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Program Leader

Md. Hafizul Haque Khan

Edited by

Md. Hafizul Haque Khan
Dr. M.M. Rahman
Dr. M. G. F. Chowdhury

Compiled by

Dr. M. G. F. Chowdhury
Dr. M. M. Molla
S. Pervin
A. A. Sabuz

Postharvest Technology Division
Bangladesh Agricultural Research Institute
Gazipur-1701
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Content

OPTIMIZATION OF PROCESSING PARAMETERS FOR FROZEN TENDER JACKFRUIT

M.G.F. CHOWDHURY, A.A. SABUZ, M.H.H. KHAN, M. M. MOLLA, S. PERVIN

Abstract

The present study aimed at processing tender jackfruit as fresh like vegetable meat and stored at frozen condition applying different postharvest pretreatment as such, (T_1) 0.3% citric acid (CA) + 1% $CaCl_2$; (T_2) 0.3% ascorbic acid (AA) + 1% $CaCl_2$; (T_3) 0.3% potassium metabisulphite (KMS) + 1% $CaCl_2$; (T_4) 0.3% CA + 0.3% AA + 1% $CaCl_2$; (T_5) 0.3% CA + 0.3% KMS + 1% $CaCl_2$; (T_6) 0.3% AA + 0.3% KMS + 1% $CaCl_2$; (T_7) 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$, and (T_8) water soaking. After the pretreatment, jackfruits were stored at -10^{o}C and different quality parameters were studied over 6 months at 2 months' intervals. Results revealed that moisture and total acidity content in all samples were slightly increased throughout the storage period. The bioactive compounds such as ascorbic acid, beta-carotene, and total phenolic contents were significantly decreased with the storage period increased. All pretreated frozen tender jackfruit showed potent antioxidant properties being treatments T_6 (0.3% AA + 0.3% KMS + 1% $CaCl_2$) and T_7 (0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$) showed the antioxidant capacity. The physical observation for external color, flavor and texture revealed that these parameters were not significantly changed upto 6 months of storage except in some samples where slight brownish color was developed. Moreover, all samples were in edible stage after 6 months of storage with some decrement of nutritional quality. In conclusion, based on the overall findings of this study, tender jackfruit pretreated with T_5 (0.3% CA+ 0.3% KMS+1% $CaCl_2$), T_6 (0.3% AA+0.3% KMS+1% $CaCl_2$), and T_7 (0.3% AA+0.3% KMS+0.3% CA+1% $CaCl_2$) could be stored at frozen condition for longer storage (>6 months) without appreciable quality change.

Introduction

Jackfruit (*Artocarpus heterophyllus*) is the largest edible fruit in the world and is the national fruit of Bangladesh. It is a very popular fruit considering its taste, flavor, availability etc. in our country. The annual production of jackfruit is about 10.97 lakh metric tons covering an area of 44.63 thousand acres during 2020-2021 (BBS, 2021). The poor people of the jackfruit growing area used to consume this fruit instead of rice, for one of their daily meals. Hence, jackfruit is called "poor man's food". People consumed it mostly as a fruit when it is ripened but also cooked as a vegetable meat in the unripe stage. In culinary use, tender fruit is made into various local delicious dishes including chutney and paste besides various types of curries (Rana *et al.*, 2018). The jackfruit significantly contributes to the nutrition of the people of the country as a source of vitamins, minerals, and calories (Swami *et al*., 2012). Both tender and ripe fruits, as well as the seeds, are rich in minerals and vitamins (Yi *et al*., 2016). Thus, jackfruit provides a huge opportunity for livelihood as well as nutritional and food security in the rural communities of Bangladesh. Jackfruit in its tender form is consumed as a vegetable because of its versatile flavor and meat-like texture. In South Asian countries, the commercial value for tender jackfruit is very high. However, due to its sticky nature, most of people do not like to consume tender jackfruit as vegetables. Therefore, proper processing and storage will help to reduce the postharvest loss of jackfruit as well it would make this fruit usable to a wide range of consumers. This point of view, this study was conducted to preserve tender jackfruit in frozen conditions applying different postharvest pretreatment.

Materials and Methods

Collection of jackfruits

Fresh and tender jackfruits (6-7 weeks) of unknown cultivar having average fruit weight, 3-5 kg was collected from the farmer's field and Cotton Research, Training and Seed Multiplication Farm under Cotton Development Board (CDB) of Sreepur under Gazipur district and transported to the laboratory of Postharvest Technology Division (PHTD), BARI, Gazipur for conducting the study.

Preparation of tender jackfruit slices

The collected tender jackfruit was first cleaned with tap water to remove the adhering dust. Then the jackfruit was cut longitudinally and peeled to remove the outer green layers. Thereafter, the jackfruit was cut into small pieces and soaked in different solutions of potassium metabisulphite, citric acid, ascorbic acid for 10-15 min. The concentration and treatments were as follows: (T_1) 0.3% citric acid (CA) + 1% $CaCl_2$; (T_2) 0.3% ascorbic acid (AA) + 1% $CaCl_2$; (T_3) 0.3% KMS + 1% $CaCl_2$; (T_4) 0.3% CA + 0.3% AA + 1% $CaCl_2$; (T_5) 0.3% CA + 0.3% KMS + 1% $CaCl_2$; (T_6) 0.3% AA + 0.3% KMS + 1% $CaCl_2$; (T_7) 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$, and (T_8) water soaking. After soaking, the tender jackfruit pieces were blanched in hot water for 2 min and cooled immediately in ice water, remove the superficial water, packed in high-density polyethylene, and stored in laboratory deep freeze at -10^oC.

Determination of moisture content and percent acidity

The moisture was determined based on the AOAC official methods (AOAC, 2005). Total acidity was determined following the methods of Ranganna (1986).

Determination of bioactive compounds

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 beta-carotene content was determined by the methods of Igbokwe *et al.* (2013) with some modifications. Total phenolic content was determined by the Folin-Ciocalteu method following the procedure of Kamal *et al.* (2020) with slight modification using Gallic as the standard, and the result was expressed as mg GAE/100g of sample.

Determination of total antioxidant activity

The total antioxidant activity of frozen tender jackfruit was determined based on the DPPH free radical scavenging activity and expressed as the percentage inhibition. For this analysis, the method adopted by Kamal *et al. (*2019) was used in this study.

Physical observation during storage of frozen jackfruits

The external appearance of tender jackfruit during frozen storage was recorded by visual observation. For this data on color, flavor and texture were recorded at the specified time intervals.

Evaluation of nutritional quality of frozen jackfruits

The nutritional quality of the stored tender jackfruits was evaluated at two (2) months intervals up to six (6) months.

Statistical analysis

The data obtained were analyzed using the SPSS statistical software and the results were represented as the mean ± standard error of each parameter. Analysis of variance at a 5% level of significance was used to separate the mean of the respective parameters for different treatments during 6 months' storage periods.

Results and Discussion

Effect of pretreatment on the moisture content of frozen tender jackfruits during storage

Table 1 shows the effect of different pretreatments on the moisture content of frozen tender jackfruit during 6 months of storage. It can be seen that initially, the moisture content was between 84.54-87.25% (wb), which ranged to 88.54-92.02% (wb) after 6 months of storage. It is also observed that the moisture content was slightly increased during the storage period, which might be due to the humidity changes in the freezer as well as the pore in the packages that facilitate on the accumulation of moisture.

Table 1. The moisture content (%) of frozen tender jackfruits during 6 months of storage

Treatments	Initial	2 months	4 months	6 months
T_1	85.87±0.11	87.76±0.11	88.77±0.13	90.64±0.12
T_2	84.54±0.65	86.43±0.65	87.74±0.77	89.61±0.76
T_3	85.54±0.05	87.23±0.05	88.50±0.10	90.37±0.09
T_4	85.28±0.46	86.97±0.46	88.14±0.47	89.67±0.31

Treatments	Initial	2 months	4 months	6 months
T_5	85.86±0.55	87.21±0.55	88.35±0.53	89.72±0.51
T_6	85.54±0.07	87.33±0.07	88.45±0.08	89.86±0.06
T_7	87.25±0.12	89.04±0.12	90.59±0.14	92.02±0.11
T_8	84.92±0.56	85.35±0.83	87.11±0.81	88.54±0.80

N.B.: T_1 = 0.3%, w/v citric acid (CA) + 1% $CaCl_2$; T_2 = 0.3%, w/v ascorbic acid (AA) + 1% $CaCl_2$; T_3 = 0.3%, w/v potassium metabisulphite (KMS) + 1% $CaCl_2$; T_4 = CA (0.3%) + AA (0.3%) + 1% $CaCl_2$; T_5 = CA (0.3%) + KMS (0.3%) + 1% $CaCl_2$; T_6 =- AA (0.3%) + KMS (0.3%) + 1% $CaCl_2$; T_7 =– AA (0.3%) + KMS (0.3%) + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values are mean ± standard error of the mean.

Effect of pretreatment on the total acidity of frozen tender jackfruit during storage

The effect of pretreatment on the total acidity of frozen tender jackfruit during storage is presented in Table 2. It is observed from Table 2 that the acidity of frozen tender jackfruit become increased throughout the storage period. It was found that total acidity ranged between 0.58 to 0.74% at the initial stage of storage, which was ranged between 1.52-1.92% after 180 days of storage. from the Table 2 it is also observed that the treatment T_6 and T_7 produced comparatively less acidity in the frozen jackfruit throughout the storage period.

Table 2. Total acidity (%) of frozen tender jackfruits during 6 months of storage.

Treatments	Initial	2 months	4 months	6 months
T_1	0.65±0.03	0.81±0.01	1.16±0.01	1.64±0.01
T_2	0.68±0.02	0.93±0.01	1.29±0.04	1.72±0.04
T_3	0.65±0.01	0.89±0.03	1.22±0.02	1.61±0.03
T_4	0.67±0.02	0.88±0.01	1.31±0.07	1.64±0.08
T_5	0.66±0.01	0.88±0.03	1.47±0.03	1.92±0.03
T_6	0.58±0.02	0.68±0.01	1.15±0.01	1.52±0.01
T_7	0.59±0.02	0.64±0.03	1.11±0.03	1.55±0.01
T_8	0.74±0.06	1.08±0.01	1.55±0.02	1.77±0.03

N.B.: T_1 = 0.3% CA + 1% $CaCl_2$; T_2 = 0.3% AA + 1% $CaCl_2$; T_3 = 0.3% KMS + 1% $CaCl_2$; T_4 = 0.3% CA + 0.3% AA + 1% $CaCl_2$; T_5 = 0.3% CA + 0.3% KMS + 1% $CaCl_2$; T_6 =- 0.3% AA + 0.3% KMS + 1% $CaCl_2$; T_7 =– 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values are mean ± standard error of the mean.

Effect of pretreatment on ascorbic acid content of frozen tender jackfruits during storage

Table 3 shows the trend of ascorbic acid content of frozen tender jackfruits durning 6 months of storage. It was observed that the ascorbic acid content decreased in all samples and ranged between 8.74-10.00 mg/100g at the initial stage and it ranged from 6.30-7.45 mg/100g after 6 months of storage. Among the pretreatment, treatment T_3 (0.3% KMS+1%$CaCl_2$), T_6 (0.3% AA + 0.3% KMS + 1% $CaCl_2$) and T_7 (0.3%AA+0.3% KMS+0.3%CA+1%$CaCl_2$) retained the maximum ascorbic acid after 6 months of storage. The decrease in ascorbic acid in frozen tender jackfruits might be the influence of heat during the blanching as well as the reaction of metallic constituents of jackfruit with the phenolic compounds and the influence of light exposure (Kamal *et al*., 2019).

Table 3. Ascorbic acid (mg/100g) of frozen tender jackfruits during 6 months of storage.

Treatments	Initial	2 months	4 months	6 months
T_1	9.03±0.24	8.27±0.24	7.31±0.25	6.30±0.023
T_2	8.74±0.26	8.35±0.26	7.36±0.27	6.44±0.29
T_3	9.88±0.17	9.39±0.18	8.40±0.17	7.42±0.20
T_4	10.00±0.19	9.66±0.19	8.79±0.20	7.28±0.20
T_5	9.75±0.37	9.36±0.38	8.63±0.37	7.26±0.35
T_6	9.94±0.18	9.55±0.16	8.82±0.18	7.45±0.16
T_7	9.88±0.05	9.67±0.05	8.68±0.05	7.31±0.09
T_8	9.50±0.04	9.07±0.06	8.68±0.03	6.36±0.05

N.B.: T_1 = 0.3% CA + 1% $CaCl_2$; T_2 = 0.3% AA + 1% $CaCl_2$; T_3 = 0.3% KMS + 1% $CaCl_2$; T_4 = 0.3% CA + 0.3% AA + 1% $CaCl_2$; T_5 = 0.3% CA + 0.3% KMS + 1% $CaCl_2$; T_6 =- 0.3% AA + 0.3% KMS + 1% $CaCl_2$; T_7 =– 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values

are mean ± standard error of the mean.

Effect of pretreatment on beta-carotene content of frozen tender jackfruits during storage

The data obtained for the effect of pretreatment on the ßcarotene content of frozen tender jackfruits during 6 months of storage is accumulated in Table 4. It was observed that the ß-carotene content sharply reduced during the storage period. On the initial storage day, ß-carotene content of tender jackfruits ranged between 47.81-50.63 mg/100g and it was changed to 21.35-37.85 mg/100g during 6 months of storage. The maximum ß-carotene was retained by the treatment T_5 (0.3% CA + 0.3% KMS + 1% $CaCl_2$) and T_7 (0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$), which might be the reason for applied pretreatment to mask the sample to protect them from the degradation of ß-carotene during 6 months' storage.

Table 4. ß-carotene (mg/100g) of frozen tender jackfruit during 6 months' storage.

Treatments	Initial	2 months	4 months	6 months
T_1	48.88±0.39	44.80±0.38	35.20±0.23	22.52±0.59
T_2	48.99±0.37	43.09±0.36	34.08±0.37	26.92±0.46
T_3	49.64±0.28	43.91±0.25	34.64±0.23	29.42±0.37
T_4	50.25±0.71	44.88±0.72	35.89±0.61	28.59±0.83
T_5	50.63±0.60	46.05±0.60	39.95±0.71	37.85±0.23
T_6	49.09±0.38	44.50±0.39	38.83±0.39	35.33±1.05
T_7	48.49±0.78	43.70±0.80	39.11±0.81	37.37±0.75
T_8	47.81±0.11	41.42±0.10	31.40±0.05	21.35±0.34

N.B.: T_1 = 0.3% CA + 1% $CaCl_2$; T_2 = 0.3% AA + 1% $CaCl_2$; T_3 = 0.3% KMS + 1% $CaCl_2$; T_4 = 0.3% CA + 0.3% AA + 1% $CaCl_2$; T_5 = 0.3% CA + 0.3% KMS + 1% $CaCl_2$; T_6 =- 0.3% AA + 0.3% KMS + 1% $CaCl_2$; T_7 =– 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values are mean ± standard error of the mean.

Effect of pretreatment on total phenolic content of frozen tender jackfruits during storage

Phenolic compounds are considered bioactive compounds which have potent antioxidant properties to reduce several degenerative diseases like cancer, heart attack, cardiovascular diseases, diabetes etc. Table 5 shows the data for the total phenolic content of frozen tender jackfruits during 6 months' storage. It was observed from Table 5 that the total phenolic content ranged between 177.85-297.55 mg GAE/100g at the initial stage, which becamedecreased to 120.53-245.51 mg GAE/100g after 6 months of storage. The maximum phenol was recorded for treatment T_7 (0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$) and T_3 (0.3% KMS + 1% $CaCl_2$) after the end of the storage period.

Table 5. Total phenol (mg GAE/100g) of frozen tender jackfruits during 6 months of storage

Treatments	Initial	2 months	4 months	6 months
T_1	251.15±1.67	185.23±1.78	164.21±2,15	137.02±1.88
T_2	264.97±5.08	253.95±5.09	232.93±1.93	205.74±2.06
T_3	293.52±2.91	282.50±2.21	261.48±4.08	234.29±4.09
T_4	272.12±3.72	261.10±4.63	240.34±3.95	213.15±2.91
T_5	265.35±3.85	254.33±3.11	233.57±2.98	206.38±2.01
T_6	283.96±1.67	272.94±2.67	256.61±1.60	229.42±1.78
T_7	297.55±2.67	286.53±1.45	272.70±2.89	245.51±1.27
T_8	177.85±2.64	166.83±2.57	147.72±1.07	120.53±1.09

N.B.: T_1 = 0.3% CA + 1% $CaCl_2$; T_2 = 0.3% AA + 1% $CaCl_2$; T_3 = 0.3% KMS + 1% $CaCl_2$; T_4 = 0.3% CA + 0.3% AA + 1% $CaCl_2$; T_5 = 0.3% CA + 0.3% KMS + 1% $CaCl_2$; T_6 = 0.3% AA + 0.3% KMS + 1% $CaCl_2$; T_7 =– 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values are mean ± standard error of the mean.

Effect of pretreatment on the total antioxidant properties of frozen tender jackfruits during storage

The antioxidant capacity of pretreated frozen tender jackfruits was determined using the DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) free radical scavenging activity and expressed as %DPPH inhibition. The antioxidant activity of frozen tender jackfruits prepared using different pretreatments

were shown in Table 6. It was observed from Table 6 that the antioxidant properties of frozen tender jackfruits ranged from 77.85 to 93.96% on the day of processing which was found to fluctuate from 52.53 to 65.51% after 6 months of storage. It can be seen that the antioxidant properties were found to decrease in all pretreated frozen tender jackfruits irrespective of the storage period. However, a significant amount of antioxidants was preserved in all samples during 6storage period. From Table 6, it was also seen that tender jackfruits pretreated by T_5 (0.3% CA + 0.3% KMS + 1% $CaCl_2$) and T_6 (0.3% AA + 0.3% KMS + 1% $CaCl_2$) retained and shown the maximum amount of antioxidant activities. The antioxidant capacity of frozen tender jackfruits might be the presence of different phenolics and other phytochemical compounds present in the jackfruits (Saxena *et al.,* 2009). Also, the frozen storage conditions and the pretreatments applied may retard the excessive biochemical reaction that might slow down the rapid antioxidant loss in frozen tender jackfruits.

Table 6. Total antioxidant properties (DPPH radical scavenging activity, % inhibition) of frozen tender jackfruits during 6 months of storage.

Treatments	Initial	2 months	4 months	6 months
T_1	89.15±1.71	78.23±1.18	61.21±1.35	54.02±1.19
T_2	90.97±2.18	81.95±2.19	72.93±1.13	61.74±1.16
T_3	93.52±2.31	82.50±1.11	71.48±2.18	64.29±2.10
T_4	92.12±2.12	81.10±2.31	70.34±2.15	63.15±1. 13
T_5	89.35±2.15	77.33±2.31	69.57±2.18	61.38±1.11
T_6	93.96±2.71	82.94±1.17	73.61±1.16	65.42±1.17
T_7	92.55±2.57	81.53±1.15	72.70±1.19	65.51±1.21
T_8	77.85±2.64	66.83±1.27	58.72±1.13	52.53±1.19

N.B.: T_1 = 0.3% CA + 1% $CaCl_2$; T_2 = 0.3% AA + 1% $CaCl_2$; T_3 = 0.3% KMS + 1% $CaCl_2$; T_4 = 0.3% CA + 0.3% AA + 1% $CaCl_2$; T_5 = 0.3% CA + 0.3% KMS + 1% $CaCl_2$; T_6 = 0.3% AA + 0.3% KMS + 1% $CaCl_2$; T_7 =– 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values are mean ± standard error of the mean.

Physical observation of frozen tender jackfruits during 6 months of storage

The observed data obtained for the external appearance of frozen tender jackfruits is shown in Table 7. It was found that the color of all treated tender jackfruit samples were good enough upto 4 months of storage except for the untreated sample (T_8) which became brown in color. After 6 months of storage, almost all the samples slightly turned brown. There were no changes in the flavor and texture of the frozen jackfruits throughout the storage periods.

Table 7. Physical observation of frozen tender jackfruits during 6 months of storage

Treatments	Parameters	Storage period				Remarks
		Initial	2 months	4 months	6 months	Edible
T_1	Color	Good	Good	Good	Brownish color	√
	Flavor	Normal	Normal	Normal	Good	
	Texture	Good	Good	Good	Good	
T_2	Color	Good	Good	Good	Turned to brown	√
	Flavor	Normal	Normal	Normal	Good	
	Texture	Good	Good	Good	Good	
T_3	Color	Good	Good	Good	Turned to brown	√
	Flavor	Normal	Normal	Normal	Good	
	Texture	Good	Good	Good	Good	
T_4	Color	Good	Good	Slight yellowish	Turned to brown	√
	Flavor	Normal	Normal	Slight off flavor	Good	
	Texture	Good	Good	Turned softening	Good	
T_5	Color	Good	Good	Good	Slightly brown	√
	Flavor	Normal	Normal	Normal	Normal	
	Texture	Good	Good	Good	Good	

Treatments	Parameters	Storage period				Remarks
		Initial	2 months	4 months	6 months	Edible
T_6	Color	Good	Good	Good	Slightly brown	√
	Flavor	Normal	Normal	Normal	Normal	
	Texture	Good	Good	Good	Good	
T_7	Color	Good	Good	Good	Slightly brown	√
	Flavor	Normal	Normal	Normal	Normal	
	Texture	Good	Good	Good	Good	
T_8	Color	Good	Turned slight brownish	Brown color increasing	Turned browned	√
	Flavor	Normal	Normal	Normal	Normal	
	Texture	Good	Good	Good	Good	

N.B.: T_1 = 0.3% CA + 1% $CaCl_2$; T_2 = 0.3% AA + 1% $CaCl_2$; T_3 = 0.3% KMS + 1% $CaCl_2$; T_4 = 0.3% CA + 0.3% AA + 1% $CaCl_2$; T_5 = 0.3% CA + 0.3% KMS + 1% $CaCl_2$; T_6 = 0.3% AA + 0.3% KMS + 1% $CaCl_2$; T_7 =– 0.3% AA + 0.3% KMS + 0.3% CA + 1% $CaCl_2$ and T_8 = No pretreatment (dipping into water); Values are mean ± standard error of the mean.

Conclusion

Jackfruit is a highly nutritious fruit, but, its consumption rate is low due to its odd flavor and gummy nature of tender jackfruit. However, reprocessing and application of some treatments could overcome such hassles, which would make this fruit usable to a wide range of consumers. For this, this study applied different pretreatment for processing tender jackfruit and stored at frozen condition. From the physical observation and findings from different quality parameters, it is concluded that tender jackfruits pretreated with T_5 (0.3% CA+0.3% KMS+1% $CaCl_2$), T_6 (0.3% AA +0.3% KMS +1% $CaCl_2$), and T_7 (0.3% AA+0.3% KMS +0.3% CA+1% $CaCl_2$) could be stored at frozen condition for longer storage without appreciable quality change.

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STANDARDIZATION OF PACKAGES FOR VACUUM FRIED JACKFRUIT CHIPS

M.G.F. CHOWDHURY, M.H.H. KHAN, M.M. MOLLA, S. PERVIN, A.A. SABUZ

Abstract

The objective of this study was to standardize the packaging material best suited for the storage of vacuum fried jackfruit chips. For this five different packages (high-density polyethylene, double layer aluminium foil, single layer aluminium foil, polypropylene, and metalax foil packet) have been used in this study. The study was conducted for 120 days from the initial processing day. The results revealed that the moisture content varied irregularly from 2.43 to 4.44% (wb) at the beginning and ranged between 2.88 to 5.60% (wb) after 120 days of storage for different packages. The acidity content slightly increased throughout the storage period. All packaged chips retained a significant amount of antioxidant properties although their values decreased over the storage period. Also, the bioactive compounds like ascorbic acid, total carotenoids, and total phenolic content become decreased for all packages used during the storage period. The color properties indicated that the yellowish color becomes faded, however, vacuum fried jackfruit chips packed in double-layer aluminium foil and metalax foil keep the nutritional quality as well as the color properties. The consumer perception taste revealed excellent score and acceptability of the vacuum fried jackfruit chips packaged in high-density polyethylene, double layer aluminium foil, and metalax foil packet Therefore, for the storage of vacuum fried jackfruit chips, it is recommended to use double-layer aluminium foil and metalax foil packages.

Introduction

Jackfruit (*Artocarpus heterophyllus*) is the largest edible fruit in the world and is the national fruit of Bangladesh. It is a very popular fruit and its annual production is about 10.97 lakh metric tons covering an area of 44.63 thousand acres during 2020-2021 (BBS, 2021). The poor people of the Jackfruit growing area used to eat this fruit instead of rice, for one of their daily meals. Hence, Jackfruit is called “poor man’s food”. People consumed it mostly as a fruit when ripe but also as a vegetable in the unripe stage. The jackfruit significantly contributes to the nutrition of the people of this country as a source of vitamins, minerals, and calories (Yi *et al.,* 2016). Both tender and ripe fruits, as well as the seeds, are rich in minerals and vitamins (Swami *et al.,* 2012). Due to its perishable nature, jackfruit cannot be stored for a long time because of its inherent compositional and textural characteristics. Every year, a considerable amount of jackfruit, specially obtained in the glut season (June-July) in every year goes waste due to a lack of proper postharvest knowledge during harvesting, transporting, and storing both in quality and quantity. Proper postharvest technology for prolonging shelf life is, therefore, necessary. Besides, alternate ways of using jackfruits in on-season plays significant roles in reducing postharvest losses. Among them, the processing is important ones. It adds diversified and attractive food items in the dietary menu as well as contributes to the generation of income and employment.

Chips are the most popular snack item in many fast food outlets. Fried jackfruit chips may be one of the important potential jackfruit products in Bangladesh. Jackfruit chips may be also easily salable snack food in the markets. For longer shelf life, crispiness and chips quality moisture content is the most important factor as far as storage stability is concerned. Bacteria and other microorganisms cannot grow easily in a lower percentage of moisture content in chips. Visual color is the major quality criterion for determining the commercial quality with respect to consumers’ preferences and the cost of the chips (Molla *et al.,* 2008). Packaging and storage conditions are the most important quality control factors of chip preservation. Storage stability depends on packaging. Good packaging and storage conditions extend the storage duration of chips. Chips are packed in packages of various dimensions and materials, including cellophane and waxed glassine. Fiberboard cartons are used to casing the packages of chips (Ahmed, 1977). In Bangladesh, few research works have been considered in this regard. Keeping this view, the research program was undertaken to standardize of packages for keeping vacuum fried jackfruit chips with maintaining quality at ambient condition.

Materials and Methods

Collection of jackfruits

Fresh and mature ripe (not juicy) jackfruits (Khaja type) of unknown cultivar having average fruit weight, –6-10 kg was collected from the farmer's field and Cotton Research, Training and Seed Multiplication Farm under Cotton Development Board (CDB) of Sreepur under Gazipur district and transported to the laboratory of PHTD, BARI, Gazipur for conducting the study.

Preparation of jackfruit chips

Jackfruit chips were prepared using lab scale vacuum fried machine designed and fabricated in the PHTD, BARI, Gazipur. Several trial experiments using different pre-treatments and time-temperature combinations were followed for development of vacuum fried jackfruit chips. Matured jackfruits were collected and were washed, peeled, removed the seed from the bulb and sliced length wise during the experimentation. Then jackfruit slices were packed in Hydensity Polyethyelene (HDPE) packet and stored at -18^{o}C for 36 hrs. in deep fridge. The jackfruit slices were then fried in a vacuum fryer at 100^{o}C for 20 min using vegetable oil (800 g raw slices per batch). After frying, the chips were de-oiled for 2 min and finally were packed in different packages, which included as follows: (high-density polyethylene, double layer aluminium foil, single layer aluminium foil, polypropylene, and metalax foil packet). The developed protocol was as follows (Figure 1 & Figure 2):

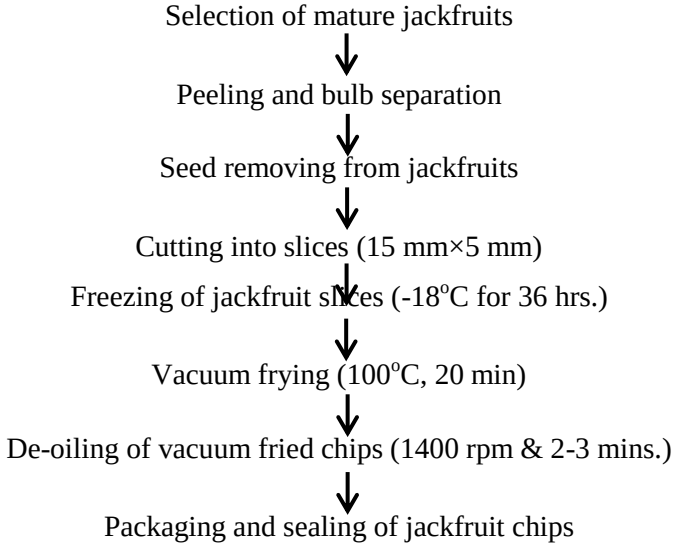


Figure 1. Process flow diagram for vacuum fried jackfruit chips

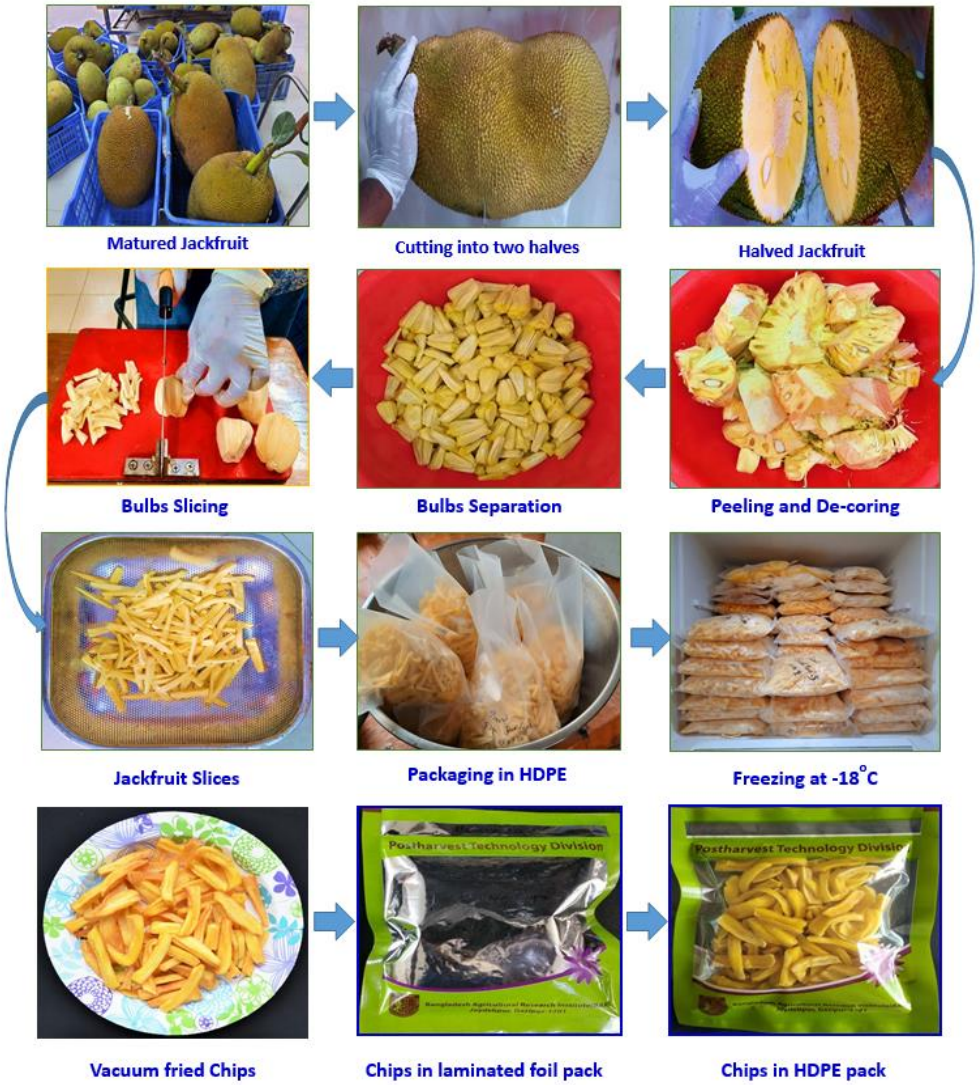


Figure 2. Photographic view of vacuum fried jackfruit chips.

Determination of moisture and acidity content

The moisture content was determined based on the AOAC official methods (AOAC, 2005) and the percent otal acidity was determined by following the methods of Ranganna (1986).

Determination of bioactive compounds

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

Determination of total antioxidant activity

The total antioxidant activity of vacuum fried jackfruit chips was determined based on the DPPH free radical scavenging activity and expressed as the percentage inhibition. For this analysis, the method adopted by Kamal *et al.* (2019) was used in this study.

Determination of external appearance

Color attributes of the vacuum fried jackfruit chips were determined as L (lightness), a* (red/green), and b* (yellow/blue) values using the Chroma meter (CR-410, Konica Minolta, Inc., Japan).

Sensory evaluation

The sensory attributes of the vacuum fried jackfruit chips were evaluated based on the 9-point hedonic scale. For this, 15 experts and semi-trained panelists were asked to score on the parameters such as color, flavor, crispiness, taste, and overall acceptability.

Statistical analysis

The data obtained were analyzed using the SPSS statistical software and the results were represented as the mean ± standard error of the replicated data. Analysis of variance at a 5% level of significance was used to separate the mean of the respective parameters for different packaging materials.

Results and Discussion

Table 1. The moisture content of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
High-density polyethylene (HDPE)	3.64±0.23	5.89±0.06	6.83±0.19	6.10±0.04	4.76±0.04
Double-layer aluminum foil	2.43±0.05	3.94±0.05	3.40±0.21	2.08±0.03	3.60±0.09
Single-layer aluminum foil	3.76±0.12	2.05±0.11	4.14±0.10	2.48±0.01	3.08±0.03
Polypropylene	4.44±0.02	2.26±0.14	5.55±0.34	2.54±0.04	4.08±0.03
Metalax foil	2.86±0.03	2.54±0.12	2.81±0.10	2.41±0.08	2.88±0.04

N.B.: Values are mean ± standard error of the mean.

Effect of packaging on the moisture content of vacuum fried jackfruit chips

Table 1 shows the effect of different packages on the moisture content of vacuum fried jackfruit chips stored for 120 days at ambient conditions. It can be seen that the moisture content varied from 2.43 to 4.44% (wb) for different packages on the processing day while it ranged between 2.88-4.76% (wb) after 120 days of storage. It can be observed that the moisture content changed in an irregular way throughout the storage period. Table 1 also shown that double-layer aluminium foil and metalax foil were found to keep relatively consistent moisture barrier properties for the vacuum fried chips during storage period.

Table 2. Total acidity content of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	0.32±0.01	0.39±0.02	0.49±0.01	0.57±0.08	0.86±0.06
Double-layer aluminum foil	0.21±0.02	0.32±0.01	0.32±0.01	0.32±0.01	0.44±0.01
Single-layer aluminum foil	0.32±0.03	0.44±0.06	0.32±0.01	0.36±0.01	0.51±0.01
Polypropylene	0.35±0.01	0.59±0.02	0.28±0.01	0.28±0.01	0.63±0.01
Metalax foil	0.36±0.01	0.36±0.01	0.60±0.01	0.67±0.01	0.64±0.01

N.B.: Values are mean ± standard deviation of the mean.

Effect of packaging on the total acidity content of vacuum fried jackfruit chips

The total acidity content of vacuum fried jackfruit chips packaged in different packages and stored for 120 days at ambient conditions were presented in Table 2. It was observed that the total acidity content of vacuum fried jackfruit chips was increased slightly throughout the storage period irrespective of packages used. The ranges for the total acidity content were 0.32 to 0.86%, 0.21 to 0.44%, 0.32 to 0.51%, 0.35 to 0.63% and 0.36 to 0.64% for HDPE, double layer aluminium foil, single layer aluminium foil, polypropylene, and metalax foil packages respectively. It can also be found that the double layer aluminium foil maintained a consistent and lower acidity of vacuum fried jackfruit chips during the storage period.

Table 3. Total Ascorbic acid content of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	28.06±1.01	27.17±1.79	23.55±0.35	18.03±0.39	14.70±1.69
Double-layer aluminum foil	26.95±1.48	24.32±0.48	22.14±0.53	25.43±1.91	17.64±1.27
Single-layer aluminum foil	25.05±0.76	24.79±1.27	23.52±1.11	18.03±1.15	18.90±0.90
Polypropylene	26.46±1.69	23.48±1.69	22.73±2.78	21.32±1.23	17.22±1.52

Metalax foil	25.51±0.53	23.52±0.85	21.15±0.58	21.55±1.36	20.58±1.17

N.B.: Values are mean ± standard deviation of the mean.

Effect of packaging on the total ascorbic acid content of vacuum fried jackfruit chips

Ascorbic acid is considered the most unstable compound because it became degraded due to light, heat, exposure to metallic elements, oxygen etc. (Kamal *et al.,* 2019). The total ascorbic acid content of vacuum fried jackfruit chips packaged in different packages and stored for 120 days at ambient conditions is presented in Table 3. It was observed that the total ascorbic content of vacuum fried jackfruit chips decreased slightly throughout the storage period irrespective of packages used. The ranges for total ascorbic acid were 14.70 to 28.06 mg/100g, 17.64 to 26.95 mg/100g, 18.90 to 25.05 mg/100g, 17.22 to 26.46 mg/100g, and 20.58 to 25.51 mg/100g for HDPE, double-layer aluminium foil, single-layer aluminium foil, and metalax foil packages respectively. It can also be noticed that the vacuum fried jackfruit chips packed in metalax foil retained maximum ascorbic acid during the storage period.

Table 4. Total carotenoids content of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	6.39±0.08	5.97±0.12	4.52±0.06	4.19±0.03	3.71±0.05
Double-layer aluminum foil	8.46±0.13	5.20±0.27	4.37±0.22	2.44±0.04	2.04±0.12
Single-layer aluminum foil	8.59±0.18	4.54±0.08	4.99±0.55	3.90±0.02	2.52±0.03
Polypropylene	7.77±0.50	7.39±0.33	6.68±0.19	4.30±0.03	1.45±0.10
Metalax foil	8.97±0.17	4.94±0.40	4.96±0.06	4.54±0.05	2.49±0.19

N.B.: Values are mean ± standard deviation of the mean.

Effect of packaging on the total carotenoid content of vacuum fried jackfruit chips

Carotenoids are considered one of the important bioactive compounds for human life. Like ascorbic acid, it degraded due to light, heat, exposure to metallic elements, oxygen etc. Table 4 represents the total carotenoid content of vacuum fried jackfruit chips packaged in different packages and stored for 120 days at ambient conditions. It was observed that the total carotenoid content of vacuum fried jackfruit chips was very low and decreased throughout the storage period irrespective of packages used. At the beginning of storage, the total carotenoids content of vacuum fried jackfruit chips was 6.39 mg/100g, 8.46 mg/100g, 8.59 mg/100g, 7.77 mg/100g, and 8.97 mg/100g for HDPE, double-layer aluminium foil, single-layer aluminium foil, and metalax foil packages respectively, which was found as 3.71 mg/100g, 2.04 mg/100g, 2.52 mg/100g, 1.45 mg/100g, and 2.49 mg/100g respectively for the mentioned packages after 120 days of storage. It can be observed that the vacuum fried jackfruit chips packed in HDPE preserved the maximum total carotenoids during the storage period.

Table 5. Total phenolic content of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	405.67±6.94	298.90±2.94	252.15±4.33	279.35±7.37	234.28±3.88
Double-layer aluminum foil	429.35±7.47	363.58±5.64	335.65±5.83	312.63±5.30	173.54±1.30
Single-layer aluminum foil	432.28±6.93	324.20±14.46	269.45±7.21	224.28±7.80	192.55±2.97
Polypropylene	420.40±5.65	369.15±1.18	368.65±14.40	352.78±5.96	207.73±2.09
Metalax foil	452.75±18.12	438.21±6.54	228.30±2.36	228.85±5.67	218.28±1.52

N.B.: Values are mean ± standard deviation of the mean.

Effect of packaging on the total phenolic content of vacuum fried jackfruit chips

Total phenolic content represents the antioxidant properties of foodstuffs, which are essential to combat several degenerative diseases. The total phenolic content of vacuum fried jackfruit chips packed in different packages are shown in Table 5. It was observed that the total phenolic contents of vacuum fried jackfruit chips decreased throughout the storage period irrespective of packages used. At the beginning of storage, the total phenolic content of vacuum fried jackfruit chips was 405.67 mg GAE/100g, 429.35 mg GAE/100g, 432.28 mg GAE/100g, 420.40 mg GAE/100g, and 452.75 mg

GAE/100g for HDPE, double-layer aluminium foil, single-layer aluminium foil, and metalax foil packages respectively, which was found as 234.28 mg GAE/100g, 173.54 mg GAE/100g, 192.55 mg GAE/100g, 207.73 mg GAE/100g, and 218.28 mg GAE/100g respectively for the mentioned packages after 120 days of storage. It can also be found that the vacuum fried jackfruit chips packed in the HDPE and metalax foil packages preserved the maximum total phenols during the storage period.

Table 6. Total antioxidant properties (DPPH radical scavenging activity, % inhibition) of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	68.67±4.49	59.90±2.94	51.15±3.13	49.35±2.27	44.28±3.28
Double-layer aluminum foil	68.85±3.74	63.58±3.64	57.61±4.53	52.13±2.20	47.34±1.19
Single-layer aluminum foil	68.28±5.38	58.20±4.34	52.35±3.41	45.19±2.10	42.15±2.71
Polypropylene	68.40±3.53	59.15±3.18	49.85±4.10	43.68±2.16	39.71±2.01
Metalax foil	68.75±4.42	62.21±2.54	58.13±3.36	52.65±2.17	47.78±1.32

N.B.: Values are mean ± standard deviation of the mean.

Effect of packaging on the total antioxidant properties of vacuum fried jackfruit chips

The total antioxidant properties of vacuum fried jackfruit chips were determined based on the DPPH free-radical scavenging activities (DPPH-RSA) and expressed as the percentage inhibition. The data obtained for DPPH-RSA was presented in Table 6. It can be found that the DPPH-RSA ranged between 68.28 to 68.85% on the initial day of processing, which was found to range from 39.71 to 47.78% after 120 days of storage irrespective of the packaging material used. It was also observed that the antioxidant properties of vacuum fried jackfruit chips were found to decrease in all samples throughout the storage period. It can be noticed that the vacuum fried jackfruit chips packed in metalax foil and double layer aluminum foil preserved the maximum antioxidantproperties throughout the storage period. It is stated from the results that the packaging materials had a significant role in preserving the bioactive compounds of vacuum fried jackfruit chips (Table 6). The change in antioxidant properties might be the result of the reaction of the constituent molecules which might be accelerated by the action of heat and oiling conditions of the chips along with the reaction with phenolic compounds present in the jackfruit chips.

Table 7. Lightness (L*) value of vacuum fried jackfruit chips stored in different packages

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	60.30±0.25	61.70±0.74	61.69±0.25	63.44±0.68	63.48±1.35
Double-layer aluminum foil	62.93±1.16	64.32±1.17	67.67±1.19	64.31±0.83	67.91±0.51
Single-layer aluminum foil	67.70±1.57	68.76±0.81	68.65±1.93	69.89±1.86	69.09±0.88
Polypropylene	68.32±0.40	68.34±1.14	69.90±0.59	71.40±0.90	72.69±0.90
Metalax foil	62.78±1.29	65.09±1.19	66.34±0.97	67.66±1.63	67.73±0.97

N.B.: Values are mean ± standard deviation of the mean.

Effect of packaging on the external appearance of vacuum fried jackfruit chips

The changes in color properties of vacuum fried jackfruit chips packed in different packages are shown in Tables 7, Table 8, and Table 9. From Table 7, it was observed that the lightness (L) value slightly increased from the beginning to the end of the storage period and ranged between 60.30-63.48, 62.93-67.91, 67.70-69.89, 68.32-72.69, and 62.78-67.73 for HDPE, double-layer aluminium foil, single-layer aluminium foil, and metalax foil packages respectively. From Table 8, the values for a* (red/green) was ranged from 1.48-3.71, 1.48-1.62, 1.48-2.35, 1.48-1.78, and 1.48-2.00 for HDPE, double-layer aluminium foil, single-layer aluminium foil, and metalax foil packages, respectively.

Table 8. R**ed/green (a*) value of vacuum fried jackfruit chips stored in different packages**

Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	1.48±0.06	2.53±0.32	2.13±0.15	3.39±0.67	3.71±0.40
Double-layer aluminum foil	1.48±0.06	1.19±0.05	1.28±0.11	1.54±0.16	1.62±0.40
Single-layer aluminum foil	1.48±0.06	2.33±0.06	1.56±0.22	2.00±0.22	2.35±0.31

Polypropylene	1.48±0.06	1.59±0.10	1.79±0.12	1.40±0.04	1.78±0.19
Metalax foil	1.48±0.06	2.00±0.69	1.56±0.36	1.05±0.20	1.50±0.30

N.B.: Values are mean ± standard deviation of the mean.

Table 9. Yellow/blue (b*) value of vacuum fried jackfruit chips stored in different packages

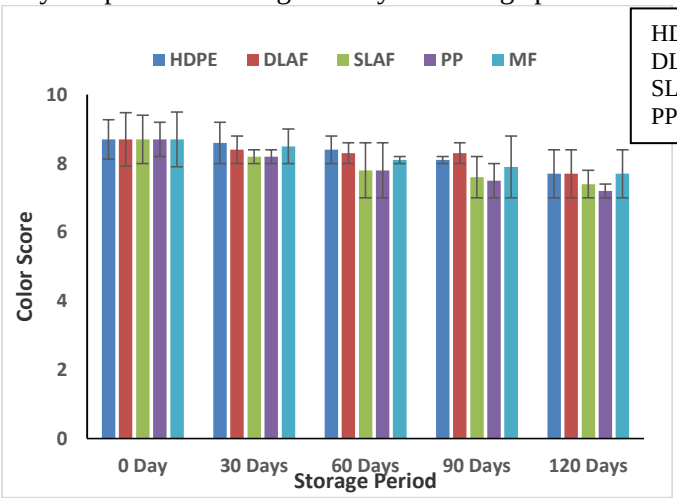
Packages	0 Day	30 Day	60 Day	90 Day	120 Day
HDPE	45.99±0.85	39.24±1.07	35.55±1.60	39.03±1.91	33.16±0.09
Double-layer aluminum foil	45.99±0.85	36.76±1.39	36.71±0.59	36.48±0.39	35.84±0.50
Single-layer aluminum foil	45.99±0.85	37.50±0.29	35.82±0.91	32.37±1.54	34.63±0.06
Polypropylene	45.99±0.85	33.50±0.55	34.00±1.68	32.34±0.84	30.75±0.39
Metalax foil	45.99±0.85	38.08±1.38	42.72±0.58	38.38±0.74	34.35±0.64

N.B.: Values are mean ± standard deviation of the mean.

On the other hand, the b* (yellow/blue) value of vacuum fried jackfruit chips packed in different packages are shown in Table 9. It can be observed that initially the b* value was 45.99 while it was decreased for all packages and was found to range between 30.75 to 35.84 during 120 days of storage. The highest yellow color was retained in the double-layer aluminum foil package while it was the lowest in the case of polypropylene packet. As it is known that product color largely depends on the reaction of product ingredients and the oxidation of phenolic compounds within the package environment.

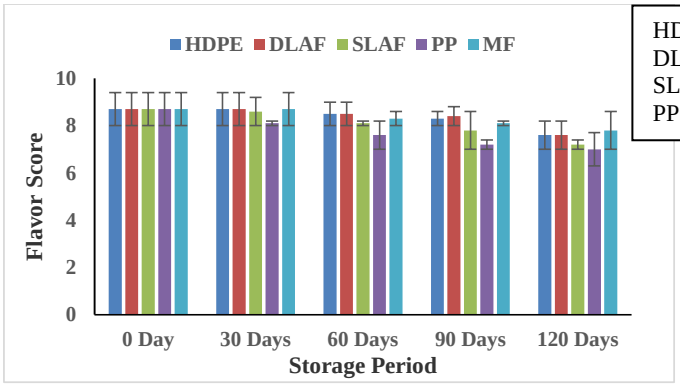
Effect of packaging on the sensory properties of vacuum fried jackfruit chips

The effect of different packaging on the sensory quality of vacuum fried jackfruit chips during the storage period is presented in Figures 3a-3e. It was found that the sensory score for color, flavor, crispiness, taste, and overall acceptability decreased slightly over the storage period and varied significantly among the packages used. However, those properties tested were excellent up to 90 days of storage. After 120 days of storage, the color and crispiness became decreased in almost all samples, however, other properties were acceptable. Among the packages used, HDPE, double layer aluminium foil, and metalax foil packet preserved the sensory properties, which were reflected in the sensory scores provided by the panelists during 120 days of storage period.



