leached into the steam blanching medium (Hailemariam and Wudineh, 2020). The increase ascorbic acid content by traditional process might be due to concentrated oil and water into the cooking medium by heating process.

Total anthocyanin

Anthocyanin content of the leafy vegetables was affected by the different cooking methods with statistically significant differences (Table 3). In this study, the highest anthocyanin content of the leafy vegetables was noted as 51.17±0.14 and 52.69±0.02 mg/100 gm by steam blanching process using both soybean and extra virgin olive oil. The lowest anthocyanin content was recorded as 16.13±0.02 and 22.02±0.01 mg/100 gm by traditional cooking using both soybean and extra virgin olive oil. The anthocyanin content of the fresh (uncooked) leafy vegetables was calculated as 23.28±0.07 mg/100 gm. Results indicating that the leafy vegetables blanched by steam blancher increased the anthocyanin content followed by both traditionally cooked and uncooked (fresh) vegetables. The increased anthocyanin content by the steam blanching process might be the effect of presenting polyphenol oxidase that contributes to degrade the enzyme. In heating process, the polyphenol oxidases are inactivated that may contribute to holding more anthocyanin although it is highly water soluble. The microstructures of the cooked vegetables are destroyed by the heating process that persuades the better extraction of anthocyanin content (Brown et al., 2008; Lachman et al., 2012). The cooking process comprises changes to the structural integrity of the cellular matrix, softening the vegetable tissues and, consequently, increasing anthocyanin's extraction and concentration (Chaovanalikit and Wrolstad, 2004; Murador et al., 2014)

Total carotenoid

Total carotenoid content of the cooked and uncooked (fresh) samples were highly significantly differed. The highest total carotenoid content of the steam blanched leafy vegetables using soybean oil

and extra virgin olive oil recorded as 24.01±0.0.01 and 43.69.52±0.02 mg/100 gm whereas the traditional cooking process using soybean oil and extra virgin olive oil found 17.85±0.0.07 and 20.69±0.02 mg/100 gm (Table 3). The uncooked vegetables retained total carotenoid content 21.03±0.02 mg/100 g. Results indicate that steam blanching leafy vegetables using soybean and extra virgin olive oil increased the total carotenoid content followed by other process. In case oil effect, the extra virgin olive oil increased the total carotenoid as compared to soybean oil cooked leafy vegetables. Higher carotenoid content exhibited by steam blanching process are strongly supported with the findings of Bernhardt and Schlich (2006) and Gliszczynska-Swiglo et al. (2006), those reported that the carotenoid content of the broccoli, Brussels sprouts, cabbage and cauliflower increased by boiling and steaming process through breakdown of cellulose in the plant cell, thus contributed to better extraction of carotenoids.

Total phenolic content

Total phenolic content of the leafy vegetables cooked and uncooked process, using soybean oil and extra virgin olive oil significantly differed (Table 3). The steam blanched leafy vegetables using extra virgin olive oil exhibited higher amount of total phenolic content than the vegetables cooked using soybean oil by traditional cooking process. These results are partially supported with the findings of tropical green leafy vegetables that were reported by the Adefegha and Oboh (2011). Several researchers conclude that cooking process as well as boiling, steaming and microwave assisted cooking enhance the total phenolic content than the fresh (uncooked) one (Faller and Fialho, 2009; Blessington et al., 2010). Tian et al. (2016) also reported that shorter times and lower temperatures enhance the more retention of total phenolic content by the steaming; boiling and microwave based cooking process. The enhancement of the total phenolic content by different cooking process might be endorsed due to the breakdown of the structural process which may increases the quantification of the total phenols from the cellular atmosphere and inspires the discharge of dietary fiber-bound polyphenols creating the free phenolic compounds (Ruiz-Rodriguez et al., 2008).

Table 3. Phytochemicals of the leafy vegetables under different cooking conditions

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
Ascorbic acid (mg/100 g)	12.91±0.01	5.05±0.02	3.49±0.02	5.05±0.04	31.73±0.02	**
Anthocyanin (mg/100 g)	16.13±0.02	22.02±0.01	51.17±0.14	52.69±0.02	23.28±0.07	**
Total carotenoid (mg/100 g)	17.85±0.07	20.69±0.02	24.01±0.01	43.69±0.02	21.03±0.02	**
Total Phenolic (mg GAE/100	3.69±0.02	6.41±0.02	11.49±0.13	18.55±0.18	6.41±0.02	**

*All values are means of triplicate determinations ± SD. ** indicate significant results at p<0.01levels.*

Effect of steam blanching and traditional cooking on color of leafy vegetables

Color is the foremost quality considered by consumers at the time of purchasing a product. The effect of color values on the uncooked (fresh), steam blanched and traditional cooked leafy vegetables are testified in Fig.1. The external surfaces of the cooked leafy vegetables were considered. The color of the uncooked, steam blanched and traditionally cooked leafy vegetables had a lightness (*L**) of 39.80, 33.57 and 38.01 respectively. The Chroma (*c*)* of the uncooked, steam blanched and traditionally cooked leafy vegetables were 23.04, 16.49 and 93.27 whereas the hue angle (*h*)* of the uncooked, steam blanched and traditional cooked vegetables were 117.19, 95.69 and 93.27 respectively. Results indicate that *L** and *h** values expressively declined after steam blanched and traditionally cooked leafy vegetables. The external color of the steam blanched and traditionally cooked vegetables was less bright (*L**) and hue (*h**) than the uncooked sample color. A significant loss of bright color (*c**) for the uncooked and steam blanched leafy vegetables decreased whereas a significant C increase was noticed for the traditional cooked leafy vegetables. The hue angle significantly increased for the uncooked cooked vegetables in comparison to the steam blanched and traditionally cooked vegetables. It is well reported that the color of the uncooked, cooked and steam blanched vegetables are affected by the α-carotene and ß-carotene content (Bao and Chang, 1994). In our study, it shows that the highest ß-carotene content was retained in steam blanching leafy vegetables by the steam

blancher followed by uncooked and traditionally cooked vegetables (Table 1). The lowest ß-carotene content was retained by our uncooked vegetables, which is may be directly related to increase the hue angle (*h**) of the vegetables (Fig.1). Our results obtained by this study are strongly supported with the findings of Sulaeman et al. (2004), who reported that a high negative correlation was observed between this color parameter and the carotene content of deep fried carrots. The larger decrease of Chroma (*C**) and lightness (*L**) might be due to increase of ß-carotene content by the steam blanching process. Our findings are strongly supported with the findings of Hart and Scott (1995), those reported that higher ß-carotene content found in the carrot may be contributed to the remarkable loss of Chroma (*C**) and lightness (*L**).

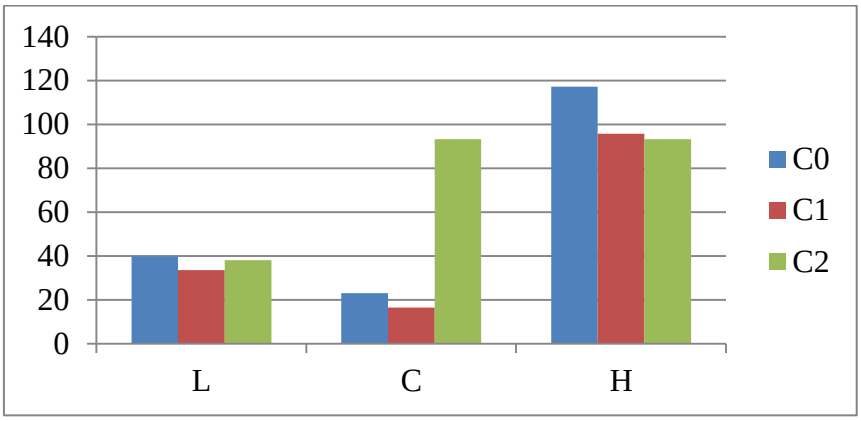

Figure 1. *Color of the uncooked, cooked and steam blanched leafy vegetables; C_0= Uncooked (fresh) leafy vegetables, C_1= Steam blanched leafy vegetables, C_2= traditionally cooked leafy vegetables.*

Texture profile of leafy vegetable

Fig.2 represents the texture of the leafy vegetables cooked by traditional and steam blanching process. Then the traditionally cooked and steam blanched leafy vegetables were compared with the uncooked (fresh) vegetables. The rupture force (FR) was measured in order to evaluate their hardness and softness. The maximum, medium and lowest peak was recorded in uncooked fresh (control), steam blanched and traditionally cooked leafy vegetables. Between the cooked vegetables, the highest peak obtained by the steam blanched leafy vegetables, might be due to the less broken of the cell membrane to attain more hardness than the traditionally cooked vegetables.

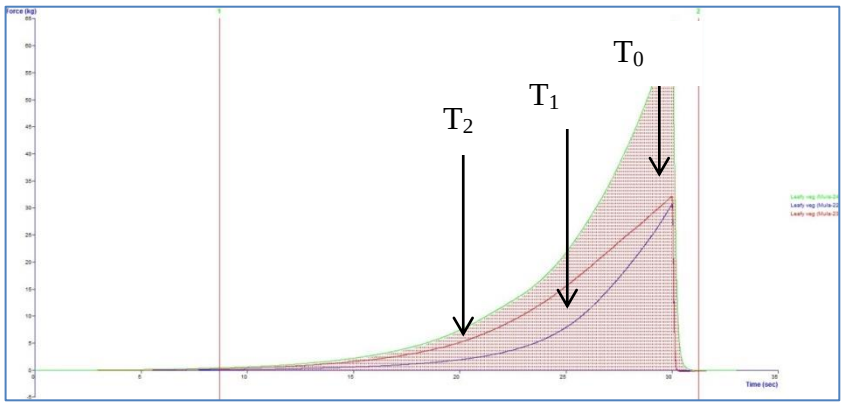

Figure 2. *Texture profile of the leafy vegetables cooked under different cooking condition, T_0= Fresh (uncooked) leafy vegetables, T_1= leafy vegetables cooked by steam blancher, T_2= Leafy vegetables cooked by traditional process*

Sensory evaluation

The leafy vegetables cooked by traditional and steam blanching process was subjected to sensory evaluation based on 9-point hedonic scale (Table 4). The expert judgment scored the leafy vegetables in terms of their color, flavor, taste, softness and overall acceptability. Results indicate that all the sensory attributes were statistically non-significant differences. But most of the judgment expressed

their opinion on the color of the steam blanched leafy vegetables. But the highest score for overall acceptability (7.07±0.68) obtained by the traditional cooking process followed by steam blanching process. These might be due to the eating behavior of the country (Bangladesh) people as the peoples are accustomed with traditional cooking process.

Table 4. Sensory evaluation of the leafy vegetables under different cooking conditions

Parameter	Treatment		LSD
	T1	T2	
Color	7.10±1.10	7.40±1.20	NS
Flavor	6.50±1.58	6.80±0.611	NS
Taste	7.40±1.42	6.50±1.77	NS
Softness	7.30±0.82	6.30±2.49	NS
Overall acceptability	7.07±0.68	6.75±1.59	NS

T_1=Traditionally cooked leafy vegetables, T_2= Steam blanched Leafy vegetable; All values are means of triplicate determinations ± SD. NS means a non-significant result.

Conclusion

The present study obviously indicates that physicochemical, nutritional qualities, phytochemicals, texture and color value of the leafy vegetables are significantly influenced by the different cooking methods. The traditional cooking process used here, selected to imitate the common Bangladeshi cooking practices for the leaf of the BARI Mula-2. The steam blanching process used here followed by the steam blancher. Both cooking process followed here, done with the focus to cooking pattern. Results confirm that steam blanched leaf of the BARI Mula-2 enriched the nutrient and phytochemicals values than the traditional process. The steam blanching process also improved the texture and color of the leaf of the BARI Mula-2 that might be contributed to retained more ß-carotene content as compared to traditional process. The lower crude fat and carbohydrate content and higher energy values are also reserved by the steam blanching process. Moreover, the steam blanched leaf of the BARI Mula-2 using extra virgin olive oil may be recommended to the consumer those would like to reduce their overweight.

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EFFECT OF PINEAPPLE POMACE ON THE QUALITY OF PEANUT BAR AND THEIR PHYSICOCHEMICAL AND NUTRITIONAL PROPERTIES

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Abstract

The study was conducted to maximum utilize the pineapple pomace for formulation of peanut bar using jaggery (cane sugar). The study was laid out in complete randomized design (CRD) with 3 replications. Developed pineapple pomace peanut bar were stored in PET boxes for 2 months for observation. The market sample was collected from the local market of the Gazipur city to compare with our nut bar. Then the collected sample was stored and analyzed for its color, texture, sensory attributes, nutritional and physicochemical properties. Results revealed that our developed nut bar is the rich source of crude fiber (6.48±0.48 %), crude protein (13.06±0.05 %), vitamin-C (23.28±0.21 mg/100 g) and ß-carotene (16.32±0.03 µg/100 g) than market sample. Nutritional and physicochemical properties of our nut bar and the market sample (Badam topi) gradually decreased with the advancement of storage periods. An increasing trend of water activity (a_w) found in our developed and market samples with increasing storage periods. The maximum hardness was found in market sample as compared to our developed anut bar. Statistically insignificant sensory score was obtained for all the formulated and market samples. The storage studies confirmed that the marketability of our nut bar T_3 could be extended 2 months more using without any excessive quality deterioration. These findings may be applied for the manufacturing of pineapple pomace peanut bar as health beneficial. These peanut bars can be practically used for the school nutrition programs to uplift the nutritional status of the school going children.

Keywords: Crude fiber, crude protein, vitamin-C, color, texture, sensory attributes.

Introduction

Pineapple is a major fruit of Bangladesh and grows to all over the country. Especially its main growing area is concentrated to Modhupur of Tangail district, Sreemongal of Moulvibazar district, Rangamati, Khagrachari and Bandarban of Chattagram Hill Areas of Bangladesh. In present, it is cultivated 15.05 thousand hectares of land with a production of 218.05 thousand metric tons (BBS, 2020). The fruit contains sufficient amount of vitamin A, B and C. Every year the fruit goes to postharvest loss due to lack of proper processing and preservation techniques.

Food is an elementary requirement of the human and may contribute to play a vital role to make a self sufficiency of Bangladesh. The country achieved improvement for the production of food but food security and safe food is still a major problem. Various processed products are made from pineapple fruits in the worldwide viz. jam, jelly, leather, cheese, nectar, squash, dried powder, toffee, ice-cream, candy, syrup, juice, concentrated puree, canned fruit segments, ready to serve drink (Jain and Asati, 2004) but after production of pineapple processed items results in massive waste generations called pineapple pomace. The drying, storage and shipment of this wastage is cost effective and hence efficient, inexpensive and eco-friendly utilization is becoming more and more necessary. Further, the utilization of the pomace may contribute to minimize the substantial amount of postharvest losses of pineapple and many health beneficial effects. It (pomace) is a rich source of dietary fiber. Many literatures suggest that the dietary fiber can contribute to reduce the body weight and different cardiovascular diseases (heart attack, stroke, coronary heart disease, liver injury, cancer etc.). Therefore, the utilization of this pomace is very crucial for the country. Hence, the present study has undertaken to develop pineapple pomace peanut bar by utilizing pineapple pomace for maximizing the use of pineapple fruits.

Materials and Methods

Selection of pineapple

Physiologically matured pineapple fruits (*Emblica officinalis* Gaertn) were procured 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.

Processing and manufacturing of pineapple pomace peanut bar

Collected fresh fruits were thoroughly washed with fresh tap water. Peels were removed and pulp was collected to extract the juice for the preparation of pineapple jelly and marmalade. The core was used for the preparation of candy (although it was not our objective). After processing into jelly, marmalade and candy then the fresh pomace (as wastage) was incorporated for the processing (Figure 1) and formulation (Table 1) of pineapple pomace pea-nut bar (Figure 2). The formulated pea-nut bar was packed into high density polyethylene (HDPE) pouches and finally placed it into PET boxes for further proximate, nutritional and storage studies.

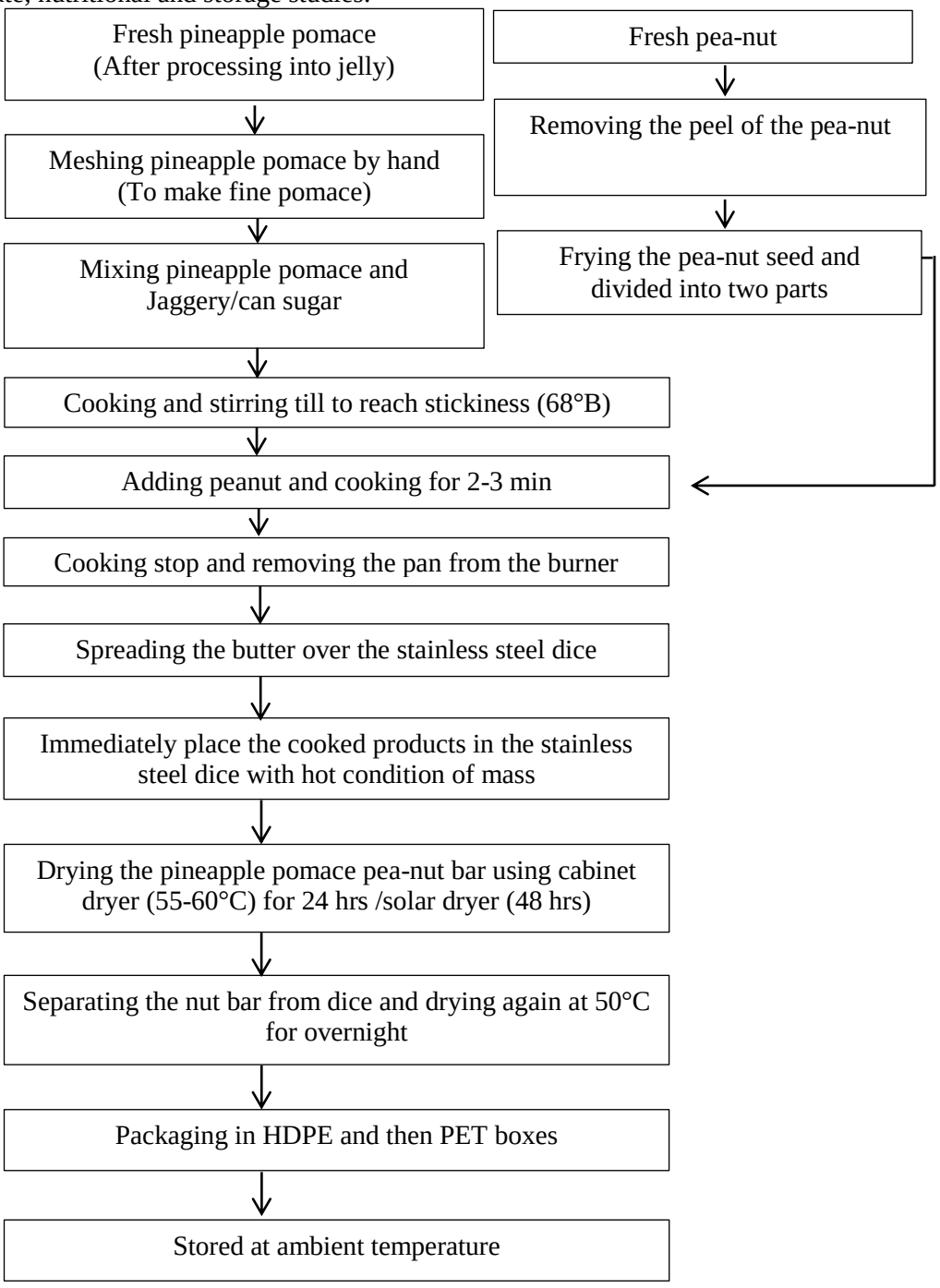

Figure 1. Processing flow chart of pineapple pomace peanut bar

Table 1. Formulation of peanut bar containing pineapple pomace

Ingredients	T_1 (g)	T_2 (g)	T_3 (g)	T_4 (g)
Pineapple pomace	250	250	250	-
Peanut	150	150	150	∨
Jaggery/cane sugar	200	300	400	∨
Puffed rice	10	10	10	∨
Ghee/butter	2	2	2	∨
Glucose	-	-	-	∨
Salt	-	-	-	∨
Vegetable oil	-	-	-	∨

Sign '∨' indicates ingredients used in market sample whereas the ingredients were reserved secret by the Industry. Sign '-' indicates not used in our treated samples.

Figure 2. Processing appearance of pineapple pomace based peanut bar

Proximate and nutritional composition studies

The proximate and nutritional analysis of crude protein, crude fat, moisture, total sugar, reducing sugar, vitamin-C and ß–carotene content was determined according to the method described by Ranganna (1995).

Color measurement

Pineapple pomace- peanut bar 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 previous paper Molla et al. (2020) using cross-sectional prove by a Texture Analyzer TA.XT plus (Stable Micro System, Godalming, UK) by 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

The sensory attributes were performed following the procedure of Joshi (2006). It was performed using a 9-point hedonic scale, i.e. 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely. A judgment panel was formed by the thirty expert members from the BARI inter-divisional Scientists to evaluate their color, flavor, texture, mouth feel, spreadable capacity and overall acceptability. The score obtained by the panelist was analyzed by statistical analysis.

Statistical analysis

All data was expressed in duplicate as means ± standard deviation. One-way ANOVA with post-hoc using Turkey Multiple Comparison Test were 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

The proximate and nutritional composition of the fresh (on the day of storage) and stored pea-nut bar are shown in Table 2 and Table 3.

Crude protein content

Table 2 and Table 3 show the physicochemical and nutritional composition of the pineapple pomace nut bar at on the day of storage and after 2 months of storage. All the treated samples were significantly differed. At on the day of storage, the protein content of the treated samples was ranged from 8.53-13.06 % whereas the collected market sample was 3.18 % (Table 1). But after 2 months of storage, the protein content of the treated samples ranged from 5.40-6.35 % whereas the market sample possessed 3.01 % (Table 3). The results indicate that the protein content decreased with the increasing of storage periods. The decrease in protein content may have been affected by tannins reported to form complexes with protein, limiting their availability (Sahore et al., 2007). The results are strongly supported with the findings of Zhang et al. (2017), those reported that a slight decrease in protein content was found in walnut male florescence's from 1-8 days of storage. The decreased amplitude of protein content might be due to spontaneity of the proteolytic activity at ambient condition. Our results obtained by this study shown higher amount of protein content than the results obtained by Aigster et al. (2011), those reported that the protein levels of the cereal nut bar containing pineapple peel flour ranged from 6.31 to 7.08% and 4.47–6.62%, respectively. Therefore, the protein content of our formulated pineapple pomace nut bar was satisfactory. The reason might be due to use of pineapple fresh pomace by us directly in the jaggery instead of several heating, milling and grinding process was used by the Aigster et al. (2011), as the protein is denatured by heating process.

Crude fiber content

Fiber content differentiation was highly significant among the different treatments of the prepared pineapple pomace bar at on the day of preparation and after storage (Table 2 and Table 3). The fiber values of the treated samples T_1, T_2, T_3 and T_4 were calculated as 5.05 %, 5.56 %, 6.48 % and 0.98 % at initial day of storage (Table 1) but after 2 months of storage, the values were noted as 5.18%, 6.06%, 7.34 % and 1.18 % respectively (Table 3), indicates that the fiber was gradually increased with the advancement of storage periods. The change of fiber during storage for various treatments is in conformity with the findings of Rokhsana et al. (2007), who reported that fiber content changed non-significantly in legume and vegetable based soup powder from 0.65- 0.70% during storage of 6 months. The lowest fiber content was obtained by the market sample than the treated all samples. As a reason it's may be mentioned that the market sample prepared using nut, sugar, salt, vegetable oil, ghee and glucose whereas the treated samples prepared using pineapple pomace, pea-nut, Jaggery, cardamom seed and ghee. Pomace is a byproduct from fruit processing which contains considerable amounts of dietary fiber, bioactive components and antioxidant (Larrauri et al., 1997; Figuerola et al., 2005). The synergistic effect of phytochemicals and fiber content presence in our prepared nut bar, may have ability to decrease body weight or attenuate weight gain could be contributed to several important factors for beneficial effects on the treatment and prevention of obesity and diabetes (Tucker, 2009; Weickert and Pfeiffer, 2008), reduced CVD (Liu, 1999) and decreased incidence of certain types of cancer (Ferguson et al., 2001).

Crude fat content

Different treatments of the pineapple pomace nut bar and the market samples were statistically significant at on the day of storage and after 2 months of storage (Table 2 and Table 3). On the day of storage, the fat content of the treated sample ranged from 1.41-1.83% whereas the market sample found 2.11% fat content. After 2 months of storage, the treated samples found 1.01-1.33 % fat content whereas the market sample was 1.61% fat content (Table 3). The results indicate that the market sample possessed higher amount of fat content than the formulated treated samples. The fat content for both treated and market samples were gradually decreased with the advancement of storage

periods. Our results are completely inverse relation with the formulated sesame bars developed by Abbas et al. (2017), those who reported that fat content increased from 0.63-0.77% with the advancement of different storage intervals. The dissimilarity and increased fat content of our treated and market samples might be due to conversion of higher amount of carbohydrate into sugar and in later the sugar might be accumulated into fat content by fat adoption and metabolism process.

Ash content

The analysis of variance for ash contents of different treatments of pineapple pomace nut bars at on the day of storage and after 2 months of storage showed that the difference in ash contents among different treatments is highly significant (Table 2 and Table 3). On the day of storage, the mean values of ash contents for treatments ranged from 4.05±0.04 to 3.43 ± 0.03% whereas the market sample was 4.04±0.03% (Table 2). But after 2 months of storage, ash contents of the treated samples ranged from 4.62±0.04 to 5.54±0.03% whereas the market sample was 4.44±0.07% (Table 3). The results indicate that lowest ash content was found in the market samples and the highest ash content was in the treated samples. It is noteworthy that there was a gradual increase in ash contents with increasing storage periods of the formulated pineapple pomace nut bar, due to increased quantity of crude fiber content in our treated samples as the ash content is directly related to the fibre content of the pineapple pomace nut bars.

Moisture content

Moisture content of the pineapple pomace nut bars was observed to be highly significant among the treatments and market sample. The mean values for moisture content of our treated samples ranged from 5.14±0.03 to 5.4± 0.04 % whereas the market sample was 1.31±0.13% (Table 2) at on the day of storage but after 2 months of storage the moisture content of the treated samples ranged from 5.72±0.04 to 5.87 ± 0.03% whereas the market sample was 1.59±0.18% (Table 3). After storage, the moisture difference was significantly high in our treated samples as compared to market sample. Having the highest moisture content of our treated samples, it was acceptable by the sensory evaluator due to its softness comparatively than the marketable sample. The lowest moisture content obtained by the market sample contributed to achieve more hardness than our treated samples. The variation in moisture content between the treated and market sample might be due to use of different ingredients during formulations. The results also show that the moisture content gradually increased upto 60 days of storage in both treated and market sample. Increase in the moisture of the pomace nut bars was vastly significant, possibly due to absorption of moisture from the surrounding areas, as a result of two main factors i.e. packed in non-airtight polyethylene terephthalate (PET) boxes and polypropylene pouches and exposure to the atmosphere at times. The lowest moisture content in the marketable sample might be contributed to achieve higher a_w than the treated sample (Table 2 and Table 3).

Carbohydrate content

Comparing the total carbohydrate contents among the formulated pomace nut bar and the market sample, there were significant differences ($p<0.05$) at on the day of storage and after 2 months of storage (Table 2 and Table 3). On the day of storage, the carbohydrate contents of the formulated samples ranged from 68.31±0.96 to 75.40±0.02% whereas it was 88.18±0.35% in market sample. After 2 months of storage, the ranges of the carbohydrate contents in formulated samples were 74.05±0.50 to 77.85±0.42% whereas the market sample was 88.39±0.55% (Table 2 and Table 3). Our findings were comparable to the results obtained by Souza et al. (2014), the carbohydrate contents obtained in their study ranged between 68.33 and 71.57%. Mendes et al. (2013) reported 61.61% as the carbohydrate content of their cereal bar made with fruit peels and baru. The results in this current effort were therefore comparable to our formulated pomace bar having higher carbohydrate contents of their cereal bars. The high contents of carbohydrate found in our formulated samples might be due to the addition of pineapple pomace and Jaggery in the formulation of the pomace nut bars. Another reason might be due to deposition of fat into carbohydrate by fat adoption and metabolism process.

ß-carotene content

β-carotene is the main safe dietary source of vitamin A. In our present study, we therefore tried to formulate and manufacturing vitamin A rich pineapple pomace peanut bar. The results show that the formulated samples contained β-carotene content ranged from 15.49±0.02 to 16.32±0.03 µg/100 gm on the day of storage and after 2 months of storage, the β-carotene content varied from 7.72±0.02 to 9.41±0.04 µg/100 gm (Table 2 and Table 3). In case of market sample, the β-carotene content was 12.22±0.28 µg/100 g at on the day of storage but after 2 months of storage, it was 7.35±0.29 µg/100 gm (Table 2 and Table 3). It can be seen that the β-carotene decreased 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 cooking process (Molla et al., 2017). Moreover, the formulated pineapple pomace nut bar was the rich source of β-carotene content than the cereal nut bar (market sample).

Vitamin-C content

Vitamin-C content of the treated samples varied significantly higher than the collected market sample (T_4). Highest vitamin-C content observed in our treated samples and ranged from 21.18±0.27 to 23.28±0.21 mg/100 gm whereas the market sample was 20.11±0.16 mg/100 gm on the day of storage (Table 1) but after 2 months of storage, the vitamin-C content of the formulated pomace nut bar was 15.88±0.02 to 16.23 ±0.02 mg/100 gm whereas it was 14.91±0.10 mg/100 gm (Table 2). The results indicate that vitamin-C content decreased with the advancement of storage periods. Among the formulated and market samples, the highest vitamin-C content was recorded in the formulated pineapple pomace nut bar, might be due to enrich of the nut bar using pineapple pomace as compared to traditional market sample. The decreased vitamin-C content of the both formulated and market sample may be affected by the cooking temperature and long term storage at ambient condition. The results are in agreement with 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 in room temperature.

Total sugar

On the day of storage, total sugar content in the treated samples ranged from 17.21±0.11 to 19.22±0.01% (Table 2) whereas it was 17.25±0.14% in the market sample. But after 2 months of storage, the total sugar content ranged from 17.51±0.10 to 19.81±0.09% while the market sample was 17.85±0.41% (Table 3). It means that total sugar was increased with the increasing of storage periods. Among the treated samples, high sugar content was found in the treated samples than the market sample. Its might be the total sugars were positively correlated to acidity as the nut bar was formulated by the fresh pineapple pomace. The positive correlation between total sugars and acidity, means that plants produced pineapple with high sugars generally have more free organic acids and less hydrogen ion concentration than cereals plants with low sugars (Molla et al., 2017). Here it is noteworthy that the acidity of our formulated pineapple pomace nut bar was higher than the market sample and increased entire the storage periods (Table 2 and Table 3).

Reducing sugar

The variation in reducing sugar content on the day of storage and after 2 months of storage for both formulated and market sample was significantly different (Table 2 and Table 3). The total reducing sugars decreased during the entire storage period (Table 2). The reduction in sugar content was strongly influenced by the storage time and acidity. The reduction in sugar content may be contributed to achieve high protein content of the formulated pomace nut bar. The results are supported by the findings of Pallavi et al. (2015).

Total soluble solid (TSS)

Total soluble solids of the formulated pomace pea-nut bar ranged from 6.78±0.03 to 8.50±0.03°B whereas the market sample was 4.61±0.10°B at on the day of storage but after 2 months of storage the TSS ranged were from 7.40±0.03 to 9.60±0.05°B while the market sample was 5.44±0.04°B, indicate that TSS increased with the advancement of storage periods. The highest TSS was recorded in the

formulated samples than the market sample (T_4) at on the day of storage and after 2 months of storage (Table 2 and Table 3). The increase in TSS might be due to partial hydrolysis of polysaccharides like cellulose, starch and pectic substances into simple substance or due to solidification of pulp constituents during storage (Pandita and Gupta, 2019). Similar results were also have been reported by Pathak (1988) in aonla jam.

Water activity (a_w)

The water activity (a_w) of the formulated pea-nut bar ranged from 0.73±0.00 to 0.74±0.00 and the market sample was 0.45±0.05 on the day of storage but after storage it ranged from 0.82±0.00 to 0.83±0.00 in the formulated nut bar whereas it was 0.53±0.06 in the market sample, indicates that the a_w increased with the increasing of storage periods. The highest a_w was recorded in our formulated pomace nut bar than the collected market sample (T_4) and statistically both the samples (formulated and market sample) were significantly differed. The highest a_w in the market sample might be due to lower moisture content (1.31%) whereas our formulated pomace nut bar possessed moisture content from 5.14-5.41 % (Table 3). It is worth mentioning that this difference may be due to the different formulations and methodologies used for the manufacture of the pineapple pomace nut bar and cereal bars (Aigster et al., 2011).

Acidity

On the day of preparation, the titratable acidity in pineapple pomace pea-nut bar ranged from 0.11±0.02 to 0.13±0.02% at on the day of storage while the market sample was 0.11±0.02% but after storage the ranges were from 0.25±0.04 to 0.38±0.02% whereas it was 0.15±0.01% in the market sample (Table 2 and Table 3), indicates that the acidity were increased with the advancement of storage periods. The highest acidity recorded in the treated pineapple pomace nut than the market sample. As a reason it is said that the organic acids may be presented in greater quantities in the pineapple, thus conferring a higher acidity to the pomace nut bar. Other reason might be due to the effects of lactic acid bacterium producing substances.

pH

The values for pH in the formulated pomace nut bar and market sample at on the day of storage and after storage are shown in Table 2 and Table 3. Statistically insignificant differences in pH values for both market and treated samples were observed and it was decreased with the advancement of storage periods. It's might be the addition of pineapple pomace nut bar caused a significant decrease in pH values indicate that there was an inverse relationship with acidity of the treated samples. Generally the pH goes down as the acid goes up and vice-versa. The exact relationship differs from sample to sample and depends on esoteric concepts like 'buffering capacity' which will vary for a whole host of reasons. On the other hand, this phenomenon might be possible due to oxidation of acid during storage resulting in lower pH and also might have been genetically dissimilarities fruit varieties, soil texture, soil pH and other nutrients (Islam et al., 2013).These results are in agreement with the findings of Ahmed and Singh (2000).

Energy content

Initially, the energy content of the pea-nut bar ranged from 3801.10±2.07 to 4037.70±3.50 cal/gm while the market sample possessed 3478.30±5.28 cal/gm (Table 2) and after 2 month of storage the range was 4006.10±1.00 to 4051.27±1.05 cal/gm whereas it was 3578.20±5.28 cal/g in the market sample (Table 3). The energy content increased with the increase of storage periods. The highest energy was found in treated sample T_3 whereas the lowest was recorded in the market sample (T_4). With reference to the statistical analysis in Table 2 and Table 3, results obviously demonstrate that highly significant differences were observed in the calorific value of formulated and market sample with the advancement of storage periods. Increase in gross energy may be influenced by the storage condition (Gandhi and Taimini, 2009).

Table 2. Proximate and nutritional composition of pineapple pomace pea-nut bar on the day of storage

Parameter	Treatment			
	T_1	T_2	T_3	T_4
Crude protein (%)	8.53±0.03c	10.50±0.05b	13.06±0.05a	3.18±0.13d
Crude fiber (%)	5.05±0.03c	5.56±0.19b	6.48±0.48a	0.98±0.19d
Crude fat (%)	1.83±0.05b	1.83±0.02b	1.41±0.10c	2.11±0.10a
Ash (%)	4.05±0.04b	4.09±0.01b	5.03±0.03a	4.04±0.03b
Moisture content (%)	5.14±0.03a	5.33±0.16a	5.41±0.04a	1.31±0.13b
Carbohydrate (%)	75.40±0.02b	72.69±0.19c	68.61±0.96d	88.18±0.35a
ß-carotene (µg/ 100 g)	15.49±0.02b	16.22±0.03a	16.32±0.03a	12.22±0.28c
Vitamin-C (mg/100 g)	21.18±0.27b	21.76±0.53b	23.28±0.21a	20.11±0.16c
Total sugar (%)	17.21±0.11c	18.28±0.03b	19.22±0.01a	17.25±0.14c
Reducing sugar (%)	9.27±0.03d	10.85±0.05c	12.15±0.03a	11.55±0.17b
Total soluble solid (°B)	6.78±0.03b	6.80±0.03b	8.50±0.03a	4.61±0.10c
Water activity (a_W)	0.73±0.00a	0.74±0.00a	0.74±0.00a	0.45±0.05b
Acidity (%)	0.11±0.02	0.13±0.02	0.12±0.02	0.11±0.02
pH	6.23±0.03	6.46±0.04	6.48±0.31	6.40±0.17
Energy (Cal/g)	3801.10±2.07a	4031.78±3.05a	4037.70±3.50a	3478.30±5.28b

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c indicates significant result (p<0.05). No letter means no significant difference.

Table 3. Proximate and nutritional composition of pineapple pomace pea-nut bar after 2 months of storage

Parameter	Treatment			
	T_1	T_2	T_3	T_4
Crude protein (%)	5.40±0.06b	5.82±0.03ab	6.35±0.06a	3.01±0.03c
Crude fiber (%)	5.18±0.42b	6.06±0.03b	7.34±0.54a	1.18±0.28c
Crude fat (%)	1.33±0.05b	1.33±0.02b	1.01±0.01c	1.61±0.10a
Ash (%)	4.62±0.04	4.95±0.06	5.54±0.03	4.44±0.07
Moisture content (%)	5.72±0.04a	5.87±0.03a	5.71±0.04a	1.59±0.18b
Carbohydrate (%)	77.75±0.42b	75.97±0.25c	74.05±0.50d	88.39±0.55a
ß-carotene (µg/ 100 g)	7.72±0.02c	8.53±0.03b	9.41±0.04a	7.35±0.29c
Vitamin-C (mg/100 g)	15.88±0.02b	16.21±0.02a	16.23±0.02a	14.91±0.10c
Total sugar (%)	17.51±0.10c	18.59±0.22b	19.81±0.09a	17.85±0.41c
Reducing sugar (%)	8.88±0.10d	10.34±0.15c	11.80±0.20a	11.05±0.04b
Total soluble solid (°B)	7.40±0.03c	8.40±0.03b	9.60±0.05a	5.44±0.04d
Water activity (a_w)	0.83±0.00a	0.82±0.00a	0.82±0.00a	0.53±0.06b
Acidity (%)	0.38±0.02a	0.38±0.02a	0.25±0.04b	0.15±0.01c
pH	5.23±0.23	5.46±0.05	5.40±0.05	5.48±0.31
Energy (Cal/g)	4006.10±1.00a	4044.11±1.00a	4051.27±1.05a	3578.29±5.28b

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicates significant result (p<0.05). No letter means no significant difference.

Color measurement of the pineapple pomace pea-nut bar

Consumer satisfaction is depending on the quality of the product whereas appearance is the greatest common criteria used to decide the excellence of any materials. Color, size, shape and surface conditions are associated with the appearance of the product. A result obtained from the study shows that at initial day of storage and after 2 months of storage, lightness (L) value for the treatment T_3 and T_4 was recorded higher than the treated sample T_1 and T_2, indicates that the treated sample T_1 and T_2 had a little dark color than the treated sample T_3 and market sample T_4. The C value of the treated sample T_1 and T_2 was higher than others, indicates that the color of the T_1 and T_2 was more saturated than the treated sample T_3 and market sample T_4. At initial day of storage (0 day), all the treated sample T_1 T_2, T_3 and market sampleT_4 showed hue value (h*) 74.19±5.76, 71.99±1.71, 74.18 ± 3.48

and 71.54±1.59 whereas the value of hue was73.12±1.87, 71.15±1.67, 70.54 ± 0.43 and 69.87±0.65 after 2 months of storage indicates that all the sample was in the 0/360° region, confirm that all the pea-nut bar color was red (Table 4).

Table 4. Color changes of pineapple pomace-pea-nut bar on the day of storage and after 2 months of storage

Treatment	Color					
	On the day of preparation			After storage		
	L*	C*	H*	L*	C*	H*
T_1	30.85±1.46d	21.97±1.42	74.19±5.76	30.52±1.28d	21.54±1.36	73.12±1.87
T_2	37.73±2.04c	28.23±4.60	71.99±1.71	37.20±1.73c	27.30±1.01	71.15±1.67
T_3	48.22±4.00ab	19.03±2.27	74.18±3.48	47.69±1.14ab	18.90±1.24	70.54±0.43
T_4	52.87±2.15a	20.98±3.97	71.54±1.59	52.43±1.17a	20.44±1.08	69.87±0.65

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d indicates significant result (p<0.05). No letter means non-significant difference.

Sensory evaluation of the pineapple pomace pea-nut bar

The sensory evaluation of the treated samples on the day of storage and after storage was performed based on 9-point hedonic scale and shown in Table 5 and Table 6. The score obtained by the expert judgment in terms of color, flavor, texture, mouth feel, hardness, softness and overall acceptability. On the day of storage, no significant differences were found in terms of color, flavor, softness and overall acceptability (Table 5). The maximum score was obtained by the treated sample T_3 in terms of their mouth feel and hardness than the market and other treated samples. But after storage, the lower mouth feel and hardness score were obtained by the treated sample T_3 as compared to market sample but no other treated samples (Table 6). After storage, no significant differences were found among the treated samples for its color, flavor, texture, mouth feel, softness and overall acceptability (Table 6). Hardness was significantly differed whereas the low hardness was found in sample T_1 and T_2 and highest hardness was noted in treatment T_3 and market sample T_4. The overall acceptability was not significantly differed but the highest score was confirmed by the panelist for the treated sample T_3 and market sample T_4. Data obtained from the results also confirmed that there was inverse relation between the hardness and softness of the prepared pea-nut bar. None of the expert members of the sensory evaluation like very hardness and softness of the pea-nut bar.

Table 5. Sensory evaluation of the pineapple pomace pea-nut bar on the day of storage

Sensory attributes	Treatment			
	T_1	T_2	T_3	T_4
Color	7.40±1.26	6.80±0.91	6.90±1.10	6.70±0.67
Flavor	7.00±0.81	6.90±0.99	7.00±0.66	7.10±0.56
Texture	6.30±0.48b	6.50±0.70ab	7.00±0.66ab	7.10±0.56a
Mouth feel	6.50±0.70bc	6.20±0.42c	7.30±0.67a	7.10±0.56ab
Hardness	6.40±0.51c	6.50±0.84bc	7.20±0.42a	7.10±0.31ab
Softness	6.10±0.31	6.40±0.84	6.70±0.82	6.90±0.87
Overall acceptability	6.61±0.36	6.55±0.58	7.01±0.37	7.00±0.29

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b indicates significant result (p<0.05). No letter means non-significant difference.

Table 6. Sensory evaluation of the pineapple pomace pea-nut bar after 2 months of storage

Sensory attributes	Treatment			
	T_1	T_2	T_3	T_4
Color	6.20±1.22	6.60±1.07	7.20±1.75	7.10±0.75
Flavor	6.60±1.07	7.00±0.66	7.00±0.81	6.90±0.18
Texture	6.30±0.48	6.50±0.71	6.90±0.73	7.00±0.83
Mouth feel	6.20±0.42	6.50±0.71	7.00±0.66	7.10±0.06
Hardness	6.60±0.56b	6.70±1.33b	6.90±0.67ab	7.00±0.07a
Softness	5.90±0.56	6.00±0.24	6.70±0.83	6.00±0.83
Overall acceptability	6.26±0.77	6.39±0.51	6.78±0.38	6.80±0.18

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b indicates significant result ($p<0.05$). No letter means non-significant difference.