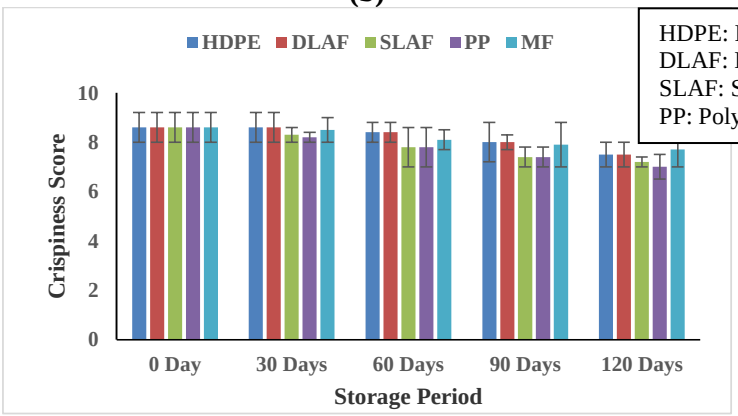
HDPE: High-density polyethylene
DLAF: Double-layer aluminum foil
SLAF: Single-layer aluminum foil
PP: Polypropylene; MF: Metalex foil

(a)



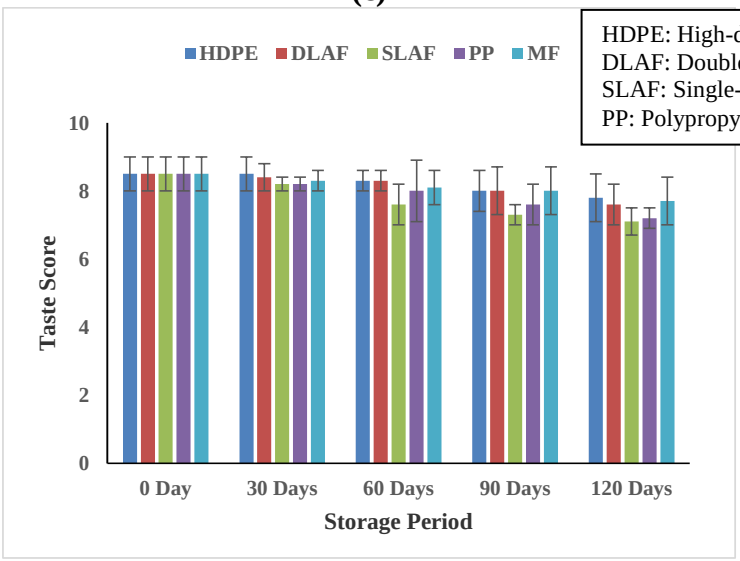
HDPE: High-density polyethylene
DLAF: Double-layer aluminum foil
SLAF: Single-layer aluminum foil
PP: Polypropylene; MF: Metalex foil

(b)



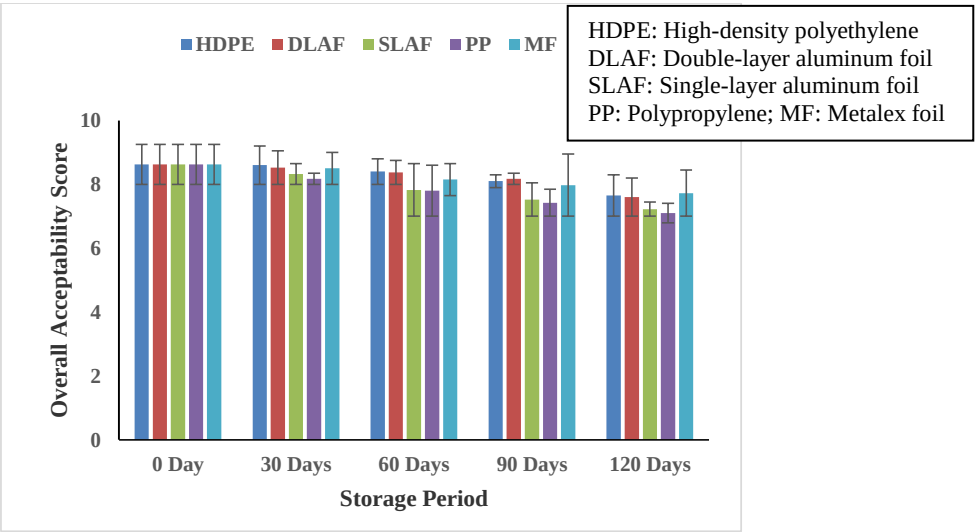
HDPE: High-density polyethylene
DLAF: Double-layer aluminum foil
SLAF: Single-layer aluminum foil
PP: Polypropylene; MF: Metalex foil

(c)



HDPE: High-density polyethylene
DLAF: Double-layer aluminum foil
SLAF: Single-layer aluminum foil
PP: Polypropylene; MF: Metalex foil

(d)



(e)

Figure 3. Sensory properties of vacuum fried jackfruit chips packed in different packages: (a) color, (b) flavor, (c) crispiness, (d) taste, and (e) overall acceptability during storage period.

Conclusion

Jackfruit is a highly nutritious fruit, but its consumption rate is low due to its strong flavor. However, this fruit can be processed into value-added products like vacuum fried jackfruit chips. On the other hand, the quality of chips highly depends on the packages used. In this study, it was found that vacuum fried jackfruit chips packed in double-layer aluminium foil and metalax foil keep the nutritional quality, color as well as sensory properties. Therefore, for longer storage of jackfruit chips, it is recommended to use double-layer aluminium foil and metalax foil packages.

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DEVELOPMENT OF A SUITABLE PACKET FOR KEEPING VACUUM FRIED JACKFRUIT CHIPS

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

Abstract

The aim of the study was to fabricate a suitable packet for keeping vacuum jackfruit chips on the basis of existing packaging materials of fried chips product available in the market. The length and width of the proposed packet were selected from the existing information of the packet available in the market. To sustain the new product on market, it is required to choose an attractive packet in proper way. Predicting the opportunity, a market survey was conducted to analyze the existing chips packet and then propose a new one for fabricating jackfruit chips packet for the stakeholders. Packet thickness varied as per the product specification. The tensile strength was recommended among seven best samples according to the laboratory test result. The packet should able to show the highest tensile strength such as 39.47 N/mm^2 with the lowest elongation such as 14.08 mm before bursting. The study showed that the suitable packet thickness should be recommended a range 63-65 µm for four layers including print ink where the length and width might be with a range 19-21 mm and 15.5-16.5 mm, respectively. The permissible moisture content should be maintained between 0.8% and 2.3% for the average weight of the chips packet (50 g or more). The size of the packet can be modified maintaining the same ratio of the design and fulfilling the design criteria.

Introduction

Chips are a popular food snacks and it is consumed mostly by the kids or by any aged people anytime if anyone wishes. Fried chips are one the snack item which is usually eaten between meals. In Bangladesh, potato chips are almost everywhere available as a craker and few agro-processing industry is preparing and marketing this product both in domestic and international market. The real potato chips are prepared using deep oil frying by the local vendor. It is found generally in the street vendor duing movement by the transport from one area to another area. Very few food processing company is producing real potato chips such as Sun chips or Alooz. There are many crakers in the market found as different brand name. But jackfruit chips are fully absent in our country. It is the most popular snack product in the international market and its demand is high because of its nutritional value, favorable crispy texture and flavor (Nansereko & Muyonga, 2021).

Jackfruit is the national fruit in Bangladesh and it is grown plenty amount everwhere in the country. Since Bangladesh is an agriculturally based country and has lots of fertile land to produce fruits and different types of crops. Fruits are grown in a comparatively higher amount than in other countries. A substantial amount of fruit is wastage or damage during the harvesting season because of lack of appropriate processing technology and less demand in the market compared to the other fruits availability in the same season (Molla *et al.*, 2008). To reduce this type of loses, it is required to think of alternative ways to create new demand. The alternative way may be to produce jackfruit chip as a value added product development using vacuum fryer and their availability in the market by fabricating a smart packet for longer storage with maintaining quality. Attractive packet design is essential to fulfil the consumers demand as well as the best use for keeping quality of the product.

Packaging means covering or keeping the product to protect from damage, leakage, dust, pollution, contamination and from environment impact. It also creates the product preference to the customer and act as a vehicle by which the brand of a product is carried through the consumer which is a powerful selling tool (Natarajan *et al.*, 2014). There is a little difference between packet and package that is the package is something which is packed such as a parcel, a box, an envelope and the packet is a small pack or package such as a packet of letters, a packet of biscuits, a packet of chips like potato, banana, jackfruit chips etc. Jackfruit chips is a crispy product and is needed to packet to increase its shelf life and retain, quality as well as supplying in the market for the customer.

The quality of fried chips product highly depends on the packet and its design characteristics. But the package design and development starts with the identification of all the requirements such as structural design, graphic design, storage life, quality assurance, logistics, legal, regulatory, end-use, environmental aspect etc with the design constraints such as the resources, cost, performance,

completion time (Chandon, 2013). The demand of jackfruit chips is higher in international market due to its nutritional composition.

The process of preparing chips is not so difficult only needs to peel and slice of jackfruit to produce fried chips using a vacuum fryer to retain quality. Predicting the opportunity in this sector, an effort of developing jackfruit chips packet is required to enhance shelf life with quality. Therefore, the study was conducted for designing and fabricating a packet of jackfruit chips on the basis of different physico-chemical parameters existing fried chips packet available in the market.

Materials and Methods

Assessment of existing fried chips packet

To analyze the existing fried chips packet, the five steps are as follows:

Step 1: Sample collection
Step 2: Information collection
Step 3: Evaluation of moisture content
Step 4: Determination of fried chips color
Step 5: Estimation of tensile strength

Additionally, some inspections were conducted during the experimentation such as,

- Analyzing chips quality-
  - Color
  - Crispness
  - Odor/Aroma
- Testing of packet (Types of tests required for the polymer packet)
  - Print inspection
  - Zipper lock re-sealability
  - Moisture permeability
  - Micro porosity

Sample collection

The chips packet which are available on the local market were collected to record the desired information and to conduct the required test. The information of collected samples is given below:

Data collection

The size, thickness and wight of the collected 41 fried chips packets are listed below presented in Table 1.

Table 1. Existing packet size, thickness and weight of the fried chips samples

Sl. No.	Chips packet	Manufacturer	Thickness (mm)	Inner length (cm)	Outer length (cm)	Width (cm)	Claimed wt. (g)	Actual wt. (g)
1	French fry	NZL dairy pro.	0.096	16.9	19	13.6	15	21.47
2	propper	NZL dairy pro.	0.096	18	19.7	14.8	25	31.55
3	Destos	NZL dairy pro.	0.100	18	20	15	30	37.41
4	Yokozona	NZL dairy pro.	0.100	17.7	19.8	14.8	25	31.63
5	X fun	ACI	0.082	17.5	19.7	14.8	22	27.37
6	Pastazz	Pepsico	0.064	18.9	20.9	16	37	42.63
7	Lays	Pepsico	0.055	17.2	18.8	13.6	30	28.35
8	Kurkure	Pepsico	0.061	17.2	19.7	14.8	45	49.02
9	Kean	Elsa	0.076	18.3	20.4	15.8	22	26.02
10	Friends potato	Pran	0.065	17.5	19.9	15.1	18	23.84
11	Diamond potato	Pran	0.073	17.2	19.8	15	18	22.88
12	Zero chips	Pran	0.067	17.8	20.2	14.9	17	21.62
13	Potato sticks	Pran	0.063	16.5	19	14.9	14	18.63

Sl. No.	Chips packet	Manufacturer	Thickness (mm)	Inner length (cm)	Outer length (cm)	Width (cm)	Claimed wt. (g)	Actual wt. (g)
14	Mothu Patlu potato crackers	Pran	0.064	18.8	18.1	16.5	14	18.74
15	Potato crackers	Bomby sweets	0.065	17.6	19.9	14.9	20	24.74
16	Nachoz	Bomby sweets	0.075	17.7	19.7	15	30	36.34
17	Alooz	Bomby sweets	0.072	17.5	19.8	14.8	25	30.60
18	Ring chips	Bomby sweets	0.068	17.7	19.9	14.8	20	24.70
19	Mr. Chicken	Bomby sweets	0.069	16.4	18.4	14.9	25	28.72
20	Mr. Twist	Bomby sweets	0.069	21.8	23.9	14.9	25	31.33
21	Sun prawn crackers	Kasem	0.076	17.6	19.8	13.8	20	23.67
22	Sun chips	Kasem	0.074	17.4	19.9	13.9	22	27.60
23	Eggy pillow	Ifad	0.075	15.3	17.9	13.6	20	25.33
24	Eggy stix	Ifad	0.074	15.2	17.9	13.6	20	24.31
25	Cheese puffs	Akij	0.076	17	19.6	15	20	26.43
26	Baked cheese	Akij	0.080	17.5	19.7	15	20	26.57
27	Ruchi potato	Square	0.086	17.9	20.1	14.1	22	29.05
28	Pillow chocolate	A.T Haque	0.083	16.8	18.2	12.2	20	24.20
29	BD potato crack	BD food	0.079	17.6	19.8	15.1	20	23.67
30	Meridian real thai chicken	Meridian	0.074	13.8	16.6	14.6	15	17.90
31	Crispy chicken sticks	Meridian	0.074	16	19.2	14.7	15	22.72
32	Dong Dong chips	Azam food	0.054	12.7	18.4	12.9	22	23.81
33	Asha chips	Asha food	0.060	14.7	17.5	12.6	40	35.42
34	Mothu Patlu	Mayer doya	0.075	12.5	15.1	11.6	15	19.01
35	Ruchi potato	Square	0.085	14.3	16.7	12.3	10	14.55
36	Nameless	Local	0.036	8	14	12.7	8	8.32
37	Packet-1	Sample only	0.073	0.073	15	19.2	40	40.00
38	Packet-2	Sample only	0.123	0.123	19.5	23.2	50	50.00
39	Packet-3	Sample only	0.063	0.063	18.2	23	40	40.00
40	Packet-4	Sample only	0.047	0.047	17.3	20.3	40	40.00
41	Packet-5	Sample only	0.096	0.096	15.2	19.4	50	50.00

N: B: NZL=New Zealand

Measurement of moisture content

Moisture content was determined according to the method described by Ranganna (2007) with slight modification. 3-5 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 moisture content was calculated using the following formula:

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

Measurement of external appearance

On the basis of method described by Dervisi *et al.* (2001), the external color of the fried 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.

Tensile Strength test

Lays and Kurkure chips are made by same manufacturer so one of them is needed to reduce for further testing. Among of them the Lays chips has eliminated, as its moisture content is higher than the Kurkure chips.

The following steps are considered for testing of tensile strength test

- Cutting each sample into stripe as the length is 50 mm and the width is 14 mm.
- Measuring thickness of each strip.
- Visualizing primary mechanical defect of the samples.
- Recorded the data during testing.

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 Discussions

Table 2 presents the moisture contents, time spending and number of layers of the collected fried chips sample.

Table 2. Moisture content of the existing collected chip's samples at different locations

Sl. No.	Chips packet	Manufacturer	Moisture (%)	Duration (month)	No. of layer (Color+Poly + Metal film)	Thickness (mm)
1	French fry	NZL dairy pro.	3.99	3	3	0.096
2	Propper	NZL dairy pro.	2.42	3	3	0.096
3	Destos	NZL dairy pro.	3.19	2	3	0.100
4	Yokozona	NZL dairy pro.	2.42	3	3	0.100
5	X fun	ACI	1.98	3	3	0.082
6	Pastazz	Pepsico	2.35	2	3	0.064
7	Lays	Pepsico	2.27	3	3	0.055
8	Kurkure	Pepsico	1.92	3	3	0.061
9	Kean	Elsa	1.37	2	3	0.076
10	Friends potato	Pran	5.96	4	3	0.065
11	Diamond potato	Pran	2.76	3	3	0.073
12	Zero chips	Pran	2.19	3	3	0.067
13	Potato sticks	Pran	2.62	3	3	0.063
14	Mothu Patlu potato crackers	Pran	4.34	2	3	0.064
15	Potato crackers	Bomby sweets	1.17	2	3	0.065
16	Nachoz	Bomby sweets	1.92	2	3	0.075
17	Alooz	Bomby sweets	2.41	3	3	0.072
18	Ring chips	Bomby sweets	1.99	2	3	0.068
19	Mr. Chicken	Bomby sweets	1.44	2	3	0.069
20	Mr. Twist	Bomby sweets	2.11	3	3	0.069
21	Sun prawn crackers	Kasem	2.19	3	3	0.076
22	Sun chips	Kasem	1.50	3	3	0.074
23	Eggy pillow	Ifad	5.62	3	3	0.075
24	Eggy stix	Ifad	2.83	3	3	0.074
25	Cheese puffs	Akij	0.83	2	3	0.076
26	Baked cheese	Akij	2.22	3	3	0.080
27	Ruchi potato	Square	3.74	4	3	0.086

Sl. No.	Chips packet	Manufacturer	Moisture (%)	Duration (month)	No. of layer (Color+Poly + Metal film)	Thickness (mm)
28	Pillow chocolate	A.T Haque	2.81	2	3	0.083
29	BD potato crack	BD food	1.76	2	3	0.079
30	Meridian real thai chicken	Meridian	3.36	3	3	0.074
31	Crispy chicken sticks	Meridian	3.83	3	3	0.074
32	Dong Dong chips	Azam food	0.80	2	3	0.054
33	Asha chips	Asha food	1.94	2	1	0.060
34	Mothu Patlu	Mayer doya	2.82	2	3	0.075
35	Ruchi potato	Square	4.72	6	3	0.085
36	-	Local products	4.29	1	1	0.036
37	Packet-1	Sample only	3.78	1	1	0.073
38	Packet-2	Sample only	2.50	1	3	0.123
39	Packet-3	Sample only	3.92	1	3	0.063
40	Packet-4	Sample only	4.64	1	1	0.047
41	Packet-5	Sample only	2.95	1	3	0.096

N.B.: NZL=New Zealand

Table 3 represents the physical appearance (color) of the existing collected fried chips.

Table 3. The recorded chips color of existing fried chips collected in different locations

Sl. No.	Chips packet	Manufacturer	MC (%)	Color			Claimed wt. (g)	Actual wt. (g)
				L*	a	b		
1	French fry	NZL	3.99	64.70	8.70	25.93	15.00	21.47
2	propper	NZL	2.42	86.46	-1.67	33.86	25.00	31.55
3	Destos	NZL	3.19	63.05	9.51	31.40	30.00	37.41
4	Yokozona	NZL	2.42	58.80	5.48	21.37	25.00	31.63
5	X fun	ACI	1.98	62.97	15.11	29.40	22.00	27.37
6	Pastazz	Pepsico	2.35	61.95	9.74	27.91	37.00	42.63
7	Lays	Pepsico	2.27	67.52	0.55	23.89	30.00	28.35
8	Kurkure	Pepsico	1.92	57.70	11.66	27.77	45.00	49.02
9	Kean	Elsa	1.37	59.19	14.71	29.48	22.00	26.02
10	Friends potato	Pran	5.96	63.29	7.14	22.17	18.00	23.84
11	Diamond potato	Pran	2.76	60.31	10.65	25.33	18.00	22.88
12	Zero chips	Pran	2.19	60.28	5.53	18.73	17.00	21.62
13	Potato sticks	Pran	2.62	55.68	9.41	21.55	14.00	18.63
14	Mothu Patlu potato crackers	Pran	4.34	76.58	7.27	25.68	14.00	18.74
15	Potato crackers	BS	1.17	67.11	9.48	21.61	20.00	24.74
16	Nachoz	BS	1.92	59.28	12.89	27.66	30.00	36.34
17	Alooz	BS	2.41	41.34	12.70	19.46	25.00	30.60
18	Ring chips	BS	1.99	53.33	7.58	23.15	20.00	24.70
19	Mr. Chicken	BS	1.44	75.40	5.09	31.97	25.00	28.72
20	Mr. Twist	BS	2.11	70.21	4.28	24.61	25.00	31.33
21	Sun prawn crackers	Kasem	2.19	60.86	7.34	21.00	20.00	23.67
22	Sun chips	Kasem	1.50	63.46	3.80	25.99	22.00	27.60
23	Eggy pillow	Ifad	5.62	62.91	8.80	24.27	20.00	25.33
24	Eggy stix	Ifad	2.83	63.80	8.81	22.76	20.00	24.31
25	Cheese puffs	Akij	0.83	58.19	23.54	29.90	20.00	26.43
26	Baked cheese	Akij	2.22	67.04	1.87	27.87	20.00	26.57
27	Ruchi potato	Square	3.74	67.28	9.09	26.42	22.00	29.05
28	Pillow chocolate	A.T Haque	2.81	51.58	8.68	11.07	20.00	24.20
29	BD potato crack	BD food	1.76	67.54	6.00	22.56	20.00	23.67

Sl. No.	Chips packet	Manufacturer	MC (%)	Color			Claimed wt. (g)	Actual wt. (g)
				L*	a	b		
30	Meridian real thai chicken	Meridian	3.36	57.06	10.96	21.35	15.00	17.90
31	Crispy chicken sticks	Meridian	3.83	61.69	9.23	21.92	15.00	22.72
32	Dong Dong chips	Azam food	0.80	59.43	11.04	25.03	22.00	23.81
33	Asha chips	Asha food	1.94	69.95	9.65	27.06	40.00	35.42
34	Mothu Patlu	Mayer doya	2.82	56.47	8.00	21.63	15.00	19.01
35	Ruchi potato	Square	4.72	61.87	7.41	23.19	10.00	14.55
36	-	Local	4.29	76.46	2.54	28.66	8.00	8.32

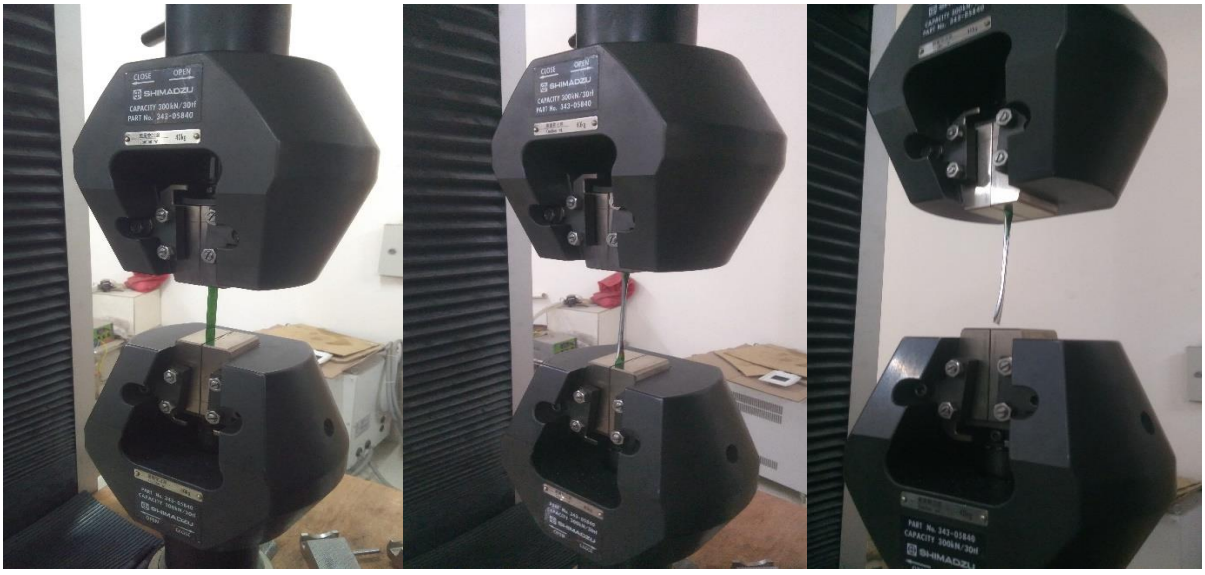
N.B.: * NZL=New Zealand dairy product; BS= Bombay sweets; MC= Moisture content

Tensile Strength test

Lays and Kurkure chips are made by same manufacturer so one of them is needed to reduce for further testing. Among of them the Lays chips were eliminated as its moisture content was higher than the Kurkure chips. Another consideration was that, to compare the tensile strength of final samples (Table 3) with other packet, additionally packet-2 and packet-5 were taken for the test (Figure 1). The tested data are presented in Table 4.

Table 4. The best seven samples list of tensile strength test.

Sl. No.	Chips packet	Manufacturer /Brand	MC (%)	Duration (month)	No. of layer (Color+Poly+ Metal film)	Thickness (mm)
32	Dong Dong chips	Azam food	0.80	2	3	0.054
33	Asha chips	Asha food	1.94	2	1	0.060
8	Kurkure	Pepsico	1.92	3	3	0.061
44	Packet-3	-	2.07	2	3	0.063
15	Potato crackers	Bomby sweets	1.17	2	3	0.065
56	Packet-5	-	1.41	4	3	0.096
53	Packet-2	-	2.10	4	3	0.123



Starting Elongation Breaking

Figure 1. Tensile strength test of the collected chips packet in different locations

Relation between packet thickness and moisture content of fried chips

The histogram of the packet thickness and moisture content are shown in Figure 2.

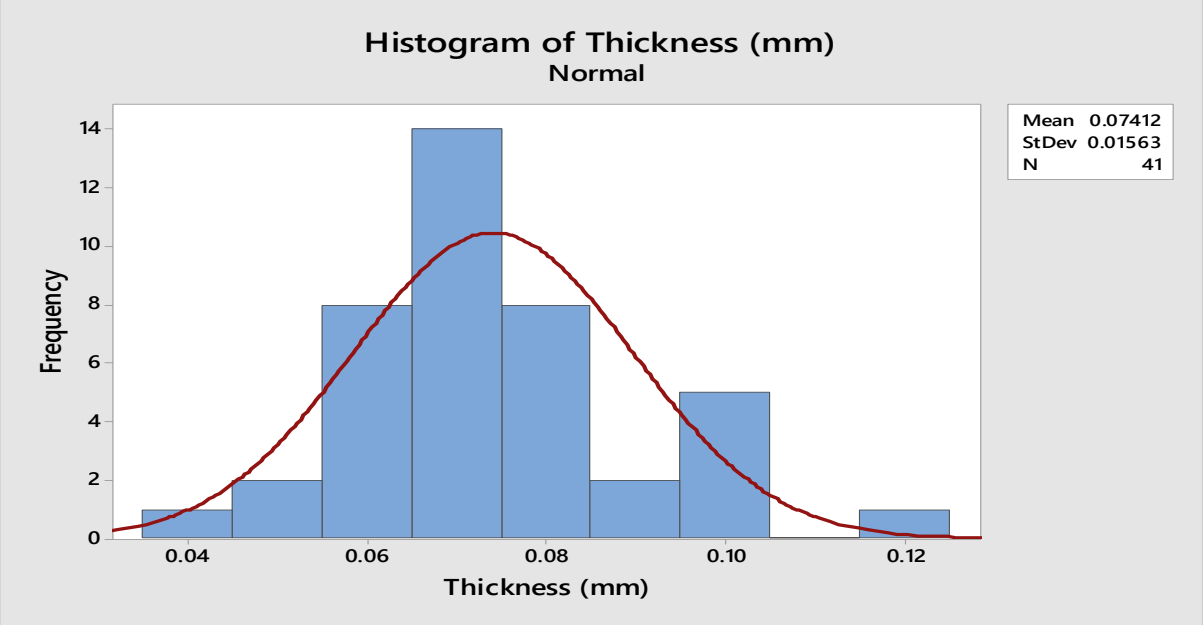


Figure 2. Histogram and Normal distribution curve of packet thickness.

From Figure 2, the thickness bar chart indicates that most of the packet thicknesses are lied between 0.068 mm to 0.084 mm and it follows normal distribution where the mean value will be the average thickness of the samples.

The lowest thickness is desirable for chips that's why it is needed to choose the thickness below the mean value. Although, selecting the lowest thickness will reduce the cost and weight of the packet but it also increases the moisture permeability through the chips packet. On the other hand, if the thickness of the packet is increased the cost and weight of the packet will be also increased. So, the reasonable packet thickness range will be beneficial. For this let -1.5 to -0.5 standard deviation will be the selected range of the permissible thickness.

The equation of the measuring range is:

Thickness = Mean + n * Standard deviation; where n = Number of standard deviations.

Hence,

- The thickness is -1.5 where, standard deviation standsbelow the mean value
  = 0.07412 + (-1.5) *0.01563
  = 0.051 mm, and
- The thickness is -0.5 where, standard deviation stands below the mean value
  = 0.07412 + (-0.5) *0.01563
  = 0.066 mm.

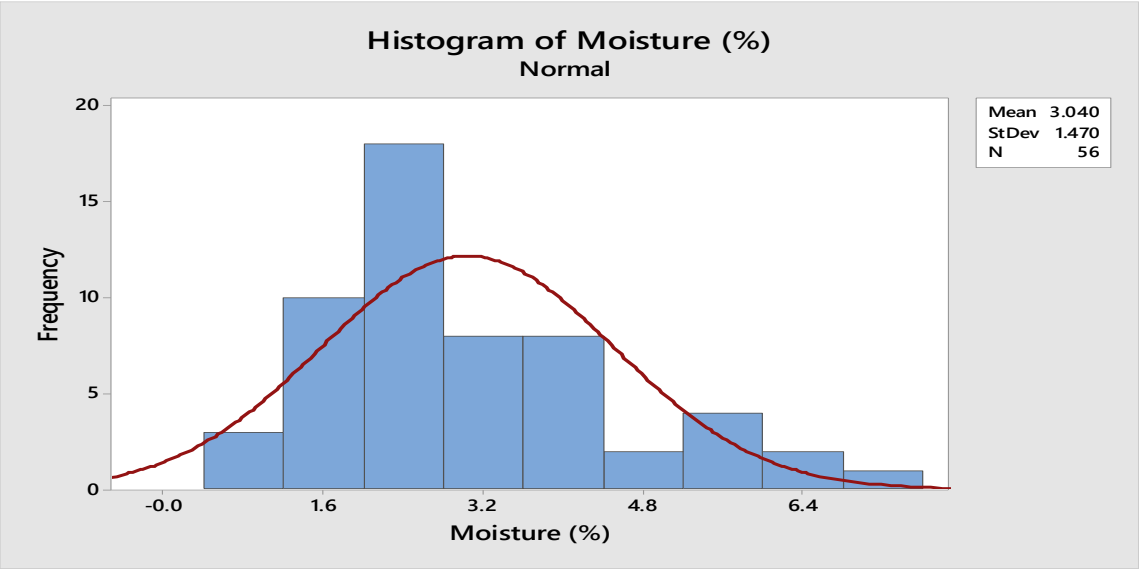


Figure 3. Histogram and normal distribution curve of the moisture content for fried chips.

From Figure 3, the bar chart indicates that most of the moisture content of the chips is observed in the packets are lies between 2 to 2.8 percent and follows normal distribution where the mean value will be 3.04 percent.

The lowest moisture content is desirable for the fried chips which is is needed to choose the moisture content below the mean. Actually, the lowest moisture is found when the thickness of the packet is maximum but this result is increased with the cost of packet and also its weight. So, it is required to select the reasonable range that is beneficial. For this let -1.5 to -0.5 standard deviation is selected range of permissible moisture content.

The equation of measuring the range is,

Moisture content= Mean + n * Standard deviation. Where, n = Number of standard deviations.

Hence,

- The moisture content that is -1.5 standard deviation below the mean = 3.04 + (-1.5) *1.47
  - = 0.8 percent and
- The moisture content that is -0.5 standard deviation below the mean = 3.04 + (-0.5) *1.47
  - = 2.3 percent.

The relation between moisture content versus thickness is shown below:

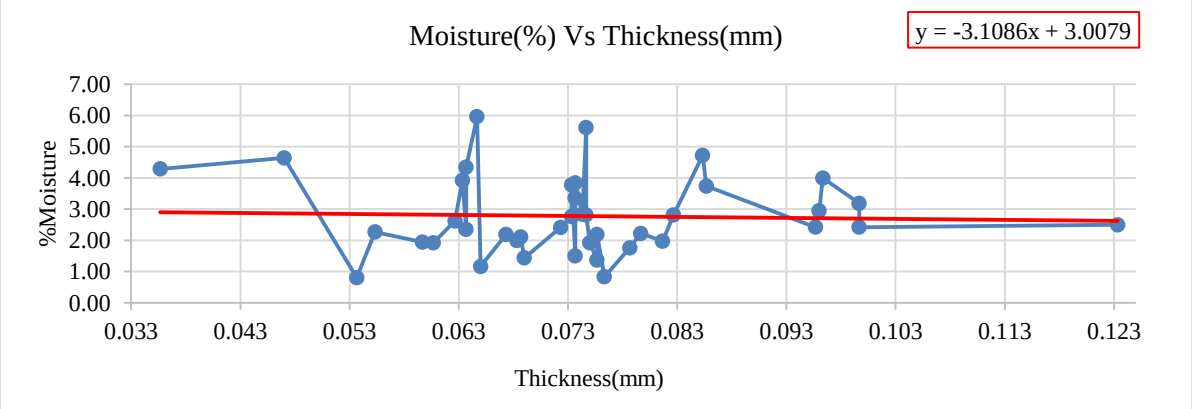


Figure 4. Relation between the thickness and the moisture content

The physico-chemical analysis of jackfruit chips sample

Figure 5. Experimental samples

From the above Figure 5, it is shown that different types of packaging materials are used to fabricate a chips packet.

The raw material of the packets are as follows:

- Packet-1: High density polyethylene pouch
- Packet-2: Biaxially oriented high density polyethylene pouch
- Packet-3: VMPET or LDPE foil pouch
- Packet-4: Polypropylene pouch
- Packet-5: Metalized biaxially oriented polypropylene pouch

Table 5 represents the moisture content of jackfruit chips sample during four months of storage

Table 5. The moisture content (MC) of the experimental samples during five months of storage

Months	Packet 1	Packet 2	Packet 3	Packet 4	Packet 5
1	3.78	2.50	3.92	4.64	2.95
2	6.42	2.23	2.07	2.32	5.85
3	6.83	3.40	4.14	5.55	2.81
4	6.10	2.10	2.48	2.61	1.41

The variation of moisture content in packet 1 is as follows

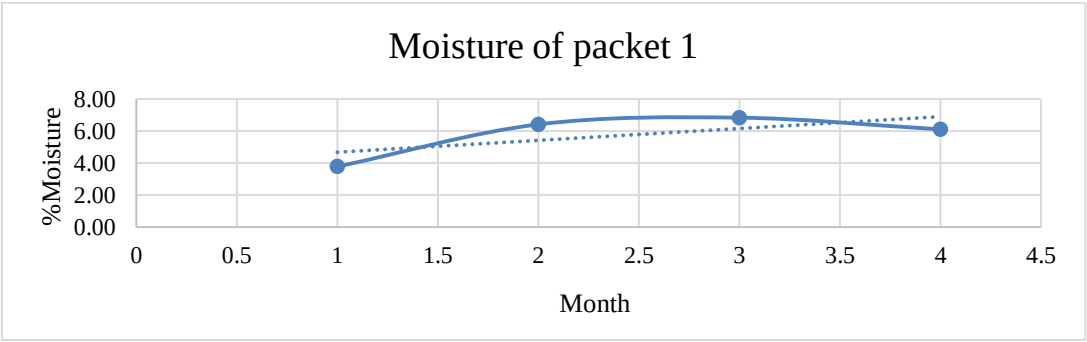


Figure 6. Moisture content variation of Packet-1 during five months of storage.

The moisture content variation in packet 2 is as follows:

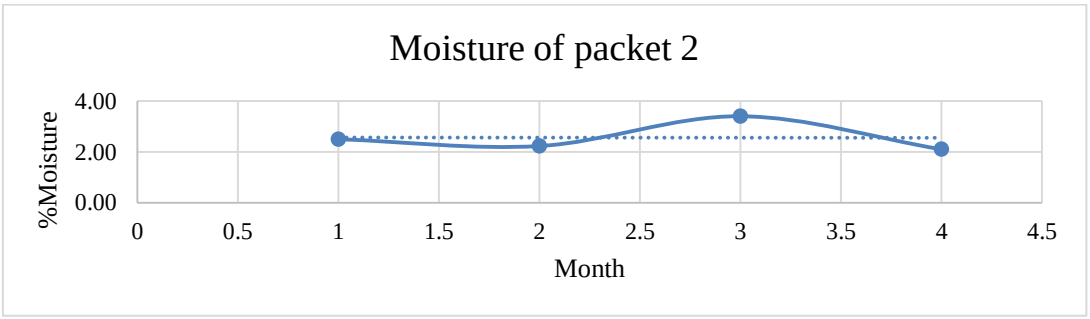


Figure 7. Moisture content variation in Packet-2 during five months of storage.

The moisture content variation in the packet 3 is as follows:

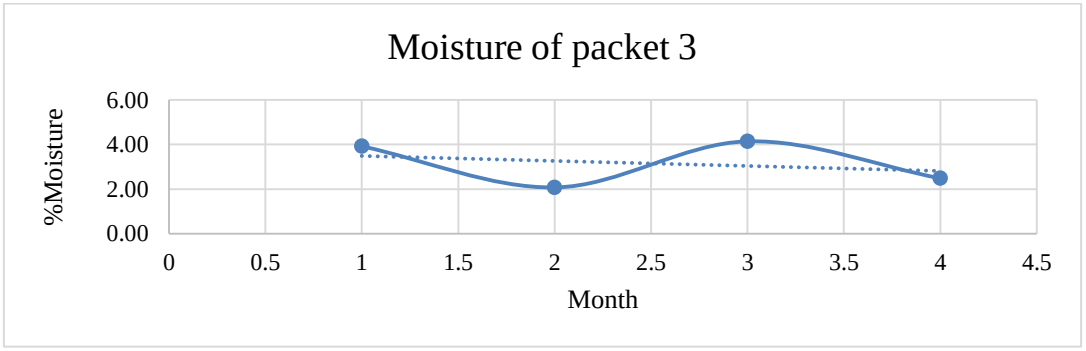


Figure 8. Moisture content variation in Packet-3 during five months of storage.

The moisture content variation in packet 4 is as follows:

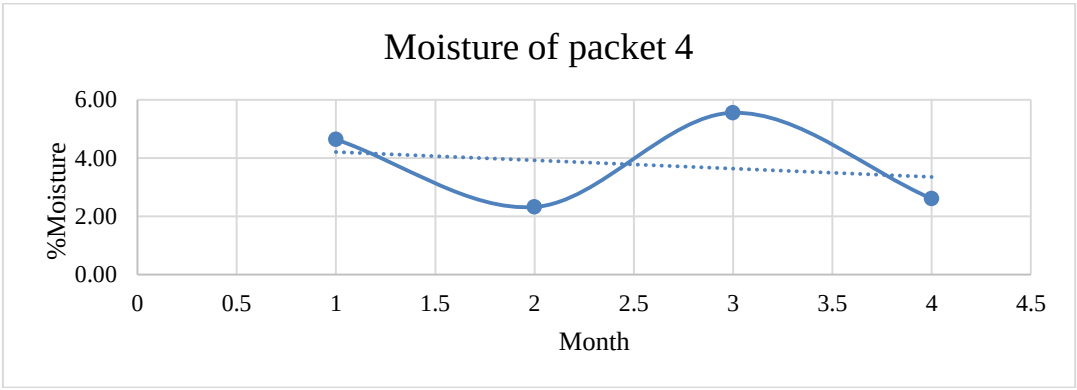


Figure 9. Moisture content variation inPacket-4 during five months of storage.

The moisture content variation inpacket 5 is as follows:

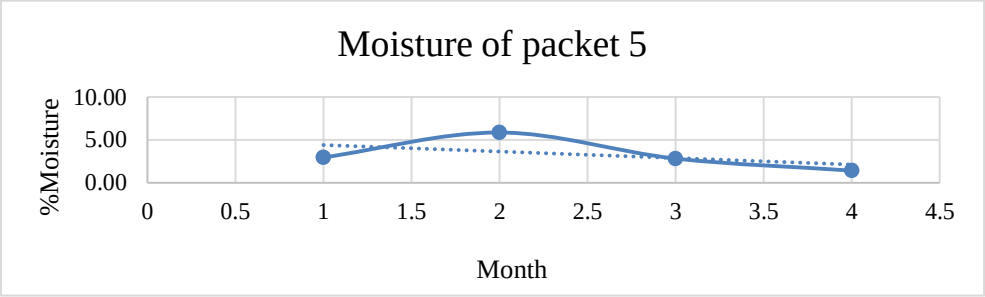


Figure 10. Moisture content variation in Packet-5 during five months of storage.

Packaging and storage studies of jackfruit chips in relation to moisture content

The moisture content of jackfruit chips during storage is dependent on relative humidity, storage structure etc. Storage at low relative humidity is helpful to preserve crispiness of the prepared chips. The moisture content was observed in fresh jackfruits (86%). On the day of preparation (0 day), the moisture content of jackfruit chips was maintained 4%. During four months of storage, moisture content was increased in all the packaging materials. This might be due to absorption of moisture through sealing error. Irrespective of storage periods significant variations were found in moisture content (%) and weight gain (%) in fried chips in different packaging materials (Figure 6, 7, 8, 9 and 10). Among the tested packet, the lowest moisture content 1.41% was observed in samples packed in Metalized BOPP pouch (Packet-5) (Figure 10). This might be due to its double layer of polyethylene. On the other hand, chips packed in polypropylene pouch obtained the highest percentage of moisture 6.83% (Packet-1) (Figure 6).

After four months of storage periods, chips packed in all the packaging materials have some variations. This might be due to absorbed moisture and experimental error. But during four months of storage, the average moisture content of Biaxially oriented high density polyethylene pouch (Packet-2) (Figure 7) was lowest among of the samples and it is happened due to its good sealing capabilities.

On average this analysis indicates that the chips packed in Metalized BOPP pouch performed the best and packed in polypropylene pouch could not be kept for the longer period.

Results and Discussions

Identifying the best group of samples

Three criteria were considered to fabricate the suitable packet.

First: Since the weight and cost of the packet is proportional to the thickness of the packet so, to reduce cost of the packet, the lowest thickness should be chosen for the final packet thickness.

Second: The permeability of moisture in the packet indicates that the quality of packaging material isn't good and at the result the crispiness and the shelf life of the chips will be reduced. So, selecting the lowest moisture content for the packet is needed.

Third: The lowest moisture content will be found when the thickness of the packet will be maximum but this result will be increased the cost of packet and also its weight. So, choosing the reasonable range will be beneficial.

After considering the three criteria the thickness and permissible moisture are assumed. Hence, the decided range of packet thickness and moisture content to select the best group of samples are,

- The thickness that is -1.5 standard deviation below the mean is 0.051 mm and
- The thickness that is -0.5 standard deviation below the mean is 0.066 mm.
- The moisture that is -1.5 standard deviation below the mean is 0.8 percent and
- The moisture that is -0.5 standard deviation below the mean is 2.3 percent.

Best group of sample selection

The samples after ascending the moisture content between 0.8 to 2.3 percent.

Table 6. The samples which moisture content is between 0.8 to 2.3 percent

Sl. No.	Chips packet	Manufacturer	Moisture (%)	Time (month)	No of layer (Color+Poly+ Metal film	Thickness (mm)
32	Dong Dong chips	Azam food	0.80	2	3	0.054
25	Cheese puffs	Akij	0.83	2	3	0.076
15	Potato crackers	Bomby sweets	1.17	2	3	0.065
9	Kean	Elsa	1.37	2	3	0.076
56	Packet-5	Experimental sample	1.41	4	3	0.096
19	Mr. Chicken	Bomby sweets	1.44	2	3	0.069
22	Sun chips	Kasem	1.50	3	3	0.074
29	BD potato crack	BD food	1.76	2	3	0.079
16	Nachoz	Bomby sweets	1.92	2	3	0.075
8	Kurkure	Pepsico	1.92	3	3	0.061
33	Asha chips	Asha food	1.94	2	1	0.060
5	X fun	ACI	1.98	3	3	0.082
18	Ring chips	Bomby sweets	1.99	2	3	0.068
44	Packet-3	Experimental sample	2.07	2	3	0.063
53	Packet-2	Experimental sample	2.10	4	3	0.123
20	Mr. Twist	Bomby sweets	2.11	3	3	0.069
21	Sun prawn crackers	Kasem	2.19	3	3	0.076
12	Zero chips	Pran	2.19	3	3	0.067
26	Baked cheese	Akij	2.22	3	3	0.080
43	Packet-2	Experimental sample	2.23	2	3	0.123
7	Lays	Pepsico	2.27	3	3	0.055

The samples after ascending the thickness between 0.051 to 0.066 mm.

Table 7. Samples containing 0.8 to 2.3% moisture and thickness 51 to 66 µm.

Sl. No.	Chips packet	Manufacturer	Moisture (%)	Time (month)	No of layer (Color+Poly+ Metal film)	Thickness (mm)
32	Dong Dong chips	Azam food	0.80	2	3	0.054
7	Lays	Pepsico	2.27	3	3	0.055
33	Asha chips	Asha food	1.94	2	1	0.060
8	Kurkure	Pepsico	1.92	3	3	0.061
44	Packet-3		2.07	2	3	0.063
15	Potato crackers	Bomby sweets	1.17	2	3	0.065

Relation among thickness and yield stress and yield strain

The relation between yield stresses with the thickness is depicted below:

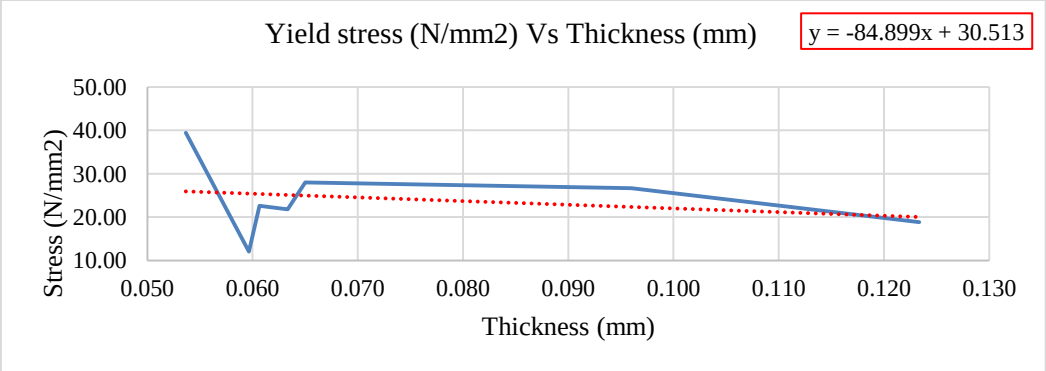


Figure 11. Relation between the thickness and the stress of the packaging material.

Yield stress indicates the strength of a material before yielding or starting permanent deformation. The higher the value yield stress, the more strength of the material. Since a packet required much

strength to withstand its shape after packaging and also for transportation, hence the highest yield stress should be considered. From the graph, it is indicated that the Dong Dong chips packet were the highest yield stress and that was 39.47 N/mm^2 (Table 7).

Table 8. The moisture content of chips is between 0.8 to 2.3%.

Chips packet	Manufacturer	Moisture (%)	Thickness (mm)	Yield stress (N/mm^2)	Yield strain (%)	Elongation (mm)
Dong Dong	Azam food	0.80	0.054	39.47	4.43	14.08
Potato crackers	Bomby sweets	1.17	0.065	27.97	4.63	5375.50
Packet-5	Experimental sample	1.41	0.096	26.63	3.77	31.49
Kurkure	Pepsico	1.92	0.061	22.57	4.27	18.08
Packet-3	Experimental sample	2.07	0.063	21.77	4.73	38.73
Packet-2	Experimental sample	2.10	0.123	18.87	3.23	20.63
Asha chips	Asha food	1.94	0.060	12.03	21.83	162.32

Although the yield stresses of the packet-2 and packet-5 were observed higher values except Dong Dong chips packet but their thicknesses were comparatively higher than others chip packet. Among other samples, the Potato cracker packet was positioned at the 2nd place keeping its stress 27.97 N/mm^2 and ignoring the packet-5, Kurkure packet was 3rd position with 22.57 N/mm^2 without the two packets.

Finally, the sample Packet-4 remains at 4th position whose yield stress is 21.77 N/mm^2. Packet-2 and packet-5 are not acceptable for their excessive thickness as the packets were just used to compare with other samples packet to find the best chips packet.

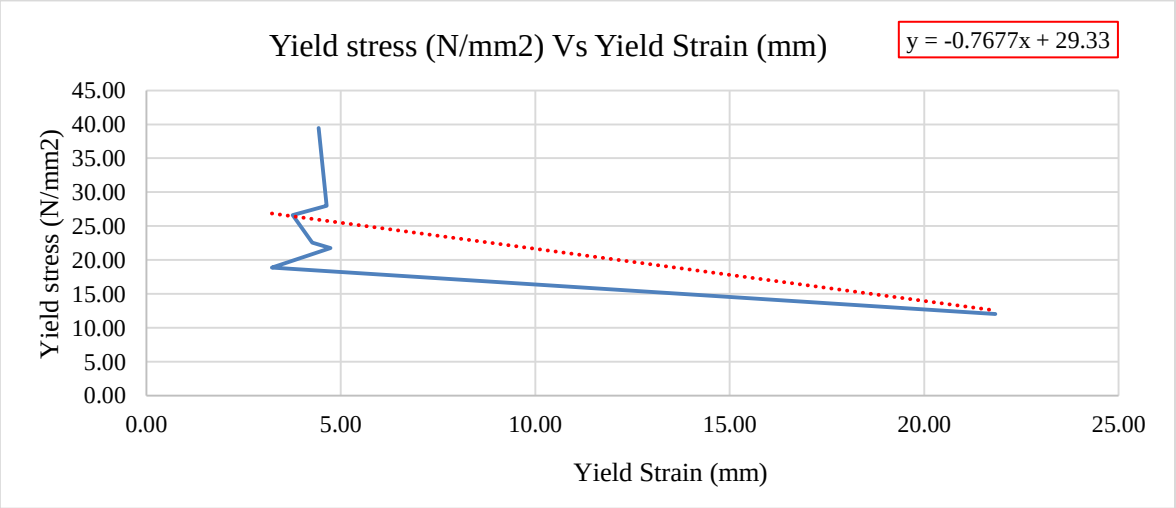


Figure 12. Relation between the yield stress and the yield strain of the packaging material.

The relation between stress and percent strain are varying 3.23 to 4.63 except the Asha chips packet, whose average percent strain is 4.18. The percent strains of Dong Dong chip packet and Packet-5 are nearer to this average value. Hence the final result was found based on all criteria.

Therefore, the decisions are,

- Dong Dong chips packet is the best packet among all the chips packet available in market.
- Packet-3 will also be the best one among the tested samples which were kept as a sample in this project.
- Among the tested packaging materials, metalized LDPE film will be the best packaging material for keeping jackfruit chips.