Texture profile of pineapple pomace pea-nut bar

The hardness of the pea-nut bar depends on the amount of final moisture content and duration of storage. After storage, the values of rupture force (FR) were measured in order to assess the hardness of the treated pea-nut bar at on the day of storage (Figure 3) and after storage (Figure 4). The maximum peak was recorded in market sample T_4 both on the day of storage and after storage whereas the treated sample showed lowest peak. Among the treated sample, T_3 showed maximum hardness than T_1 and T_2. The maximum hardness obtained by the market sample T_4 and our treated sample T_3 (Figure 3) might be due to presence of lower moisture content than others (Table 2 and Table 3). The lower moisture content and high amount of Jaggery added in the products might be contributed to achieve hardness with the advancement of storage periods. Here, it is noted that the hardness of the nut bar found lowest at on the day of storage both market and our treated samples. But the hardness was increased with the increasing of storage periods. Its might be due to the jaggery syrup effect on the nut bar that may be contributed to make hard bond throughout the storage periods (Figure 3 and Figure 4). However, among the treated samples, the maximum FR was recorded in T_3 with its highest hardness. Hence it was acceptable by the panelist of the sensory evaluator (Table 5).

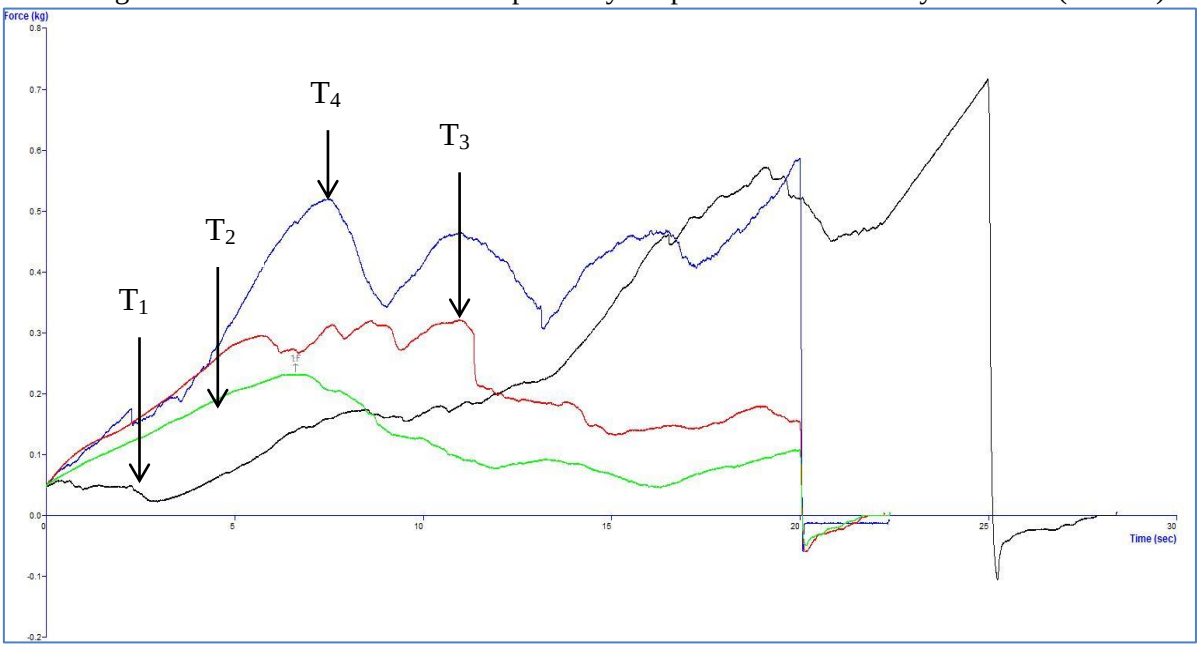

Figure 3. Texture profile of the pineapple pomace-peanut bar on the day of storage

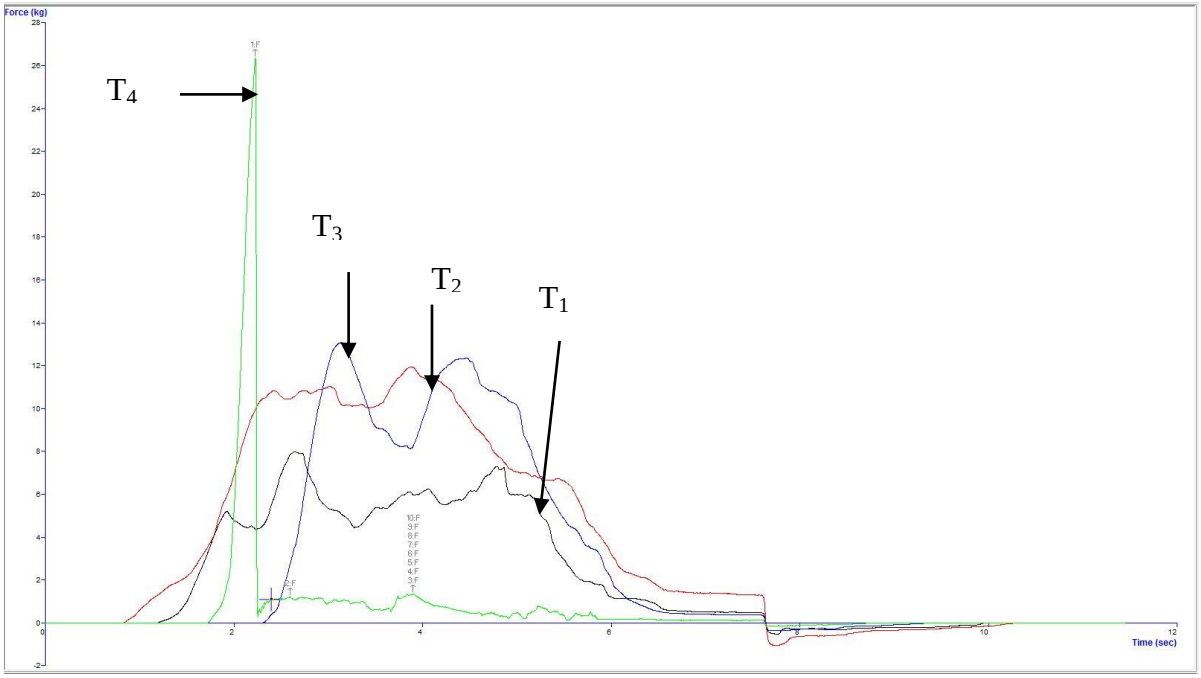

Figure 4: Texture profile of the pineapple pomace-peanut bar after storage

Conclusion

Findings suggest that the pineapple pomace peanut bar formulated from pineapple pomace is a rich source of crude fiber, crude protein and energy content. Formulation T_3 ((pineapple pomace 250gm+ peanut 150 gm + cane sugar 400 gm+ puffed rice 10 gm+ Ghee 2 gm) obtained highest score by the expert's sensory evaluator for its color, flavor, texture, mouth feel (taste), softness and less hardness. The marketable life of the developed pea-nut bar could be extended more than 2 months without any quality deterioration. By applying this technology, protein & energy malnutrition can be overcomed. In the current scenario, development of this nutritious bar is a good substitute to other junk foods. The pomace bar have great market potential to boost up energy and maintain performance by providing high amount of vitamin-C, pro-vitamin A (ß-carotene), protein and dietary fiber. Pineapple pomace supplemented bar can be used for the school nutrition programs to uplift the nutritional status of the school going children.

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EFFECT OF ORANGE PEEL CONCENTRATION ON THE QYALITY OF SAPOTA MARMALADE IN TERMS OF PROXIMATE AND NUTRITIONAL COMPOSITION

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Abstract

The study explored to find out the possible strategy for 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 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. 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 (T_1). On the day of storage and after storage, 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 panel judges, 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.

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

Introduction

Bangladesh is bestowed with varied agro climatic conditions, so it can produce a wide variety of fruits and vegetables. Now, it is the occupied position in the world as 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 to 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 a plenty of minerals, nutrients, bioactive compounds and 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 principle bitter component.

The availability of fresh sapota fruit is very short throughout its production time. The fresh fruit cannot be stored long time due to its perishability nature. Therefore, a substantial amount of postharvest loss of sapota is occurred due to lack of proper processing and storage techniques. The fruit is mostly eaten as fresh fruit. According to the 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. With this view, the efforts have been made in the present investigation to develop value added marmalade from sapota using different concentration 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 for naturally ripen.

Extraction of sapota pulp

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

Processing of sapota marmalade

The measured pulp, sugar and water (according to Table 1) were taken in a cooking sauce pan, and heated on a gas burner. When the total soluble solid (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 into the sauce pan. The pectin was mixed with equal amount of sugar and then it was added into the sauce pan. When the TSS reached up to 64°B then the sodium benzoate was added into the sauce pan with little amount of water (100 mL). The final consistency of the prepared marmalade was maintained 65.30°B. No artificial color or flavoring agent was used. The finished product was poured into glass jars with hot mass condition and immediately the lid was put on the jars. Then the jars were stayed at ambient condition for overnight for better settlement.

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 marmalade 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 previous paper Molla et al. (2020) using probe p/5 by a Texture Analyzer TA.XT plus (Stable Micro System, Godalming, UK) by 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 on the basis of 9-point hedonic scale of all the prepared marmalade was done by 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 was subjected to statistical analysis and all data was expressed in duplicate as means ± standard deviation. One-way ANOVA with post-hoc using Turkey Multiple Comparison Test were 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).

Table 1. Formulation of Sapota marmalade

Treatment	Ingredients						
	Sapota pulp (g)	Sugar (%)	Orange peel (%)	Lemon juice (%)	Pectin (%)	Water (%)	Sodium benzoate (%)
T_1	1000	40	0	10	0.15	0.75	0.01
T_2	1000	40	5	10	0.15	0.75	0.01
T_3	1000	40	10	10	0.15	0.75	0.01
T_4	1000	40	15	10	0.15	0.75	0.01
T_5	1000	40	20	10	0.15	0.75	0.01

Results and Discussion

Proximate and nutritional composition of sapota marmalade

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. Here, 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 (Table 2 and Table 3). The increase in TSS might be due to the enzymatic conversion of monosaccharide's into sugar molecules and degradation of pectin resulting in an increase of total soluble solids (Er. Patil, 2013).

Vitamin C

Vitamin-C content was significantly differed on the day of storage and after storage periods (Table 2 and Table 3). On the day of storage, the vitamin-C content ranged from 4.68±0.02 to 5.84±0.03 mg/100 gm whereas it ranged from 2.36±0.01 to 3.62±0.06 mg/100 gm. The results indicate the vitamin-C content was decreased with the progression of storage periods. These findings are fully supported with 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 in room temperature. On the day of storage and after storage, the highest vitamin-C (5.84±0.03 mg/100 gm and 3.62±0.06 mg/100 gm) content detected in the treated sample T_5 followed by others. This could be due to the use of higher amount of orange peel (25 %) with the sapota pulp. Several researchers reported that orange peel is

the 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 achieve 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 gm 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 gm (Table 2 and Table 3). 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 cooking process (Molla et al., 2017).

Total carotenoid

Statistically the significant differences were observed between only 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 (Tble 2 and Table 3). The highest total carotenoid content 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 the combined mixture of sapota pulp and orange peel as well as the orange peel is the rich source of antioxidants and phytochemicals. 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 Table 1 and Table 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 2) whereas it ranged from 22.28±0.03 to 20.11±0.01% after 6 months of storage (Table 3). The results indicate that total sugar content increased with the increasing 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 have 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 (Table 2 and Table 3). 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 show that reducing sugar content increased with the advancement of storage periods. The highest reducing sugar content observed in only 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 arrange peel subsequently exhibited lower amount of reducing sugar content (Table 1 and table 2). The reason might be due to the positive correlation among the total sugars, reducing sugars and acidity, means that orange produced peel has high acidity than the fresh pulp of sapota (Table 2 and Table 3). The low acidity presented in the formulated sapota pulp may be contributed to achieve higher amount of total and reducing sugar content (Table 2 and Table 3). Moreover, it is assured that the increased acidity presence in the orange peel treated marmalade may be contributed to achieve lower amount of total and reducing sugar content. The 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 (Table 2 and Table 3). 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 resulting in an increase of 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 (Table 2 and Table 3). 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. Similarly, results were obtained by Iboyaima Singh et al. (2000) while working on enzymatic liquefaction of mango pulp. Our results confirm that pH and acidity is the inverse relation with each other indicates 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 different treated samples was highly significant. On the day of storage, the ash content of the treated marmalade ranged from 0.31±0.01%, to 0.67±0.02% whereas it ranged from 0.41±0.01% to 0.89±0.01% after 6 months of storage (Table 2 and Table 3) indicating that the ash content was increased with the advancement of storage periods. The increases of ash content also indicate that the products were stable entire the storage periods. The results are in agreement with the findings of Khan et al. (2016), Khan et al. (2021).

Moisture content

The shelf life of the products depends on the moisture content. Higher the moisture content enhances the 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 differed but 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 (Table 2 and Table 3). The moisture content obtained in our marmalade is strongly supported with the findings of sapota jam by Ahmed et al. (2011); Khan et al. (2016).

Table 2. Proximate and nutritional composition of sapota marmalade on the day of storage

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
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. ** and * indicate significant results at p<0.01 and p<0.05 levels. NS means non-significant difference.*

Table 3. Proximate and nutritional composition of sapota marmalade after 6 months of storage

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
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. ** and * indicate significant results at p<0.01 and p<0.05 levels. NS means non-significant difference.*

Color of the sapota marmalade

Color appearance by the consumer is to be a very important criterion for the initial acceptability of the product. The color difference, values (*L**, *c**, and *h** values) of the different treated marmalade (T_1, T_2, T_3, T_4 and T_5) was measured (Table 4). The result obtained from the study shows that at 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, 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) indicates that 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, indicates 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 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 spotal pulp (without orange peel) treated marmalade showed 50.30±2.18, indicates that orange peel treated marmalade (T_2, T_3, T_4 and T_5) was in the 0/360° region, prove that orange peel treated marmalade (T_2, T_3, T_4 and T_5) turned to red color more than the spotal 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), 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 fully supported with the same findings of Tung-Sun et al. (1995) for the plum juice.

Table 4. 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. ** and * indicate significant results at p<0.01 and p<0.05 levels. NS means non-significant difference.*

Sensory evaluation of the developed sapota marmalade

The sensory evaluation of the developed marmalade was performed on the basis of grade score obtained by the expert product sensory evaluator. The obtained data was analyzed statistically using SPSS software 17.0 and ANOVA (Analysis of variance). The sensory attributes in terms of color, aroma, mouth feel, bitterness, spreadable, hardness and overall acceptability presented in Table 5 and Table 6 shows that all the attributes were not statistically differed on the day of storage and after storage. At 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 T5 might be due to its excess use of orange peel pieces that sometimes changed the sense of the evaluator. But nutritional it was superior followed by others. Only spota pulp treated (without orange peel) marmalade secured 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.

Table 5. 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.

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

Parameter	Treatment					LSD
	T_1	T_2	T_3	T_4	T_5	
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.

Texture profile of the sapota marmalade

The texture of 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) (Figure 1 and Figure 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 presence of lower moisture content than without orange peel treated marmalade both on the day of storage and after storage (Table 2 and Table 3). Another significant reason might be due to use of orange peel pieces in orange peel treated marmalade (T_2, T_3, T_4 and T_5) that might be interrupted the texture probe (p/5) to easily penetrate the probe into the

bottom of the marmalade jars. This hindrance may be contributed to achieve 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).

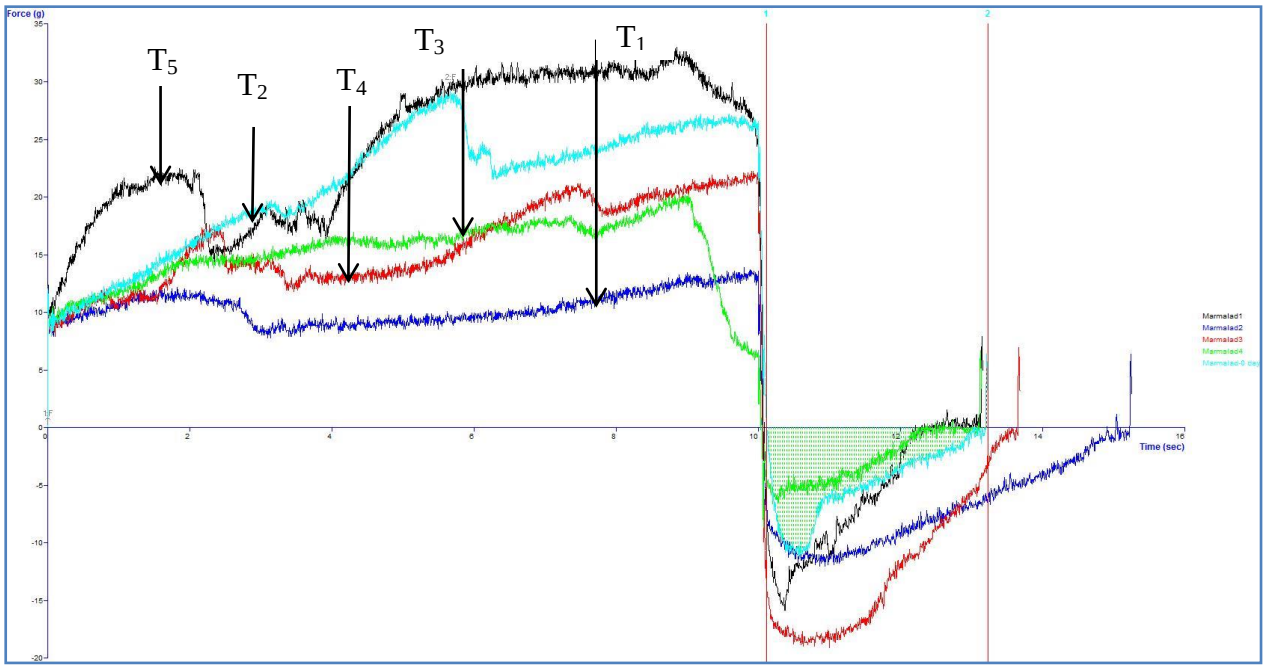

Figure 1. Texture of the sapota marmalade on the day of storage

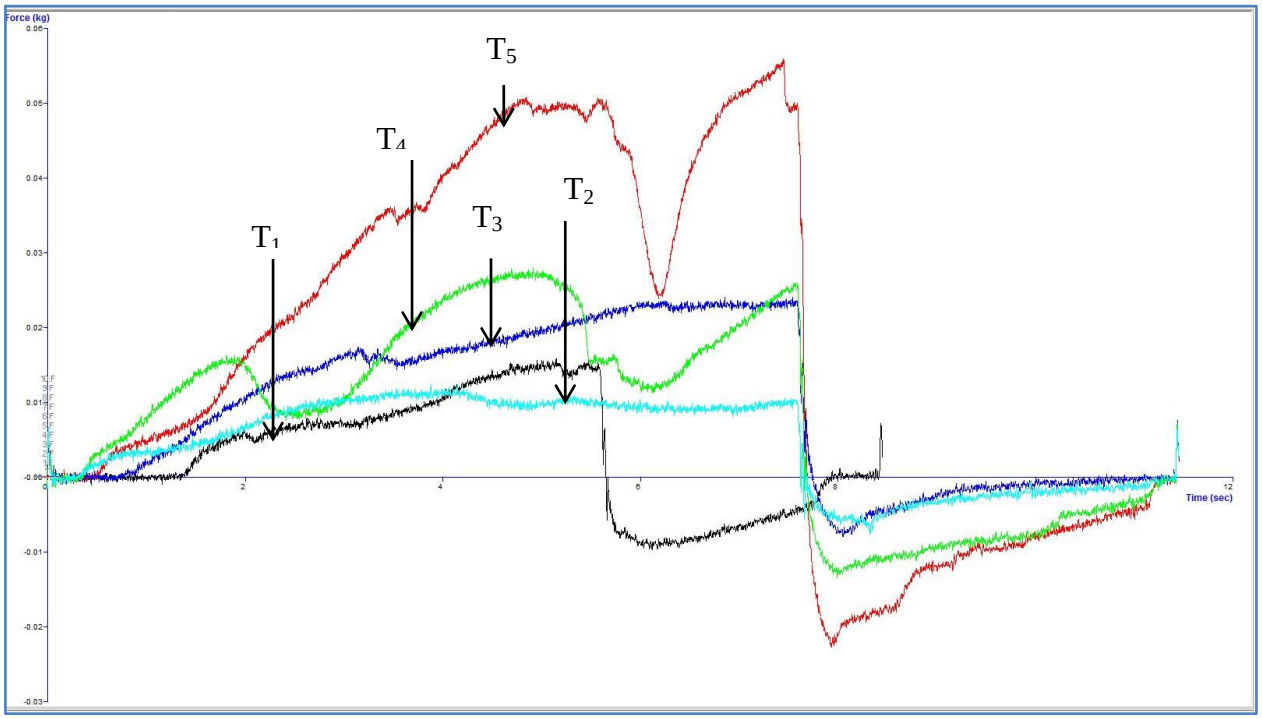

Figure 2. Texture of the sapota marmalade after 6 months of storage

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 was 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 be contributed to proper use of sapota fruit with 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 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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EFFECT OF STEAM BLANCHING AND COOKING OILS ON PHYSICOCHEMICAL, NUTRITIONAL, MINERALS AND BIOACTIVE COMPOUNDS OF MIXED VEGETABLES

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Abstract

Cooking is a crucial part of our daily life. Several cooking methods and oil exert their effects on nutritional, physicochemical, minerals and phytochemical compounds. Most of them are directly or indirectly include with human health merits and demerits. Hence, the present study was conducted to find out the effect of extra virgin olive and soybean oil on the nutritional, physicochemical, minerals and phytochemical compounds under different cooking conditions. Results revealed that steam blanching mixed vegetables minimized more nutrient loss than the traditional one. The mixed vegetables cooked using soybean oil by traditional cooking process exhibited higher amount of crude fat content (31.09±0.08 %) whereas the fat content is below 1.00 % (0.15±0.00 to 0.39±0.00 %) by the extra virgin olive oil in steam blanching process. The lower carbohydrate (6.01±0.01 %) and higher energy value (6293.29±0.15 cal/g) had also predominant in the steam blanching process using extra virgin olive oil followed by the traditionally cooked vegetables using soybean oil (12.33±0.02 % and 5869.81±0.24 cal/g), our staple food rice (81.58±0.42 % and 3439.33±0.15 cal/g), wheat bread (79.32±0.95 % and 3486.66±3.55 cal/g) and oats (68.91±0.48 % and 4020±1.00 cal/g). Most of the minerals especially human body essential Ca, Mg, Fe, Cu and Zn found notable in steam blanched vegetables using extra virgin olive oil than the traditional one. The leading phytochemical compounds ß-carotene, anthocyanin, total carotenoid and total phenolic content of the steam blanched mixed vegetables using extra virgin olive oil was noticed as 26.24±0.24 µg/100 g, 42.87±0.13 mg/100 g, 4.52±0.48 mg/100 g and 20.09±0.09 mg GAE/g whereas the less amount of this phytochemicals were present in traditional cooking process using soybean oil. The findings obtained from this study may be helpful for the consumer to change their eating behavior and dietary lifestyle as well as fat adaptation and minimizing overweight and obesity.

Key words: Cooking process, Cooking oil, Crude fat, Carbohydrate, minerals, phytochemicals.

Introduction

Overweight and obesity is rising alarmingly in Bangladesh as well as glove particularly in Australia, Canada, UK, USA and several European countries. In developing countries, this is an emerging issue now due to the several factors like eating behavior, poor dietary habit, physical inactivity, unhealthy food habit, indiscriminate life style and living pattern (Nahar et al., 2013). Lack of proper and timely diet, unhealthy food and physical inactivity causes overweight. Unhealthy food can be defined as especially fast food item, snacks, chips, ice cream, burger, cold drinks etc. Overweight, obesity, carbohydrate and energy intake is closely related to each other. Energy consumption per capita/day is 2190 kcal (urban 2094, rural 2223kcal) (Nahar et al., 2013). It appears that the current energy consumption is about 240kcal deficient compared to the requirements of the average adult Bangladeshi population. According to intra-household energy distribution, adult males are consuming adequate energy whereas females are still energy deficient. About 40% of the population take more than 75% of total calorie from carbohydrate which may have a linked with obesity and related diseases. Forty percent of the population takes less than 10% of total calorie from protein sources and 53% of the population take less than 15% of total calorie from fat which reflects the scenario of stunting wasting and underweight in the country.

Fruits and vegetables are noble sources of vitamins, minerals and dietary fibre. Green leafy vegetables, yellow orange vegetables and fruits are especially good sources of dietary fibre, folate, and a wide range of carotenoids and vitamin C. Fibre in vegetables and fruits help to remove waste as well as eliminate excess cholesterol and some carcinogenic compounds. Regular consumption of these fruits helps to prevent vitamin A deficiency and anemia.

In Bangladesh all kinds of vegetables and other cooking process perform using different edible oils like vegetable oil, soybean oil, rice bran oil, sunflower oil and so on. The cooking process is mainly perform by the domestic (traditional) process using direct heat treatment by gas oven, electric oven, induction oven, earthen oven etc. Recent science shows that proper cooking methods can enhance the nutrient level of the vegetables. In the world, several cooking methods used for vegetables like steaming, roasting, boiling, frying, sautéing, sous vide, microwave and pressure-cooking. Proper cooking methods have been shown health beneficial as well as cholesterol-lowering

effect. Recent researches have shown significant differences among the different cooking methods. Kahlon et al.(2007) reported, the influence of cooking in vitro bile acid binding by various vegetables. Their research confirmed that bile acid binding reduces the cholesterol levels in the blood, serving to decrease the risk of coronary heart diseases (Tiwari and Cummins, 2013). They stated that steam cooking improved bile acid binding for various vegetables like beets, eggplant, asparagus, carrots, green beans and cauliflower when compared to the fresh uncooked vegetables. In later, they resolved with controversy that sautéing is the cooking method with the most health potential (binding bile acids) for mustard greens, kale, broccoli, cabbage and green bell pepper. Heat treatments significant have effect on physical and physicochemical properties of vegetables (Turkmen et al., 2006). Cooking quality depends on the color, texture and consumer preferences. Improper cooking process and time with its oil nature show poor quality in terms of color, flavor, texture, nutritional, minerals and phytochemical compounds in assessment with uncooked fresh one (Turkmen et al., 2006; Poelman et al., 2013). Many recent literatures suggest that steam blanching and extra virgin olive oil may have positive impact on the physicochemical, nutritional, minerals and bioactive phytochemical compounds. In view on mind the above issues, the present research has undertaken to investigate the steam blanching effect using modern 'Boiler free Steamer' (model:E64005D10000200, Accutemp Products Inc. Fort Wayne, Indiana USA) to compare with domestic cooking process. The second purpose of the study was to compare the cooking oil effect on physicochemical, nutritional, minerals and phytochemical compounds. The third purpose of the study was, to compare the results obtained from this study with the results of staple food of rice, wheat bread (roti) and oats.

Materials and Methods

Processing of vegetables

The vegetables were cultivated and harvested from the Research Field of Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh. The harvested vegetables were shifted to the pre-cooling room of the Division to remove field heat. After sorting, grading, peeling and cutting, then the vegetables were treated according to the following treatments.

Treatments

Factor A: Cooking process

A_0= Control

A_1= Domestic/ traditional cooking

A_2= Steam blanching

Factor B: Cooking oil

B_0= Control

B_1= cooking with soybean oil

B_2= cooking with extra virgin olive oil

Steam blanching

After pre-processing, all the vegetables and ingredients measured according to the Table 1, were steam blanched using Boiler free Steamer' (model:E64005D10000200), Accutemp Products Inc. Fort Wayne, Indiana USA at 212°F for 20 minutes.

Domestic/traditional cooking

All the measured vegetables and ingredients (Table 1) were cooked in a stainless steel pan using gas burner at the temperature of 212±10°F for 20 minutes.

Table 1. Cooking recipe of mixed vegetables

Sl. No.	Ingredients	Quantity (g)
1	Cauliflower	1000
2	Cabbage	1000
3	Carrot	250
4	Potato	250
5	Country bean	250
6	Onion	140
7	Green chili	40
8	Extra virgin olive oil	100

Sl. No.	Ingredients	Quantity (g)
9	Soybean oil	100
10	Turmeric powder	30
11	Salt	100

Color measurement

The color of the steam blanched and traditionally cooked vegetables were 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 of the steam blanched and traditionally cooked vegetables were done based on our previous paper Molla et al. (2020) using cylindrical prove by a Texture Analyzer TA.XT plus (Stable Micro System, Godalming, UK) by 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^{-1}force.

Nutritional and physicochemical studies

The nutritional and physicochemical analysis of crude fat, moisture, ash, Ascorbic acid and ß–carotene content was determined according to the method described by Ranganna (1995). pH was determined using digital pH meter **(**Delta 320, Mettler, Shanghai).Total carbohydrate content was determined according to method of Neilson et al. (1981).

Analysis of minerals

The minerals analyzed in this study were: sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), sulphur (S), boron (B), copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn). Before quantification of their amounts, the dried fruits powder were digested in nitric and perchloric acid solution at 320^{o}C, cooled, diluted to an appropriate concentration, and filtered. This filtrate was considered as the stock solution for further analysis. Ca and Mg were determined by KCl extractable method. K, Cu, Fe, Mn and Zn were determined by $NaHCO_3$ extraction followed by Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Tokyo, Japan). B was determined by $CaCl_2$ extraction method. P was determined by Bray and Kurtz method while S by turbidimetric method with $BaCl_2$. Individual minerals were quantified by comparing the corresponding standard mineral procured from the Sigma Aldrich Chemical Co., USA.

Determination of phytochemicals

Total phenolic content

Twenty milligrams (0.02g) of powder were dissolved in 1 mL of methanol to prepare a stock-solution for experiments. A volume of 0.5 mL of the each extract (100 µg/mL) was mixed with 2 mL of the Folin-Ciocalteu reagent (diluted 1:10 with de-ionized water) and were neutralized with 4 mL of sodium carbonate solution (7.5%, w/v). The reaction mixture was incubated at room temperature for 30 min. with intermittent shaking for color development. The absorbance of the colored solution was measured at 765 nm using double beam UV-Vis spectrophotometer. The total phenolic content was determined from the linear equation of a standard curve prepared with gallic acid. The content of total phenolic compounds expressed as mg/g gallic acid equivalent (GAE) of dry extract. Determination of total phenolic content in the extracts was determined according to the Folin-Ciocalteu method (Ough and Amerine, 1988) with gallic acid (GAE) as the standard and expressed (mg) as gallic acid equivalents (GAE)/g of extract (Aoshima and Ayabe, 2007).

Analysis of total anthocyanin

The anthocyanin content of the fruit powder was adopted according to the method described by (Chaovanalikit and Wrolstad, 2004) with little modification. The 10 g powder was mixed with 20 mL acetone and sonicated with an ultrasonic cleaning device for 10 min, and then filtered using Whatman nr 1 paper (Whatman Inc., Clifton, N.J., U.S.A.) on a Büchner funnel. The filter cake was re-extracted with 10 mL 70% acetone (30% water and 70% acetone, vol/vol) twice. Filtrates were combined and mixed with 80 mL chloroform and then centrifuged at 5000 rpm for 20 min with a Himac Compact Centrifuges RX II Series (Model CF 15 RX II, Hitachi, Japan). The supernatant was collected and

evaporated under room temperature until the residual acetone was removed (about 20 min). The aqueous extract was made up to 25 mL with acidified water (0.01% HCl [vol/vol] in deionized, distilled water) and stored at -80 °C until subsequent analyses. Sample extractions were replicated twice.

The monomeric anthocyanin pigment content of the aqueous extracts was determined using adjusting the pH 1.00 and 4.50 using digital pH meter **(**Delta 320, Mettler, Shanghai**).** A Shimadzu Double Beam UV spectrophotometer (Shimadzu Inc., Kyoto, Japan) and a 1-cm path length disposable cell were used for spectral measurements at 510 and 700 nm. Pigment content was calculated as milligrams cyanidin-3-glucoside/100 g fresh weight using an extinction coefficient of 26900 L/cm/mol and molecular weight of 449.2 g/mol.

Analysis of ß-carotene content

ß-carotene content was determined based on the method described by Molla et al. (2017) with minor modification. A 3 g of freeze dried powder was diluted with acetone (Fisher Scientific Ltd., UK) and petroleum ether. It was further purified with acetone, metabolic potassium hydroxide (KOH) and distilled water. The subsequent solution was filtered with anhydrous sodium sulphate and the absorbance was measured by UV-Vis Double Beam Spectrophotometer at 765 nm against petroleum ether as a blank.

Analysis of total carotenoid content

The total carotenoid content was determined based on the method described by Gupta et al. (2015) with little modification using High Pressure Liquid Chromatography (HPLC).

Standard preparation

Stock solutions of carotenes were prepared in methanol of 0.1 mg/mL. The exact concentration of stock solution was determined by spectrophotometry using the absorption coefficients A (1%, 1 cm) of the respective carotenoid. After determination of concentration, the standards were evaporated under nitrogen, and solubilized in methanol/MTBE (60/40, v/v) to obtain a final concentration of 5 µg/mL, that was used for HPLC analysis.

Extraction procedure

Freeze-dried powder (~150 mg) was homogenized using a high speed grinder and sieved by 80 mesh sieve. Then the sample was homogenated 1.5 mL of chloroform:dichloromethane (2:1, v/v). The subsequent suspension was mixed for 20 min using a high speed refrigerated centrifuge (1000 rpm at 4°C). For phase separation, 0.5 mL of 1 M sodium chloride solution was added and contents were mixed by inversion. After centrifuged at 4000 rpm for 10 min the organic phase was collected. The aqueous phase was re-extracted with 0.75 mL of chloroform: dichloromethane (2:1, v/v), centrifuged and again organic phase was collected. Both organic phases were pooled together, dried by centrifugal evaporation and re-dissolved in 1 mL of methanol/MTBE (25/75, v/v). Then it was re-dissolved in 1 mL and 200 µL of methanol/MTBE (60/40, v/v) prior to analysis. A final volume of 20 µL was used for injection into HPLC.

Isomerization of carotenoid standards

One mL solution (1 µg/mL) of all-trans forms of β-carotene was subjected to photoisomerization for generation of cis-isomers of carotenoids (Rajendran et al., 2005). The tubes containing standards were illuminated with three 30W fluorescent light tubes for 24 h at 25‡1°C at a distance of 30 cm and light intensity of 2500–3500 lx. The standards were evaporated to dryness, dissolved in 100 µL Methyl-t-Butyl Ether (MTBE)/ methanol (MeOH) (75/25, v/v) and a 20 µL was injected for determination of retention time.

HPLC analysis of carotenoids

High-performance liquid chromatography (Shimadzu SPD-M10A) and C30 column with the absorbance range of 250-700 nm were used to determine the total carotenoid content of the samples in a shorter run time of 23 minutes as described by Gupta et al. (2015). Concentration of each analyte was calculated from the calibration curve of the corresponding standard. All standard solutions were prepared as described above in standard preparation section. The standard curves ranging from 10, 25, 50, 75 and 100 ng were remained for the standard mix. Carotenoid concentrations were then calculated using a linear regression $y = mx + c$, where y = concentration and x = area of the five-point standard curve. The regression equation and correlation coefficient (R2) were obtained using Microsoft® Excel 2013. The cis-isomers of carotenoids were quantified using the standard curves of

all-trans carotenoids because of similarity in extinction coefficient (Lin et al., 2003). Results were expressed as beta-carotene equivalent per 100 g of powder (mg/100 g).

Sensory evaluation

Steam blanched and traditionally cooked vegetables were subjected to evaluate the sensory attributes according to the procedure described by Joshi (2006). It was performed using a 9-point hedonic scale, i.e. 9= Like extremely, 8= like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much and 1=Dislike extremely. A judgment panel was formed by the thirty expert members from the BARI inter-divisional Scientists to evaluate their color, flavor, softness, mouth feel and overall acceptability. The score obtained by the panelist was analyzed by statistical analysis.

Statistical analysis

All data was expressed in duplicate as means ± standard deviation. One-way ANOVA with post-hoc using Turkey Multiple Comparison Test were 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

Effect of steam blanching and domestic cooking process on the physicochemical composition of mixed vegetables

Numerous biochemical and physicochemical variations may happen during cooking of the food. The effect of steam blanching mixed vegetables and traditional cooking process is shown in Table 2.

Titrable acidity

The titratable acidity of the mixed vegetables was significantly differed as compared to rice, wheat bread and oats. The highest acidity was calculated as 3.43±0.02% in vegetables cooked by soybean oil under traditional cooking process. The lowest acidity recorded as 1.75±0.04% in the steam blanched vegetables using extra virgin olive oil. The results obtained from this study indicate that cooking methods significantly affect the acidity content of the mixed vegetables.

pH

The pH of the steam blanched mixed vegetable using extra virgin olive oil and the traditional cooked vegetable using soybean oil varied significantly with the range of 6.01±0.03 to 6.49±0.04 and 5.84±0.03 to 6.28±0.03. Results indicating that the pH of the steam blanched vegetables using extra virgin olive oil increased as compared to traditional process using soybean oil. Degradation of heat liable and soluble acid during steaming may be contributed to the rise in pH (Kaushal et al., 2013; Quarcoo and Wireko-Manu, 2016). The rises in pH might also be attributed to the decrease of obtainable carboxylic groups of proteins, but also the proclamation of calcium and magnesium ions from proteins (Ergezer and Gokce, 2011). The results also confirm that there is a negative relation between the pH and acidity (Table2).

Crude fat

The crude fat content of the mixed vegetables were statistically significantly differed. The fat content of the steam blanched vegetables cooked by extra virgin olive oil shown lower amount of fat content (0.15±0.00% and 0.39±0.00%) than the results obtained by the traditionally cooked vegetables using soybean oil whereas it had exhibited the fat content 36.57±0.06% and 31.09±0.08% respectively (Table 2). The results indicate that the vegetable cooked in native process influenced to attain higher amount of fat content than the steam blanched vegetables. The increased fat content might be due to conversion of higher amount of carbohydrate obtained by traditional cooking process into sugar and in later the sugar might be accumulated into fat content by fat adoption and metabolism process. Another reason, soybean oil used in the traditional cooking process may be hydrolyzed more than the steam blanched vegetables. The hydrolysis of oil in traditionally cooking process may enhance the acid value of the oil for the production of free fatty acids from triglycerides (Kumar et al., 2017). In market survey, it shows that the acidity level of the extra virgin olive is below 1.00% whereas it is higher in the soybean oil. The higher acidity may be donated to advance higher fat content in the soybean oil.

Carbohydrate

The carbohydrate content may be affected by the cooking process, which might source of health beneficial or hazards. The acrylamide might be produced due to presence of high carbohydrate or low protein constituents in the food. It may be caused through Maillard reaction due to exposure in high temperature (Mottram, Wedzicha, & Dodson, 2002). Several factors such as time of cooking, temperature and the quantity of the reducing sugars may produce the acrylamide in foods (Cheong, Hwang, & Hyong, 2005). In this study, the carbohydrate content of the mixed vegetables cooked by traditional method and steam blanching significantly differed (Table 2). The highest carbohydrate content (12.33±0.02%) exhibited by the soybean oil in traditionally cooked vegetables whereas the lowest carbohydrate content (6.01±0.01%) possessed by the extra virgin olive oil in steam blanched vegetables. In case of rice, wheat bread (roti) and oats, the highest carbohydrate content was recorded as 81.58±0.42% for the rice as compared to wheat bread (roti) and oats. However, the findings confirm that mixed vegetable cooking by steam blancher using extra virgin olive oil contained lower amount of carbohydrate than other treated vegetables and rice, wheat bread and oats.

Ash content

The ash content of the steam blanched vegetables and traditionally cooked vegetables using extra virgin olive and soybean oil varied significantly. The ash content of the traditionally cooked vegetables using soybean oil ranged from 3.70±0.18 to 5.17±0.07% whereas the steam blanched vegetables with extra virgin olive oil ranged from 3.74±0.04 to 5.67±0.11%, representing that the mixed vegetables are the amusing source of minerals. The ash content of the traditionally cooked vegetables using soybean oil significantly reduced than the steam blanched vegetables using extra virgin olive oil. The reduction in ash content of the traditionally cooked vegetables using soybean oil might be owing to the declined of cell membrane (Ferracane et al., 2008) in vegetable tissues due to the over heat and thus few minerals might have been leaked out through this process.

Moisture content

Moisture content of the steam blanched vegetables using extra virgin olive oil and traditional cooking process using soybean oil exhibited highly significant difference. The mean values of the steam blanched vegetables ranged from 79.00±9.22 to 84.84±1.13% whereas the traditionally cooked vegetables ranged from 58.85±1.29 to 85.66±1.66% (Table 2). The highest moisture content was observed in fresh (uncooked) mixed vegetables and the lowest moisture content was observed in our staple food rice and wheat bread (roti) and minor cereal oats. The variation in moisture content between the cooked and fresh (uncooked) sample might be due to cooked and uncooked condition. The highest moisture content found in uncooked (fresh) vegetables might be due to non-disruption of cell walls and membrane whereas the cooked samples might be influenced by the heating process to interference of cell walls and membranes allowing water to fill spaces.

Energy content

Statistically highly significant differences were observed between the cooked and uncooked (control) vegetables. Steam blanched mixed vegetables using extra virgin olive oil exhibited high energy content (6293.29±0.15 cal/gm) as compared to traditionally cooked vegetables using soybean oil and other carbohydrate rich rice, wheat bread (roti) and oats (Table 2). Results show that the higher energy content was found in the low carbohydrate comprises food, confirming that steam blanching vegetables using extra virgin olive oil contain low carbohydrate; hence it is the rich source of high energy (Table 2).

Table 2. Physicochemical properties of mixed vegetables under different cooking condition

Treatment	Titrable Acidity (%)	pH	Crude fat (%)	Carbohydrate (%)	Ash (%)	Moisture (%)	Energy (Cal/g)
A_0B_0	2.92± 0.01bcd	6.31± 0.01abc	11.74± 0.03e	9.66± 0.06e	1.21± 0.02g	87.57± 1.68a	6103.14 ± 5.04b
A_0B_1	2.40± 0.10cde	6.28± 0.03abc	36.57± 0.06a	9.79± 0.01f	4.30± 0.20d	58.85± 1.29c	6053.70 ± 0.69bc
A_0B_2	2.09± 0.01de	6.43± 0.02ab	0.39± 0.00j	7.13± 0.02h	5.37± 0.26ab	83.92± 0.23ab	6286.99 ± 0.02a
A_1B_0	2.53± 0.02cde	5.84± 0.03e	12.41± 0.25d	10.94± 0.04d	5.17± 0.07c	61.15± 1.84c	5804.90 ± 0.48d

Treatment	Titrable Acidity (%)	pH	Crude fat (%)	Carbohydrate (%)	Ash (%)	Moisture (%)	Energy (Cal/g)
A_1B_1	3.43± 0.02b	6.01± 0.01de	31.09± 0.08b	12.33± 0.02d	3.10± 0.18e	85.66± 1.66ab	5869.81 ± 0.24d
A_1B_2	3.18± 0.02bc	6.37± 0.02abc	10.12± 0.11f	7.05± 0.05h	4.53± 0.22d	84.46± 0.69ab	6003.69 ± 0.65c
A_2B_0	2.41± 0.02cde	6.34± 0.04abc	2.64± 0.15h	8.70± 0.03g	4.33± 0.20d	84.83± 1.27ab	6116.61 ± 0.45b
A_2B_1	2.03± 0.02de	6.49± 0.04a	18.61± 0.20b	9.75± 0.04f	3.74± 0.04e	79.00± 9.22b	5594.80 ± 0.25e
A_2B_2	1.75± 0.04ef	6.26± 0.05abc	0.15± 0.00j	6.01± 0.01i	5.67± 0.11a	84.84± 1.13ab	6293.29 ± 0.15a
R28	2.29± 0.17cde	6.30± 0.05abc	1.02± 0.02i	81.58± 0.42a	1.18± 0.06g	12.43± 0.05d	3439.33 ± 6.49g
Wb	4.63± 1.10a	5.79± 0.22e	1.33± 0.15i	79.32± 0.95b	1.22± 0.04g	11.48± 0.85d	3486.66 ± 3.55g
Ot	0.83± 0.16f	6.13± 0.15cd	8.70± 0.20g	68.91± 0.48c	2.01±0. 04f	13.20± 0.06d	4020.00 ± 1.00f

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f, g, h, I, j indicate significant result ($p<0.05$).

Minerals

The mineral contents of the traditionally cooked and steam blanched mixed vegetables are shown in Table 3 and Table 4. The fresh (uncooked) mixed vegetables were found rich source of Ca, Mg, K, Cu, Fe, Mn and Zn than the steam blanched using extra virgin olive oil and traditionally cooked vegetables using soybean oil. The highest P was found in the wheat bread (roti) and oats than others. The highest Na was found cooked by soybean oil under traditional and steam blanching process. In case of cooking process, steam blanched mixed vegetable using extra virgin olive oil exhibited higher amount of Ca, Mg, S, Cu, Fe, Mn, Zn and B as compared to traditionally cooked mixed vegetables using soybean oil. Losses of minerals in traditional cooking process using soybean oil may be caused due to destruction by heating and leaching into the cooking oil (Puupponen-pimia et al., 2003). Moreover, the steam blanched mixed vegetables using extra virgin olive oil resulted in the greatest retention of most of the minerals. Thus it may consider best cooking process to preserve more soluble nutrients than traditionally cooking using soybean oil (Odland and Eheart, 1975). K is the most ample source of mineral in vegetables where the maximum amount of it (K) retained by the uncooked fresh (control) mixed vegetables as compared to others. The ample source of Ca, Mg and K by the uncooked fresh vegetables probably due to their bound to the plant tissue and were not involved any cooking and leaching process.

Table 3. Minerals (Ca, Mg, K, P, Na and S) changes under different cooking conditions

Treatment	Minerals (%)					
	Ca	Mg	K	P	Na	S
A_0B_0	1.40±0.01a	0.74±0.01a	3.17±0.02a	0.39±0.01c	3.14±0.01c	0.22±0.01cd
A_0B_1	0.73±0.00ef	0.40±0.01d	2.54±0.01d	0.16±0.10f	3.60±0.01a	0.25±0.01c
A_0B_2	0.90±0.10bcd	0.48±0.00c	2.46±0.01e	0.32±0.01e	3.19±0.00c	0.17±0.00e
A_1B_0	0.60±0.10fg	0.29±0.01e	2.60±0.01c	0.39±0.01c	3.60±0.10a	0.21±0.01d
A_1B_1	0.53±0.01g	0.28±0.01e	0.68±0.01f	0.39±0.01c	1.12±0.01d	0.20±0.01de
A_1B_2	0.77±0.01de	0.40±0.00d	0.68±0.01f	0.45±0.01b	1.01±0.01e	0.08±0.01g
A_2B_0	0.88±0.00bcd	0.47±0.00c	2.47±0.05e	0.38±0.00cd	3.34±0.00b	0.41±0.01a
A_2B_1	0.76±0.01de	0.40±0.01d	2.70±0.01b	0.37±0.00cd	3.55±0.00a	0.37±0.00b
A_2B_2	0.88±0.01bcd	0.47±0.00c	2.59±0.01c	0.35±0.01ef	3.14±0.00c	0.12±0.00f
R28	1.00±0.02bc	0.53±0.02b	0.31±0.01g	0.38±0.02c	0.11±0.01f	0.41±0.01a
Wb	1.03±0.02b	0.54±0.01b	0.28±0.00g	0.57±0.01a	0.12±0.01f	0.25±0.01c
Ot	1.01±0.01bc	0.53±0.02b	0.23±0.02h	0.58±0.02a	0.14±0.01f	0.25±0.02c

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f, g, h, I, j indicate significant result ($p<0.05$).

Table 4. Minerals (Cu, Fe, Mn, Zn, and B) changes under different cooking conditions

Treatment	Minerals (ppm)				
	Cu	Fe	Mn	Zn	B
A_0B_o	23.38±0.13a	319.85±0.55a	169.00±0.51a	42.32±0.27a	25.10±0.09b
A_0B_1	12.08±0.07d	78.25±0.35e	15.31±0.15j	18.34±0.30h	17.50±0.50d
A_0B_2	15.04±0.03b	88.80±0.00c	41.39±0.20e	26.94±0.12c	8.94±0.12i
A_1B_0	12.35±0.25d	84.85±1.55d	45.36±0.35d	20.75±0.25f	11.35±0.05f
A_1B_1	8.37±0.06e	27.51±0.45jk	14.44±0.35k	8.35±0.05i	9.30±0.29hi
A_1B_2	8.43±0.25e	29.12±0.10j	46.47±0.51c	7.40±0.39j	9.64±0.56ghi
A_2B_0	14.49±0.35c	73.20±0.30f	38.54±0.35f	26.33±0.18c	58.40±0.39a
A_2B_1	12.24±0.20d	92.50±0.50b	49.11±0.10b	19.40±0.39	19.50±0.30c
A_2B_2	14.46±0.30c	79.40±0.39e	42.12±0.10e	28.07±0.11b	14.30±0.10e
R28	6.94±0.03f	38.35±0.05i	16.44±0.03i	18.86±0.05gh	7.15±0.05j
Wb	7.14±0.04f	46.45±0.35h	20.05±0.04h	22.45±0.35e	9.05±0.05i
Ot	7.06±0.03f	58.14±0.04g	24.93±0.04g	24.62±0.01d	10.15±0.05g

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f, g, h, I, j, k indicate significant result ($p<0.05$).

Effect of steam blanching and traditional cooking process on the phytochemical composition of mixed vegetables

Ascorbic acid

Ascorbic acid content of the fresh mixed vegetables, steam blanched and traditionally cooked vegetables were significantly differed (Table 5). The highest ascorbic acid content was recorded as 70.56±1.00 mg/100 g in the fresh mixed vegetables. The ascorbic acid content of the steam blanched mixed vegetables using extra virgin olive oil ranged from 39.40±1.00 to 54.13±0.15 mg/100 gm whereas it ranged from 29.40±0.40 to 31.75±0.05 mg/100 gm by traditional cooking process using soybean oil. Results indicate that ascorbic acid content drastically changed by the cooking process than the fresh one. The damaging outcome was found by the traditionally cooking process using soybean oil than the steam blanching mixed vegetables using extra vergin olive oil. The reduction in ascorbic acid content with traditional cooking process is in agreement with the point that ascorbic acid may be oxidized on exposure to air and heat (Gupta et al., 2008, 2013; Oyetade et al., 2012) and due to water soluble nature.

ß-carotene content

The effect of steam blanching and traditional cooking using soybean oil and extra virgin olive oil had significant effect on the ß-carotene content of the mixed vegetables (Table 5). The ß-carotene content of the steam blanched vegetables using extra virgin olive oil ranged from 14.49±0.49 to 26.24±0.24 µg/100 gm whereas it was 13.26±0.20 to 18.63±0.38 µg/100 gm by traditional cooking process using soybean oil. The highest ß-carotene content was recorded by steam blanching using extra virgin olive oil followed by control and the traditional cooking process using soybean oil. The showing less amount of ß-carotene content by the traditional cooking process might be owing to the effect of heating process as the ß-carotene content are more susceptible to heat damage (Mazzeo et al., 2011). Less amount of ß-carotene content (12.80±0.20 µg/100 g) shown in the fresh (uncooked) mixed vegetables might be due to partial diluted in the soluble that may be hampered the better extraction of ß-carotene content.

Total anthocyanin

Anthocyanin is the most essential classification of the flavonoids that are highly unstable and water soluble. In this study, anthocyanin content of the mixed vegetables cooked by different process significantly differed. Several environmental factors like temperature, pH, oxygen and light influence the anthocyanin of the sample (Tian et al., 2016). The anthocyanin of the steam blanched mixed vegetables using extra virgin olive oil ranged from 37.26±0.26 to 42.87±0.13 mg/100 g whereas the traditional cooking process using soybean oil shown from 18.24±0.24 to 36.07±0.07 mg/100 g. The anthocyanin content of the fresh (uncooked) mixed vegetables was calculated as 11.41±0.01 mg/100 g. Results show that cooking process both steam and traditional increased the anthocyanin content than the fresh (uncooked) one. The steam blanching using extra virgin olive oil retained more anthocyanin content than the traditionally cooking by soybean oil (Table 5). The increased

anthocyanin content might be the effect of presenting polyphenol oxidase that contributes to degrade the enzyme. In heating process, the polyphenol oxidases are inactivated that may contribute to holding more anthocyanin although it is highly water soluble. The microstructures of the cooked vegetables are destroyed by the heating process that persuades the better extraction of anthocyanin content (Brown et al., 2008; Lachman et al., 2012). The cooking process comprises changes to the structural integrity of the cellular matrix, softening the vegetable tissues and, consequently, increasing anthocyanins extraction and concentration (Chaovanalikit and Wrolstad, 2004; Murador et al., 2014)

Total carotenoid

Traditional cooking and steam blanching significantly affected the total carotenoid content of the mixed vegetables (Table 5). The total carotenoid content of the steam blanched mixed vegetables using extra virgin olive oil ranged from 3.48±0.12 to 4.52±0.48 mg/100 g whereas the traditional cooking process using soybean oil shown from 2.35±0.35 to 4.04±0.05 mg/100 g. The total carotenoid content of the fresh (uncooked) mixed vegetables was calculated as 1.31±0.20 mg/100 g. Results indicate that steam blanching and traditional cooking by heating process increased the total carotenoid in comparison with the fresh (uncooked) one. Higher carotenoid content exhibited in the steam blanched vegetables using extra virgin olive oil than the carotenoid content found in the traditional cooking process using soybean oil. These findings are strongly supported with the findings of Bernhardt and Schlich (2006) and Gliszczynska-Swiglo et al. (2006), those reported that the carotenoid content of the broccoli, Brussels sprouts, cabbage and cauliflower increased by boiling and steaming process through breakdown of cellulose in the plant cell, thus contributed to better extraction of carotenoids. Another reason, the complexes of the carotenoid-protein may be denatured by the heating during cooking of the vegetables (De Sa and Rodriguez-Amaya, 2003).

Total phenolic content

Highly statistical significant differences were observed between the control and different cooking process of the mixed vegetables (Table 5). The steam blanched mixed vegetables using extra virgin olive oil exhibited higher amount of total phenolic content than the vegetables cooked using soybean oil by traditional cooking process. The range of the stream blanched mixed vegetables noted as 12.10±0.10 to 20.09±0.09 mg GAE/g whereas it shown 3.93±0.06 to 5.94±0.06 mg GAE/g by traditional cooking process using soybean oil. Moreover, the steam blanched vegetables using extra virgin olive oil shown significant effect on the total phenolic content compared to fresh (uncooked) and traditional process. These results are partially supported with the findings of tropical green leafy vegetables that were reported by the Adefegha and Oboh (2011). Several researchers conclude that cooking process as well as boiling, steaming and microwave assisted cooking enhance the total phenolic content than the fresh (uncooked) one (Faller and Fialho, 2009; Blessington et al., 2010). Tian et al. (2016) also reported that shorter times and lower temperatures enhance the more retention of total phenolic content by the steaming; boiling and microwave based cooking process. The enhancement of the total phenolic content by different cooking process might be ascribed due to the breakdown of the structural process which may increases the quantification of the total phenols from the cellular atmosphere and inspires the discharge of dietary fiber-bound polyphenols creating the free phenolic compounds (Ruiz-Rodriguez et al., 2008).

Table 5. Phytochemicals of the mixed vegetables under different cooking conditions

Treatment	Phytochemicals				
	Ascorbic acid (mg/100 g)	ß-carotene (µg/100 g)	Anthocyanin (mg/100 g)	Total carotenoid (mg/100 g)	Total phenol (mg GAE/g)
A_0B_0	70.56±1.00a	12.80±0.20g	11.41±0.01i	1.31±0.20e	1.10±0.10h
A_0B_1	31.75±0.05e	13.26±0.26f	36.07±0.07f	4.04±0.05ab	4.49±0.49g
A_0B_2	41.16±0.96d	20.87±0.13b	38.57±0.20d	3.55±0.06bc	12.10±0.10e
A_1B_0	30.57±1.00e	18.63±0.38d	18.24±0.24h	3.37±0.13bc	5.94±0.06f
A_1B_1	29.40±0.40e	14.02±0.02e	39.21±0.21c	2.35±0.35d	3.93±0.06g
A_1B_2	39.40±1.00d	14.49±0.49e	37.26±0.26e	3.48±0.12bc	13.22±0.22d
A_2B_0	52.91±1.01b	19.42±0.42c	40.91±0.09b	3.70±0.30b	15.68±0.32c
A_2B_1	45.86±0.94c	18.86±0.12d	21.93±0.07g	3.49±0.49bc	18.09±0.09b
A_2B_2	54.13±0.15b	26.24±0.24a	42.87±0.13a	4.52±0.48a	20.09±0.09a

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b, c, d, e, f, g, h indicate significant result ($p<0.05$).

Effect of steam blanching and traditional cooking on color of mixed vegetables

Color is the foremost quality considered by consumers at the time of purchasing a product. The effect of color values on the uncooked (fresh), steam blanched and traditional cooked mixed vegetables are shown in Fig.1. The external surfaces of the cooked mixed vegetables were considered. The color of the uncooked, steam blanched and traditionally cooked mixed vegetables had a lightness (*L**) of 39.80, 33.57 and 38.01 respectively. The Chroma (*c**) of the uncooked, steam blanched and traditionally cooked mixed vegetables were 23.04, 16.49 and 93.27 whereas the hue angle (*h**) of the uncooked, steam blanched and traditional cooked vegetables were 117.19, 95.69 and 93.27 respectively. Results indicate that *L** and *h** values expressively declined after steam blanched and traditionally cooked mixed vegetables. The external color of the steam blanched and traditionally cooked vegetables was less bright (*L**) and hue (*h**) than the uncooked sample color. A significant loss of bright color (*c**) for the uncooked and steam blanched mixed vegetables decreased whereas a significant *c** increase was noticed for the traditional cooked mixed vegetables. The hue angle significantly increased for the uncooked cooked vegetables in comparison to the steam blanched and traditionally cooked vegetables. It is well reported that the color of the uncooked, cooked and steam blanched vegetables are affected by the α-carotene and ß-carotene content (Bao and Chang, 1994). In our study, it shows that the highest ß-carotene content was retained in steam blanching mixed vegetables by the steam blancher followed by uncooked and traditionally cooked vegetables (Table 6). The lowest ß-carotene content was retained by our uncooked vegetables, which is may be directly related to increase the hue angle (*h**) of the vegetables (Fig.1). Our results obtained by this study are strongly supported with the findings of Sulaeman et al. (2004), those who reported that a high negative correlation was observed between this color parameter and the carotene content of deep fried carrots. The larger decrease of Chroma (*c**) and lightness (*L**) might be due to increase of ß-carotene content by the steam blanching process. Our findings are strongly supported with the findings of Hart and Scott (1995), those reported that higher ß-carotene content found in the carrot may be contributed to the remarkable loss of Chroma (*c**) and lightness (*L**).

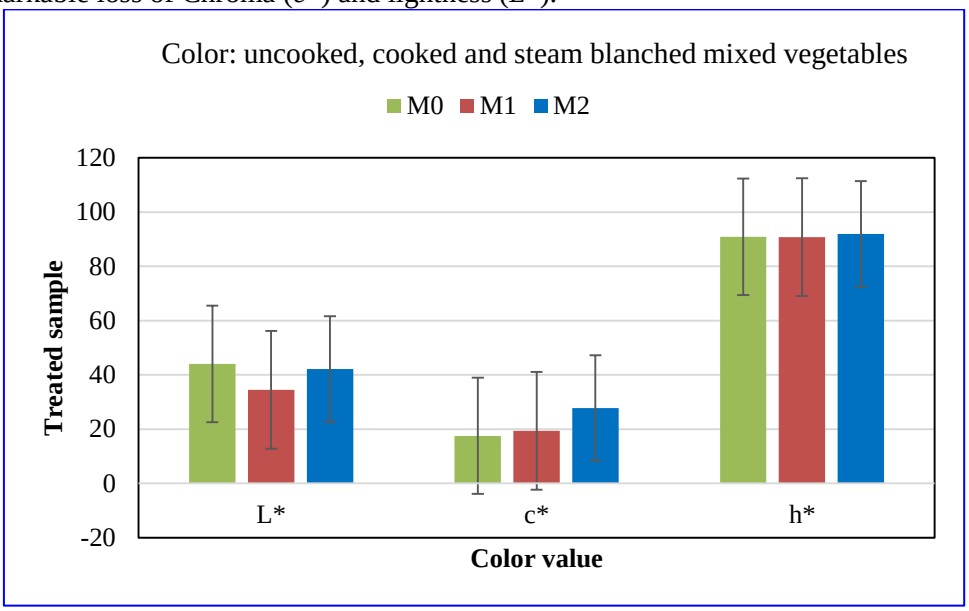

Fig.1. Color profile of the mixed vegetables under different cooking conditions. M0= fresh vegetables (uncooked), M1= domestically cooked (traditional) vegetables, M2= stream blanched vegetables.

Texture profile

The texture depends on the hardness, softness and on the amount of moisture content presence in the vegetables. The rupture force (FR) was measured in order to assess the hardness and softness of the mixed vegetables cooked by traditional and steam blanching process (Fig. 2). The maximum, medium and lowest peak was recorded in uncooked fresh (control), steam blanched and traditionally cooked vegetables. Between the cooked vegetables, the highest peak obtained by the steam blanched extra virgin olive oil might be due to the less broken of the cell membrane to attain more hardness than the traditionally cooked vegetables.

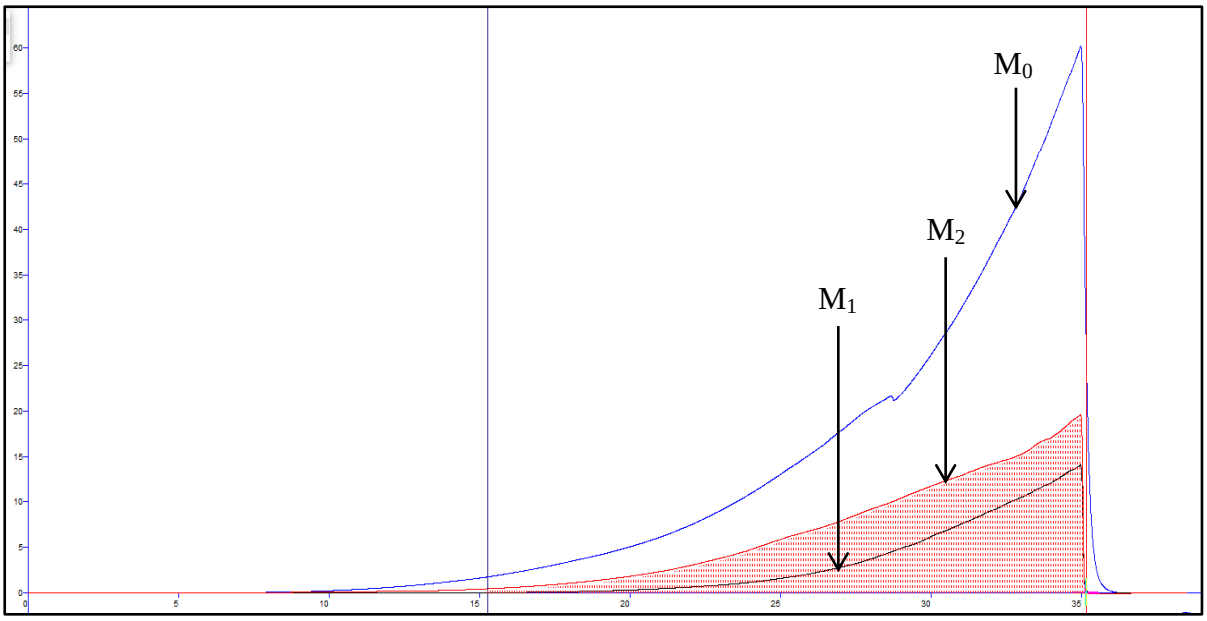

Figure 2. Texture profile of the mixed vegetables under different cooking conditions. M_0= Fresh vegetables (uncooked), M_1= Oven cooked (traditional) vegetables, M_2= Stream blanched vegetables

Sensory evaluation

The steam blanched mixed vegetables using extra virgin olive oil and traditionally cooked vegetables using soybean oil were subjected to sensory evaluation based on 9-point hedonic scale (Table 6). The score obtained by the expert judgment in terms of color, flavor, mouth feel, softness and overall acceptability. Flavor, mouth feel and softness were statistically non-significant whereas the color was significantly differed. Most of the judgment opined that steam blanching using extra virgin olive oil enhanced the color of the vegetables. The highest score 8.16±0.38, 7.33±1.15, 7.41±0.51and 7.50±0.62 obtained by the evaluator in terms of color, flavor, softness and overall acceptability for the steam blanched mixed vegetables except mouth feel. The highest mouth feel obtained by the traditional cooking process might be due to the eating behavior of the country (Bangladesh) people as the peoples are accustomed in this process.

Table 6. Sensory evaluation of the mixed vegetables under different cooking conditions

Parameter	Cooking method		LSD
	M_1	M_2	
Color	5.91±1.78	8.16±0.38	**
Flavor	6.41±1.16	7.33±1.15	NS
Mouth feel	7.50±0.67	7.08±0.90	NS
Softness	7.25±1.13	7.41±0.51	NS
Overall acceptability	6.77±0.90	7.50±0.62	*

*M_1=Oven cooked (traditional) vegetables, M_2= Stream blanched vegetables, All values are means of triplicate determinations ± SD. * and ** indicate significant results at $p<0.05$ and $p<0.01$ level. NS denotes non-significant difference.*

Conclusion

In this study, steam blanching and traditional cooking process was applied with two cooking oils namely i) extra virgin olive oil and ii) soybean oil. The soybean oil is mostly consumed by the cent percent of consumer. Recently, the peoples are suffering different non-communicative and chronic diseases. Type 2 diabetes, stroke and heart attack are the vulnerable issue now in the country as well as globe. Obesity and over weight is considered main cause of diabetes and coronary heart diseases (CHD). Cooking oil is one of the primers of the CHD. Although our study was not involved with randomized control trial but our research study confirms that steam blanching and traditional cooking, extra virgin olive and soybean oil have effect on nutritional values, physicochemical properties, minerals and bioactive compounds. The steam blanched mixed vegetables using extra virgin olive oil

retained more bioactive compounds, minerals and nutritional values than the traditionally cooked vegetables using soybean oil. Except our analytical data, the consumer preferences based on sensory evaluation also confirm that steam blanching process improved the color, flavor and texture of the mixed vegetables than the traditional one although still now, the peoples are accustomed to the traditional cooking process. Future study may be conducted to disseminate this technology to change the dietary life style of the traditionally accustomed people.

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KINETICS OF DEHYDRATION AND APPRECIATION OF THE PHYSICOCHEMICAL PROPERTIES OF OSMO-DEHYDRATED PLUM

S. PERVIN, M.G. AZIZ AND M. MIARUDDIN

Abstract

The experiment was conducted to evaluate the dehydration kinetics and quantify its effect on the various physicochemical properties of the osmo-dehydrated plum during storage at an ambient condition. The six treatments with a combination of three different sucrose-sodium chloride concentrations and two peeling conditions were selected in the experiment. Among the treatments, peeled plum dipped into 5 percent NaCl solution exhibited a faster drying rate. Concerning the rehydration properties of the osmo-dehydrated plum, the whole plum immersed into 50^0B sucrose solution showed the highest reconstitution behavior and the lowest moisture content (wb). The highest values of water activity of 0.514 and the lowest values of texture 1.79 N-mm^2 were investigated in 50^0B sucrose treated whole plum. The peeled plum obtained the highest lightness, redness (a*) and yellowness (b*) compared to the unpeeled plum. Osmo-dehydrated plum with high sugar solution contained more sugar and less total phenolic content nevertheless using only 5 percent NaCl resulted in less sugar and more total phenolic content after the treatment. The osmo-dehydrated whole plums prepared in 50^0B sucrose scored the highest overall acceptability (8.0 e.g. like very much) followed by the 50^0B sucrose with peeled plum envisaged the sensory evaluation analysis. In conclusion, the osmo-dehydrated plum treated in 50^0B sucrose and unpeeled condition performed better with a view to the overall plum quality, color, and acceptability judged by the expert panelists even after 12 months of storage at room temperature.

Introduction

In Bangladesh, the demand of plum (*Prunus domestica*) usually meets up by importing from other countries like India, China, Thailand (Mozumder et al., 2017). Spices Research Center of Bangladesh Agricultural Research Institute (BARI) released a plum variety namely "BARI Alu bukhara-1" which is high yielding and profit potential (Anonymous, 2014) but there is no available processing method to utilization of recently produced plum in Bangladesh. Hence, the suitable plum processing technique is needed. Various food processing techniques can be engaged to preserve fruits and vegetables; and dehydration is one of the most important operations that are widely practiced because of long time consumption (Chavan & Amarowicz, 2012). In recent years, there is growing demands by the customer for osmo-dehydrated plum with a comparatively long-life span, which preserve the attributes of fresh plum. In the case of fruit like plum, to obtain a fresh like plum implies certain operations such as whole or peeled and dip in sucrose-sodium chloride solution or often, partial dehydration of the plum. Osmotic dehydration has been the main effective method of dehydration with some advantages over other methods of drying. Therefore, osmotic dehydration has received remarkable attention in the use of moderate operating temperature, low energy process, reduced loss of volatile compounds, and better quality of the developed dehydrated plum (Lama, 2018).

Osmotic dehydration is a preservation process that is sometimes used as a pre-treatment to enhance the quality of conventional dried plum (Monnerat et al., 2006). One of the most exoteric osmotic agents for fruits is sucrose because of its low cost, but other agents such as glucose or concentrated fruit juices, are also used (Mandala et al., 2005; Rastogi et al., 2002). Osmotic dehydration is a counter flow process that results in solids gain, improving the textural and rheological properties of plum and other related fruits. It elevated the overall quality of plums as compared to conventional drying methods (Birwal et al., 2016). Consequently, the characteristics of the osmo-dehydrated plum can be varied by controlling temperature, sugar syrup concentration, the concentration of osmosis solution, time of osmosis, etc., which require osmotic concentration process faster. For fruits, the most commonly used osmotic agents were sucrose, glucose, and NaCl for vegetables (Chavan & Amarowicz, 2012). Bongirwar & Sreenivasan (1977) pointed out that the high temperature above 60°C modifies the tissue characteristics favoring impregnation phenomena and thus solid gain. Rahman & Lamb (1991) indicated the rate of sucrose diffusion is a function of solute concentration and temperature. As osmotic dewatering is a simultaneous counter-current mass transfer process there are many changes in the chemical composition of food after osmotic treatment (Lewicki et al., 2005; Sablani & Rahman, 2007; Robert, 2008).

The process of reintroducing water to dried foods to reach similar water levels as in their initial state is called rehydration (Vega et al., 2009). The factor which affects rehydration of any osmo-dehydrated plum is the chemical composition of the dried fruits and vegetables, method and

conditions of dehydration, solvent medium, and temperature (Taiwo & Adeyemi 2009). In view of the physicochemical properties of fresh plum that could assist the dehydration and rehydrating properties of the osmo-dehydrated plum this might be established in the present research.

The kinetics of dehydration, rehydration properties, and quality characteristics of dehydrated fruits such as mango, guava and reola (Kumar & Sagar 2014), banana, apple, apple slices (Ghasemkhani et al., 2016), kiwifruit (Maskan, 2001), and longan (Chunthaworn et al., 2012). From the viewpoints of the above studies, the research on dehydration behavior of plum and physicochemical quality attributes of osmo-dehydrated plum is scare. Therefore, the effect of processing variables on the dehydration kinetics of plum along with the assessment of the physicochemical and rehydration properties of the osmo-dehydrated plum produced from fresh plum are the objectives set for the study.

Materials and Methods

Collection and method of processing of plum

The plum fruits were collected from the Spices Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The fruits were sorted, washed, and cleaned. Then, it was blanched in boiling water for 5 min and the plum was peeled by hand. The whole and peeled plum were dipped into 50^0B sucrose, 45^0B sucrose plus 5 percent sodium chloride solution, and only 5 percent sodium chloride solution for 1.5 hours. Then, they were heated at 100^0C for 2 min. For the preservation purpose, the KMS (1g/l) and acetic acid (6g/l) were added. The dehydration temperature was maintained at 60^0C. After drying, the fruits were preserved in glass containers. Finally, the dehydrated fruits were analyzed at an interval of 3 months during storage for 1 year at room temperature.

There were six treatments in the experiment such as T_1=50^0B sucrose in whole plum; T_2=50^0B sucrose in peeled plum; T_3=45^0B sucrose+5% NaCl in whole plum; T_4=45^0B sucrose+5% NaCl in peeled plum; T_5=5% NaCl in whole plum and T_6=5% NaCl in peeled plum.

Mechanical drying

Cabinet dryer, Model OV-165 (Gallen Kamp Company) was used for the dehydration of the plum. The dryer consists of a chamber in which wetted plum could be placed. Air was blown by a fan pass through a heater and then across the trays of plums to be dried. The velocity of air was recorded (0.6 m/sec) by an Anemometer. The dehydrated plum was taken for the determination of moisture content. Fresh plums (without peel and peel) at a constant loading density (0.5 kg/ft^2) were placed in trays in the drier and drying was commenced in the drier at a constant air velocity (0.6 m/sec) and a specific air-dry bulb temperature of 60°C. Weight loss was used as a measure of the extent of drying.

Fick's second law of diffusion (for plum dehydration) is applied for describing mass transfer during drying. The expression is-

$$\frac{\delta M}{\delta t} = \Delta^2 D_e M$$

Where, M = Moisture content (dry basis); t = Time; D_e = Effective diffusion coefficient

The solution for an infinite slab, when dried from one major face (Booker, Bakker & Hall, 1974; Islam, 1980 & Crank, 1975) is:

$$MR = \frac{M_t - M_0}{M_0 - M_t} = \frac{8}{\pi^2} \sum_{n=0}^{\alpha} Exp. \left[\frac{-(2n+1)^2 \pi^2 D_e t}{L^2} \right] .....(1)$$

For low M_e values and for moisture ratio, MR <0.6 equation (1) reduces to:

$$\frac{M_t}{M_0} = \frac{8}{\pi^2} e \frac{-\pi^2 D_e t}{L^2} = \frac{8}{\pi^2} e^{-me} .....(2)$$

Where, $m = \frac{\pi^2 D_e}{L^2}$ = drying rate constant, sec^{-1}

Rearranging equation (2) gives:

$$In \frac{M_t}{M_0} = In \frac{8}{\pi^2} - mt .....(3)$$

Consequently, a straight line was obtained when plotting in MR versus time (t).

Rehydration properties

Determination of dehydration ratio

The dehydration ratio of the dried plum (without peel and peel) was calculated by the following formula:

$$\text{Dehydration ratio} = \frac{\text{Weight of prepared material before drying}}{\text{Weight of dried plums}}$$

General procedure for rehydration (reconstitution)

Rehydration means refreshing the dehydrated or dried plums in water. Six beakers of each 500 ml capacity were taken and 100 ml of hot water (60^0C) and 5g of the dried samples were poured into each beaker. The wetted plum weight was taken in 5 min intervals up to 30 min. During the weighing process, the liquid portion was drained off and solid contents were transferred to a 4-inch diameter Buchner funnel separately fitted with filter paper to remove excess water from the plum by applying a gentle suction for a few seconds. The rehydrated materials were removed from the funnel and the weight is taken individually and finally, the following relations were found:

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated material}}{\text{Weight of dehydrated material}}$$

$$\text{Co}-\text{efficient of reconstitution} = \frac{\text{Rehydration ratio}}{\text{Dehydration ratio}}$$

Water activity

Water activity of the dehydrated plum was determined by the chilled mirror technique using a Novasina water activity meter (Decagon devices Inc.,Pullman, Wash , USA).

Measurement of osmo-dehydrated plum color

Dehydrated plum color was determined using a tristimulus colorimeter (CR-400, Minolta Corp., Japan) with 8-mm aperture and C light source at two equidistant points on the equator of each sample by using CIE color system on the L, a*, b* color space where L, a*, b* coordinates were recorded using D65 illuminants. A 10° standard observer was used as a reference system. L (lightness), a* (-greenness to +redness) and b* (-blueness to +yellowness) are the chromaticity coordinates.

Measurement of texture

Osmo-dehydrated plum texture was analyzed using cross-sectional prove of Texture Analyzer TA.XT plus by back extrusion method. The test mode compression was used to determine the working capacity of the instrument with a test speed of 1mm/s and distance was 2.50 cm. The data analysis was performed by Texture Exponent Lite version 6.1.14.0 software (Stable Micro System, Godalming, UK) to find out the rupture force and it was expressed as N.

Measurement of sugar

Total sugar and reducing sugar were determined by Nelson (1944).

Reducing sugars were estimated as percent and calculated it as given below:

$$\text{Reducing sugar}\,(\%) = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Weight of sample}} \times 100$$

The total sugar was estimated as percent and calculated as given under:

$$\text{Total invert sugar}\,(\%) = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre} \times \text{Weight of sample taken}} \times 100$$

% Sucrose = (% Total invert sugars - % Reducing sugars) x 0.95

% Total sugars = (% Reducing sugars + % Sucrose)

Total phenol

Total phenolic content was extracted with 80 percent ethanol and was estimated based on their reaction with an oxidizing agent phosphomolybdate in Folin-Ciocalteau reagent under alkaline conditions (Bray & Thorpe, 1954). The developed blue color was measured at 650 nm in a UV-VS spectrophotometer (Shimadzu, Japan). The standard curve was prepared using different concentrations (8-32 µg/mL) of catechol and the result was expressed as mg per 100g on a fresh weight basis.

Sensory evaluation

The sensory evaluation of the osmo-dehydrated plum was carried out at every 3 months interval during storage using a sensory taste questionnaire judged by expert sensory panelists. Each treatment was assigned a letter code to avoid biases among the panelists. The samples were presented to panelists in different orders to avoid order preference among the panelists. The osmo-dehydrated plum was rated by 10 experienced panelists who were asked to score samples based on the plum external color, off-flavor, firmness, sweet-sour balance, and overall acceptance using a 9-point hedonic scale.

Data analysis

The experiment was carried out Completely Randomized Design (CRD) and all six treatments were replicated three times. The data were analyzed for ANOVA using computerized statistical software of R to compare the means and the level of significance of data.

Results and Discussion

Dehydration kinetics

Effects of peeling and sucrose-sodium chloride concentrations on dehydration time

The fresh mature plum (whole and peeled) osmosed in different solutions were dried in the cabinet dryer at a constant temperature of 60°C using a single layer of material. The experimental data were analyzed by using equation 3; and moisture ratio (MR) versus drying time (hr) were plotted on a semi-log coordinate and regression lines were drawn in Figure 1. At constant loading density and constant temperature, the faster drying was observed for peeled plum than that of the whole plum. It was noted that the plum peel has a profound influence on dehydration rate and it offers higher resistance in both heat and mass transfer with resultant higher drying time for peel less plum. For osmo-dehydrated plum, the drying rate constant and R-squared values were less in 50^0B sucrose with whole plum and more in 50^0B sucrose with peeled plum; the same trend was observed in another treated sample for whole plum and peeled plum, respectively as shown in Table 1. It could be concluded that the rate constant of osmo-dehydrated peeled plum was decreased in all cases. This implies that at a specific moisture ratio, more amount of water is evaporated per unit area for a given time from the samples of peeled plum than that of the whole plum. This behavior is attributed due to broader mass transfer resistance given by the plum peel compared to the rest of the plum material (i.e. starchy endosperm, tube cell, epidermis, etc). A similar result was reported by Pervin et al. (2007) for the effect of drying on bean seeds. It was observed that the NaCl concentration in plum gave a faster drying rate than that of the sucrose concentration.

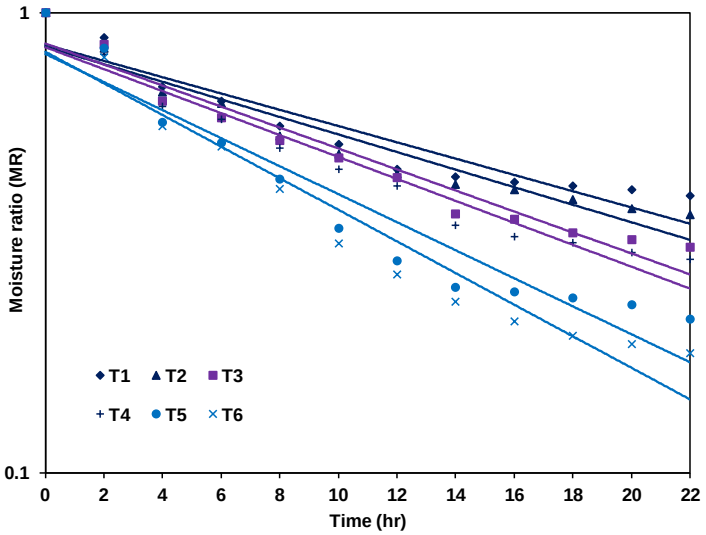

Figure1. Effect of peeling and various sucrose-sodium chloride concentrations on dehydration rate of plum at a constant temperature of 60^0C.

Abbreviations: T1, 50^0B sucrose in whole plum; T2, 50^0B sucrose in peeled plum; T3, 45^0B sucrose+5% NaCl in whole plum; T4, 45^0B sucrose+5% NaCl in peeled plum; T5, 5% NaCl in whole plum; T6, 5% NaCl in peeled plum.

Table 1. Effect of peeling and solute concentrations on dehydration rate constant and R^2 of dehydrated plum

Treatments	Dehydration rate constant	R-squared
T_1	0.041	0.8223
T_2	0.044	0.8389
T_3	0.053	0.8528
T_4	0.055	0.8573
T_5	0.070	0.8063
T_6	0.079	0.8229

Abbreviations: T_1, 50^0B sucrose in whole plum; T_2, 50^0B sucrose in peeled plum; T_3, 45^0B sucrose+5% NaCl in whole plum; T_4, 45^0B sucrose+5% NaCl in peeled plum; T_5, 5% NaCl in whole plum; T_6, 5% NaCl in peeled plum.

Rehydration characteristics of dehydrated plum

For dehydrated plum, the rehydration ratio for the peeled plum was higher than that of the whole plum for all the treated samples. For peeled plum the highest rehydration ratio was 1.61 (T_6) followed by the whole plum it was 1.47 (T_5) and the same result was investigated in other treated samples. It was obvious that the plum peel has a significant effect on the rehydration of the plum. The peeled plum resulted in higher rate of drying that might have increased the rehydration rate of the plum as because of the cellular and structural disruption during drying. The reduced rate of shrinkage of the peeled plum has also influenced the attained of a higher rate of rehydration. The coefficient of reconstitution for whole and peeled plum; the highest values were 0.55 and 0.52 in the 50^0B sucrose concentration, respectively which was followed by the values of 0.44 and 0.43 in 45^0B sucrose+5% NaCl concentration, respectively, and the lowest values of 0.32 and 0.29 in only 5% NaCl concentration, respectively (Table 2) which indicated that the osmo-dehydrated plum possessed better reconstitution properties using different sucrose concentration than that of NaCl counterparts. This behavior may be attributed to the change in the rate of drying during osmotic treatments using various solutions (Kueneman et al., 1975).

Table 2. Effect of peeling and various solutes concentrations on the rehydration characteristics of dehydrated plum

Treatments	Weight (g) of the rehydrated sample at different duration in min							Rehydra-tion ratio for 30 min	Dehydr-ation ratio	co-efficient of reconstituti-on	% m.c. (wb) of rehydrated plum
	0	5	10	15	20	25	30				
T_1	5	5.85	6.05	6.29	6.65	6.77	6.85	1.37	2.50	0.55	37.97
T_2	5	6.26	6.45	6.77	6.88	7.23	7.15	1.43	2.74	0.52	40.04
T_3	5	5.95	6.19	6.45	6.62	6.75	6.95	1.39	3.16	0.44	37.97
T_4	5	6.34	6.48	6.84	6.91	7.1	7.24	1.45	3.33	0.43	40.21
T_5	5	6.25	6.65	6.75	6.78	7.21	7.37	1.47	4.55	0.32	40.35
T_6	5	6.31	7.2	7.51	7.71	7.65	8.07	1.61	5.56	0.29	44.89

Physico-chemical properties of osmo-dehydrated plum

The osmo-dehydrated plum was stored in an ambient condition for one year. The changes in-water activity (a_w) of stored osmo-dehydrated plum was seen in Table 3. There were significant differences observed due to variation in the solute concentrations as well as the peeling condition of the plum. In case of the peeling effect, initial a_w (0.50) was found the highest in the whole plum and the lowest was 0.49 in the peeled plum. During the prolonged storage, a_w was increased by 20.0% and 10.2 percent in whole and peeled plum, respectively. For the effect of solute concentrations, the plum in 50^0B sucrose showed the highest a_w (0.51) followed by the plum in 45^0B sucrose+5% NaCl which scored the second-highest a_w (0.49). Concerning the interaction between peeling conditions and solute concentrations, the a_w for the whole plum was 0.514, 0.511 and 0.479 for the treatments of T_1, T_3 and T_5, respectively and the percent increase was 21.79%, 21.14% and 13.78% for the same treatments, respectively which assumed due to the presence or absence of sucrose and NaCl in the plum. It might be happened due to temperature and humidity changes round the year during storage. The highest values of a_w mean the increasing rate of water content for the treated sample of 50^0B sucrose in the whole plum. In dehydrated plum, the higher water content may decrease the browning rate by diluting

the reactive components of the plum and a similar investigation was observed by Labuza & Saltmarch (1981).

Table 3. Effect of peeling and various sucrose-sodium chloride concentrations on the water activity (a_w) of osmo-dehydrated plum during storage

Factors/Treatments	a_w of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
Peeling conditions					
Whole plum	0.50a	0.52a	0.54a	0.57a	0.60a
Peeled plum	0.49b	0.50b	0.52b	0.53b	0.54b
CV (%)	0.787	0.670	0.851	0.776	0.867
$LSD_{0.1\%}$	0.004	0.004	0.005	0.004	0.005
Level of concentrations					
50^0B sucrose	0.51a	0.53a	0.55a	0.57a	0.60a
45^0B sucrose+5% NaCl	0.49b	0.51b	0.52b	0.54b	0.56b
5% NaCl	0.48c	0.50c	0.51c	0.53c	0.55c
CV (%)	0.787	0.670	0.851	0.776	0.867
$LSD_{0.1\%}$	0.005	0.004	0.006	0.005	0.006
Treatments					
T_1	0.514a	0.534a	0.559a	0.594a	0.626a
T_2	0.508ab	0.527b	0.547b	0.559b	0.578b
T_3	0.511a	0.531ab	0.555ab	0.591a	0.619a
T_4	0.503b	0.517c	0.531c	0.547c	0.571b
T_5	0.479c	0.481d	0.493d	0.517d	0.545c
T_6	0.4566	0.460e	0.467e	0.471e	0.479d
CV (%)	0.787	0.670	0.851	0.776	0.867
$LSD_{0.1\%}$	0.007	0.006	0.008	0.008	0.009

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

The color of osmo-dehydrated plums is an important quality parameter. Color values of L (lightness), a* (redness), and b* (yellowness) of the initial and three-month intervals up to twelve months stored plums are depicted in Table 4. The peeled plum obtained the highest lightness compared to the whole plum and the trend of decreasing lightness continued even after 12 months of storage. Concerning the osmotic reagents and their concentration effect, it was observed that the highest lightness was found in the 50^0B sucrose treated plums. For the interactive effects of peeling conditions and solute concentrations, the highest lightness was found in the treatment T_6 and the second-highest was in the treatment T_4. The reduction of lightness during storage may be explained by the degradation of thermo-labile pigments happening during the formation of dark compounds that blow up luminosity, and non-enzymatic browning reaction because of heat effect as reported by Dutta et al. (2006) & Goncalves et al. (2007). In the case of color coordinates a*; the highest values was found in the peeled plum and the lowest was observed in the whole plum considering the effect of peeling used as treatments. In the case of sucrose-NaCl concentrations, using 5% NaCl scored the highest values of color coordinate a*. For treatment interactions as the peeling conditions and the level of sucrose-sodium chloride concentrations, the highest values of a* were found in treatment T_4 and the second-highest was in treatment T_6 and gradually it was decreased up to 12 months of storage. Initially the plum color was red and it decreased slowly up to the end of the storage period concerning the color coordinates a*. For the color coordinates b*, it was observed that the highest values were found in the peeled plum and the lowest was in the whole plum due to the effect of sucrose-sodium chloride concentrations. With regard to the sucrose-sodium chloride concentrations, the 5% NaCl treated plums showed the highest values of b*. In the case of treatment interactions of peel conditions and solute concentrations, the highest color coordinates b* values were found in the treatment T_6 followed by the treatment T_4 and gradually it was decreased month by month during storage. The osmo-dehydrated plum color was turned into yellowish to brownish color after 12 months of storage regarding color coordinates b*. This could be explained by the degradation of carotenoids in the plum tissue during storage (Miranda et al., 2009). The influence of temperature on heat-sensitive

compounds, such as carbohydrates, proteins, and vitamins are responsible for the color degradation in fresh foods in addition to browning actions and pigment deterioration with drying processes (Maskan et al., 2002; Hawlader et al., 2006). Similar investigation has been pointed out by Prothon et al. (2001) for apples; Scala & Crapiste (2008) for red peppers; Koca et al. (2007) for carrots; Vega et al. (2007) for red peppers. The plum color alterations might be explained by the carotenoid degradation by heat; non-enzymatic browning due to the degeneration of color. However, the effect of temperature on lightness and the coordinate was the same as that of on a* and b* values, meaning that the lightness of the osmo-dehydrated plum was increased with the increasing of temperature (Adiletta et al., 2018).