Analyzing the size of the packet samples

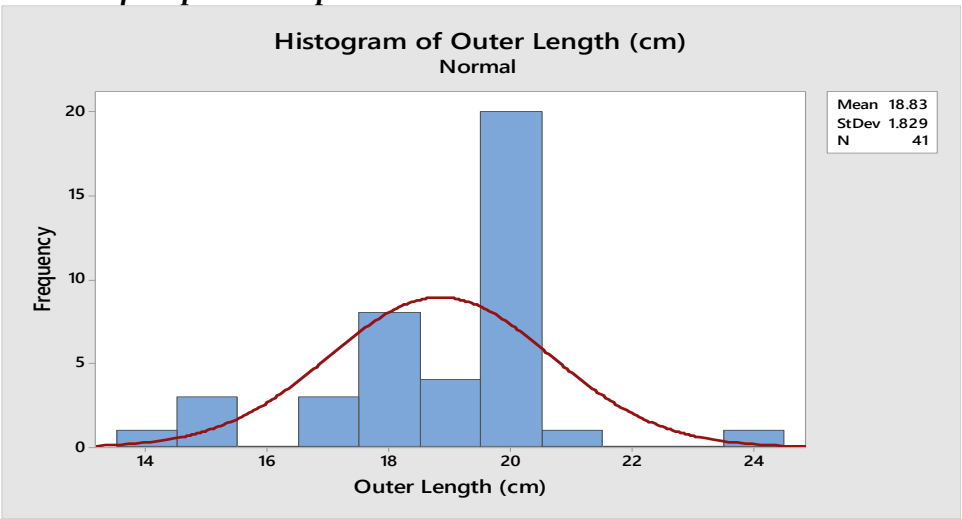


Figure 13. Histogram and Normal distribution curve of packet length.

From the outer length, bar chart (Figure 13) indicates that most of the length of the chip's packets are lied between 17.8 to 19.7 cm (0.5 SD below and above the mean) and follows normal distribution where the mean value (18.83 mm) will be the average length of the chips packet of the samples.

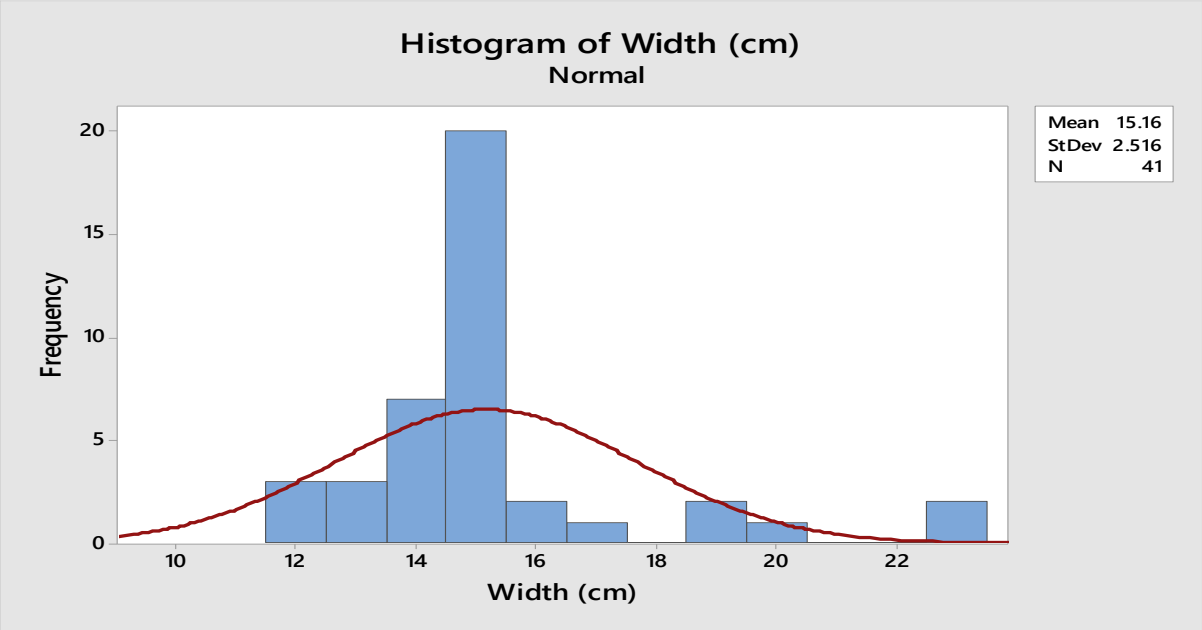


Figure 14. Histogram and Normal distribution curve of packet width.

In bar chart Figure 14, it is stated that most of the width of the chip's packets are lied between 14.2 cm to 16.8 cm (0.5 SD below and above the mean) and follows normal distribution where the mean value (15.16 mm) will be the average width of the chips packet of the samples.

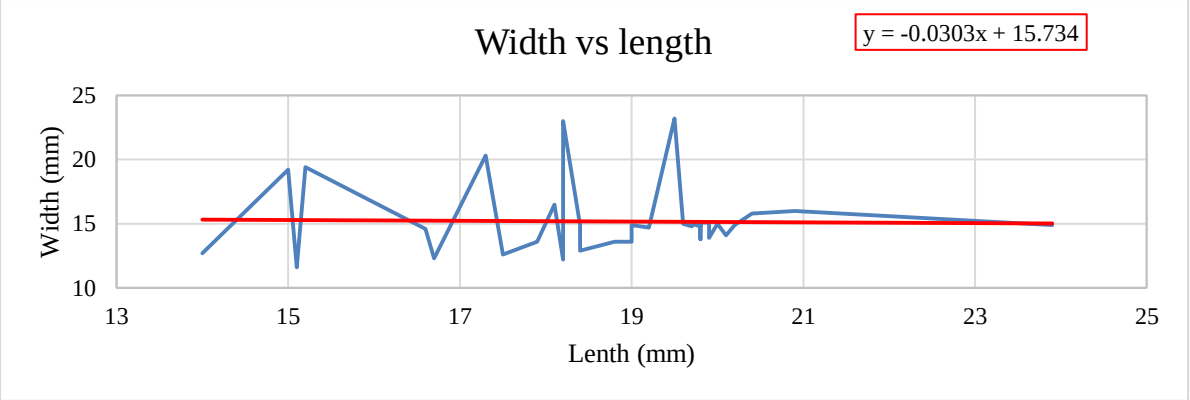


Figure 15. The relation between length and width of the samples.

The width of the chips packet remains approximately constant respect to the length of the samples. Just the variation of length affects the size of the chip packet (Figure 15). Some design variation was observed that depending on the manufacturers. Some manufacturers selected different size although their product weight was same.

Length and width of the packet were used to find average packet size. The length 18 mm and width 15 mm were proposed for the jackfruit packet size.

The moisture content and the weight of the chips were measured to identify the chips quality as the quality of packet mostly characterized with it. The rage of permissible moisture content from 0.8 to 2.3 percent were selected for the jackfruit chips where the weight of the chips was 50 g or more.

The thickness of the packet was evaluated to find out the packet weight as the weight of packet highly influenced the cost of the packet. After analysis, it was found that the thickness was from 50 to 80 micron which was most identical and economical.

Finally, the tensile strengths of the packet were measured to check the ability of withstanding at high pressure and the impact on it in any situation. Analyzing the stress of the samples the four packets such as Dong Dong chips, Potato crackers, Kurkure and Packet-3 are placed at the highest stress capability respectively. The first sample among the top four was the most acceptable as its highest yield stress (39.47 N/mm^2). On the other hand, not only the moisture content (0.08%) but also the thickness (0.05 mm) of Dong Dong chips were found the lowest value among the samples.

With the view of the experimental samples, Packet-3 was positioned at the top level among the five tested packets. So, the packet-3 may be used as the prototype packet for jackfruit chips packaging and distributing in the market.

Table 9. The difference between the best two chips packet from the two groups of sample

Name	Experimental samples	Collected samples
Packet name	Packet-3	Dong Dong chips
Thickness (µm)	63	54
Length (cm)	23	18.4
Width (cm)	15.3	12.9
Moisture content (%)	2.07	0.8
No. of layers	3	3
Material	VMPET or LDPE Foil pouch	VMLDPE foil pouch
Tensile Yield strength (N/mm^2)	21.77	39.47
Elongation (mm)	38.73	14.08
Appearance	Good	Excellent

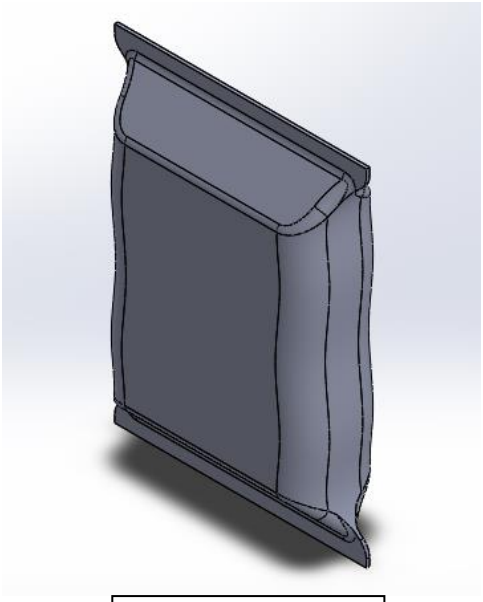
The recommend design specification of jackfruit chips packet are tabulated below:

Thickness (μm)…….	51 - 66 (63)
Length (cm)……..	18.8 - 19.7 (18.83)
Width (cm)……	15.2 - 16.8 (15.16)
Moisture content (%)……	0.8 - 2.3 (0.8)
No of layers……..	3 (4)
Material……...	VMPET or LDPE foil or pouch
Tensile Yield strength (N/mm^2)…….	39.47
Elongation (mm)……..	14.08
Weight of chips in packet (g)……	50

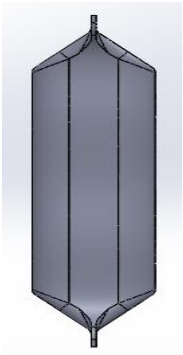
N.B: Value in bracket indicates the most recommendation.

A probable prototype of external appearance of jackfruit chips packet was designed (by Adobe Illustrator CS software), which was shown below:

The 3D appearance of jackfruit chips packet

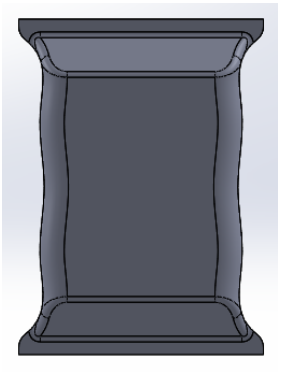


Isometric view



Right side view

Top view



Front view

Figure 16. Appearance of jackfruit chips packet.

Conclusion

The preparation of jackfruit chips is very simple and can easily be processed. Considering moisture content (%), weight gain (%), quality aspects and sensory attributes like crispiness, color, flavor and overall acceptability, VMPET or LDPE foil pouch were found most suitable for packaging of jackfruit chips. The prepared chips can be stored at ambient condition keeping in VMPET or LDPE foil for two months without loss of organoleptic quality. In rural areas where modern facilities of processing do not exist, this technology can be easily achieved. Many food industries also can adopt the procedure for medium and in large scale processing. Establishment of small-scale processing unit at grower's and cottage level could utilize the jackfruit for processing of chips, which will be helpful to get this product during off season, ultimately minimizes postharvest losses of jackfruit and generate income to the stakeholders. This technology will add value in agro-processing industry for producing quality VF chips and will assist to reduce postharvest loss of our country. The economic analysis will be conducted for further study.

Acknowledgements

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OPTIMIZATION OF PROCESSING PARAMETERS FOR FREEZE DRIED CHIPS FROM JACKFRUIT

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

Abstract

The aim of the study was to optimize the freeze-dried jackfruit chips processing to produce quality jackfruit products. Freeze dried jackfruit chips were prepared using 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 treated with 5%, 10%, 15% maltodextrin and 40% sugar solution then packaged in high density polyethylene (HDPE) packet (~60 micron) and frozen at -18ºC for 24-36 hrs. Then the frozen slices were dried in freeze dryer at -53^{o}C for 72 hours (main drying 36 hrs., final drying 36 hrs.) at 0.0010 mbar pressure. Freeze dried jackfruit chips were c packaged in metalex foil (~50 micron) packet without nitrogen gas and sealed for storage at ambient temperature (26±2^{o}C & 75±5% RH). The changes of physico-chemical properties for different maltodextrin and sugar concentration as well as consumer preference test were evaluated by expert panelists. According to the sensory panelists judgement, initially jackfruit chips coated with 10% maltodextrin and then dried in freeze-drier exhibited better quality in terms of overall acceptability score (7.10) (Like moderately to like very much). 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 quality freeze dried 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 South-East 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 (Goldenberg *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 gets 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. Freeze drying process is applicable to manufacturing of certain pharmaceuticals and biological products that are unstable in aqueous solutions for prolonged storage periods, but that are stable in the dry form. Traditionally drying is done by heating but in freeze drying process drying is conducted by freezing which is quite different (Shukla, 2011). In freeze drying process water in the product is frozen first then drying is done in two steps, firstly through sublimation and then by desorption. (Gaidhani *et al.*, 2015). As prior to freeze drying, product is frozen different freezing parameter (rate, duration) and frozen layer temperature during drying has effect on the final freeze-dried product (Karel and Flink, 1973). For removing moisture from frozen product, the pressure is lowered to such point where the moisture will change from its solid form to directly gaseous form skipping the liquid form. Freeze-drying is a process where moisture is sublimed from the product after freezing the product (Akers *et al.,* 1978*).*

Keeping this in view, the research program was undertaken to study the processing, packaging and quality aspect of freeze dried chips from jackfruit and thus suggest ways and means for production of good quality freeze dried jackfruit chips.

Materials and Methods

Collection of jackfruits

Fresh and mature ripe (not juicy) jackfruits (Khaja type) of unknown cultivar having average fruit weight, 8-10 kg was collected from the farmer's field and Cotton Research, Training and Seed Production Farm, Sreepur, Gazipur under Cotton Development Board and transported to the laboratory of PHTD, BARI, Gazipur for conducting the study.

Preparation of freeze-dried jackfruit chips

For preparing freeze-dried jackfruit chips, several trial experiments were conducted using different pretreatments and freeze drying time where drying temperature was fixed (-55^{o}C). The jackfruits were washed, peeled, removed the seed from bulb and sliced length-wise. Then jackfruit slices were pretreated with different maltodextrin concentration (5%, 10%, 15%) and 40% sugar solution. Another treatment was without any pretreated sample considered as control treatment. After pretreatments, the slices were packed in HDPE packet and stored at -18^{o}C till frozen (~24-36 hrs.). The slices were dried in laboratory scale freeze dryer at -53^{o}C for 60-72 hrs. maintaining the vacuum pressure at 0.001 mBar. After drying, the chips were packed in laminated aluminium foil packet and stored at room temperature (26±2^{o}C & 75±5% RH) in a dry and cool place. The treatment was (a) fully mature and ripe jackfruit slices, (b) jackfruit slices coated with 5% maltodextrin, (c) jackfruit slices coated with 10% maltodextrin, (d) jackfruit slices coated with 15% maltodextrin, (e) jackfruit slices coated with 40% sugar solution. Jackfruit slices were soaked in maltodextrin solution for 10-15 min and at least 1 hour in other solutions.

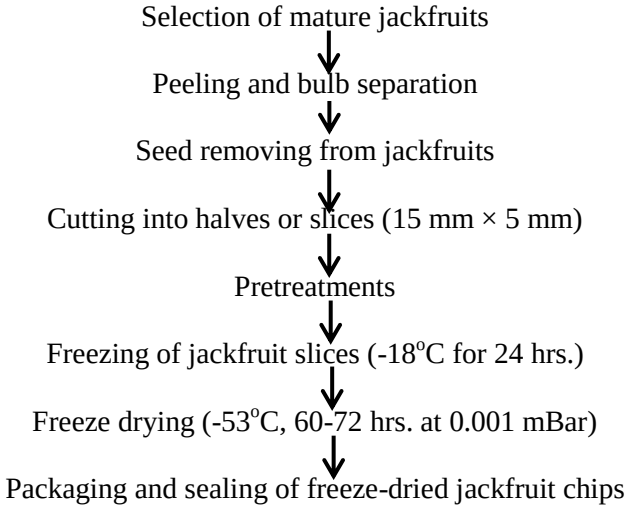

Figure 1. Process flow diagram for freeze-dried jackfruit chips

Determination of physical appearance and texture of freeze-dried jackfruit chips

Color attributes were measured based on the CIEL a*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. 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.

Textural properties of freeze dried jackfruit chips were determined to estimate resistance by a texture analyzer (Stable Micro System, Godalming, UK). The analyzer probe (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.

Determination of physico-chemical properties of freeze-dried jackfruit chips

Measurement of moisture and ash content

The moisture and ash content were determined based on the AOAC official methods (AOAC, 2005). The total acidity was determined following the methods of Ranganna (2007).

Measurement 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 oven at 105^{o}C for 3-4 hrs. Finally, weight of the conical flask was recorded.

Determination of phenolic compounds of freeze-dried jackfruit chips

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/100 g of sample.

Sensory Evaluation

Processed freeze-dried jackfruit chips were examined by a panel of judges comprising of scientific staff for appearance, color, texture, aroma, crispiness, taste and overall acceptability. Hedonic scale was used to make the different parameters. In this scale 'like extremely', is given the highest score of '9' and 'dislike extremely' is given the lowest score '1'. Others are given intermediate scores.

Statistical analysis

All the obtained data were analyzed using IBM SPSS (Version 22.0, SPSS Inc., Chicago, IL) statistical software and the results were expressed as the mean value ± standard deviation of three replicates. The Duncan's Multiple Range Test (DMRT) was used and to evaluate the statistically significant differences among the mean values of the analyzed parameters at $p<0.05$.

Results and Discussions

Changes of physical appearance and firmness of freeze dried jackfruit chips

Color changes of freeze-dried jackfruit chips can be visually detected, but in this study lightness (L*), chroma (C*) and hue angle (H*), color indicators were measured using a chromameter and it was mentioned in Table 1. Initially the lightness (L*) value of freeze-dried jackfruit chips were not significantly difference among the treatments (Table 1). In case of chroma value, there were observed significant difference among the treatments. The highest chroma value was found in jackfruit slices coated with 10% maltodextrin solution (35.53 a) followed by 5% maltodextrin coated freeze-dried jackfruit chips (32.78 b). The lowest chroma value was noticed in 15% maltodextrin coated jackfruit slices (24.41 d) (Table 1). On the other hand, hue angle value was also significantly difference initially among the treatments. The maximum hue angle value was observed in 15% maltodextrin coated jackfruit slices (88.95 a) followed by 40% sugar coated jackfruit chips (86.88 b) and the lowest was found in 10% maltodextrin coated (84.73 d) jackfruit slices (Table 1). Overall, the color value indicated that chlorophyll composition and degradation became changed with storage condition where carotenoid degradation and enzymatic action happened (Pantastico, 1997). In addition, the changes in color during frying were the results of starch gelatinization and non-enzymatic browning reactions (Garayo and Moreira, 2002).

In Table 1, it was also found that the firmness of freeze-dried jackfruit chips was highly significant difference at initial stage ($p<0.05$). The maximum firmness (23.71 a N) was observed in 10% maltodextrin coated freeze-dried jackfruit chips followed by 15% maltodextrin coated product (15.09 b N) and the minimum (11.72 c N) was noticed in 40% sugar coated freeze-dried jackfruit chips (Table 1). Firmness increased with breaking force at the end of storage period. The increased 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.* (2001) observed the increase in breaking force of banana chips, which was stored in polypropylene film packet during storage. The data recording is in progress during storage study.

Table 1. Effect of physical appearance and firmness on freeze-dried jackfruit chips at initial stage

Treatment	Lightness (L*)	Chroma (C*)	Hue angle (H*)	Firmness (N)
Control	76.75	28.71 c	85.82 c	12.15 c
5% MD	75.19	32.78 b	85.27 cd	14.68 b
10% MD	75.93	35.53 a	84.73 d	23.71 a
15% MD	76.56	24.41 d	88.95 a	15.09 b
40% Sugar	76.78	24.75 d	86.88 b	11.72 c
Level of significance	ns	***	***	***

Note: MD=Maltodextrin, ns=Not significant at $p<0.05$

Changes in physicochemical properties of freeze-dried jackfruit chips

Moisture content was presented in Table 2 that all treatments were highly significant differences at initial stage. From the observation in Table 2, it was found that an increase in the freezing time resultant in a significant reduction ($p<0.05$) of moisture retention in freeze dried jackfruit chips with the same pressure. The maximum moisture percentage was found in 5% maltodextrin coated sample (6.61%) and control treatment (6.52%). Similarly, at initial stage, the percent ash content was highly significantly differences among the treatments. The highest ashwas observed in control treatment (2.63%) followed by 10% maltodextrin coated sample (1.43%) and the lowest was found in 15% maltodextrin (0.86%) and 40% sugar coated sample (0.80%). In case of percent fat, there were highly significant differences among the treatments. The range of fat content was (0.32 - 7.09%) where the maximum was observed in control treatment (7.09%) followed by 15% maltodextrin coated product (3.50%) (Table 2). The percent total acid varied from 0.49% to 1.02%. Initially the percent total acid value was highly significantly difference for all treatments ($p<0.05$). The maximum percent total acid was found in control treatment (1.02%) and 15% maltodextrin coated sample (1.02%) whereas the minimum was exhibited in 40% sugar coated samples (0.49%) (Table 2). In case of total phenol, initially all treatments were highly significant differences (Table 2). The highest total phenol was observed in control treatment (10.86 mg GAE/100g) followed by 15% maltodextrin coated product (9.39 mg GAE/100g) and the lowest was found in 10% maltodextrin coated freeze-dried jackfruit chips (9.08 mg GAE/100g) (Table 2). The data recording is in progress for keeping quality of freeze dried jackfruit chips during ambient storage.

Sensory evaluation

To find out the best processing parameters of freeze dried jackfruit chips, organoleptic test was performed with a 9-points hedonic score based on appearance, color, texture, aroma, crispiness, taste and overall acceptability by the expert sensory panelists (Table 3a & Table 3b). It was observed in Table 3b that initially the highest overall acceptability scores 7.10 (Like moderately to like very much) was observed in 10% maltodextrin coated freeze-dried jackfruit chips followed by 5% maltodextrin (7.00) coated jackfruit slices and the lowest (6.30) was found in control treatment without any sugar added product (Table 3b). Considering all sensory attributes score, 10% maltodextrin coated sample performed better among the treatments initially after development of the freeze-dried jackfruit chips (Table 3). The data recording and analysis is in progress for storage study.

Table 2. Effect of physicochemical properties (% Moisture, % ash, % fat, % total acid, mg GAE/100 g total phenol) on freeze-dried jackfruit chips at initial stage

Treatment	Moisture (%)	Ash (%)	Fat (%)	Total acid (%)	Total phenol (mg GAE/100g)
Control	6.52 a	2.63 a	7.09 a	1.02 a	10.86 a
5% MD	6.61 a	1.22 c	0.60 c	0.64 c	9.20 c
10% MD	5.37 b	1.43 b	0.51 d	0.89 b	9.08 d

Treatment	Moisture (%)	Ash (%)	Fat (%)	Total acid (%)	Total phenol (mg GAE/100g)
15% MD	5.45 b	0.86 d	3.50 b	1.02 a	9.39 b
40% Sugar	5.14 b	0.80 d	0.32 e	0.49 d	8.29 e
Level of significance	***	***	***	***	***

Note: MD=Maltodextrin, ns=Not significant at $p<0.05$

Table 3a. Sensory evaluation of freeze-dried jackfruit chips at initial stage

Treatment	Mean value of sensory attributes			
	Appearance	Color	Texture	Aroma
Control	6.60	6.20	6.50	6.30
5% MD	6.40	6.60	6.70	6.70
10% MD	6.70	6.80	6.70	7.00
15% MD	5.10	4.70	4.90	4.70
40% Sugar	5.80	6.00	6.50	6.20

Note: MD=Maltodextrin; 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 3b. Sensory evaluation of freeze-dried jackfruit chips at initial stage

Treatment	Mean value of sensory attributes		
	Crispiness	Taste	Overall acceptability
Control	6.10	6.20	6.30
5% MD	6.80	6.60	7.00
10% MD	7.00	7.00	7.10
15% MD	5.20	5.10	5.00
40% Sugar	7.50	7.00	6.50

Note: MD=Maltodextrin; 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 processing parameters of freeze-dried jackfruit chips at ambient condition. Without proper processing, freeze-dried jackfruit chips turn into brownish or grayish rapidly due to catalase enzymatic action that hampered the appearance of the products. In addition, improper freeze-drying of jackfruit chips the product may loss its crispiness or may hard where sweetness increase in the product. To retain quality and enhance shelf life of the product, proper packaging is necessary. If moisture transfer happens inside the packet, then mold and different microbes have possibility to grow. In this case, the product becomes start rotting and develop off-flavor. According to the sensory panelists evaluation, initially jackfruit chips coated with 10% maltodextrin exhibited better quality in terms of overall acceptance (7.10) (Like moderately to like very much). The study will be continued for nutritional quality and keeping quality during storage.

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EFFECT OF FRYING TEMPERATURE AND TIME ON PHYSICOCHEMICAL CHANGES AND SHELF LIFE OF VACUUM FRIED CHIPS FROM GIANT TARO

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

Abstract

The aim of the study was to optimize the vacuum fried giant taro chips processing to produce quality giant taro chips fried at suitable temperature and frying time. Ginat taro chips were prepared from matured giant taro. The harvested matured giant taro was cut and then packaged in high density polyethylene (HDPE) packet (~60 micron) and frozen at -18ºC for 24 - 48 hrs. in deep fridge. Then the frozen taro slices were fried instantly using BARI Vacuum Frying Machine at 100,110 and 120ºC for 12, 14 and 16 mins., respectively. The fried chips were de-oiled using BARI De-Oiling Machine at 1400 rpm for 2-3 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°C & 75±5%RH). Then the changes of physicochemical properties with different frying temperature and time at two-month interval upto six months and consumer preference test was evaluated by expert sensory panelists. According to the test panelists, the best frying temperature and time combination was found at 110ºC for 14 minutes, where sensory parameters ranked was exhibited the highest score (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 giant taro chips and thus mitigate the postharvest losses by extending the shelf life and marketability of chips product.

Introduction

Taro (*Alocasia macrorrhizos*) occupies a significant place in the agriculture of the Asia-Pacific Region. It is in this region, more than any other in the world, that the crop attains its greatest importance as a staple food. In many parts of the Asia and Pacific region, the name for tannia is a modification or qualification of the name for taro. In Papua New Guinea for example, taro is called "taro tru" while tannia is called "taro singapo". In Tonga, taro is called "talo Tonga" while tannia is called "talo Futuna". In some of the world literature, taro and tannia are collectively called cocoyams, while in a place like Malaysia, the local name for taro (keladi) also applies to all the other edible aroids.

Its raw corm is relatively low in protein (1.5%) and fat (0.2%) and this is similar to many other tuber crops. It is a source of starch (70–80 g/100 g dry taro) and contains a fair amount of fiber (0.8%) and ash (1.2%) (Jane *et al.,* 1992; Quach *et al.,* 2000). Taro corm hasreasonably high contents of potassium and magnesium, whose ranges are 2251-4143 and 118-219 mg/100 g dry matter, respectively. It is a moderately good source of water - soluble vitamins, such as thiamin, riboflavin and ascorbic acid, compared to other tropical roots. Essential amino acid contents of taro corm proteins are fairly similar to the FAO reference pattern, except for the contents of sulfurcontaining amino acids, tryptophan and histidine (Huang *et al.,* 2007).

Fresh taro corm is difficult to store and is subject to deterioration during storage. 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).

Materials and Methods

Collection of giant taro, processing and frying conditions

Physiologically matured giant taro was collected from commercial farmer's field of Daulatpur, upazilla under Khulna district. Giant taro were sorted out from any harvesting and transportation injured and cleaned by washing with potable water. After that giant taro were cut by sharp knives into pieces with uniform size and were removed outer skin. After peeling, giant taro was cut into specific shape by sharp knives and then put into stainless steel tray. After that taro were washed and sliced into uniform size by sharp knives for final chips products. Then, sliced taro were dipped into turmeric solutions and then put into strainer for few minutes to remove surface solutions and then blanched for 2-3 mins. After blanching, giant taro was sealed in HDPE packets and frozen at -18ºC in deep fridge for 24-48 hrs. (Figure 1). One batch/kilogram of processed giant taro slices were placed in the vessel and fried in 15 L of soyabean oil below atmospheric pressure. After vacuum frying, the fried taro chips were de-oiled for 2-3 mins. at 1400 rpm using BARI De-Oiling Machine to remove the excess frying oil. After de-oiling, the fried taro chips were cooled and then added required spices and packed in HDPE packet with proper sealing and stored at ambient temperature (26±2ºC & 75±5%RH). The treatments studied in this work were: (1) Giant taro chips were fried at the temperature (100-120ºC, 10-degree interval); (2) maintained frying time from 4-20 mins. at 4 mins. interval. Shelf-life study with physicochemical properties changes were evaluated upto six (06) months at two-month interval. The following steps were followed to process the giant taro for preparing quality vacuum fried giant taro chips.

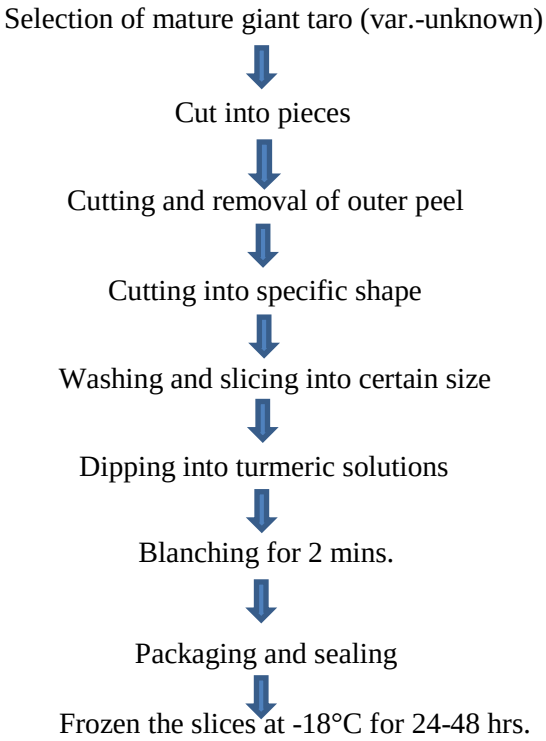

Figure 1. Diagram for the processing of Giant Taro chips.

Measurement 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.

Measurement 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:

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

Measurement of total carotenoids content

Total carotenoids in the vaccum fried giant taro chips were determined with slight modification of the method described by kuti (2004). At first extracted the total carotenoids from 5 g of sample with a solvent mixture containing 40 ml acetone (Fisher Scientific Ltd., UK) and 60ml petroleum ether the vacuum fried (VF) taro 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 giant taro chips of different frying temperature and time combination. Few panel tests were performed at two-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

Changes of physicochemical properties of giant taro chips at different frying conditions during storage

Changes of moisture content during storage

The moisture loss from the giant taro bulbs under vacuum condition at different frying temperature and time is illustrated in Table 1. There were significant ($p<0.05$) differences of moisture content observed in the VF giant taro chips. From the observation, the results indicated that each temperature frying at 4 and 8 mins. produced incomplete fried chips due to less crispiness. Though 4 and 8 mins frying time did not produce a desire level of taro chips, therefore, the data for 4 and 8 mins were not considered for the discussion. The moisture content of the giant taro chips was ranged from 21.31% to 1.64% at 100°C for 4 mins and 120°C for 20 mins, 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 ranged from 4.56% to 14.34% 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 giant taro slices without much warm-up phase. The phenomenon is in accordance with the findings for vacuum fried potato chips (Yagua and Moreira, 2011).

Changes of ash content during storage

Ash content represent the total content of different mineral substances. The values for ash content of VF taro chips were showed in Table 2. It can be seen that ash content was significantly differed among the samples. Its content was ranged from 1.35 to 2.39% and 0.78 to 2.55% on the beginning and end of the storage period, respectively. After 06 months of storage the maximum and minimu percentage ash were found in VF taro chips fried at 110^{o}C for 4 min (2.55%) and VF taro chips fried at 100^{o}C for 4 minutes (0.78%) but those chips were spoiled because of incomplete frying.

Changes of total acid content during storage

The total acidity of VF taro chips was summarized in Table 3 which showed that the prepared samples were low in acid content VF chips fried from 12 to 16 minutes and ranged between 0.16 to 0.58% on the processing day and 0.33 to 0.64% after 6 months of storage. It was found that the values of total acidity significantly differed among the sample irrespective of storage periods (Table 3). The acidity of the prepared sample was increased in all samples with the storage period.

Changes of vitamin C content during storage

Natural antioxidants are widely reported to restrict oxidation-induced degenerative changes in cell physiology and ageing. Ascorbic acid (vitamin C) has an important role as a phytochemical, due to its functionality as an antioxidant. The ascorbic acid content was recorded in Table 4. It was found in Table 4 that vitamin C ranged from 5.49 to 10.04 mg/100g at processing day, which was found to varied significantly among the samples and ranged between 5.89 to 8.88 mg/100g after 6 months of storage VF giant taro chips fried from 12 to 20 minutes. In the present study, the ascorbic acid content followed a decreasing trend throughout the storage period for all VF giant taro chips products (Table 4) 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).

Changes of total phenolic content during storage

Phenolic compounds are considered as the most important group of phytochemicals that provide antioxidant properties against oxidative stress. The phenolic content of VF giant taro chips is presented in Table 5. It is observed from Table 5 that the total phenolic content ranged from 1.26 to10.65 mg GAE/100g of sample at the beginning of the storage and it was found to varied between 4.30 to 6.30 mg GAE/100g of sample after 6 months of storage at ambient condition. It is also found from Table 5 that the total phenolic content varied significantly ($p<0.05$) with the increase in concentration of sugar used as osmotic agent. Besides, the total phenolic content was also decreased with the increase in storage period (Table 5). 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*).*

Changes of ß-carotene content during storage

Carotenoids are the pigments present in food staffs have some beneficial health effects. ß-carotene content in VF taro chips obtained in this study is shown in Table 6. It is observed from Table 6 that ß-carotene among the samples ranged between 7.91 to 24.20 mg/100g on the processing day while it was fluctuated within 5.89 to 8.43 mg/100g after 6 months of storage period. As like ascorbic acid, ß-carotene content also shown decreasing trends throughout the storage periods. It is clearly demonstrated in Table 6 that ß-carotene shown a significantly variation among the samples throughout the storage period. However, a significant amount of ß-carotene 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).

Sensory evaluation at different frying conditions during storage

Vacuum fried giant taro chips were assessed for sensory acceptability in terms of appearance, taste, flavor, crispiness, oiliness, itching and overall acceptability. The sensory score for taro color was rated high during chips frying at higher temperature with time. It was observed that the creamy flesh color turned into light yellowish or a bit brownish during vacuum frying. Taro chips fried at higher temperature 120°C with longer frying time (over 20 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 for initial frying, the highest overall acceptability (7.70) were observed in the treatment of 110°C for 20 min which was followed by taro chips fried at 110°C for 16 min (7.60) and 120°C for 16 min (7.60) and 20 min (7.60), respectively (Table 7). After 6 months of storage, taro chips fried at 120°C for 16 min (5.50) and 20 min (5.70) performed better interms of overall acceptability score (Table 8). In the experimentation, temperatures 100°C, 110°C and 120°C for 4 and 8 min did not produce quality chips and others were belonged to sensory score under 5 (Neither like or dislike) for the development of the VF taro chips due to incomplete frying and less crispiness (Table 8).

Table 1. Effect of frying temperature-time combination on moisture (%) of VF taro chips during 6 months of storage at ambient condition

Treatments		Moisture (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	4	21.31 b	20.67 b	3.93 c	10.53 b
	8	23.82 a	23.39 a	4.08 c	9.53 c
	12	14.97 c	13.62 c	4.24 c	14.34 a
	16	4.36 d	4.34 d	7.18 b	4.56 e
	20	2.28 e	2.18 e	9.17 a	6.48 d
Level of significance		***	***	***	***
110°C	4	14.53 a	3.42 b	7.64 b	8.56 a
	8	11.78 b	11.59 a	11.03 a	7.69 b
	12	2.26 d	2.41 c	11.58 a	4.91 d
	16	5.17 c	3.25 b	5.22 c	6.38 c
	20	2.93 d	3.09 b	4.60 c	5.12 d
Level of significance		***	***	***	***
120°C	4	10.33 a	10.49 a	5.12 d	5.09b
	8	2.61 d	3.12 c	16.95 a	6.36 a
	12	5.44 b	5.30 b	6.77 c	5.58 b
	16	3.56 c	3.16 c	8.03 b	6.57 a
	20	1.64 e	2.33 d	4.49 e	5.40 b
Level of significance		***	***	***	***

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

Table 2. Effect of frying temperature-time combination on ash content (%) of VF taro chips during 6 months of storage at ambient condition

Treatments		Ash (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	4	1.58 c	1.32 a	2.47 a	0.78 d
	8	1.35 d	0.90 b	1.34 c	1.13 cd
	12	1.92 b	0.77 b	1.51 c	1.56 bc

Treatments		Ash (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	16	2.08 a	1.28 a	2.16 b	1.82 b
	20	1.82 b	1.39 a	2.11 b	2.35 a
Level of significance		***	***	***	***
	4	1.85 bc	1.03 a	4.48 a	2.55 a
	8	1.75 cd	0.54 c	1.32 c	2.54 a
110°C	12	1.66 d	0.77 b	1.35 bc	2.14 b
	16	2.11 a	0.58 c	1.24 c	2.20 ab
	20	1.91 b	1.07 a	1.52 b	2.08 b
Level of significance		***	***	***	*
	4	2.38 a	1.58 b	2.76 a	2.24 a
	8	1.44 b	1.74 a	1.54 b	2.25 a
120°C	12	2.22 a	1.17 c	1.73 b	1.49 b
	16	2.37 a	1.24 c	1.16 c	1.69 b
	20	2.39 a	1.70 ab	1.20 c	1.50 b
Level of significance		***	***	***	***

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 3. Effect of frying temperature-time combination on total acid content (%) of VF taro chips during 6 months of storage at ambient condition

Treatments		Total acid (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	4	0.47 a	0.54 a	0.66 b	5.19 a
	8	0.15 d	0.22 c	0.65 b	1.29 b
100°C	12	0.22 c	0.25 c	1.25 a	0.33 d
	16	0.26 b	0.35 b	1.40 a	0.92 c
	20	0.25 b	0.40 b	0.51 b	0.51 d
Level of significance		***	***	***	***
	4	0.74 a	0.25 d	14.90 a	2.52 a
	8	0.23 c	0.25 d	3.46 b	0.45 b
110°C	12	0.24 c	0.35 c	3.59 b	0.37 b
	16	0.27 c	0.66 b	1.72 b	0.40 b
	20	0.58 b	0.95 a	0.65 b	0.46 b
Level of significance		***	***	***	***
	4	0.93 a	0.29 a	0.66 b	0.61 a
	8	0.23 b	0.26 ab	0.74 b	0.36 c
120°C	12	0.26 b	0.29 a	0.90 a	0.49 b
	16	0.16 c	0.18 c	0.50 c	0.51 b
	20	0.25 b	0.23 b	0.95 a	0.64 a
Level of significance		***	**	***	***

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 4. Effect of frying temperature-time combination on vitamin C (mg/100g) of VF taro chips during 6 months of storage at ambient condition

Treatments		Vitamin C (mg/100g)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	4	5.33 b	5.31 ab	15.94 a	5.02 b

Treatments		Vitamin C (mg/100g)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	8	5.19 b	3.62 b	10.86 b	6.44 a
	12	8.40 a	7.36 a	11.73 b	6.41 a
	16	5.49 b	4.55 b	12.68 b	5.99 a
	20	7.85 a	7.60 a	12.77 b	6.31 a
Level of significance		***	**	**	**
	4	9.07 a	7.55 bc	8.86 b	5.69 b
	8	8.33 a	5.63 d	10.76 b	7.00 a
110°C	12	6.08 b	7.26 c	4.47 c	7.44 a
	16	8.38 a	7.95 b	15.52 a	6.96 a
	20	8.71 a	9.80 a	10.60 b	5.90 b
Level of significance		***	***	***	**
	4	10.37 a	6.95 b	16.19 a	7.16 bc
	8	7.60 b	6.85 b	12.72 b	6.65 cd
120°C	12	7.84 b	4.98 d	10.66 b	5.89 d
	16	6.11 c	5.57 c	12.61 b	8.88 a
	20	10.04 a	8.05 a	15.55 a	7.77 b
Level of significance		***	***	*	***

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 5. Effect of frying temperature-time combination on total phenol (mg GAE/100g) of VF taro chips during 6 months of storage at ambient condition

Treatments		Total phenol (mg GAE/100g)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
	4	1.91 c	15.18 a	6.66 c	4.84 b
	8	1.72 c	5.02 b	7.12 b	4.97 b
100°C	12	1.26 c	3.76 b	7.24 b	4.30 b
	16	10.65 a	3.85 b	5.85 d	5.68 a
	20	3.86 b	5.36 b	7.74 a	4.85 b
Level of significance		***	***	***	*
	4	3.25 c	5.13 b	-	5.70 a
	8	6.95 a	4.91 b	2.03 d	4.36 c
110°C	12	2.85 c	5.22 b	6.20 a	5.52 ab
	16	6.08 ab	13.60 a	1.89 d	5.00 b
	20	5.26 b	3.74 b	2.96 c	5.89 a
Level of significance		***	***	4.68 b	**
	4	3.76 ab	7.63 a	7.85 b	7.28 a
	8	3.68 ab	5.85 b	5.70 d	7.00 a
120°C	12	3.83 a	5.92 b	5.95 d	6.30 ab
	16	2.68 c	6.10 b	10.01 a	5.60 b
	20	3.27 b	7.23 a	6.76 c	5.92 b
Level of significance		**	***	***	*

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 6. Effect of frying temperature-time combination on ß-carotene content (mg/100g) of VF taro chips during 6 months of storage at ambient condition

Treatments		ß-carotene (mg/100g)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	4	12.86 b	11.67 bc	9.49 ab	6.90 b
	8	14.82 b	12.89 ab	6.82 c	8.71 a
	12	16.17 b	9.62 d	7.62 bc	7.72 ab
	16	14.73 b	10.78 cd	11.42 a	7.63 ab
	20	24.20 a	13.89 a	8.61 bc	8.43 a
Level of significance		***	***	**	*
110°C	4	13.51 a	9.66 b	7.17 b	7.25 a
	8	10.04 b	7.61 c	5.21 b	7.23 a
	12	8.72 bc	12.72 a	5.19 b	7.73 a
	16	15.00 a	5.73 d	9.33 a	7.88 a
	20	7.91 c	12.42 a	5.09 b	5.89 b
Level of significance		***	***	**	*
120°C	4	13.61 c	13.50 ab	7.23 b	7.91 ab
	8	14.27 bc	13.48 ab	14.22 a	8.02 ab
	12	15.73 ab	14.99 a	13.04 a	6.86 b
	16	16.59 a	14.75 a	9.03 b	7.13 b
	20	17.67 a	12.80 b	9.14 b	8.40 a
Level of significance		**	ns	**	ns

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 7. Consumer preference test of VF taro chips initially after frying

Treatments		Sensory attributes					
Temperature	Time (min)	Appearance	Taste	Crispiness	Oiliness	Itchiness	Overall acceptability
100°C	4	1.00	1.00	1.20	1.00	1.00	1.10
	8	4.40	2.60	2.60	2.80	3.80	3.20
	12	6.30	4.20	4.20	4.40	6.60	5.10
	16	7.80	7.00	6.80	6.80	7.00	7.10
	20	7.10	6.60	7.50	7.10	7.40	7.10
110°C	4	1.00	1.00	1.20	1.00	1.00	1.10
	8	3.00	1.60	2.00	2.00	2.40	2.20
	12	7.50	6.40	6.70	6.30	6.80	6.70
	16	7.60	7.30	7.90	7.50	7.80	7.60
	20	7.60	7.50	7.90	7.40	8.00	7.70
120°C	4	1.00	1.00	1.00	1.00	1.00	1.00
	8	7.90	6.30	5.40	5.30	6.60	6.30
	12	7.80	7.10	6.90	7.00	7.80	7.30
	16	7.60	7.50	7.50	7.40	8.20	7.60
	20	7.60	7.30	7.30	7.50	8.20	7.60

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 8. Consumer preference test of VF taro chips after 6 months of storage at ambient condition

Treatments		Sensory attributes					
Temperature	Time (min)	Appearance	Taste	Crispiness	Oiliness	Itchiness	Overall acceptability
100°C	4	0.00	0.00	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00	0.00	0.00
	12	0.00	0.00	0.00	0.00	0.00	0.00
	16	6.40	4.40	4.20	3.20	4.40	4.50
	20	5.00	4.00	4.40	3.40	4.40	4.20
110°C	4	0.00	0.00	0.00	0.00	0.00	0.00
	8	0.00	0.00	0.00	0.00	0.00	0.00
	12	5.60	4.60	4.80	3.60	4.20	4.60
	16	4.20	4.00	5.20	3.40	4.20	4.20
	20	4.40	5.20	5.20	3.40	4.40	4.50
120°C	4	0.00	0.00	0.00	0.00	0.00	0.00
	8	5.00	5.00	5.00	5.40	4.80	5.00
	12	4.40	5.20	6.00	5.40	4.80	5.20
	16	6.00	5.60	5.80	5.40	4.80	5.50
	20	5.60	6.20	6.20	5.40	5.00	5.70

N.B.: 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 VF taro chips processing protocol to produce export oriented taro 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. Taros are needed to slice at about 5 mm thickness to make it chips form with attractive slick shape. The taro 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. 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 retain for longer time. This technology will add value in agro-processing industry for producing quality VF taro chips and will assist to reduce postharvest loss of taro of our country. The economic analysis will be conducted for further study.

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COMPARISON OF COOKING METHODS AND OILS ON PHYSICOCHEMICAL, NUTRITIONAL, MINERALS AND BIOACTIVE COMPOUNDS OF MIXED VEGETABLES

M.M. MOLLA, M.H.H. KHAN, A. A. SABUZ, M.G.F. CHOUDHURY AND S. PERVIN

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 different edible oils viz. soybean oil, mustard oil, extra virgin coconut oil and extra virgin olive oil on the nutritional, physicochemical, minerals and phytochemical compounds under different cooking conditions. Results revealed that steam cooked 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 (26.90±0.10 %) whereas the low fat content is found by the other edible oils. The low fat content was recorded by the traditional and steam cooked vegetables without oil. The highest crude fiber (5.68±0.20 to 6.48±0.02) was documented by the steam cooked vegetables as compared to traditionally cooked vegetables. The highest crude protein content was found by the traditionally cooked vegetables using mustard oil. The lower carbohydrate (49.42±0.03 %) content was also recorded by the steam cooked vegetables using extra virgin olive oil. Most of the minerals especially human body essential Ca, Mg, Fe, Cu and Zn found notable in traditionally cooked and steam cooked vegetables using mustard oil and extra virgin olive oil. The leading phytochemical compounds ß-carotene was found by the steam cooked vegetables using mustard oil. The highest anthocyanin and ascorbic acid found by the steam cooked vegetables without oil. Total carotenoid and total phenolic content was dominant in the steam cooked vegetables using extra virgin coconut and extra virgin olive oil. Highest lycopene was noted by the traditionally cooked vegetables using extra virgin coconut oil. However, the findings obtained from this study confirm that except soybean oil, all the edible oils used in this study retained more bioactive compounds and essential minerals although no oil is good for the better dietary life style. Only limited amount of oil may be required for the more functioning of vitamin A, D, E and K.

Key words: Cooking process, Cooking oil, Crude fat, Carbohydrate content, minerals content, phytochemical compounds.

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 performing 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 cooking 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 document and compare the cooking oil effect on physicochemical, nutritional, minerals and phytochemical compounds and then draw a concrete conclusion regarding use of edible oils.

Materials and Methods

Processing of vegetables

The vegetables were collected from the farmers filed of Marta, Sreepur, Gazipur, 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_1= Domestic/ traditional cooking

A_2= Steam cooking

Factor B: Cooking oil

B_1= Control (without oil)

B_2= Cooking with soybean oil

B_3= Cooking with mustard oil

B_4= Cooking with extra virgin coconut oil

B_5= Cooking with extra virgin olive oil

Steam cooking

After pre-processing, all the vegetables and ingredients measured according to the Table 1, were steam cooked 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	Turmeric powder	30
9	Salt	100
10	Soybean oil	100
11	Mustard oil	100
12	Extra virgin coconut oil	100
13	Extra virgin olive oil	100

Color measurement

The color of the steam cooked 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 cooked 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-1force.

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 was 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 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).

Microbial count

Microbial load of the guava-pineapple natural jelly was determined with the use of plate count agar. The microbial load count was performed 2 months' interval up to 8 months' storage. In the process of counting, a 10g jelly was homogenized with 90 ml 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:

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

Sensory evaluation

Steam cooked 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.

Moisture content

Moisture content of the steam cooked vegetables using extra virgin olive oil and traditional cooking process using soybean oil exhibited highly significant difference. The mean values of the steam cooked vegetables ranged from 5.07±0.02 to 5.40±0.10% whereas the traditionally cooked vegetables ranged from 4.27±0.08 to 4.64±0.13% (Table 2). The highest moisture content was observed in steam cooked cooked vegetables without oil (A_2B_1) and the lowest moisture content was observed in traditionally cooked vegetables without oil (A_1B_4) (Table 2). The variation in moisture content between the traditionally cooked and steam cooked vegetables might be due to the cooking condition effect. The highest moisture content found in steam cooked vegetables might be due to non-disruption of cell walls and membrane whereas the cooked samples might be influenced by the vapor heating process to interference of cell walls and membranes allowing water to fill spaces.

Ash content

The ash content of the steam cooked vegetables and traditionally cooked vegetables using different oils varied significantly. The ash content of the traditionally cooked vegetables using different oils ranged from 1.97±0.30 to 2.36±0.05% whereas the steam cooked vegetables using different oils ranged from 2.31±0.01 to 2.40±0.01%, representing that the steam cooked vegetables are the amusing source of minerals than the traditional one. The ash content of the traditionally cooked vegetables using soybean oil significantly reduced the ash content (1.97±0.30) than the steam cooked vegetables using extra virgin olive oil (2.43±0.01%). 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.