Table 4. Effect of peeling and various solutes concentrations on the color parameters of osmo-dehydrated plum during storage

Factors/Treatments	Color parameters of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
	Lightness (L)				
Peeling conditions					
Whole plum	34.55b	31.81b	29.63b	26.46b	24.82b
Peeled plum	40.17a	36.46a	31.90a	28.87a	26.68a
CV (%)	0.888	0.905	0.933	0.959	0.946
$LSD_{0.1\%}$	0.348	0.324	0.302	0.279	0.256
Level of concentrations					
50^0B sucrose	39.46a	33.15b	29.43b	27.08b	25.43c
45^0B sucrose+5% NaCl	37.26b	33.26b	29.79b	27.86a	25.76b
5% NaCl	35.36c	36.01a	33.09a	28.06a	26.08a
CV (%)	0.888	0.905	0.933	0.959	0.946
$LSD_{0.1\%}$	0.427	0.397	0.369	0.341	-
$LSD_{1.0\%}$	-	-	-	-	0.313
Treatments					
T_1	31.13f	30.09e	28.74d	25.84d	24.01d
T_2	37.84c	33.63c	29.93c	28.15b	26.19b
T_3	35.85e	32.46d	30.51b	25.98d	24.49c
T_4	39.59b	36.21b	30.12bc	28.32b	26.84a
T_5	36.67d	32.89d	29.64c	27.57c	25.97b
T_6	43.07a	39.55a	35.66a	30.13a	27.02a
CV (%)	0.888	0.903	0.933	0.959	0.946
$LSD_{0.1\%}$	0.603	0.561	0.522	0.483	0.443
	Coordinates (a*)				
Peeling conditions					
Whole plum	14.26b	11.80b	10.70b	9.32b	7.75b
Peeled plum	22.73a	19.17a	16.33a	13.95a	12.06a
CV (%)	0.921	1.009	1.008	0.990	0.955
$LSD_{0.1\%}$	0.179	0.164	0.143	0.121	0.099
Level of concentrations					
50^0B sucrose	17.88c	14.79b	12.80b	11.21b	9.68b
45^0B sucrose+5% NaCl	18.12b	14.42c	12.74b	10.55c	8.85c
5% NaCl	19.50a	17.24a	15.01a	13.17a	11.20a
CV (%)	0.921	1.009	1.008	0.990	0.955
$LSD_{0.1\%}$	0.219	0.201	0.175	0.148	0.122
Treatments					
T_1	11.70f	9.46f	8.54f	7.26f	6.03f
T_2	21.61c	17.92c	15.45c	12.11c	10.55c
T_3	16.47d	15.01c	13.54d	11.73d	10.09d
T_4	24.05a	20.12a	17.06a	15.145a	13.32a
T_5	14.62e	10.92e	10.03e	8.98e	7.14e
T_6	22.53b	19.46b	16.47b	14.60b	12.31b

Factors/Treatments	Color parameters of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
CV (%)	0.936	1.001	1.020	0.980	0.958
$LSD_{0.1\%}$	0.315	0.282	0.251	0.207	0.173
	Coordinates (b*)				
Peeling conditions					
Whole plum	13.81b	11.33b	9.41b	7.79b	6.84b
Peeled plum	20.77a	16.90a	14.52a	12.50a	11.08a
CV (%)	0.788	0.816	0.791	0.895	0.896
$LSD_{0.1\%}$	0.143	0.121	0.099	0.095	0.084
Level of concentrations					
50^0B sucrose	18.02b	14.58b	12.85b	10.89a	9.28b
45^0B sucrose+5% NaCl	15.02c	12.47c	9.95c	8.96c	8.16c
5% NaCl	18.84a	15.29a	13.11a	10.57b	9.45a
CV (%)	0.788	0.816	0.791	0.895	0.896
$LSD_{0.1\%}$	0.175	0.148	0.122	0.117	0.103
Treatments					
T_1	14.87d	12.10d	9.98d	8.40d	7.54d
T_2	17.02c	14.22c	11.42c	10.53c	9.98c
T_3	13.54e	11.17e	9.79e	7.56e	6.66e
T_4	21.17b	17.06b	15.71b	13.39b	11.02b
T_5	13.01e	10.73f	8.47f	7.40e	6.33f
T_6	24.13a	19.42a	16.43a	13.58a	12.23a
CV (%)	2.521	0.808	0.793	0.882	0.865
$LSD_{0.1\%}$	0.793	0.207	0.173	0.163	0.141

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e, & f indicates significant result (p<0.001 & <0.01).

The effect of peeling and solute concentrations on the texture of osmo-dehydrated plum during storage are given in Table 5 and the texture profile of osmo-dehydrated plum after 12 months of storage are shown in Figure 2. As shown in the Table, initially the texture of the peeled plums was 2.42 N-mm^{-2} and that of the whole plum was 2.22 N-mm^{-2}. It was observed that the texture of the plum changed significantly due to different concentrations of sucrose-NaCl in the treatments. The highest texture of 2.51 N-mm^{-2} was observed in only 5% NaCl plums and the lowest 2.08 N-mm^{-2} was in the 50^0B sucrose treated plums. However, the texture was gradually decreased after 12 months of storage. In connection with the interaction between peeling condition and concentrations, the highest texture of 2.77 N-mm^{-2} was seen in treatment T_6 and the lower of 1.79 N-mm^{-2} in treatment T_1. The lower values of texture indicated that the good quality of osmo-dehydrated plums. The texture reduction may be associated with the degradation of components responsible for the structural rigidity of the fruit, mainly insoluble pectin and protopectin discussed by Maftoonazad et al. (2008). The higher texture conservation in pretreated samples along the storage time can be attributed to the use of different sucrose-NaCl concentration in the osmotic dehydration as well as the peeling condition; the same result was investigated by Cristhiane et al. (2013) for fresh-cut melon.

Table 5. Effect of peeling and various sucrose-sodium chloride concentrations on the texture (N-mm^{-2}) of osmo-dehydrated plum during storage

Factors/Treatments	The texture of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
Peeling conditions					
Whole plum	2.22b	1.70b	1.53b	1.44b	1.35b
Peeled plum	2.42a	1.86a	1.66a	1.55a	1.42a
CV (%)	1.467	1.331	2.018	1.862	2.586
$LSD_{0.1\%}$	0.036	0.025	0.034	0.029	-
$LSD_{1.0\%}$	-	-	-	-	0.038
Level of concentrations					

Factors/Treatments	The texture of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
50^0B sucrose	2.08c	1.65c	1.50c	1.40c	1.34b
45^0B sucrose+5% NaCl	2.38b	1.77b	1.55b	1.51b	1.39a
5% NaCl	2.51a	1.92a	1.75a	1.59a	1.43a
CV (%)	1.467	1.331	2.018	1.862	2.586
$LSD_{0.1\%}$	0.044	0.030	0.041	0.036	-
$LSD_{1.0\%}$	-	-	-	-	0.046
Treatments					
T_1	1.79f	1.49f	1.35e	1.29e	1.26e
T_2	2.14e	1.61e	1.41d	1.41d	1.34d
T_3	2.25d	1.69d	1.57c	1.44d	1.35cd
T_4	2.36c	1.81c	1.65b	1.51c	1.41bc
T_5	2.62b	1.92b	1.68b	1.60b	1.44ab
T_6	2.77a	2.15a	1.93a	1.73a	1.50a
CV (%)	1.467	1.331	2.018	1.862	2.586
$LSD_{0.1\%}$	0.062	0.043	0.059	0.051	0.065

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e, f indicates significant result (p<0.001 & <0.01).

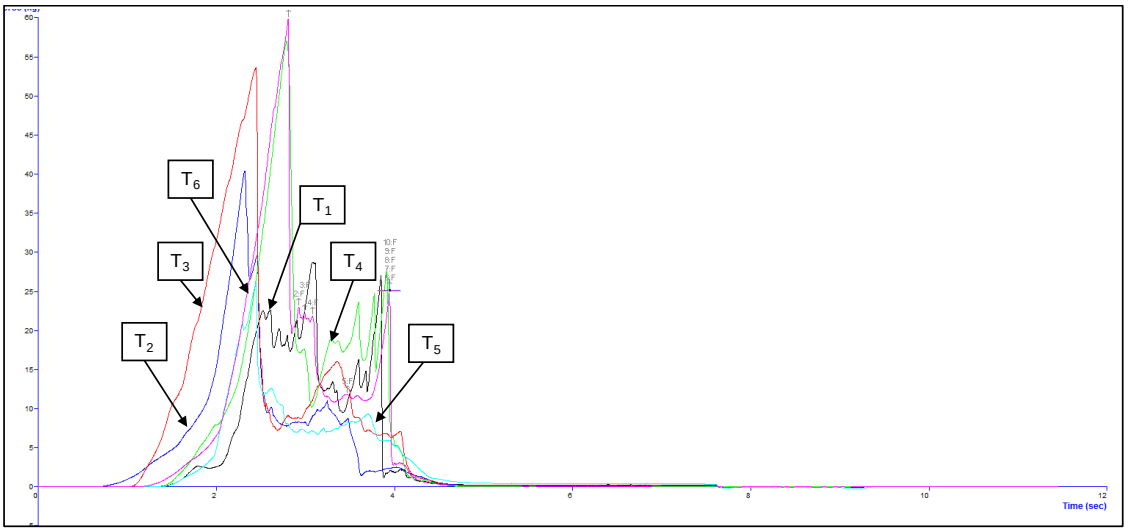

Figure 2. Texture of osmo-dehydrated plum after 12 months of storage (Force Vs Time)

The changes in sugar (reducing and total) of stored osmo-dehydrated plum because of the effect of peeling and various sucrose-NaCl concentrations are depicted in Table 6. The fresh plum TSS was 8.9. Concerning the effect of peeling condition, it was observed that the highest content of reducing sugar of 26.42 was found in the whole plum and the lowest was 24.03 in the peeled plum. However, it was decreased month by month up to 12 months of storage. Coming to the effect of concentrations, the highest reducing sugar of 34.92 was observed in 50^0B sucrose followed by 22.12 which was found in 45^0B sucrose+5% NaCl concentration. As for the interaction between peeling condition and concentrations, initially, the highest reducing sugar of 41.66 was seen in treatment T_1 and the lowest value was 39.13 in treatment T_2. Interestingly, reducing sugar was gradually decreased after 12 months of storage. For the total sugar content of the osmo-dehydrated plums, the highest content in the whole plum was 43.12 and the lowest was 40.35 in the peeled plum as a part of the peeling effect. Concerning the effect of solute concentrations, plum dipped into 50^0B sucrose showed the highest content of sugar of 59.68 which was followed by the values of 35.13 for 45^0B sucrose+5% NaCl concentration. Concerning the interaction between peeling condition and sucrose-NaCl concentrations variation, the total sugar content for only sucrose treated plum was initially 68.12 and 64.51 for the T_1 and T_2 treatments, respectively but after 12 months of storage it was decreased to 41.66 and 39.70, respectively. The total sugar was decreased by 38.84% and 38.46 percent for the

treatments of T_1 and T_2, respectively. Nevertheless, in the beginning the total sugar content of the NaCl treated osmo-dehydrated plum was 5.74 and 5.32 in the treatments of T_5 and T_6, respectively, subsequently after 12 months of storage it was decreased to 5.19 and 4.72, respectively. The reduction of total sugar content of NaCl treated plum was 9.58% and 11.28 percent for the treatments T_5 and T_6, respectively. The observed variation was due to increase in moisture content and might also be due to conversion of sugar due to non-enzymatic browning reactions in the osmo-dehydrated plum (Nazaneen et al., 2015; Tomar et al., 1990). Sugar content in various treated plums was varied significantly due to the variation of the sucrose-NaCl concentrations during osmotic treatments and peel conditions. As sucrose is used in plum, an increase in the content of sucrose makes the plum more caloric. For the reduction of the energy value of dried plums, sodium chloride can be used as an osmotic agent and a similar result was found by Robert (2008). The plums treated with a higher percentage of sucrose along with peeling attributed to the higher values of reducing sugar and total sugar. This might be due to the effect of sugar syrups used for osmosis and the expose of the flesh of the plum after removal of the peel (Kumar & Sagar, 2014). The osmo-dehydrated plum gives a higher percentage of sucrose when sucrose is used as an osmotic agent as reported for the dehydrated mango slices and osmo-dried apple rings, respectively during storage (Kumar, 2013).

Table 6. Effect of peeling and various sucrose-sodium chloride concentrations on the reducing sugar and total sugar of osmo-dehydrated plum during storage

Factors/Treatments	The sugar content of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
Reducing sugar (%)					
Peeling conditions					
Whole plum	26.42a	23.33a	20.62a	19.63a	18.74a
Peeled plum	24.03b	21.07b	19.04b	18.95b	18.05b
CV (%)	1.197	1.252	1.033	0.889	0.680
$LSD_{0.1\%}$	0.317	0.292	0.215	0.180	0.131
Level of concentrations					
50^0B sucrose	34.92a	30.58a	27.69a	26.48a	25.66a
45^0B sucrose+5% NaCl	22.12b	18.72b	16.59b	16.77b	15.18b
5% NaCl	18.65c	17.30c	15.22c	14.64c	14.35c
CV (%)	1.197	1.252	1.033	0.889	0.680
$LSD_{0.1\%}$	0.389	0.357	0.264	0.221	0.161
Treatments					
T_1	41.66a	35.13a	31.25a	29.41a	27.30a
T_2	39.13b	32.72b	28.72b	29.17a	26.11b
T_3	32.5c	30.14c	26.15c	25.12b	24.67c
T_4	28.17d	26.03d	24.13d	23.54c	24.01d
T_5	5.10e	4.72e	4.46e	4.37d	4.25e
T_6	4.79e	4.45e	4.28e	4.15d	4.02e
CV (%)	1.189	1.274	1.008	0.898	0.769
$LSD_{0.1\%}$	0.546	0.515	0.364	0.315	0.257
Total sugar (%)					
Peeling conditions					
Whole plum	43.12a	39.22a	34.73a	30.61a	27.95a
Peeled plum	40.35b	36.71b	33.31b	28.66b	27.06b
CV (%)	0.915	0.882	0.648	1.089	0.888
$LSD_{0.1\%}$	0.401	0.352	0.232	0.339	0.257
Level of concentrations					
50^0B sucrose	59.68a	54.01a	49.10a	43.05a	39.21a
45^0B sucrose+5% NaCl	35.13b	30.85b	27.18b	23.43b	22.45b
5% NaCl	30.41c	29.04c	25.79c	22.40c	20.87c
CV (%)	0.915	0.882	0.648	1.089	0.888
$LSD_{0.1\%}$	0.491	0.431	0.284	0.415	0.314

Factors/Treatments	The sugar content of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
Treatments					
T_1	68.12a	59.13a	52.14a	46.54a	41.66a
T_2	64.51b	56.23b	49.01b	41.56b	39.7b
T_3	55.50c	53.06c	46.71c	40.01c	37.01c
T_4	51.23d	48.89d	46.06d	39.56c	36.76c
T_5	5.74e	5.47e	5.35e	5.29d	5.19d
T_6	5.32e	5.01e	4.87f	4.79d	4.72e
CV (%)	0.758	0.833	0.657	1.067	0.891
$LSD_{0.1\%}$	0.575	0.575	0.407	0.575	0.446

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e, f indicates significant result ($p<0.001$).

The changes in total phenolic contents of stored osmo-dehydrated plum are presented in Table 7. For the effect of peeling, it was observed that the total phenolic content of 889.78 mg/100g was found as the highest in the peeled plum and 860.78 mg/100g as the lowest in the whole plum during storage, it was decreased slowly month by month. As to the effect of sucrose-sodium chloride concentrations, at beginning the highest total phenol of 937.61 mg/100g was observed using only 5% NaCl concentrations which was followed by the value of 859.60 for the 45^0B sucrose+5% NaCl concentration. The interaction between peeling condition and various solute concentrations, initially, the highest total phenol of 990.05 mg/100g was seen in treatment T_6 and the lowest of 723.06 mg/100g in treatment T_1. Finally, the total phenolic content was slightly decreased after 12 months of storage at room temperature. It was happened because of the slower enzymatic reactions in dried plum at a lower temperature of storage as the temperature is a major factor in the initiation and feasibility of a chemical reaction. The phenolic contents occur to produce yellowish to brownish color (Clifford, 2000 & Kumer, 2013) at different transformations for the time of food processing. Generally, the dried plum showed higher total phenolic contents as compared to the fresh plum (356 mg/100g) and the similar investigation observed by Stacewicz-Sapuntzakis et al. (2001) & Dowling (2014).

Table 7. Effect of peeling and various solutes concentrations on the total phenol (mg/100g) of osmo-dehydrated plum during storage

Factors/Treatments	Total phenol of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
Peeling conditions					
Whole plum	860.78b	765.09b	686.43b	623.25b	566.74b
Peeled plum	889.80a	797.31a	714.82a	645.79a	585.43a
CV (%)	0.528	0.528	0.500	0.475	0.420
$LSD_{0.1\%}$	4.859	4.329	3.681	3.169	2.541
Level of concentrations					
50^0B sucrose	828.67c	744.14c	654.67c	583.25c	513.83c
45^0B sucrose+5% NaCl	859.60b	765.42b	703.14b	643.51b	598.88b
5% NaCl	937.61a	834.04a	744.06a	676.81a	615.55a
CV (%)	0.528	0.528	0.500	0.475	0.420
$LSD_{0.1\%}$	5.951	5.302	4.509	3.881	3.112
Treatments					
T_1	723.06f	647.12f	598.03e	537.26e	484.50f
T_2	745.07e	663.71e	602.14e	542.23e	492.32e
T_3	885.17d	781.01d	657.11d	587.70d	510.28d
T_4	934.27c	841.16c	711.31c	629.24c	543.16c
T_5	974.12b	867.13b	804.14b	744.79b	705.44b
T_6	990.05a	887.07a	831.01a	765.91a	720.81a
CV (%)	0.524	0.528	0.494	0.473	0.425
$LSD_{0.1\%}$	8.337	7.501	6.302	5.458	4.456

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e, f indicates significant result ($p<0.001$).

The dehydrated plum overall acceptability by the consumer is highly dependent on its sensory attributes. In addition to visual appearance, color, flavor and textural attributes are critical in determining their degree of acceptance. The organoleptic attributes of the osmo-dehydrated plum with different combinations of sucrose-sodium chloride concentrations as well as the conditions of peeling were assessed after three months interval up to twelve months of storage. Comparative sensory evaluation of different quality attributes of the osmo-dehydrated plums according to the opinion of taste panel judges comprising 10 members are presented in Table 8. It was observed that the color, flavor, taste, sweet-sour balance, bitterness had a significant effect on its overall acceptance. According to the Table, it was observed that the overall acceptability of 7.17 was found as the highest for the whole plum and 6.67as the lowest for the peeled plum. As for the effect of concentrations, initially, the highest overall acceptability of 7.75 was observed in 50^0B sucrose and followed by the value of 6.75 for 45^0B sucrose+5% NaCl treated plum. With regard to the interaction between peeling conditions and concentrations, initially, the highest overall acceptability of 8.50 was investigated in treatment T_1 and 8.0 was in treatment T_2 securing the second-highest score. Finally, the highest overall acceptability was continued in treatment T_1 up to the end of storage and it was 8.0 (i.e., like very much) that was judged by the panelists. Panelists liked the osmo-dehydrated plums because of the balance of sodium chloride-sucrose percentage, less bitterness, attractive color, and overall taste as mentioned during judgment. The best color of the osmo dried plum might be owing to the effect of KMS used in different treatments as well as the color retained due to the faster dehydration of the treated plum (Ahrne et al., 2003; Akpinar & Bicer, 2005).

Table 8. Effect of peeling and various solutes concentrations on the overall acceptability of osmo-dehydrated plum during storage

Factors/Treatments	Overall acceptability of osmo-dehydrated plum at different storage (months)				
	0	3	6	9	12
Peeling conditions					
Whole plum	7.17a	7.08a	6.92a	6.67a	6.50a
Peeled plum	6.67b	6.58b	6.17b	6.17b	5.92b
CV (%)	5.593	4.984	4.603	3.688	2.774
$LSD_{0.1\%}$	-	-	0.316	-	0.181
$LSD_{1.0\%}$	-	-	-	0.249	-
$LSD_{5.0\%}$	0.406	0.358	-	-	-
Level of concentrations					
50^0B sucrose	7.75a	7.63a	7.50a	7.25a	7.13a
45^0B sucrose+5% NaCl	6.75b	6.63b	6.25b	6.13b	5.88b
5% NaCl	6.25c	6.25b	5.88b	5.88b	5.63c
CV (%)	5.593	4.984	4.603	3.688	2.774
$LSD_{0.1\%}$	0.498	0.438	0.387	0.304	0.222
Treatments					
T_1	8.50a	8.50a	8.50a	8.00a	8.00a
T_2	8.00ab	8.00ab	7.50b	7.50b	7.25b
T_3	7.50bc	7.50b	7.25b	7.25b	7.00b
T_4	7.00c	6.75c	6.50c	6.50c	6.25c
T_5	5.50d	5.25d	5.00d	4.75d	4.50d
T_6	5.00d	5.00d	4.50d	4.50d	4.25d
CV (%)	5.594	4.984	4.604	3.688	2.776
$LSD_{0.1\%}$	0.704	0.620	0.548	0.431	0.314

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d indicates significant result ($p<0.001$, <0.01 & <0.05).

Conclusion

The research results were analyzed under the parameters of drying kinetics, rehydration properties, water activity, color, texture, sugar, total phenol, and overall acceptability of the osmo-dehydrated plum through sensory evaluation to assess the drying kinetics and the quality attributes of the osmo-dehydrated plum prepared from fresh plum during one-year storage in an ambient condition. The

osmo-dehydrated plum prepared from whole plums osmosed in 50^0B sucrose solution performed better considering the dehydration kinetics and analysis of the different quality attributes of the plums even after 12 months of storage at room temperature. Therefore, the developed technique would be helpful for the farmers/growers and traders for preparing osmo-dehydrated plum from fresh plum to prevent post-harvest losses in addition to fulfill nation demand.

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STUDY ON PHYSICO-CHEMICAL CHARACTERISTICS OF PLUM DURING PRESERVATION AT DIFFERENT CONCENTRATIONS OF SODIUM CHLORIDE

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Abstract

The study was undertaken to find out the effect of sodium chloride concentration on plum to investigate the shelf life of plum in an ambient condition. There were five treatments using various sodium chloride solutions for the experiments. The stored plum firmness, color parameters, pH, acidity, β-carotene, vitamin C and TSS data were analyzed up to six month; it was noticed that in an ambient condition the plum firmness, pH, β-carotene and vitamin C content were decreased as compared to an initial as well as fresh plum but the acidity and TSS of plum was increased during storage. The color parameters of lightness was decreased at prolonged storage and the color coordinates a* and b* values was responsible for the plum color during storage. However, using 8 percentage sodium chloride concentrations in plum; the less decreased and increased was found for each quality parameters of stored plum than that of the other concentrations in an ambient condition.

Introduction

Brining or salting is the oldest and cheapest way of preserving fruits, vegetables, meat, fish and other foods whilst maintaining a fair amount of their nutritional value. Salt absorbs much of the water in the fruits and vegetables and makes it difficult for microorganisms to survive (Fraser, 2005). Traditionally, sodium chloride (salt) has been viewed as a food preservative that enhances human health by killing or limiting growth of foodborne pathogens and spoilage organisms (IOM, 2004). Microbial growth and activity has been inhibited or suppressed by the use of brine solution and it reduces the spoilage of foods but produces a salty product. Salt reduces the water availability in the food (Bahl, 1987). On the other hand, brining works by the process of osmosis (Evans, 1961). Natural sodium levels in foods generally account for only about 10% of dietary intake. Most dietary sodium is ingested in the form of sodium chloride (Mattes & Donnelly, 1991). In Asian countries, salt added in home cooking and at the table accounts for an estimated 72% to 76% of dietary intake. Soysauce, miso, salted vegetables, fruits, and fish contribute significantly to dietary sodium (Brown *et al.*, 2009; Doyle & Glass, 2009). Vegetables and fruits are extremely important in human nutrition as they are important sources of nutrients, dietary fiber, and phytochemicals as well as for the reduction in disease risks (Boeing *et al.,* 2012).

Preservation of food has been used since ancient times. The preservation process will restrain the development of microbial such as bacteria and fungi The aims of food preservations include, maintaining food taste, texture, flavour, quality and nutritional value; to reduce the wastage of excess food; to maintain a product's accessibility for a longer time even in places it is not being produced; to preserve the food materials during transportation; and to ease the handling of food materials (Sharif, 2017). In another way, processing and preservation of fruits and vegetable reduce wide fluctuation of prices between the peak harvesting period and off season. It encourages and initiates efficient food production practices and simultaneously reduces losses due to spoilage and decay in harvested foods. Fruits and vegetables is an important processed product from viewpoint of its export potential. Bangladesh is an agricultural country whose economic development depends on the accomplishment of higher efficiency in food production and utilization of the available supply of food to the best advantage. There is good scope to preserve fruits and vegetables on commercial scale. In present study, keeping plum is also important consideration where plums are stored. Normally, packaging is carried out to protect foods from physical damage, chemical attack and contamination from biological vectors including micro-organisms, insects and rodents (Potter & Hotchkiss, 2007; Victor & Obele, 2013). Bottling is the most popular method (Evans, 1961). So, glass bottle is chosen for stored plum.

The effects of the brining conditions, salt concentrations, storage temperature, duration of brining effects on the physicochemical, sensory properties and microbial growth of brined fruits and vegetables have been investigated by different researchers and they were reported as cabbages (Kim *et al.,* 2018), radishes (Kim *et al.,* 1990), cucumbers (Park *et al.,* 2003), perilla leaves (Lee *et al.,* 2002), *Acanthopanax cortex* shoots (Kim *et al.,* 2012), mume fruits (Otoguro, 1996), and olives (Minguez-Mosquera *et al.,* 1989). From the viewpoints of above studies, plum is a minor fruit produced in the country and they are characterized by their perishability and seasonality. Postharvest

losses of these fruits are very high due to lack of proper storage facilities and mishandling operations. Alternately, there are no standard packages for storage of plum. It should be standard for future use of fresh plum. Now, it has become the national need to standardize the packages for plum with a view to reduce the postharvest losses and also to maintain the keeping quality. Therefore, the overall objective of the research is to process and preserve fresh plum using various concentration of sodium chloride to investigate the shelf life of plum with quality concern in an ambient condition.

Materials and Methods

Collection of plum

Plum (BARI Alu bukhara-1) having optimum maturity and firm texture was collected from the Spices Research Center of Bangladesh Agricultural Research Institute (BARI) and local farmer. The plums were transported in plastic crates to the Postharvest Technology Division Laboratory of BARI, Gazipur. After sorting, the plum was washed and dried under a ceiling fan.

Method of processing

At first the fresh plum was collected, sorted, measured and took it in net bag. Then, the plum was blanched with 80^0C for 3 min and cool. Take 10 liters of clean water in a pan and heat it. In hot water added required amount of NaCl and cool it. During cooling, added acetic acid of 6 ml/lit and KMS of 1 gm/lit into warm water for making NaCl solution. The solution was put into the sterilize glass bottle and blanched plum kept in it. Finally, the cap of the bottle was air-tight and kept in an ambient condition as treatment wise.

There were five treatments as T_1 = Plum kept in glass container using 0% NaCl solution; T_2= Plum kept in glass container using 4% NaCl solution; T_3= Plum kept in glass container using 8% NaCl solution; T_4= Plum kept in glass container using 12% NaCl solution; and T_5= Plum kept in glass container using 16% NaCl solution

Firmness of plum

Plum firmness, as the force required to puncture the fruit, was measured using an Instron-Universal testing machine (Model 4201, USA) and expressed as kg-f/cm^2.

Measurement of product appearance/color

Plum color was determined using a tristimulus colorimeter (CR-400, Minolta Corp., Japan) with 8-mm aperture and C light source at two equidistant points on the equator of each sample by using CIE color system on the L, a*, b* color space where L a* b* coordinates were recorded using D65 illuminants. A 10° standard observer was used as a reference system. *L* (lightness), *a** (-greenness to +redness) and *b** (-blueness to +yellowness) are the chromaticity coordinates.

Measurement of pH

The sample (5 g) was diluted with 45 mL distilled water, and pH was measured with glass electrode (EUTECH Instruments, Selangor, Malaysia).

Measurement of titratable acidity

The titratable acidity (TA) was analyzed using the titration method. Pulp sample (10 g) were homogenised using a kitchen blender with 40 ml of distilled water. The mixture was then filtered through cotton wool. The filtrate (5 ml) with one to two drops of phenolphthalein (0.1%) as indicator was titrated using 0.1 N NaOH to an endpoint pink (p^H 8.1). The results were expressed as the percentage citric acid per 100g fresh weight.

Measurement of β-carotene

The estimation of β-carotene was done by the extraction of 3g product sample with acetone (Fisher Scientific Ltd., Uk) and petroleum ether. It was further purified with acetone, metabolic KOH and distilled water. The resulting solution was filtered with anhydrous sodium sulphate and read on a spectrophotometer (T-80, PG Instrument Ltd., UK) at 451nm against petroleum ether as a blank. A standard graph was plotted using synthetic crystalline B-carotene (Fluka, Germany) dissolved in petroleum ether and its optical density measured at 451 nm (Alasalvar *et. al.* 2005).

Measurement of ascorbic acid

Ascorbic acid content was determined as per AOAC (1995) method using 2, 6- dichlorophenol indophenol dye. The sample extracted in 3% m-phosphoric acid was titrated with dye to pink colour end point. The results was expressed as mg per 100g of sample and calculated by using the following formula:

$$\text{Ascorbic acid}\,(\text{mg}/100\text{g}) = \frac{\text{Titre} \times \text{Dye factor} \times \text{Vol. made up}}{\text{Aliquot of extract taken} \times \text{Weight of sample taken}} \times 100$$

Measurement of total soluble solid (TSS)

Total soluble solid in the extracted juice of plum was measured by a refractometer (ATAGO (Brix=0 to 32%) and the results were expressed as % Brix.

Data analysis

The experiment was carried out Completely Randomized Design (CRD) and all five treatments were replicated three times. The data were analyzed for ANOVA using computerized statistical software of R to compare the means and level of significance of data.

Results and Discussion

The fresh blanched plum kept in glass container using different percentages of NaCl solution and stored in an ambient condition for six month. The physicochemical parameter of fresh plum is presented in Table 1.

Table 1. Chemical compositions of fresh plum

Parameters	Content
Firmness (kg-f/cm^2)	3.68
pH	2.89
Acidity (%)	2.56
β- carotene (μg/100g)	60
Vitamin C (mg/100gm)	15
TSS (%)	8.5

Measurement of Firmness of plum

The effect of NaCl concentrations on the firmness (kg-f/cm^2) of plum during storage were depicted in Table 2. Initially, the blanched plum firmness was 1.79 kg-f/cm^2 but it was decreased month by month. The highest firmness was found in 0.42 kg-f/cm^2 using 8% NaCl solution in plum (treatment T_3) after six months of storage. It was indicated that the plum was good in NaCl solution after six months of storage as compared to the other treatments. On the other hand, treatments T_2 and T_4 give the second highest values of firmness. The similar investigation was found by Kim & Chung (1995) and reported that the firmness of persimmon fruits declined during brining. The reduction of puncture force might be due to the failing of the cell structures in relation to the osmotic pressure of NaCl (Rhee, 1987; Park *et al.*, 2003; Choi *et al.*, 1998).

Table 2. Effect of NaCl concentrations on the firmness (kg-f/cm^2) of plum during storage

Treatments	Firmness of plum at different storage period (months)						
	0	1	2	3	4	5	6
T_1 = 0% NaCl solution		1.11a	0.91a	0.62b	0.35b	0.31b	0.13c
T_2= 4% NaCl solution		0.87b	0.71c	0.55c	0.29c	0.23cd	0.21b
T_3= 8% NaCl solution	1.79	0.73c	0.78b	0.69a	0.53a	0.48a	0.42a
T_4= 12% NaCl solution		0.46d	0.35d	0.31d	0.29c	0.21d	0.19b
T_5= 16% NaCl solution		0.36e	0.31e	0.29d	0.27c	0.25c	0.21b
CV (%)		3.262	3.427	4.453	4.287	4.273	5.452
$LSD_{0.1\%}$		0.049	0.038	0.040	0.027	0.023	0.023

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d indicates significant result ($p<0.001$).

Measurement of product appearance/color

The changes of lightness (L) and color co-ordinates (a* and b*) of stored brined plum in different NaCl solutions were shown in Table 3. Initially, the higher NaCl percentage gave the lowest lightness than that of the low NaCl percentage used in the treatments. But, the lightness was decreased during the prolonged storage. The similar investigations have previously been reported that the lightness values of perilla leaves, persimmon fruits and persimmon leaves were decreased with brining (Lee et al., 2002; Kim & Chung, 1995; Cha et al., 2003; Chung et al., 2020). The color coordinates a* values (greenness to + redness) increased with increasing NaCl concentrations in the treatments. The *a** values were higher at the beginning of storage however it was gradually decreased up to the end of the

storage. In the reduction of color coordinates *a** during storage, it was represented that the brined plum color was the light purple to light red. Substantial differences were also observed in the a* values of the brined plum among the different NaCl treatments. This result might be described by the concentrated NaCl solution successfully controlling the degradation of chlorophyll. In previous, the similar low a* value have been found for the brined cucumbers (Park et al., 2003) and persimmon leaves (Chung et al., 2020) and the value was continued using concentrated brining solutions. Nevertheless, the detailed explanation of this effect is yet to be clarified. On the other hand, the effects of the NaCl concentration on the b* values (- blueness to + yellowness) of the brined plum was observed to be similar to the effects on the L values. The b* values of the plum treated with NaCl solutions was greater than those of the fresh plum. Nevertheless, the b* values of the other treated samples decreased with increasing concentrations of NaCl. The effect of NaCl concentration on the b* values of the plum was similar to that stated for perilla leaves and persimmon leaves (Lee et al., 2002; Chung et al., 2020). Initially, the color coordinates *b** was lower and it was increased during storage and the brined plum color turned into light yellow to yellow.

Table 3. Effect of NaCl concentrations on the color parameters of plum during storage

Treatment	Color parameters of plum at different storage period (months)						
	0	1	2	3	4	5	6
Lightness (L)							
T_1 = 0% salt solution		68.54a	67.12b	65.71b	64.32b	61.02c	60.11bc
T_2= 4% salt solution		68.38a	65.10c	63.74c	62.78c	60.03d	59.88c
T_3= 8% salt solution	69.26	68.11a	68.05a	67.76a	66.23a	65.23a	65.20a
T_4= 12% salt solution		64.87b	64.04d	63.54c	63.01c	62.05b	60.79b
T_5= 16% salt solution		64.15b	63.02e	61.11d	58.89d	54.86e	50.12d
CV (%)		0.915	0.747	0.672	0.681	0.774	0.700
$LSD_{0.1\%}$		1.112	0.889	0.787	0.781	0.853	0.755
Coordinates (a*)							
T_1 = 0% salt solution		4.26d	4.03c	3.71c	3.49d	2.98d	2.31c
T_2= 4% salt solution		4.97c	4.77b	4.54a	3.88c	3.51c	2.47c
T_3= 8% salt solution	11.78	5.09c	4.95b	4.76a	4.55a	4.41a	4.34a
T_4= 12% salt solution		5.92b	4.91b	4.63a	4.15b	3.98b	3.87b
T_5= 16% salt solution		6.31a	5.65a	4.12b	3.28e	3.12d	2.41cd
CV (%)		3.094	3.106	3.021	2.896	2.582	2.610
$LSD_{0.1\%}$		0.299	0.275	0.239	0.204	0.169	0.146
Coordinates (b*)							
T_1 = 0% salt solution		43.38a	46.89a	47.97a	48.05a	51.41a	51.86a
T_2= 4% salt solution		42.41b	46.54a	47.45b	47.98a	50.79b	51.01b
T_3= 8% salt solution	36.87	41.87c	46.01b	47.04b	47.13b	50.13c	50.64b
T_4= 12% salt solution		41.61c	45.58c	46.11c	46.87b	49.01d	49.54c
T_5= 16% salt solution		41.03d	44.57d	45.07d	46.01c	47.11e	47.87d
CV (%)		0.514	0.501	0.535	0.571	0.583	0.622
$LSD_{0.1\%}$		0.393	0.418	0.454	0.491	0.527	0.568

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

Measurement of pH of plum and NaCl solution

The changes in pH of brined plum and pH of NaCl solutions were given in Table 4. An initial pH of fresh plum was 2.89, which was investigated to decrease with increasing concentrations of NaCl used for brining. The higher NaCl percentage gave the less amount of pH in stored plum and it was decreased during storage. These results are similar to those investigated for persimmon fruits and persimmon leaves, and might be attributed to the concentrated NaCl used for brining leading to the exudation of tannins, and preventing the growth of yeast (Kim & Chung, 1995; Chung et al., 2020). The earlier observed decrease in pH in plum brined with high NaCl may have been due to the growth of halophilic microorganisms and the preservation of initial acids contained within the plum by high NaCl (Choi et al., 1998; Park et al., 2003; Cho et al., 2004). However, the pH of NaCl solution was

initially higher as compared to the different storage period and it was investigated less pH in the higher concentrations of NaCl at different treatments. On the other hand, the pH was decreased in every month up to six month of storage. The pH of the various samples might be declined due to the conversion of pectin into organic acid or also owing to the least increment in acidity during the storage period (Imran et al., 2001).

Table 4. Effect of NaCl concentrations on the pH content of plum and NaCl solution during storage

Treatments	pH of plum and NaCl solution at different storage period (months)						
	0	1	2	3	4	5	6
				pH of plum			
T_1 = 0% salt solution		3.18a	3.11a	3.07a	3.01a	2.96a	2.91a
T_2= 4% salt solution		3.01b	2.97b	2.93b	2.88b	2.83b	2.79b
T_3= 8% salt solution	2.89	2.95c	2.93c	2.91b	2.87b	2.81b	2.75b
T_4= 12% salt solution		2.86d	2.84d	2.81c	2.78c	2.71c	2.66c
T_5= 16% salt solution		2.79e	2.75e	2.72d	2.63d	2.60d	2.58d
CV (%)		1.058	0.668	0.805	0.773	0.788	0.849
$LSD_{0.1\%}$		0.057	0.035	0.042	0.040	0.040	0.042
				pH of NaCl solution			
T_1 = 0% salt solution	3.19a	3.14a	3.11a	3.08a	3.03a	2.96a	2.93a
T_2= 4% salt solution	3.03b	2.99b	2.96b	2.91b	2.88b	2.84b	2.80b
T_3= 8% salt solution	3.00bc	2.97b	2.95b	2.92b	2.90b	2.82b	2.77c
T_4= 12% salt solution	2.97c	2.93c	2.86c	2.83c	2.81c	2.72c	2.67c
T_5= 16% salt solution	2.96c	2.86d	2.75d	2.73d	2.65d	2.62d	2.58d
CV (%)	1.033	0.655	0.794	0.757	0.768	0.832	0.845
$LSD_{0.1\%}$	0.057	0.035	0.042	0.040	0.040	0.042	0.042

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

Measurement of acidity of plum

The changes of acidity in stored brined plum were given in Table 5. An initial acidity of fresh plum was 2.56 but, acidity was decreased after one month storage then it was increased with increasing concentrations of NaCl in treated plum as well as prolonged storage. However, the increase in acidity during ripening may be due to the increase in malic acid. Some enzymes can have an influence on the level of organic acids in banana; malate synthase, activity of which decreases during ripening; malic enzyme, which is involved in the decarboxylation of malic acid and phosphoenol pyruvate carboxylase, which plays a part in the formation of malic acid, decrease of which may play a pivotal role to increase in fruit acidity during storage (John and Marchal, 1995).

Table 5. Effect of NaCl concentrations on the acidity of plum during storage

Treatments	Acidity (%) of plum at different storage period (months)						
	0	1	2	3	4	5	6
T_1 = 0% salt solution		1.02c	1.05d	1.12c	1.21c	1.27c	1.31c
T_2= 4% salt solution		1.09b	1.17c	1.24b	1.29b	1.34bc	1.37bc
T_3= 8% salt solution	2.56	1.15b	1.19bc	1.25b	1.31b	1.37b	1.41b
T_4= 12% salt solution		1.22a	1.23b	1.26b	1.33b	1.39b	1.44ab
T_5= 16% salt solution		1.28a	1.31a	1.35a	1.41a	1.47a	1.52a
CV (%)		3.178	2.762	2.516	2.752	3.119	3.602
$LSD_{0.1\%}$		0.067	0.060	0.057	0.066	-	-
$LSD_{1.0\%}$		-	-	-	-	0.078	0.092

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d indicates significant result ($p<0.001$ & <0.01).

Measurement of β-carotene of plum

The changes of β- carotene content of stored brined plum were shown in Table 6. An initial β-carotene content of fresh plum was 52.6 µg/100gm but it was decreased drastically over the period of 30 days and then it was slightly decreased during stored up to 6 months in various treated samples. The higher NaCl concentrations gave the higher amount of β-carotene but it was decreased during

storage. In β-carotene content, both in isomerization and oxidation process it could be decreased and the degradation could potentially occur in a real food product (Aruna et al., 1999; Penicaud *et al.,* 2011). For the storage period increases, there was significant decrease in the β-carotene content of the plum and the loss of β-carotene could be due to non-oxidative changes or oxidative changes on exposure to light and oxygen. The similar change was found by Dutta *et al.* (2005) for carrot and Aruna et al. (1999) for papaya during the investigation of β-carotene content of stored product.

Table 6. Effect of NaCl concentrations on the β-carotene (μg/100g) content of plum during storage

Treatments	β-carotene content of plum at different storage period (months)						
	0	1	2	3	4	5	6
T_1 = 0% salt solution		37.74d	34.50d	29.14d	24.50d	21.10c	16.40e
T_2= 4% salt solution		46.40c	42.50c	39.70b	36.40a	30.75a	25.40b
T_3= 8% salt solution	52.6	50.07a	46.40a	42.50a	36.50a	30.77a	26.70a
T_4= 12% salt solution		47.17c	44.30b	37.80c	32.40c	29.30b	23.10d
T_5= 16% salt solution		48.70b	44.80b	38.40c	33.70b	29.70b	23.90c
CV (%)		1.327	1.150	1.153	1.312	1.656	1.795
$LSD_{0.1\%}$		1.111	0.889	0.787	0.780	0.853	0.755

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d indicates significant result (p<0.001).

Measurement of vitamin C of plum

The changes of vitamin C content of stored brined plum were depicted in Table 7. The vitamin C content of the plum before brining was 7.10 mg/100gm, and it was observed to decrease in brining solution depending on the NaCl concentration. The vitamin C content was lower when the concentration of the NaCl solution was higher. It has previously been described that brining reduced the vitamin C content in radishes; this might have been owing to vitamin C exudation with water due to the osmotic pressure of NaCl (Kim et al., 1990). It has also been stated that the vitamin C content of persimmon fruits and persimmon leaves decreased after brining (Song & Kim, 19830; Chung et al., 2020). The vitamin C has the least stability among all kinds of vitamins and is easily destroyed during processing and storage, depending on many variables such as pH (Munyaka et al., 2010b; Wechtersbach et al., 2011), temperature (Rattanathanalerk et al., 2005; Tiwari et al., 2009a&b), light (Zhan et al., 2012; Noichinda et al., 2007), and the presence of enzymes (Munyaka et al., 2010a) and oxygen (Martínez-Sánchez et al., 2011).

Table 7. Effect of NaCl concentrations on the vitamin C (mg/100g) content of plum during storage

Treatments	Vitamin C content of plum at different storage period (months)						
	0	1	2	3	4	5	6
T_1 = 0% salt solution		6.00a	5.50a	5.00a	4.50a	4.02a	3.65a
T_2= 4% salt solution		5.20b	4.70b	4.20b	3.92b	3.75b	3.55a
T_3= 8% salt solution	7.10	3.90c	3.40c	3.00c	2.91c	2.82c	2.67b
T_4= 12% salt solution		3.50d	3.10d	2.92c	2.84c	2.76cd	2.54b
T_5= 16% salt solution		3.00e	2.90d	2.85c	2.75c	2.64d	2.37b
CV (%)		3.094	3.852	3.658	3.312	2.907	2.719
$LSD_{0.1\%}$		0.299	0.275	0.239	0.204	0.169	0.146

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result (p<0.001).

Measurement of total soluble solid (TSS) of plum

The changes in TSS content of stored brined plum in various NaCl solutions were expressed in Table 8. The measurement showed no consistent pattern between the treatments, but generally the TSS content of stored brined plum in all treatments increased after storage time perhaps due to conversion of sugar. The similar investigation was reported by Apai (2010) and Hai et al. (2011 & 2014) for longan fruits; Chowdhury et al. (2008) for apple and papaya.

Table 8. Effect of NaCl concentrations on the total soluble solid (TSS) content of plum during storage

Treatments	TSS (%) content of plum at different storage period (months)						
	0	1	2	3	4	5	6
T_1 = 0% salt solution		6.30e	6.50e	6.60e	6.70e	6.80e	6.80d
T_2= 4% salt solution		8.60d	8.90d	9.20d	9.40d	9.70d	9.80c
T_3= 8% salt solution	8.7	10.20c	10.50c	11.70c	11.90c	12.10c	12.50b
T_4= 12% salt solution		11.30b	11.90b	12.20b	12.40b	12.50b	12.80b
T_5= 16% salt solution		12.70a	13.30a	14.10a	14.40a	14.70a	15.10a
CV (%)		1.205	1.287	1.403	1.556	1.705	1.871
$LSD_{0.1\%}$		0.215	0.239	0.275	0.310	0.346	0.388

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

Conclusion

The plums were spoilage or misuse by the farmers or growers due to lack of processing practice in Bangladesh. The preservation of plum will be one of the ideas for farmers and uses it in off season. Industrial food processing was often incriminated in lowering the nutritional value of process products. However, there will be an increasing demand to understand and prevent the degradation of nutrients during processing and storage. In considering the overall possibilities of brine preservation as a method of shelf life extension for fruits like plum, several factors will have to be considered. Not considering only the advantages and disadvantages of the processing method, but also the quality of the stored plum under the varying brine concentrations. The experiment indicated that brine at strong levels of concentration can be satisfactorily employed as a shelf life extension method for plum, with minimal effects on its physio-chemical properties. The results revealed that the plum kept in glass container using 8 percent NaCl solution and stored at room temperature (25 to 30ºC) showed better quality brined plum for future consumption. Finally, it could be suggested that the study will perform as a commercial purpose of plum growers to extension of shelf life of their produce plum for secondary uses.

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EFFECT OF VARIOUS COMBINATIONS OF SODIUM CHLORIDE AND SUCROSE CONCENTRATIONS ON THE QUALITY OF PLUM PICKLE DURING STORAGE

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Abstract

The study was undertaken to standardize the processing conditions of plum pickles to enhance the diversified use of the plums. There were six treatments with a combination of three different sodium chloride and sucrose concentrations. The research was conducted to examine the quality parameters such as pH, acidity, product color and microbial growth and organoleptic test at various treatments. After twelve months of storage, the pH was slightly decreased and acidity was increased. In the case of color of the pickle, the highest lightness was found in a sample containing 3% sodium chloride plus 12 percent sucrose and the lowest lightness was investigated in the 5% sodium chloride plus 12 percent sucrose treated plum pickle. For color co-ordinates a*; initially, it was seen light red color but slowly increased during storage. Regarding the color co-ordinates b*, it turned into light yellow to yellow color during 12 months of storage. The microbial growths of the plum pickle were detected at the end of storage and the load was found to vary between 7×10^{-2} and 32×10^{-1}. Regarding the comparative sensory evaluation of the plum pickles, the overall acceptability was remained as the highest attribute for the combination of 4 to 5% NaCl plus 12% sucrose treated plum pickle and the score was 9.0 (i.e., like extremely). Therefore, the plum pickle treated in 4 to 5% NaCl plus 12% sucrose performed better with a view to the overall pickle quality, color, and acceptability until 12 months of storage at room temperature.

Introduction

Due to various health benefits, plum (*Prunus domestica*) plays an important role in our diet and nutrition and it is believed to have a natural remedy against various diseases (Sabarez & Price, 1999). For higher moisture content, it becomes highly fragile which makes it unsuitable for human consumption within 3-4 days (Sharma & Lal, 1999). The fact that the plum production is increasing due to improved horticultural practices and production technologies. But, the inadequacies in handling, storage, transportation and marketing pose a greater threat during glut season and result in heavy post-harvest losses and fetches low price to the farmers. The proper utilization of these valuable fruits is still unorganized and primitive in Bangladesh. Therefore, the processing and preservation would be needed to get a realistic value by the producer of plum. There are several methods for the preservation of perishable items like a plum. So, pickles may be the realistic and most convenient method for plum processing. It is one of the oldest and most victorious methods of food preservation known to humans. Most of the women in our country made pickles by their own method.

The term pickle is derived from the Dutch word pekel, meaning brine. It is called "achar" in South Asia. It has several name known as Achar in Punjabi, Hindi, Bengali; Uppinakaayi in Kannada, Lonacha in Marathi, orukai in Tamil, oragaya in Telugu which are mainly made from different varieties of fruits and vegetables (Hassan & Raghuram, 2001). Pickles in South Asia are generally prepared always in home-made, and every district, village and family has its secret formulae, closely protected and handed down from mother to their daughters. The popular pickling medium is mustard oil (Premi *et al.*, 2002). In Bangladesh, pickles are a widely acceptable and usable food item. The ingredients are used in proper proportions the pickles can be retained for a long time without any deterioration (Srivastava & Kumar, 2002).

Pickles are made through the natural fermentation of fruits and vegetables, and besides having nutritional value; pickles also act as food accompaniment and deliciousness enhancers (Joshi & Bhat, 2000; Savitri & Bhalla, 2007). Pickles are an edible product that has been conserved and flavored in a solution of brine and edible acetic acid (glacial). Salt, sugar, acid and spices are commonly used in complementary action in pickle preparation. Spices fluctuate in their antibacterial activity, some (mustard oil) being very active and others (pepper and turmeric powder) having little activity (Desrosier, 1977).

As an agricultural-based country of Bangladesh whose economic development depends on the accomplishment of higher efficiency in food production and utilization of the available supply of food to the best benefits. Hence, there is good scope to produce fruit pickles on a commercial scale (Sultana *et al.* 2014). In this regard, the overall aim of the research is to optimize the preparation condition and preserve plum pickles for long time consumption. The specific objectives of the research are to find out optimum combinations of sodium chloride and sucrose for preparing plum

pickle; to determine the nutritional quality and microbial growth of fresh and stored pickle; and finally to conduct organoleptic taste to assess the acceptability and shelf life of developed plum pickle.

Materials and Methods

Collection of plum and formulation of plum pickle

The plum (*Prunus domestica*) fruits having optimum maturity and firm texture were collected from the Spices Research Centre and was transported through plastic crates to the Postharvest Technology Division laboratory of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. After sorting, the plums were washed with clean water and dried under a ceiling fan. The following ingredients were used during the preparation of plum pickle:

Item	Quantity
Plum	1.0kg
Garlic	30.0g
Ginger	60.0g
Chilli powder	20.0g
Turmeric powder	10.0g
Mustard powder	20.0g
Cumin powder	205.0g
Fenugreek powder	5.0g
Mustard oil	400ml
Acetic acid	15ml

Salt and sugar were more prominent ingredient among the formulations of a pickle as described by Srivastava & Kumar (2002). The content of acetic acid and mustard oil was more in pickle formulations as described by Etehells *et al.* (1973). There were six treatments for the preparation of plum pickles. They are: T_1= plum with 3% sodium chloride and 10% sucrose; T_2= plum with 3% sodium chloride and 12% sucrose; T_3= plum with 4% sodium chloride and 10% sucrose; T_4= plum with 4% sodium chloride and 12% sucrose; T_5= plum with 5% sodium chloride and 10% sucrose; and T_6= plum with 5% sodium chloride and 12% sucrose

Preparation of plum pickle

The plum pickle preparation process is shown in the flow chart below:

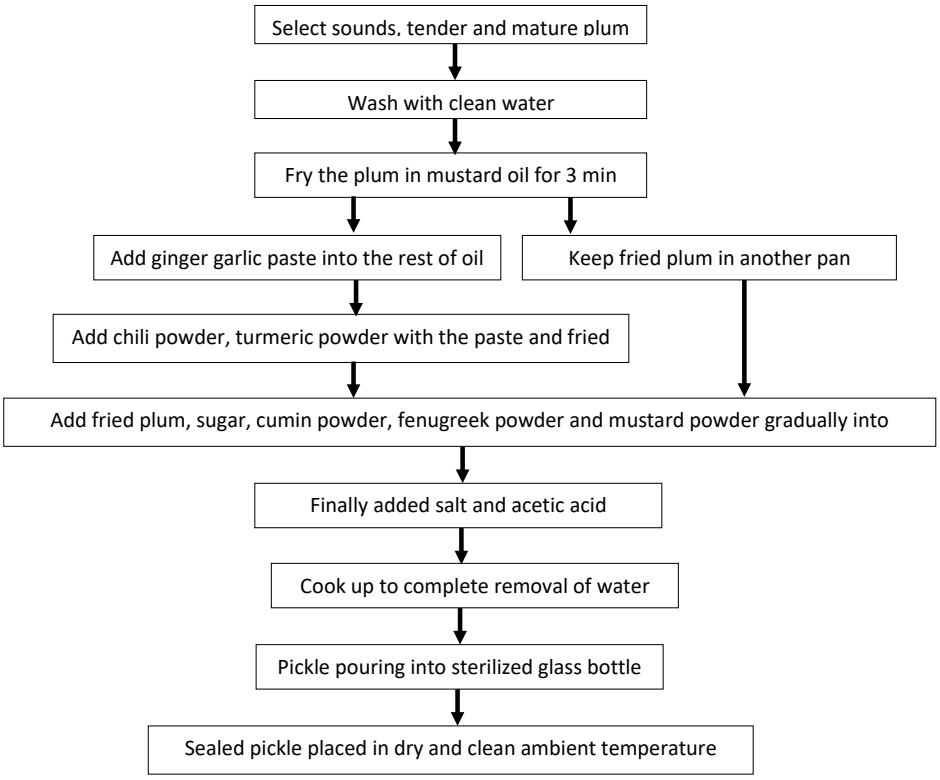

Figure 1. Process of flow diagram for plum pickle preparation

Measurement of pH

The sample (5 g) was diluted with 45 mL distilled water, and pH was measured with a glass electrode (EUTECH Instruments, Selangor, Malaysia).

Measurement of titratable acidity

The titratable acidity (TA) was analyzed using the titration method. Plum pulp (10 g) with 40 ml of distilled water was homogenized using a kitchen blender. The mixture was then filtered through cotton wool. The filtrate (5 ml) with one to two drops of phenolphthalein (0.1%) as an indicator was titrated using 0.1 N NaOH to an endpoint colour of pink (p^H 8.1). The results were expressed as the percentage citric acid per 100 g fresh weight.

Measurement of product appearance/color

Plum pickle color was determined using a tristimulus colorimeter (CR-400, Minolta Corp., Japan) with an 8-mm aperture and C light source at two equidistant points on the equator of each sample by using CIE color system on the L, a*, b* color space where L a* b* coordinates were recorded using D65 illuminants. A 10° standard observer was used as a reference system. *L* (lightness), *a** (-greenness to +redness) and *b** (-blueness to +yellowness) are the chromaticity coordinates.

Microbial count

The microbial load of the plum pickle was determined with the use of plate count agar. The microbial load count was performed at every two-month interval up to 12 months of storage. In the process of counting, a 10g pickle sample was homogenized with 90ml buffer peptone water solution and then 10µL suspension inoculated in the plate count agar (PCA) medium through 10-fold serial dilution. Then, the inoculated plate was incubated at 37^0C for 24 hrs in an incubator (Model: SHC-4A1). Different bacterial colony grown in that medium was counted. For the number of colony count in cfu/g the following formula was used:

$$\text{Colony For min g Unit}\left(\frac{\text{cfu}}{\text{g}}\right) = \frac{\text{No. of colony} \times \text{Dilution} \times \text{Time of dilution}}{\text{Sampale inoculated to plate / media}}$$

Sensory evaluation

The sensory evaluation of the plum pickle was carried out at every 2 months interval during storage using a sensory taste questionnaire judged by expert sensory panelists. Each treatment was assigned a letter code to avoid biases among the panelists. The samples were presented to panelists in different orders to avoid order preference among the panelists. The plum pickle was rated by 10 experienced panelists who were asked to score samples based on the plum external color, off-flavor, firmness, sweet-sour balance, and overall acceptance using a 9-point hedonic scale.

Data analysis

The experiment was carried out Completely Randomized Design (CRD) and all six treatments were replicated three times. The data were analyzed for ANOVA using statistical software of R to compare the means and level of significance of data.

Results and Discussion

Measurement of pH of plum pickle during storage

The effect of sodium chloride and sucrose concentrations on the pH values of a plum pickle during storage are presented in Table 1. Concerning the effect of sodium chloride concentration, the initial pH of 2.96 was found the highest in the 5% sodium chloride and the lowest was 2.81 in the 3% salt-treated samples. The trend of decreasing pH continued even after 12 months of storage. For the effect of sucrose concentration, initially, the highest pH of 2.89 was observed at 12% sucrose treated pickle followed by 2.86 for 10% sucrose treated pickle. Regarding the treatment interaction between sodium chloride and sucrose, initially, the highest pH of 2.97 was seen in treatment T_6 and the lowest pH of 2.79 was in treatment T_1. However, the pH was slowly decreased in stored pickles up to 12 months of storage. The initial pH of plum pickle was higher than that of the final product and similar results were reported by Panwar (1996) in karonda pickle and Sharma (2002) in a lime pickle. The higher solute concentrations increase the pH of plum pickle, while the bacteria's fastest growth is in acidic circumstance; this investigation was similar to Pundir & Jain (2010) and Felix (2014).

Table 1. Effect of sodium chloride and sucrose concentrations on the pH content of plum pickle during storage

Factors/Treatments	pH content of pickle at different storage period (months)						
	0	2	4	6	8	10	12
Sodium chloride							
3 percent	2.81b	2.77b	2.73b	2.69b	2.65b	2.59c	2.56b
4 percent	2.86ab	2.83ab	2.78ab	2.73b	2.67b	2.64b	2.61b
5 percent	2.96a	2.90a	2.85a	2.82a	2.79a	2.76a	2.68a
CV%	2.623	2.290	2.327	1.547	1.656	1.280	2.024
$LSD_{0.1\%}$	-	-	-	-	0.058	0.044	-
$LSD_{1.0\%}$	-	-	-	0.055	-	-	0.068
$LSD_{5.0\%}$	0.097	0.083	0.083	-	-	-	-
Sucrose							
10 percent	2.86	2.81	2.76	2.71b	2.67b	2.68a	2.60
12 percent	2.89	2.85	2.81	2.77a	2.73a	2.66b	2.63
CV%	2.623	2.290	2.327	1.547	1.656	1.280	2.024
$LSD_{5.0\%}$	ns	ns	ns	0.045	0.047	0.036	ns
Treatments							
T_1= 3% sodium chloride and 10% sucrose	2.79	2.75	2.71	2.67c	2.64b	2.58c	2.55
T_2= 3% sodium chloride and 12% sugar	2.82	2.78	2.75	2.70bc	2.65b	2.60c	2.57
T_3= 4% sodium chloride and 10% sucrose	2.85	2.82	2.78	2.72bc	2.66b	2.63c	2.60
T_4= 4% sodium chloride and 12% sucrose	2.87	2.83	2.77	2.74bc	2.67b	2.64bc	2.61
T_5= 5% sodium chloride and 10% sucrose	2.94	2.87	2.79	2.75b	2.72b	2.70b	2.65
T_6= 5% sodium chloride and 12% sucrose	2.97	2.93	2.91	2.88a	2.86a	2.81a	2.71
CV (%)	2.623	2.290	2.327	1.547	1.656	1.280	2.024
$LSD_{5.0\%}$	ns	ns	ns	-	0.081	-	ns
$LSD_{10.0\%}$	ns	ns	ns	0.077	-	0.062	ns

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, & c indicates significant result (p<0.001 to <0.1), ns-Non significant up to 10% level of significance.

Measurement of Acidity of plum pickle during storage

Table 2 showed the effect of solute concentration on the quality of plum pickles during storage. Initially, 5% sodium chloride concentration resulted in the higher acidity content (2.47) whereas the lowest (2.40) was observed in 3 percent NaCl. Finally, it was increased monthlies up to 12 months of storage. Regarding the concentration of sucrose in the pickle, the highest acidity was observed in the treated plum pickle containing 12% sucrose. The treatment interaction between various sodium chloride-sucrose concentrations used pickle preparation, the highest acidity was seen in treatment T_6 containing 5% NaCl plus 12% sucrose and the lowest in the treatment T_1 containing 3% NaCl plus 10% sucrose. The reason may be due to the diffusion of acetic acid and the process, which is similar to first-order type reaction with an identical rate constant (Iqbal & Islam, 2005; Ferdous *et al.* 2007). The trend of the increasing of the acidity content was continued during storage up to 12 months. These changes in acidity in pickles due to lactic acid fermentation and fermentation have been notorious to increase acidity in several foods (Gupta 1998; Fleming 1982; Basnett 1992). The increase in acidity during storage might be due to lactobacilli bacteria, generated in pickles during fermentation, which converted sugar into lactic acid as reported by Srivastava & Kumar (2002); and Rekha (2004) in Kachari pickle. The investigated results were in concordance with those found by Stella *et al*. (2011) in orange nectars; Touati *et al*. (2013) in fruits beverages; Touati *et al.* (2016) in fruit nectars.

Table 2. Effect of sodium chloride and sucrose concentrations on the acidity content of plum pickle during storage

Factors/ Treatments	Acidity content of pickle at different storage period (months)						
	0	2	4	6	8	10	12
Sodium chloride							
3 percent	2.40b	2.49b	2.52b	2.55b	2.57b	2.60b	2.64b
4 percent	2.44ab	2.54a	2.56a	2.59b	2.62b	2.65b	2.68b
5 percent	2.47a	2.55a	2.59a	2.65a	2.70a	2.74a	2.80a
CV%	1.600	1.349	1.333	1.635	1.703	2.085	2.786
$LSD_{1.0\%}$	-	-	-	0.055	0.058	0.071	0.097
$LSD_{5.0\%}$	0.050	0.044	0.044	-	-	-	-
Sucrose							
10 percent	2.43	2.51a	2.54a	2.58	2.61	2.65	2.69
12 percent	2.45	2.54a	2.57a	2.61	2.64	2.67	2.70
CV%	1.600	1.349	1.333	1.635	1.703	2.085	2.786
$LSD_{10.0\%}$	ns	0.036	0.036	ns	ns	ns	ns
Treatments							
T_1= 3% sodium chloride and 10% sucrose	2.39	2.48	2.51	2.54	2.56	2.59	2.62
T_2= 3% sodium chloride and 12% sugar	2.41	2.49	2.52	2.55	2.57	2.61	2.65
T_3= 4% sodium chloride and 10% sucrose	2.43	2.51	2.54	2.57	2.6	2.63	2.67
T_4= 4% sodium chloride and 12% sucrose	2.45	2.57	2.58	2.61	2.64	2.66	2.69
T_5= 5% sodium chloride and 10% sucrose	2.46	2.54	2.57	2.64	2.68	2.73	2.79
T_6= 5% sodium chloride and 12% sucrose	2.48	2.56	2.61	2.66	2.71	2.75	2.81
CV (%)	1.600	1.349	1.333	1.635	1.703	2.085	2.786
LSD	ns	ns	ns	ns	ns	ns	ns

Note: All values are means of triplicate determinations; ns-Non significant up to 10% level of significance.

Measurement of plum pickle appearance/color during storage

The color of plum pickles is an important quality parameter. Color values of L (lightness), a* (redness), and b* (yellowness) of the initial and two-month intervals up to twelve months stored pickle are depicted in Table 3. According to the table, using 3% sodium chloride and 12% sucrose plum pickle obtained the highest lightness compared to the 4% sodium chloride and 12% sucrose pickle. The trend of decreasing lightness continued even after 12 months of storage. Concerning the individual effect of NaCl and sucrose concentrations, it was observed that the highest lightness was found in the 3% sodium chloride and 12% sucrose-treated pickles. For the interactive effects of sodium chloride-sucrose concentrations, the highest lightness was found in the treatment T_2 and the second-highest was in the treatment T_4. The lightness was significantly decreased with a longer storage period and it was observed by Kim & Joo (2004) for mushroom pickle. The reduction of lightness during storage may be explained by the humiliation of pigments occurrence during the formation of dim compounds that blow up the brightness, and non-enzymatic browning reaction as reported by Dutta, Dutta, Raychaudhuri & Chakraborty (2006); Goncalves *et al.* (2007). In the case of color coordinates a*; the highest color coordinates were found in 5% NaCl concentrated plum pickle and the lowest was observed in the 3% concentration considering the effect of NaCl used as treatments. In the case of sucrose concentrations, it was observed that the highest values of color coordinate a* were found using 12 sucrose. For the treatment interactions as the level of sodium chloride-sucrose concentrations used in various treatments, initially, the highest color coordinates a* value were found in treatment T_6 and the second-highest was in treatment T_4 and gradually it was increased monthly up to 12 months of storage. In the case of color coordinates a*, initially, the pickle color was very light red, which increased slowly up to the end of the storage period; similar results

were investigated by Park *et al.* (2003) for cucumber pickle. For the color coordinates b*, it was observed that the highest values were found in the 3% sodium chloride concentrated pickle and the lowest was in the 5% NaCl due to the effect of sodium chloride concentrations treatments. With regard to the sucrose concentrations, the 12% sucrose-treated pickle showed the highest values of color coordinates b*. In the case of treatment interactions of solute concentrations, initially, the highest color coordinates b* values were found in the treatment T_2 followed by the treatment T_4 and gradually it was increased monthly during storage. The plum pickle color was turned into light yellow to yellow color after 12 months of storage regarding color coordinates b*. The b* values were increased with a longer storage period and similar findings were found by Son *et al.* (2003) to prepare turnip pickles. This could be explained by the degradation of carotenoids in the plum tissue during storage (Miranda *et al.* 2009). Therefore, the browning phenomenon progresses over time that can be seen by the changes in L, a* and b* values.

Table 3. Effect of sodium chloride and sucrose concentrations on the color parameters of a plum pickle during storage

Factors/ Treatments	Color parameters of pickle at different storage period (months)						
	0	2	4	6	8	10	12
				Lightness (L)			
Sodium chloride							
3 percent	21.78a	21.11a	18.9a	17.12a	16.03a	14.75a	13.65a
4 percent	20.12b	19.43b	17.82b	15.86b	14.54b	13.78b	12.52b
5 percent	17.64c	16.47c	15.81c	13.87c	12.43c	11.10c	9.83c
CV%	1.671	1.625	1.640	1.699	1.700	1.736	1.755
$LSD_{0.1\%}$	0.427	0.397	0.369	0.341	0.313	0.295	0.271
Sucrose							
10 percent	16.55b	16.09b	14.88b	13.26b	12.35b	11.46b	10.54b
12 percent	23.14a	21.91a	20.14a	17.97a	16.31a	14.96a	13.46a
CV%	1.671	1.625	1.640	1.699	1.700	1.736	1.755
$LSD_{0.1\%}$	0.348	0.324	0.302	0.279	0.256	0.241	0.221
Treatments							
T_1= 3% sodium chloride and 10% sucrose	19.51c	19.29d	17.46c	15.25d	14.41d	13.65b	12.17c
T_2= 3% sodium chloride and 12% sugar	24.04a	22.93a	20.34a	18.98a	17.64a	15.84a	15.13a
T_3= 4% sodium chloride and 10% sucrose	16.65d	16.49e	15.14d	13.81e	12.91e	11.78c	10.91d
T_4= 4% sodium chloride and 12% sucrose	23.59a	22.36b	20.5a	17.91b	16.16b	15.78a	14.12b
T_5= 5% sodium chloride and 10% sucrose	13.48e	12.48f	12.03e	10.72f	9.72f	8.94d	8.54e
T_6= 5% sodium chloride and 12% sucrose	21.8b	20.45c	19.58b	17.02c	15.14c	13.25b	11.12d
CV (%)	1.671	1.622	1.640	1.699	1.695	1.743	1.748
$LSD_{0.1\%}$	0.603	0.561	0.521	0.481	0.442	0.419	0.382
				Coordinates (a*)			
Sodium chloride							
3 percent	10.42c	10.73b	10.10c	11.27c	11.40c	11.44c	11.60c
4 percent	11.13b	11.38a	11.55b	12.10b	12.14b	12.51b	12.66b
5 percent	11.53a	11.60a	11.94a	12.59a	12.95a	13.43a	13.90a
CV%	1.616	1.657	1.744	1.852	2.003	2.130	2.181
$LSD_{0.1\%}$	0.229	0.239	0.258	0.286	0.313	0.341	0.357
Sucrose							
10 percent	9.64b	9.88b	10.13b	10.92b	11.15b	11.54b	11.95b
12 percent	12.41a	12.58a	12.86a	13.05a	13.18a	13.37a	13.50a
CV%	1.616	1.657	1.744	1.852	2.003	2.130	2.181

Factors/ Treatments	Color parameters of pickle at different storage period (months)						
	0	2	4	6	8	10	12
$LSD_{0.1\%}$	0.187	0.195	0.210	0.233	0.256	0.279	0.291
Treatments							
T_1= 3% sodium chloride and 10% sucrose	9.02	9.50	10.01d	10.51d	10.66c	10.71d	10.97c
T_2= 3% sodium chloride and 12% sugar	11.81	11.95	11.98c	12.02b	12.14b	12.17a	12.23b
T_3= 4% sodium chloride and 10% sucrose	9.80	9.97	10.14d	10.78d	10.73c	11.04d	11.21c
T_4= 4% sodium chloride and 12% sucrose	12.46	12.78	12.95b	13.41a	13.54a	13.97a	14.14a
T_5= 5% sodium chloride and 10% sucrose	10.09	10.17	10.24d	11.47c	12.05b	12.87a	13.66a
T_6= 5% sodium chloride and 12% sucrose	12.97	13.02	13.64a	13.71a	13.85a	13.98a	14.14a
CV (%)	1.623	1.666	1.740	1.853	2.004	2.130	2.181
$LSD_{0.1\%}$	ns	ns	0.364	-	-	0.483	0.505
$LSD_{1.0\%}$	ns	ns	-	0.404	0.443	-	-
	Coordinates (b*)						
Sodium chloride							
3 percent	16.43a	19.81a	22.17a	23.10a	25.62a	27.76a	28.75a
4 percent	15.78b	19.59a	20.90b	21.78b	23.84b	24.93d	25.80b
5 percent	15.34c	19.27b	20.73b	21.65b	23.39c	23.68c	24.78c
CV%	1.329	1.172	1.146	1.197	1.182	1.213	1.254
$LSD_{0.1\%}$	0.271	-	0.313	0.341	0.369	0.397	0.427
$LSD_{1.0\%}$	-	0.295	-	-	-	-	-
Sucrose							
10 percent	13.26b	17.42b	18.65b	19.81b	23.32b	24.75b	26.06b
12 percent	18.43a	21.69a	23.87a	24.54a	25.23a	26.16a	26.82a
CV%	1.329	1.172	1.146	1.197	1.182	1.213	1.254
$LSD_{0.1\%}$	0.221	0.241	0.256	0.279	0.302	0.324	0.348
Treatments							
T_1= 3% sodium chloride and 10% sucrose	13.40d	17.61	18.91c	20.01c	24.16bc	26.91	28.12b
T_2= 3% sodium chloride and 12% sugar	19.46a	22.01	25.42a	26.18a	27.07a	28.61	29.38a
T_3= 4% sodium chloride and 10% sucrose	13.25d	17.43	18.64cd	19.78c	23.02d	24.12	25.37d
T_4= 4% sodium chloride and 12% sucrose	18.30b	21.74	23.15b	23.78b	24.65b	25.74	26.22c
T_5= 5% sodium chloride and 10% sucrose	13.13d	17.23	18.41d	19.65c	22.79d	23.21	24.69e
T_6= 5% sodium chloride and 12% sucrose	17.54c	21.31	23.05b	23.65b	23.98c	24.14	24.87de
CV (%)	1.324	1.177	1.142	1.193	1.182	1.213	1.254
$LSD_{0.1\%}$	0.382	ns	0.442	0.481	-	ns	-
$LSD_{1.0\%}$	-	ns	-	-	0.522	ns	0.603

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e, and f indicates significant result (p<0.001 to <0.01), ns-Non significant up to 10% level of significance.

Microbial count of stored plum pickle

The effects of sodium chloride and sucrose concentration on the microbial count of a plum pickle during storage are depicted in Table 4. No microorganism was traceable initially due to the higher

dilution used for the enumeration. The microbial growths of the plum pickle of different treatments were not detected up to ten months of storage. However, the microbial growths of the plum pickle were seen to vary between 7×10^{-2} to 32×10^{-1} for high to low concentrations and the final pH found in the treated pickle. It was an acceptable limit for human consumption in different treatments after twelve months of storage. The lactic acid bacterial counts were found to increase with lowered pH as well as solute concentrations and end of fermentation up after twelve months of storage. It was a same agreement with the research of Doyle et al. (2001) who described an increase in lactic acid bacterial counts favored by free of oxygen, dropped pH and solute content.

Table 4. Effect of sodium chloride and sucrose concentrations on the microbial count of plum pickle during storage

Treatments	Microbial count of pickle at different storage period (months)						
	0	2	4	6	8	10	12
T_1= 3% sodium chloride and 10% sucrose	ND	ND	ND	ND	ND	ND	32×10^{-1}
T_2= 3% sodium chloride and 12% sugar	ND	ND	ND	ND	ND	ND	8×10^{-1}
T_3= 4% sodium chloride and 10% sucrose	ND	ND	ND	ND	ND	ND	6×10^{-1}
T_4= 4% sodium chloride and 12% sucrose	ND	ND	ND	ND	ND	ND	1×10^{-1}
T_5= 5% sodium chloride and 10% sucrose	ND	ND	ND	ND	ND	ND	14×10^{-2}
T_6= 5% sodium chloride and 12% sucrose	ND	ND	ND	ND	ND	ND	7×10^{-2}

Note: ND-Not detected

Sensory evaluation of plum pickle

The overall acceptability of the plum pickle by the consumer is highly dependent on its sensory attribute. In addition to visual appearance, color, flavor and textural attributes are critical in determining their degree of acceptance. The organoleptic attributes of the plum pickle with different combinations of sodium chloride and sucrose concentrations were evaluated after two months interval up to twelve months of storage. Comparative sensory evaluation of different quality attributes of the pickle according to the opinion of taste panel judges comprising 10 members is presented in Table 5. It was observed that the color, flavor, taste, sweet-sour balance, bitterness and overall acceptability had a significant effect on its overall acceptance. According to the Table, it was observed that the overall acceptability score of 9.0 was found as the highest for the plum pickle with 4 to 5% sodium chloride plus 12% sucrose concentration and 6.0 as the lowest for the 4 % sodium chloride plus 10% sucrose pickle. As for the effect of sodium chloride concentrations, initially, the highest overall acceptability score of 7.75 was observed in the 5% concentration which was followed by the value of 7.0 for 4% NaCl concentration pickles. On the other hand, only for the effect of sucrose concentration, the highest overall acceptability score of 8.17 was observed using 12% sucrose concentration which was followed by the value of 7.17 for 10% concentration pickle even after 12 months of storage. With regard to the effect of interaction between sodium chloride-sucrose concentrations, initially, the highest overall acceptability score of 8.50 was investigated in treatments T_4 and T_6 which was followed by treatments T_1 and T_5 securing the second-highest score of 7.0. Finally, the overall acceptability was continued as highest in treatments T_4 and T_6 and the score was 9.0 (i.e., like extremely) which was judged by the panelists. Panelists liked the plum pickles because of the balance of sodium chloride and sucrose percentage, less bitterness, attractive color, and overall taste as mentioned during judgment. Overall acceptability of the pickle for all treated samples was increased with storage time increases and a similar investigation was found by Shim (2012) for the study of yacon pickle. For keeping quality, taste and flavor, the pickle would be good in condition after a long time of storage in the jar but it became softer after three months, otherwise, all quality parameters remained satisfactory during storage as reported by Kumar (1985) for the development of watermelon pickle. The higher sucrose concentration represented the increased acceptability of pickle for the taste is notably prejudiced by sweetness, it was observed by Bhuiyan *et al*. (2012) for preparation of hog plum pickle. Overall acceptability of pickles improved extensively with the increase storage period. Taste, flavor, texture, consistency showed perfection in their quality but color showed decreasing trend which might be due to increase browning. The increase in organoleptic quality in a pickle during the storage period can be accredited to continuing the fermentation process

which might have resulted in softening of pickles. A similar consequence was obtained by Gupta (1998) in oil-less mango pickle, Sharma (2002) in a lime pickle and Rekha (2004) in Kachri pickle, Jiang et al. (2004) in harvested litchi fruit.

Table 5. Effect of sodium chloride and sucrose concentrations on the overall acceptability of plum pickle during storage

Factors/ Treatments	Overall acceptability of pickle at different storage period (months)						
	0	2	4	6	8	10	12
Sodium chloride							
3 percent	6.00c	6.50c	6.50c	6.50c	7.00b	7.00b	7.00b
4 percent	7.00b	7.00b	7.00b	7.00b	7.25b	7.50b	7.50b
5 percent	7.75a	7.75a	8.25a	8.25a	8.25a	8.50a	8.50a
CV%	3.421	3.421	3.264	3.264	3.864	5.833	4.442
$LSD_{0.1\%}$	0.304	0.304	0.304	0.304	0.373	0.575	0.438
Sucrose							
10 percent	6.50b	6.50b	6.67b	6.67b	7.00b	7.17b	7.17b
12 percent	7.63a	7.33a	7.83a	7.83a	8.00a	8.17a	8.17a
CV%	3.421	3.421	3.264	3.264	3.864	5.833	4.442
$LSD_{0.1\%}$	0.249	0.249	0.249	0.249	0.304	0.470	0.358
Treatments							
T_1= 3% sodium chloride and 10% sucrose	7.0b	7.0b	7.0d	7.0d	7.5b	7.5b	7.5b
T_2= 3% sodium chloride and 12% sugar	5.0d	6.0c	6.0e	6.0e	6.5c	6.5c	6.5c
T_3= 4% sodium chloride and 10% sucrose	5.5c	5.5d	5.5f	5.5f	6.0c	6.0c	6.0c
T_4= 4% sodium chloride and 12% sucrose	8.5a	8.5a	8.5b	8.5b	8.5a	9.0a	9.0a
T_5= 5% sodium chloride and 10% sucrose	7.0b	7.0b	7.5c	7.5c	7.5b	8.0b	8.0b
T_6= 5% sodium chloride and 12% sucrose	8.5a	8.5a	9.0a	9.0a	9.0a	9.0a	9.0a
CV (%)	3.421	3.421	3.264	3.264	3.864	5.833	4.442
$LSD_{0.1\%}$	0.431	0.431	0.431	0.431	0.527	0.814	0.620

Note: 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like nor dislike, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely.
All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e, and f indicates significant result ($p<0.001$).

Conclusion

In relation to plum pickle so far literature ascertained Bangladesh is an insufficient production country and almost not available in the local market. The plum fruits are spoilage or misuse by the farmers or growers due to a lack of processing practice in Bangladesh. Therefore, preparing plum pickle is one of the new ideas for long time consumption and uses it in offseason. This research has investigated the effect of pH, acidity, product color and microbial growth in a stored plum pickle as well as carried out the organoleptic test to evaluate the processing method of a plum pickle at various percentages of sodium chloride and sucrose used in a pickle at different treatments. The results revealed that the plum pickle prepared using 4 to 5 percent sodium chloride plus 12 percent sucrose kept in a glass container and stored at room temperature (25 to 30ºC) showed better quality product for long time consumption.

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EFFECTS OF VARIOUS SUCROSE CONCENTRATIONS ON THE QUALITY OF PLUM CHUTNEY DURING STORAGE

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Abstract

The study was undertaken to optimize the processing of plum chutney to extend the variegated use of the plum. There were five treatments using various sucrose percentages were used for the experiments. The chutney was stored for six month. The p^H was slightly increased where acidity was decreased. The intensity of light yellow color of the chutney was gradually increased and turn into light red color during storage. No microbial growths of the plum chutney were seen in all the treatments up to five but in six month seen acceptable microbial count. Comparative sensory evaluation of different quality attributes of the plum chutney is judged and found the treatments T_3 (using 40 percent sucrose in plum) scored highest overall acceptance (8.5 e.g. like very much to like extremely) followed by treatment T_2 (using 30 percent sugar in plum) scored of 7.5 (e.g. like moderately to like very much).

Introduction

Plum can be used as fresh dessert fruit, dried or cooked. The prune juice is widely used as flavoring agent in the food processing industries like biscuit making industry (Doymaz, 2006). Due to lack of transportation, preservation and marketing facilities, plums are being damaged, spoiled and wasted especially during the peak season. Chutney may be the representative and most suitable approaches for processing plum. Chutneys are pleasant preserves of mainly fruits and vegetables, and are a good accompaniment of India as well as continental foods (Marwaha & Marwaha, 2000)**.** Chutneys and pickles of various kinds are prepared in Bangladesh homes and also on a commercial scale. In the first case, standard recipes have been modified by local taste. Fruits such as apples, peaches, plums, apricots and mangoes, and vegetables like turnips, cauliflowers, carrots, etc., are the basic raw materials for these products. Onion, garlic, spices, herbs, etc., are added for flavor. Vinegar, common salt and sugar also are used to make them more palatable. Vinegar serves as a preservative to some extent. Thus, it was necessary to find out optimal formulation of plum chutney and examine the shelf life of the prepared chutney.

Materials and Methods

Collection of fresh plum

Plum (BARI Alu bukhara-1) having optimum maturity and firm texture was collected from the Spices Research Center of BARI and local farmer. The plums were transported in plastic crates to the Postharvest Technology Division Laboratory of BARI, Gazipur. After sorting, the plum was washed and dried under a ceiling fan.

Formulation of plum chutney

The following ingredients were used during the preparation of plum chutney:

Item	Quantity
Plum	1.0kg
Sugar	Recommended dose
Salt	32.0g
Salt (bit labon)	5.0g
Red chilli powder	6.0g
Fenugreek powder	5.0g
Mustard powder	12.0g
Cumin powder	2.5g
Kawlanji	8.0g
Black pepper powder	1.0g
Cloves powder	0.5g
Cinnamon powder	1.0g
Joyfal	1.0g
Joytri	0.5g
Mustard oil	100ml
Acetic acid	6.0 ml
Sodium benzoate	0.75g

Preparation of plum chutney

For the preparation of chutney, first of all the dried spices like black pepper, cumin, kawlanji, cinnamon, red chili, clove and cardamom were ground into a powder form. Select fully mature plum, sorting and washing. After washing boil, the plum until it becomes soft. Remove the pan from the burner and after cooling separate the pulp by pressing the hand. Then add required amount of sugar and heat it. Add oil, salt and dry spices powder one by one and continue the heating. When the mixture becomes concentrated add acetic acid and cook until the brix rises to 62^0B and then add sodium benzoate. Remove the pan from the burner and transferred the chutney into sterile glass jar. All the packed products were properly labeled and stored at ambient (20-30^{o}C). The physico-chemical and sensory characteristics of all the products were analyzed at one-month interval for 6 months of storage.

There were four treatments: T_1 = Using 20% sucrose in plum; T_2 = Using 30% sucrose in plum; T_3 = Using 40% sucrose in plum; T_4 = Using 50% sucrose in plum; and T_5 = Using 60% sucrose in plum

The below flow chart indicated the plum chutney preparation process as shown in Figure 2:

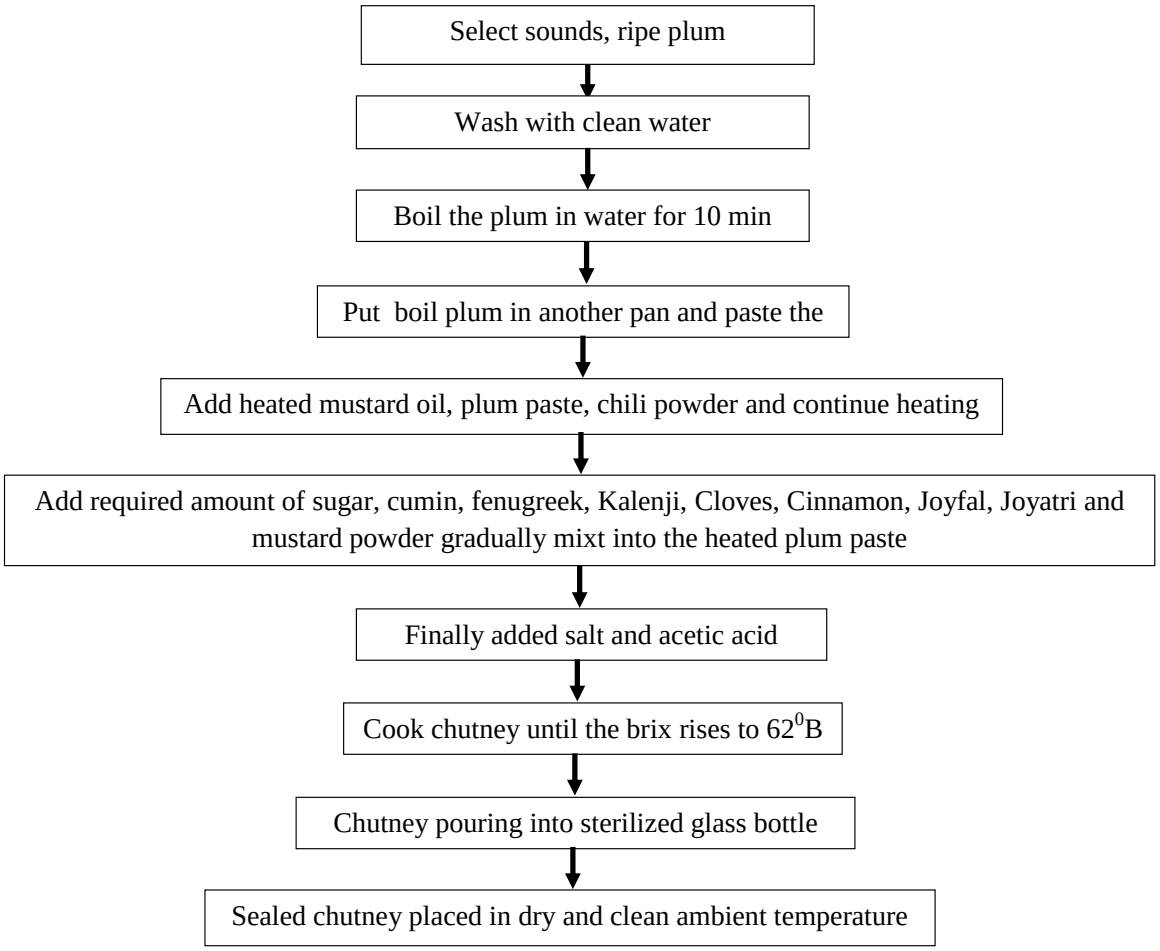

Figure 2. Process of flow diagram for plum chutney preparation

Measurement of pH

The sample (5 g) was diluted with 45 mL distilled water, and pH was measured with glass electrode (EUTECH Instruments, Selangor, Malaysia).