Total acid

The total acid of the mixed vegetables using different cooking oils and cooking conditions were significantly differed (Table 2). The total acid of the traditionally cooked vegetables ranged from 2.17±0.03 to 3.45±0.04% whereas the steam cooked vegetables ranged from 1.28±0.02 to 1.53±0.02%. The highest acidity was calculated as 3.45±0.04% in traditionally cooked vegetables without oil (A_1B_1). The lowest acidity recorded as 1.28±0.02 % in the steam cooked vegetables using extra virgin olive oil (A_2B_5). 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 cooked mixed vegetable and the traditional cooked vegetable using different oil varied significantly with the range of 5.44±0.01 to 5.77±0.03 and 6.60±0.43 to 6.15±0.03. Results indicating that the pH of the steam cooked vegetables using soybean 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 was statistically differed. The fat content of the traditionally cooked vegetables was ranged from 1.94±0.04 to 20.61±0.04 % whereas the steam cooked vegetables from 21.51±0.09 to 26.90±0.10 % respectively (Table 2). The lowest fat

(21.51±0.09 to 26.90±0.10 %) was recorded by the steam cooked vegetables without oil (A2B1) and the highest was documented by the steam cooked vegetables using soybean oil (A_2B_2).

The results indicate that the vegetable cooked in soybean oil influenced to attain higher amount of crude fat content than the other oils. The increased fat content might be due to more conversion of carbohydrate by the soybean oil 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 cooking process may be hydrolyzed more than the steam cooked vegetables. The hydrolysis of oil in the 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.

Crude fiber

The crude fiber content of the cooked vegetables using traditional and steam were statistically differed. The fiber content of the traditionally cooked vegetables ranged from 4.74±0.06 to 6.89±0.05% whereas the steam cooked vegetables were from 5.51±0.04 to 6.48±0.02 % respectively (Table 2). The lowest fiber content was recorded as 4.73±0.06 % whereas the highest fiber content was recorded as 6.89±0.05% by the traditionally cooked vegetables without oil (A_1B_1). The results indicate that the vegetable cooked without oil influenced to attain higher amount of crude fiber content than the others.

Crude protein

The crude protein content of the cooked vegetables using traditional and steam were statistically differed. The protein content of the traditionally cooked vegetables ranged from 9.10±0.30 to 13.30±0.10% whereas the steam cooked vegetables were from 5.94±0.05 to 11.17±0.03 % respectively (Table 2). The lowest protein content was recorded as 5.94±0.05 % by the steam cooked vegetables using soybean oil. The highest protein content was recorded as 13.30±0.10% by the traditionally cooked vegetables using mustard oil (A_1B_3). The results indicate that the vegetable cooked using mustard oil influenced to attain higher amount of crude protein content than the other oils.

Total carbohydrate

The total 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 cooking significantly differed (Table 2). The highest carbohydrate content (75.51±0.09 %) exhibited by the steam cooking without oil whereas the lowest carbohydrate content (49.42±0.03%) possessed by the extra virgin olive oil. Molla reported that the carbohydrate content of rice, wheat bread (roti) and oats are recorded as 81.58±0.42 %, 79.32±0.42 % and 68.91±0.48% respectively (Table 2). However, the findings confirm that mixed vegetable cooked by steam blancher using extra virgin olive oil contained lower amount of carbohydrate than other treated vegetables and rice, wheat bread and oats.

Table 2. Physicochemical and Nutritional properties of the vegetables under different cooking conditions

Treatment	Moisture content (%)	Ash (%)	Total acid (%)	pH	Crude fat (%)	Crude fiber (%)	Crude protein (%)	Total carbohydrate (%)
A_1B_1	4.64± 0.13c	2.13± 0.05bcd	3.45± 0.04a	5.44± 0.01e	1.94± 0.04f	6.89± 0.05a	11.01± 0.01bc	73.28± 0.08b

Treatment	Moisture content (%)	Ash (%)	Total acid (%)	pH	Crude fat (%)	Crude fiber (%)	Crude protein (%)	Total carbohydrate (%)
A_1B_2	4.41± 0.06cd	1.97± 0.30d	2.43± 0.04c	5.77± 0.03d	20.61± 0.04de	4.73± 0.06g	9.10± 0.30f	54.65± 0.05g
A_1B_3	4.63± 0.17c	2.09± 0.05cd	2.17± 0.03d	5.47± 0.03e	19.33± 0.03e	5.08± 0.08f	13.30± 0.10a	60.11± 0.10c
A_1B_4	4.27± 0.08d	2.36± 0.03	2.17± 0.03d	5.46± 0.04e	19.68± 0.02e	6.65± 0.05b	10.79± 0.04cd	56.19± 0.06f
A_1B_5	4.33± 0.05cd	2.36± 0.05abc	2.81± 0.04b	5.50± 0.03e	19.31± 0.09e	5.40± 0.10e	11.19± 0.06b	57.38± 0.07e
A_2B_1	5.40± 0.10a	2.33± 0.05abc	1.53± 0.02e	6.21± 0.02a	1.21± 0.04f	5.68± 0.20d	10.82± 0.03cd	75.51± 0.09a
A_2B_2	5.40± 0.10a	2.40± 0.01ab	1.53± 0.02e	6.15± 0.03ab	26.90± 0.10a	5.62± 0.03d	5.94± 0.05g	49.54± 0.06i
A_2B_3	5.30± 0.20ab	2.31± 0.01abc	1.53± 0.02e	6.04± 0.04c	21.51± 0.09cd	5.51± 0.04de	11.17± 0.03b	59.65± 0.05d
A_2B_4	5.09± 0.00ab	2.40± 0.01ab	1.53± 0.02e	6.13± 0.02abc	22.14± 0.06c	6.10± 0.10c	10.14± 0.06e	53.11± 0.04h
A_2B_5	5.07± 0.02b	2.43± 0.01a	1.28± 0.02f	6.06± 0.04bc	25.43± 1.51b	6.48± 0.02b	10.50± 0.05cd	49.42± 0.03i

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 ($p<0.05$).

Minerals

The mineral contents of the traditionally cooked and steam cooked mixed vegetables are shown in Table 3 and Table 4. The traditionally and steam cooked mixed vegetables were found rich source of Ca, Mg, K and P than the vegetables cooked using other edible oils. The highest Na was found in the traditionally and steam cooked vegetables using extra virgin olive oil. The highest S was found vegetable cooked by steam cooking process using mustard oil and extra virgin olive oil. The highest Cu, Fe, Mn and Zn was found by the traditionally cooked vegetables using mustard oil. Leaching of minerals in traditional cooking process and further its concentered to the same soluble oils may be contributed to gain higher amount of Zn, Mn, Fe and Cu. K is the amplest source of mineral in vegetables where the maximum amount of it (K) retained by the traditionally cooked vegetables using mustard oil.

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

Treatment	Minerals (%)					
	Ca	Mg	K	P	Na	S
A_1B_1	0.91±0.01bcd	0.47±0.01c	2.44±0.05e	0.33±0.04e	3.15±0.04c	0.18±0.10e
A_1B_2	0.70±0.40ef	0.39±0.05d	2.53±0.05d	0.15±0.11f	3.59±0.12a	0.26±0.03c
A_1B_3	1.43±0.08a	0.75±0.06a	3.19±0.05a	0.49±0.01a	3.15±0.03c	0.21±0.07cd
A_1B_4	0.61±0.11fg	0.30±0.02e	2.61±0.02c	0.40±0.02c	3.61±0.15a	0.22±0.03d
A_1B_5	0.54±0.02g	0.29±0.03e	0.69±0.05f	0.40±0.04c	1.13±0.05d	0.21±0.05de
A_2B_1	0.78±0.04de	0.41±0.00d	0.69±0.02f	0.46±0.02b	1.00±0.02e	0.09±0.03g
A_2B_2	0.75±0.01de	0.40±0.01d	2.70±0.01b	0.37±0.00cd	3.14±0.00c	0.37±0.00b
A_2B_3	1.10±0.05bc	0.55±0.02b	0.33±0.01g	0.39±0.02c	0.13±0.01f	0.43±0.01a

Treatment	Minerals (%)					
	Ca	Mg	K	P	Na	S
A_2B_4	0.89±0.05bcd	0.47±0.00c	2.59±0.01c	0.35±0.01ef	3.55±0.00a	0.12±0.00f
A_2B_5	0.89±0.05bcd	0.48±0.01c	2.48±0.01e	0.38±0.00cd	3.35±0.10b	0.43±0.02a

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 condition

Treatment	Minerals (ppm)				
	Cu	Fe	Mn	Zn	B
A_1B_1	6.91±0.01f	38.25±0.05i	15.04±0.01i	18.76±0.01gh	7.13±0.04j
A_1B_2	12.07±0.03d	78.13±0.35e	15.20±0.04j	18.44±0.19h	17.10±0.51d
A_1B_3	23.49±0.13a	313.85±0.13a	160.00±0.51a	42.42±0.71a	25.03±0.09b
A_1B_4	12.45±0.05d	85.05±0.86d	45.36±0.35d	20.85±0.15f	11.05±0.05f
A_1B_5	8.39±0.01e	27.01±0.04jk	14.01±0.01k	8.41±0.44i	9.11±0.29hi
A_2B_1	8.41±0.20e	29.10±0.02j	45.51±0.05c	7.30±0.04j	9.14±0.01ghi
A_2B_2	14.51±0.03c	73.10±0.09f	38.04±0.10f	25.33±0.18c	58.39±0.05a
A_2B_3	12.21±0.08d	92.31±0.13b	49.01±0.10b	19.30±0.11g	19.70±0.80c
A_2B_4	14.45±0.05c	79.30±0.05e	41.10±0.10e	28.0710.08b	14.25±0.13e
A_2B_5	18.04±0.03b	89.70±0.50c	42.09±0.21e	27.45±0.03c	8.99±0.13i

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 cooked and traditionally cooked vegetables were significantly differed. The highest ascorbic acid content was recorded as 42.31±0.01 mg/100 g in the traditionally cooked vegetables without oil. The ascorbic acid content of the steam cooked mixed vegetables ranged from 14.13±0.02 to 25.89±0.02 mg/100 g whereas the traditionally cooked vegetables ranged from 21.18±0.01 to 42.31±0.01mg/100 g respectively (Table 2). Results indicate that ascorbic acid content drastically changed by the cooking process and the different oils. The ascorbic acid retained more the traditionally cooked vegetables than the steam cooked vegetables. The reduction in ascorbic acid content by steam cooking process may be due to leaching of more cooking solution in the steam tray by the high vapor process. The traditionally cooked vegetables and their leaching solution may be concentrated more during the traditional process. The results are 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 cooked and traditionally cooked vegetables using different oils significant effect on the ß-carotene content (Table 2). The ß-carotene content of the steam cooked vegetables using different oils ranged from 9.72±0.03 to 67.04±0.04 mg/100 g whereas the traditionally cooked vegetables ranged from 5.91±0.04 to 53.84±0.03 mg/100 g respectively. The highest ß-carotene content was recorded as 67.04±0.04 mg/100 g by the steam cooked vegetables using mustard oil (A_2B_3). The lowest ß-carotene content was documented as 5.91±0.04 mg/100 g by the traditionally cooked vegetables using soybean oil (A_1B_2). 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 (5.91±0.04 mg/100 g) shown in the traditionally cooked 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 cooked mixed vegetables using different oils ranged from 11.75±0.03 to 26.90±0.05 mg/100 g whereas the traditional cooked vegetables using different oils shown from 7.28±0.03 to 32.69±0.02 mg/100 g. The highest anthocyanin content was recorded as 67.04 ±0.04 mg/100 g by the steam cooked vegetables using mustard oil (A2B3). The lowest anthocyanin was calculated as 5.91±0.04 mg/100 g by the traditional cooking using soybean oil. The steam cooked vegetables using extra virgin olive oil retained more anthocyanin content than the traditionally cooked vegetables using 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

Traditionally cooked and steam cooked vegetables significantly affected the total carotenoid content of the mixed vegetables (Table 5). The total carotenoid content of the steam cooked mixed vegetables using different oils ranged from 8.58±0.02 to 31.60±0.05 mg/100 g whereas the traditionally cooked vegetables using different oils reserved from 16.71±0.04 to 23.66±0.04 mg/100 g. Higher carotenoid content exhibited in the steam cooked vegetables using extra virgin coconut oil than the carotenoid content found in the steam cooked vegetables without 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 traditionally heating process during cooking (De Sa and Rodriguez-Amaya, 2003).

Total phenolic content

Highly statistical significant differences were observed between the traditional and steam cooked vegetables using different oils (Table 5). The steam cooked 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 cooked mixed vegetables noted as 1.70±0.03 to 3.11±0.04 mg GAE/g whereas it shown 1.35±0.03 to 2.97±0.03 mg GAE/g by traditional cooking process using different oils. Moreover, the steam cooked vegetables using extra virgin olive oil shown significant effect on the total phenolic content compared to 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 others (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).

Lycopene

Traditionally cooked and steam cooked vegetables insignificantly differed for the lycopene content of the mixed vegetables (Table 5). The lycopene content of the steam cooked mixed vegetables using different oils ranged from 0.02±0.01 to 0.12±0.03 mg/100 g whereas the traditionally cooked vegetables using different oils calculated as 0.02±0.01 to 0.26±0.20 mg/100 g. Higher lycopene content recorded as 0.26±0.20 mg/100 g in the traditionally cooked vegetables using extra virgin coconut oil than the steam cooked vegetables without oil (0.02±0.01).

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

Treatment	Phytochemicals					
	Ascorbic acid (mg/100 g)	ß-carotene (mg/100 g)	Anthocyanin (mg/100 g)	Total carotenoid (mg/100 g)	Total phenol (mg GAE/g)	Lycopene (mg/100 g)
A_1B_1	42.31±0.01a	53.84±0.03d	32.69±0.02a	23.66±0.04bc	2.97±0.03b	0.06±0.02
A_1B_2	21.18±0.01d	5.91±0.04	7.28±0.03h	16.71±0.04cde	1.35±0.03h	0.08±0.02
A_1B_3	21.18±0.01d	21.21±0.04f	12.00±0.01f	18.41±0.04bcd	2.87±0.03bc	0.12±0.03
A_1B_4	23.53±0.01c	9.56±0.04h	13.36±0.03e	20.98±0.02bcd	1.59±0.02g	0.26±0.20
A_1B_5	21.18±0.02d	9.72±0.03g	10.97±0.02	16.33±0.02cde	2.74±0.04d	0.09±0.02
A_2B_1	21.18±0.01d	6.32±0.03	11.75±0.03fg	8.58±0.02e	1.39±0.02h	0.02±0.01
A_2B_2	14.13±0.02f	66.23±0.07b	21.41±0.04d	12.38±0.02de	2.23±0.07e	0.04±0.02
A_2B_3	23.53±0.01c	67.04±0.04a	24.42±0.03c	26.61±0.04b	2.77±0.03cd	0.12±0.03
A_2B_4	18.83±0.02e	63.44±0.04c	27.55±0.05b	31.60±0.05a	1.70±0.03f	0.13±0.03
A_2B_5	25.89±0.02b	24.20±0.04e	26.90±0.05b	25.55±0.05bc	3.11±0.04a	0.11±0.04

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 ($p<0.05$).

Energy content

Statistically highly significant differences were observed between the traditionally cooked and and steam cooked vegetables. Steam cooked and traditionally cokked mixed vegetables using mustard oil, extra virgin coconut oil and extra virgin olive oil exhibited high energy content as compared to vegetable cooked using soybean oil.

Table 6. Energy content of traditionally and steam cooked mixed vegetables using different edible oils.

Treatment	Energy (Cal/g)
A_1B_1	9157.41±0.50j
A_1B_2	11112.33±1.02i
A_1B_3	13677.10±1.00d
A_1B_4	13229.03±0.98e
A_1B_5	14085.89±1.01b
A_2B_1	12760.56±0.95g
A_2B_2	11847.92±1.00h
A_2B_3	15321.51±1.01a
A_2B_4	13127.75±0.96f
A_2B_5	13855.54±1.41c

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 ($p<0.05$).

Color of the traditionally cooked and steam cooked mixed vegetables

Color is the foremost quality considered by consumers at the time of purchasing a product. The effect of color values on steam cooked and traditional cooked mixed vegetables are shown in Fig.1. The external surfaces of the cooked mixed vegetables were considered. The color of the traditionally cooked and steam cooked mixed vegetables had a lightness (L^*) ranged from 34.36 to 45.25 and 40.74 to 46.58 respectively. The Chroma (c^*) of the traditionally cooked and steam cooked mixed

vegetables ranged from 27.87 to 29.52 and 30.14-32.52 respectively. The hue angle (*h**) of the traditional cooked and steam cooked vegetables were 83.17 to 90.86 and 80.49 to 91.84 respectively. Results indicate that *L** and *h** values expressively increased in the traditionally cooked and steam cooked vegetables using mustard oil and extra virgin olive oil as compared to other oils. A significant gain of bright color (*c**) were observed for the traditionally cooked and steam cooked vegetables without oils. But a significant loss of bright color was observed by oils for the traditionally and steam cooked vegetables. It is well reported that the color of the cooked and steam cooked 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 cooked mixed vegetables by the steam blancher followed by traditionally cooked vegetables (Table 2). The lowest ß-carotene content was retained by the A_1B_2 and A_2B_1, which is may be directly related to decrease the hue angle (*h**) of the vegetables (Fig.1). The results obtained by this study are strongly supported with the findings of Sulaeman et al. (2004), who reported that a high 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 decrease of ß-carotene content by the steam cooking process. The findings are also 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**).

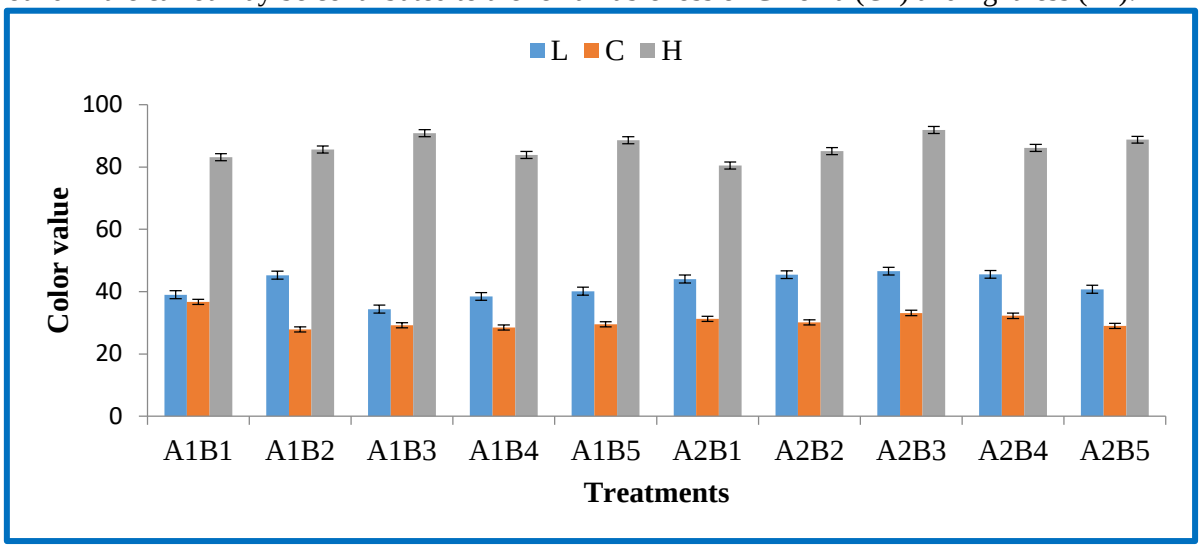

Fig.1. Color of the mixed vegetables under different cooking conditions

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 cooking process (Fig. 2). The maximum/medium and lowest peak was recorded in, steam cooked and traditionally cooked vegetables. Between the cooked vegetables, the highest peak obtained by the steam cooked vegetables might be due to the less broken of the cell membrane to attain more hardness than the traditionally cooked vegetables.

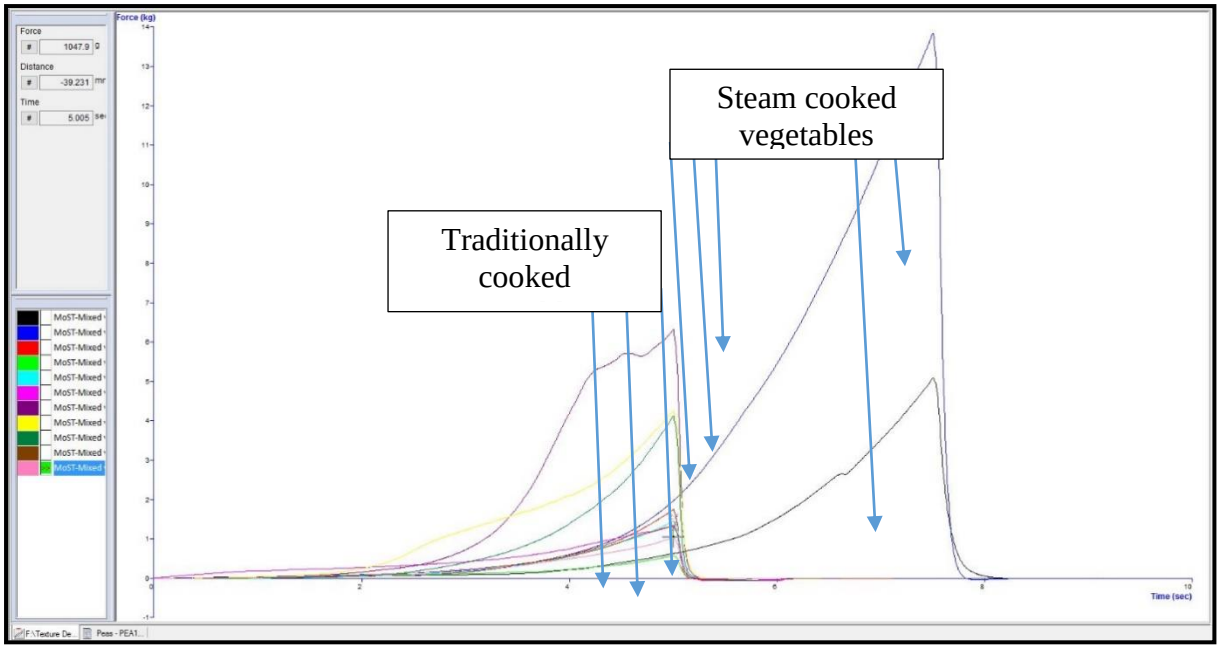

Fig.2. Texture profile of the mixed vegetables under different cooking conditions.

Shelf life of the cooked mixed vegetables

The shelf life of the cooked vegetable decreased with the advancement of storage periods. All the stored cooked vegetables were consumable condition up to 9 days (but 7 days is better) at refrigerated temperature 5±1°C.The lowest marketable life (less than one day) was recorded in control sample (Fig.3).

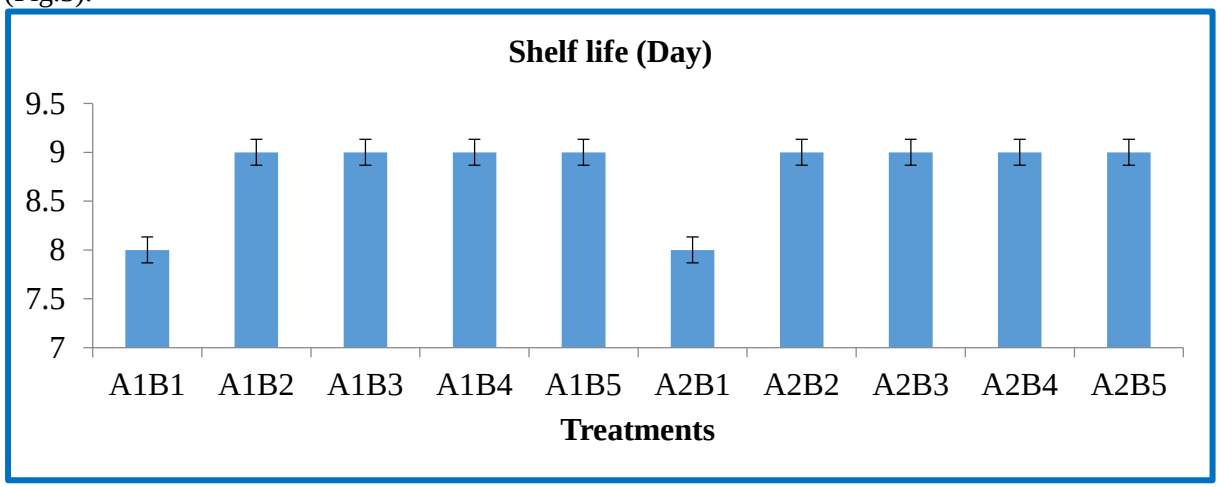

Fig.3. Shelf life of the cooked mixed vegetable

Microbial count of the cooked vegetables

Table 7 shows the microbial count of the steam and traditionally cooked vegetables after 9 days' storage at refrigerator condition (5±1ºC). No microorganism was observed initially due to the higher dilution used for the enumeration. After 9 days of storage, no aspergillus, shijella and e-coli was detected in the treated vegetables. Storage from 9-14 days, few aspergillus, Shijella and E-coli was detected. But after 14 days of storage, aspergillus, Shijella and E-coli widely grown in the sample

(Fig.3). However, the results confirm that all the cooked vegetables using different edible oils were found to be free from microbial count.

Table 7. Microbial counts of the cooked vegetables during different storage periods

Treatments	Microbial counts (storage periods)				
	3rd Day	6th Day	9th Day	12th Day	15th Day
			Aspergillus (cfu/g)		
A_1B_1	ND	ND	ND	38×10^{10}	Unlimited
A_1B_2	ND	ND	ND	31×10^{8}	Unlimited
A_1B_3	ND	ND	ND	$14x\ 10^{9}$	Unlimited
A_1B_4	ND	ND	ND	15×10^{9}	Unlimited
A_1B_5	ND	ND	ND	18×10^{7}	Unlimited
A_2B_1	ND	ND	ND	29×10^{9}	Unlimited
A_2B_2	ND	ND	ND	24×10^{8}	Unlimited
A_2B_3	ND	ND	ND	13×10^{7}	Unlimited
A_2B_4	ND	ND	ND	14×10^{9}	Unlimited
A_2B_5	ND	ND	ND	15×10^{9}	Unlimited
			Shijella (cfu/g)		
A_1B_1	ND	ND	ND	31×10^{10}	Unlimited
A_1B_2	ND	ND	ND	21×10^{8}	Unlimited
A_1B_3	ND	ND	ND	12×10^{9}	Unlimited
A_1B_4	ND	ND	ND	14×10^{9}	Unlimited
A_1B_5	ND	ND	ND	15×10^{9}	Unlimited
A_2B_1	ND	ND	ND	31×10^{9}	Unlimited
A_2B_2	ND	ND	ND	21×10^{8}	Unlimited
A_2B_3	ND	ND	ND	12×10^{7}	Unlimited
A_2B_4	ND	ND	ND	12×10^{9}	Unlimited
A_2B_5	ND	ND	ND	14×10^{9}	Unlimited
			E-coli (cfu/g)		
A_1B_1	ND	ND	ND	4.3×10^{10}	Unlimited
A_1B_2	ND	ND	ND	4.3×10^{7}	Unlimited
A_1B_3	ND	ND	ND	4.5×10^{10}	Unlimited
A_1B_4	ND	ND	ND	4.3×10^{7}	Unlimited
A_1B_5	ND	ND	ND	4.3×10^{10}	Unlimited
A_2B_1	ND	ND	ND	5.3×10^{10}	Unlimited
A_2B_2	ND	ND	ND	5.5×10^{5}	Unlimited
A_2B_3	ND	ND	ND	5.1×10^{5}	Unlimited
A_2B_4	ND	ND	ND	5.2×10^{5}	Unlimited
A_2B_5	ND	ND	ND	5.5×10^{5}	Unlimited

ND= Not Detected

Fig.4.Microbialcount (E-coli) of the cooked vegetables

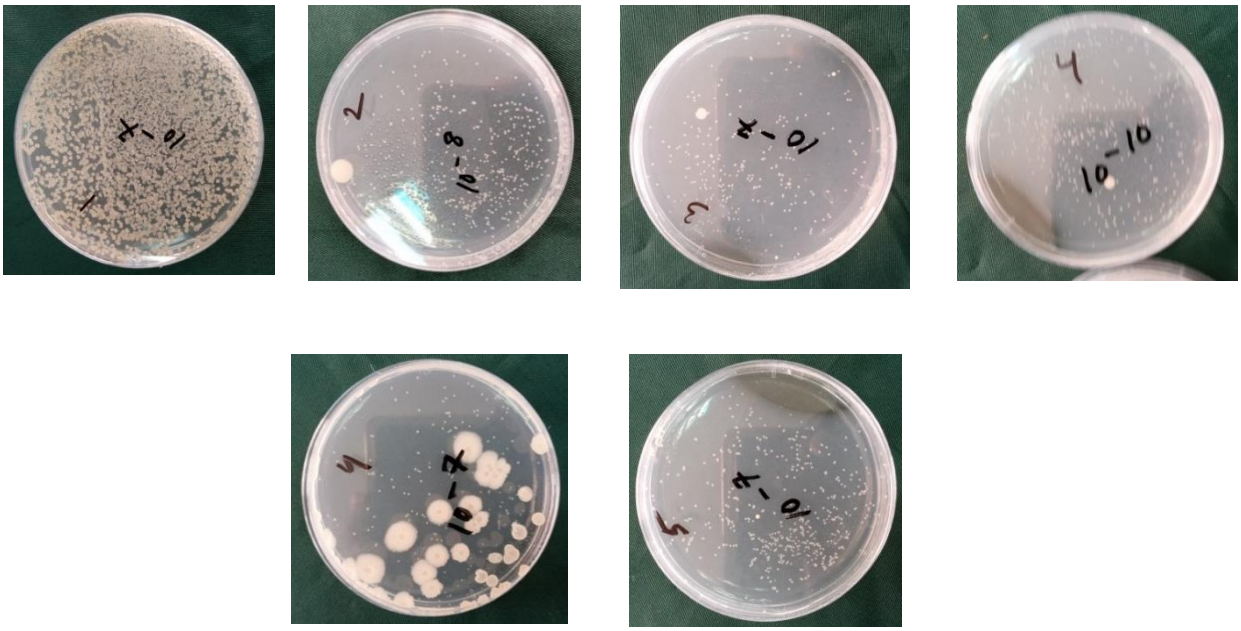

Fig.5.Microbialcount (Aspergillus and Shijella) of the cooked vegetables

Sensory evaluation

The steam cooked mixed vegetables and traditionally cooked vegetables using different oils were subjected to sensory evaluation based on 9-point hedonic scale (Table 8). The score obtained by the expert judgment in terms of color, flavor, mouth feel, softness and overall acceptability. Color, flavor, mouth feel, softness and overall acceptability were statistically significant. The highest color was recorded for the steam cooked vegetables than the vegetables cooked by the traditional oven process. The highest flavor was gained by the traditionally cooked vegetables using soybean, mustard and extra virgin olive oil. The highest mouth feels and softness was recorded by the traditionally cooked vegetables using mustard oil. However, the overall acceptability was gained by the traditionally cooked vegetables using mustard oil (7.04±0.90) and extra virgin olive oil (7.03±0.86). The highest mouth feels and overall acceptability score was secured by the sensory evaluator in traditionally cooked vegetables might be due to the eating behavior of the country (Bangladesh) people as the peoples are accustomed in this process.

Table 8. Sensory evaluation of the mixed vegetables under different cooking condition

Treatment	Sensory attributes				
	Color	Flavor	Softness	Mouth feel	Overall acceptability
A_1B_1	4.67±0.47c	4.67±0.84b	4.72±0.71d	4.44±0.68c	4.62±0.57c

Treatment	Sensory attributes				
	Color	Flavor	Softness	Mouth feel	Overall acceptability
A_1B_2	5.20±0.42bc	6.50±0.64a	7.00±0.05abc	7.00±0.94ab	6.45±0.83ab
A_1B_3	6.60±0.40ab	6.84±0.10a	7.45±0.83a	7.23±0.31a	7.04±0.90a
A_1B_4	5.39±0.28bc	6.11±0.09ab	6.89±0.11abc	6.00±0.50abc	6.37±0.82ab
A_1B_5	7.00±0.05a	6.89±0.11a	7.22±0.91ab	6.89±0.11ab	7.03±0.86a
A_2B_1	6.39±0.99ab	5.50±0.66ab	5.67±0.47cd	5.56±0.49bc	5.55±0.47bc
A_2B_2	7.11±0.11a	5.89±0.87ab	5.56±0.34cd	5.61±0.24bc	6.07±0.80ab
A_2B_3	7.22±0.90a	6.44±0.89ab	5.89±0.87bcd	5.56±0.42bc	6.31±0.92ab
A_2B_4	7.78±0.78a	6.22±0.22ab	5.78±0.22bcd	5.56±0.16bc	6.35±0.95ab
A_2B_5	7.67±0.82a	5.89±0.44ab	6.22±0.11abc	5.67±0.50abc	6.39±0.90ab

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

Conclusion

In this study, steam cooking and traditional cooking process was applied with different edible oils namely soybean oil, mustard oil, extra virgin coconut oil and extra virgin olive 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 cooking and traditionally cooking vegetables using different edible oils have effect on nutritional values, physicochemical properties, minerals and bioactive compounds. The steam cooked mixed vegetables using mustard and extra virgin coconut and extra virgin olive oil retained more bioactive compounds, minerals, nutritional values and less crude fat than the vegetables cooked traditionally using soybean oil. The consumer preferences based on sensory evaluation focuses that the consumer would like the traditionally cooking vegetables using mustard oil. The sensory results also confirm that the peoples are still now very far to accustomed with the steam cooking vegetables.

Acknowledgment

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THE NUTRITIONAL, PHYSICOCHEMICAL, MINERALS AND BIOACTIVE COMPOUNDS ANALYSIS OF SELECTED BARI MOSUR (LENTIL) VARIETIES

M.M. MOLLA, M.H.H. KHAN, A.A. SABUZ, M.G.F. CHOWDHURY, S. PERVIN, M.S. ZAMAN, R. PODDER AND P. BHOWMIK

Abstract

Fresh lentils contain huge amount of bioactive compounds, antioxidant activity, amino acid, vitamins and minerals profile but during dehulling, milling and flouring most of them are going to nutritionally loss. Hence, the first attempt has been taken to collect the BARI Mosur (lentil) varieties and their bioactive compounds, antioxidant activity, amino acid, vitamins and minerals profile analysis under both fresh and dehulled lentils. The selected fresh BARI Mosur (lentil)-3, BARI Mosur (lentil)-6, BARI Mosur (lentil)-7, BARI Mosur (lentil)-8 and BARI Mosur (lentil)-9 has been collected from the Pulse Research Center (PRC), BARI, Ishurdi, Pubna. After collection, these five fresh varieties were incorporated for its analysis of physicochemical, nutritional, minerals, phytochemicals and energy value. All the analysis has been performed by internationally recognized method using HPLC and Double Beam Spectrophotometer. Then the obtained data has been varified with reputed national and international journals and books. Results rtevealed that BARI Mosur-3 and BARI Mosur-6 is the lycopene rich. BARI Mosur-3 is the superior of energy value. BARI Mosur-8 is the rich source of β–carotene, total phenol, Fe and Zn. BARI Mosur-9 is the rich source of anthocyanin and ascorbic acid.

Introduction

Lentils are dietary important seeds as they contain significant amounts of proteins and hence could contribute to the need of reducing the consumption of animal food sources against vegetable sources (Makri et al., 2005). In addition, legumes along with vegetables are an essential part of Mediterranean diet which has many benefits in human health (Avellone et al., 2003; Panagiotakos, 2005). Nutritionally, all legume storage proteins are relatively low in sulphur-containing amino acids, methionine, cysteine and tryptophan, but the amounts of another essential amino acid, lysine, are much greater than in cereal grains (Duranti, 2006). Therefore, with respect to lysine and sulphur amino acid contents, legume and cereal proteins are nutritionally complementary. Thermal treatment of legumes and cereals is used for the improvement of their nutritive, hygienic, physico-chemical and other characteristics. It improves the nutritive value of some nutrients, enhances sensory characteristics, ensures the microbiological correctness of the product and lowers the concentrations of the present thermolabile antinutrients. Furthermore, a number of methods are used for processing legume proteins into texturized products. Twin screw extrusion cooking has proven to be instrumental in the development of many new food products. Extrusion cooking technology can replace many conventional processes in food and feed industry, as being unique among heat processes in that the material is subjected to intense mechanical shear; moistened starchy or proteinaceous foods are worked into viscous, plastic-like dough and cooked before being forced through the die. Extrusion has been used to develop various types of snack foods, mainly from corn meal, rice, wheat flour, or potato flour, in many shapes and variety of textures. Product quality can vary considerably depending on the extrusion processing conditions such as extruder type, screw configuration, feed moisture, and temperature profile in the barrel sections, screw speed, and feed rate (Frame, 1994). Pulses are low in sodium and fat, cholesterol-free, as well as being rich in protein and fibre, so they can help reduce the risk of a variety of health problems such as obesity, heart disease, cancer and diabetes. Hence, the present study has undertaken to develop lentil extruded chips by using single screw extruder and their physicochemical and nutritional properties, minerals profiling, phytochemical, energy values, amino acid compositions, phenolic acid profile and protein fractions of the BARI developed lentil varieties.

Materials and methods

The research was conducted by the postharvest Technology Division (PHTD) of BARI and with collaboration of GIFS, Canada. Five different varieties of lentils provided by the scientists of pulse Research Center (PRC), Ishordi, Pubna was incorporated to analyze the physicochemical and

nutritional properties, minerals profiling, phytochemical composition analysis and energy value of the fresh selectd lentil varieties. After knowing their nutritional profile, then the lentil was incorporated to initially trialed to prepare lentil chips.

Determination of physicochemical parameter

The physicochemical properties of the fruit in terms of moisture, ash, total soluble solids (TSS), pH and total acidity were determined as per the method mentioned by AOAC (2005). Total sugar content was determined based on the procedure of Ranganna (1995) .

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 was 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 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).

Determination of ascorbic acid content

Ascorbic acid was extracted from 0.5 g of dried fruits powder in 4.5 mL of 5% w/v aqueous solution of metaphosphoric acid containing 1% w/v dithiothreitol (DTT) method described by Cho et al. (2013) using high-performance liquid chromatography (Shimadzu SPD-M10A). The ascorbic acid content was expressed in mg/100 g dry weight (DW).

Determination 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 no. 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.

Determination 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.

Sensory evaluation

Sensory evaluation on the basis of 9-point hedonic scale of all the prepared fresh lentil varieties was done according to the method described by Joshi (2006) by taste panel. The tasting panel was consisting of 30 members. They were asked to evaluate the color, flavor, mouth feel, texture, crispiness 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

Data obtained for each analysis were expressed in duplicate as means (3 replications) ± standard deviation. Data was analyzed by One-way ANOVA with post-hoc using Turkey Multiple Comparisons Test. The significance 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 Benefits

Proximate and physicochemical characters such as moisture, ash, total acidity, pH, total sugar, carbohydrate, fat, protein and dietary fiber of the BARI Mosur (lentil) varieties are shown in Table 1.

Moisture content

The analysis of moisture content is essential to the food industry to control for the quality of the food, as well as the shelf life. Moisture determination is one of the most important and most widely used measurements in the processing and testing of foods. Since the amount of dry matter in a food is inversely related to the amount of moisture therefore it is of direct economic importance to the processor and the consumer. Pulse that contains too much water is subject to rapid deterioration from mold growth, heating, insect damage, and sprouting. In this study, an attempt has undertaken to determine the moisture content of the BARI Mosur (lentil) varieties whereas all the varieties were statistically insignificant and it remains constant value (13.40%) for the all varieties during analysis (Table 1). The highest moisture content maintained constant by drying process soon after collection from the research field whereas it was collected from the Pulse Research Center (PRC) of BARI, Ishordi, Pabna.

Ash content

The analysis of ash content in foods is simply the burning away of organic content, leaving inorganic minerals. This helps to determine the amount and type of minerals in food. It is important because the amount of minerals can determine physiochemical properties of foods, as well as retard the growth of microorganisms. The ash content of the BARI lentil varieties was statistically significantly and it ranged from 2.11-2.72 % respectively. Results show that the highest ash content was recorded as 2.72 % for the BARI Mosur (lentil) variety-6. Late harvesting of lentil may contribute to an increase in the ash content of the BARI Mosur (lentil)-6 whereas the early harvest may decrease the ash content of the lentil.

Titrable acidity

Microorganisms, including yeasts, molds, and bacteria, are sensitive to a food's pH. Very low or very high pH values prevent microbial growth. As a practical matter, no unprocessed food has a pH value

high enough to offer much preservative value. In this study, the range of the pH values were from 0.47 to 0.95% indicates that the acidity level was comparatively low due to the effect of fresh lentil. The highest acidity obtained by the BARI Mosur (lentil)-3 might be due to the formation of acid by the degradation of polysaccharides and oxidation of sugars or by the breakdown of pectic substances and uronic acid (Hummel and Okay, 1950; Iqbal et al., 2001; Hussain et al., 2008).

pH

A definition of pH is the measurement of the acidity or alkalinity of a solution, commonly measured on a scale of 0 to 14. pH 7 is considered neutral, with lower pH values (less than 7) being acidic and higher values (greater than 7) being alkaline or caustic. pH is the most common of all analytical measurements in food processing. Since it is a direct measure of acid content [H+], it clearly plays an important role in food processing. The pH value of the BARI Mosur (lentil)-3, Mosur (lentil)-6, Mosur (lentil)-7, Mosur (lentil)-8 and Mosur (lentil)-9 was identified as 6.38, 6.33, 6.29, 6.36 and 6.30 respectively (Table 1). The results indicate that the selected BARI Mosur (lentil) varieties were acedic instead of alkaline. Among the varieties, the highest pH value was recorded in BARI Mosur (lentil)-3. The highest acidity was also recorded in BARI Mosur (lentil)-3 (0.95%). It indicates that pH and acidity have a strong relationship with each other, means that if the pH of the BARI Mosur (lentil) varieties goes up, the acidity also goes up.

Total sugar

Sugar is a carbohydrate that occurs naturally in many foods. The body mostly uses carbohydrates as an energy source. Food producers also add sugar to many products, which can lead a person's blood sugar levels to become too high. Consuming excessive amounts of added sugar can have adverse health effects to raise the risk of several dangerous health problems, including obesity, type 2 diabetes, increasing pressure on the heart and blood vessels, and dental decay. Although the sugar has adverse effect but it is used as sweeteners and has important technological functions in foods, providing texture, bulk, colour and acting as preservative agents. It can be difficult to keep a healthy balance of nutrients in the food. Sugar is one of these nutrients, and the cells in the body would die without it. In this study, the total sugar content of the BARI Mosur (lentil) varieties ranged from 3.17 to 3.51 % respectively (Table1). The highest sugar content was found in BARI Mosur (lentil)-7 (3.51%) whereas the the lowest was recorded in BARI Mosur (lentil)-8 (3.17%). It indicates that there was highly correlation between the acidity and total sugar of the BARI Mosur (lentil) varieties. However, the findings strongly suggest that lower level of acidity contribute to achieve the higher level of sugar content (Table 1).

Carbohydrate

The primary role of carbohydrates is to supply energy to all cells in the body. Many cells prefer glucose as a source of energy versus other compounds like fatty acids. Some cells, such as red blood cells, are only able to produce cellular energy from glucose. The brain is also highly sensitive to low blood-glucose levels because it uses only glucose to produce energy and function (unless under extreme starvation conditions). About 70 percent of the glucose entering the body from digestion is redistributed (by the liver) back into the blood for use by other tissues. Cells that require energy remove the glucose from the blood with a transport protein in their membranes. Although there are numerous health benefits associated with eating carbohydratesbut eating too many carbohydrats can lead to health problems and unwanted weight gain and elevated blood sugar. Hence, the Dietary Guidelines for Americans recommend that carbohydrates make up 45% to 65% of total daily calories. In this study, the carbohydrate ranges of the BARI Mosur (lentil) varieties was from 31.95 to 39.95 % whereas the highest was recorded in BARI Mosur (lentil)-3. Results indicate that higher the carbohydrate content contributed to gain highefr amount of fat content (Table 1).

Crude fat

Fats enhance the taste and acceptability of foods; lipid components largely determine the texture, flavour and aroma of foods. Dietary fats provide essential fatty acids (EFA) and facilitate the absorption of lipid-soluble vitamins. The Expert Consultation agreed that there was convincing evidence that energy balance and dietary patterns are critical to maintaining healthy body weight and

ensuring optimal nutrient intakes, regardless of macronutrient distribution expressed in energy percentage. The requirement for total fat intake ranges between 20% and 35% of energy (E) (Elmadfa and Kornsteiner, 2009; FAO, 2010). In this study, the crude fat content of the BARI Mosur (lentil) varieties were significantly differed and ranged from 4.04 to 5.92 T% respectively. The fat content of the BARI Mosur (lentil)-3 showed lower amount of fat content (4.04%) whereas the highest amount was recorded in BARI Mosur (lentil)-3 (5.92%). The results indicate that higher acidity and pH influenced to attain higher amount of fat whereas the lower acidity and pH is subjected to achieve lower fat content. The higher sugar content also contributred to gain lower fat conytent in the BARI Mosur (lentil) varieties. In contrast, the high carbohydrate content in BARI Mosur (lentil)-3 contributed to obtain higher amount of fat in the analyzed sample (table 1). Thus, it can strongly be said that intake of high carbohydrate content may increase the fat content in the human body.

Protein

Proteins are the building blocks of life. Every cell in the human body contains protein. The basic structure of protein is a chain of amino acids. Our body needs dietary protein to supply amino acids for the growth and maintenance of our cells and tissues. The dietary protein requirement changes throughout life. The European Food Safety Authority (EFSA) recommends adults consume at least 0.83 g of protein per kg body weight per day (58 g/day for a 70 kg adult). Plant and animal-based proteins vary in their quality and digestibility, but this is not usually a concern for most people if their total protein meets their needs. We should aim to consume protein from a variety of sources that benefits both our health and the planets. Lentils are known to be an abundant source of protein storage, providing essential and non-essential amino acids to the human body. The predominant proteins in lentils are globulin (47% of the total seed proteins) and an adequate quantity of albumin (Lombardi-Boccia et al., 2010). High quantities of these proteins and essential amino acids in lentils offer an important dietary source for low and middle-income countries (Hoover et al., 2010). In this study, the protein content of the BARI Mosur (lentil) varieties ranged from 27.59 to 29.63 % respectively. The highest protein content was recorded in BARI Mosur (lentil)-8 whereas the lowest shown in BARI Mosur (lentil)-6. The results confirm that BARI Mosur (lentil) varieties capable to meet the daily protein requirement of all ages people.

Dietary fibre

Dietary fibres are regarded as one of the most important bioactive constituents of pulses. There are several definitions of dietary fibre some include starch polysaccharides while others do not. Tharanathan and Mahadevamma (2003) described dietary fibres as the macromolecules that cannot be digested by human endogenous enzymes and are essentially composed of plant cell wall components. According to the American Association of Cereal Chemists International (AACCI) dietary fibre is the edible part of plants and analogous carbohydrates that resist the digestion and absorption processes in the human small intestine with partial or complete fermentation in the large one (Rebello et al. 2014). In this study, the dietary fiber of the BARI Mosur (lentil) varieties ranged from 13.32 to 14.12 % respectively (Table 1). The total dietary fibre (TDF) content of different pulses (beans, chickpeas, lentils, and peas) ranged from 14 to 32 %, with SDF and IDF ranging from 0–9 and 10–28 %, respectively against 3.00–15.02, 0.86–4.33, and 2.14–10.79 %, respectively for cereals like wheat, rice and barley (Yadav et al. 2010a; Rebello et al. 2014; Duen˜as et al. 2016). However, the highest dietary fiber (14.12 %) found in the BARI Mosur (lentil)-8 whereas the lowest one was recorded in BARI Mosur (lentil)-3. It is amazing findings that there is a strong relationship between the total phenols and the dietary fiber of the BARI Mosur (lentil) varieties (Table 1 and Table 2). In this study, the higher the phenols influenced the higher amount of health benefits of dietary fibres. The pulse fibres can interact with the polyphenolic compounds present in pulses through the formation of hydrogen and hydrophobic linkages between polyphenols and cell wall components.

Table 1. Physicochemical characteristics of BARI lentil varieties.

Parameter	Lentil variety				
	BARI Mosur-3	BARI Mosur-6	BARI Mosur-7	BARI Mosur-8	BARI Mosur-9
Moisture (%)	13.40±0.01	13.40±0.01	13.40±0.01	13.40±0.01	13.40±0.01
Ash (%)	2.11±0.01e	2.72±0.02a	2.54±0.01c	2.42±0.01d	2.63±0.02b
Total acidity (%)	0.95±0.00a	0.79±0.01b	0.47±0.00e	0.70±0.00c	0.56±0.01d
pH	6.38±0.01a	6.33±0.02bc	6.29±0.02d	6.36±0.01ab	6.30±0.01cd
Total sugar (%)	3.32±0.01b	3.24±0.01c	3.51±0.00a	3.17±0.01d	3.32±0.02b
Carbohydrate (%)	39.95±0.04a	39.21±0.01b	34.71±0.01c	31.95±0.04e	32.75±0.03d
Fat (%)	5.92±0.01a	4.42±0.02d	4.04±0.03e	5.09±0.01c	5.83±0.04b
Protein (%)	27.68±0.03c	27.59±0.19c	27.85±0.05c	29.63±0.05a	28.25±0.15b
Total dietary fiber (%)	13.32±0.01e	13.49±0.01d	13.64±0.01c	14.12±0.02a	13.90±0.09b

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

Minerals profiling of the selected BARI Mosur (lentil) varieties

Minerals are the inorganic components present in foodstuff such as ash when food is cremated. Generally, two forms of minerals are present in lentils – macro and micro minerals, both play important metabolic roles in our body functioning (Reilly, 2002) and contribute to our daily diet. In this study, eleven (11) minerals were measured from the selected BARI Mosur (lentil) varieties those results are presented in Table 2 and Table 3. It can be seen that all the varieties contained significant amounts of macro minerals more or less.