Measurement of titratable acidity

The titratable acidity (TA) was analyzed using the titration method. Pulp sample (10 g) were homogenised using a kitchenblender with 40 ml of distilled water. The mixture was then filtered through cotton wool. The filtrate (5 ml) with one to two drops of phenolphthalein (0.1%) as indicator was titrated using 0.1 N NaOH to an endpoint pink (p^H 8.1). The results were expressed as the percentage citric acid per 100g fresh weight.

Product appearance/color

Plum color was determined using a tristimulus colorimeter (CR-400, Minolta Corp., Japan) with 8-mm aperture and C light source at two equidistant points on the equator of each sample by using CIE color system on the L, a*, b* color space where L a* b* coordinates were recorded using D65 illuminants. A 10° standard observer was used as a reference system. *L* (lightness), *a** (-greenness to +redness) and *b** (-blueness to +yellowness) are the chromaticity coordinates.

Microbial count

Microbial load of the plum chutney was determined with the use of plate count agar. The microbial load count was performed each month interval up to 6 months' storage. In the process of counting, a 10g pickle sample was homogenized with 90ml buffer peptone water solution and then 10µL suspension inoculated in the plate count agar (PCA) medium through 10-fold serial dilution. Then, the inoculated plate was incubated at 37^0C for 24 hrs in an incubator (Model: SHC-4A1). Different bacterial colony grown in that medium was counted. For the number of colony count in cfu/g the following formula was used:

$$\text{Colony Formin g Unit}\left(\frac{\text{cfu}}{\text{g}}\right)=\frac{\text{No. of colony}\times\text{Dilution}\times\text{Time of dilution}}{\text{Sampale inoculated to plate / media}}$$

Sensory evaluation

The sensory evaluation of the plum chutney was determined in each month interval during storage using a sensory taste questionnaire judged by expert sensory panelists. Each treatment was assigned a letter code to avoid biases among the panelists. The samples were presented to panelists in different orders to avoid order preference among the panelists. The plum chutney was rated by 10 experienced panelists who were asked to score samples based on the plum external color, off-flavor, firmness, sweet-sour balance, and overall acceptance using a 9-point hedonic scale.

Data analysis

The experiment was carried out Completely Randomized Design (CRD) and all five treatments were replicated three times. The data were analyzed for ANOVA using computerized statistical software of R to compare the means and level of significance of data.

Results and Discussion

The plum chutney was stored in an ambient condition for six months. The changes in various physico-chemical parameters of the plum chutney were presented in Table 1 to Table 5.

Measurement of pH of stored plum chutney

The effects of sucrose on the pH content of stored chutney during storage as seen in Table 1. Initially the highest pH of 2.73 was seen in treatment T_5 and the lower of 2.59 in treatment T_1. But, the pH was increases month by month up to 6 month of storage.

Table 1. Effect of sucrose on the pH content of plum chutney during storage

Treatments	pH content of plum chutney at different storage period (months)						
	0	1	2	3	4	5	6
T_1=20% sucrose	2.59d	2.69c	2.72d	2.74c	2.76c	2.78c	2.81d
T_2=30% sucrose	2.63d	2.71bc	2.73cd	2.76bc	2.77c	2.79c	2.83cd
T_3=40% sucrose	2.67b	2.74ab	2.75bc	2.77bc	2.79bc	2.81bc	2.85c
T_4=50% sucrose	2.71a	2.75a	2.76ab	2.79ab	2.81ab	2.83ab	2.88b
T_5=60% sucrose	2.73a	2.76a	2.78a	2.81a	2.83a	2.85a	2.91a
CV (%)	0.750	0.613	0.540	0.665	0.570	0.693	0.519
$LSD_{0.1\%}$	0.036	-	-	-	-	-	0.027
$LSD_{1.0\%}$	-	0.030	0.027	0.034	0.029	0.035	-

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d indicates significant result (p<0.001 & <0.01).

Measurement of acidity of stored plum chutney

In Table 2 showed the effect of sucrose on acidity (%) content of stored plum chutney during storage. During preparation the measurement of initial acidity content was higher in treatment T_5 and the lower in treatment T_1. But, the acidity content decreased significantly month by month during storage

and the lowest values was 0.85 in the treatment T_1 after 6 months. It might be attributed to hydrolysis of polysaccharides and non-reducing sugar, where acid is utilized for converting these to hexose sugars (reducing sugars) and analogous explanations were stated by Thakur (2017) for wild pomegranate chutney. It could be explained due to the differences in physico-chemical composition among various treatments and changes in the physico-chemical composition of the products during storage. The results are similar to those of Chaudhary and Verma (2012) in aonla chutney. Statistically a significant decrease in average acidity content was found month by month. The acidity in the processed products is lost due to the oxidation and direct effect of ambient storage temperatures.

Table 2. Effect of sucrose on the acidity content of plum chutney during storage

Treatments	Acidity content of plum chutney at different storage period (months)						
	0	1	2	3	4	5	6
T_1=20% sucrose	1.79c	1.58c	1.52c	1.45c	1.41d	0.93e	0.85e
T_2=30% sucrose	1.82bc	1.66c	1.59c	1.51c	1.47c	1.23d	1.21d
T_3=40% sucrose	1.92b	1.81b	1.78b	1.75b	1.62b	1.52c	1.42c
T_4=50% sucrose	2.05a	1.90ab	1.86ab	1.81ab	1.74a	1.65b	1.57b
T_5=60% sucrose	2.10a	1.91a	1.87a	1.83a	1.76a	1.71a	1.65a
CV (%)	3.638	2.866	2.481	2.159	1.957	2.334	2.732
$LSD_{0.1\%}$	0.128	0.092	0.078	0.066	0.057	0.060	0.067

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

Measurement of appearance/color of stored plum chutney

Color is an important factor in the perception of plum chutney. The changes in the chutney color were monitored by estimating the color coordinates (a* and b*) and lightness (L) during storage in an ambient condition using different percentages of sucrose used in plum chutney. The values are presented in Table 3 and it indicated that the intensity of light yellow color of the chutney was gradually increased and turns into light red color during storage after six months. The highest lightness was observed in treatment T_1 and lowest in treatment T_5 but the lightness values was increased up to 6-month storage. It was noticed that the lightness decreases with the increases of sucrose percentage in the product. The color co-ordinates a* value represent that the initial product color was light red and it increases slowly up to 6 month of storage. On the other hand, the color co-ordinates b* shown that the product color was light yellow and finally it turns yellow color up to 6 month of storage. Less sucrose percentage in the product was responsible for the yellow color and more sucrose percentage provided the light yellow color of the product. A significant decrease in colour of chutney was seen during prolong storage. It might be happened due to changes in chemical constituents or certain enzymatic and non-enzymatic actions also in case of degradation of anthocyanins pigment in the products. The present outcomes as the tendency of decrease in colour intensity are in conformity with those of Chauhan *et al*. (1994) in wild pomegranate chutney; Sahni (1997) in amla chutney and Verma and Chopra (2010) in aonla-mango mixed fruit products.

Table 3. Effect of sucrose on the color parameters of plum chutney during storage

Treatment	Color parameters of plum chutney at different storage period (months)						
	0	1	2	3	4	5	6
Lightness (L)							
T_1=20% sucrose	22.64a	24.27a	28.95a	33.64a	36.01a	47.10a	56.13a
T_2=30% sucrose	22.12a	22.89b	27.50b	32.11b	35.73ab	44.82b	49.46b
T_3=40% sucrose	20.83b	21.90c	26.91b	31.91b	35.19b	37.96c	40.51c
T_4=50% sucrose	20.12bc	21.03d	24.04c	27.04c	32.29c	32.07d	37.07d
T_5=60% sucrose	19.64c	20.68d	23.49c	26.29c	30.13d	31.66d	36.04d
CV (%)	1.985	1.874	1.791	1.420	1.277	1.263	1.393
$LSD_{0.1\%}$	0.761	0.755	0.853	0.780	0.787	0.889	1.111
Coordinates (a*)							
T_1=20% sucrose	11.79a	12.69a	12.94a	13.19a	13.66a	13.71a	13.78a
T_2=30% sucrose	11.08b	11.41b	11.58b	11.74b	11.89b	11.98b	12.04b

Treatment	Color parameters of plum chutney at different storage period (months)						
	0	1	2	3	4	5	6
T_3=40% sucrose	10.12c	10.24c	10.65c	11.05c	11.77b	11.87b	11.97b
T_4=50% sucrose	8.26d	8.56d	8.87d	9.17d	9.37c	10.17c	10.87c
T_5=60% sucrose	7.78e	7.83e	8.07e	8.31e	8.78d	9.17d	9.87d
CV (%)	1.719	1.744	1.821	1.966	2.073	2.195	2.244
$LSD_{0.1\%}$	0.307	0.322	0.345	0.382	0.418	0.454	0.478
Coordinates (b*)							
T_1=20% sucrose	13.41a	15.31a	16.89a	18.47a	28.77a	33.55a	34.87a
T_2=30% sucrose	11.11b	12.28b	14.76b	17.24b	18.35b	22.58b	28.24b
T_3=40% sucrose	8.78c	12.07b	12.41c	12.75c	14.16c	19.46c	29.77c
T_4=50% sucrose	7.05d	9.47c	10.71d	11.95d	13.05d	15.32d	27.53d
T_5=60% sucrose	6.11e	8.32d	9.73e	11.14e	12.12e	13.84e	26.91e
CV (%)	2.131	1.883	1.783	1.740	1.563	1.383	1.060
$LSD_{0.1\%}$	0.360	0.394	0.418	0.453	0.492	0.527	0.568

Note: All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

Microbial count of stored plum chutney

In Table 4 depicted the effects of sucrose percentage on the microbial count of plum chutney during storage. No microorganism was traceable initially due to the higher dilution used for the enumeration. The microbial growths of the plum chutney of different treatments were not detected up to five months of storage. However, the microbial growths of the plum chutney were seen in minor count and that was acceptable limit for the human consumption in different treatments at six months of storage. The change was noticed after 6 months of preservation and the chutney remarked as unacceptable to consume. The changes occurred possibly due to fermentation in presence of fungus (mold and yeast) as Fraziar and Westheff (1978) describe that main spoilage organism for fruit products are mold and yeast. It was clear that the storage stability of chutney was lower than the pickle described by (Gupta, 1992 & Bhuyan *et al.* 2012).

Table 4. Effect of sucrose on the microbial growth of plum chutney during storage

Treatments	Microbial count of plum chutney at different storage period (months)						
	0	1	2	3	4	5	6
T_1=20% sucrose	ND	ND	ND	ND	ND	ND	$23*10^{-8}$
T_2=30% sucrose	ND	ND	ND	ND	ND	ND	$14*10^{-5}$
T_3=40% sucrose	ND	ND	ND	ND	ND	ND	$3*10^{-5}$
T_4=50% sucrose	ND	ND	ND	ND	ND	ND	$13*10^{-6}$
T_5=60% sucrose	ND	ND	ND	ND	ND	ND	$4*10^{-7}$

Note: ND-Not detected

Sensory evaluation of plum chutney

The organoleptic attributes of the plum chutney with different combination of sucrose are evaluated in every month's storage. Comparative sensory evaluation of different quality attributes of the plum chutney according to the opinion of test panel judges comprising 10 expert members are presented in Table 5. It was observed that the color, flavor, taste, sweetness, sour, bitterness as well as overall acceptability have the effect on its evaluation for acceptance of the product. As shown in Table 5, among the treatments, panelists indicated the highest score of the overall acceptability of chutney prepared with 40 percent sucrose (treatment T_3) followed by 30 percent sucrose (treatment T_2). The overall acceptability was noticed that the treatment T_3 was the highest overall acceptance of 8.5 (i.e., like very much to like extremely) followed by treatment T_2 an overall acceptance of 7.5 (i.e., like moderately to like very much). Panelist liked this plum chutney because of the balance of optimum sucrose percentage, less bitterness, attractive color and overall taste as remarked in the recorded data sheet. A significant decrease was seen in an overall acceptability during store. This might be due to changes in chemical constituents or certain enzymatic and non-enzymatic changes in the products. The present findings are in conformity with those of Khan *et al.* (2012) in strawberry jam and Verma and Chopra (2010) in aonla-mango mixed fruit products. However, in most of the treatments

organoleptic score of the products remained above the acceptable level even at the end of the storage. The decreased in sensory scores during storage was also observed by Veerapandian *et al.* (2014) in ready-to-eat peanut chutney and Ullah *et al.* (2018) in carrot and apple blended jam.

Table 5. Effect of sucrose on the overall acceptability of plum chutney during storage

Treatments	Overall acceptability of plum chutney at different storage period (months)						
	0	1	2	3	4	5	6
T_1=20% sucrose	4.5c	4.0c	4.0d	4.0e	4.0e	3.5e	3.5e
T_2=30% sucrose	7.0a	6.5b	7.0b	7.0b	7.5b	7.5b	7.5b
T_3=40% sucrose	7.5a	8.0a	8.0a	8.0a	8.5a	8.5a	8.5a
T_4=50% sucrose	5.5b	6.0b	6.0c	6.0c	6.5c	6.5c	6.5c
T_5=60% sucrose	5.0bc	4.5c	4.5d	4.5d	4.5d	4.0d	4.0d
CV (%)	5.570	7.355	4.853	3.651	3.748	3.939	3.844
$LSD_{0.1\%}$	0.598	0.776	0.521	0.399	0.423	0.423	0.399

Note: 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like nor dislike, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely

All values are means of triplicate determinations. Means within columns with different letters a, b, c, d, e indicates significant result ($p<0.001$).

Conclusion

In relation to plum chutney as we know, Bangladesh is insufficient production country and almost not available in local market. The plum fruits are spoilage or misuse by the farmers or growers due to lack of processing practice in Bangladesh. Therefore, the preparing plum chutney from plum fruits is one of the new ideas for long time consumption and uses it in off season. This research was investigated the changes in pH, acidity, color of the product and microbial growth in stored plum chutney as well as carried out the organoleptic test to evaluate the processing method of plum chutney using different sucrose percentages. The results revealed that the considering different quality parameters of chutney, the best formulation was using plum with 40 percent sucrose. The prepared product kept in glass container and stored at room temperature (25 to 30ºC) showed better quality product for long time consumption. Consequently, the developed technology has a scope for commercial exploration at industry level for manufacturing shelf-stable products of these fruits for their efficient and profitable utilization thereby ensuring reduction in post-harvest losses and better returns to the growers.

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EFFECT OF PRETREATMENTS AND STORAGE TEMPERATURES ON THE PHYSICO-CHEMICAL PARAMETERS AND QUALITY OF PLUM

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Abstract

The study was undertaken to compare physico-chemical parameters and quality of the plum at different pretreatments and storage temperatures for long time use of fresh plum. There were nine treatments using various pretreatments and temperatures for the experiments. For analyzed stored plum firmness, pH, vitamin C and TSS data; it was noticed that in an ambient condition after 7 days stored plum was spoilage but in cold room when the storage temperature was $(10\pm1)^0$C, the stored plum was good in condition upto 42 days; whereas the stored plum was also good in condition upto 70 days if the storage temperature was $(5\pm1)^0$C and the plum was wash with clean water as well as it washed with 150 ppm NaOCL solution.

Introduction

Worldwide production of plum is about 9, 738, 908 metric tonne and more than 50% of the world production is received from China, producing about 5, 664, 826 metric tons annually. Romania, USA, Serbia, Montenegro, Germany, France and Turkey are another main producer of plum in the world (FAO, 2010). In Bangladesh, the demand of plum (*Prunus domestica*) usually meets up by importing from other countries like India, China, Thailand (Mozumder *et al.*, 2017). Spices Research Center of Bangladesh Agricultural Research Institute (BARI) released a plum variety namely "BARI Alu bukhara-1" which is high yielding and profit potential (Anonymous, 2014). Plums and their juice contain mild laxatives including phenolic compounds, sorbitol, dietary fiber are thus common home remedies for constipation (Miletic *et al.*, 2012). Plum also have a high antioxidant content which retards ageing (Stacewicz *et al.*, 2001). Bangladesh is an agriculture-based country and its economy mostly depends on agriculture. We have lots of problems and/or limitations for proper production of our agricultural crops. Though, we have problems but our researchers as well as growers are dedicated in exploring new ways for the best production. Despite, the fact that the plum production is increasing due to improved horticultural practices and improved production technology, the inadequacies in handling, storage, transportation and marketing pose a greater threat during glut season and result in heavy post-harvest losses and fetches low price to the farmers. Therefore, the development of suitable plum processing technology was an avenue for immediate exploration to match the challenges of increased production and thereby augmenting the income of the growers.

The fresh fruit and the processed products made from the plum have been widely consumed due to its possible health benefits. Storage technique and temperature is the most important environmental factor in the postharvest life of plum fruits. Ripening process is associated with increasing of lycopene and carotenoids content but the ripening process is influenced by the high temperature (Tadesse *et al.*, 2015). The vegetables and fruits stored at low temperature (4^oC or below 4^oC) slow down the ripening process and there is a possibility to degradation of lycopene and carotenoids content. Low temperature freezing causes minimal loss of β-carotene because of retention of most of the nutrient at low temperature (Dutta *et al.*, 2005). On the other hand, the fruits and vegetables at low temperature often are susceptible to chilling injury when cooled below 13 to 16^oC (Kitinoja & Kader, 2015). Therefore, the effect of pretreatments and temperatures on quality of plum is necessary to identify the shelf life.

Materials and Methods

Collection of fresh plum

Plum (BARI Alu bukhara-1) having optimum maturity and firm texture was collected from the Spices Research Center of BARI and local farmer. The plums were transported in plastic crates to the Postharvest Technology Division Laboratory of BARI, Gazipur. After sorting, the plum was washed and dried under a ceiling fan.

Preparation of fresh plum storage

The fresh plum was stored in an ambient condition as well as at cold room for the temperature of $(5\pm1)^0$C and $(10\pm1)^0$C, respectively. There were three washing techniques of the plum such as no wash, clean water wash and wash with NaOCL. The changes in firmness, internal and external color, decay index, weight loss, pH, acidity, vitamin C, β-carotene and TSS data were collected from laboratory analysis. There were nine treatments:

T_1, T_2 and T_3 = without wash plum stored at ambient condition, $(5\pm1)^0$C and $(10\pm1)^0$C temperature respectively;
T_4, T_5 and T_6 = Plum wash with clean water and stored at ambient condition, $(5\pm1)^0$C and $(10\pm1)^0$C temperature, respectively;
T_7, T_8 and T_9 = Plum wash with NaOCl (150 ppm) and stored at ambient condition, $(5\pm1)^0$C and $(10\pm1)^0$C temperature, respectively

Firmness of plum

Plum firmness, as the force required to puncture the fruit, was measured using an Instron-Universal testing machine (Model 4201, USA) and expressed as kg-f/cm^2.

Product appearance/color

Stored plum external/outside and internal/inside colors were determined using a tristimulus colorimeter (CR-400, Minolta Corp., Japan) with 8-mm aperature and C light source at two equidistant points on the equator of each sample by using CIE color system on the L, a*, b* color space where L, a*, b* coordinates were recorded using D65 illuminants and a 10° standard observer as a reference system. *L** is lightness, *a** (-greenness to +redness) and *b** (-blueness to +yellowness) are the chromaticity coordinates.

Decay index (%)

Plum decay was visually evaluated initially and after three days' storage interval. Any plum with visible mold growth was considered as decay. For this purpose, first fruit decay rate was assessed by measuring the extent of decay area on each plum, and will term as: 0, no decay; 1, less than ¼ decay; 2, 1/4–1/2 decay; 3, 1/2–3/4 decay. The average extent of plum decay was expressed as decay index and was determined using the following formula as described by Wang *et al*. (2005).

% Decay index = [(1×N1+2×N2+3×N3) ×100/ (3×N)]

Measurement of weight loss

The stored plum weight loss was calculated in each interval from the initial weight to the particular day's weight and it expressed as percentage.

Measurement of pH

The sample (5 g) was diluted with 45 mL distilled water, and pH was measured with glass electrode (EUTECH Instruments, Selangor, Malaysia).

Measurement of titratable acidity

The titratable acidity (TA) was analyzed using the titration method. Pulp sample (10 g) were homogenised using a kitchenblender with 40 ml of distilled water. The mixture was then filtered through cotton wool. The filtrate (5 ml) with one to two drops of phenolphthalein (0.1%) as indicator was titrated using 0.1 N NaOH to an endpoint pink (p^H 8.1). The results were expressed as the percentage citric acid per 100 g fresh weight.

Measurement of β-carotene

The estimation of β-carotene was done by the extraction of 3g product sample with acetone (Fisher Scientific Ltd., Uk) and petroleum ether. It was further purified with acetone, metabolic KOH and distilled water. The resulting solution was filtered with anhydrous sodium sulphate and read on a spectrophotometer (T-80, PG Instrument Ltd., UK) at 451nm against petroleum ether as a blank. A standard graph was plotted using synthetic crystalline B-carotene (Fluka, Germany) dissolved in petroleum ether and its optical density measured at 451 nm (Alasalvar *et al.*, 2005).

Measurement of ascorbic acid

Ascorbic acid content was determined as per AOAC (1995) method using 2, 6- dichlorophenol indophenol dye. The sample extracted in 3% m-phosphoric acid was titrated with dye to pink colour end point. The results were expressed as mg per 100g of sample and calculated by using the following formula:

$$\text{Ascorbic acid}\,(\text{mg}/100\text{g}) = \frac{\text{Titre} \times \text{Dye factor} \times \text{Vol. made up}}{\text{Aliquot of extract taken} \times \text{Weight of sample taken}} \times 100$$

Measurement of total soluble solid (TSS)

Total soluble solid in the extracted juice of plum was measured by a refractometer (ATAGO (Brix = 0 to 32%)) and the results were expressed as % Brix.

Results and discussion

The fresh plum was stored in an ambient condition as well as at cold room for the temperature of $(5\pm1)^0$C and $(10\pm1)^0$C, respectively. There were three washing techniques for the plum such as no wash, clean water wash and wash with NaOCL. The changes in firmness, internal and external color, decay index, weight loss, pH, acidity, vitamin C, β-carotene and TSS data were collected from laboratory analysis; the mean values of all data are shown in Table 1 to 7, respectively.

Firmness of plum

The effect of different washing and storage temperatures on the firmness of plum was shown in Table 1. The reduction in plum fruit firmness was recorded from 3.31 to 2.11kg-f/cm^2 and 3.35 to 2.45kg-f/cm^2 for the treatments of clean water wash and NaOCL wash, respectively and both are stored at $(5\pm1)^0$C while higher firmness was recorded in T_8 (2.456kg-f/cm^2) followed by T_5 (2.11kg-f/cm^2) after 70 days. The maximum decrease (36.25%) in firmness was observed in T_5 and low decrease was noted in T_8 (26.87%). These results are in conformity with Jan et al. (2013) showed that mean value for firmness was significantly higher for calcium salt treated apples compared to untreated samples at (5±1) °C during storage.

Table 1. Effect of different washing and storage temperatures on the firmness of plum

Treatments	Firmness (kg-f/cm^2) of plum at different duration (day)						
	0	7	14	28	42	56	70
T_1 = No wash & store at TA		1.42	spoil	spoil	Spoil	spoil	Spoil
T_2 = No wash & store at $(5\pm1)^0$C		3.13	3.05	2.78	2.51	2.23	CI
T_3 = No wash & store at $(10\pm1)^0$C	3.68	2.72	2.56	2.13	1.87	spoil	Spoil
T_4 = Clean water wash & store at TA		1.91	spoil	spoil	Spoil	spoil	Spoil
T_5 = Clean water wash & store at $(5\pm1)^0$C		3.31	3.21	2.97	2.72	2.57	2.11
T_6 = Clean water wash & store at $(10\pm1)^0$C		2.87	2.62	2.54	2.23	spoil	Spoil
T_7 = NaOCl Wash & store at TA		1.94	spoil	spoil	Spoil	spoil	Spoil
T_8 = NaOCl Wash & store at $(5\pm1)^0$C		3.35	3.29	3.07	2.83	2.61	2.45
T_9 = NaOCl Wash & store at $(10\pm1)^0$C		2.93	2.68	2.57	2.38	spoil	Spoil

Note: TA- Ambient Temperature, CI- Chilling Injury

Product appearance/color

The effect of different washing and storage temperatures on the external and internal color parameters of plum is depicted in Table 2 and 3. The plum fruit pericarp color including L and b* values is one of the most important factors of visual appearance to attract consumers. Color development is closely associated with a climacteric peak in all the treatments including untreated fruits (Tapas *et al.*, 2016). The color development which started prior to the onset of climacteric was completed at the peak climacteric (Leoseck, 1950). From this study, it is evident that the plum fruits which have undergone washing treatments retained quality and showed good visual appearance. The change in color was first noticed in the untreated fruits and then in the treated fruits but at the end of storage period there was no significant difference in between the treated and untreated fruits.

As shown in Table 2, the L values of treated and control fruits tended to decrease with increasing storage time, and higher L values were found in NaOCL treated sample during the storage period. The L values gradually decrease with increasing storage time, but dipping in 150 ppm NaOCL significantly delayed the decrease in these values, indicating that NaOCL could maintain lightness of plum; similar investigation was observed for b* values and it indicating that NaOCL could maintain yellowness of the plum. This investigation was confirmed by Khunpon *et al.* (2011) for longan and they used dipping solution of 0.001-0.05% sodium chlorite. On the other hand, investigating internal color of the plum in Table 3, the L and a* values of treated and control fruit sample tended to increase with increasing storage time, and higher L and a* values were found in NaOCL treated sample during the storage period but the reduction of b* values were also maintained same as fruit external color.

Table 2. Effect of different washing and storage temperatures on the external plum color

Treatments	Color parameters of plum at different duration (day)						
	0	7	14	28	42	56	70
Lightness (L)							
T_1 = No wash & store at TA	45.17	27.86	spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		40.78	36.19	35.63	30.56	28.98	CI
T_3 = No wash & store at (10±1)^{0}C		36.17	34.18	31.58	29.58	spoil	Spoil
T_4 = Clean water wash & store at TA	48.68	31.41	spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		42.16	39.01	37.13	31.45	29.71	25.11
T_6 = Clean water wash & store at (10±1)^{0}C		42.18	40.03	33.14	31.36	spoil	Spoil
T_7 = NaOCl Wash & store at TA	52.19	32.86	spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		45.12	41.11	38.41	33.56	31.17	25.72
T_9 = NaOCl Wash & store at (10±1)^{0}C		44.03	41.36	35.97	32.74	spoil	Spoil
Coordinates (a*)							
T_1 = No wash & store at TA	20.32	23.97	Spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		20.9	21.35	22.36	23.01	24.56	CI
T_3 = No wash & store at (10±1)^{0}C		21.79	23.56	24.78	26.41	spoil	Spoil
T_4 = Clean water wash & store at TA	21.43	24.12	Spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		21.12	22.07	22.88	24.74	25.12	27.35
T_6 = Clean water wash & store at (10±1)^{0}C		22.12	24.91	26.14	28.79	spoil	Spoil
T_7 = NaOCl Wash & store at TA	22.46	25.01	Spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		21.97	22.76	23.06	24.97	25.97	28.17
T_9 = NaOCl Wash & store at (10±1)^{0}C		23.78	26.12	29.01	30.11	spoil	Spoil
Coordinates (b*)							
T_1 = No wash & store at TA	19.43	10.03	Spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		18.43	17.03	16.12	14.71	12.61	CI
T_3 = No wash & store at (10±1)^{0}C		17.14	16.12	12.31	9.71	spoil	Spoil
T_4 = Clean water wash & store at TA	26.33	12.03	Spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		25.33	23.45	21.55	18.17	14.31	12.74
T_6 = Clean water wash & store at (10±1)^{0}C		22.12	18.96	17.72	12.02	spoil	Spoil
T_7 = NaOCl Wash & store at TA	30.63	13.81	Spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		26.57	23.74	22.05	20.09	15.09	13.31
T_9 = NaOCl Wash & store at (10±1)^{0}C		27.32	20.14	18.35	14.03	spoil	Spoil

Note: TA- Ambient Temperature, CI- Chilling Injury

Table 3. Effect of different washing and storage temperatures on the internal/inside color parameters of plum

Treatments	Color parameters of plum at different duration (day)						
	0	7	14	28	42	56	70
Lightness (L)							
T_1 = No wash & store at TA	42.32	39.78	Spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		43.56	44.03	45.13	47.47	49.14	CI
T_3 = No wash & store at (10±1)^{0}C		44.95	46.13	49.01	51.71	spoil	Spoil
T_4 = Clean water wash & store at TA		46.36	Spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		45.03	47.17	49.48	51.52	52.13	53.49

Treatments	Color parameters of plum at different duration (day)						
	0	7	14	28	42	56	70
T_6 = Clean water wash & store at $(10\pm1)^0$C		47.16	49.17	51.14	53.46	spoil	Spoil
T_7 = NaOCl Wash & store at TA		51.03	Spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at $(5\pm1)^0$C		46.15	49.12	51.37	52.79	53.66	54..07
T_9 = NaOCl Wash & store at $(10\pm1)^0$C		49.52	50.61	51.94	54.09	spoil	Spoil
Coordinates (a*)							
T_1 = No wash & store at TA		13.19	Spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at $(5\pm1)^0$C	7.04	9.30	13.76	20.17	22.71	25.13	CI
T_3 = No wash & store at $(10\pm1)^0$C		11.72	16.98	23.12	27.43	spoil	Spoil
T_4 = Clean water wash & store at TA		15.11	Spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at $(5\pm1)^0$C	7.80	10.74	16.56	21.03	23.46	27.02	30.12
T_6 = Clean water wash & store at $(10\pm1)^0$C		13.19	18.14	26.17	30.29	spoil	Spoil
T_7 = NaOCl Wash & store at TA		16.31	Spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at $(5\pm1)^0$C	8.38	11.12	17.14	22.13	24.04	28.17	31.41
T_9 = NaOCl Wash & store at $(10\pm1)^0$C		14.02	19.11	28.08	32.12	spoil	Spoil
Coordinates (b*)							
T_1 = No wash & store at TA		14.26	Spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at $(5\pm1)^0$C	19.58	16.01	11.75	9.87	7.05	6.25	CI
T_3 = No wash & store at $(10\pm1)^0$C		10.32	8.97	7.03	6.52	spoil	Spoil
T_4 = Clean water wash & store at TA		16.12	Spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at $(5\pm1)^0$C	20.34	17.12	13.65	10.92	8.14	7.74	5.67
T_6 = Clean water wash & store at $(10\pm1)^0$C		12.45	9.24	7.89	7.24	spoil	spoil
T_7 = NaOCl Wash & store at TA		17.08	spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at $(5\pm1)^0$C	21.51	18.72	14.03	11.74	8.91	8.05	6.35
T_9 = NaOCl Wash & store at $(10\pm1)^0$C		13.97	10.13	8.31	7.69	spoil	Spoil

Note: TA- Ambient Temperature, CI- Chilling Injury

Decay index (%) and percent weight loss

The effect of different washing and storage temperatures on the decay index and weight losses of plum is given in Table 4. The highest decay percentage was observed in untreated no wash plum fruit (28.99%) in treatment T_1 followed by treatment T_4 (24.69%) and T_7 (16.67%) for wishing with clean water and 150ppm NaOCl, respectively after 7 days of storage. No decay percentage was observed when stored at $(5\pm1)^0$C and $(10\pm1)^0$C after 7 days. On the other hand, after 42 days the plum stored at $(10\pm1)^0$C; the highest decay percentage was observed in untreated plum fruit in treatment T_3 (27.50%) followed by treatment T_6 and T_9 due to the reason of washing but in the same duration plum stored at $(5\pm1)^0$C, there was no decay percent was seen in treatments T_2, T_5 & T_8. After 70 days the plum was stored at $(5\pm1)^0$C, the highest decay percentage was observed in untreated plum in treatment T_2 (29.89%) followed by the treatments T_5 and T_8. The control sample had the highest disease development and flesh rot along with the highest browning index during the storage period (Apai, 2009). Also, increased decay of produced wilt and freshness decrease and caused in browning on the pericarp (Shodchit *et al*., 2008). The lower decay index indicated that an inhibiting microbial effect and reduced respiration rate because of washing effect on plum fruits. This finding is reliable with the described data on fruit decay of untreated longan fruits (Apai, 2010; Hai *et al.*, 2011 & 2014).

Loss of weight in fresh fruit and vegetables is mainly due to the loss of water caused by transpiration and respiration processes. For ambient temperature, the highest weight losses were observed in untreated sample in treatment T_1 (8.53) followed by treatments T_4 & T_7 after 7 days of

storage. For stored at $(10\pm1)^0$C temperature, the highest weight losses were observed in no wash sample in treatment T_3 (14.12) followed by treatments T_6 (wash with clean water) and T_9 (wash with NaOCl) after 42 days of storage. On the contrary, the highest weight losses were observed of 21.27 in treatment T_2 (no wash) and the lowest was 13.17 in T_8 (wash with NaOCl) after 70 days of stored at $(5\pm1)^0$C it might be happened due the wishing effect of plum as well as the biochemical and physical structure of plum fruits depends on the cultivar, ripeness, harvest stage, climatic and cultural conditions (Possingham *et al.,* 1967). The significant effect of storage temperature was seen using fresh plum wash with clean water and wash with sodium hypochlorite. Ohtha (2017) stated that more than 5% of weight loss caused a reduction in retail value of vegetables and fruits. Maximum rate of respiration might be responsible for increased weight loss in untreated sample whereas clean water and sodium hypochlorite solution might have decreased respiration rates in treated fruit samples during storage as reported by Faust (1978). Correspondingly, Akhtar *et al.,* (2010) showed lower weight losses in treated apricots compared to untreated one which stored at 4°C for ten weeks.

Table 4. Effect of different washing and storage temperatures on decay index and weight losses of plum

Treatments	Decay index and weight loss of plum at storage (day)					
	Decay index (%)			Weight loss (%)		
	7	42	70	7	42	70
T_1 = No wash & store at TA	28.99	-	-	8.53	-	-
T_2 = No wash & store at $(5\pm1)^0$C	0.00	0.00	29.89	2.44	13.39	21.27
T_3 = No wash & store at $(10\pm1)^0$C	0.00	27.50	-	3.66	14.12	-
T_4 = Clean water wash & store at TA	24.69	-	-	7.80	-	-
T_5 = Clean water wash & store at $(5\pm1)^0$C	0.00	0.00	26.67	2.20	12.63	18.43
T_6 = Clean water wash & store at $(10\pm1)^0$C	0.00	24.17	-	3.17	13.15	-
T_7 = NaOCl Wash & store at TA	16.67	-	-	7.55	-	-
T_8 = NaOCl Wash & store at $(5\pm1)^0$C	0.00	0.00	16.26	1.96	9.42	13.17
T_9 = NaOCl Wash & store at $(10\pm1)^0$C	0.00	17.50	-	2.93	10.14	-

Note: TA- Ambient Temperature

Measurement of pH and acidity

The effect of different washing and storage temperatures on the pH and acidity content of plum are shown in Table 5. Initially the pH was observed in the sample was 2.8 but the highest increase of pH was 3.16 seen in treatment T_1 and the lower was 2.85 in treatment T_9 after 7 days of storage at ambient temperature, it might be given due to untreated and treated sample with washing effects. However, the pH was increased day by day up to 70 days of storage compared with starting for the temperature of $(5\pm1)^0$C. This increase in pH could be related to a possible decrease in the respiratory metabolic activity, because the levels of O2 and CO2 change during storage and different parameters were determined to assess the quality of the fruits stored at different temperatures (Silva et al. 2013).

At the beginning of storage, acidity was observed in the sample 2.56 but the highest decrease of acidity was 1.63 seen in treatment T_7 and followed by the treatments T_4 and T_1 after 7 days of storage at ambient temperature; it might be observed due to the treated and untreated sample with the effects of washing. But, the acidity was decreased day by day up to 70 days of storage at the temperature of $(5\pm1)^0$C. Organic acids usually decrease in several fruits except in banana as they are respired or converted to sugar (Seymour, 1993). Several enzymes can have an influence on the level of organic acids caused decrease in the rate of respiration and delayed the climacteric peak, which may be the reason for lower value of acidity of fruits (John and Marchal, 1995).

Table 5. Effect of different washing and storage temperatures on the pH and acidity content of plum

Treatments	pH and acidity of plum at different duration (day)						
	0	7	14	28	42	56	70
pH							
T_1 = No wash & store at TA		3.16	spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		2.89	2.93	2.97	3.01	3.09	3.15
T_3 = No wash & store at (10±1)^{0}C	2.8	3.05	3.18	3.24	3.41	spoil	Spoil
T_4 = Clean water wash & store at TA		3.03	spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		2.87	2.89	2.92	2.98	3.04	3.13
T_6 = Clean water wash & store at (10±1)^{0}C		2.99	3.15	3.18	3.29	spoil	Spoil
T_7 = NaOCl Wash & store at TA		3.01	spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		2.85	2.87	2.91	2.97	3.02	3.10
T_9 = NaOCl Wash & store at (10±1)^{0}C		2.91	3.07	3.14	3.24	spoil	Spoil
Acidity (%)							
T_1 = No wash & store at TA		1.80	spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		2.33	2.31	1.87	1.75	1.65	1.52
T_3 = No wash & store at (10±1)^{0}C		2.4	2.28	2.09	1.78	spoil	Spoil
T_4 = Clean water wash & store at TA	2.56	1.75	spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		2.25	1.99	1.83	1.73	1.63	1.49
T_6 = Clean water wash & store at (10±1)^{0}C		2.23	2.15	2.06	1.65	spoil	Spoil
T_7 = NaOCl Wash & store at TA		1.63	spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		2.21	1.96	1.78	1.71	1.61	1.47
T_9 = NaOCl Wash & store at (10±1)^{0}C		2.21	2.05	1.94	1.35	spoil	Spoil

Note: TA- Ambient Temperature

Measurement of vitamin C and β-carotene

The effect of different washing and storage temperatures on the vitamin C and β-carotene content of plum are depicted in table 6. Initially the vitamin C was observed in the sample was 15 mg/100g but the highest decrease of vitamin C was 8.5 mg/100g seen in the treatment T_1 followed by 9.20 mg/100g and 9.50 mg/100g for the treatments of T_4 and T_7, respectively after 7 days of storage at ambient temperature, it might be given due to untreated and treated sample with washing effects. However, the vitamin C was also decreased day by day up to 70 days of storage as compared to the start of storage with the temperature of (5±1)^{0}C. The vitamin C has the least stability among all kinds of vitamins and is easily destroyed during processing and storage, depending on many variables such as pH (Munyaka et al., 2010b; Wechtersbach et al., 2011), temperature (Rattanathanalerk et al., 2005; Tiwari et al., 2009a&b), light (Zhan et al., 2012; Noichinda et al., 2007) and the presence of enzymes (Munyaka et al., 2010a).

During start of experiment, β-carotene was investigated in the sample 60.00 μg/100g but the highest decrease of β-carotene was 22.63 seen in treatment T_1 and followed by the treatments T_4 and T_7 after 7 days of storage at ambient temperature; it might be observed due to the untreated and treated sample with the effects of washing. But, the β-carotene was decreased day by day up to 70 days of storage associated with an initial stage of treated sample for the temperature of (5±1)^{0}C. In β-carotene content, for the storage period increases, there was significant decrease in the β-carotene content of the stored plum and the loss of β-carotene could be due to non-oxidative changes or oxidative changes on exposure to light and oxygen. The analogous variation was observed by Dutta *et al.* (2005) for carrot and Aruna et al. (1999) for papaya during the investigation of β-carotene content of stored product.

Table 6. Effect of different washing and storage temperatures on the vitamin C and β-carotene content of plum

Treatments	Vitamin C and β-carotene of plum at different duration (day)						
	0	7	14	28	42	56	70
				Vitamin C (mg/100g)			
T_1 = No wash & store at TA		8.50	spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		12.46	11.54	10.07	8.70	6.70	6.10
T_3 = No wash & store at (10±1)^{0}C		11.05	9.15	8.17	7.60	spoil	Spoil
T_4 = Clean water wash & store at TA	15.00	9.20	spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		12.91	11.82	11.17	9.91	7.69	7.11
T_6 = Clean water wash & store at (10±1)^{0}C		11.78	9.74	8.54	8.61	spoil	Spoil
T_7 = NaOCl Wash & store at TA		9.50	spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		13.02	12.14	11.94	10.54	7.98	7.45
T_9 = NaOCl Wash & store at (10±1)^{0}C		11.87	10.02	9.65	8.92	spoil	Spoil
				β-carotene (µg/100g)			
T_1 = No wash & store at TA		22.63	spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		43.01	35.15	32.17	28.74	25.06	23.11
T_3 = No wash & store at (10±1)^{0}C		33.91	26.01	16.33	12.58	spoil	Spoil
T_4 = Clean water wash & store at TA	60.00	23.05	spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		45.14	37.41	33.35	29.17	25.97	24.12
T_6 = Clean water wash & store at (10±1)^{0}C		34.01	27.07	18.05	13.15	spoil	Spoil
T_7 = NaOCl Wash & store at TA		23.97	spoil	spoil	spoil	spoil	Spoil
T_8 = NaOCl Wash & store at (5±1)^{0}C		45.79	38.01	33.97	29.89	26.14	24.97
T_9 = NaOCl Wash & store at (10±1)^{0}C		36.11	28.13	18.49	14.41	spoil	Spoil

Note: TA- Ambient Temperature

Measurement of total soluble solid (TSS)

The effect of different washing and storage temperatures on the total soluble solid (TSS) of plum were expressed in Table 7. The measurement showed that the initial TSS content of the sample was 8.5, but generally the TSS content of stored plum in all the treatments were increased after prolong storage. It might be happened during ripening was due to breakdown of starch and polysaccharides into simple sugars, although maturation and ripening could also have been due to partial breakdown of pectin's and celluloses (De Lima *et al.*, 2001). This result has conformity with other researchers and reported by Apai (2010) and Hai et al. (2011 & 2014) for longan fruits; Chowdhury et al. (2008) for apple and papaya.