Fe is an essential nutrient in the body. Almost 50% of pre-school children and pregnant women in developing countries experience iron-deficiency anaemia (Gropper et al., 2005). The Fe and Cu, participate in oxidation-reduction reactions in energy metabolism. Iron, as a constituent of hemoglobin and myoglobin, also plays a vital role in the transport of oxygen (National Research Council of USA, 1989). In this study, the BARI Mosur (lentil)-8 found superior Fe than other varieties. Zn is a major player in the creation of DNA, growth of cells, building proteins, healing damaged tissue, and supporting a healthy immune system. Low dietary zinc intake in the diet may causes several zinc deficiency problems like physical growth and development, Diarrhea, Pneumonia, malabsorption syndromes and inflammatory diseases of the bowel and so on. Studies have shown that BARI Mosur (lentil)-8 is the rich source of P, S, Fe and Zn than the other varieties (Roohani et al., 2013). Hence, the consumption of BARI Mosur (lentil)-8 in the diet may prevents iron deficiency anemia (Devergnas et al., 2004), iron being a very important mineral, which is required daily, especially for adolescents and pregnant women.

Phosphorus is a mineral that makes up 1% of a person's total body weight. It is the second most abundant mineral in the body. It is present in every cell of the body. Most of the phosphorus in the body is found in the bones and teeth. It helps to regulate the kidney function, muscle contractions, normal heartbeat and nerve signaling functions. It works with the vitamin B. In this study, the highest P, S and B were identified in the BARI Mosur (lentil)-9 as compared to other varieties. Sulfur is associated with protein foods with amino acids, such as dairy products, eggs, fish, meat, poultry and seafood. Sulfur helps these amino acids maintain their shapes so that they can perform their roles in the human body. Sulfur helps to make cells rigid, such as those that are found in the hair, nails and skin (Jacqueline and Marcus, 2013). Low boron profile has been related with poor immune function, increased risk of mortality, osteoporosis, and cognitive deterioration. High boron status revealed injury to cell and toxicity in different animals and humans (Khaliq et al., 2018). Boron has reported to show positive effects in the development and protection of liver through significant reductions of very low-density lipoprotein (VLDL) and serum triglyceride (TG) levels (Basoglu et al., 2002). Cu and Mn found seuperior in the BARI Mosur (lentil)-3 whereas Ca and Mg found superior in the BARI Mosur (lentil)-6 as compared to others. K and P found superior in the BARI Mosur (lentil)-7 than the other varieties. Magnesium is an important for maintaining a healthy heartbeat. It naturally competes with

calcium, which is essential for generating heart contractions. It is also essential for absorption and metabolism of vitamin D and Ca. However, all the selected varieties of BARI Mosur (lentil) were a rich source of essential minerals that may provide health beneficial effect for human health (National Research Council of USA, 1989).

Table 2. Ca, Mg, K, Na, P and S of the selected BARI Lentil varieties

Parameter	BARI Mosur (lentil) varieties				
	BARI Mosur-3	BARI Mosur-6	BARI Mosur-7	BARI Mosur-8	BARI Mosur-9
Ca (%)	3.34±0.02c	3.55±0.02a	3.18±0.02d	3.45±0.03b	2.85±0.02e
Mg (%)	1.04±0.03bc	1.11±0.03a	0.98±0.02c	1.07±0.02ab	0.85±0.02d
K (%)	0.94±0.02d	1.02±0.02bc	1.14±0.04a	1.07±0.03ab	0.99±0.01cd
Na (%)	0.16±0.01	0.16±0.01	0.15±0.01	0.16±0.01	0.51±0.01
P (%)	0.30±0.02b	0.30±0.02b	0.43±0.02a	0.39±0.02a	0.37±0.02a
S (%)	0.02±0.00b	0.01±0.00b	0.03±0.00b	0.13±0.01a	0.12±0.02a

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

Table 3. Cu, Fe, Mn, Zn and B of the selected BARI Lentil varieties

Parameter	BARI Mosur (lentil) varieties				
	BARI Mosur-3	BARI Mosur-6	BARI Mosur-7	BARI Mosur-8	BARI Mosur-9
Cu (ppm)	13.80±0.10a	13.50±0.36a	11.30±0.10b	11.20±0.02b	10.20±0.04c
Fe (ppm)	199.00±2.00b	201.00±4.00b	160.00±5.00c	267.00±2.00a	169.00±4.00c
Mn (ppm)	7.79±0.02a	7.74±0.02a	7.63±0.06b	6.68±0.02d	7.53±0.02c
Zn (ppm)	20.50±0.20c	13.20±0.30e	15.20±0.07d	43.50±0.36a	27.00±1.00b
B (ppm)	17.00±2.00c	30.00±3.00b	20.00±1.00c	18.00±1.00c	40.00±1.00a

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

Phytochemical properties of the selected BARI Mosur (lentil) varieties

Phytochemicals or bioactive compounds e.g. ascorbic acid, β-carotene, anthocyanin, total phenol and lycopene, naturally exist in foodstuffs including fruits, vegetables, herbs, legumes, lentil and spices (Tiburski et al., 2011). These components supposed to have the ability to lower the prevalence of different degenerative diseases such as cancer, heart attack, and cardiovascular disease etc. by terminating the free radical's activity (Wang et al., 2010). Literature supports that stages of fruit maturity, cultural practice and processing technique are directly influenced these phytochemicals (Tiburski et al., 2011). Various bioactive compounds or secondary metabolites like ascorbic acid, β-carotene, anthocyanin, total phenol and lycopene are detected in the BARI lentil varieties, which are listed in Table 4.

Ascorbic acid

Studies evidenced that ascorbic acid is considered as the most powerful antioxidants in foodstuffs whose regular intake lowers the cancer risks in the human body (Almeida et al., 2011). However, ascorbic acid is also 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. (Mondal et al., 2017). Therefore, the indication of nutrient loss in foodstuffs is evaluated through the containment of its ascorbic acid. Interestingly, the ascorbic acid content of the BARI Masur varieties ranged from 2.71±0.03 to 4.52±0.04 mg/100g while the highest amount of ascorbic acid was found in BARI Masur-9 (Table 4). The ascorbic acid content of raw, sprouted and cooked Chinese lentils was reported by Ganesun and Baijun (2017) as 3.40-4.50 mg/100 g, 12.70-16.50 mg/100 g and 1.50-3.00 mg/100 g. Here it is noteworthy that the results obtained by BARI Mosur (fresh lentil) varieties are almost similar to the findings of the Chinese fresh lentil variety. According to Jukes (1974), the RDA of vitamin C, i.e. ascorbic acid to prevent scurvy for adults is about 10 mg, which indicates that the current study from the BARI Mosur (lentil) varieties found a higher amount of ascorbic acid that can

prevent scurvy adequately with daily consumption of 100 g of lentil. In comparison variety to variety, BARI Mosur (lentil)-8 (3.62±0.02 mg/100 g) and BARI Mosur (lentil)-9 (3.62±0.02 mg/100 g) was found higest amount of ascorbic acid than other varieties.

β-carotene

Carotenoid has a crucial part in human nutrition and health, which can lessen the risks of cancer and heart diseases because of the activity of pro-vitamin A (Tiburski et al., 2011). β-carotene is the main safe dietary source of vitamin A. It is essential for normal growth and development, immune system functioning and vision (Liji and Dibakar, 2015). The results obtained by the study suggest that BARI Mosur (lentil) varieties is the rich source of total β-carotene content where it ranged from 32.24±0.02 mg/100 g to 64.65±0.05 mg/100 g respectively (Table 4). In comparison variety to variety, BARI Mosur (lentil)-8 possessed superior amount of β-carotene content (64.65±0.05 mg/100 g) than other varieties. The β-carotene content of raw, sprouted and cooked Chinese lentils was reported by Ganesun and Baijun (2017) as 2.00-2.50 mg/100 g, 1.80-2.00 mg/100 g and 0.00 mg/100 g. It is remarkable that the β-carotene content obtained from the BARI Mosur (fresh lentil) varieties were 15-30 folds higher than the findings of the Chinese fresh lentil variety. Molla et al. (2020) reported that the β-carotene content of the BARI mango-4, BARI mango-6 and commercial cultivar Langra were recorded as 28.17±0.03 mg/100 g, 65.84±0.04 mg/100 g and 31.00±0.90 mg/100 g respectively (Molla et al., 2020). It is seen that the results obtained by the BARI lentil varieties are fully agreement with the findings of Molla et al. (2020).

Total phenol

Polyphenol-rich lentils have potential health benefits as complementary and alternative medicines, which are exerted in the form of antioxidant, antibacterial, anti-fungal, antiviral, cardioprotective, anti-inflammatory, nephroprotective, antidiabetic, anticancer, anti-obesity, hypolipidemic and chemopreventive. Total phenol of the BARI selected five lentil varieties e.g. BARI Mosur-3, BARI Mosur-6, BARI Mosur-7, BARI Mosur-8 and BARI Mosur-9 were recorded as 4.28±0.04 mg GAE/100g, 4.69±0.06 mg GAE/100g, 5.44±0.04 mg GAE/100g, 11.65±0.10 mg GAE/100g and 7.87±0.07 mg GAE/100g respectively (Table 4). Results revealed that BARI Mosur-8 had the highest total phenolic content in comparison to other BARI Mosur varieties. The lower phenolic content was recorded for the BARI Mosur-3 as compared to others. This might be due to the effect of varietal characteristics, maturity, time of harvest, soil and field nutrient management practices during the release of variety. The total phenolic content of the different millets e.g. foxtail millet, proso millet, pearl millet and finger millet was calculated as 81.0 mg GAE/100g, 40.1 mg GAE/100g, 147.80 mg GAE/100g and 62.05 mg GAE/100 g respectively. The phenolic content from this study reported here show that lentil (Mosur) varieties contained lower content of total phenols in comparison with millets, rice, wheat and maize (McDough et al., 2000). Other study by Goufu and Trinidade (2014) reported that the millet contains (40.10-147.80 mg GAE/100 g) higher content of total phenolic content than rice (37.60-144.50 mg GAE/100 g) and maize (60.10-164.30 mg GAE/100 g) but not from wheat (134.20-187.30 mg GAE/100 g) (Molla, 2016). However, these findings suggest that millets, rice, maize and wheat are phenols superior to the widely promoted lentils.

Anthocyanin

One of the important bioactive compounds existent in foodstuffs is the anthocyanin. Previous research supported that this compound showed potent antioxidant capacity. The anthocyanin content of the BARI lentil (Mosur) varieties were significantly differed and ranged from 0.26±0.04 to 0.65±0.05 mg/100g (Table 4). The study on fresh five lentil varieties showed that BARI Mosur (lentil)-9 found superior anthocyamnin content as compared to otrher varieties. Total anthocyanin content of the Cherry cultivars was recorded by Chaovanalikit and Wrolstad (2004), those reported that the edible portion of cultivar Royan Ann and Rainier was 0.5 mg/100 g and 0.5 mg/100 g respectively. This value is well supported with our present findings. But the anthocyanin content of the edible portion (skin plus flesh) was highest for Bing cherries (29.7 mg/100 g) and Montmorency (8.7 mg/100 g) followed by cultivar Royan Ann and Rainier. There can be considerable variation in pigment content from variety to variety, soil type and their nutrient management during cultivation. In case of soybean

cultivars, the anthocyanin content of fresh China Black Soybean varieties of Dongbeichun, Beifangchun and Nanfangchun were recorded as 98, 10 and 83 mg/100 g respectively (Astadi et al. 2009 and Xu et al., 2010). The result indicates that soybean is the rich sourch of anthocyanin than the selected lentil varieties.

Lycopene

Lycopene is a naturally occuring red carotenoid pigment that is responsible in red to pink colors seen in tomatoes, pink grapefruit, and other foods (Story et al., 2010). It may undergo extensive isomerization that allows 1056 theoretical cis-trans configurations; however, the all-trans configuration of lycopene is the most predominant isomer found in foods (Story et al., 2010; Shi and Maguer, 2000) that give the red hue. Lycopene is a non-essential human nutrient that is classified as a non-provitamin A carotenoid pigment since it lacks a terminal beta ionone ring (Story et al., 2010) and does not mediate vitamin A activity. However, it is a potent antioxidant molecule that scavenges reactive oxygen species (ROS) singlet oxygen. From the antioxidant point of view, the selected BARI Mosur (lentil) varieties were studied where it shows that the BARI Mosur varieties ranged from 0.07-0.57 mg/100 g respectively (Table 4). All the varieties were statistically significant but the variety BARI Mosur-3 possessed hihest amount of lycopene although the BARI Mosur-3 and BARI Mosur-6 was statistically non-significant.

Table 4. Phytochemical compositions of BARI lentil varieties.

Parameter	Lentil variety				
	BARI Mosur-3	BARI Mosur-6	BARI Mosur-7	BARI Mosur-8	BARI Mosur-9
Ascorbic acid (mg/100 g)	2.73±0.02c	2.71±0.03c	2.72±0.03c	3.62±0.02b	4.52±0.04a
β-carotene (mg/100g)	56.14±0.01b	32.24±0.02e	33.54±0.06d	64.65±0.05a	53.16±0.04c
Anthocyanin (mg/100g)	0.41±0.02b	0.57±0.03a	0.26±0.04c	0.30±0.05c	0.65±0.05a
Total Phenol (mg GAE/100g)	4.28±0.04e	4.69±0.06d	5.44±0.04c	11.65±0.10a	7.87±0.07b
Lycopene (mg/100 g)	0.57±0.03a	0.56±0.04a	0.42±0.02b	0.16±0.04c	0.07±0.03d

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

Energy

Energy is essential for rest, activity, growth, and maintenance of sound health. Its content is of concern to health-conscious consumers (Liji and Dibakar, 2015). The energy content of the BARI Mosur (lentil)-3, BARI Mosur (lentil)-6, BARI Mosur (lentil)-7, BARI Mosur (lentil)-8 and BARI Mosur (lentil)-9 varieties were estimated as 8.59±0.02 Kcal/g, 7.96±0.04 Kcal/g, 8.24±0.04 Kcal/g, 7.78±0.02 Kcal/g and 8.21±0.02 Kcal/g respectively (Table 5). The results show that all the varieties were statistically highly significant in the calorific value of whereas the highest energy content (8.59±0.02 Kcal/g1) found in BARI Masur (lentil)-3 and the lowest was recorded as 7.78±0.02 Kcal/g in BARI Mosur-8.

Table 5. Energy of selected BARI Mosur (lentil) varieties

Parameter	Lentil variety				
	BARI Mosur-3	BARI Mosur-6	BARI Mosur-7	BARI Mosur-8	BARI Mosur-9
Energy (Kcal/g)	8.59±0.02a	7.96±0.04c	8.24±0.04b	7.78±0.02d	8.21±0.02b

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

Conclusion

Selected BARI Mosur (lentil) varieties have been collected from the PRC, BARI, Ishordi, Pubna. All the varieties incorporated for its analysis of physicochemical properties, minerals profiling, phytochemical compositions and energy value. Amino acid compositions, vitamins profile, anti-nutritional factors, protein fractions, phytic acid profie and phenolic acids profile analysis are going on. Results indicate that all the selected BARI Mosur (lentil) varieties were rich source of nutrition, minerals and bioactive compounds. BARI Mosur-3 and BARI Mosur-6 is the lycopene rich. BARI Mosur-3 is the superior of energy value. BARI Mosur-8 is the rich source of β–carotene, total phenol, Fe and Zn. BARI Mosur-9 is the rich source of anthocyanin and ascorbic acid.

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EFFECT OF MOISTURE CONTENT ON THE PROCESSING AND QUALITY OF BARI MOSUR (LENTIL) CHIPS USING SINGLE SCREW EXTRUDER

M.M. MOLLA, M.H.H. KHAN, A.A. SABUZ, M.G.F. CHOWDHURY, S. PERVIN, M.S. ZAMAN, R. PODDER AND P. BHOWMIK

Abstract

The study was conducted to develop lentil chips through find out the proper moisture level and barrel temperature of the single screw extruder. The single screw extruder was installed successfully in the postharvest Technology Division of BARI. The initial trial has been conducted to develop lentil chips. The trialed product has been sensory evaluated by the formation of judgment panel. The initially produced product has been packed in to metalex and polypropylene pouches for storage studies under the room temperature. Results show that the uncontrolled moisture content increases the barrel temperature and pressure of the single screw extruder. The increased barrel temperature (more than 100^{o}C) reduces the feed rate and finally burn the product. However, the moisture level 10% (T_1) and 20% (T_2) assisted to produce the quality product initially.

Key words: moisture level, barrel temperature, barrel pressure, product quality

Introduction

Extrusion is a thermal processing that involves the application of high heat, high pressure, and shear forces to an uncooked mass, such as cereal foods (Kim et al., 2006). Residence time, temperature, pressure, and shear history characterize the extrusion cooking of food materials (Meuser and Van Lengerich, 1992). It is an emerging technology for the food industries to process and market a large number of products of varying size, shape, texture, and taste. It is becoming popular over other common processing methods due to its low capital cost, feasible process to produce non-fried (without oil) products, automated control, high capacity and high productivity. During extrusion, high temperature and large shearing forces cause disintegration of the product. Both shear and thermal fields in a single screw extruder affect the fragmentation of the product at higher temperatures and lower moisture level. As the proper temperature and moisture level information is meager for producing lentil extruded products, hence the present study has undertaken to fulfill the above objectives.

(i) To determine the proper moisture level for producing quality and economically feasible extruded lentil chips.
(ii) To study the physical, chemical and nutritional changes of the lentil chips during processing and after storage.
(iii) To give the detailed outline about the potential of lentil chips.

Treatments

T_1= 10 % moisture content
T_2= 20 % moisture content
T_3= 30 % moisture content
T_4= 40 % moisture content

Results and discussion

Moisture content and barrel temperature influenced the quality of lentil chips. Hence, it was subjected to evaluate the moisture content and barrel temperature. The barrel temperature could be minimized by lowering the moisture content and increasing the higher feed rate.

Effect of moisture and temperature on the quality of lentil chips

Fig. 1 shows the variations of apparent moisture and temperature on the quality of lentil chips. Higher moisture content increased the barrel temperature of the single screw extruder. Elevated moisture content increased the barrel temperature. The increase of extrusion temperature decreases melt viscosity, which would favor the bubble growth during extrusion (Mercier et al., 1989). Furthermore,

the degree of superheating water in the extruder would increase at higher temperatures leading to greater expansion, which was observed in this work. A well expanded product will have low apparent density. Extrusion feed rate influences the degree of fill in the extruder barrel. The increased feed rate elevates the final viscosity of the product.

Feed moisture content and material ratio affected significantly apparent density and expansion ratio. This trend could reflect its influence on elasticity characteristics of the starch-based material (Ding et al., 2005). The increase in feed moisture content would change the macromolecular structure of the extruded melt reducing the melt elasticity thus decreasing the expansion and favoring the formation of more compact extrudates. The incorporation of lentil flour in the mixture led to products with increased density. Lentil flour is rich in proteins. So the increase in density could be related to the increased protein content of the extrudates. There are several studies supporting this observation (Anton et al., 2009; Bhattacharya, 1997; Onwulata et al., 2001; Sun and Muthukumarappan, 2002). The increase in extrusion temperature decreased modulus of elasticity. At elevated levels of extrusion temperatures, the produced extrudates become more expanded, as indicated above. A well expanded extrudate has soft texture and thinner cell walls than a denser product and less expanded product. The reduction of stiffness of extruded snacks with temperature has been reported for corn, wheat and rice based extrudates (Bhattacharya, 1997; Ding et al., 2005; Ryu and Ng, 2001). Moreover, the chips color and crispiness performed good than other treatments but not T_2. The chips have more swelled with its better color and crispiness. The chips have turned to little dark color and less crispiness. The barrel temperature has increased due to the flour adhesive in the barrel. The product could not outlet through the barrel due to increasing barrel temperature owing to their more adhesive. Hence the product has burned and the color showed dark color.

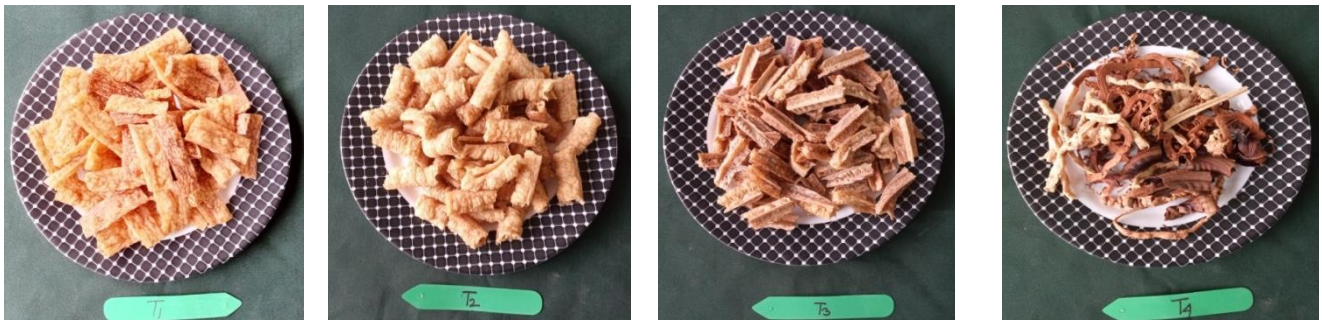

Fig.1. Effect of moisture content on the quality of lentil chips.

Storage studies

The initial trialed product has been packed into polypropylene (PP) pouches and then it stored for crispiness and storage studies. Results revealed that the trialed chips were crispiness up to 3 months of stoage. But the storage studies are going on.

Fig.2. Trialed lentil chips after 3 months of stoarge

Sensory evaluation

The score obtained for $T_1$and T_2 by the expert judgment in terms of color, flavor, texture, mouthfeel, crispiness and overall acceptability was higher than others (Table 1). The highest crispiness (8.10) score was found in the treatment T_1, while the lowest (6.20) score was obtained by the treatment T_4. Most of the expert panelists concluded that the treatment T_4 possessed low color, flavor, texture, mouthfeel, crispiness and overall acceptability, indicate theat higher moisture content influenced to increase the barrel temperature and low feed rate. Hence, T_4 was not liked by the panel of judges. On the other hand, the low moisture content contributed to achieved higher feed rate and minimize the barrel temperature. Temperature ranged from 90-95^{o}C contributed to produce high feed rate and quality of chips. But the temperature increased more than 100^{o}C responsible to gain low feed rate and high barrel temperature. The increased barrel temperature of the single screw extruder burned the product and low colr and quality of chips (T_4). However, the moisture content 10% (T_1) and 20% (T_2) produced the quality chips than the other moisture level and it was accepted by the consumers.

Table 1. Sensory evaluation of lentil chips at on the day of preparation

Treatment	Color	Flavor	Texture	Mouthfeel	Crispiness	Overall acceptability
T_1	8.38±0.32^a	8.20±1.03^a	8.30±0.95^a	8.40±0.52^a	8.10±0.96^a	8.19±0.38^a
T_2	8.00±0.66^a	7.70±0.48^{ab}	8.10±0.56^a	7.50±0.53^b	7.90±0.56^a	7.84±0.27^a
T_3	5.43±0.814^b	6.80±1.03^b	6.60±0.96^b	6.50±0.97^c	7.70±1.63^a	6.30±0.63^b
T_4	5.10±0.0.99^b	5.20±1.03^c	4.90±1.19^c	5.30±0.82^d	6.20±1.03^b	5.72±0.66^c

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

Conclusion

Initial products have been trialed using existing single screw extruder and compared to maize (pocorn) chips. The trial confirms that barrel temperature, pressure and moisture content should be fixed by more and more trials. The initial product was very amazing as it's free of oil and sugar. Further trials should be continued to fix the moisture level and barrel temperature.

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The research was conducted by the financial assistance provided by the Krishi Gobena Foundation, BARC, Bangladesh and Global Institute of Food Security (GIFS), Canada under the project entitled 'Development of a novel technique to fortify lentils with multiple vitamins and minerals using hot extrusion technology (HET) in global and domestic markets', Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701.

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EFFECT OF VEGETABLE POMACE ON THE FORMULATION OF PROBIOTIC PICKLE

M.M. MOLLA, S. PERVIN, A.A. SABUZ, M.G.F. CHOWDHURY, M.H.H. KHAN

Abstract

The present Investigation was carried out to assess the lactic acid bacteria during fermentation of the selected vegetables and after fermentation, to develop probiotic pickle using the fermented vegetables. The sauerkraut method and three acidic media viz. lactic acid, glacial acetic acid and apple cider vinegar was used to ferment the vegetables. The 5.00% acidic media was used to ferment the vegetables. After pre-processing, all the vegetables were fermented and the relevant data was recorded at on the day of fermentation and after 30 days of interval during fermentation. Results revealed that the TSS, total acid and pH values were increased with the advancement of fermentation periods. The vitamin-C content was decreased dramatically with increasing fermentation time. But the highest vitamin-C values were retained by the apple cider vinegar due to its pH value maintained at lower than 5.00. The study will be continued for its application to produce probiotic bacteria enriched vegetable pickles.

Key words: Fermentation, Vitamin-C, TSS, Acidity, pH and Probiotic bacteria

Introduction

Fermentation has been used as a simple, economical, and effective food preservation process since ancient times (Joshi and Sharma, 2009; Kabak and Dobson, 2011; Hunaefi et al., 2013). Some significant advantages of fermentation include: (1) increasing acidity and pH reduction with the production of organic acids, such as lactic acid by lactic acid bacteria (LAB) and (2) enhancing nutrition, organoleptic, and shelf life properties of foods through by-product (e.g. lactic acids, acetic acids and other volatiles) formation (Joshi and Sharma, 2009; Hunaefi et al., 2013), and synthesizing essential amino acids and many vitamins (Kabak and Dobson, 2011) by either useful bacteria, such as lactic acid bacteria or beneficial yeasts, or both (Food and Agriculture Organization, 1998).

Various fermented foods are consumed in the world, such as fermented dairy, meats, cereal, and vegetable products. Fermented dairy and meat products are more commonly produced and consumed when compared to fermented vegetables, and they have a better commercial market than fermented vegetables (Cetin, 2011). Fermented vegetables however, are processed at home using locally grown vegetables (Cetin, 2011). Hence, fermented vegetables will have better marketability in the local food movement as alternative nutritional sources. Traditional fermented foods have been consumed since ancient times. Besides foods such as fermented dairy, meat and cereal products, fermented vegetables are part of food culture in homes throughout the world (Swain et al., 2014). However, the renewed interest in fermented foods is mainly based on nutrition, health and wellness attributed to fermented foods, in addition to their role in increasing the shelf-life of food products by bio-preservation (Martins et al., 2013; Swain et al., 2014). Consumption of foods with probiotics, including fermented products, is increasing world-wide because of the potential health benefits and nutrient composition (Martins et al., 2013). Many studies have shown that fermentation can improve the nutritional value of the foods.

Probiotics are evolved with the increasing interest in the use of viable bacterial supplements and in relation to the progress made in understanding their mechanisms of action. There is increasing evidence in favor of the claims of beneficial effects attributed to probiotics, including improvement of intestinal health, enhancement of the immune response, reduction of serum cholesterol and cancer prevention. These health properties are strain specific and are impacted by the various mechanisms. Some of health benefits are well documented like in the treatment of acute diarrhea diseases, prevention of antibiotic-associated diarrohea and improvement of lactose metabolism.

Fresh vegetables can be preserved using various fermentation methods: (a) Fermentation with dry salting, where vegetables are subjected 2 to 3% salt addition (w/w), such as sauerkraut, (b) fermentation in brine, where vegetables are subjected to brine (i.e. high content of salt dissolved in water), such as dill pickles, and (c) non-salting fermentation, such as gundruk, which is a cauliflower

and cabbage leaves non-salted fermented product (Swain et al., 2014). In this study, the sauerkraut fermentation method has been used for fermentation of the selected vegetables. Sauerkraut produced from Brassica vegetables is a popular natural fermented vegetable in the world, both traditionally and commercially. Sauerkraut is produced from shredded and salted white cabbage via spontaneous fermentation by various lactic acid bacteria present on white cabbage leaves (Kalac et al., 2000; Hunaefi et al., 2013).

In this study, cauliflower, cabbage and carrots are chosen for several reasons, including the availability of fermentable sugar, and they can be locally grown. Carrot is a common root vegetable consumed both raw and cooked. Carrot is high in ß-carotene content, which is an antioxidant (Aizawa and Inakuma, 2007; Arslan and Ozel, 2012), a precursor of vitamin A (Deming et al., 2000) and rich in carbohydrates, vitamins (such as A, B1, B2, C, E, thiamin and riboflavin) and minerals (such as calcium, phosphorus, iron, potassium) (Arslan and Ozel, 2012). Besides being rich in nutrients, carrot has other important benefits, such as sweetening, diuretic and antianemic properties (Joshi et al., 2008). Cabbage and cauliflower is the preferred vegetable for lactic acid fermentation due to its high fermentable sugar content. Recent literature has limited information about vegetables fermented and their probiotic pickles. Therefore, the aim of this present study was to grow lactic acid bacteria through fermentation of the selected vegetables and after fermentation, to develop probiotic pickle using the fermented vegetables.

Materials and methods

Vegetables and other materials

Cauliflower, cabbage and carrot were collected from the farmers' field of Marta, Sreepur, Gazipur, Bangladesh. All the vegetables were harvested in the morning and then it shifted to the pre-cooling room of the Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh. After pre-cooling, all the vegetables were sorted and graded according to the unexpected leaves and card, pest and disease infestation. Then the vegetables were treated according to the following treatments for the fermentation and storage. During treatments, 5% acidic value was used for each treatment. All the treatments were replicated three times. The experiment was design in Complete Randomized Design (CRD). In the experiment, the fermentation lids were tight strongly to maintain anaerobic conditions during fermentation.

Preparation of vegetables for fermentation

Selected vegetables were fermented spontaneously using sauerkraut method (Viander et al., 2003; Thakur and Kabir, 2015). The vegetables were washed with distilled water and the outer leaves of the cabbage and cauliflower were removed. Carrots were peeled after washing. Cabbage was cut into 2-3 mm thick strips (Hunaefi et al., 2013), while peeled carrot was cut into angular size. Pickling salt (6% by weight) was mixed with the mass of vegetable based on the traditional sauerkraut-making method (Viander et al., 2003; Thakur and Kabir, 2015). The grated vegetables were packed into pre-sterilized plastic jars and pressed until brine was observed on the surface of the packed vegetable. After packing, lids containing fermentation locks were placed tightly on the jars. Vegetables were fermented naturally at room temperature (21-24^{o} C) for 14 days. Samples were analyzed at on the day of fermentation and at 30 days of interval to perform physicochemical and nutritional analysis.

Treatments

T_1= Lactic acid fermentation
T_2= Acetic acid fermentation
T_3= Apple cider vinegar fermentation

Results and discussion

pH

The pH value is one of the most important physicochemical characteristics of lactic acid fermentations. On the day of fermentation, the pH values of all the acidic media was recorded as 3.45, 3.74 and 2.98 respectively. After 90 days of fermentation, the pH levels of all the acidic media was

found 4.45, 4.34 and 4.45 respectively. Results show that the pH value was gradually increased up to the 90 days of fermentation. Viander et al. (2003) similarly reported the pH values (4.0-4.3) after 6 days of fermentation of white cabbage, which was subjected to two different salt and mineral salt concentrations. Likewise, Hunaefi et al. (2013) observed pH values of approximately 4.3 and 3.8 in red cabbage that was fermented using 1.5% NaCl of natural or inoculated lactic acid bacteria fermentation for 7 days. However, the results obtained from this study are strongly supported by the findings of Viander et al. (2003) and Hunaefi et al. (2013).

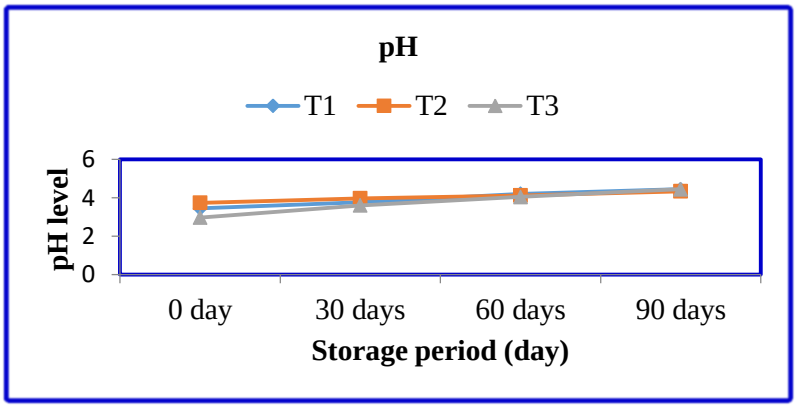

Fig.1. The changes of pH values in fermented vegetables during different storage periods

Total acid

Total acid is another important criterion to understand the impact of lactic acid fermentation. When total acid increases during the fermentation period, indicates that lactic acid bacteria are grown and utilized sugars in plant materials to produce primarily lactic acid and other by-products. Total acid at the beginning of fermentation were recorded as 0.16%, 0.38% and 0.13% respectively but after the entire the fermentation period, the acid was calculated as 0.23%, 0.51% and 0.45% respectively (Fig.2). Results obtained from the study indicate that the total acid was increased with the advancement of fermentation periods (Fig.2). The changes of total acid values in fermented vegetables during fermentation periods are well noted in the Fig.2. The values of means were presented with bars of standard errors. Among all the acidic media, the glacial acetic acid contributed to gain maximum amount of total acid level than other acids. In this study, the total acid was analyzed and maximum was found 99.49% in glacial acetic acid (T_2). Total acid value was recorded as 51.20 % and 3.58% by the lactic acid bacteria (T_1) and apple cider vinegar (T_3). The maximum acid value obtained by the glacial acetic acid might be due to its purity (99.50%-99.99%) mentioned by the manufacturer.

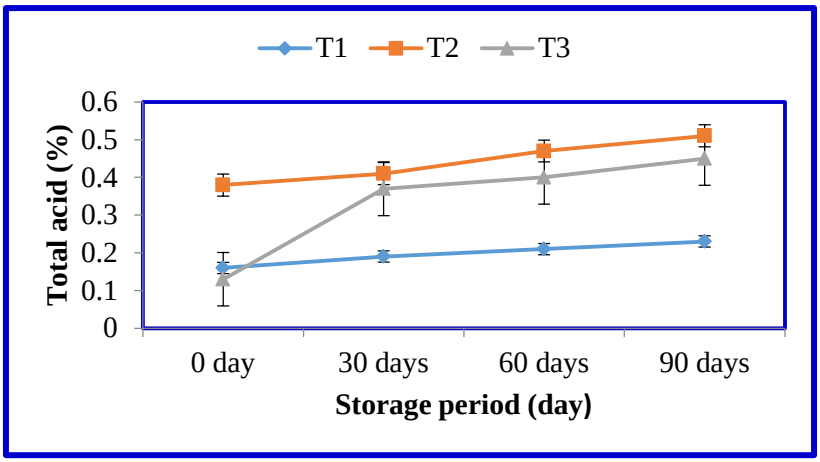

Fig.2. The changes of total acid values in fermented vegetables during different storage periods

TSS (Brix) Value

TSS values of the fresh vegetables (on the day of storage) at the beginning of fermentation were recorded as 5.20 (^{o}B), 6.5 (^{o}B) and 6.2 (^{o}B). After 30 days of fermentation, all the TSS value was increased and this increasing nature continued up to entire the fermentation periods (90 days). Among the all acids medium, the highest TSS was recorded by the lactic acid media where it contributed to dramatically changed the TSS content than other acids, although all the acidic media donated to increase the TSS value during the fermentation time. Results suggest that the TSS value increased with the advancement of storage periods (Fig.3). The increase in TSS values might be related to the soluble solids. Fermented vegetables with added salt, as a result of their increased surface area, facilitate lactic acid bacteria growth and water extraction, compared with whole or larger pieces of vegetables. Thus, TSS values increase rapidly due to the increase in the soluble solids removal in the fermented vegetables. The soluble solids are formed by the addition of salt and any soluble materials that leach from the vegetables during fermentation. Small reductions in soluble solids in the brine during the later fermentation days' lead to reduced TSS values. Joshi and Sharma (2009) also observed an increase in TSS value of fermented vegetables up to 8 days of fermentation.

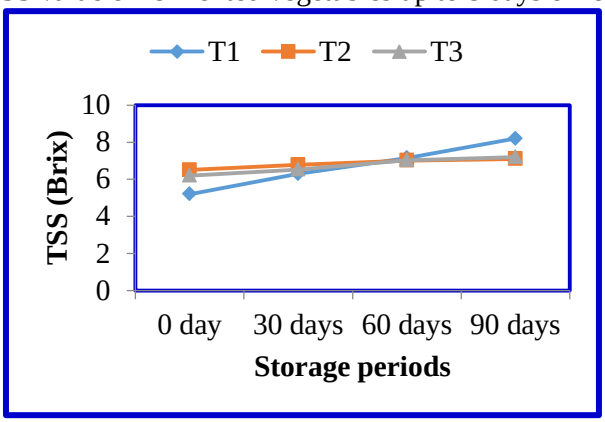

Fig.3. The changes of TSS values in fermented vegetables during different storage periods

Vitamin-C content

Before fermentation (0 day; on the day of preparation) and after fermentation, the vitamin-C content of the vegetables are presented in Fig. 4. The results show that the highest vitamin-C content was recorded as 10.86 mg/100 g, 9.05 mg/100 g and 13.58 mg/100 g by the fermentation medium lactic acid, glacial acetic acid and apple cider vinegar at on the day of preparation. Vitamin-C values of the all fermented vegetables by the all acids medium decreased significantly ($p < 0.05$) entire the fermentation periods (Fig.4). Among all the acids, the vegetables fermented by the apple cider vinegar retained more vitamin-C content than other acids. The retained in more vitamin-C values by the

fermentation media apple cider vinegar might be related to the pH. The highest pH value but lower than 5.00 may be contributed to retain maximum vitamin-C content by the apple cider vinegar. The results are strongly supported by the Gunsalus and Niven (1948), those reported that pH value lower than 5.00 may increase the efficient fermentation and vitamin-C value of the fermented vegetables.

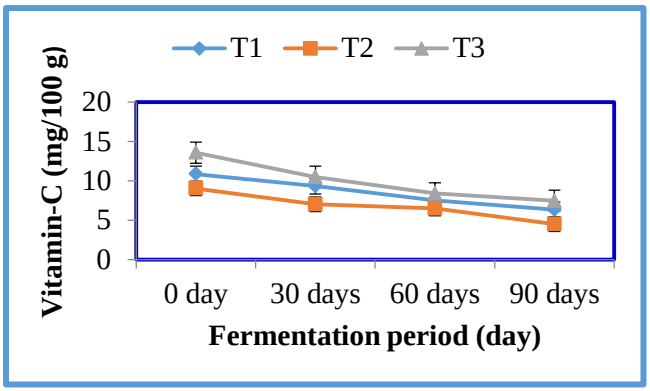

Fig.4. The changes of vitamin-C value in fermented vegetables during different storage periods

TSS, pH, Acidity and Vitamin-C content of the different acids used during fermentation

TSS, pH, Acidity and Vitamin-C content of the different acids were recorded during fermentation and are presented in Table 1. Highest TSS (50.00±3.00) was recorded in lactic acid solution as compared to other acids. Maximum pH value was found in the apple cider vinegar. In addition to acetic acid, apple cider vinegar may also contain a small amount of malic acid and citric acid. That is why the highest pH value of apple cider vinegar was recorded in the sample than the other acids which is considered mildly acidic. Highest acidity (99.49%) value was found in glacial acetic whereas the least was recorded as 3.52 % in apple cider vinegar. These results are supported by the vinegar definition where it contains 4-6% of acetic aqueous solution. It is very interesting findings that the apple cider vinegar contains higher amount of vitamin-C content than others. The reason might be due to accumulation of acetic acid, malic acid and citric acid in the apple cider vinegar. Gunsalus and Niven (1948) reported that the efficient fermentation is achieved within the limiting of pH value 5.00 or lower than pH value 5.00. In this study, the results confirm that the highest pH value 2.98 was recorded by the apple cider vinegar that may be contributed to increase the rate of fermentation. The increased fermentation by the apple cider vinegar thus may be contributed to achieve highest amount of vitamin-C content than other acids during fermentation.

Table 1. TSS, pH, Acidity and Vitamin-C content of the different acids during fermentation

Parameter	**Different acids**		
	Lactic acid	Glacial acetic acid	Apple cider vinegar
TSS (Brix)	50.00±3.00a	24.20±0.20b	6.20±0.20c
pH	0.42±0.02c	0.89±0.02b	2.98±0.02a
Acidity (%)	51.20±0.20b	99.49±0.85a	3.58±0.02c
Vitamin-C (mg/100 g)	0.95±0.05c	1.81±0.02b	4.53±0.03a

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

Color Value

The L, a, and b values were recorded from day 0 to day 90 days at an interval of 30 days (Table 2). Fermented cauliflower, cabbage and carrot color values were significantly changed over the storage periods ($p < 0.05$) during fermentation (Table 21). The color difference is an indicator of color stability of fermented food products, where lower color difference values suggest better color stability. Among all the fermented vegetables, color changes were least during fermentation, although the change in color values of these samples was significantly differed. Lactic acid, acetic acid and

apple cider vinegar fermentation takes place under anaerobic conditions; thus, oxygen availability was limited and may be this is the reason to change minimum color during fermentation (Lee, 1997).

Table 2. The changes in color of the vegetables during fermentation

Fermentation period (day)	**L**			**a***			**b***		
	Cauli flower	Cabb age	Carrot	Cauli flower	Cabb age	Carrot	Cauli flower	Cabb age	Carrot
0	75.85± 2.79a	79.18± 1.14a	53.33± 3.50b	0.66± 0.06b	0.97± 0.04b	36.34 ±0.28a	22.78± 0.25b	17.48± 0.07c	47.49± 0.10a
30	75.79± 2.71a	79.17± 0.14a	53.31± 3.51b	0.65± 0.03b	0.96± 0.04b	36.33 ±0.24a	22.76± 0.29b	17.46± 0.02c	47.47± 0.10a
60	75.78± 2.7a	79.13± 0.15a	53.29± 3.51b	0.64± 0.05b	0.95± 0.05b	36.31 ±0.21a	22.74± 0.26b	17.44± 0.05v	47.45± 0.10a
90	75.74± 2.79a	79.10± 0.15a	53.27± 3.51b	0.62± 0.04b	0.93± 0.05b	36.29 ±0.28a	22.76± 0.26b	17.42± 0.04c	47.43± 0.10a

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

Conclusion

Market demand for fermented vegetables, as with other fermented products, has increased due to their rich nutritional properties, better organoleptic characteristics, and for being safe products and a source of probiotics. These fermentation benefits make the fermented vegetables ideal candidates as alternative nutritional food sources both at home and, potentially, at commercial scale by the local food movement participants. The results from this study, show that the natural fermentation of vegetables can be completed in either 7 days or 14 days based on the observed physicochemical characteristics of vegetables. More research is needed to compare dry-salting methods. The use of a fermentation weight might be useful to prevent the growth of surface mold in dry-salted carrot, and it also may improve the surface color of dry-salted vegetables, because the weight forces the vegetables under the brine surface. Fermented vegetables, particularly produced through the dry-salting method, can be used as alternative fermented food products in the daily diet, especially because they can be produced easily at home.

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COMPARATIVE STUDY OF DOMESTIC AND INTERNATIONALLY PRODUCED JAM AND JELLY IN TERMS OF THEIR PHYSICOCHEMICAL, NUTRITIONAL, COLOR, TEXTURE AND SENSORY EVALUATION

M.M. MOLLA, M.H.H. KHAN, A.A. SABUZ, M.G.F. CHOWDHURY AND S. PERVIN

Abstract

The study was performed to collect the domestic and overseas jam and jelly from the local and city market of Bangladesh and evaluate their physicochemical and nutritional composition, color, texture and sensory evaluation. Domestically produced jelly and jam was compared to the internationally produced jelly and jam highlighting their softness, spread ability, color, flavor, taste and sugar content. Study shows that jelly sample J_5 (guava natural jelly) and the jam sample Ja_2 (PHTD Bael jam) and Ja_7 (PRAN mixed fruit jam) was acceptable by the sensory evaluator. Considering the color index, the jelly J_5 (guava natural jelly) and the jam Ja_3 (PHTD bael jam) and Ja_4 (PHTD jackfruit jam) was the region of 90º performed as red color. Texture study confirm that jelly J_2 (RESCO brand guava jelly) and J_3 (Ahmed Food products produced guava jelly) was more softness than other samples. Physicochemical and nutritional study shows that the highest TSS (66.26ºB), ß-carotene (12.18 mg/100 g), total (34.31%) and reducing sugar (28.66%) found in Malaysian jelly as compared to others. Highest moisture (36.50%), vitamin-C (22.63 mg/100 g) and energy content (5.62 Kcal/g) was recorded by the guava natural jelly than others. In case of the collected jam, highest TSS (75.30ºB), total (39.88%) and reducing sugar (33.36%) found in the PHTD developed pineapple jam. The highest TSS may be contributed to gain more hardness of the PHTD developed pineapple jam although is the rich source of ascorbic acid. Highest energy (7.43 Kcal/g) found in the sample Ja_5 (Foster clarks mixed fruit jam, made by Italy). The results of this study will contribute to improve and up calling the PHTD of BARI produced products, small and commercial manufacturer products.

Keywords: nutrition, color, texture, sensory evaluation.

Introduction

Processing may include preservation by several methods, such as processing into gel products (jams, jellies, marmalade etc.), juice production, freezing, fermentation, and drying. Jams are very attractive and popular products among consumers. The jam recipe, processing procedures, storage conditions, and duration are important factors for jam quality. Jam formulation varies, due to the composition of the matrix ingredients that have an impact on the rheology of the produced jam. Any small alteration in the jam matrix (for example, replacing part of the sugar with other sweeteners, or using different pectin) can create changes in the food matrix constituents. As a consequence of changes in the interactions, jam quality will be dramatically affected (Javanmard and Endan, 2010). Fruit jams are usually prepared, as the producers own techniques that keeping secreted by them. Traditionally jam is stored at room temperature in glass jars in warehouses and stores. Low temperature is generally not regarded as necessary to prevent degradation, as the jam during processing is added both preservatives and sugar, and the pH of the produce is usually low.

Quality parameters of jams, such as color, texture, sweetness, softness, hardness, physicochemical and nutritional properties, can be affected by processing conditions, as well as heating time, temperature, settlement type, time, storage conditions, thus, proper selection and balance of those parameters, next to ingredients selection, is of great importance for the production of and maintain quality of foods (Abers and Worlsted,1979; Kansci et al., 2003; Ocibisz and Mitek, 2007).

Many factors can influence the stability of temperature, pH, light, oxygen, sugar, enzymes, presence of ascorbic acid, sulfite salts, metal ions and co-pigments. Thermal processing during preparation of the jelly and jam also influenced the quality of the jam and jelly. Excess heating time may increase the hardness of the product. Hence, the present concentrations have been paid to collect the local and overseas market products and evaluate their nutritional, color, texture, softness and overall acceptability by the formatted consumers so that it can be compared to the BARI developed products for its further modification.

Materials and methods

Collection and coding of the sample

All the samples were collected from the local and city market of the Bangladesh. Then the collected samples were pooled together and coded according to the following coded.

For Jelly:

J_1= PHTD developed traditional jelly
J_2= RESCO branded guava natural jelly
J_3= Ahmed Food Products manufactured guava jelly
J_4= Malayasian jelly
J_5= PHTD modified guava natural jelly

For Jam:

Ja_1= PHTD developed pineapple jam
Ja_2= PHTD developed bael jam
Ja_3= PHTD developed jackfruit jam
Ja_4= RESCO branded pineapple natural jam
Ja_5= Forest clarks mixed fruit jam (Italy)
Ja_6= Fruit of forest jam (Newzealand)
Ja_7= PRAN mixed fruit jam

Physicochemical and nutritional analysis

The physicochemical properties of the collected jelly and jam concerning moisture, protein, ash, ascorbic acid, total, and reducing sugar content were determined according to the procedure described by Ranganna (1995). ß-carotene was analyzed according to the method described by Molla et al. (2017) and the value was expressed in the unit mg/100g of the jelly and jam. 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). The water activity of the sample was recorded using Lab Touch-aw (Novasina, AG, CH-8853, Switzerland).

Sensory evaluation

The sensory attributes for different treatments were evaluated following the procedure of Joshi (2006) based on 9-point hedonic scale. A judgment panel was formed comprising thirty expert members from the BARI inter-divisional Scientists to evaluate color, flavor, texture, mouthfeel, spreadable capacity, and overall acceptability of the products. The score obtained by the panelists was analyzed by statistical analysis.

Color Measurement

The color of the collected jelly and jam was assessed according to the method described by Dervisi et al. (2001) with little modification using 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 adjusted to measure the values of L*, C*, and H* and was replicated three times for each treatment. The established color parameters were as follows: L* (lightness-0 is black, and 100 is white); C* (the color saturation value (chroma)), as well as h* (the hue angle (from 0-90◦ for red, over 90◦ for yellow and 180◦ for green, up to 270◦ for blue and back to 0◦).

Texture analysis

Texture of the jelly and jam was measured by a texture analyzer (Stable Micro System, Godalming, UK). The analyzer probe (p-5) was directly inserted in the jar of jelly by the back extrusion method. The instrument working parameters were determined by the test mode compression with test speed at

1mm/s, and a distance of 2.50 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 expressed in the unit N.

Statistical analysis

All data was expressed in duplicate as means ± standard deviation. One-way ANOVA with post-hoc using Turkey's Multiple Comparison Test was performed to analyze the data. The connotation was distinct at the 95% confidence level. SPSS 17.0 (IBM INC., New York) software was used for statistical analysis.

Results and discussion

Physico-chemical and Nutritional Properties

The physico-chemical and nutritional analysis of the collected samples are presented in Table 1 and Table 2.