Table 7. Effect of different washing and storage temperatures on the total soluble solid (TSS) of plum

Treatments	TSS (%) of plum at different duration (day)						
	0	7	14	28	42	56	70
T_1 = No wash & store at TA		8.9	spoil	spoil	spoil	spoil	Spoil
T_2 = No wash & store at (5±1)^{0}C		8.5	8.7	8.8	8.9	9.1	CI
T_3 = No wash & store at (10±1)^{0}C		9.0	9.3	9.9	10.3	spoil	Spoil
T_4 = Clean water wash & store at TA	8.5	9.1	spoil	spoil	spoil	spoil	Spoil
T_5 = Clean water wash & store at (5±1)^{0}C		8.6	8.8	8.9	9.0	9.2	9.3
T_6 = Clean water wash & store at (10±1)^{0}C		9.2	9.5	10.1	10.5	spoil	Spoil
T_7 = NaOCl Wash & store at TA		9.2	spoil	spoil	spoil	spoil	Spoil

Treatments	TSS (%) of plum at different duration (day)						
	0	7	14	28	42	56	70
T_8 = NaOCl Wash & store at $(5\pm1)^0$C		8.7	8.9	9.1	9.2	9.3	9.5
T_9 = NaOCl Wash & store at $(10\pm1)^0$C		9.4	9.6	10.3	10.8	spoil	Spoil

Note: TA- Ambient Temperature, CI- Chilling Injury

Conclusion

For analyzed stored plum firmness, internal and external color, decay index, weight loss, pH, acidity, vitamin C, β-carotene and TSS data, it was noticed that in an ambient temperature (treatments T_1, T_4 and T_7) after 7 days stored plum was spoilage. However, in cold room when the storage temperature was $(10\pm1)^0$C for the treatments of T_3, T_6 and T_9; the plum quality was good up to 42 days of storage with minor chilling injury after that it was spoilage. On the other hand, the stored plum temperature was maintained at $(5\pm1)^0$C for the treatments of T_2, T_5 and T_8; the plum was stored up to 70 days without any spoilage just found some chilling injury. Therefore, newly introduced technology has a scope for commercialization of fresh plum at industry level for manufacturing shelf-stable products using these stored fruits for their efficient and profitable utilization to ensure reduction in post-harvest losses.

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CHANGES IN THE QUALITY CHARACTERISTICS DURING STORAGE OF PLUM JAM AND ITS OPTIMAL PREPARATION CONDITIONS

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Introduction

Functional food development and consumption is gaining momentum worldwide. Currently, there is an awaken awareness on preventive rather than curative health care. And it has been discovered that consumption of functional foods will serve as vital instrument for preventive health care; globally, the consumption of functional foods is being encouraged. In fact, in bakery products developments, there is a new trend of research into the development of flours with health benefits by incorporating fruit pomaces, fibres and legumes to cereals (Awolu et al., 2016 & 2017). Fruits are important foods with excellent nutritional and functional properties. Populations that consume diet rich in fruits and vegetables have significantly lower rates of many types of cancers (Fila et al., 2013). Fruit and vegetables are either consumed directly or after being processed to products such as fruit purees or jams (Marjan & Johari, 2010).

Plums belong to the Prunes genus of plants and are relatives of the peaches, apricots, almonds and nectarines. Jams are thick; sweet spreads made by cooking crushed or chopped fruits with sugar. They tend to hold their shape, but are generally less firm than jellies (Barbara, 2008). Availability of fruits is seasonal and therefore, jam production from fruits helps the availability of fruits at off-seasons. Jam enjoys substantial shelf life and thus can be made available round the year. Jam production requires right proportion of the right ingredients to get the desired result, which are; fruits, acid, pectin and sugar (Awolu et al., 2018). Therefore, the overall objective of the research is to prepare and standardized plum jam to analyze the quality characteristics of prepared jam at various concentrations of sugar and to extend the shelf life of the developed product.

Materials and Methods

Collection of plum

Plum (BARI Alu bukhara-1) having optimum maturity and firm texture was collected from the Spices Research Center of Bangladesh Agricultural Research Institute (BARI) and local farmer. The plums were transported in plastic crates to the Postharvest Technology Division Laboratory of BARI, Gazipur. After sorting, the plum was washed and dried under a ceiling fan.

Method of processing of plum jam

At first the fresh plum was collected, sorted, measured, clean and heated the plum in boiling water. After twenty minute boiling then it cool and separate seeds by bamboo made chalni. Then, the blended pulp took in a pan and adding sugar and heated continuously. Add citric acid and cook slowly and stir randomly and heated until the Brix reached to 65^{o}C. Then 1.2% (w/w) pectin and KMS was added and mixed properly. Heating was continued until the TSS reached to 67- 68^{o} Brix. The prepared jam was then poured in previously sterilized glass bottle and caped. Thereafter, the prepared plum jam was stored in room temperature (27±3^{o}C) and observed visually for 60 days and analyzed the quality parameters two months' interval up to twelve months of storage.

There were five treatments as:

T_1 = using 0% sugar in plum pulp;
T_2= using 25% sugar in plum pulp;
T_3= using 50% sugar in plum pulp;
T_4= using 75% sugar in plum pulp;
T_5= using 100% sugar in plum pulp;

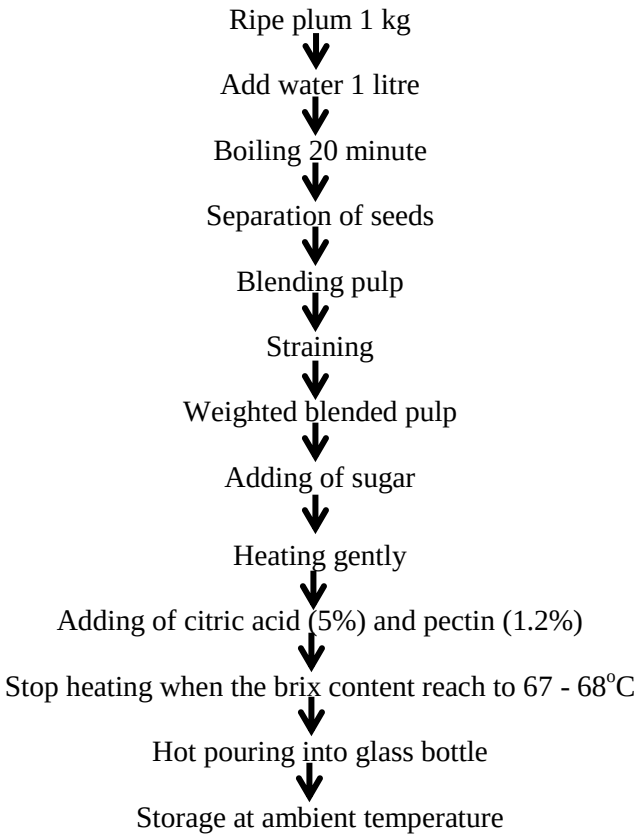

Figure 1. Process flow diagrams for plum jam preparation

Product appearance/color

Stored plum jam colors were determined using a tristimulus colorimeter (CR-400, Minolta Corp., Japan) with 8-mm aperature and C light source at two equidistant points on the equator of each sample by using CIE color system on the L, a*, b* color space where L, a*, b* coordinates were recorded using D65 illuminants and a 10° standard observer as a reference system. *L** is lightness, *a** (-greenness to +redness) and *b** (-blueness to +yellowness) are the chromaticity coordinates.

Measurement of pH

The sample (5 g) was diluted with 45 mL distilled water, and pH was measured with glass electrode (EUTECH Instruments, Selangor, Malaysia).

Measurement of titratable acidity

The titratable acidity (TA) was analyzed using the titration method. Jam sample (10 g) were homogenised using a kitchenblender with 40 ml of distilled water. The mixture was then filtered through cotton wool. The filtrate (5 ml) with one to two drops of phenolphthalein (0.1%) as indicator was titrated using 0.1 N NaOH to an endpoint pink (p^H 8.1). The results were expressed as the percentage citric acid per 100 g fresh weight.

Measurement of ascorbic acid

Ascorbic acid content was determined as per AOAC (1995) method using 2, 6- dichlorophenol indophenol dye. The sample extracted in 3% m-phosphoric acid was titrated with dye to pink colour end point. The results were expressed as mg per 100g of sample and calculated by using the following formula:

$$\text{Ascorbic acid}\,(\text{mg}/100\text{g}) = \frac{\text{Titre} \times \text{Dye factor} \times \text{Vol. made up}}{\text{Aliquot of extract taken} \times \text{Weight of sample taken}} \times 100$$

Measurement of β-carotene

The estimation of β-carotene was done by the extraction of 3g product sample with acetone (Fisher Scientific Ltd., Uk) and petroleum ether. It was further purified with acetone, metabolic KOH and distilled water. The resulting solution was filtered with anhydrous sodium sulphate and read on a spectrophotometer (T-80, PG Instrument Ltd., UK) at 451nm against petroleum ether as a blank. A

standard graph was plotted using synthetic crystalline B-carotene (Fluka, Germany) dissolved in petroleum ether and its optical density measured at 451 nm (Alasalvar *et al.,* 2005).

Measurement of total soluble solid (TSS)

Total soluble solid in the extracted juice of plum jam was measured by a refractometer (ATAGO (Brix = 0 to 32%)) and the results were expressed as % Brix.

Total phenol

Total phenolic content was extracted with 80 percent ethanol and was estimated based on their reaction with an oxidizing agent phosphomolybdate in Folin-Ciocalteau reagent under alkaline conditions (Bray & Thorpe, 1954). The developed blue color was measured at 650 nm in a UV-VS spectrophotometer (Shimadzu, Japan). The standard curve was prepared using different concentrations (8-32 μg/mL) of catechol and the result was expressed as mg per 100g on a fresh weight basis.

Microbial count

Microbial load of the plum jam was determined with the use of plate count agar. The microbial load count was performed each month interval up to 12 months' storage. In the process of counting, a 10g pickle sample was homogenized with 90ml buffer peptone water solution and then 10μL suspension inoculated in the plate count agar (PCA) medium through 10-fold serial dilution. Then, the inoculated plate was incubated at 37^0C for 24 hrs in an incubator (Model: SHC-4A1). Different bacterial colony grown in that medium was counted. For the number of colony count in cfu/g the following formula was used:

$$\text{Colony Formin g Unit}\left(\frac{\text{cfu}}{\text{g}}\right) = \frac{\text{No. of colony} \times \text{Dilution} \times \text{Time of dilution}}{\text{Sampale inoculated to plate / media}}$$

Sensory evaluation

The sensory evaluation of the plum jam was carried out at every 2 months interval during storage using a sensory taste questionnaire judged by expert sensory panelists. Each treatment was assigned a letter code to avoid biases among the panelists. The samples were presented to panelists in different orders to avoid order preference among the panelists. The osmo-dehydrated plum was rated by 10 experienced panelists who were asked to score samples based on the plum external color, off-flavor, firmness, sweet-sour balance, and overall acceptance using a 9-point hedonic scale.

Research progress

The establishment of this experiment has been finished just last month and data has not been collected yet. From this month, laboratory data will be analyzed to measure jam color, pH, acidity, vitamin C, β-carotene, TSS, total phenol, microbial count and sensory evaluation. The plum jam will be stored in an ambient condition for 1 year. For the time being, data will be collected, analyzed and presented in later.

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EFFECT OF DIFFERENT FRUIT JUICE ON THE PHYSICOCHEMICAL PROPERTIES, BIOACTIVE COMPOUNDS AND SHELF LIFE OF JACKFRUIT LEATHER

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Abstract

Fruit leathers are nutritious products that are made by dehydrating a thin layer of fruit puree or juice under specific conditions to obtain a chewy snack. The aim of this study was to prepare jackfruit leather using lemon and tamarind juice to reduce the strong jackfruit flavor. Fully ripe Gala jackfruit cultivar was collected from the farmer's orchard and peeled and then cut longitudinally to separate the bulb. The bulb was blended and extracted the pulp. Tamarind and lemon were collected to prepare the juice. For this 10% of lemon and tamarind juice were added into jackfruit pulp to prepare jackfruit leather and jackfruit leather without fruit lemon or tamarind juice was used as the control treatment. Results revealed that after 4 months of storage, the moisture content ranged from 10.29 to 15.76% and the ash content varied from 2.00 to3.10%. The acidity and reducing sugar increased with the storage period while total sugar decreased. All the jackfruit leather contained significant amount of energy value (394 to 542 KCal/100g). The color of jackfruit leather was bright yellow to dark yellow. Results also showed that prepared jackfruit leather contained satisfactory amounts of different bioactive compounds and exhibited antioxidant properties during 120 days of storage at ambient temperature (27±2^{o}C & 75±5%RH). The overall sensory qualities of jackfruit leather were acceptable; however, lemon juice added leather showed higher acceptability than the other treatments. Therefore, it can be concluded that use of fruit juice in jackfruit leather would improve the nutritional quality of jackfruit leather with consumer acceptability.

Introduction

Fruit leather is also called a fruit bar or a fruit slab, is a dehydrated fruit-based confectionery dietary product which is often eaten as snack or dessert (Joshipura *et al.,* 2001; Safei *et al.,* 2019). It is chewy and flavorful, naturally low in fat and high in fiber and carbohydrates; it is also lightweight and easily stored and packed (Diamante *et al.,* 2014). Consuming fruit leather is an economic and convenient value-added substitute for natural fruits as a source of various nutritional elements. Furthermore, the fruit leather has far fewer calories, ≤ less than 100 Kcals per serving, than many other snacks (Fransiska *et al.,* 2015). The fruit leathers are restructured fruit made from fresh fruit pulp or a mixture of fruit juice concentrates and other ingredients after a complex operation that involves a dehydration step (Fransiska *et al.,* 2015; Huang *et al.,* 2006). Fruit pulp-based fruit leathers are nutritious and organoleptically acceptable to the customers. They contain substantial quantities of dietary fibers, carbohydrates, minerals, vitamins, and antioxidants (which remain constituents of the finished product) (Diamante *et al.,* 2014; Torres *et al.,* 2015). There are large numbers of fruit leather products available on the market, such as mango leather, apricot fruit leather, grape leather, berry leather, and kiwifruit leather. In addition, mixed fruit leathers like guava and papaya fruit leather are also available in many countries.

Among the tropical fruits, jackfruit is an important underutilized fruit and often called the poor man's fruit because of its affordability and availability in large quantities during the fruiting season. Jackfruit trees are mostly gown in the homestead garden without any management practices. This is the national fruit of Bangladesh which is grown almost in all districts. The annual production of jackfruit is about 10.02 lakh metric ton covering an area of 40.90 thousand acres during 2019-2020 (BBS, 2020). Jackfruit is nutritionally very rich and contains high amount of vitamins and minerals. The fruit is rich in carotene and carbohydrates and moderately rich in ascorbic acid. It also contains some minerals like calcium and potassium and vitamin B like thiamin, riboflavin, and niacin (Saxena *et al.,* 2009; Swami *et al.,* 2012). Thus, jackfruit provides huge opportunity for livelihood as well as nutritional and food security of the rural communities of Bangladesh. Jackfruits can be processed into a variety of products such as canned fruit, dried fruit and pulp, jackfruit jam, dehydrated jackfruit, chips etc. (Swami *et al.,* 2012; Swami and Kalse, 2019) Therefore, jackfruit has great potential for value addition to minimize postharvest loses and to enhance the non-seasonal unavailability. Despite being a store-house of different health beneficial properties, the fruit is less popular and people dislike consuming it due to its strong flavor. At the same time, people are highly conscious to their health and very much interested to have products with different health beneficial properties such as ascorbic acid, phenolic, carotenoids etc. Different initiatives are taken time to time to reduce this odd flavor, among

them, incorporation of lemon, and tamarind could be a potential alternative in this regards. These fruits are known for their high nutritive values along with different health favorable compounds like carotenoids, polyphenols, flavonoids, and antioxidant properties. In the present study, lemon and tamarind juice have been used during preparation of jackfruit leather and their impact was assessed in terms of physicochemical properties and bioactive compounds during storage.

Materials and Methods

Collection and preparation of raw materials

Fresh and fully ripe jackfruit of Gala cultivar was collected from the farmer's orchard of Gazipur, Bangladesh. The fruit was washed with running tap water, cut longitudinally to separate the bulb. The pulp was made by blending the bulb after removing the seed. Tamarind and lemon was collected from the local super markets and their juice was prepared. Other ingredients were used from the laboratory stock. Analytical grade chemicals and reagents were purchased from the Merck, Germany through local traders.

Preparation of jackfruit leather

The general process of making fruit leather involves the preparation of the fruit puree, with or without addition of other ingredients before mixing and then drying (Figure 1). These processes may vary depending on the fruit used, the nature of the additional ingredients and the drying method with technology. In the present study, jackfruit leather was prepared from the pulp along with other ingredients such as: pulp-1 kg, sugar-100g, salt-1g, black salt-2g, red chilli powder-1g, turmeric powder-1g and mixed spice-1g. Fruit juices (lemon, tamarind and mixed juice, 1:1) were incorporated at the rate of 100 mL (10%) per 1 kg of jackfruit pulp. The protocol of jackfruit leather processing is given below:

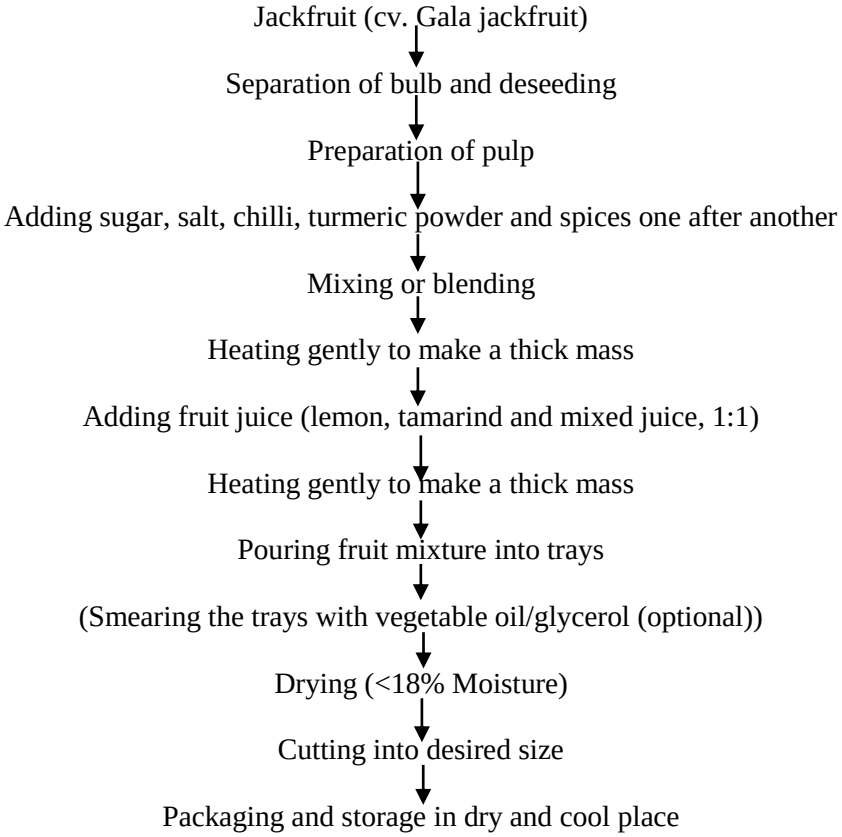

Figure 1. Processing protocol of jackfruit leather

The prepared samples were stored at room temperature and the shelf life was evaluated over four months (4) months at 2 months interval.

Determination of physicochemical properties

The moisture and ash content were determined based on the AOAC official methods (AOAC, 2005). Total acidity was determined following the method of Ranganna (2007). Firmness was measured using the texture analyzer (TX.Plus, Stable Microsystem, Germany) and expressed as the

kg/cm^2. Total sugar content was determined following the procedure of Ranganna (2007). The calorific value was determined using the bomb calorimetric method. Color attributes were measured based on the CIELa*b* color coordinates using a Chroma meter (CR-410, Konica Minolta, Inc., Japan), where L denotes the lightness, a* represents green/red, and b* implies blue/yellow.

Determination of bioactive compounds and antioxidant activity

Ascorbic acid content was determined by 2,6-dichlorophenolindophenol titrating methods following the description of Kamal *et al.* (2019) and the result was expressed as mg/100g. The total carotenoids was determined by the methods of Baria *et al.* (2018) with some modification. The total phenolic content was evaluated following the protocols of Kamal *et al.* (2020) with slight modification using gallic acid as the standard, and the result was expressed as mg GAE/100g of sample. The antioxidant activity of jackfruit leather was evaluated in terms of DPPH free radical scavenging activity, which was expressed as percent inhibition (Kamal *et al.*, 2019).

Sensory evaluation

The sensory properties such as, color, taste, flavor, texture, and overall acceptability of jackfruit leather were evaluated twice over the storage period (initial and final storage day) by 15-trained panelists using 9-point hedonic scale.

Statistical analysis

Statistical analysis was carried out using the software package SPSS (version 22.0, SPSS Inc., Chicago, IL) by using one-way analysis of variance (ANOVA). Duncan Multiple Range Test (DMRT) at the significance level 5% ($P<0.05$) was used to determine significant differences among the samples during 4 months of storage periods.

Results and Discussions

Physicochemical properties of jackfruit leather

Table 1 represents the physicochemical composition of jackfruit leather. It is observed from the table 1 that the moisture content of jackfruit leather varied between 14.25 to 19.01% and 10.29 to 15.76% at the initial and after 120 days of storage. It is noticed that initially there was no significant difference among the jackfruit leather samples except control treatment (T_1), however, significant difference existent after 2 month and 4 months of storage. Also, the moisture content become decreased with the storage period. The ash content is an important quality parameter of foodstuffs as it is reflected the mineral constituents. The ash content of jackfruit leather was found to range from 1.88 to 2.82% at the beginning of storage, which was changed to 2.00 to 3.10% after 4-months of storage (Table 1). It is noticed that ash content significantly different among the samples, however, very little changes was observed during the storage period for all the treatments. Moreover, the maximum ash was recorded in the jackfruit leather prepared using lemon juice followed by control treatment and mixed sample and tamarind juice used leather sample, respectively (Table 1). The changes occurred may be due to the compositional difference as the moisture content decreased, which could increase the values of other constituents. From Table 1, an increasing trend was observed for the total acidity of the prepared jackfruit leathers samples during 4-months of storage, whose values were ranged from 0.94 to 4.58% at the beginning and 2.87 to 5.98% after 4-months of storage at ambient temperature (27±2^{o}C, 75±5%RH). It is noticeable from Table 1 that no significant difference was observed for jackfruit leather prepared using lemon and tamarind juice (T_2-T_4), however, the control treatment (T_1) differed significantly at 5% level of significance. The maximum acidity was recorded in treatment T_2 (lemon juice added leather) while minimum in the control treatment (T_1). The higher content of acidity value might be due to the addition of fruit juices (lemon and tamarind), which are regarded as high acidic fruits. The reducing sugar and the total sugar content of jackfruit leather were presented in Table 1. Initially, the reducing sugar content ranged between 9.63 to 12.56% and the total sugar varied from 26.04 to 28.45% while after 4-months of storage, it was found as 12.08-14.74% and 24.75-25.99%, respectively. It is observed that the changes in the sugar content of jackfruit leather was significant among the samples. Furthermore, reducing sugar content increased with storage time while the total sugar content decreased for all samples. The increasing trends of reducing sugar in jackfruit leather might be conversion of total and non-reducing sugars by acid hydrolysis and thereby inversion of total and non-reducing sugars to reducing sugars (Rahman *et al.*, 2012; Meyer, 1966; Roy and Singh, 1979). The calorific value was fluctuated between 393.92 to 426.89 KCal/100g and 505.47 to 542.25 KCal/100g at initial and after 120 days of storage, respectively (Table 1). It is observed that the

calorific value was increased with extension of storage time and these changes were significant. Among the treatments, treatment T_3 (tamarind juice used jackfruit leather) had the maximum calorific value while the control treatment (T_1) contained the minimum. The containment of calorific value mainly attributed by the content of protein, fat, carbohydrate present in the samples and varied with the changes in composition of the sample. Another important property of jackfruit leather was its firmness with very hard or firm sample significantly influences the quality of the product. In the present study, the firmness of jackfruit leather found in the range of 42.89-47.10 N and 55.45-75.20 N on the processing day and after 4-months of storage (Figure 2). It is seen that the firmness value became increased with the storage period. Initially, no significant difference was observed for firmness value for all the treatments, however, with extension of storage period, firmness value differed significantly among the treatments. After 120 days of storage, treatment (lemon juice used jackfruit leather) T_2-T_4 (mixed juice used jackfruit leather) was found as relative softer than the control treatment (T_1). The variation in the firmness of jackfruit leather might be the extent of drying that significantly reduced the moisture from the control treatment than the other treatments.

Color properties of jackfruit leather

The consumers purchase behavior is highly depending on the surface color of products. The color properties of jackfruit leather are presented in Table 2. The luminosity (L) decreased slightly in all samples during storage from 0 to 120 days and ranged between 32.69 to 37.16 and 28.83 to 33.17 at initial and 120 days of storage, respectively. The color parameter a* (green/redness) also decreased throughout the storage period irrespective of treatments and ranged between 7.57-9.74 and 5.44-6.98 at initial and 120 days of storage, respectively. On the other hand, the blue/yellowness (b*) ranged from 11.77-15.22 and 14.70-15.68 at initial and 120 days of storage, respectively. It is clearly demonstrated in Table 2 that with extending the storage period the color of jackfruit leather turned bright yellow to dark yellow for all samples. The changes in color values might be due to the enzymatic reactions induced by the presence of protein and carbohydrate substances in the jackfruit leather along with pigments degradation during drying (Kamal *et al.,* 2020).

Bioactive compounds and antioxidant activity

Bioactive compounds constitute an important groups of substances that have several health beneficial effect on human. These compounds include mostly secondary metabolites such as polyphenols, phenolic acids, flavonoids, flavones, ascorbic acids, carotenoids and so on (Molla *et al.,* 2021, Kamal *et al.,* 2019). Table 3 represents the bioactive compounds of jackfruit leather. It was noticed that the ascorbic acid content was found to range from 12.05-14.88 mg/100g and 8.23-9.29 mg/100g at the initial and 120 days of storage, respectively. The maximum ascorbic acid was recorded in treatment T_2 (lemon juice used jackfruit leather) while the minimum was recorded in control treatment (T_1). Table 3 also revealed that ascorbic acid was decreased in all samples throughout the storage period and differed significantly ($P<0.05$). Previous studies evidenced that the ascorbic acid is the most unstable substance which become reduced as a function of heat, light, reactions with metallic substances and so on (Kamal *et al.,* 2019; Mondal *et al.,* 2017).

The carotenoids content represent the combination of different pigment substances, which provide antioxidant activity and help the body to fight against different degenerative diseases. The total carotenoids of jackfruit leather presented in Table 3. It was observed that the carotenoids content of jackfruit leather varied significantly among the samples irrespective of storage period. These values were ranged between 17.41-26.49 mg/100g at initial stage while it was varied within 12.08-16.65 mg/100g after 120 days of storage. Table 3 also showed that the highest total carotenoid content was recorded in control treatment (T_1) while the lowest was in treatment T_4 (mixed fruit juice used jackfruit leather). From Table 3, it was observed that the total carotenoids were found to decrease during the storage periods, however, considerable amount was retained in all treatments. Previous studies evidenced that the carotenoid pigments are one of the vulnerable substance, which become lost during food processing operations such as drying, heating or boiling and also due to exposure in light sources (Kamal *et al.,* 2019). Furthermore, fruit maturity also influences the carotenoids content in foodstuffs. The total phenolic content of jackfruit leathers were summarized in Table 3. It was observed that initially the total phenolic content was found to range from 668.68-732.05 mg GAE/100g while it was ranged between 794.25 to 826.55 mg GAE/100g after 120 days of storage. It was noticed from Table 3 that the total phenolic content for all treatments at initial and 60 days of storage differed significantly while there was no significant difference observed after 120 days of

storage. Furthermore, the total phenolic content became increased with the increment of storage time (Table 3). The higher content of total phenolic content might be the reduction in enzyme reaction i.e., polyphenoloxidase activity that may be responsible for the release of phenolic compounds (Kamal *et al.,* 2020; Paul and Das, 2018). Moreover, the content of total phenolic content also influenced by the conjugation of polyphenols with other components of food matrices including proteins, sugar, organic acids and so on (Xu *et al.,* 2007; Kamal *et al.,* 2020).

The antioxidant property of jackfruit leather was evaluated based on the DPPH free radical scavenging activity and expressed as the % inhibition of DPPH radicals and the results obtained are shown in Figure 3. In the present study, the DPPH values for jackfruit leathers were varied between 53.31 to 73.45% on the initial storage day, which were found to range between 47.53 to 58.72% after 120 days of storage. It was clearly demonstrated in Figure 3 that the values of DPPH differed significantly ($P<0.05$) among the samples and were also found to decrease with the storage period increased. However, a significant amount of antioxidant activity was showed after 120 days of storage. The presence of flavonoids and different phenolic compounds along with the addition of different fruit juice boosted the antioxidant capacity of jackfruit leathers (Kamal *et al.,* 2019; Kulkarni & Aradhya, 2005).

Sensory attributes of jackfruit leather

The sensory evaluation of the jackfruit leather was conducted twice (at the initial day and 120 days) throughout the storage period. The results obtained for sensory attributes of jackfruit leather is demonstrated graphically in Figure 4. Sensory evaluation is one of the determinants of consumer's choice of a product. Color is one of the most important quality parameters of any products and is closely related to the perception of the product. It was observed that the color score for jackfruit leather was ranged from 8.40 to 8.60 points at the initial day, which was ranged from 7.30 to 8.20 points after 120 days of storage (Figure 4).

The flavor attribute was ranged from 8.10 to 8.80 at the beginning and 7.50 to 8.40 points after 120 days of storage period. The texture was ranged from 7.80 to 8.30 at the beginning and 7.10 to 7.90 after 120 days of storage (Figure 4). The taste property ranged from 8.30 to 8.60 at the initial day and 7.70 to 8.10 points after 120 days of storage. While the overall accessibility of jackfruit leather was ranged between 8.15 to 8.58 points at the beginning and 7.40 to 8.15 after 120 days of storage. It was observed that the sensory attributes were slightly decreased from the initial to 120 days of storage. It is noticeable that all the sensory attributes were acceptable while the texture value was slightly lower, which might be due to over drying or cell degradation during drying that created a hard texture of the jackfruit leather. It can be concluded from figure 4 that the sample prepared using lemon and tamarind juice provided the best sensory scores for all attributes and may be applied commercially for the production of jackfruit leather.

Table 1. Changes in physicochemical properties of jackfruit leather during 120 days of storage

Treatment	Moisture (%)			Ash (%)		
	0 Day	60 Days	120 Days	0 Day	60 Days	120 Days
T_1	14.25±0.51b	12.88±0.24c	10.47±0.52b	2.29±0.01b	1.88±0.13b	2.45±0.01b
T_2	18.79±0.84a	17.03±0.30b	14.72±0.27a	2.82±0.08a	2.66±0.21a	3.10±0.01a
T_3	19.01±0.03a	19.28±0.12a	10.29±0.22b	1.88±0.01c	1.94±0.14b	2.06±0.02c
T_4	18.51±0.08a	16.65±0.68b	15.76±0.22a	2.20±0.02b	1.79±0.06b	2.00±0.01d
Treatment	Acidity (%)			Reducing sugar (%)		
	0 Day	60 Days	120 Days	0 Day	60 Days	120 Days
T_1	0.94±0.02b	1.40±0.13c	2.87±0.05b	12.56±0.0a3	13.20±0.02a	13.41±0.04b
T_2	4.56±0.33a	5.27±0.02a	5.98±0.11a	10.89±0.27b	12.31±0.03b	14.74±0.19a
T_3	4.58±0.01a	4.84±0.20ab	5.60±0.40a	10.09±0.19c	13.21±0.03a	14.55±0.21a
T_4	4.26±0.08a	4.62±0.17b	5.60±0.04a	9.63±0.21c	13.22±0.04a	12.08±0.08c
Treatment	Total sugar (%)			Calorific value (KCal/100g)		
	0 Day	60 Days	120 Days	0 Day	60 Days	120 Days
T_1	27.63±0.05b	28.08±0.18a	25.20±0.05c	393.92±7.15b	432.90±5.93a	505.47±5.34b
T_2	28.45±0.14a	26.86±0.15b	24.75±0.14d	410.11±7.41ab	378.13±2.98c	508.77±1.11b
T_3	28.45±0.02a	26.18±0.24bc	25.65±0.07b	426.89±8.08a	405.69±7.81b	542.25±1.03a
T_4	26.04±0.35c	25.52±0.30c	25.99±0.03a	419.32±3.81a	392.80±4.86bc	510.98±0.95b

Values are mean ± standard error of mean (n=3); Means followed by different lowercase letters in each column are significantly different at P<0.05. T_1-Control; T_2-Lemon juice added; T_3-Tamarind juice added; T_4-Mixed Juice added

Table 2. Changes in color attributes of jackfruit leather during 120 days of storage

Treatment	L		
	0 Day	60 Days	120 Days
T_1	32.69±0.38b	32.52±0.63b	28.83±0.68b
T_2	34.59±0.61ab	32.89±0.66ab	30.54±0.04b
T_3	37.16±0.42a	34.62±0.31a	33.17±0.62a
T_4	36.21±0.28a	33.19±0.56ab	29.22±0.14b
Treatment	a*		
	0 Day	60 Days	120 Days
T_1	7.57±0.18b	5.53±0.21b	5.96±0.40ab
T_2	9.17±0.49a	6.42±0.24b	6.08±0.13ab
T_3	8.92±0.09a	8.91±0.75a	5.44±0.17b
T_4	9.74±0.28a	8.14±0.29a	6.98±0.40a
Treatment	b*		
	0 Day	60 Days	120 Days
T_1	12.67±0.21b	14.72±0.47b	15.68±0.06b
T_2	11.77±0.22c	12.88±0.36c	14.72±0.58b
T_3	15.22±0.25a	15.32±0.21b	17.02±0.18a
T_4	12.91±0.11b	16.75±0.38a	14.70±0.14b

Values are mean ± standard error of mean (n=3); Means followed by different lowercase letters in each column are significantly different at P<0.05. T_1-Control; T_2-Lemon juice added; T_3-Tamarind juice added; T_4-Mixed Juice added

Table 3. Changes in bioactive compounds of jackfruit leather during 120 days of storage

Treatment	Ascorbic acid (mg/100g)		
	0 Day	60 Days	120 Days
T_1	12.05±0.15b	11.17±0.34a	8.97±0.07a
T_2	14.88±0.38a	10.03±0.53a	9.29±0.03a
T_3	14.50±0.38a	11.24±0.08a	8.23±0.01b
T_4	13.72±0.39a	10.97±0.39a	8.69±0.08ab
Treatment	Total carotenoids (mg/100g)		
	0 Day	60 Days	120 Days
T_1	26.49±0.11a	18.82±0.27a	16.65±0.06a
T_2	18.16±0.14c	17.67±0.52b	12.31±0.01c
T_3	24.09±0.05b	16.71±0.17b	16.40±0.04b
T_4	17.41±0.03d	14.44±0.28c	12.08±0.03d
Treatment	Total phenol (mg GAE/100g)		
	0 Day	60 Days	120 Days
T_1	693.60±0.95c	704.72±16.47c	753.83±29.03a
T_2	732.05±1.32a	766.95±6.41b	809.93±9.69a
T_3	699.45±1.52b	822.78±17.46a	794.25±26.16a
T_4	668.68±1.34d	676.80±5.15c	826.55±96.28a

Values are mean ± standard error of mean (n=3); Means followed by different lowercase letters in each column are significantly different at P<0.05. T_1-Control; T_2-Lemon juice added; T_3-Tamarind juice added; T_4-Mixed Juice added.

Conclusion

Results of this study revealed a good content of nutritional and bioactive compounds along with excellent sensory performance of the jackfruit leather were observed. Based on the overall quality assessment for jackfruit leather, it can be concluded that lemon and tamarind juice can be added to jackfruit pulp during preparation of leather, which could boost up different nutritional as well as health beneficial compounds.

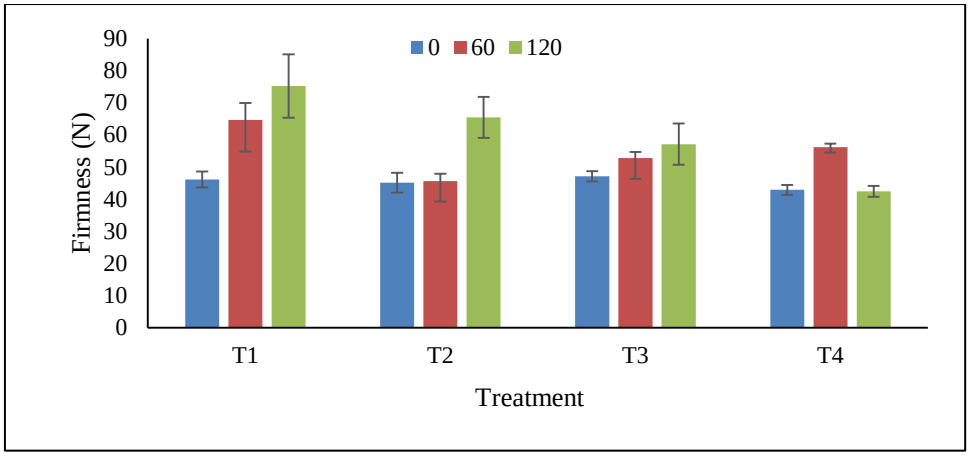

Figure 2. Firmness of jackfruit leather (T_1-Control; T_2-Lemon juice added; T_3-Tamarind juice added; T_4-Mixed juice added)

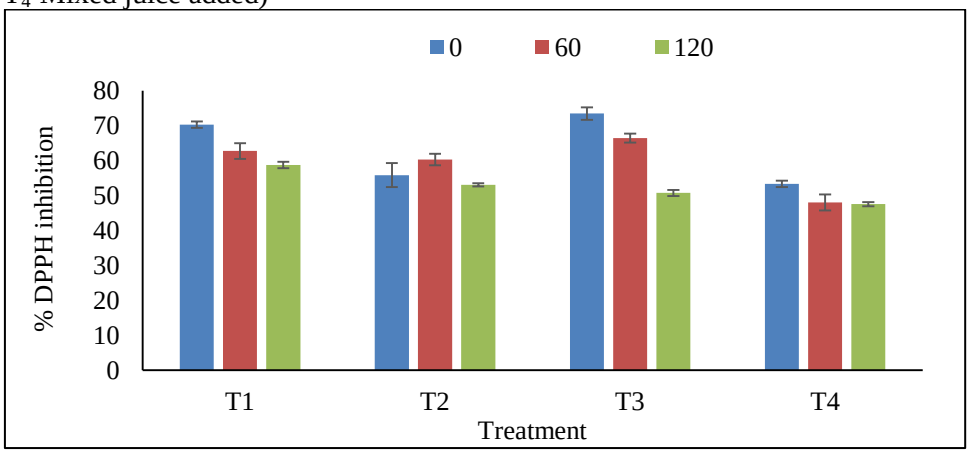

Figure 3. Antioxidant activity of jackfruit leather (T_1-Control; T_2-Lemon juice added; T_3- Tamarind juice added; T_4-Mixed juice added)

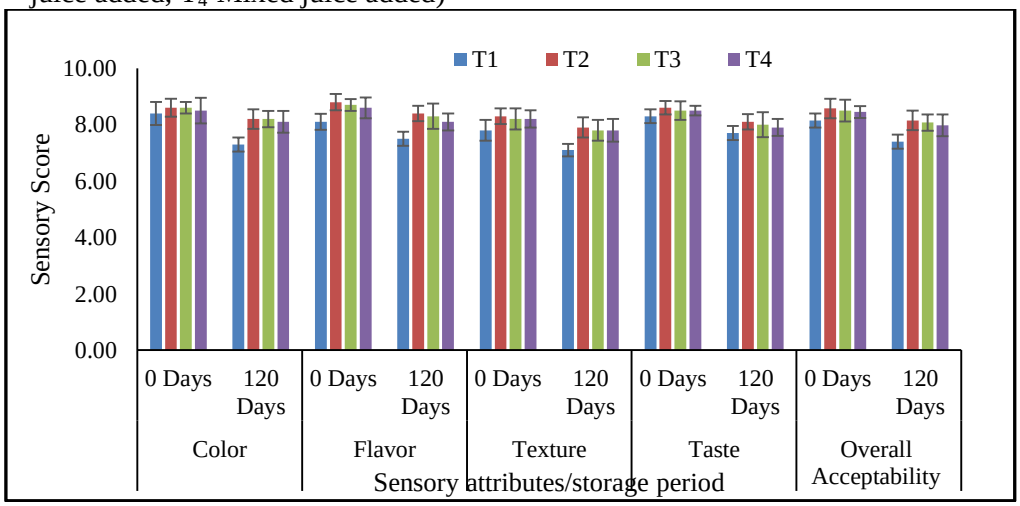

Figure 4. Sensory score of jackfruit leather during storage (T_1-Control; T_2-Lemon juice added; T_3-Tamarind juice added; T_4-Mixed juice added)

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BASELINE SURVEY ON EXISTING HAZARDS INFRESH CUT FRUITS AND SALAD VEGETABLES USED IN STREET VENDOR, HOTELS AND RESTAURANT AT SELECTED LOCATIONS IN BANGLADESH

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Abstract

The baseline survey was conducted with a view to generate information on existing status of hazardous agents in fresh-cut fruits and salad vegetables used for customer's consumption in hotels, restaurants, street vendor etc. at selected locations of Bangladesh. The baseline information was collected from three selected districts namely Dhaka, Gazipur and Bogura by an interview using pre-tested questionnaire. Fifteen respondents were randomly selected to collect the information from each location both from producer to consumer. The findings was that most of the hawkers of Dhaka was 21-40 years old (75%) followed by similar aged person of Bogura (62.5%). The result also showed that eighty percent people were above 20 years old engaged in fresh-cut fruits and salad vegetables processing and direct selling. 30% vendors of Bogura and 16.67 % vendors of Dhaka use hand gloves during processing time, respectively. Most of the vendors did not have much knowledge regarding the hazards (physical, chemical, microbiological and cross contamination) and hygienic practices which exists in environment in different ways. Most of the street and mobile vendors sell their food in consumable plate or normal poly bag. Almost 100% vendors don't use any sanitizer to wash the produce or clean the processing place. Most of the vendors serve immediately after cutting fresh-cut fruits and salad vegetables to the customers.

Introduction

Fresh-cut fruits and salad vegetable are popular in all over world and fresh-cut fruits and vegetables processing industry is expanding rapidly because of high demand to the customers for providing direct nutrient in our body. It plays an important role for nutritional security of any person who is health conscious. The fresh-cut market is popularizing day by day in Bangladesh. Street food vendor serve fresh-cut fruits and salad vegetables as a complement to the main dish. However, fresh-cut fruits and salad vegetables used in street food vendor should pay attention. These street food vendors pay less attention to maintain proper sanitation practice. Where they sale the produce is mainly crowded streets with a high pollution level. The fresh-cut fruits and vegetable salad served to the vendors has the potential to be contaminated by different hazards like microbiological, chemical and physical hazards. Microbiological hazards comprise any type of microbial contamination such as bacteria, virus, fungi, protozoa and parasites (Kitinoja and Kader, 2002). Fresh fruits and vegetables processing require proper handling and management practice because of its high perishable nature otherwise it faces enormous quality problems (Azad and Akter, 1994). Low sanitation practices in street food shop or open place selling could further increase the presence of microbiological hazards and affect foodborne illnesses for the human (Handa and Walia, 1996). The pathogenic bacteria *Escherichia coli* and *Salmonella* receive the most study attention as they potentially cause illnesses with a low infection dose. Enteropathogenic *Escherichia coli* has been found in some fresh fruits and vegetables salad products in many countries such as the US, Korea and Iran. Foodborne pathogens are causing a great number of diseases with significant effects on human health and economy. More than 200 different food-borne diseases have already been identified (Mead *et al.*, 1999).