Moisture content

Moisture content of the collected samples were significantly differed. The maximum moisture content was found in the sample J_5 (36.50±0.10%) whereas the minimum was recorded for the sample J_3. Product having high moisture content has minimum shelf stability (Ayub et al., 2005). Although the low moisture content contributes to make the jam and jelly hardness that has low spread ability on the loaf. Hence, the hard jam jelly is not acceptable by the consumers.

Ash content

Ash content of all the samples were not significantly differed but the differences among the samples are varied from each other's (Table1 and Table 2). The range of the ash content of the collected jelly and jam were 0.16±0.04 to 0.21±0.04 (Table 1). The ash content of the jam ranged from 1.26±0.04 to 7.50±0.10. Results indicate that highest ash content was recorded as 0.21±0.04 in the J_1 and Ja_7 sample (Table 1 and Table 2).

Total acid

Total acid of the collected samples was significantly differed. The maximum acidity was found in the sample J_5 (2.11±0.04%) whereas the minimum was recorded for the sample J_3(0.26±0.04). There was an inverse relation between the total acid and pH of the collected sample.

pH

In this study, the range of the pH values were from 2.81±0.04 to 4.15±0.05 for the jelly whereas the jam ranged from 3.03±0.03 to 3.98±0.02. Results show that the highest pH was recorded for the jelly sample J_3 (3.98±0.02) and the lowest was for the sample J_2 (3.03±0.03) (Table 1). In case of jam, the maximum pH was calculated as 3.98±0.02 Ja_4) whereas the lowest was 3.03±0.03 in (Ja_5) (Table 2).

Ascorbic acid

Ascorbic acid of all the samples were highly significantly differed. The range of the ascorbic content of the collected jelly and jam were 22.63±0.07 to 8.14±0.03 (Table 1) and 22.63±0.03 to 2.72±0.03 (Table 2). The highest ascorbic was recorded as 22.63±0.07 in the sample J_1 and J_4 sample (Table 1) whereas it was found highest for the jam sample Ja_1 (22.63±0.03) and the lowest for the sample Ja_6 (2.72± 0.03) (Table 2).

ß-carotene

ß-carotene is a crucial part in human nutrition and health, which can lessen the risks of cancer and heart diseases because of the activity of pro-vitamin A (Tiburski et al., 2011). β-carotene is the main safe dietary source of vitamin A. It is essential for normal growth and development, immune system functioning and vision (Liji and Dibakar, 2015). The results obtained by the study show that the maximum ß-carotene content 12.18±0.02 and 26.51±0.09 found in the collected jelly and jam sample J_4 and Ja_3 whereas the lowest was found as 9.11±0.04 mg/100 g and 10.05±0.05 mg/100 g in the jelly J_3 and jam Ja_7 (Table 1 and Table 2).

Crude fat

Fats enhance the taste and acceptability of foods; lipid components largely determine the texture,

flavour and aroma of foods. In this study, the crude fat content of the collected sample ranged from 0.60±0.10% to 0.36±0.04 % for the jelly whereas the fat content of the jam sample ranged from 0.41±0.04% to 0.20±0.01% respectively (Table 1 and Table 2).

Total sugar (%) and Reducing sugar (%)

Sugars are one of the most important quality parameters, because of its contribution to the flavor, quality, palatability and discoloration of jams and jellies (Anandsynal et al., 2018). The highest quantity of total (34.31±0.09%)) and reducing sugar (28.66±0.04%) was recorded in sample J_4, while the highest was recorded in the jam as 39.88±0.02% and 33.36±0.04% for Ja_1 (Table 1 and Table 2). Desrosier and Desrosier emphasized that a balance is required between the sucrose and invert sugar content of the jelly (Desrosier, 1978). Low inversion may result in crystallization, high inversion in granulation of dextrose. Egan claimed that manufacturers prefer the reducing sugar content to fall within the range of 20-40 in order to prevent separation of crystals during storage.

Energy

Energy is essential for rest, activity, growth, and maintenance of sound health. Its content is of concern to health-conscious consumers (Liji and Dibakar, 2015). The highest energy content of the jelly and jam was recorded as 5.65±0.05 Kcal/g (J_1) and 7.43±0.03 Kcal/g (Ja_5). The lowest energy content of the jelly and jam was recorded by the J3 (4.76±0.03) and Ja_6 (2.65±0.05). The results show that all the samples were statistically highly significant in the calorific value

Table 1. Physicochemical and nutritional properties of the collected jelly

Parameter	J_1	J_2	J_3	J_4	J_5
Moisture (%)	34.66±0.04d	35.23±0.01b	32.45±0.05e	35.01±0.01c	36.50±0.10a
Ash (%)	0.21±0.04	0.18±0.02	0.16±0.04	0.15±0.05	0.20±0.05
Total acid (%)	0.96±0.04d	1.41±0.04b	0.26±0.04e	1.22±0.02c	2.11±0.04a
pH	3.33±0.03b	2.81±0.04e	4.15±0.05a	2.92±0.03d	3.12±0.03c
TSS (ºB)	64.30±0.30c	64.60±0.10c	65.50±0.10b	66.20±0.20a	65.40±0.36b
Ascorbic acid (mg/100 g)	21.40±0.10b	9.95±0.05d	12.67±0.03c	8.14±0.03e	22.63±0.07a
ß-carotene (mg/100 g)	11.19±0.03b	11.25±0.05b	9.11±0.04d	12.18±0.02a	10.03±0.03c
Crude fat (%)	0.60±0.10a	0.36±0.04b	0.41±0.04b	0.38±0.02b	0.37±0.03b
Total sugar (%)	32.15±0.05c	32.21±0.04c	33.09±0.07b	34.31±0.09a	33.11±0.04b
Reducing sugar (%)	27.57±0.07c	27.68±0.08c	28.26±0.11b	28.66±0.04a	28.23±0.07b
Energy (Kcal/g)	5.65±0.05a	5.63±0.02a	4.76±0.03c	5.47±0.02b	5.62±0.02a

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

Table 2. Physicochemical and nutritional properties of the collected jam

Parameter	Ja_1	Ja_2	Ja_3	Ja_4	Ja_5	Ja_6	Ja_7
Moisture (%)	24.60± 0.10f	41.19± 0.06b	57.99± 0.01a	33.81± 0.04d	36.08± 0.08c	32.19± 0.19e	33.61± 0.10d
Ash (%)	2.07± 0.07e	2.83± 0.07c	2.43± 0.07d	1.33± 0.07	4.43± 0.07b	1.26± 0.04f	7.50± 0.10a
Total acid (%)	1.66± 0.04c	2.05± 0.05b	2.30± 0.10a	1.22± 0.02d	1.60± 0.10c	0.90± 0.10e	1.15± 0.05d
pH	3.56± 0.06b	3.38± 0.02c	3.60± 0.10b	3.98± 0.02a	3.03± 0.03d	3.07± 0.07d	3.03± 0.03d
TSS (ºB)	75.30± 0.30a	62.40± 0.40d	44.80± 0.05e	65.15± 0.21c	65.30± 0.30c	68.40± 0.40b	68.00± 0.20b

Parameter	Ja_1	Ja_2	Ja_3	Ja_4	Ja_5	Ja_6	Ja_7
Ascorbic acid	22.63±	6.33±	7.24±	4.53±	6.33±	2.72±	4.53±
(mg/100 g)	0.03a	0.03c	0.04b	0.07d	0.03c	0.03e	0.07d
ß-carotene	10.26±	10.24±	26.51±	11.17±	10.29±	13.34±	10.05±
(mg/100 g)	0.04d	0.04d	0.09a	0.03c	0.01d	0.04b	0.05e
Crude fat (%)	0.41±	0.35±	0.20±	0.34±	0.36±	0.39±	0.40±
	0.04a	0.05a	0.01b	0.01a	0.04a	0.01a	0.02a
Total sugar (%)	39.88±	33.01±	24.66±	34.53±	33.13±	35.88±	35.13±
	0.02a	0.01e	0.04f	0.03d	0.13e	0.02b	0.13c
Reducing sugar	33.36±	26.19±	19.15±	27.99±	28.90±	29.14±	28.90±
(%)	0.04a	0.06e	0.05f	0.01d	0.10c	0.14b	0.10c
Energy (Kcal/g)	5.77±	5.81±	4.78±	5.76±	7.43±	2.65±	5.47±
	0.03b	0.04b	0.02c	0.04b	0.03a	0.05d	0.03b

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

Color of the collected jelly and Jam

Appearance is the most common phenomenon used to measure the quality of any product whereas color and surface conditions performance a fundamental role in the appearance of the product. L* is an approximate quantity of lightness that can be well-thought-out as compared to the member of the greyscale, between black and white (Mumtaz et al., 2019). Chroma (C*) is a measurable characteristic of colorfulness used to measure the variance of a hue in contrast to a grey color by a similar lightness. The result obtained from the studies showed that the highest values of L* (26.71±0.71), C* (6.53±0.19) and H*(87.88±0.21) were found in the jelly sample J_5 (Table 1). The highest L* and H* value of the jam sample was calculated as 30.97±0.14 and 77.47±0.78 in the sample Ja_3 whereas the highest croma value was found in the sample Ja_1 (15.71±0.00). The results indicate that the jelly and jam is within 90° region turned to red color. However, the findings confirm that the collected sample J_5 and Ja_3 was bright color than the other samples.

Table 3. Color of the collected jelly

Collected sample	Color index		
	L*	C*	H*
J_1	20.21±0.06b	6.13±0.05a	68.36±0.24c
J_2	18.26±0.38c	2.83±0.04d	51.81±1.78d
J_3	21.57±1.17b	5.68±0.27b	72.42±2.06b
J_4	14.65±0.50d	4.46±0.11c	32.03±1.79e
J_5	26.71±0.71a	6.53±0.19a	87.88±0.21a

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 4. Color of the collected jam

Collected sample	**Color index**		
	L*	C*	H*
Ja_1	27.08±0.20b	15.71±0.00a	54.84±0.22c
Ja_2	27.00±0.10b	6.70±0.20d	62.73±0.15b
Ja_3	30.97±0.14a	15.12±0.14b	77.47±0.78a
Ja_4	21.24±0.27c	11.65±0.08c	77.23±0.12a
Ja_5	19.50±0.04d	4.41±0.06f	40.54±0.80d
Ja_6	12.99±0.21f	1.06±0.07g	8.51±0.37e
Ja_7	13.97±0.01e	5.38±0.08e	3.93±0.33f

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

Sensory evaluation of the fortified RTS sapota powder

The score obtained for J_5 and Ja_2 by the expert judgment in terms of color, flavor, mouth feel, softness and overall acceptability was higher than others (Table 5 and Tabl6). The lowest score in terms of color, flavor, mouth feel, softness and overall acceptability was found in the sample $J_1$and Ja_4. However, the jelly sample J_5 and jam sample Ja_2 was liked by the panel of judges (Table 5 and Table 6).

Table 5. Sensory evaluation of the collected jelly

Sample	Sensory Attributes				
	Color	Flavor	Mouth feel	Softness	Overall acceptability
J_1	6.90±1.10	7.00±1.15	7.50±0.70	5.80±1.68b	5.64±0.61b
J_2	7.30±1.25	7.30±0.94	7.60±0.96	7.60±0.96a	6.36±0.68ab
J_3	7.40±1.17	6.80±1.31	7.40±1.17	6.90±1.52ab	6.30±0.95ab
J_4	6.50±1.26	6.70±1.25	6.60±1.17	6.70±1.25ab	6.10±0.75ab
J_5	7.40±1.42	7.60±0.69	7.60±1.17	7.50±0.84a	7.02±0.66a

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

Table 6. Sensory evaluation of the collected jam

Sample	Sensory Attributes				
	Color	Flavor	Mouth feel	Softness	Overall acceptability
Ja_1	6.20±0.63	6.50±1.35	7.20±0.78a	7.30±0.82a	6.80±0.62ab
Ja_2	7.40±1.26	7.10±0.73	7.50±1.08a	7.30±1.59a	7.32±0.79a
Ja_3	6.20±1.54	6.20±1.31	6.50±1.35ab	6.60±1.83a	6.37±0.84ab
Ja_4	6.50±1.35	5.80±1.39	5.60±1.50b	4.50±1.64b	5.60±1.09b
Ja_5	6.50±0.97	6.50±1.08	7.50±0.70a	6.50±1.35a	6.75±0.63ab
Ja_6	6.40±1.64	6.90±0.87	6.80±0.63ab	6.60±1.07a	6.67±0.84ab
Ja_7	7.20±1.22	7.00±1.33	6.70±1.56ab	6.70±1.49a	6.90±1.22a

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

Texture analysis of the collected jelly and jam

The rupture forces (FR) of the collected jelly and jam are illustrated in Figs.1 and 2. The lowest FR was found in the collected jelly sample J_2 and J_3. In case of the collected jam sample Ja1, Ja2, Ja3 and Ja7 found lowest FR than the other samples. The lowest FR obtained by the sample indicates that the jelly and jam is comparatively soft than other samples.

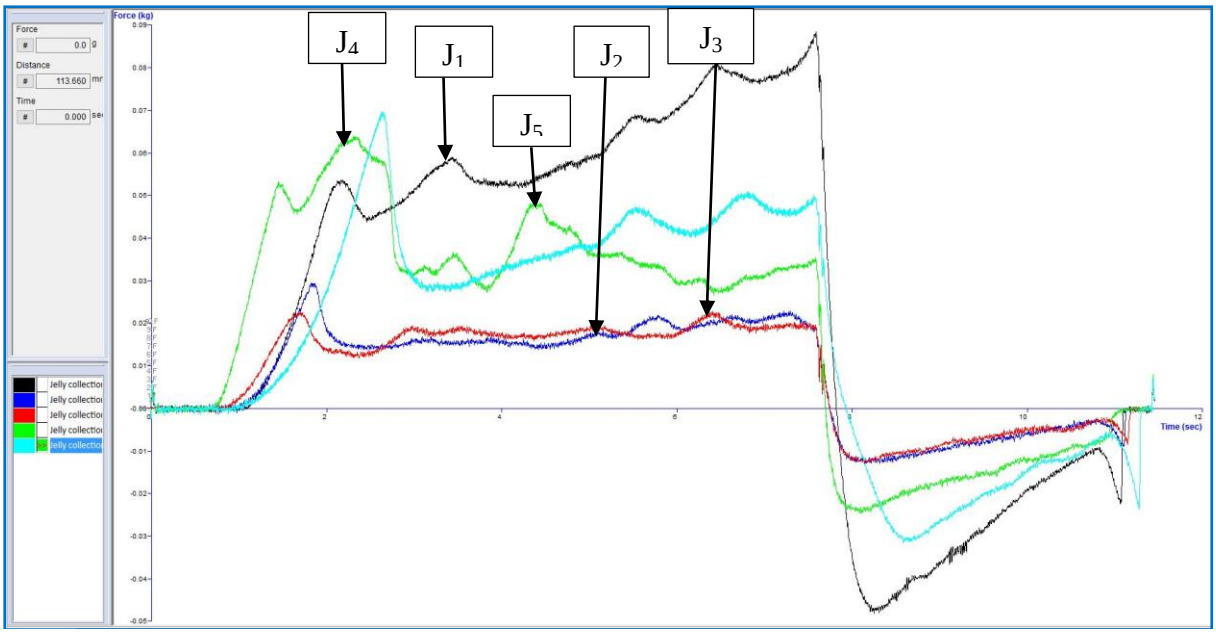

Fig.1. Texture of the jelly; J_1=PHTD guava jelly, J_2=RESCO formulated jelly, J4=Malayasian jelly and J5= Guava natural jelly

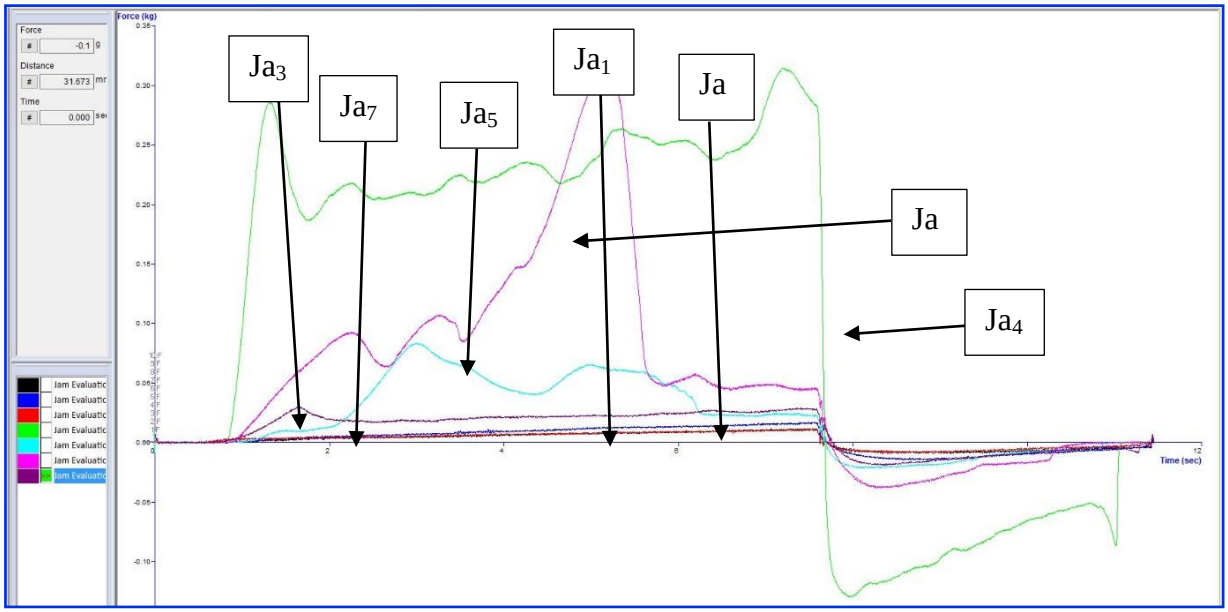

Fig.2. Texture of the jam; Ja_1=PHTD pineapple natural jam, Ja_2=PHTD Bael jam, Ja_3=PHTD Jackfruit jam, Ja_4=RESCO pineapple natural jam, Ja_5=Foster clerks mixed fruit jam (Italy), Ja_6=Fruit of forest jam (Newzealand), Ja_3=PRAN mixed fruit jam.

Conclusion

In this study, the physicochemical and nutritional properties, color, texture and sensory evaluation of the collected different jelly and jam were evaluated. Jelly sample J_5 (guava natural jelly) and the jam sample Ja_2 (PHTD Bael jam) and Ja_7 (PRAN mixed fruit jam) was acceptable by the sensory evaluator. Considering the color index, the jelly J_5 (guava natural jelly) and the jam Ja_3 (PHTD bael jam) and Ja_4 (PHTD jackfruit jam) was the region of 90º, indicates red color. Texture study confirm that jelly J_2

(RESCO brand guava jelly) and J_3 (Ahmed Food products produced guava jelly) was more softness than other samples. Physicochemical and nutritional study shows that the highest TSS, ß-carotene, total and reducing sugar found in Malaysian jelly as compared to others. Highest moisture, vitamin-C and energy content was recorded by the guava natural jelly than others. In case of the collected jam, highest TSS, total and reducing sugar found in the PHTD developed pineapple jam. The highest TSS may be contributed to gain more hardness of the PHTD developed pineapple jam although is the rich source of ascorbic acid. Highest energy found in the sample Ja_5 (Foster clarks mixed fruit jam, made by Italy). However, the several samples show different nutritional and color and textural properties.

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EXTRACTION OF ANNATTO COLOR AND EVALUATION THEIR MICROBIAL AND ANTIMICROBIAL ACTIVITY BEFORE APPLYING IN FOOD PROCESSING

M.M. MOLLA, A.A. SABUZ, M.H.H. KHAN, M.G.F. CHOWDHURY, S. PERVIN, S. BRAHMA AND M.S. UDDIN

Abstract

Preservatives are natural or synthetic substances that are added to fruits, vegetables, prepared food items, cosmetics and pharmaceuticals in order to increase their shelf life and maintain their quality and safety by inhibiting, retarding or arresting their fermentation, acidification, microbial contamination and decomposition. Adulteration in foods is a serious problem nowadays and is considered an alarming issue to ensure safe food consumption for all ages of people. Due to the consumption of synthetic foods, people suffer from different diseases; even in some cases, they do not recover using synthetic medicine. In recent years, public concern about synthetic pigments and preservatives' safety has led to increasing interest in developing natural food colorants and preservatives from plant tissues, especially from some edible sources. Therefore, the aimed of the present study was to extract natural color from the annatto and develop annatto powder using freeze dryer for its further application into food processing industry like jam, jelly, marmalade etc processing. Annato (Bixa orrelana L.) has been renowned as a tropical plant rich in carotenoid pigments such as nonpolar bixin and polar norbixin. The extraction was carried out by maceration for 10 mins using distilled water as the extraction solvent at various pH and extraction temperatures. The variations of solvent pH used in this research were below 7 and above 7 following three extraction temperatures viz. 70, 80, and 90oC. The potential of annatto extract as an antimicrobial agent was tested by analyzing the extract's ability to inhibit pathogens and its physicochemical, phytochemicals and nutritional compounds. The extracted powder was evaluated for its microbiological as well as carcinogenesis viz. mycotoxin, aflatoxin and Antimicrobial activity. Results revealed that the Annatto powder was rich source of ascorbic acid (45.25 mg/100 g), ß-carotene (269.25 mg/100 g) and free from carcinogenesis. Therefore, it could have recommended that the extracted powder could be utilized in the food processing industry.

Key words: Color extraction, phytochemical composition, carcinogenesis evaluation, antimicrobial activity.

Introduction

In recent years, public concern about synthetic pigments and preservatives' safety has led to increasing interest in developing natural food colorants and preservatives from plant tissues, especially from some edible sources (He et al., 2015; Ramli et al., 2017). Annatto is one of the plants that have high potential as a colorant. Annatto obtained from Bixa orellana fruit is one of the natural pigments used as a natural food colorant. The main pigment of annatto is carotenoid composed of bixin and norbixin (Gallardo Cabrera and Rojas-Barahona, 2015) as well as β carotene, cryptoxanthin, lutein, zeaxanthin, and methyl bixin (Scotter et al., 2000). Annatto pigment has a high tinctorial value and an outer colour range comprising red, orange, and yellow hues (Husa et al., 2018). This range of colors is an additional advantage of the annatto carotenoids over other carotenoids such as carrot and beetroot, which only show their respective colors (Silva et al., 2008). Bixin (nonpolar) is more soluble in vegetable oil; on the other hand, norbixin (polar) is more soluble in an aqueous solution. As a colorant, annatto is used in cheeses, sausages, meat, and candies industries (Silva et al., 2008). The dairy industry is the biggest usage of annatto pigment. Annatto extract, apart from being a potential colorant, also has the potential to be a natural antimicrobial (Venugopalan and Giridhar, 2012; Yolmeh et al., 2014).

Three main commercial processes are commonly used to extract the pigment from dried annatto seeds, direct extraction into oil, direct extraction into aqueous alkali, or indirect extraction with solvents (Scotter et al., 2000). The major coloring principles produced by direct oil extraction are 9′-cis-bixin, all-trans-bixin, to provide a color formulation suitable for fat- or oil-based products such as margarine. Annatto extracts are susceptible to oxidative degradation.

Annatto extraction using distilled water is profitable since distilled water is an edible solvent, easy to obtain, and cheap. In this study, annatto extraction was carried out using acidic and alkaline distilled water at several different extraction temperatures. According to Satyanarayana et al. (2003),

yellowness of extract increased, and redness decreased with an increase in temperature. However, the color characteristics and antibacterial activity of distilled-water based extract at acidic and alkaline pH and various extraction temperatures have not been widely published. Therefore, the present study has undertaken to extract the annatto color as powder form using cheapest source of distilled water and its application to the food processing (jam, jelly, marmalade etc.) instead of synthetic food color to make the product profitable.

Materials and methods

The present study was conducted in the Postharvest Technology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.

Collection of annatto seed

The fresh annatto was collected from the Regional Spices Research Center, BARI, Gazipur-1701, Bangladesh and shifted to the laboratory of Postharvest Technology Division, BARI.

Annatto extraction:

Annato extraction was carried out in accordance with studies conducted by Rosamah et al. (2009), Abayomi et al. (2014) and Sabuz et al. (2020). A total of 1000 g (1kg) of annatto seeds was taken and added to the distilled water as the solvent at the annatto seeds: distilled water 1:1.50 (Fig.1). Maceration was performed through a magnetic stirrer at three heating temperatures of 70, 80, and 90^{o}C for 30 mins. Two acidity levels of distilled water were applied, pH below 7 and above 7. Distilled water with pH below 7 was adjusted by adding citric acid, while that with pH above 7 was adjusted using $Ca(OH)_2$. After extraction, the mixture was filtered to separate the extract from the annatto seeds.

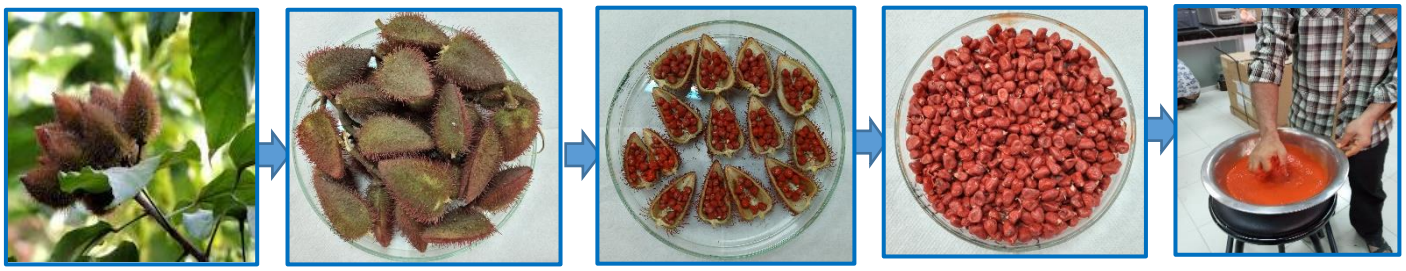

Fig.1. Extraction of annatto using distilled water

Annatto powder extraction

The extracted liquid form of annatto was transferred to the 500 mL volumetric flask. Then the flask was pooled tightly to the freeze dryer so that outside air cannot suction by the vacuum suction pump (Fig.2).

Fig.2. Extraction of annatto powder using freeze dryer

Physicochemical and nutritional composition analysis

The physicochemical and nutritional analysis of moisture and ash content was determined according to the method described by Ranganna (1995). Vitamin-C and ß-carotene content was determined by

AOAC (2020). 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).

Evaluation of microbiological properties

Microbiological assay in terms of the total viable count was done by standard plate count method. Specific bacterial counts such as *Enterobacteriaceae*, *Faecal streptococci*, *Listeria*, *Salmonella*, *Vibrio cholera*, *Pseudomonas aeruginosa*, *Staphylococcus Aureus*, total coliform, *E. coli and* mycotoxins e.g. aflatoxin B1, B2, G1, G2, Ochratoxin A, and Patulin count were performed based on their standard selective medium(s) and experimental procedures.

Results and discussion

Physicochemical and nutritional composition of the extracted annatto powder

The extracted annatto color was dried by freeze dryer and then it was subjected to physicochemical and nutritional analysis. Table 1 shows, the moisture content, ash content, total acid, pH, crude fat and anthocyanin content as 8.52%, 1.09 %, 2.84%, 6.65, 16.65 % and 0.78 mg/100 g respectively. Results revealed that the annatto powder was the rich source of ascorbic acid (45.25 mg/100 g) and ß-carotene (269.25 mg/100 g) at pH below 7.

Table 1. Physicochemical and nutritional composition of the annatto extracted powder

Compositions	Quantity
Moisture content (%)	8.52
Ash (%)	1.09
Total acid (%)	2.84
pH	6.65
Ascorbic acid (mg/100g)	45.25
ß-carotene (mg/100 g)	269.25
Anthocyanin (mg/100 g)	0.78
Crude fat (%)	16.65

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

Antibacterial activity of extracts

Evaluation of the antibacterial activity of annatto extracts was determined by measuring the inhibition zone against E. coli and S. aureus (Table 2). As seen in Table 2, all the extracts were potent antimicrobials against E. coli and S aureus. Annato extract produced from pH below 7 at 80^{o}C showed the highest degree of inhibition against S aureus with a diameter of 0.93±0.06 mm, while the lowest degree was produced from pH above 7 at 70^{o}C. Based on the inhibition zone's diameter, the annatto extract produced at pH below 7 had moderate inhibition at pH above 7. According to Tari and Handayani (2015), the antibacterial activity of a bacterium is determined based on the diameter of the bacterial inhibition zone against indicator bacteria, which are generally pathogenic bacteria with a range of >20 mm = very strong, 10-20 mm = strong, 5-10 mm = moderate and < 5mm = weak.

In this study, S. aureus was more susceptible to the tested extracts than E. coli. Indeed, the majority of the compound's extracts assayed for their antibacterial properties showed a more pronounced effect against the Gram-positive bacteria. The resistance of Gram-negative bacteria has been ascribed to their hydrophilic outer membrane, which can block the penetration of antibacterial compounds into the target cell membrane. The wall of Escherichia coli is very rich in lipopolysaccharide (LPS) that prevents antibacterial molecules such as phenol. The resistance of Staphylococcus aureus to some plant extracts can be explained by the heterogeneous wall structure of the bacteria: the presence of the exopolysaccharide containing an outer layer (glycocalyx), the presence of certain components such as the teichoic acid, and links between the various components highly cross-linked polymer give the walls an unknown tertiary structure (Bouyahya, 2016).

Table 2. Antimicrobial activity of annatto extract

Treatment		Inhibition zone	
Distilled water extraction	Temperature	E. coli	S. Aureous
Below 7 (6.65)	70	6.10±1.01b	6.00±1.01b
	80	6.70±1.21a	5.70±1.21c
	90	6.61±1.30a	6.50±1.30a
Above 7 (7.80)	70	2.33±0.58c	5.33±1.08a
	80	3.41±1.00b	4.30±1.11ab
	90	5.61±1.13a	4.31±1.03b

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

Color extract measurement determined using Munsell color chard

Hue value was determined using the Munsell colour chart (Ruck and Brown, 2015). The results of the color readings of annatto extract using the Munsell chart showed that the use of different pH of the solvent and temperature extraction produces different extract hue. The hue of extract determination using the Munsell Chart is shown in Table 3, indicates that the hue of all off extracts was YR, which showed yellowish red (orange). Extraction using pH below 7 of distilled water at 80^{o}C and 90 ^{o}C resulted in the highest hue of annatto extract. Acidic solutions at high temperatures are thought to be more capable of extracting pigment compounds to produce a higher hue Saputri et al. (2017). High temperature, acidic pH solvent, and stirring using a magnetic stirrer are thought to enhancement abrasion of the annatto seed exocarp, thereby increasing color intensity. The highest color of the annatto extract was 7.5 YR of hue produced by extraction at pH below 7 at 80^{o}C and 90 ^{o}C.

Increasing the extraction temperature from 70^{o}C to 80^{o}C at pH below 7 increased the color intensity of the extract indicated by the hue's enhancement. The increase in hue level indicates a higher orange (yellowish-red) color. An increase in extraction temperature may be causes a change in stereoisomers from cis-bixin to trans-bixin, which is more stable (Satyanarayana et al., 2003). Cis bixin is most soluble in organic polar solvents, giving it an orange color. High temperature can change cis bixin to trans bixin, which is more stable and gives a red color. Rosamah et al. (2009) also reported that Annatto pigment is more stable at acidic pH.

Table 3. The hue of extract based on measurement using Munsell Chart

Treatment	Color Criteria	
pH	Temperature (^{o}C)	Hue
Below 7 (6.65)	70	2.20 YRb
	80	7.30YRa
	90	7.30YRa
Above 7 (7.80)	70	3 YRb
	80	4YRa
	90	4 YRa

All values are means of triplicate determinations ± SD. Means within columns with different letters a, b indicate significant result ($p<0.05$). YR: Yellow Red color

Microbiological properties

Microorganisms are the leading culprit to deteriorate the quality of food and create different health hazards after consumption. The microbiological profiles of examined *Annatto* for bacteria and mycotoxins are analyzed before applying in food processing which are presented in Table 4. The viable bacterial count of *Annatto* was 1.06×10^{8} CFU/g. Among the different bacterial species, *Enterobacteriaceae* and *Faecal streptococci* were found as 7.10×10^{5} CFU/g and 4.01×10^{5} CFU/g, respectively while total coliform, *Staphylococcus aureus*, and *E. coli* were presented as 1.0×10^{5}

MPN/g, < 3 MPN/g, and < 3 MPN/g, respectively. It is a matter of concern that *Listeria spp.* (per 25g), *Salmonella spp.* (per 25g), and *Pseudomonas aeruginosa* (per g) was presented in *Annatto* although *Vibrio cholera* (per 25g) was absent. Among the mycotoxins studied, aflatoxins (B1, B2, G1, and G2) were absent, however, Ochratoxin A (2.50 µg/kg) and Patulin (20.0 µg/kg) were not detected in *Annatto*. The absent of different microorganisms in *Annatto* might be due to lower amount of moisture present in *Annatto*. Moreover, proper processing and handling conditions might have contributed to the absent of microorganisms in the *Annatto*. Therefore, the extracted powder form the Annatto could be utilized in the food processing industry as they are free from carcinogenesis.

Table 4. Microbiological properties of Annatto extracted powder.

Bacterial profile	Quantity
Total plate count (CFU/g)	1.06×10^8
Enterobacteriaceae (CFU/g)	7.10×10^5
Faecal streptococci (CFU/g)	4.01×10^5
Staphylococcus aureus (MPN/g)	$<10^3$
Total coliform (MPN/g)	1.0×10^3
E. coli (MPN/g)	$<10^3$
Listeria spp. (per 25g)	Absent
Salmonella spp. (per 25g)	Absent
Vibrio cholera (per 25g)	Absent
Pseudomonas aeruginosa (per g)	Absent
Mycotoxin profile	**Quantity**
Aflatoxin B1 (ppb)	ND
Aflatoxin B2 (ppb)	ND
Aflatoxin G1 (ppb)	ND
Aflatoxin G2 (ppb)	ND
Ochratoxin A (ppb)	ND
Patulin (ppb)	ND

ND - Not Detected; CFU – Colony Forming Unit; MPN – Most Probable Number; ppb-parts per billion

Conclusion

Annatto extraction using distilled water at a temperature of 70 to 90^{o}C produces extracts containing phytochemicals alkaloid, phenol, tannins, and saponins, which can be antibacterial against E. coli and S aureus with low to moderate inhibition power. Annatto extraction using distilled water pH below 7 at 80 and 90^{o}C results in the highest extract color, namely 7.5 YR of hue. The extracted powder is the rich source of vitamin-C and ß–carotene. Microbiological evaluation also confirm that the extracted annatto powder is free from carcinogenesis effect which could be utilized in the food processing industry.

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MORPHOLOGICAL, PHYSICOCHEMICAL, NUTRITIONAL, MINERALS AND BIOACTIVE COMPOUNDS ANALYSIS OF FRESH FIGS (FICUS CARICA L.) INDIGENOUS TO BANGLADESH

M.M. MOLLA, M.G.F. CHOWDHURY, S. PERVIN, A.A. SABUZ, M.H.H. KHAN AND M.H. PATWARY

Abstract

The aim of the present study was to evaluate morphological, physicochemical, nutritional, minerals, color and bioactive compounds of round and oval shape fresh fig fruits (Ficus carica L.). The maximum fruit breadth, stem length and stem breadth was noted in oval shape fig fruit as 3.26 cm, 2.40 cm and 0.45 cm respectively. The maximum fruit length was found in round shape fig fruits (3.86 cm). The maximum fruit and seed weight was calculated as 35.34 g and 11.09 g in the oval shape fruit. The lowest fruit and seed weight was found in round shape fruit and calculated as 28.87 g and 10.26 g respectively. The highest edible portion was found in the round shape fruits as 98.35 g with its minimum non-edible portion (1.65 g). The oval shape fig fruits irradiated green-colored than the round shape fig fruits. The moisture content of the fresh fig fruits recorded as 80.01±0.78 % and 80.50±1.00 % respectively. The a_w of the round and oval shape fresh fig fruits calculated as 0.61 and 0.59 respectively. The highest values of bioactive compounds viz. vitamin-C, ß-carotene, TSS and pH were found in fresh oval fig fruits and recorded as 26.57±0.47 mg/100 g, 7.49±0.19 mg/100 g, 14.15±0.14 and 5.18±0.05 respectively. However, the results confirm that oval shape fig fruits retained more morphological, physicochemical, nutritional, minerals, color and bioactive compounds than the round shape fresh fig fruits.

Introduction

Fig (Ficus carica L.) is a deciduous tree from the Moraceae family, native to southwest Asia, and typically grown in the Mediterranean region. This plant is one of the earliest cultivated trees. Fig fruits are an important crop worldwide for both dry and fresh consumptions (Çaliskan and Aytekin Polat, 2011; Tanwar et al., 2014). Turkey, Greece, Egypt, Morocco, Italy, Spain, Brazil, and other countries were among the main fig producers due to the proper climatic conditions such as hot and dry summers, and mild winters (Soni et al., 2014). The color of figs varies from dark purple to green (Solomon et al., 2006). The consumption of figs has positive health effects due to the numerous nutraceutical compounds that may help prevent cardiovascular diseases and the growth of carcinoma cells (Allegra et al., 2017). Fresh and dried figs, as well as its syrup possess laxative action (Morton, 1987). The consumption of figs is recommended well for eyesight as well as for liver and spleen diseases (Gani et al., 2018). Figs are used as an expectorant and diuretic. In addition, juice from figs mixed with honey can be used for haemorrhages (Soni et al., 2014). Oily macerates prepared from dried figs were also used for consumption because of the antioxidative and antimicrobial properties (Debib et al., 2018). The dried and fresh figs are reported to be a good source of amino acids, carbohydrates, sugars, fibres, minerals (copper, manganese, magnesium, potassium, and calcium), vitamins, organic acids, and phenolic compounds (Veberic et al., 2008; Slatnar et al., 2011) similar to some edible mushrooms (Dospatliev, 2018). The phytochemicals of figs also include arabinose, β-amyrins, β-carotenes, glycosides, β-sitosterols, xanthotoxol, alkaloids, flavonoids, coumarins, saponins, and terpenes (Gilani et al., 2008; Jeong et al., 2009). Fresh fig is an important source of polyphenols such as rutin (up to 28.7 mg/100 g fresh weight (fw), (+)-catechin, (−)-epicatechin, chlorogenic acid (up to 1.71 mg/100 g fw), gallic acid (up to 0.38 mg/100 g fw) and syringic acid (up to 0.10 mg/100 g fw) (Veberic et al., 2008). Moreover, hydroxycinnamic acids (3-O- and 5-O-caffeoylquinic acids and ferulic acid), flavonoid glycosides (quercetin-3-O-glucoside and quercetin3-O-rutinoside) and furanocoumarins as psoralen and bergapten have also been found in figs (Oliveira et al., 2009; Debib et al., 2014). Because of these natural compounds, figs are an important constituent in the Mediterranean diet. In Bangladesh, there is no popular fig cultivars. View on this mind, the fruit trees were planted at the Khamar Division of Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Two types namely round and oval shape fig are planted to evaluate their morphological, physicochemical, nutritional, minerals and bioactive compounds.

Materials and methods

Collection of fresh fig fruits

Two types of fresh fig fruits namely round and oval shape fruits were collected from the Khamar Division of Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh. The fruits were harvested at their fully mature stage in three replicates.

Analysis of fig fruits

All the morphological characteristics, color variations and physicochemical, nutritional and bioactive compounds of the figs were recorded as fresh weight basis. Minerals profiling of the fig fruits were recorded as dry weight basis.

Standards and reagents

All standards and reagents used in the present study were of analytical grade and purchased from Sigma-Aldrich (Germany).

Color measurement

The color of fresh fig was assessed according to the method described by Dervisi et al. (2001) with little modification using a Chroma Meter (Model CR-400, Minolta Corp Japan). International Commission on Illumination (CIE) lightness (L*), green (a*), and blue (b*) 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 adjusted to measure the values of L*, a*, and b* and was replicated three times for each treatment.

Physicochemical, nutritional and bioactive compounds analysis

The physicochemical and nutritional analysis of moisture and ash content was determined according to the method described by Ranganna (1995). Vitamin-C and ß-carotene content was determined by AOAC (2020). 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). The water activity of the sample was recorded using Lab Touch-aw (Novasina, AG, CH-8853, Switzerland).

Minerals Analysis

The minerals analyzed in this study were: sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), sulfur (S), boron (B), copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn). Atomic absorption spectrophotometry (Model-AA-7000S, Shimadzu, Tokyo, Japan) was used to assess Na, Fe, Cu, Zn, B, Mn, Ca, and Mg. K was measured using flame photometry, while P and S were assessed with the spectrophotometric method. Individual minerals were quantified by comparing the corresponding protocol procured from the Sigma Chemical Co., USA.

Statistical analysis

All data was expressed in duplicate as means ± standard deviation. One-way ANOVA with post-hoc using Tukey's Multiple Comparison Test was performed to analyze the data. The connotation was distinct at the 95% confidence level. SPSS 17.0 (IBM INC., New York) software was used for statistical analysis.

Results and discussion

Morphological characteristics of fig fruits

Leaf area of the round and oval shape fresh fig fruits were recorded as bottom, middle and top of the leaf. The calculated unit was cm^2 per leaf per plant. The leaf area was statistically significantly differed (Table 1). The bottom and middle area of the round fig was higher than the oval shape fruit. The top leaf area of the oval shape fruit was higher than the round shape fig fruit (Table 1). Fruit length, fruit breadth, stem length, stem breadth, fruit weight, seed weight, fruit edible and non-edible portion of the fruits were recorded (Table 2). Fruit length, fruit breadth, stem length and stem breadth was statistically not differed. But the maximum fruit breadth, stem length and stem breadth was recorded as 3.26 cm, 2.40 cm and 0.45 cm in the oval shape fig fruits as compared to round shape fig fruits. The fruit length was maximum in round shape fig fruits (3.86 cm) as compared to oval shape fruits. Fruit and seed weight was found maximum (35.34 g and 11.09 g) in the oval shape fruit

whereas the lowest was found in round shape fruit as 28.87 g and 10.26 g respectively (Table 2). The highest edible portion was found in the round shape fruits as 98.35 g whereas its non-edible portion was recorded minimum (1.65 g).

Table 1. Leaf area of fresh figs

Parameter	Figs		LSD
	Round	Oval	
Bottom of the leaf (leaf area/plant, cm^2)	261.34±0.34	337.68±0.20	**
Middle of the leaf (leaf area/plant, cm^2)	518.83±0.17	369.07±0.07	**
Top of the leaf (leaf area/plant, cm^2)	351.74±0.26	365.08±0.08	**

All values are means of triplicate determinations ± SD. ** indicates significant result at $p<0.01$.

Table 2. Morphological characteristics of fresh figs

Parameter	Figs		LSD
	Round	Oval	
Fruit length (cm)	3.86±0.20	3.83±0.05	NS
Fruit breadth (cm)	3.16±0.12	3.26±0.05	NS
Stem length (cm)	2.33±0.15	2.40±0.10	NS
Stem breadth (cm)	0.43±0.05	0.45±0.05	NS
Fruit weight (g)	28.87±0.22	35.34±0.10	**
Seed weight (g)	10.26±2.00	11.09±0.58	NS
Fruit edible portion	98.35±0.76	97.91±0.07	NS
Fruit non-edible portion	1.65±0.76	2.09±0.07	NS

All values are means of triplicate determinations ± SD. ** indicates significant result at $p<0.01$. NS means non-significant differences.

Color variations of fig fruits

Color is one of the important quality attributes for consumer acceptability of foods, particularly for fresh fruits and vegetables (Molla et al., 2017). In figs, the color is mainly due to the presence of bioactive natural compounds such as anthocyanin, color, or carotenoids. Figs possess wide diversity of colors, ranging from dark purple to green (Solomon et al., 2006). The color variation of the two types of figs are described in Table 3. In this study, the round and oval shape figs contained more colors and ß-carotene. As fresh fruits, the color values were recorded as L*, a* and b*. L* and b* values were found statistically insignificant whereas a* found statistically significant. The values for color L*, a* and b* obtained in the present study was higher in oval shape fig in comparison to round shape fig (Table 3). Results indicate that oval shape figs irradiated green-colored than the round shape figs (Silva et al., 2009). The values for the ß-carotene content obtained in the present study was higher in the oval shape fresh figs (table 4), thus its biochemical changes may be contributed to retain more green color in oval shape fig fruit.

Table 3. Color changes of the fresh figs

Color value	Figs		LSD
	Round	Oval	
L*	28.63±0.94	29.04±0.15	NS
a*	11.51±0.53	12.80±0.33	*
b*	75.49±3.89	76.94±3.54	NS

All values are means of triplicate determinations ± SD. * indicates significant result at $p<0.05$. NS means non-significant differences.

Physicochemical, nutritional and bioactive compounds of figs

The physicochemical, nutritional and bioactive compounds of round and oval shape fig fruits are presented in Table 4. The results show that moisture content and water activity (a_w) insignificantly

differed. The moisture content of the fresh fig fruits was recorded as 80.01±0.78 % and 80.50±1.00 % respectively (Table 4). The moisture content is one of the important factors as many of the physicochemical properties of edible fruits may vary due to changing its value (Omobuwajo et al., 2003). The analysis of ash content in foods is simply the burning away of organic content, leaving inorganic minerals. This helps to determine the amount and type of minerals in food. It is important because the amount of minerals can determine physiochemical properties of foods, as well as retard the growth of microorganisms. The ash content of the round and oval shape figs was statistically significantly and it recorded as 0.86±0.02 % and 0.96±0.02 % respectively. Microorganisms, including yeasts, molds, and bacteria, are sensitive to a food's pH. Very low or very high pH values prevent microbial growth. As a practical matter, no unprocessed food has a pH value high enough to offer much preservative value. In this study, the pH values of the round and oval shape fruits were calculated as 5.00±0.10 and 5.18±0.05. The acidity level of the round and fig fruits was recorded as 0.31±0.01% and 0.22±0.03 % respectively, indicates that the acidity level was comparatively low in high concentration of pH figs. The results confirm that there was an inverse relation between pH and acidity level of the round and oval shape fruits.

The vitamin-C content of the round and oval shape fig fruits was statistically significantly differed. The highest vitamin-C content was possessed by the oval shape fig (26.57±0.47 mg/100 g) as compared to round shape fig (17.64±1.18 mg/100 g). The vitamin-C content present in the fruit is considered as the most powerful antioxidants in foodstuffs whose regular intake lowers the cancer risks in the human body (Almeida et al., 2011). Vitamin-C is also 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. (Mondal et al., 2017). However, according to Jukes (1974), the RDA of vitamin C, i.e. ascorbic acid to prevent scurvy for adults is about 10 mg, which indicates that the current study from the fig fruits found a higher amount of vitamin-C that can prevent scurvy adequately with daily consumption of 100 g of fig. β-carotene is the main safe dietary source of vitamin A. It is essential for normal growth and development, immune system functioning and vision (Liji and Dibakar, 2015). The β-carotene content was statistically significant. The highest concentration was recorded as 7.49±0.19 mg/100 g in oval shape fig fruit whereas the lowest was recorded as 6.68±0.13 in the round shape fig fruits. The results obtained by this study suggest that both round and oval shape fig is the rich source of β-carotene content.

Table 4. Physicochemical, nutritional and bioactive compounds of the fresh figs

Parameter	Figs		LSD
	Round	Oval	
Moisture content (%)	80.01±0.78	80.50±1.00	NS
Ash content (%)	0.86±0.02	0.96±0.02	*
Total acid (%)	0.31±0.01	0.22±0.03	*
Vitamin-C content (mg/100 g)	17.64±1.18	26.57±0.47	**
β-carotene (mg/100 g)	6.68±0.13	7.49±0.19	*
TSS (^{o}B)	13.65±0.15	14.15±0.14	*
pH	5.00±0.10	5.18±0.05	*
aw	0.61±0.01	0.59±0.01	NS

All values are means of triplicate determinations ± SD. * indicates significant result at $p<0.05$. ** indicates significant result at $p<0.01$. NS means non-significant differences.

Minerals profiling

The essential minerals are important components of the daily diet required in greater quantity and represent 1% or less of body weight (Macrae et al., 1993). The results regarding the mineral and trace element levels in the figs show that potassium (0.72±0.02) has the highest concentration in the round fig whereas the oval shape fig has the highest concentration of Ca (1.30±0.10%), Mg (0.67±0.03 %). Na was found lowest in both round (0.01±0.00 %) and oval shape (0.02±0.01%) figs. Potassium (K) is one of the important nutrients for controlling human blood pressure, therefore round fig is

recommended for reducing hypertension in the human body. Similarly, calcium (Ca) is a major component of bone and assists in tooth development (Brody, 1994). In these findings, the highest Ca was reported in the oval shape fig. It is indicated that oval shape fig fruits constitute a relatively higher amount of Ca and Mg than round shape fig. These minerals also act as cofactors for many enzymes in the human body (Akpanabiatu et al., 1998). The recommended daily Ca intake for adults' ranges from 1000 mg to 1500 mg. It is also recommended to take supplements with food to aid in absorption. Compared with other metals, the Ca ion and most of its compounds have low toxicity (Lewis, 1996). Iron (Fe) content was highest in the oval shape fig fruits (88.70±0.30 ppm) whereas the lowest was recorded in round shape fig fruits (87.10±0.10 ppm). An adequate level of Fe is required for hemoglobin formation in blood, while excessive intake can result in hemochromatosis. Iron-containing enzymes and proteins participate in many biological oxidations and in transport (Alessandra and Robert, 2005). The copper (Cu), zinc (Zn) and manganese (Mn) content of the figs were recorded as17.40±0.40 ppm, 26.00±0.40 ppm and 46.10±0.10 ppm in the round fig whereas the oval shape fruit contains 18.40±0.40 ppm, 21.90±0.10 ppm and 46.90±0.10 ppm. Results indicate that the oval fig is the rich source of Cu and Mn whereas the round shape fig is the rich source of Zn (Table 6). It is reported that a deficiency of Mn, Zn and Cu may lead to bone deformities, reduced hair growth and cardiac abnormalities (Mills, 1981). The variation of K, Ca, Mg, Fe, Zn and Cu might be due to geographical variations, growth conditions, cultural and soil nutrient management of the fig. However, the results obtained from this study confirm that both round and oval shape fig is the rich source of trace elements.