A survey of 100 stalls conducted by the World Health Organization (WHO) showed that the primary safety issues pertaining to food served by the food stalls include raw or undercooked food, infected stalls and low hygiene during processing and storage of food (WHO, 2015). Based on those issues, it is necessary to determine the microbiological contamination in fresh fruits and salad vegetables caused due to inadequate sanitary practices of the stalls. Furthermore, the exposure level of microbiological hazards to the consumers of the food shop/stalls in Bangladesh still remains unknown because of the unavailability of proper training and literacy. On the above circumstances, the baseline survey was conducted in the selected locations of Bangladesh to generate information on existing status of fresh-cut fruits and salad vegetables from processing to marketing for measuring the sanitation level of the street food vendor, hotels and restaurants during directly serving fresh-cut fruits and salad vegetables to the customers.

Materials and Methods

Questionnaire development and conducting the baseline survey

A detailed survey questionnaire was prepared with the assistance of the Agricultural Economics Division of Bangladesh Agricultural Research Institute (BARI), Gazipur. The questionnaire was pre-

tested in the selected areas and then finalized for data collection. The baseline information was recorded from three districts namely Dhaka, Gazipur and Bogura. Fifteen vendors were randomly selected from each location to collect the information by the selected questionnaire. During the survey the complete data from restaurant to street food vendor was recorded. The information of the questionnaire was: hygiene practice, awareness on physical, chemical and microbial hazardous agents, packaging etc. The processing pattern with their cutting/slicing practice, washing practice, source of water, packing and packaging materials, storage etc. were recorded during the baseline survey. Street food vendor, hotel and restaurant based questionnaire covered all qualitative and quantitative data.

Data collection and data analysis

The collected information was organized in a tabular form by using MS-Excel data sheet and then analyzed. MS Excel was used for statistical analysis which provided different information from fresh-cut fruits and salad vegetables from processing to marketing status in the survey area. The information also represented different comparative study among the parameters.

Results and Discussions

Baseline survey

In Bangladesh, fresh-cut fruits and salad vegetables are available commonly in urban areas. During the survey with the help of pre-tested questionnaires, the complete data from restaurant to street food vendor was recorded and analyzed for the specific location. The information was accumulated from the respondent of different locations such as academic institutions (school, college), park, station, hotels and restaurants, in front of market, public gathering place etc. Processing pattern with their washing practices, food handling practices, food safety knowledge, hygiene practice, packaging, storage etc. were also collected and analyzed. The baseline information with sample collection activities in Dhaka, Gazipur and Bogura were shown, respectively.

In Table 1 it was observed that most of the vendors were aged between 21-40 years. However, in Dhaka and Gazipur region some vendors were below 20 years old who were engaged as street vendor for selling fresh-cut fruits and salad vegetables such as cucumber, pineapple, guava, olive, golden apple, papaya, carrot etc. instantly after processing for direct consumption. In Dhaka, 75% vendors were in the age group of 21-40 years whereas in Gazipur, 50% were age group above 40 years and most of them were illiterate. In Dhaka 58.34% respondents belonged primary education who have no knowledge regarding hazards and its severity for human health. Overall the literacy rate was very poor in Gazipur people compared to other districts, who were completely unknown about hygienic practice.

In Table 2, it was observed that most of the vendors don't use hand gloves during processing fresh-cut fruits and salad vegetables. 50% and 16.67% of vendors of Bogura and Dhaka use hand gloves during processing time, respectively. In Table 3, it was found that vendors of Gazipur and Bogura wash their food container with water 100% and 62.5%, respectively. In Dhaka region only 25% vendors wash their food container with detergent. Most of the vendors use bucket to wash the utensils and fruits/vegetables by immersion into water but it doesn't ensure the processing equipment and fresh-cut fruits or salad vegetables will be free from hazards. Any dirt exists in the environment may accumulate in the washing water that can then be transferred to the other utensils and fresh produces rapidly. The condition would further worsen if the vendors do not change the washing water regularly. The result presented in Table 4 shown, 100% vendors of Bogura and 50% vendors of Gazipur sterilized knife, scissors etc. Most of the vendors were aware of to wash their hand after sneezing, coughing or touching unclean objects but some of vendors were not interested (Table 5).

Most of the vendors wash their fruits and vegetables after collecting the produce. In Table 6, it was observed that about 42% vendors in Dhaka don't wash their produce instantly after collecting the produce. In Dhaka, Gazipur and Bogura region vendors use tap water 41.67%, 70% and 50%, respectively (Table 7). Most of the vendors sell their food in plate/poly bag. Vendors are unknown about the use of sanitizer for removal of microbe on the surface of the produce especially direct consumption of fresh fruits and salad vegetables such as cucumber, guava, carrot etc. Almost all vendors don't practice to use any chemicals or sanitizer for washing fresh-cut fruits or salad vegetables.

In case of different hazards i.e., physical, chemical, microbiological and cross contamination and hygienic practices, most of the vendors don't have much knowledge (Table 11) regarding the

hazardous agents. On average 87.50% and 70% vendors of Bogura and Gazipur wash fresh-cut fruits and salad vegetables after processing whereas in Dhaka only 16.67% vendors wash after slicing the fresh-cut product (Table 12). Table 13 shown that most of the vendor serves immediately after cutting fruits and salad vegetables to the customers for direct consumption or purchase the fresh-cut product for home consumption which had possibility to enter microbes by cross contamination.

Table 1. General information of fresh cut fruits/salad vegetables collected from street food vendors and hotel in selected areas of Bangladesh

Items	Dhaka	Gazipur	Bogura
A. Age distribution (%)			
≤ 20 years	8.33	50.00	-
21-40 years	75.00	50.00	62.50
41-60 years	16.67	-	37.50
B. Education level (%)			
Illiterate	8.33	90.00	37.50
Primary level	58.34	10.00	37.50
Secondary level	25.00	-	12.50
HSC & above	8.33	-	12.50

Table 2. Information on 'Hand gloves use during fresh-cut fruits and salad vegetables' processing in the survey area

Districts	Fruits/Vegetables	Use (%)	Not use (%)
Dhaka	Guava, pineapple, cucumber, carrot	16.67	83.33
Gazipur	Guava, pineapple, cucumber, carrot	10.00	90.00
Bogura	Guava, pineapple, cucumber, carrot	50.00	50.00

Table 3. Information on 'Wash container of fresh cut fruits and salad vegetables' in the survey area

Districts	Fruits/Vegetables	Water (%)	Detergent (%)	Without wash (%)
Dhaka	Guava, pineapple, cucumber, carrot	33.33	25.00	41.67
Gazipur	Guava, pineapple, cucumber, carrot	100.00	-	-
Bogura	Guava, pineapple, cucumber, carrot	62.50	-	37.50

Table 4. Information of 'Sterilize of fresh-cut fruits and salad vegetables cutting knife and scissors'

Districts	Fruits/Vegetables	Sterilize	Not sterilize
Dhaka	Guava, pineapple, cucumber, carrot	41.67	58.33
Gazipur	Guava, pineapple, cucumber, carrot	50.00	50.00
Bogura	Guava, pineapple, cucumber, carrot	100.00	-

Table 5. Information on 'Wash hand after sneezing, coughing or touching other unclean objects'

Districts	Fruits/Vegetables	Wash (%)	Don't wash (%)	Sometimes (%)
Dhaka	Guava, pineapple, cucumber, carrot	16.67	58.33	22.00
Gazipur	Guava, pineapple, cucumber, carrot	60.00	40.00	-
Bogura	Guava, pineapple, cucumber, carrot	87.50	12.50	-

Table 6. Information on 'Wash fruits/vegetables after sourcing' water

Districts	Fruits/Vegetables	Wash (%)	Don't wash(%)
Dhaka	Guava, pineapple, cucumber, carrot	58.33	41.67
Gazipur	Guava, pineapple, cucumber, carrot	80.00	20.00
Bogura	Guava, pineapple, cucumber, carrot	100.00	-

Table 7. Information on 'Source of water' for fruits/vegetables wash

Districts	Fruits/Vegetables	Tap (%)	Submersible (%)	Others (%)	Don't wash
Dhaka	Guava, pineapple, cucumber, carrot	41.67	8.33	8.33	41.67
Gazipur	Guava, pineapple, cucumber, carrot	70.00	-	10.00	20.00
Bogura	Guava, pineapple, cucumber, carrot	50.00	50.00	-	-

Table. 8. Information on 'Packaging of fresh cut fruits/salad vegetables during selling time'

Districts	Fruits/Vegetables	Poly bag/plate (%)	Bag (%)	Nothing (%)
Gazipur	Guava, pineapple, cucumber, carrot	91.67	-	8.33
Bogura	Guava, pineapple, cucumber, carrot	80.00	-	20.00
Dhaka	Guava, pineapple, cucumber, carrot	87.50	-	12.50

Table 9. Information on 'Chemicals use to preserve fresh-cut fruits/salad vegetables'

Districts	Fruits/Vegetables	Use (%)	Not use (%)
Gazipur	Guava, pineapple, cucumber, carrot	-	100
Bogura	Guava, pineapple, cucumber, carrot	-	100
Dhaka	Guava, pineapple, cucumber, carrot	-	100

Table 10. Information on 'Sanitizer use to disinfect fresh-cut fruits/salad vegetables'

Districts	Fruits/Vegetables	Use (%)	Not use (%)
Gazipur	Guava, pineapple, cucumber, carrot	-	100
Bogura	Guava, pineapple, cucumber, carrot	-	100
Dhaka	Guava, pineapple, cucumber, carrot	-	100

Table 11. Awareness regarding hazardous agents exist in fresh-cut fruits and salad vegetables

Districts	Physical		Chemical		Microbiological		Cross contamination	
	Aware (%)	Not aware (%)	Aware (%)	Not aware (%)	Aware (%)	Not aware (%)	Aware (%)	Not Aware (%)
Gazipur	8.33	91.67	-	100	-	100	-	100
Bogura	-	-	-	100	-	100	-	100
Dhaka	30.00	70.00	-	100	-	100	-	100

Table 12. Information on 'Wash fresh-cut fruits/salad vegetables after cutting/slicing'

Districts	Fruits/Vegetables	Yes (%)	No (%)
Gazipur	Guava, pineapple, cucumber, carrot	16.67	83.33
Bogura	Guava, pineapple, cucumber, carrot	70.00	30.00
Dhaka	Guava, pineapple, cucumber, carrot	87.50	12.50

Table 13. Information regarding 'After slicing fresh-cut fruits/salad vegetables serve immediately'

Districts	Fruits/Vegetables	Yes (%)	No (%)	Both (%)
Dhaka	Guava, pineapple, cucumber, carrot	58.33	16.67	25.00
Gazipur	Guava, pineapple, cucumber, carrot	30.00	30.00	40.00
Bogura	Guava, pineapple, cucumber, carrot	100.00	-	-

Conclusion

The baseline survey was conducted in selected locations represented the information regarding available fresh-cut fruits/salad vegetables from processing to marketing in Bangladesh. The findings of this study indicated that most of the vendors involved in fresh-cut fruit and salad vegetables processing were illiterate and they were unconcerned about proper processing technique in hygienic condition, which is associated with food safety issue as well as to secure food products for human health. Street food vendors also do not have hands on training with knowledge for food safety and sanitation as well as to maintain good handling practices in processing place. All the food vendors had still not implemented sanitation practices on critical elements such as not washing hands regularly with soap before and after handling food, not washing the equipment with running water, not washing fruits or salad vegetables with running water, not using an appropriate container/food handling packet for storing food or direct consumption. Finally, it can be concluded that appropriate processing practice is necessary to be ensured hygienic condition to be food or food products safe for the customers' consumption.

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DETERMINATION OF MICROBIAL HAZARDS IN FRESH-CUT FRUITS AND SALAD VEGETABLES USED IN STREET FOOD VENDOR, HOTELS AND RESTAURANT AT SELECTED LOCATIONS IN BANGLADESH

A.A. SABUZ, M.H.H. KHAN, M.G.F. CHOWDHURY, M.M. MOLLA, T.KARIM, M.M.ISLAM

Abstract

This study was conducted to identify and quantify the hazardous agents (microbial load) in fresh-cut fruits and salad vegetables collected at different selected locations of Bangladesh. Different fresh-cut fruits and salad vegetables such as guava, pineapple, cucumber and carrot were collected from various restaurants to street vendor. All samples were analyzed to detect the existing different microbial agents such as *Salmonella spp*., *Escherichia coli* (*E. coli)*, *Staphylococcus aureus*, *Listeria monocytogenes* total plate count (cfu/g), etc. The aims were to find out the microbial agents of fresh-cut fruits and salad vegetables to analyze the fresh-cut fruits/salad vegetables qualities of the restaurants, hotel and street food vendor and also to compare it with different standards to assess the health risk of people. Results indicated that most of the samples were significantly positive to colony forming unit cfu/gm. Most of the sample contaminated by *Escherichia coli* (*E. coli*) and *Staphylococcus aureus.* On the other hand *Salmonella spp*. was not found in all the samples.Our recommendations are therefore, restaurant owners, hotel owners and street vendor should take necessary steps for the maintenance of microbial quality of water and microbial assessments should be done very often to leading a hygienic practice.

Introduction

In recent times, there is much concern about microbiological load in fruits and vegetables. The practice of consuming fresh cut fruit/salad vegetable remains popular around the world due to nutritional value and the case of availability. However, fresh-cut fruits and salad vegetables may come in contact with an array of microorganisms resulting in various diseases.

Contamination and growth of spoilage microorganisms usually limit the self-life of fresh fruits and vegetables. Load of microorganisms in fresh fruits and vegetables depend on various intrinsic and extrinsic factors, including acidity and water activity, redox potential, food poisoning etc. Contamination of vegetables may take place at all stages during pre and post-harvest techniques (De Roever, 1999). Raw fruits and vegetables are potential source of a wide range of microorganisms, including human pathogens (Ec-Scf, 2002). Food borne bacterial pathogens commonly detected in fresh fruits and vegetables are coliform bacteria, *E. coli, Salmonella spp., Staphylococcus aureus, Listeria monocytogene*s in Bangladesh (Tambekar and Mundhada, 2006). Microorganisms capable of causing human illness and others whose food borne disease potential is uncertain, such as *Aeromonas hydrophila, citrobacter, freundii, Enterobacter cloacae* and *Klebsiella spp.* have been isolated in vegetables. (Francis *et al*., 1999). Numerous food borne molds can produce mycotoxins and some yeasts and molds are responsible for human and animal infections (Beuchat and Cousin, 2001). Contaminated food is a common source of human infections. Microbes, mainly the coliforms group has been used extensively as an indicator of the main indicators of microbiological quality of water and food. Their presence indicates improper treatment or post-disinfection contamination and their significant differences in the microbiological quality of fresh-cut fruits and salad vegetables from restaurant to street vendor level in different areas in Bangladesh.

Hence, for qualitative survey, fresh-cut fruit/salad vegetable different samples were collected to determine hazardous agent (microbiological load) from selected locations in Bangladesh. The aim was to get baseline data on microbial load of selected fresh-cut fruits and salad vegetables from restaurant to street vendor level and to compare the microbial load with the detectable range.

Materials and Methods

The study was carried out at the Postharvest Technology Division, BARI, Gazipur and Waffen Research Laboratory, Dhaka, Bangladesh during the year 2021. Total of 25 fresh samples were collected from three districts such as Gazipur, Bogura and Dhaka to analyze for microbial load (*Salmonella spp., E. coli, Shigella* and total plate count (cfu/g). Individual sample was placed in the sterile high density polyethylene (HDPE) packet. *Salmonella spp*., *E. coil* and total plate count (cfu/gm) were isolated within 24 hrs. from collected the fresh samples. For the isolation of *Salmonella spp.*, approximately 10g samples were placed in 50mL buffered peptone water (BPW) HIMedia laboratories at 37^0C for 18 hrs. BPW is a pre-enrichment medium for increasing the recovery of *Salmonella spp.* from foods prior to selective media for isolation. After incubating the samples, 100

μL suspension were plated in Bismuth Sulphite Agar (BSA) medium with 10-fold dilution (10^{-8}) and were incubated at 37^0C for 24 hrs. Typical black colony of *Salmonella spp.* were grown in the medium (Figure1).

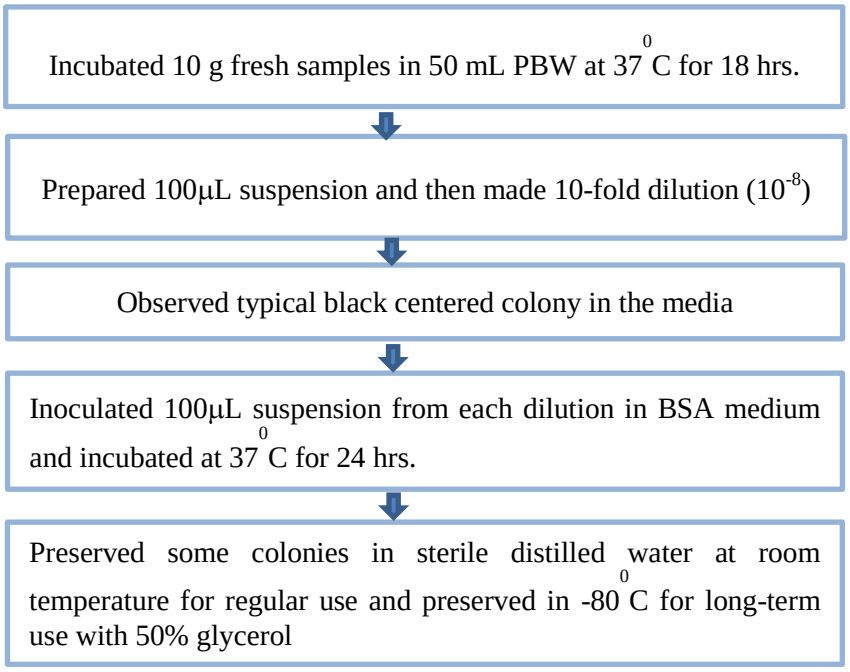

Figure 1. Flow-chart for the isolation of *Salmonella spp.* from selected fruits and vegetables

For the isolation of *E.coli*, 10 g fresh samples were also placed in 50 mL water and after 10 min. of incubation, 100 μL suspension were plated in CT-MacConKey medium with 10-fold dilution at 37^0C for 24 hrs. Violet and pink typical colonies were observed in the medium. In addition, for the counting of total plate (cfu/g), after making suspension of bacteria (10g samples/50 mL sterilized distilled water), 100 μL suspensions were plated in Luria-Bertani Agar (LBA) medium with 10-fold dilution at 28^0C for 24 hrs. Different colored bacteria (presumably different genera) were grown in the medium. For the counting of cfu/g the following formula was used:

$$Colony\ Forming\ Unit\ (\frac{cfu}{g}) = \frac{No.\ of\ colony\ \times Dilution \times time\ of\ dilution}{Sample\ add\ to\ plate/media}$$

Results and Discussions

The analytical results of microbiological load *(Salmonella spp, E. coli, Shigella)* in detectable range in collected fruits and vegetables sample are summarized in Table 2. From the above Table 2, it was noted that three restaurant samples of fresh-cut fruits and vegetables (100%) were contaminated by *Escherichia coli*. and *Staphylococcus aureus.* In sample R_4 the total plate count was found 8.9×10^{10} cfu/g which belonged unsatisfactory level of hygienic indicator on the other hand *Salmonella spp*. was absent that is hygienic indicator according to Table 2. In case of samples collected from street vendor, three samples were contaminated by *Escherichia coli*, *Staphylococcus* and *Salmonella spp. w*as not detected. Heavy loads of *Escherichia coli.* and *Staphylococcus aureus* were found to be present whereas *Salmonella spp.* were not present in the all samples collected from Gazipur district. In restaurant samples R_1 was found lower amount of bacteria (cfu/g) than all other samples.

In Table 3, it was observed that nine samples from restaurant, hotel and street vendor were contaminated by *Escherichia coli* and *Staphylococcus aureus.* In hotel sample R_4 contained 1.42×10^7 (cfu/g) was present which was lower than all other samples. *Staphylococcus aureus* was not detected from street vendor samples whereas *Escherichia coli* found in restaurant and hotel samples. *Salmonella spp.* was absent in all samples that is satisfactory level of hygienic indicator. *Escherichia coli* was present in restaurant, hotel and street vendor samples which is found unsatisfactory level of hygienic indicator. It's highly risk for human health. Seven samples of fresh-cut fruits and salad

vegetables were examined during the study presented in Table 4. Most of the samples were significantly positive to cfu/g values were significantly high. Higher amount of bacteria found in hotel sample, R_1 (3.00×10^{10}) (cfu/g).

Table 1. Guidelines on the interception of result for hygiene indicator organism in ready-to-cut food in general

Hygiene indicator Organism	Result [colony-forming-unit(cfu/g)]		
	Satisfactory	Borderline	Unsatisfactory
Salmonella spp.	Not detected in 25g	Borderline result not applicable	Detected
Escherichia Coli	<20	20-<100	>100
Staphylococcus aureus	<20	20 - ≤ 10000	>10000
Listeria monocytogenes	<10	10 - ≤100	≥100

Source: Microbiological Guidelines for Food, August 2014 (Revised), Guidelines for Assessing the Microbiological Safety of Ready-to-Eat Foods Placed on the Market, November 2009 © Health Protection Agency.

Table 2. Identification of food borne bacteria and quantification of the microbial load in fresh-cut fruits and salad vegetables (Sample collected from Gazipur)

Sample code	Total plate count (cfu/g)	*E. coli*	*Staphylococcus aureus*	*Salmonella spp.*
Sample collected from restaurant				
R_1	9.0×10^7	3.00×10^6	1.48×10^4	Absent
R_2	1.27×10^9	2.72×10^6	1.27×10^4	Absent
R_3	6.7×10^8	2.21×10^6	1.08×10^4	Absent
Sample collected from hotel				
R_4	8.9×10^{10}	2.03×10^6	9.6×10^3	Absent
R_5	1.48×10^{10}	1.05×10^6	1.23×10^4	Absent
R_6	7.5×10^8	3.00×10^6	1.42×10^4	Absent
Sample collected from street vendor				
R_7	3.0×10^9	2.43×10^6	1.02×10^4	Absent
R_8	2.4×10^9	1.56×10^6	1.10×10^4	Absent
R_9	2.7×10^9	2.71×10^6	1.32×10^4	Absent

Note: Detectable range followed by Table 1.

Table 3. Identification of food borne bacteria and quantification of the microbial load in fresh-cut fruits and salad vegetables (Sample collected from Bogura)

Sample code	Total plate count (cfu/g)	*E. coli*	*Staphylococcus aureus*	*Salmonella spp.*
Sample collected from restaurant				
R_1	3.00×10^9	2.97×10^7	7.8×10^3	Absent
R_2	2.57×10^9	4.5×10^7	1.15×10^4	Absent
R_3	3.02×10^8	3.00×10^7	1.17×10^4	Absent
Sample collected from hotel				
R_4	1.42×10^7	2.21×10^7	6.4×10^4	Absent
R_5	1.54×10^9	1.49×10^7	7.6×10^4	Absent
R_6	2.21×10^9	2.60×10^7	8.1×10^4	Absent
Sample collected from street vendor				
R_7	1.68×10^9	3.30×10^7	Absent	Absent
R_8	1.89×10^9	4.00×10^7	Absent	Absent
R_9	2.7×10^8	3.00×10^7	Absent	Absent

Note: Detectable range followed by Table 1.

Table 4. Identification of food borne bacteria and quantification of the microbial load in fresh-cut fruits and salad vegetables (Sample collected from Dhaka)

Sample code	Total plate count (cfu/g)
Sample collected from hotel	
R_1	3.00×10^{10}
R_2	2.30×10^{10}
R_3	1.19×10^{10}
Sample collected from street vendor	
R_1	1.66×10^{10}
R_2	1.01×10^{10}
R_3	1.36×10^{10}
R_4	2.77×10^{10}

Note: Detectable range followed by Table 1.

Conclusion

Fresh-cut fruits and salad vegetables are infected by different microorganisms such as *Salmonella spp., Escherichia coli and Staphylococcus aureus* in restaurant, hotel and street vendor. The present investigation were on the microbial load of fresh-cut fruits and salad vegetables used in popular restaurants of Dhaka City Corporation showed that it was highly unsafe for human consumption. Results remarked that those fresh-cut fruits and salad vegetables samples were contaminated by total plate count (cfu/g). Those organisms may create different disease in human body. It is necessary to find out the causes of microbial contamination in fresh-cut fruits and salad vegetables both in restaurant and street vendor. This study will be continued for next year to evaluate other hazardous agents in different locations and will be cross checked for conformation.

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The authors wish to acknowledge and thanks to the supporting staffs of PHTD, BARI and other associated persons who provided information, technical and logistic support during the conducted survey. The author also expressed thanks and gratitude to the Nutrition Unit, Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh for funding the Program Based Research Grant (PBRG) under National Agricultural Technology Program (NATP) Phase-II Project (ID#103). The authors also thanks to the Plant Pathology Division of BARI for their continuous assistance to share information and consultation during the study.

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EFFECT OF DIFFERENT SANITIZERS ON PHYSICOCHEMICAL, MICROBIOLOGICAL LOAD AND SHELF LIFE OF SPINACH

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Abstract

The present study was conducted to evaluate the efficacy of selected sanitizers such as, acetic acid (0.5%), trisodium phosphate (1%) and calcinated calcium (0.01%) on physicochemical, microbiological load and shelf life of fresh vegetables spinach. Spinach was collected and dipped into the selected sanitizer solution and stored at refrigerator condition (4 ± 0.1^0C). Different physicochemical properties including physiological weight, chlorophyll, total acidity (%) and ascorbic acid (mg/100g) were evaluated in addition with the microbial load (cfu/g). Results indicated that most of the studied parameters were significantly differed during the storage period. On the other hand, microbial study revealed that control sample contained the highest number of viable bacteria (cfu/g) while 0.01% calcinated calcium treated sample had reduced a significant number of microorganisms throughout the storage period. From this study, it can be concluded that spinach can be stored upto 6 days with considerable retention of nutrients. However, in terms of microbial load, spinach treated with calcinated calcium was acceptable upto 4 days of storage beside control sample tremendously increased microorganism initially after harvest exhibited at unsatisfactory level.

Introduction

The current worldwide drive for a healthier lifestyle has led to a rising demand for convenient fresh foods from additives with high nutritional value including antioxidant and free radical scavenging properties to be consumed both at home and in food service. In this way, fruits and vegetables offer great advantages for consumers (Wiley, 1994; Artes, 2004). Moreover, shelf-life of fruits and vegetables commodities are affected by pre-processing factors such as crop varieties, cultivation conditions, harvesting, ripening stage, processing factors such as shorting, washing, drying, packaging and distribution condition such as temperature, relative humidity, atmosphere composition and processed under highly integrated systems where all processing steps are considered in combination (Shewfelt and Prussia, 1993; Artes, 2004). However, the activities or operations followed such as collecting and washing in different water sources is a serious concern for the contamination by the microorganisms, which may be detrimental to the health of consumers (Leistner and Gould, 2002). Although those kinds of minimal processing keep commodities alive, it destroys plant structure and therefore increases the rate of tissues damage and reduces their resistance to microbial spoilage (Artes *et al.,* 2007). In this regard, the nutritional quality and shelf life of the fresh commodities became reduced that expected from the whole intact product (Wiley, 1994).

In order to achieve the produce fresh like quality, safety and high nutritional value, the industry needs to implement improved standard procedures for sanitation or maintaining hygienic condition. Effect of different sanitizer on postharvest quality of selected fresh fruits and vegetables are keys for reducing the microbial load in addition with the retention of nutritional quality. In the above circumstances, the present study was conducted to evaluate the effect of different sanitizer on physicochemical, microbial load and shelf life of spinach during storage in refrigerator.

Materials and Methods

Freshly harvested leafy green spinach were collected from the research field of Postharvest Technology Division (PHTD), BARI, Gazipur. Then spinach were immediately carried out to the PHTD pack house for sorting, grading and removing dirt from spinach bunch. After sort out of dirt, roots and damaged leaves, spinach were cooled at 20^oC to remove field heat. Spinach vegetables were kept in 0.5% perforated polypropylene packet (~45 micron) and each packet contained 200 g spinach, which was considered as replication. The sorted spinach vegetables were treated according to the following treatments and standard method for nutritional quality and shelf life study (Figure 1). After soaking of spinach in selected sanitizers mixed solution, the excess surface water was removed by using pedestal fan. Three organic acid such as trisodium phosphate, acetic acid and calcinated calcium with best one concentrations of organic acid were used for the study. The treatments with three replications were as follows:

T_1 = Control (Non-treated)
T_2 = Acetic Acid (AA) 0.5%
T_3 = Trisodium Phosphate (TSP) 1.0%
T_4 = Calcinated calcium (CCa) 0.01%

Sanitizer application protocol for identification and quantification of microbial load

The application of sanitizer protocol is as follows:

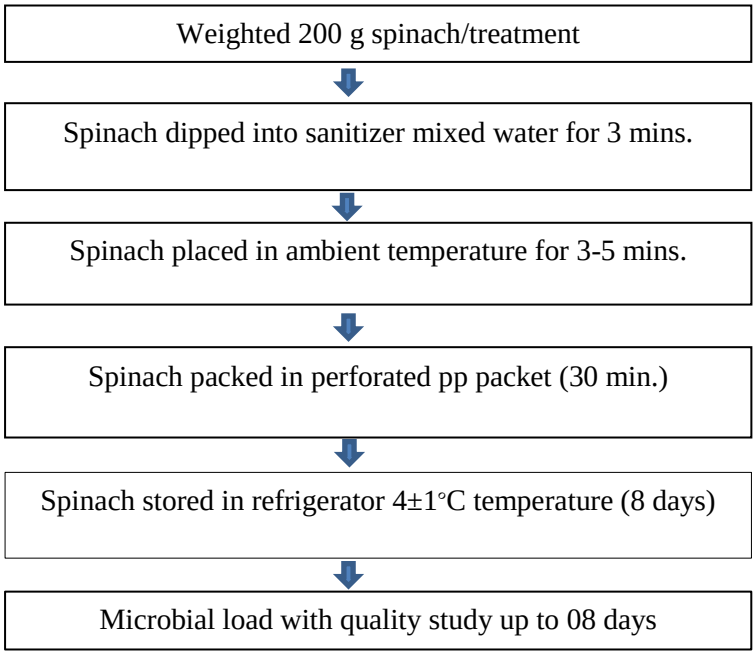

Figure 1. Flow chart of sanitizer application protocol

Determination of physicochemical properties

All treated spinach vegetables were stored at ambient condition (25±2^{o}C & 75±5%RH) and the physicochemical properties in terms of physiological weight, chlorophyll content, total acidity, ascorbic acid content were determined by the method of Ranganna (2007). Total carotenoids by Tee (1991), total phenolic content and microbial load were determined by the methods described by Kamal *et al.,* (2019a). The shelf life of the treated spinach were evaluated at 2 days' interval upto 6 days of storage at refrigerator (4±1^{0}C).

Results and Discussions

Changes of physiological weight

It was observed in Figure 1 that negligible amount of weight reduced during storage of spinach treated with sanitizer application. Among the treatment, control treatment T_5 (without wash) reduced higher physiological weight loss compared to sanitizer used treated samples. According to Gautam *et al.,* (2017), calcinated calcium treated sanitizer is more effective to reduce weight and lower rot incidence of fresh fruits and vegetables during storage.

Changes of chlorophyll content

Most naturally green vegetables contain chlorophyll. Fresh leafy vegetables are particularly rich in chlorophyll content. It is presented in Table 1 that the amount of chlorophyll was ranged between 2.48 to 4.62 mg/100gm at the initial stage. After 2 days of storage, the chlorophyll content increased 4.15 to 5.22 mg/100gm with increased storage period and ranged between 3.26 to 3.71 mg/100g at day 4, 2.39 to 5.01 mg/100g after 6 days of storage. It was also observed that chlorophyll content differed significantly among the treatments during the storage period. Calcinated calcium (T_3) contained the highest amounts of chlorophyll (5.31 mg/100gm) while treatment T_4 (spinach wash with tap water) contained the lowest amount of chlorophyll (2.39 mg/100gm) after 6 days of storage.

Changes of total acidity content

The total acid content (%) of the spinach sample treated with different sanitizers was presented in Table 2. The total acid content of spinach sample was very low and varied between 0.17 to 0.63% on initial day. After 2 days of storage, the total acidity content increased slightly almost all treatments (0.09 to 0.29%) except treatment T_3 (0.09%) then the total acidity content was reduced slightly (0.13-0.32%) in all treatments after 6 days of storage with increased storage period. There were significant changes in total acid values of spinach fruit treated with different sanitizers.

Changes of ascorbic acid content

The data obtained for ascorbic acid content (mg/100gm) of spinach vegetables during 6 days of storage was summarized in Table 3. It was observed that the ascorbic acid was increased throughout the storage period irrespective of the treatments. And there was statistically significant difference among the treatments up to the 6 days of storage. On the processing day, ascorbic acid was ranged between 29.41 to 82.35 mg/100gm among the treatments. These values were found to range between 31.88 to 54.18 mg/100gm after 2nd days of storage, 34.98 to 44.59 mg/100gm after 4th days of storage and 27.25 to 47.12 mg/100gm after 6th days of storage. The highest amount of ascorbic acid (47.12 mg/100gm) was recorded in spinach sample treated with acetic acid (T_2) after 6 days of storage. It was evident that the ascorbic acid is the most unstable compounds that is reduced due to several factors like temperature, internal composition such as acidity, metallic content, oxygen reaction etc. (Kamal *et al*., 2019b).

Effect of sanitizer on microbiological quality of spinach

In this study, it was observed in table 4 that five different treatments of sanitizer were applied on spinach vegetables which reduced the number of microbial load total (cfu/g). Initially after applying sanitizer treatments to the fresh fruits and vegetables, no microorganism was traceable total plate count (cfu/g) among the treatments that was satisfactory level. Among the treatment, 0.01% calcinated calcium performed better after 2, 4 and 6 days of storage, respectively of total (cfu/g) count. In Table 5, it was also observed that *Escherichia coli (E. coli)* was not found initially in sanitizer treated spinach samples which was below safe limit as shown in table 5. *Escherichia coli (E. coli)* was detected in T_4 (spinach wash with tap water) and T_5 (control treatment) initially. After 6 days of storage, treatment T_3 (0.01% calcinated calcium) was performed better compared to other treatments.

Table 1. Changes in total chlorophyll content (mg/100g) of spinach during 6 days of storage

Treatment	0 Day	2nd Day	4th Day	6th Day
T_1	4.62±0.06a	5.22±0.23a	3.44±0.13c	4.10±0.03c
T_2	4.52±0.04b	4.23±0.11c	3.71±0.08a	5.01±0.05b
T_3	4.08±0.06c	4.83±0.12b	3.26±0.02d	5.31±0.02a
T_4	2.48±0.06e	4.91±0.03b	3.63±0.03ab	2.39±0.14e
T_5	2.87±0.05d	4.15±0.17c	3.56±0.04bc	3.66±0.04d

Note: Values are mean ± standard deviation (n=3); Different lowercase letters in each column are significantly different (P<0.05) among the treatments; T_1- 1% Tri-sodium phosphate; T_2- 0.5% Acetic acid; T_3- 0.01% Calcinated calcium; T_4- Tap water wash; T_5- Control treatment.

Table 2. Changes in total acidity (%) of spinach during 6 days of storage

Treatment	0 Day	2nd Day	4th Day	6th Day
T_1	0.18±0.01c	0.21±0.02c	0.25±0.03a	0.13±0.02c
T_2	0.63±0.01a	0.26±0.03b	0.13±0.01b	0.32±0.03a
T_3	0.21±0.02bc	0.09±0.03d	0.12±0.01b	0.22±0.03b
T_4	0.22±0.03b	0.29±0.04b	0.14±0.02b	0.24±0.01b
T_5	0.13±0.01d	0.53±0.02a	0.13±0.02b	0.15±0.05c

Note: Values are mean ± standard deviation (n=3); Different lowercase letters in each column are significantly different (P<0.05) among the treatments; T_1- 1% Tri-sodium phosphate; T_2- 0.5% Acetic acid; T_3- 0.01% Calcinated calcium; T_4- Tap water wash; T_5- Control treatment.

Table 3. Changes in ascorbic acid content (mg/100g) of spinach during 6 days of storage

Treatment	0 Day	2nd Day	4th Day	6th Day
T_1	82.35±0.07a	34.93±0.65c	43.60±0.66a	36.47±0.04d
T_2	29.41±0.09e	31.88±0.15e	34.98±0.66d	47.12±0.09a
T_3	37.65±0.38d	32.94±0.09d	44.59±0.63a	39.94±0.11b
T_4	59.01±0.88c	53.08±0.15b	41.14±0.21b	37.75±0.13c
T_5	74.24±0.15b	54.18±0.14a	36.46±0.82c	27.25±0.22e

Note: Values are mean ± standard deviation (n=3); Different lowercase letters in each column are significantly different (P<0.05) among the treatments; T_1- 1% Tri-sodium phosphate; T_2- 0.5% Acetic acid; T_3- 0.01% Calcinated calcium; T_4- Tap water wash; T_5- Control treatment.

Table 4. Total viable bacterial counts (CFU/g) of spinach during 6 days of storage

Treatment	0 Day	2nd Day	4th Day	6th Day
T_1	-	29×10^5b	89×10^5c	197×10^7c
T_2	-	23×10^5c	78×10^5d	162×10^7d
T_3	-	7×10^5e	57×10^5e	146×10^7e
T_4	17×10^4b	11×10^5d	158×10^5b	201×10^7b
T_5	42×10^7a	143×10^7a	273×10^7a	306×10^8a

Note: Values are mean of three replications; Different lowercase letters in each column are significantly different (P<0.05) among the treatments; T_1- 1% Tri-sodium phosphate; T_2- 0.5% Acetic acid; T_3- 0.01% Calcinated calcium; T_4- Tap water wash; T_5- Control treatment.

Table 5. *Escherichia coli* counts (cfu/g) of spinach during 6 days of storage

Treatment	0 Day	2nd Day	4th Day	6th Day
T_1	-	14×10^5c	26×10^5b	182×10^6c
T_2	-	2×10^5d	14×10^5d	160×10^6d
T_3	-	1×10^5e	11×10^5e	140×10^6e
T_4	11×10^4b	3×10^5b	23×10^5c	212×10^6b
T_5	26×10^7a	25×10^7a	96×10^7a	259×10^7a

Note: Values are mean of three replications; Different lowercase letters in each column are significantly different (P<0.05) among the treatments; T_1- 1% Tri-sodium phosphate; T_2- 0.5% Acetic acid; T_3- 0.01% Calcinated calcium; T_4- Tap water wash; T_5- Control treatment.

Conclusion

The results of the present study concluded that 0.01% calcinated calcium was effective to control microbial growth on fresh spinach. However, all treatment retained acceptable nutritional quality throughout the storage period (4 days). It worked perfectly on fresh vegetables for reduction of bacterial count and also it retained quality during storage. No noticeable effect on weight loss was observed sanitizer treated spinach samples but 0.01% calcinated calcium increased storage life of leafy vegetables at ambient condition as well as refrigerator storage. This study will assist to stakeholders to encourage recommended amount of sanitizer application on fresh agricultural produce to keep produce safe and disinfect from microorganisms.

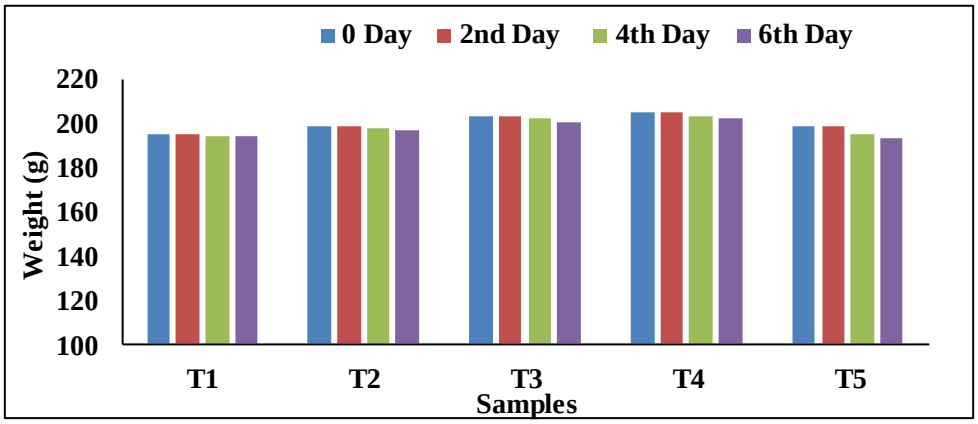

Figure 1. Changes in physiological weight (g) of spinach during 4 days of storage

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Additional works performed by the division (2020-2021)

Sl No.	Date	Name of Institute/ Person	Name of Sample	No. of Sample	No. of Parameter
01.	09.07.2020	Md. Shawkat Hossain, PhD Student	Mango	12	06
02.	24.08.2020	CSO, Hathazari, Chattogram	Guava	02	06
03.	28.08.2020	Entomology Division, BARI	Mango	03	06
04.	24.09.2020	Eshrat Tahmina, PhD Student	Sweet Potato Powder	32	01
05.	28.09.2020	Nahida Amin, PhD Student, DAE	Capsicum	18	09
06.	28.09.2020	Eshrat Tahmina, PhD Student	Potato Powder	32	05
07.	01.11.2020	HRC, BARI, Gazipur	Jackfruit Line	01	08
08.	01.12.2020	HRC, BARI, Gazipur	Wood Apple	05	09
09.	02.12.2020	HRC, BARI, Gazipur	Kaufol	01	07
10.	03.02.2020	Dr. Md. Jahir Ullah, SSO, BIRTAN	Vegetables	11	07
11.	15.02.2021	HRC, BARI, Gazipur	Wood Apple	01	07
12.	16.02.2021	Nahida Amin, PhD Student, DAE	Capsicum	18	10
13.	22.02.2021	Agriculture & Rural Development School, BOU, Gazipur	Strawberry	08	07
14.	24.02.2021	Biotechnology Division, BARI	Strawberry	10	01
15.	24.02.2021	Soil Science Division, BARI	Cauliflower	12	03
16.	09.03.2021	Farm Division, BARI	Figs	02	06
17.	16.03.2021	RARS, Jamalpur	Brinjal	05	05
18.	22.03.2021	TCRC, BARI	Sweet Potato	05	02
19.	28.03.2020	Agriculture & Rural Development School, BOU, Gazipur	Cherry Tomato	04	03
20.	29.03.2021	Agronomy Division, BARI	Tomato	05	01
21.	31.03.2021	Hoimonty Borua, PhD Student	Guava	28	05
22.	04.04.2021	PhD Student, SAU	Tomato	12	06
23.	18.05.2021	Soil Science Division, BARI	Bitter Gourd	10	02
24.	18.05.2021	HRC, BARI, Gazipur	Mango	01	07
25.	07.06.2021	Breeder Seed Production Center, Debiganj	Custard Apple	06	05
26.	09.06.2021	Eshrat Tahmina, PhD Student	Sweet Potato Powder	32	05
			Total number of sample analyzed	**276**	

Manpower status of Postharvest Technology Division Bangladesh Agricultural Research Institute Gazipur-1701

2021

Sl. No.	Name	Designation
01	Md. Hafizul Haque Khan	Chief Scientific Officer (C.C.)
02	Mohammad Mizanur Rahman	Senior Scientific Officer (Deputation)
03	Dr. Md. Golam Ferdous Chowdhury	Senior Scientific Officer
04	Dr. Mohammad Mainuddin Molla	Senior Scientific Officer
05	Shahnaj Pervin	Scientific Officer (Deputation)
06	Ashfak Ahmed Sabuz	Scientific Officer
07	Md. Rezaul Karim	Scientific Assistant
08	Gazi Md. Abu Nyeem	Scientific Assistant
09	Mrs. Nasima Aktar	Scientific Assistant
10	Md. Anwar Hossain	Steno-typist Cum Computer Operator
11	Asma Khatun	UDA
12	Nilufar Yeasmin	Office Assistant Cum Computer Operator
13	Hasna Hena	Laboratory Technician
14	Mr. Md. Azizul Haque	Laboratory Attendant
15	Md. Enaet Ullah	Laboratory Attendant
16	Jahanara Begum	Office Support Stuff