Table 5. Calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorous (P), Sulfur (S) and Sodium (Na) of the fresh figs

Parameter	Figs		LSD
	Round	Oval	
Ca (%)	1.20±0.10	1.30±0.10	NS
Mg (%)	0.63±0.03	0.67±0.03	NS
K (%)	0.72±0.02	0.48±0.02	**
P (%)	0.13±0.03	0.12±0.02	NS
S (%)	0.80±0.20	0.39±0.01	*
Na (%)	0.01±0.00	0.02±0.01	NS

All values are means of triplicate determinations ± SD. * indicates significant result at $p<0.05$. ** indicates significant result at $p<0.01$. NS means non-significant differences.

Table 6. Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn) and Boron (B) of the fresh figs

Parameter	Figs		LSD
	Round	Oval	
Cu (ppm)	17.40±0.40	18.40±0.40	**
Fe (ppm)	87.10±0.10	88.70±0.30	**
Mn (ppm)	46.10±0.10	46.90±0.10	*
Zn (ppm)	26.00±0.40	21.90±0.10	**
B (ppm)	33.00±0.50	23.40±0.40	**

All values are means of triplicate determinations ± SD. * indicates significant result at $p<0.05$. ** indicates significant result at $p<0.01$. NS means non-significant differences.

Conclusion

The present study was evaluated to determine the morphological, physicochemical, nutritional, minerals, color and bioactive compounds of round and oval shape fresh fig fruits (Ficus carica L.). Oval shape fresh figs demonstrated high levels of morphological, physicochemical, nutritional, minerals, color and bioactive compounds than the round shape fresh fig fruits. The highest values of bioactive compounds viz. vitamin-C, ß-carotene, TSS and pH were found in fresh oval fig fruits were recorded as 26.57±0.47 mg/100 g, 7.49±0.19 mg/100 g, 14.15±0.14 and 5.18±0.05 respectively.

However, the results conclude that oval shape fig fruits are the rich source of physicochemical, nutritional, minerals and bioactive compounds than the round shape fresh fig fruits.

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PHYSICO-CHEMICAL CHARACTERISTICS OF PLUM IN VARIOUS CONCENTRATIONS OF SODIUM CHLORIDE AND SUCROSE DURING PRESERVATION

S. PERVIN, M.H.H. KHAN, M.G.F. CHOWDHURY, M. M. MOLLA AND A. A. SABUZ

Abstract

The study was conducted to find out the effect of sucrose-sodium chloride concentrations on plums in order to examine the shelf life of plums under ambient conditions. There were five treatments with different sucrose-sodium chloride solutions for the experiments. The stored plum pH, acidity, β-carotene, vitamin C, TSS and sugar data were analyzed for up to six months; It was found that under ambient conditions the plum pH was decreased but acidity, β-carotene, vitamin C, TSS and sugar content were increased at 5% NaCl treated plum during storage. As the conclusion, when using 5 percent concentrations of sodium chloride in plum; for each quality parameter of the stored plum, a smaller decrease and increase was found than for the other treated sample under ambient conditions.

Introduction

Food preservation is used since prehistoric times. The process of preservation inhibits the development of microbes such as bacteria and fungi. The goals of food preservation include preserving the taste, texture, quality, and nutritional value of food; to reduce the waste of excess food; to maintain the accessibility of a product for a long time even in places where it is not manufactured; to preserve the food materials during transportation; and to facilitate the handling of food materials (Sharif, 2017). In other ways, the processing and preservation of fruits and vegetables reduce the large price fluctuations between the main harvest season and the low season. It promotes and initiates efficient food production practices while reducing spoilage and decay losses in harvested food. From the point of view of export potential, fruit and vegetables are important processed products. Bangladesh is an agricultural country whose economic development depends on achieving greater efficiency in food production and making the best possible use of the available food supply. There are good ways to preserve fruits and vegetables on a commercial scale. In the present study, the keeping of plums is also important where plums are stored. Typically, packaging is done to protect food from physical damage, chemical attack and contamination by biological vectors such as microorganisms, insects and rodents (Potter & Hotchkiss, 2007; Victor & Obele, 2013). Bottling is the most popular method (Evans, 1961). Therefore, a glass bottle is chosen for stored plums.

The brine conditions and concentrations, storage temperature, duration of salt exposure to the physicochemical, sensory properties and the microbial growth of fruits and vegetables were examined by various researchers and identified as cabbage (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). Plum is a minor fruit produced in the country and huge losses of these fruits are observed after harvest because of proper storing and mismanagement processes. Alternatively, there is no standard packaging for storing plums. It should be standard for future use of fresh plum. Now it has become a national necessity to standardize the packaging for plums in order to reduce the post-harvest losses and also to preserve the shelf life. Therefore, the overall goal of research is to process and preserve fresh plums using various concentrations of sucrose-sodium chloride to investigate the shelf life of plums with quality concerns under ambient conditions.

Materials and Methods

Collection of plum: Plum (BARI Alu bukhara-1) having optimum maturity and firm texture was collected from the 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 temp for 3 minutes 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. Then, took the sterilize bottle and blanched plum keep in it. Pour the NaCl solution in sterilize bottle into the plum. Finally, the bottle with plum was kept in an ambient condition as treatment wise.

There were five treatments:

T_1 = 45 ^{0}B in plum

T_2= 50 ^{0}B in plum

T_3= 5% NaCl in plum

T_4= (45 ^{0}B+5% NaCl) in plum

T_5= (50 ^{0}B+5% NaCl) in plum

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). Sodium chloride was determined by titration with silver nitrate (Ranganna, 1986).

Measurement of titratable acidity: The titratable acidity (TA) was analyzed using the titrationmethod. 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 100 g of sample and calculated by using the following formula:

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

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.

Measurement of sugar of plum: Total sugar and reducing sugar were determined using the following formula and the procedure was described by Nelson (1944).

The reducing sugar was estimated as a percentage and calculated as follows:

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

The total sugar was estimated as a percentage and calculated as follows:

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

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

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

Data analysis: All treatments were repeated thrice and the research was done using a Completely Randomized Design (CRD). Using statistical software of Rx64 3.6.2, all collected data were analyzed for ANOVA to compare means and the level of significance of the data up to 5%.

Results and Discussion

The fresh blanched plum kept in glass container using sucose-NaCl solution and stored in an ambient condition for six months.

Measurement of pH of plum and sucrose-NaCl solution in stored plum

The pH changes of stored plum and the pH of sucrose-NaCl solutions are given in Table 1. The pH of the fresh plum was 2.87 and, in the case of stored plums, it decreased in the 5% NaCl as well as 45 ^{0}B+5% NaCl used in the plum but it was increased only sucrose concentration used in the plum. In other investigation, pH of the sucrose-NaCl concentrations in the stored plum, it decreased lowest in 5% NaCl and second lowest was in 45 ^{0}B+5% NaCl solution used in the plum but the highest pH was observed in 50 ^{0}B. These outcomes are comparable to persons investigated for persimmon fruits as well as persimmon leaves, and could be accredited to the concentrated NaCl used for salting, mainly to excrete tannins and to prevent yeast development (Kim & Chung, 1995; Chung et al., 2020). However, the pH value of the NaCl solution was initially higher compared to the different storage times and a lower pH value was investigated in the higher concentrations of NaCl with different treatments. On the other hand, the pH was lowered every month up to six months of storage. The pH value of the various samples can drop due to the conversion of pectin into organic acid or due to the slightest increase in acid during storage (Imran et al., 2001).

Table 1. Influence of the sucrose-NaCl concentrations on the pH of the plum and sucrose-NaCl solution during storage

Treatments	pH of the plum and sucrose-NaCl solution with different storage times (months)			
	0	2	4	6
		pH of plum		
T_1 = 45 ^{0}B in plum		3.10b	2.97b	2.92b
T_2= 50 ^{0}B in plum		3.15a	3.01a	2.93a
T_3= 5% NaCl in plum	2.87	2.74e	2.65e	2.62e
T_4= (45 ^{0}B+5% NaCl) in plum		2.84d	2.77d	2.68d
T_5= (50 ^{0}B+5% NaCl) in plum		2.95c	2.85c	2.79c
CV (%)		0.668	0.805	0.773
$LSD_{0.1\%}$		0.035	0.042	0.040
		pH of sucrose-NaCl solution		
T_1 = 45 ^{0}B in plum	2.96b	2.93b	2.89b	2.87b
T_2= 50 ^{0}B in plum	3.24a	3.14a	3.07a	2.97a
T_3= 5% NaCl in plum	2.82d	2.77d	2.74e	2.73d
T_4= (45 ^{0}B+5% NaCl) in plum	2.88c	2.83c	2.79d	2.75d
T_5= (50 ^{0}B+5% NaCl) in plum	2.92b	2.87c	2.84c	2.82c
CV (%)	0.757	0.768	0.832	0.845
$LSD_{0.1\%}$	0.040	0.040	0.042	0.042

The mean values of the triplicate determinations are carried out for all the samples. The mean values in the columns are displayed in significant result ($p<0.001$) with various letters a, b, c, d and e.

Measurement of acidity in stored plum

The changes in acidity in stored plum are given in Table 2. An initial acidity of fresh plum was 2.56, but the acidity decreased after two month of storage and then increased with various sucrose-NaCl concentrations in treated plum as well as prolonged storage. However, the lowest decreased was seen in 5% NaCl treated plum. Therefore, the increase in acidity when softening plums could be due to the

increase in malic acid. Some enzymes can affect the level of organic acids in bananas; Malate synthase, the activity of which decreases during maturation; Malic acid enzyme, which is involved in the decarboxylation of malic acid, and phosphoenolpyruvate carboxylase, also involved in the formation of malic acid, the reduction of which can play a crucial role in increasing the fruit acid content during storage (John and Marchal, 1995).

Table 2. Influence of the sucrose-NaCl concentrations on the acidity of plums during storage

Treatments	Acidity (%) of the plum with different storage times (months)			
	0	2	4	6
T_1 = 45 ^{0}B in plum		1.18a	1.28a	1.31a
T_2= 50 ^{0}B in plum		1.22b	1.30a	1.34b
T_3= 5% NaCl in plum	2.56	0.64e	0.75d	0.83e
T_4= (45 ^{0}B+5% NaCl) in plum		0.98d	0.93c	0.89d
T_5= (50 ^{0}B+5% NaCl) in plum		1.12c	1.25b	1.29c
CV (%)		2.752	3.119	3.602
$LSD_{1.0\%}$		0.066	0.078	0.092

The mean values of the triplicate determinations are carried out for all the samples. The mean values in the columns are displayed in significant result ($p<0.01$) with various letters a, b, c, d and e.

Measurement of β-carotene and vitamin C in stored plum

The changes in the β-carotene and vitamin C content of the stored plum are shown in Table 3. The initial β-carotene content of fresh plums was 52.6 μg/100 g but it was decreased over the period of storage in different treated samples. The NaCl concentrations gave the higher amount of β-carotene, however, it was reduced during storage. The β-carotene value could be reduced in both the isomerization and the oxidation process and the breakdown could hypothetically occur in an actual food (Aruna et al., 1999; Penicaud *et al.*, 2011). On the other hand, the vitamin C content in fresh plum was 7.10 mg/100 g, and it was decreased in the various concentrated sucrose-NaCl solution. When stored in various treated plums, it was investigated that the lower vitamin C was found in plum with a higher sucrose concentration and it was gradually reduced. Salting has earlier been reported to condense vitamin C levels in radishes; this could be owing to the excretion of vitamin C with water because of the osmotic pressure of NaCl (Kim et al., 1990).

Table 3. Influence of sucrose and NaCl concentrations on the β-carotene (μg/100 g) and vitamin C (mg/100 g) content of the plum during storage

Treatments	**β-carotene (μg/100 g) and vitamin C (mg/100 g) content with different storage times (months)**			
	0	**2**	**4**	**6**
		β-carotene (μg/100 g)		
T_1 = 45 ^{0}B in plum		39.16d	29.16d	23.06d
T_2= 50 ^{0}B in plum		36.12e	26.09e	20.17e
T_3= 5% NaCl in plum	52.6	51.50a	50.20a	41.90a
T_4= (45 ^{0}B+5% NaCl) in plum		50.90b	49.20b	40.20b
T_5= (50 ^{0}B+5% NaCl) in plum		49.70c	46.80c	38.70c
CV (%)		1.327	1.150	1.153
$LSD_{0.1\%}$		1.111	0.889	0.787
		Vitamin C (mg/100 g)		
T_1 = 45 ^{0}B in plum		3.94d	3.42d	3.00d
T_2= 50 ^{0}B in plum		3.35d	3.10e	2.50e
T_3= 5% NaCl in plum	7.1	6.50a	4.90a	3.90a
T_4= (45 ^{0}B+5% NaCl) in plum		6.10b	4.50b	3.60b
T_5= (50 ^{0}B+5% NaCl) in plum		5.80c	4.30c	3.30c
CV (%)		3.852	3.658	3.312
$LSD_{0.1\%}$		0.275	0.239	0.204

The mean values of the triplicate determinations are carried out for all the samples. The mean values in the columns are displayed in significant result (p<0.001) with various letters a, b, c, d and e.

Measurement of total soluble solids (TSS) in stored plum

The changes in the TSS content of the stored plum in various sucrose-NaCl solutions are given in Table 4. The amount did not show a reliable pattern between treatments, but in general the TSS content of the stored plum was increased in all treatments for longer storage, possibly due to sugar conversion also sucrose used in the solution. A similar study was carried out by Apai (2010) and Hai et al. (2011 & 2014) for longan fruits; Chowdhury et al. (2008) for apple and papaya.

Table 4. Influence of the sucrose and NaCl concentrations on the total soluble solids (%) content of plums during storage

Treatments	Total soluble solids (%) content of the plum with different storage times (months)			
	0	**2**	**4**	**6**
T_1 = 45 ^{0}B in plum		30.00b	31.30b	30.50c
T_2= 50 ^{0}B in plum		30.05b	31.90b	32.30b
T_3= 5% NaCl in plum	8.70	9.30c	10.90c	11.80d
T_4= (45 ^{0}B+5% NaCl) in plum		30.50b	31.50b	31.90b
T_5= (50 ^{0}B+5% NaCl) in plum		32.00a	32.60a	33.00a
CV (%)		1.287	1.403	1.556
$LSD_{0.1\%}$		0.239	0.275	0.310

The mean values of the triplicate determinations are carried out for all the samples. The mean values in the columns are displayed in significant result (p<0.01) with various letters a, b, c and d.

Measurement of reducing sugar and total sugar in stored plum

The changes in the reducing sugar and total sugar content in the stored plum are shown in Table 5. The initial reducing sugar of fresh plums was 3.90 percent but it was increased over the period of storage in different treated samples. The only 5% NaCl concentrations gave the lowest increasing rate of reducing sugar then other combination. The similar investigation was seen in the case of total sugar counting at various treated plum. The observed variation of sugar content was due to an increase in moisture content and could also be due to the conversion of sugar due to non-enzymatic browning reactions in the plum (Nazaneen *et al.*, 2015; Tomar *et al.*, 1990). The sugar content in different treated plums varied significantly due to the variation in sucrose-NaCl concentrations.

Table 5. Influence of the sucrose and NaCl concentrations on the reducing sugar and total sugar content of the plum during storage

Treatments	Sugar content with different storage times (months)			
	0	**2**	**4**	**6**
		Reducing sugar (%)		
T_1 = 45 ^{0}B in plum		19.14a	20.03b	21.13b
T_2= 50 ^{0}B in plum		19.72a	21.83a	23.14a
T_3= 5% NaCl in plum	3.90	5.81c	5.88e	6.20e
T_4= (45 ^{0}B+5% NaCl) in plum		16.13b	17.24d	18.74d
T_5= (50 ^{0}B+5% NaCl) in plum		16.57b	18.71c	19.51c
CV (%)		0.656	0.576	0.443
$LSD_{1.0\%}$		0.373	0.312	0.228
		Total sugar (%)		
T_1 = 45 ^{0}B in plum		19.33b	20.08b	22.14b
T_2= 50 ^{0}B in plum		21.56a	22.13a	24.03a
T_3= 5% NaCl in plum	5.87	6.20e	6.70e	7.10e
T_4= (45 ^{0}B+5% NaCl) in plum		16.41d	17.89d	18.98d
T_5= (50 ^{0}B+5% NaCl) in plum		16.97c	18.71c	19.53c
CV (%)		0.446	0.224	0.591
$LSD_{1.0\%}$		0.403	0.186	0.446

The mean values of the triplicate determinations are carried out for all the samples. The mean values in the columns are displayed in significant result ($p<0.01$) with various letters a, b, c, d and e.

Conclusion

The plums were spoiled or misused by the farmers or breeders due to a lack of processing practices in Bangladesh. Preserving plums will be one of the ideas for farmers and use them in the off-season. Food processing in industry has often been associated with a decrease in the nutritional value of processed foods. However, there will be a growing demand to appreciate and avoid the deterioration in nutritional quality during processing and storage. When considering the overall possibilities of preserving brine as a method of extending the shelf life of fruits like plums, several factors need to be considered. Not only the advantages and disadvantages of the processing method are considered, but also the quality of the stored plum under the different brine concentrations. The experiment showed that 5% NaCl concentrations can be used satisfactorily as a method of extending the shelf life of plums, with minimal impact on their physicochemical properties. The results showed that the plum, which was kept in a glass container with 5 percent NaCl solution and stored at room temperature (25 to 30°C), showed better quality for future consumption. Finally, it could be suggested that the study be used as a commercial purpose by plum growers to extend the shelf life of their plums for secondary uses.

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OPTIMIZATION OF PROCESSING METHOD FOR PLUM JAM AND CHANGES IN THE QUALITY CHARACTERISTICS DURING STORAGE

S. PERVIN, M.H.H. KHAN, M.G.F. CHOWDHURY, M. M. MOLLA AND A. A. SABUZ

Abstract

The research was evaluated the processing method of plum jam to get the diverse uses of the plum with five treatments. The prepared jam was stored for twelve months in glass container. The pH was increased slightly where the acidity was decreased. The intensity of the light-yellow color of the jam was gradually increased and turned light red in color in storage. No microbial growth of the plum jam was observed for any treatment up to nine months, but an acceptable non-pathogenic germ count was identified in various treated jam after twelve months. The relative sensory assessment of the plum jam is evaluated and resulted in the maximum overall acceptance of 8.0 for treatments T_5 (100% sucrose in plum) followed by treatments T_4 with a rating of 7.0. The results showed that considering various quality parameters of the jam; the best recipe was to use plums with 100% sucrose.

Introduction

Plum (*Prunus domestica*) can use as fresh fruit for dessert, dehydrated or fit for human consumption. Plum juice is extensively researched as a flavoring in the food factory (Doymaz, 2006). But it has an astringent taste, hasn't been widely used, and has yet to be used for its use in processing. BARI Alu bukhara-1 is the new plum variety brought out by the Spice Research Center of the Bangladesh Agricultural Research Institute (BARI), which offers more yield and is beneficial to the farmers (Anonymous, 2014). The plum fruits are naturally perishable and only available for a period of time from June to July. In some cases, the ripened plums are eaten fresh. Some value-added products like jam, jelly, pickle, chutney, sauce, etc. could be made from surplus plums.

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 and Johari, 2010). 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. As far as plum jam is concerned in Bangladesh, as we know, is an insufficient producing country and almost unavailable in the local market. Therefore, making plum jam from plum fruits is one of the new ideas for long-term consumption and is used in the off-season.

Materials and Methods

Collection of fresh plum: Plum (*Prunus domestica*) with optimal ripeness was collected from local farmer. The plums were transported in plastic boxes to the laboratory of BARI's Postharvest Technology Division, Gazipur. After sorting, the plum was washed and dried under a ceiling fan.

Recipe of plum Jam: The following ingredients were used to prepare the plum jam:

Item	Quantity
Plum	1.0 kg
Sugar	Recommended dose
Citric acid	3 g/kg
Potassium-meta-bi-sulphite	0.5 g/kg

Processing of plum jam: Fully matured plum was washed with water thoroughly then heating and pulping were done to remove seed. At first sugar was added to the measured pulp and boiled with continuous stirring. Finally, citric acid and pectin, potassium meta-bi-sulphite were added and TSS was observed about 62%. Remove the pan from the burner and transfer the prepared jam to a sterile glass bottle. Cooling, waxing and capping were also done sequentially. All packaged products were properly labeled and stored at ambient temperature (25-35°C). The physicochemical and sensory properties of all products were analyzed at intervals of three months after storage for 12 months. There were five treatments: T_1 = Using 0% sucrose in plum pulp; T_2 = Using 25% sucrose in plum pulp; T_3 = Using 50% sucrose in plum pulp; T_4 = Using 75% sucrose in plum pulp; and T_5 = Using 100% sucrose in plum pulp. The following flowchart shows the plum jam preparation process as shown in Figure 1:

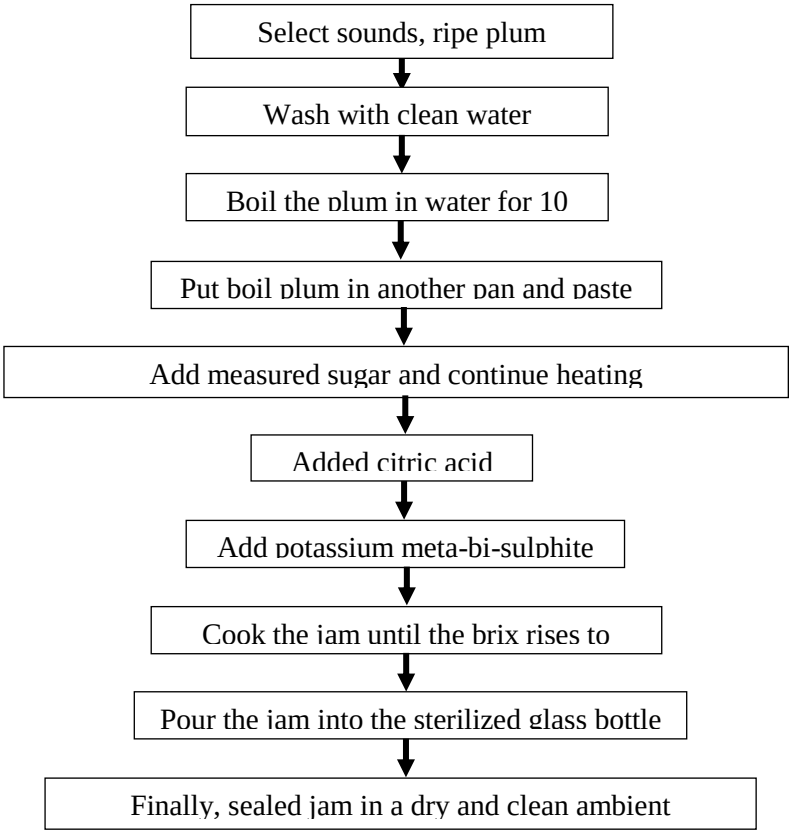

Figure 1. Step of the flow chart for the plum jam preparation

Measurement of pH: Using a glass electrode manufactured by EUTECH Instruments, Selangor, Malaysia, the pH was calculated for the jam sample of 5 g which was diluted with 45 ml of distilled water.

Measurement of titratable acidity: The titration method was used to analyze the titratable acidity (TA) of plum jam. The treated jam sample amount of 10 g was adjusted with 40 ml of distilled water with a mixture and then filtered through cotton wool. The 5 ml of filtrate used as an indicator with a drop of 0.1% phenolphthalein was titrated with 0.1 N NaOH to a pH of 8.1, which was the endpoint

for the pink color. The calculated acidity of the prepared jam was given as percent citric acid per 100 g fresh weight.

Product appearance/color: A tristimulus colorimeter (CR-400, Minolta Corp., Japan) was used to determine the color of plum jam. 10^0 typical observers were used for the relevance method, where L (brightness), a * (-green to + red) and b * (-blue to + yellow) are the color coordinates. The specific details of the measurement procedure were previously discussed by Pervin *et al.* (2021).

Microbial count: The microbial load of the plum jam was determined using plate count agar. The microbial load count was carried out at three-month interval up to 12 months of storage. During the counting process, a 10 g jam sample was homogenized with 90 ml peptone-water buffer solution and then 10µL suspension inoculated into the plate counting agar (PCA) medium by 10-fold serial dilution. Then the inoculated plate was incubated at 37 °C for 24 h in an incubator (model: SHC-4A1). Various colonies of bacteria grown in this medium were counted. The following formula was used for the number of colonies in cfu/g:

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

Organoleptic test: The organoleptic examination of the plum jam was carried out for three-month interval up to 12 months using a questionnaire that was evaluated by taste experts. The individual treatment was assigned as a letter code in order to eliminate prejudice between the panelists. The treated samples were offered to the panelists in various orders to get off preferring the sequence between the taste panels. The plum jam was evaluated by 10 skilled members who were requested to rate the treated jam based on plum color, bad odor, inflexibility, equilibrium of sweet-sour, as well as overall acceptability using a 9-point hedonic ruler.

Analysis of the experimental data: All treatments were repeated thrice and the research was done using a Completely Randomized Design (CRD). Using statistical software from R, collected data were analyzed for ANOVA to equate the means and level of significance of the data.

Results and Discussion

The plum jam was stored at ambient conditions for 12 months. The changes in various physicochemical parameters of the plum jam are shown in Table 1 to Table 5.

Measurement of the pH of stored plum jam

The effects of sucrose on the pH of stored jam during storage are depicted in Table 1. Initially, the maximum pH of 2.79 was observed with treatment T_5 and the pH of 2.53 was lowest with treatment T_1. However, the pH was increased in stored jam for a storage period of 12 months. The initial pH of the plum jam was lower than that of the final product and analogous outcomes were stated by Bhuiyan et al. (2012) in hog plum. The increased concentration of sucrose can raise the pH of plum jam due to the increase in the lactic acid fermentation process; similar results were obtained in bottle carrots by Bansett (1992). The increase in pH with increasing storage time could be due to lactobacilli, while the fastest growth of bacteria occurs under acidic conditions; this study was similar to Srivastva et al. (2002); Rekha (2004); Pundir and Jain (2010); Stella et al. (2011) and Felix (2014).

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

Treatments	pH of the plum jam with different storage times (months)				
	0	3	6	9	12
0% sucrose in plum pulp	2.53d	2.55d	2.57d	2.61d	2.67d
25% sucrose in plum pulp	2.56d	2.59c	2.63c	2.69c	2.78c
50% sucrose in plum pulp	2.68c	2.73b	2.76b	2.81b	2.85b
75% sucrose in plum pulp	2.72b	2.81a	2.85a	2.89a	2.93a
100% sucrose in plum pulp	2.79a	2.83a	2.87a	2.91a	2.97a
CV (%)	0.613	0.540	0.665	0.570	0.693

Treatments	pH of the plum jam with different storage times (months)				
	0	**3**	**6**	**9**	**12**
$LSD_{0.1\%}$	0.030	0.027	0.034	0.029	0.035

The mean values of the triplicate determinations are carried out for all values. The mean values in the columns are displayed in significant result (p<0.01) with various letters a, b, c, d.

Measurement of acidity of stored plum jam

Table 2 shows the effect of sucrose on acidity (%) of stored plum jam during storage. During preparation, the initial acidity measurement was higher for treatment T_5 and lower for treatment T_1. However, the acidity decreased significantly month by month during storage and the lowest values were 1.85 in the T_1 treatment after 12 months. This could be attributed to the hydrolysis of polysaccharides and non-reducing sugars, using acid to convert them to hexose (reducing) sugars, and analogous explanations have been given by Thakur (2017) for wild pomegranate. This could be explained by the differences in the physicochemical composition during different treatments and by the changes in the physicochemical composition of the products during storage. The results are similar to those of Chaudhary and Verma (2012) in the aonla jam.

Table 2. Effect of sucrose on the acidity (%) of plum jam during storage

Treatments	Acidity (%) content of the plum jam with different storage times (months)				
	0	**3**	**6**	**9**	**12**
0% sucrose in plum pulp	2.49e	2.13e	2.07e	1.96d	1.85e
25% sucrose in plum pulp	2.56d	2.29d	2.23d	2.19c	2.12d
50% sucrose in plum pulp	2.64c	2.35c	2.29c	2.26b	2.21c
75% sucrose in plum pulp	2.69b	2.39b	2.35b	2.32a	2.29b
100% sucrose in plum pulp	2.73a	2.44a	2.39a	2.35a	2.37a
CV (%)	3.638	2.866	2.481	2.159	1.957
$LSD_{0.1\%}$	0.128	0.092	0.078	0.066	0.057

The mean values of the triplicate determinations are carried out for all values. The mean values in the columns are displayed in significant result (p<0.001) with various letters a, b, c, d, e.

Measurement of the appearance/color of stored plum jam

Color is a significant feature when observing plum jam. Jam color changes were monitored by estimating color coordinates (a* and b*) and lightness (L) during storage under ambient conditions using various percentages of sucrose used in plum jam. The values are shown in Table 3 and show that the intensity of the light-yellow color of the jam has gradually increased and changes to a light red color during storage after 12 months. The highest brightness was observed with treatment T_1 and the lowest with treatment T_5, but the lightness values were increased up to 12 months of storage. It was found that the lightness decreases as the percentage of sucrose in the product increases. The a* value of the color coordinates indicates that the initial color of the plum jam was light red, then it gradually increases up to 12 months of storage. On other hand, the color coordinates b* showed that the product color was light yellow and finally turned yellow up to 12 months of storage. A lower percentage of sucrose in the product was responsible for the yellow color and a higher percentage of sucrose provided the light-yellow color of the product. A significant decrease in the color of the jam was observed during prolonged storage. It can occur through changes in the action of chemical components or special enzymatic and non-enzymatic effects, including the degradation of anthocyanin pigments in the products. The present results as a tendency towards a decrease in color intensity agree with those of Chauhan *et al.* (1994) in wild pomegranate chutney; and Sahni (1997) in amla chutney.

Table 3. Effect of sucrose on the color parameters of plum jam in storage

Treatments	Color parameters of the plum jam with different storage times (months)				
	0	**3**	**6**	**9**	**12**
			Lightness (L)		
0% sucrose in plum pulp	40.74a	39.74a	36.72a	35.61a	34.12a
25% sucrose in plum pulp	34.76b	33.21b	31.45b	29.45b	29.78b
50% sucrose in plum pulp	32.06c	31.12c	30.77c	30.41c	28.12c
75% sucrose in plum pulp	30.04d	29.45d	28.49d	27.71d	27.43d
100% sucrose in plum pulp	27.19e	26.54e	25.74e	25.33e	24.91e
CV (%)	1.277	1.420	1.791	1.874	1.985
$LSD_{0.1\%}$	0.787	0.780	0.853	0.755	0.761
			Coordinates (a*)		
0% sucrose in plum pulp	21.56a	20.13a	19.57a	18.69a	17.47a
25% sucrose in plum pulp	13.54b	13.08b	12.58b	12.31b	12.08b
50% sucrose in plum pulp	12.23c	12.02c	11.47c	11.09c	10.52c
75% sucrose in plum pulp	11.51d	10.31d	10.07d	9.87d	9.43d
100% sucrose in plum pulp	9.76e	9.54e	9.23e	9.12e	8.87e
CV (%)	2.244	2.195	2.073	1.966	1.821
$LSD_{0.1\%}$	0.478	0.454	0.418	0.382	0.345
			Coordinates (b*)		
0% sucrose in plum pulp	52.88a	50.12a	48.72a	47.52a	47.13a
25% sucrose in plum pulp	41.38b	40.54b	39.12b	38.42b	37.71b
50% sucrose in plum pulp	39.41c	39.14c	38.45c	37.15c	36.47c
75% sucrose in plum pulp	37.19d	36.37d	35.41d	34.74d	34.12d
100% sucrose in plum pulp	33.23e	32.29e	31.46e	30.14e	29.17e
CV (%)	1.060	1.383	1.563	1.740	1.783
$LSD_{0.1\%}$	0.568	0.527	0.492	0.453	0.418

The mean values of the triplicate determinations are carried out for all values. The mean values in the columns are displayed in significant result ($p<0.001$) with various letters a, b, c, d, e.

Microbial count of stored plum jam

Table 4 shows the effects of the sucrose percentage on the germ count of plum jam during storage. Due to the higher dilution used for the enumeration, no microorganism was initially detectable. The microbial growth of the plum jam from various treatments was not observed for up to nine months of storage. However, the microbial growth of the plum jam was observed in small numbers; these were non-pathogenic bacteria and an acceptable limit for human consumption for various treatments after 12 months. The fluctuations may be due to fermentation in the presence of fungi, as Fraziar and Westheff (1978) describe that fungi are the main spoilage organisms for fruit products.

Table 4. Effect of sucrose on microbial growth of plum jam in storage

Treatments	Microbial count of the plum jam with different storage times (months)				
	0	**3**	**6**	**9**	**12**
0% sucrose in plum pulp	ND	ND	ND	ND	$28*10^{-8}$
25% sucrose in plum pulp	ND	ND	ND	ND	$14*10^{-5}$
50% sucrose in plum pulp	ND	ND	ND	ND	$4*10^{-7}$
75% sucrose in plum pulp	ND	ND	ND	ND	$3*10^{-5}$
100% sucrose in plum pulp	ND	ND	ND	ND	$5*10^{-5}$

Note: ND-Not detected

Organoleptic test of plum jam

The organoleptic properties of the plum jam with different sucrose combinations are assessed during monthly storage. A relative sensory assessment of various quality features of the plum jam for giving to the judgment of the 10-expert jury in Table 5, which has an impact on its evaluation for the acceptance of the product. As shown in Table 5, among the treatments, the panelists gave the highest overall rating of jam made with 100% sucrose (treatment T_5) followed by 75% sucrose (treatment T_4). In terms of overall acceptance, it was found that treatment T_5 had the highest overall acceptance of 8.0 (i.e. like very much), followed by treatment T_4 with an overall acceptance of 7.0 (i.e. like moderately). Panelists liked this plum jam for its balance of optimal sucrose content, less bitterness, attractive color, and overall flavor as noted in the recorded datasheet. A significant decrease in overall acceptance was observed for stored plum jam; this result is consistent with strawberry jam and was reported by Khan *et al.* (2012). For most treatments, the organoleptic rating of the plum jam persisted up to an acceptable limit at the end of the storage period. The decrease in sensory values during storage was also shown by Ullah *et al.* (2018) for jam made from carrots and apples.

Table 5. Effect of sucrose on overall acceptance of plum jam in storage

Treatments	Overall acceptance of plum jam with different storage times (months)				
	0	**3**	**6**	**9**	**12**
0% sucrose in plum pulp	4.0e	3.5e	3.5e	3.5e	3.5e
25% sucrose in plum pulp	6.5d	6.0d	6.0d	6.0d	5.5d
50% sucrose in plum pulp	7.0c	6.5c	6.5c	6.0c	6.0c
75% sucrose in plum pulp	7.5b	7.0b	7.0b	7.0b	7.0b
100% sucrose in plum pulp	8.5a	8.0a	8.0a	8.0a	8.0a
CV (%)	3.421	3.264	3.264	3.864	5.833
$LSD_{1.0\%}$	0.431	0.431	0.431	0.527	0.814

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

The mean values of the triplicate determinations are carried out for all values. The mean values in the columns are displayed in significant result ($p<0.01$) with various letters a, b, c, d, e.

Conclusion

Making plum jam from plum is one of the new ideas for long-term consumption and is used in the off season. This study was conducted to evaluate the method of processing plum jam using different sucrose percentages. The results revealed that the considering different quality parameters of jam, the best formulation was using plum with 100 percent sucrose. The prepared product kept in glass container and stored at room temperature (25 to 35 ºC) 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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STANDARDIZATION OF PROCESSING METHOD FOR OSMO DEHYDRATED SUGAR COATED PLUM

S. PERVIN, M.H.H. KHAN, M. M. MOLLA, M.G.F. CHOWDHURY AND A. A. SABUZ

Introduction

Plum (*Prunus domestica*) is a high valued spice crop belongs to the family Rosaceae is native to Europe and Asia. *Prunus domestica* is believed to have originated in the area of the Caucusus and Asia Minor (Eryomine, 2013). Plums and their juice contain mild laxatives including phenolic compounds, sorbitol, dietary fiber are thus common home remedies for constipation (Miletic *el al.,* 2012). Plum also has a high antioxidant content which retards ageing (Stacewicz *et al.,* 2001). 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 tonnes 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 usually meets up by importing from other countries like India, China and Thailand (Mozumder *et. al.,* 2013). Spices Research Center of BARI released a variety "BARI Alu bukhara-1" in 2013 (Anon. 2014) which is high yielding and profit potential variety.

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 storage facilities and mishandling operations. Sun dried or mechanically dehydrated plum fruits have some limitations about the palatability owing to hard texture and high acidity particularly the dried fruits. Osmotic dehydration, a method of preservation has the advantage of being very easy to perform for home and small-scale processing. Now a day, there is a huge demand for dried prunes both in domestic as well as in foreign markets. Osmotic dehydration if optimized will reduce losses, improve availability and allow diversification of processed product.

Osmotically dehydrated plums require less drying time which results into improved overall quality. Several researches have been done for retention of bioactive compounds varying osmotic solution, brix, critical moisture content, drying temperature, drying time and methodology of osmotic dehydration process. Osmotic dehydration is a counter flow process which results in solids gain or impregnation, enhancing the textural and rheological properties of plum and related fruits. Reviews suggested that various osmotic agents with low molecular weight led to higher water loss. Osmotic dehydration improves the overall quality of plums and berries as compared to conventional drying methods (Birwal *et al.,* 2016).

Therefore, the research work needs to be undertaken for processing and preservation of plum by using locally available machineries and thus low-level technology involving minimal capital investment. For long term preservation, processing is considered to be the best method. Osmotic dehydration may be the realistic and most convenient methods for processing plum. As a result, the present research is aim to optimize the dehydration conditions for plum and to produce the value-added products with high quality and shelf life.

Materials and Methods

Collection of plum: Plum fruits were collected from the local farmers. Fruits were sorted, washed and cleaned. Then, the fruits were dipped in 40, 50 and 60 ^{0}Brix sugar syrup for 24 h and then it boils for 15 min. The drying temperature was maintained at 60 ^{0}C. After drying, the plum was preserved in a glass container. Finally, the treated plum will be analyzed after 3 months' interval up to 1 year in an ambient condition.

There were six treatments to prepare sugar coated osmo-dehydrated plum. These were

T_1 = using 40 ^{0}B in plum without coating

T_2 = using 40 ^{0}B in plum with sugar coating

T_3 = using 50 ^{0}B in plum without coating

T_4 = using 50 ^{0}B in plum with sugar coating
T_5 = using 60 ^{0}B in plum without coating
T_6 = using 60 ^{0}B in plum with sugar coating

Measurement of pH: Using a glass electrode manufactured by EUTECH Instruments, Selangor, Malaysia, the pH was calculated for the sugar-coated plum sample of 5 g which was diluted with 45 ml of distilled water.

Measurement of titratable acidity of osmotic dehydrated plum: The titration method was used to analyze the titratable acidity (TA) of osmotic dehydrated plum. The treated plum sample amount of 10 g was adjusted with 40 ml of distilled water with a mixture and then filtered through cotton wool. The 5 ml of filtrate used as an indicator with a drop of 0.1% phenolphthalein was titrated with 0.1 N NaOH to a pH of 8.1, which was the end point for the pink color. The calculated acidity of the treated plum was given as percent citric acid per 100 g fresh weight.

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.

Measurement of moisture content of osmo dehydrated sugar coated plum: Vacuum oven (type: VT 6130 M, Germany) drying method described by Endel Karmas (1980) was used to determine the moisture content where the temperature was maintained at 70 $^{\circ}$C and pressure 50-100 mg of Hg. A sample of 10 g is taken in a crucible and placed in an oven at 105 $^{\circ}$C for 72 h until a constant weight is reached. The percent moisture content was calculated.

Measurement of β-carotene of osmotic dehydrated plum: β-carotene was measured by extracting of 3 g of osmotically treated plum sample with acetone (Fisher Scientific Ltd., UK) and petroleum ether. Further purification was also performed using acetone, metabolic KOH and distilled water. The purified solution was filtered with anhydrous sodium sulphate and run on a spectrophotometer (T-80, PG Instrument Ltd., UK) at 451 nm against petroleum ether as a blank value. The typical curve was created with synthetic crystalline β-carotene (Fluka, Germany), liquefied in petroleum ether and its optical density was estimated at 451 nm (Alasalvar *et. al.*, 2005).

Measurement of sugar of osmotic dehydrated plum: Total sugar and reducing sugar were determined using the following formula and the procedure was described by Nelson (1944).

The reducing sugar was estimated as a percentage and calculated as follows:

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

The total sugar was estimated as a percentage and calculated as follows:

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

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

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

Measurement of appearance/color of osmotic dehydrated plum: A tristimulus colorimeter model of which was used by CR-400, Minolta Corp., Japan, to determine the color of osmotically dehydrated plum. 10^0 typical observers were used for the relevance method, where L (brightness), a * (-green to + red) and b * (-blue to + yellow) are the color coordinates. The specific details of the measurement procedure were previously discussed by Pervin *et al.* (2021).

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.

Determination of total anthocyanin: The method was adapted from Burgos *et al.* (2013): 0.2 g of freeze-dried samples was mixed with 10 mL of methanol/1.0 M HCl (75:25, v/v) and sonicated for 10 min at room temperature. The mixture was centrifuged at 5000 rpm for 10 min. and the pellet was re-

extracted. The combined supernatants were filtered and the volume made up to 25 mL with the extraction solution. Absorbance of the extract was read at 545, 535 and 515 nm and the concentration of TA was calculated using the molar extinction coefficient and molecular weight of malvidin-3-p-coumaroyl-glucoside for blue-violet pigments (545 nm, 3.02×10^4 L/mol/cm, 718.5 g/mol), pelargonidin-3-glucoside for red pigments (515 nm, 2.73×10^4 L/mol/cm, 486.5 g/mol), and cyanidin-3-glucoside for purple pigments (535 nm, 3.43×10^4 L/mol/cm, 449.2 g/mol). Results were expressed in mg/100 g DW.

Research Progress

The experiment has been established. For the time being, some quality parameters were taken but the final analyses were not done yet. The chemical compositions of fresh plum are presented in the Table 1.

Table 1: Chemical compositions of fresh plum

Items	Quantity
DM (%)	18.0
TSS (%)	8.7
P^H	2.8
Acidity (%)	2.56
Vitamin C (mg/100gm)	15.0
β- carotene (µg/100g)	60.0
Reducing sugar	1.75
Total sugar	4.12
Firmness	3.68

The observation will be investigated with the pH, acidity, TSS, moisture content, β-carotene (vitamin A), sugar, color, energy, total phenol and anthocyanin of sugar-coated dehydrated plum to optimize the dehydration conditions for the plum and to produce value-added sugar-coated dehydrated plum with high quality and shelf life. However, the experiment will be continuing for details investigation up to one year. The physicochemical parameters of the treated plum have been seen in the following Table 2 and Table 3 after one-month investigation.

Table 2: pH, acidity, TSS, moisture content, β-carotene (vitamin A) and sugar content of sugar-coated dehydrated plum after one month.

Treatments	Physicochemical quality parameters of the treated plum stored after one month						
	pH	Acidity (%)	TSS	Moisture content (%)	β-carotene (µg/100 g)	Reducing sugar (%)	Total sugar (%)
T_1 = using 40 ^{0}B in plum without coating	3.15	3.88	6.5	21.26	24.46	42.37	49.6
T_2 = using 40 ^{0}B in plum with sugar coating	3.21	4.48	7.2	22.27	24.41	43.1	50.78
T_3 = using 50 ^{0}B in plum without coating	3.22	4.52	6.7	21.87	33.87	42.48	51.65
T_4 = using 50 ^{0}B in plum with sugar coating	3.24	4.93	7.5	23.37	27.84	43.37	52.07
T_5 = using 60 ^{0}B in plum without coating	3.25	5.38	6.9	22.54	23.53	42.85	53.88
T_6 = using 60 ^{0}B in plum with sugar coating	3.26	5.76	7.7	24.05	26.99	43.81	54.37

Table 3: Color, energy, total phenol and anthocyanin of sugar-coated dehydrated plum after one month.

Treatments	Physicochemical quality parameters of the treated plum stored after one month					
	Color parameter			Energy cal/gm	Total phenol (mg/100 g)	Anthocyanin (mg/100 g)
	L	a*	b*			
T_1 = using 40 ^{0}B in plum without coating	14.69	7.86	4.33	6493.31	4.73	0.064
T_2 = using 40 ^{0}B in plum with sugar coating	17.71	7.38	4.45	6512.41	4.45	0.083
T_3 = using 50 ^{0}B in plum without coating	20.87	7.13	5.39	6595.77	4.32	0.102
T_4 = using 50 ^{0}B in plum with sugar coating	21.84	6.87	5.21	6681.09	4.29	0.11
T_5 = using 60 ^{0}B in plum without coating	18.72	6.69	4.04	6752.98	4.21	0.119
T_6 = using 60 ^{0}B in plum with sugar coating	18.87	5.56	4.79	7153.57	3.67	0.154

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OPTIMIZATION OF PROCESSING METHOD FOR DRAGON FRUIT JAM

S. PERVIN, M.H.H. KHAN, M.G.F. CHOWDHURY, M. M. MOLLA, A. A. SABUJ AND A.S.M.H. RASHID

Introduction

Dragon fruit (genus *Hylocereus*) belongs to the Cactaceae family, and it is originally from some regions of Mexico, South and Central Americas. It is widely grown in countries such as Malaysia, Vietnam, Thailand, Taiwan (Muhammad, Mohd.Zahari, Gannasin, Mohd.Adzahan & Bakar, 2014), and it has been recently introduced in Bangladesh. The fruit has several varieties, which can be all differed by characteristics such as color of its epicarp and/or mesocarp – the latter contains black seeds (Ariffin et al., 2009).

Jam is defined as an intermediate moisture food obtained upon boiling fruit pulp with sufficient quantity of sugar (sucrose), pectin, acid, and other ingredients such as preservatives, colouring agents and flavouring materials to a gel like consistency which is firm enough to hold the fruits tissues in position (Kunkel SD et al.,2012).

The fruit jam should have good constancy to spread quickly and should be firm enough to not flow like fluid. The Fruit Jam should contribute at least 68.5% of total soluble solids, and the fruit should contribute at least 45%. The study shows that 27% of essential nutrients are found in the fruit jam during the analysis using the AOAC (Association of Official Agricultural Chemists) method. The fruits jam provides a good source of carbohydrates and energy, and the sugar content lowers the water activity and increases shelf life. Fruit jams are deficient in fatty acid content.

Materials and Methods

Purple color ripe dragon fruits were collected from the agricultural research centre, Pahartoli, Chittogong. Fruits were sorted, washed and cleaned. Then, the fruits were peeled and meshed. At first sugar was added to the measured pulp and boiled with continuous stirring. Finally, citric acid and pectin, potassium meta-bi-sulphite were added and TSS was observed about 62%. Remove the pan from the burner and transfer the prepared jam to a sterile glass bottle. Cooling, waxing and capping were also done sequentially. All packaged products were properly labeled and stored at ambient temperature (25-35 °C). The physicochemical and sensory properties of all products were analyzed at intervals of three months after storage for 12 months. There were five treatments such as:

T_1 = Using 20% sucrose in dragon fruit pulp;
T_2 = Using 40% sucrose in dragon fruit pulp;
T_3 = Using 60% sucrose in dragon fruit pulp;
T_4 = Using 80% sucrose in dragon fruit pulp; and
T_5 = Using 100% sucrose in dragon fruit pulp.

Measurement of pH of dragon fruit jam: Using a glass electrode manufactured by EUTECH Instruments, Selangor, Malaysia, the pH was calculated for the dragon fruit jam sample of 5 g which was diluted with 45 ml of distilled water.

Measurement of titratable acidity of dragon fruit jam: The titration method was used to analyze the titratable acidity (TA) of osmotic dehydrated plum. The treated jam sample amount of 10 g was adjusted with 40 ml of distilled water with a mixture and then filtered through cotton wool. The 5 ml of filtrate used as an indicator with a drop of 0.1% phenolphthalein was titrated with 0.1 N NaOH to a pH of 8.1, which was the end point for the pink color. The calculated acidity of the treated dragon fruit jam was given as percent citric acid per 100 g fresh weight.

Measurement of total soluble solid (TSS) of dragon fruit jam: Total soluble solid in the extracted dragon fruit jam was measured by a refractometer (ATAGO (Brix = 0 to 32%)) and the results were expressed as % Brix.

Measurement of ascorbic acid of dragon fruit jam: According to the AOAC method (1995), the ascorbic acid content was measured using 2, 6-dichlorophenol-indophenol dye. The dragon fruit jam sample was extracted into 3% m-phosphoric acid and titration was continued to the pink end point with dye. To determine the ascorbic acid of osmosed plums, the following formula was used:

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

Measurement of moisture content of dragon fruit jam: Vacuum oven (type: VT 6130 M, Germany) drying method described by Endel Karmas (1980) was used to determine the moisture content where the temperature was maintained at 70 °C and pressure 50-100 mg of Hg. A sample of 10 g is taken in a crucible and placed in an oven at 105 °C for 72 h until a constant weight is reached. The percent moisture content was calculated.

Measurement of β-carotene of dragon fruit jam: β-carotene was measured by extracting of 3 g of treated dragon fruit jam sample with acetone (Fisher Scientific Ltd., UK) and petroleum ether. Further purification was also performed using acetone, metabolic KOH and distilled water. The purified solution was filtered with anhydrous sodium sulphate and run on a spectrophotometer (T-80, PG Instrument Ltd., UK) at 451 nm against petroleum ether as a blank value. The typical curve was created with synthetic crystalline β-carotene (Fluka, Germany), liquefied in petroleum ether and its optical density was estimated at 451 nm (Alasalvar *et. al.*, 2005).

Measurement of sugar of dragon fruit jam: Total sugar and reducing sugar were determined using the following formula and the procedure was described by Nelson (1944).

The reducing sugar was estimated as a percentage and calculated as follows:

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

The total sugar was estimated as a percentage and calculated as follows:

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

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

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

Measurement of appearance/color of dragon fruit jam: A tristimulus colorimeter model of which was used by CR-400, Minolta Corp., Japan, to determine the color of dragon fruit jam. 10^0 typical observers were used for the relevance method, where L (brightness), a * (-green to + red) and b * (-blue to + yellow) are the color coordinates. The specific details of the measurement procedure were previously discussed by Pervin *et al.* (2021).

Sensory evaluation of dragon fruit jam: The sensory evaluation of the dragon fruit jam was carried out at every 3 months' interval during storage with a sensory taste questionnaire, which was evaluated by sensory experts. The individual treatment was assigned as a letter code in order to avoid prejudice between the panelists. The samples were offered to the panelists in a different order in order to avoid preferring the order among the panelists. The dragon fruit jam was rated by 10 experienced panelists who were asked to rate the samples based on external plum color, off-flavor, firmness, sweet and sour balance, and overall acceptance using a 9-point hedonic scale.

Research Progress

The experiment has been established. For the time being, some quality parameters were taken but the final analyses were not done yet. The chemical compositions of fresh dragon fruits are presented in the Table 1.

Table 1: Chemical compositions of fresh dragon fruits

Items	Quantity
Moisture content (%)	87.76
TSS (%)	13.7
pH	4.74
Acidity (%)	0.3
Vitamin C (mg/100 g)	21.72
β- carotene (μg/100 g)	19.38

Items	Quantity
Reducing sugar (%)	5.88
Total sugar (%)	6.25
Total phenol	0.082

The observation will be investigated with the pH, acidity, TSS, vitamin C, moisture content, β-carotene (vitamin A), sugar and color of dragon fruit jam to optimize the processing method for dragon fruit jam and to produce value-added jam with high quality and shelf life. However, the experiment will be continuing for details investigation up to six months. The physicochemical parameters of the treated jam have been seen in the following Table 2 and Table 3 after one-month investigation.

Table 2: pH, acidity, TSS, vitamin C, moisture content, β-carotene (vitamin A) and sugar content of dragon fruit jam stored after one month.

Treatments	Physicochemical quality parameters of the treated dragon fruit jam stored after one month							
	P^H	**Acidity (%)**	**TSS**	**Vitamin C (mg/100 g)**	**Moisture content (%)**	**β-carotene (µg/100 g)**	**Reducing sugar (%)**	**Total sugar (%)**
T_1 = Using 20% sucrose in dragon fruit pulp;	4.06	1.02	36.8	7.69	63.61	9.801	9.25	18.38
T_2 = Using 40% sucrose in dragon fruit pulp;	3.96	1.06	44.4	8.15	56.63	8.668	11.23	22.22
T_3 = Using 60% sucrose in dragon fruit pulp;	3.91	1.24	52.4	9.96	48.14	8.396	13.15	26.04
T_4 = Using 80% sucrose in dragon fruit pulp; and	3.89	1.47	60.2	10.4	39.04	7.693	14.92	30.12
T_5 = Using 100% sucrose in dragon fruit pulp.	3.85	1.53	64.42	10.86	37.74	6.176	15.15	32.05

Table 3: Color parameters of dragon fruit jam stored after one month.

Treatments	Lightness (L)	Coordinates a*	Coordinates b*	Croma (C)	Hue angle (H)
T_1 = Using 20% sucrose in dragon fruit pulp;	9.81	25.23	7.03	26.19	15.58
T_2 = Using 40% sucrose in dragon fruit pulp;	8.59	26.51	6.41	27.27	13.58
T_3 = Using 60% sucrose in dragon fruit pulp;	8.03	27.62	5.43	27.89	11.12
T_4 = Using 80% sucrose in dragon fruit pulp; and	7.56	28.02	3.88	28.45	9.78
T_5 = Using 100% sucrose in dragon fruit pulp.	7.09	28.74	2.56	29.98	8.55

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EFFECT OF DIFFERENT SANITIZERS ON THE NUTRITIONAL QUALITY AND SHELF LIFE OF FRESH-CUT MORINGA STICKS

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

Abstract

This experiment was conducted to evaluate the effect of different sanitizers and storage temperatures on the quality and shelf life of freshcut moringa sticks. Four different treatments of tap water wash (control), hot water treatment (60°C for 1 min), 0.2% calcium chloride wash and 0.01% calcinated calcium treated fresh-cut moringa sticks with two storage condition of ambient temperature (27±1°C & 75±5% RH) and refrigerated temperature (4±1°C) were selected and studied for the experimentation. Moringa stick were peeled and cut in almost uniform size and shape and then washed with different sanitizer (400-500 g stick/L solution) for five minutes and then preserved in film packet at different storage temperatures for physicochemical quality evaluation. After 3 weeks' storage, the hot water treated fresh-cut moringa exhibited better nutritional quality among the treatments in refrigerated storage temperature. Most of the panelists preferred fresh-cut moringa sticks treated with hot water at 60°C for one minute and stored at refrigerated temperature (4±1°C) more than 3 weeks in terms of appearance (7.60), off flavor (7.20), shrinkage (7.60) and overall acceptability (7.47).

Introduction

Moringa *(Moringa oleifera*) is a natural as well as cultivated variety of the genus *Moringa* belonging to the family *Moringaceae*. Fresh-cut produces offer convenience to the consumers causing an increased demand over the past decade (Yousuf *et al.,* 2018) because of their involvement in different activities. Furthermore, they provide a wide variety of safe, nutritious and healthy products. Fresh-cut vegetables refer to peeled, cut, chopped, sliced, diced or shredded forms of vegetables facilitating small serving-size portions such as broccoli, carrots, lettuce, bittergourd, country bean, spinach, red amaranth, sweet corn, potatoes etc. Though there is an increasing demand for such products, but the fresh-cut preparation steps may accelerate the deterioration in terms of increased microbial infection as well as physical damage to tissues (Qadri *et al.,* 2015). The discoloration due to enzymatic activity and loss of phytochemical constituents are some of the major problems in fresh-cut products resulting in the reduced shelf life and triggered product quality loss. Moreover, browning on the cut surface curtails the development and commercialization of many qualities fresh-cut products (Jang and Moon, 2011).

The *Moringa oleifera* plant is grown for food and it is an exceptionally nutritious vegetable tree with varieties of potential value (Ozumba, 2011). The tree is valued mainly for its tender pods, which are esteemed as vegetables, tender leaves and flowers are also used as vegetables. There is considerable variation among nutritional values of moringa, which depends on factors like genetic background, environment and cultivation methods (Brisibe *et al*., 2009). Nutritional composition of the plant plays an important role in nutritional, medicinal and therapeutic values (Al-kharusi *et al.,* 2009). Green leaves and fruit pods of drumstick are rich sources of minerals like calcium, iron and good sources of vitamin A, B, C and protein including fair amounts of sulphur containing amino acids (Ram, 1994). Actually, the great interest in *Moringa oleifera* is related to its multipurpose uses and its ability to guarantee a good yield, where other crops cannot, in countries where people are mostly at risk of suffering from nutritional deficiencies (Leone *et al.,* 2015). In addition, providing nutrition, it also contributes to the appealing colour, texture and flavor of the food. The leaves, fruit, flowers and immature pods of this tree are used as a highly nutritive vegetable in many countries, particularly in India, Pakistan, Philippines, Hawaii and many parts of Africa (Anwar *et al.,* 2007). It is known as 'Mother's Best Friend' because of its utilization to increase woman's milk production and is sometimes prescribed for anaemia (Estrella *et al.*, 2000; Dawn *et al.*, 2015).

The need for preservation of *Moringa oleifera* is very crucial due to its medicinal and therapeutic properties. Also, the consumer's now-a-days look for the ready to eat form of food items. As it is grown in seasons and available for time it becomes necessary to preserve the drumstick. Drumstick can be utilized as flavoring and thickening agent in various dishes. It gives distinct

palatable taste and is a rich source of glutamic acid. On the above circumstances, the study was conducted last year.

Materials and Methods

Sample collection

Local variety of freshly harvested moringa were collected in the morning from local market Joydebpur bazar, Gazipur in April 2021 and then carried in the Postharvest Technology Division (PHTD) of BARI, Gazipur. The moringa were brought into packhouse of the PHTD, BARI and then sorted out to avoid injured and randomly distributed for the experiment.

Preparation of sample

Moringa sticks were first sorted out from any kind of physical injured and separated. Then they were cleaned under running water. Outer peel of each stick was pulled out and then cut as 6-8 cm longitudinal axis by stainless steel (SS) sharp knife. After cutting these needed to handle carefully. Different concentration of calcium chloride, calcinated calcium were mixed with required amount of water to make a solution as a treatment. Then the sticks were instantly dipped into the solution (400-500 g stick/L solution) for 5 mins. After dipping moringa sticks were kept in a perforated SS tray or net to remove additional water. Then the treated sticks were packed in a transparent HDPE film packet. Each packet contained 200 grams of moringa sticks. For evaluating the shelf life with quality, 4 different sanitizer treatments (Calcinated calcium, calcium chloride, normal water and hot water) and two storage conditions (Ambient and refrigerated) were selected. The moringa sticks quality were observed weekly interval upto 3 weeks of storage for the physico-chemical parameters evaluation. The experiment was designed as factorial where factor A was concentration of sanitizer and factor B represents the storage condition. The treatments were as follows:

Factor A: A_0= Control (Tap water wash), A_1= Hot water treated (60°C for 1 min), A_2= 0.2% $CaCl_2$ wash, A_3= 0.01% Calcinated calcium wash and

Factor B: B_0= Ambient temperature ((27±2°C, 75±5%RH) and

B_1= Refrigerated temperature (4±1^{o}C)

Physicochemical analysis

Physical appearance

The color of fresh-cut moringa product 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 slice/cube 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. The actual perceived color (h*) was defined by $\tan^{-1}$(b*/a*) and expressed in degree, where 0^o, 90^o, 180^o, 270^o represent red, green, yellow, and blue, respectively. Chroma color value (C*) where, $C^*=v(a^*)^2+(b^*)^2$, is the vividness (intensity) of the color represented by numbers ranging from 0 (center=gray) to 60 of the color solid radius for any given color hue angle (Machado *et al*., 2015).

Total acid (Titratable acidity) content

The titratable acidity content was analyzed using the titration method. Pasted sample of moringa (10 gm) were homogenized 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 (pH 8.1). The results were expressed as the percentage citric acid per 100 g fresh weight. Total acid was determined following the methods of AOAC (2005).

Vitamin C (Ascorbic acid) content

Ascorbic acid (Vitamin C) content was determined according to Ranganna (2002) using 10-g samples of fresh-cut moringa sticks were blended for 2 mins and homogenized with 50 mL of 3% cold metaphosphoric (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 for at least 15 seconds. The titer value was recorded for each aliquot sample. Prior to titration 2,6-dichlorophenolindophenol solution was calibrated by the ascorbic acid standard solution. The results were expressed as mg/100g.

Total carotenoids content

For total carotenoids content (TCC), 2 grams blended and homogenized samples of each replicate were weighed for carotenoid extraction (Tee, 1991). Total carotenoid extraction was done according to Lee and Castle (2001) with some modifications. The samples were placed in 50-ml graduated blue cap centrifuge tubes and 20 ml of extracting chemicals (Hexane: Ethanol, 50:50 v/v) were added before storing the sample in a freezer at -30^{o}C for at least 1 hour prior to analysis. During analysis, the mixture was thawed, agitated, and then centrifuged at 3000 rpm for 5 mins (Himac CT 6E, HITACHI, Japan). The tubes were shaken to extract all the carotenoids in the tissue then left to stand for 5 mins to get clear separation. The top layer of hexane containing the carotenoid fraction was removed and transferred into 50-ml centrifuge tubes using a 3-ml transfer pipette and the tubes covered. The sample were stored in the -18^{o}C freezer for at least 1 hour, and then placed in crushed ice. The volume of recovered hexane was adjusted to 15 to 25 ml using hexane. For the blank, only hexane was used in the cube. TCC content of each produce tissue sample was calculated by the following equation: $(AV\times10^{6})/(A^{1\%}\times100G)$, where A = absorbance, V = total volume used (e.g., 25 ml), $A^{1\%}$ = 2500, and G = sample in grams. The absorbance was measured by a Spectrophotometer (T-80, PG Instrument Ltd., UK) at 470 ηm.

Microbial load count

Microbial load of the treated moringa sticks were determined with the use of plate count agar. The microbial load count was performed weekly interval upto 3 weeks. Firstly, 10 g fresh-cut moringa sample is homogenized with 90 ml buffer peptone water solution and then after 10-fold serial dilution 10 µL suspension inoculated in the plate count agar (PCA) medium. Than the inoculated plate is incubated at 37^{0}C for 24 hrs in the incubator. Different bacterial colony is grown in that medium is counted. For the number of colony count in cfu/g the following formula was used:

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

Sensory evaluation

The sensory evaluation of the treated moringa sticks were performed at weekly interval as per sensory test questionnaire judged by expert sensory panelists. Each treatment was assigned a letter code to avoid biasness among the panelists. The samples were presented to panelists in different orders to avoid order preference among the panelists. The product was rated by 10 experienced panelists who were asked to score samples based on product external appearance, off-flavor, shrinkage and overall preference using a 9-point hedonic scale.

Results and Discussions

Color changes of the flesh of the fresh-cut moringa can be visually detected, but in this study Lightness (L*), Chroma (C*) and Hue angle (H*) color indicator were measured using a chromameter and it was stated in the Table 1, Table 2 and Table 3, respectively. Lightness (L*) of the fresh-cut moringa sticks were tends to be lower value for each treatment during storage. Treatment A_1 (Hot water treated) represents the best uniform color during storage at refrigerated temperature comparatively other treatments, where lightness ranges from 61.04 to 53.16 (Table 1). In case of control sample treatment A_0 (Control) indicated lowest lightness value from 49.28 after storage at ambient temperature due to depigmentation and enzymatic browning. Chroma (C*) value of the fresh-cut product were relatively decreased slowly, where this condition indicates that color of the fresh-cut moringa tend to be darkness. From the observation, during storage at refrigerated temperature the chroma value ranges from 24.43 to 19.62 and at ambient temperature the chroma value lowered very rapidly to 17.25 in the treatment A_2 (0.2% calcium chloride) at 2nd week. But, at 3rd week of storage,

the chroma value drops drastically as black spot was visible on the surface and microbial as well as enzymatic action were accelerated. In the 3rd week of storage, the products stored at ambient temperature found spoiled. In case of hue angle (H*), the values were noticed decreasing trend during 3rd weeks' storage period. Hue angle ranges from 114.47 to 107.28 at refrigerated temperature in the hot water treated sample (Treatment A_1) (Table 3). The changes of the flesh color were the indicator of the change of the chlorophyll composition and degradation through the carotenoid degradation and enzymatic action (Pantastico, 1997).

Total acid (Titrable acidity) content

For percent total acid (titrable acidity), it was observed that titrable acidity slowly increased during 3 weeks' storage under different storage conditions. At refrigerated temperature, the titratable acidity increased slowly from fresh produce 0.14% to 0.24% but at ambient temperature, it increased very rapidly upto 0.47% and products became spoiled and was found unacceptable for consumption. The rate of percentage acidity changes was presented graphically at Figure 1. Titrable acidity is the main indicator to evaluate the shelf life of fresh-cut products.

Vitamin C (Ascorbic acid) content

In Figure 2, it shows ascorbic acid or vitamin C content changes of the fresh-cut moringa sticks stored at refrigerated and ambient temperatures. In Figure 2, it is stated that the ascorbic acid content decreased at different treatments from 188.96 to 172.75 mg/100g during 3 weeks storage. The highest retention of ascorbic acid ranges from 174.82 to 92.67 mg/100g after 3rd week at refrigerated temperature for treatment A_3 (0.01% Calcinated calcium). It found the lowest at hot water treatment (A_1) due to sensitivity of ascorbic acid at heat treatment. Vitamin C (Ascorbic acid) content in the fresh-cut moringa sticks reduced both in refrigerated and ambient temperature with the increase of storage time. Decreasing vitamin C indicates the products became almost senescence. It might be happen through respiration process and ascorbic acid oxidation to be L-dehydroascorbaic then L-diketogulonase (Winarno, 1989).

Total carotenoids content

In Figure 3, the graphical bar diagram represents the carotenoid content changes of the fresh-cut moringa sticks stored at refrigerated and ambient temperature. In this figure, it was found that the carotenoid content on fresh-cut moringa was relatively stable and tend to be decrease at the end of shelf-life products. At refrigerated temperature storage, the total carotenoid content retains more in the treatment of calcinated calcium which ranges from 5.81 to 5.39 mg/100g. In case of storage at ambient temperature, the total carotenoids became lower upto 4.15 mg/100g in the control treatment after two weeks' storage. The total carotenoids content was related with the color changes evaluation in physical characteristics. According to Skrede (1997), carotenoid content has a positive correlation with hue index and red indicator, where high carotenoid content will make hue and red content will also increase and then will decrease till spoilage.

Total microbial load count

The presence of microbial loads in fresh-cut moringa is a key indicator for the quality and its shelf life. From the study, it was observed that the microbial load reduced because of heat treatment at initial stage 3×10^4 cfu/g and increased during 3 weeks' storage at refrigerated temperature 540×10^8 cfu/g. The fresh-cut moringa sticks stored at ambient temperature exhibited rapid increase in microbial load at 3rd week ranges from 155×10^8 cfu/g to 227×10^8 cfu/g (Table 4).

Sensory evaluation

To find out the best treatment of fresh-cut moringa sticks a 9-points hedonic score based on appearance, off-flavor, shrinkage and overall acceptability were performed by sensory panel members. In Table 5, it was found that the highest overall acceptability scored 7.47 in the treatments A_1 (Hot water treated sample) stored at refrigerated temperature during three weeks' storage. Most of the panelists preferred fresh-cut moringa sticks treated with hot water at 60°C for 1 minute and stored at refrigerated temperature (4 ± 1^oC) during 3 weeks in terms of appearance (7.60), off-flavor (7.20), shrinkage (7.60) and overall acceptability (7.47). In case of ambient temperature storage, the sensory score of the product found very low (below 5) in all treatments. The sensory result represents that the

products are not acceptable to the consumer because of rotting after three weeks, where the fresh-cut product developed off-flavor and showed black appearance.

Table 1. Lightness (L*) changes of fresh-cut moringa during 3 weeks' storage at different temperatures

Treatments	Lightness (L*)						
	Initial	Refrigerated temperature			Ambient temperature		
	W_0	W_1	W_2	W_3	W_1	W_2	W_3
A_0	58.26 d	57.93 c	56.74 c	52.20 c	55.12 d	49.28 c	Spoiled
A_1	61.10 b	60.04 ab	59.17 ab	53.16 b	59.06 b	56.60 a	Spoiled
A_2	62.84 a	60.32 a	59.82 a	55.29 a	60.39 a	53.71 b	Spoiled
A_3	59.61 c	59.55 b	58.15 b	54.60 a	57.50 c	54.75 b	Spoiled
Level of significance	***	***	**	***	***	***	-

Note: A_0= Tap water (Control), A_1= Hot water treated (60°C for 1 min), A_2= 0.2% Calcium chloride, A_3= 0.01% Calcinated calcium, W_0 = Initial, W_1 = 1st week, W_2 = 2nd week, W_3 = 3rd week.

Table 2. Chroma (C*) value changes of fresh-cut moringa products during 3 weeks' storage at different temperatures

Treatments	Chroma (C*)						
	Initial	Refrigerated temperature			Ambient temperature		
	W_0	W_1	W_2	W_3	W_1	W_2	W_3
A_0	24.43 a	21.24 a	19.62 b	19.19 ab	24.62 a	22.95 a	Spoiled
A_1	20.68 b	20.97 ab	19.69 b	19.92 a	22.75 b	20.39 c	Spoiled
A_2	20.60 b	21.10 ab	21.65 a	18.48 b	22.34 c	17.25 d	Spoiled
A_3	21.04 b	20.76 b	19.69 b	18.33 b	22.69 b	22.08 b	Spoiled
Level of significance	***	ns	***	*	***	***	-

Note: A_0= Tap water (Control), A_1= Hot water treated (60°C for 1 min), A_2= 0.2% Calcium chloride, A_3= 0.01% Calcinated calcium, W_0 = Initial, W_1 = 1st week, W_2 = 2nd week, W_3 = 3rd week.

Table 3. Hue angle (H*) value changes of fresh-cut moringa products during 3 weeks' storage at different temperatures

Treatments	Hue angle (H*)						
	Initial	Refrigerated temperature			Ambient temperature		
	W_0	W_1	W_2	W_3	W_1	W_2	W_3
A_0	113.54 b	112.75 c	110.61 a	105.34 c	111.23 a	108.57 a	Spoiled
A_1	114.47 a	110.72 d	109.68 a	107.28 b	110.47 b	107.75 b	Spoiled
A_2	113.10 c	112.87 b	110.73 a	109.60 a	111.43 a	103.40 c	Spoiled
A_3	113.53 b	113.34 a	111.46 a	110.75 a	111.36 a	103.37 c	Spoiled
Level of significance	***	ns	ns	***	**	***	-

Note: A_0= Tap water (Control), A_1= Hot water treated (60°C for 1 min), A_2= 0.2% Calcium chloride, A_3= 0.01% Calcinated calcium, W_0 = Initial, W_1 = 1st week, W_2 = 2nd week, W_3 = 3rd week.

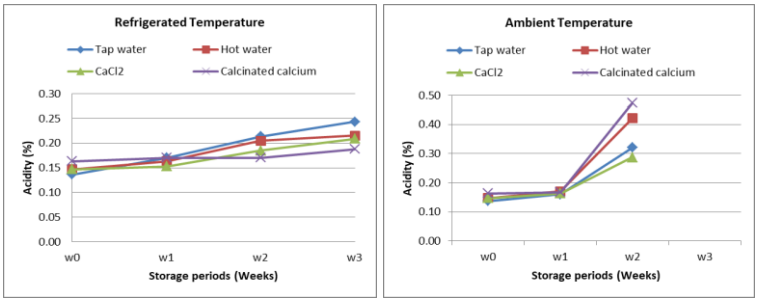

Figure 1. Effect of total acid (%) during 3 weeks' storage of fresh-cut moringa at different temperatures.

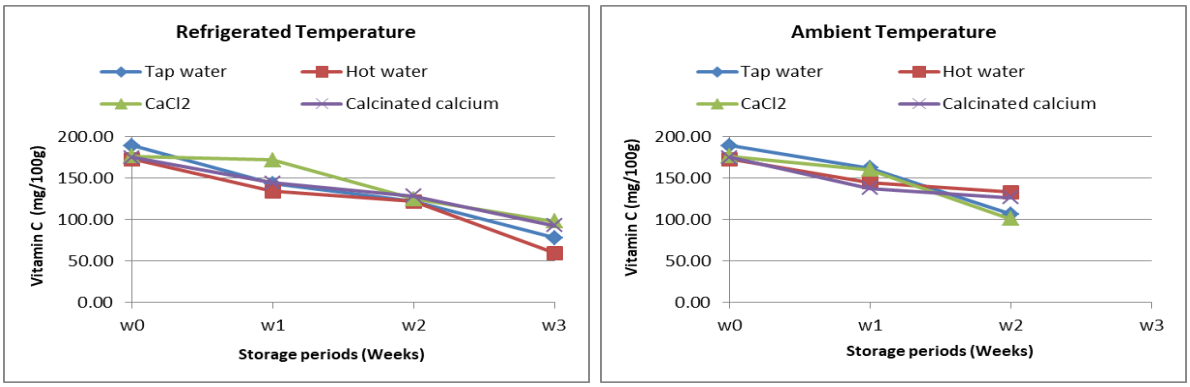

Figure 2. Effect of vitamin C (mg/100g) content during 3 weeks' storage of fresh-cut moringa at different temperatures.

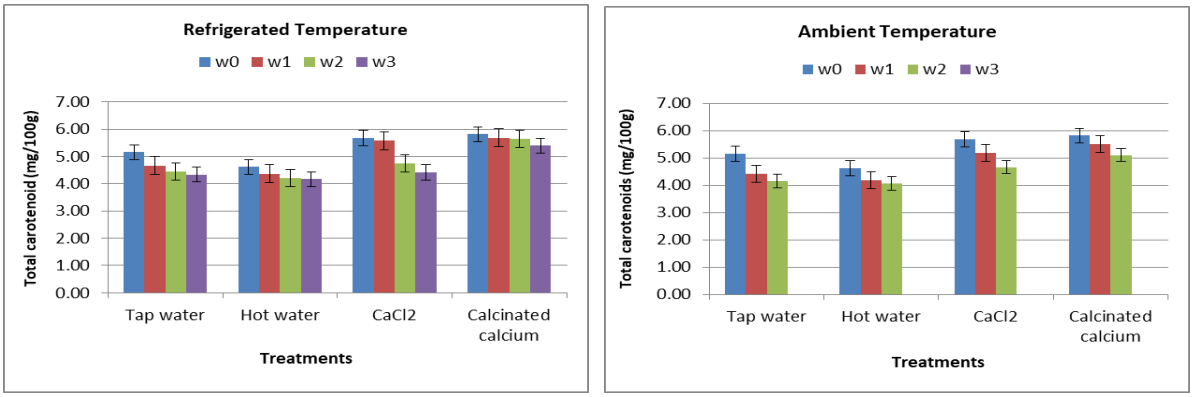

Figure 3. Effect of total carotenoid (mg/100g) content during 3 weeks' storage of fresh-cut moringa at different temperatures.

Table 4. Effect of total microbial count of fresh-cut moringa products during 3 weeks' storage at different temperatures.

Treatments	Total microbial count (cfu/g)						
	Initial	Refrigerated temperature			Ambient temperature		
	W_0	W_1	W_2	W_3	W_1	W_2	W_3
A_0	9×10^4	2.98×10^8	20.3×10^8	675×10^8	27.1×10^8	27.2×10^8	155×10^8
A_1	3×10^4	2.56×10^8	16.6×10^8	540×10^8	27.8×10^8	26.3×10^8	167×10^8
A_2	4×10^4	2.79×10^8	21.1×10^8	753×10^8	30.0×10^8	28.7×10^8	222×10^8
A_3	4×10^4	2.89×10^8	19.0×10^8	570×10^8	26.8×10^8	24.1×10^8	227×10^8

Note: A_0= Tap water (Control), A_1= Hot water treated (60°C for 1 min), A_2= 0.2% Calcium chloride, A_3= 0.01% Calcinated calcium, W_0 = Initial, W_1 = 1st week, W_2 = 2nd week, W_3 = 3rd week.

Table 5. Sensory evaluation of fresh-cut moringa products after 3 weeks' storage at different temperatures.

Treatments	Mean value of Sensory attributes							
	Refrigerated temperature				Ambient temperature			
	Appearance	Off-flavor	Shrinkage	Overall acceptability	Appearance	Off-flavor	Shrinkage	Overall acceptability
A_0	7.20	6.80	6.40	6.80	4.67	4.00	5.33	4.67
A_1	7.60	7.20	7.60	7.47	4.33	3.67	6.00	4.67
A_2	7.40	6.80	7.30	7.17	5.33	4.33	6.00	5.22
A_3	7.60	7.50	7.10	7.40	4.00	3.67	6.00	4.56

Treatments	Mean value of Sensory attributes							
	Refrigerated temperature				Ambient temperature			
	Appearance	Off-flavor	Shrinkage	Overall acceptability	Appearance	Off-flavor	Shrinkage	Overall acceptability

Note: A_0= Tap water (Control), A_1= Hot water treated (60°C for 1 min), A_2= 0.2% Calcium chloride, A_3= 0.01% Calcinated calcium, W_0 = Initial, W_1 = 1st week, W_2 = 2nd week, W_3 = 3rd week.

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 study is to increase the storage life of fresh-cut moringa in the form of ready-to-cook product. Based on the findings, it can be concluded that fresh-cut moringa can maintain its quality attributes both in physical and chemical characteristics during 3 weeks of storage at refrigerated temperature. The shelf-life of fresh-cut moringa performed better after 3 weeks at refrigerated temperature if it is treated with hot water at 60°C for 1 minute whereas only one week may be possible to store at ambient temperature. As the fresh-cut products acceptability depends on the fresh appearance and without any defects, the hot water treatment is more suitable than other treatments. Hot water treatment assists to inactive enzymatic activity and reduces microbial load to the products and refrigerated temperature acts to prevents physiological changes of the fresh-cut moringa during storage period.

Acknowledgements

The authors wish to acknowledge thanks to the supporting staffs of PHTD, BARI and other associated persons who provided information, technical and logistic support during the conducted study. The author expressed thanks and gratitude to the Nutrition Unit of 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).

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

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

Abstract

This study was conducted to identify and quantify the hazardous agents (microbial load) in fresh-cut fruits and salad vegetables collected at Rajshahi and Khulna district. Different fresh-cut fruits and salad vegetables such as guava, tomato, cucumber and carrot were collected from various hotels, restaurants and street vendor. All samples were analyzed to detect the existing different microbial agents such as *Salmonella spp*., *Escherichia coli* (*E. coli)*, 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 all samples were observed colony forming unit (cfu/g) but *Escherichia coli* (*E. coli*) and *Salmonella spp*. were absent. Our recommendations are therefore, restaurant owners, hotel owners, 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 Rajshahi and Khulna district. For qualitative survey, fresh-cut fruit/salad vegetable samples were collected to determine hazardous agent (microbiological load) from Rajshahi and Khulna district. The aim was to find out 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 of BARI in Gazipur during the year 2021-2022. Total of 20 fresh samples were collected from two districts such as Rajshahi and Khulna to analyze for microbial load (*Salmonella spp., E. coli* 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 50 mL buffered peptone water (BPW) HI Media 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 (Figure 1).

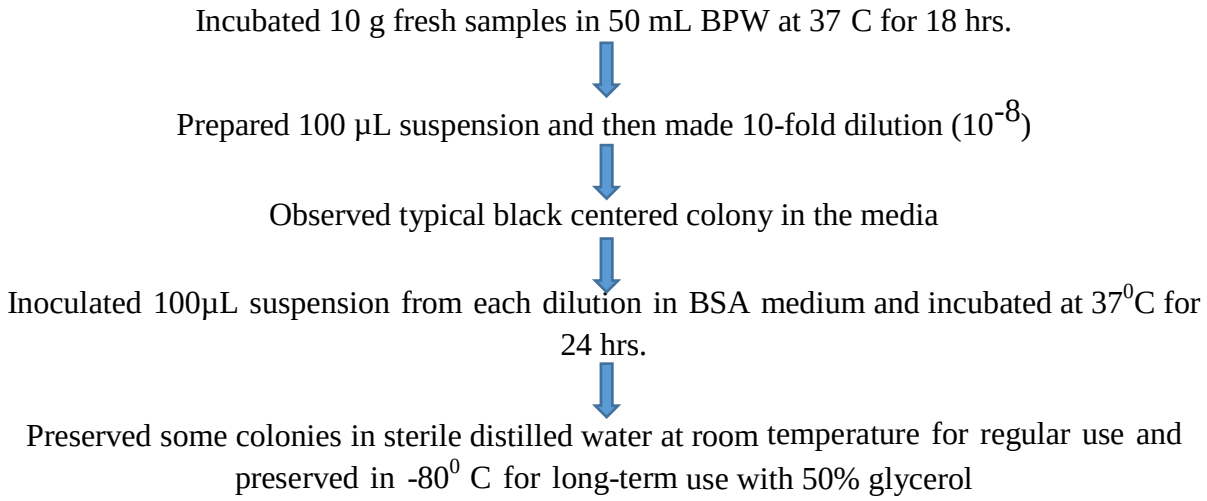

Figure 1. Flow-chart for the isolation of *Salmonella spp.* from selected fruits and salad vegetables.

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 in detectable range in collected fruits and vegetables sample are summarized in Table 2. From the below Table 2, it was noted that three restaurant samples of fresh-cut fruits and salad vegetables were not observed by *Escherichia coli* and *Salmonella spp.* only total plate count was found in both district from samples collected from three hotels, restaurant and street vendor (Table 2 & Table 3).

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 Rajshahi)

Sample code	Total plate count (cfu/g)	*E. coli* (cfu/g)	*Salmonella spp.* (cfu/g)
Sample collected from restaurant			
R_1	18×10^8	Absent	Absent
R_2	23×10^8	Absent	Absent
R_3	1200×10^8	Absent	Absent
Sample collected from hotel			
R_4	100×10^8	Absent	Absent
R_5	0.9×10^8	Absent	Absent
R_6	14×10^8	Absent	Absent
Sample code	Total plate count (cfu/g)	*E. coli (cfu/g)*	*Salmonella spp. (cfu/g)*
Sample collected from street vendor			
R_7	5×10^8	Absent	Absent
R_8	7×10^8	Absent	Absent
R_9	1.1×10^8	Absent	Absent
R_{10}	80×10^8	Absent	Absent

Table 3. Identification of food borne bacteria and quantification of the microbial load in fresh-cut fruits and salad vegetables (Sample collected from Khulna)

Sample code	Total plate count (cfu/g)	*E. coli* (cfu/g)	*Salmonella spp.* (cfu/g)
Sample collected from restaurant			
R_1	412×10^6	Absent	Absent
R_2	6730×10^6	Absent	Absent
R_3	1269×10^{-6}	Absent	Absent
Sample collected from hotel			
R_4	5960×10^6	Absent	Absent
R_5	8750×10^6	Absent	Absent
R_6	1362×10^6	Absent	Absent
Sample collected from street vendor			

R_7	9620×10^6	Absent	Absent
R_8	1338×10^6	Absent	Absent
R_9	789×10^6	Absent	Absent
R_{10}	817×10^6	Absent	Absent

Note: Detectable range followed by Table 1.

Conclusion

Fresh-cut fruits and salad vegetables are infected by different microorganisms such as *Salmonella spp. and Escherichia coli* in restaurant, hotel and street vendor. The present investigation was on the microbial load of fresh-cut fruits and salad vegetables used in popular restaurants of Rajshahi and Khulna district showed that it was safe for human consumption because they maintained hygienic condition though all parameters were not studied that time. Results remarked that those fresh-cut fruits and salad vegetables samples were contaminated which appeared during 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 to evaluate other hazardous agents in different locations and will be cross checked for conformation.

Acknowledgements

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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OPTIMIZATION OF PROCESSING TECHNIQUE FOR ROASTED JACKFRUIT SEED MAINTAINING NUTRITIONAL QUALITY

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

Abstract

Mature and full ripe jackfruit was collected from local cultivar to investigate and optimize the roasting time and temperature combination. Full ripe jackfruit bulbs were first separated from the fruit and seeds were collected from the inside of the bulb. After washing with clean tap water seeds were dried in sun at ambient condition until surface water removed. The experiment was laid out with Complete Randomized Design (CRD). All the seeds were treated as jackfruit slices roasted traditionally, jackfruit seed mixed with oil and roasted, jackfruit seed vacuum-fried and jackfruit seed mixed with oil and dried at 60^{o}C. Roasted seeds were then evaluated by forming ten judgment groups using 9-hedonic scale to determine the best treatment. According to the sensory panelists based on sensory score jackfruit seed roasted with vacuum fryer performed better at initial stage in terms of overall acceptability score 7.3 (Like moderately to like very much).

Introduction

Jackfruit (*Artocarpus heterophyllus*), national fruit of Bangladesh, grows all over in the country, mainly on the hilly area of Chattogram, Sylhet and on the highland of Gazipur, Mymensingh, Tangail, Cumilla and Jashore. It is locally known as "Kathal". In 2020-2021 around 10.97 lakh. metric tons of jackfruits have been produced from 44.63 thousand acres of land in Bangladesh (BBS, 2021). A huge portion of that amount has been destroyed or discarded due to abundance of other indigenous fruits and excess of supply than the demand. Short duration of availability is also a cause of that. Fruit may contain 100-500 seed which represents 18-25% (db) of the fruit weight. Jackfruit seeds are important by-products which consist more than 15% of total weight of a fruit (Prathima, 2008). The preliminary studies reported that this part of jackfruit is a good source of valuable nutrient components such as starch, protein and minerals (Ocloo *et al.,* 2010). Currently, jackfruit seeds are underutilized in both human and animal diets. Common reason for not consuming seeds is that it is not a traditional practice. Most peoples are not aware about the usage of seeds flour. Lack of awareness on nutrient contents and decent technologies for utilization of jackfruit seeds in food formulations are greatly responsible for such wastes of this fruit seeds (Gunasena *et al.,* 1996). The seed are light brown in color and generally 2-3 cm in length and 1-1.5 cm in diameter. Seed of ripe fruits have 55% moisture content so it cannot be stored for long period. Jackfruit seeds are good sources of thiamine and riboflavin. Both of these 'B' vitamins help turn the food to get energy and keep human skin, eyes and hair healthy. These seeds also provide at least small amounts of the minerals zinc, iron, calcium, copper, potassium and manganese. Roasted jackfruit seeds serve as great snacks. If cooked longer, it gets a potato-like, dry texture and taste like chestnuts. Roasted and dried seeds are ground to make flour that is blended with wheat flour for baking (Morton, 1987). The composition of jackfruit perianth and seed have been reported (Bobbio *et al.,* 1978; Morton, 1987; Selvaraj and Pal, 1989; Rahman *et al.,* 1995). At least one study has reported on functional properties of jackfruit flour (Odoemelam, 2005). If the seed roasted less, the product will be moister and creamy, so the seed are also perfect to make jackfruit soup. Benefits of jackfruit seeds are: to combat anemia, improve digestive health, boost vision, reduce risk of blood clots, help build muscles, fight wrinkles, make skin glow, enhance hair growth. On the above circumstance, the above study was conducted to optimize the processing parameters of roasted jackfruit seed with maintaining shelf life and nutritional quality.

Materials and Methods

Collection of jackfruit for roasted seed

Fresh and mature ripe jackfruits of unknown cultivar having average fruit weight, 8-10 kg was collected from the farmer's field of Sreepur under Gazipur district and transported to the laboratory of PHTD, BARI, Gazipur for conducting the study.

Preparation of jackfruit seeds

Matured jackfruit collected from the farmer's field Sreepur, Gazipur and were immediately transported to the PHTD laboratory for the experiment. The jackfruits were washed, peeled, and the seed were separated from the bulb. The seeds were either sliced length wise or in circular form. Then, the slices were packed in HDPE packet and stored in at -18^{o}C for further use. Before applying the treatments, jackfruit seeds were blanched for 10 min in boiling water. Following treatments were used in this study: (a) jackfruit slices roasted traditionally, (b) jackfruit seed mixed with oil and roasted, (c) jackfruit seed vacuum-fried, (d) jackfruit seed mixed with oil and dried at 60^{o}C. The roasted slices were packed in Metalax foil packet and sealed with nitrogen flash and stored in room temperature at a cool and dry place for storage study. The developed protocol is as follows (Figure 1 & Figure 2):

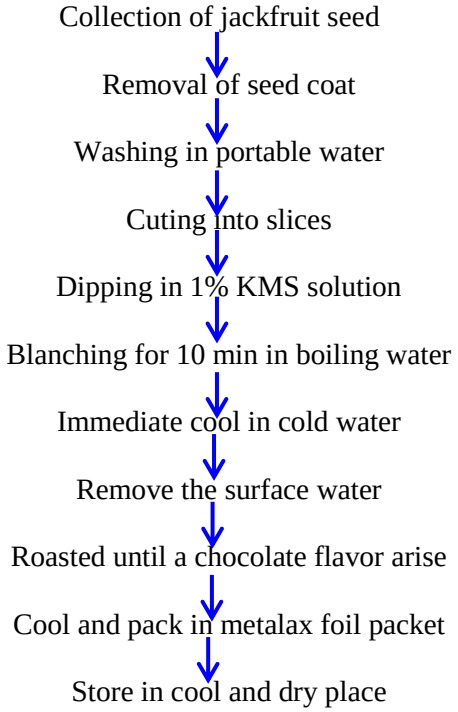

Figure 1. Process Flow Diagram for Roasted Jackfruit Seed

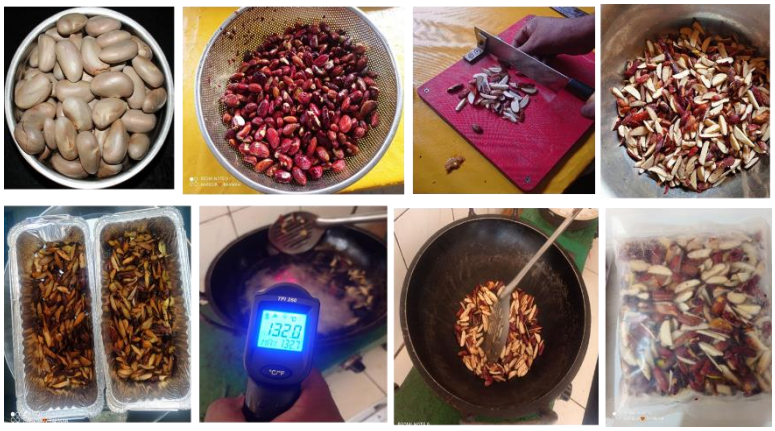

Figure 2. Photographic view of Roasted Jackfruit Seed.

Determination of physicochemical properties of roasted jackfruit seeds

Color attributes were measured based on the CIEL a*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. Textural properties of roasted jackfruit seed 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. The moisture and ash content were determined based on the AOAC official methods (AOAC, 2005).

Determination of bioactive compounds of roasted jackfruit seeds

Ascorbic acid (Vitamin C) 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 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.

Sensory evaluation of roasted jackfruit seeds

Stored roasted jackfruit slices were examined using organoleptic test by a panelists comprising of scientific staff for appearance, color, flavor, texture, aroma, crispiness, taste and overall acceptance. Hedonic scale was used to make the different parameters. In this scale 'like extremely", is given the highest score of '9' and 'dislike extremely' is given the lowest score '1'. Others are given intermediate scores.

Statistical analysis

All the obtained data were analyzed using IBM SPSS (Version 22.0, SPSS Inc., Chicago, IL) statistical software and the results were expressed as the mean value ± standard deviation of three replicates. The Duncan's Multiple Range Test (DMRT) was used to evaluate the statistically significant differences among the mean values of the analyzed parameters at $p<0.05$.

Results and Discussion

Changes of physical appearance and firmness of roasted jackfruit seeds

Color changes of roasted jackfruit seed can be visually detected, but in this study Lightness (L*), Chroma (C*) and Hue angle (H*), color indicator were measured using a chromameter and it was mentioned in Table 1. Initially lightness (L*) value of roasted jackfruit seed slices were significantly difference among the treatments. The highest lightness value was observed at vacuum fried roasted jackfruit seed slices (53.49 a) which was followed by control treatment (47.27 b) and roasted jackfruit seed mixed with oil and dried at 60^{o}C (42.59 bc) (Table 1). Similarly, chroma value and hue angle were significantly difference initially among the treatments after roasting of jackfruit seed. The maximum chroma (C*) value was observed in jackfruit seed roasted in oil fry (27.09 a) which was followed by control treatment (26.18 a) and jackfruit seed roasted with vacuum fryer (23.10 ab). The highest hue angle value was found in jackfruit seed roasted mixed with oil and dried at 60^{o}C (71.58 ab) followed by roasted with oil (69.38 ab) and control treatment (65.12 bc) (Table 1). Overall, the color value indicates that chlorophyll composition and degradation changes with storage condition where carotenoid degradation and enzymatic action occur (Pantastico, 1997). In addition, the changes in color during frying were the results of starch gelatinization and non-enzymatic browning reactions (Garayo and Moreira, 2002).

In Table 1, it was observed that firmness value of roasted jackfruit seed for all treatments were highly significant difference at initial stage ($p<0.05$). In case of firmness, the maximum (86.94 a N) was observed in jackfruit seed mixed with oil and then dried at 60^{o}C which was followed by jackfruit seed roasted with oil (39.51 b N) and the minimum (8.74 d N) was found in jackfruit seed fried using vacuum fryer followed by control treatment (26.51 c N) (Table 1). Firmness increases in breaking force at the end of storage period. 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.* (2001) observed the increase in breaking force of banana chips which was stored in polypropylene film packet during storage. The data recording is in progress during storage study.

Changes of physicochemical properties of roasted jackfruit seeds

In Table 2, it was observed that the moisture content value were highly significant difference among the treatments at initial stage. From the observation (Table 2), it was found that an increase in the oil temperature resultant in a significant reduction ($p<0.05$) of moisture retention of the fried or roasted jackfruit seed with the same pressure. The maximum moisture was found in control treatment (11.97%) followed by jackfruit seed roasted with oil and dried at 60^{o}C (7.36%) and the minimum was noticed in vacuum fried product (5.74%). Similarly, there were no significant difference in case of ash, vitamin C and total phenolic compounds initially after roasting the jackfruit seed in all treatments (Table 2). But ß-carotene was significantly difference among the treatments at initial stage. The highest ß-carotene content was found in jackfruit seed roasted in oil (17.50 mg/100g) followed by jackfruit seed fried using vacuum fryer (14.50 mg/100g) and jackfruit seed mixed with oil and dried at 60^{o}C (14.50 mg/100g) (Table 2). The data recording is in progress during storage study.

Sensory evaluation

To find out the best processing parameters of roasted jackfruit seed organoleptic test was performed with a 9-points hedonic score based on appearance, color, texture, aroma, crispiness, taste and overall acceptability by the expert sensory panelists. In Table 3a & Table 3b, it was observed that at initial stage the highest overall acceptability score 7.3 (Like moderately to like very much) was observed in jackfruit seed roasted with vacuum fryer and the lowest (4.7) was found in jackfruit seed roasted with oil and then dried at 60^{o}C. Among the treatment, jackfruit seed roasted with vacuum fryer performed better considering all sensory attributes at initial stage (Table 3a & Table 3b).

Table 1. Effect of physical appearance and firmness on roasted jackfruit seed at initial stage

Treatment	Lightness (L*)	Chroma (C*)	Hue angle (H*)	Firmness (N)
Traditionally roasted (Control)	47.27 b	26.18 a	65.12 bc	26.51 c
Roasted with oil	39.18 c	27.09 a	69.38 ab	39.51 b
Vacuum fried	53.49 a	23.10 ab	71.58 a	8.74 d
Mixed with oil & dried at 60^{o}C	42.59 bc	18.15 c	62.86 c	86.94 a
Level of significance	**	*	*	***

Table 2. Effect of physiochemical properties (% Moisture, % ash, mg/100g vitamin C, mg/100g ß-carotene and GAE/100g phenolic content) on roasted jackfruit seed at initial stage

Treatment	Moisture (%)	Ash (%)	Vitamin C (mg/100g)	ß-carotene (mg/100g)	Total phenol (GAE/100g)
Traditionally roasted (Control)	11.97 a	2.25	4.37	10.41 b	15.28
Roasted with oil	6.03 b	1.12	3.75	17.50 a	10.80
Vacuum fried	5.74 c	1.59	7.10	14.50 ab	11.69
Mixed with oil & dried at 60^{o}C	7.36 b	2.17	5.85	14.40 ab	12.35
Level of significance	***	ns	ns	*	ns

Table 3a. Sensory evaluation of roasted jackfruit seeds at initial stage

Treatment	Mean value of sensory attributes			
	Appearance	Color	Texture	Aroma
Traditionally roasted (Control)	4.9	5.0	4.7	4.9
Roasted with oil	5.3	5.2	5.2	5.2
Vacuum fried	7.4	7.1	6.9	6.8
Mixed with oil & dried at 60^{o}C	5.0	4.8	4.2	4.2

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 3b. Sensory evaluation of roasted jackfruit seeds at initial stage

Treatment	Mean value of sensory attributes		
	Crispiness	Taste	Overall Acceptability
Traditionally roasted (Control)	5.4	5.2	5.1
Roasted with oil	4.9	5.0	5.3
Vacuum fried	7.3	7.5	7.3
Mixed with oil & dried at 60^{o}C	4.6	4.1	4.7

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 processing parameters of roasted jackfruit seed with maintaining quality during longer storage at ambient condition. Without proper processing, roasted jackfruit seed turns into brownish or black rapidly due to catalase enzymatic action that hampered the appearance of the products. In addition, improper roasting of jackfruit seed the product may loss its crispiness or may hard for taste. To retain quality of the product, proper packaging is important. If moisture transfer happens inside the packet, then mold and different microbes have possibility to grow. In this case, the product becomes start rotting and develop off-flavor. According to the sensory panelists based on sensory score jackfruit seed roasted with vacuum fryer performed better at initial stage in terms of overall acceptability score 7.3 (Like moderately to like very much). The study is in progress for nutrition and keeping quality evaluation during storage.

Acknowledgements

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DEVELOPMENT OF VALUE ADDED READY TO SERVE (RTS) SAPOTA POWDER THROUGH FORTIFICATION BY ASCORBIC ACID AND β-CAROTENE

M.H.H. KHAN, M.M. MOLLA, A. A. SABUZ, M.G.F. CHOUDHURY, S. PERVIN, P.C. SARKER AND A.K. CHOWDHURY

Abstarct

This study aimed to develop a process for the development of ready to serve (RTS) sapota powder through fortification. The fortified sapota powder was stored at room temperature for storage stability and further nutritional evaluation. Results obtained from 150 days' studies show that sapota powder fortified with L-ascorbic acid and combination of L-ascorbic acid and β-carotene was excellent with retention of the primary quality attributes of ascorbic acid and β-carotene. The sapota RTS powder fortified with L-ascorbic acid and combination of L-ascorbic acid and β-carotene was acceptable by the sensory evaluation of the panel members in terms of their color, flavor, appearances, sweetness and overall acceptability. No microbial count was recorded up to 120 days (4 months) and 150 days (5 months) of storage. A negligible amount of microbial count was recorded after 150 days of storage but it was within acceptable limit. Therefore, the developed RTS sapota powder could use as an alternative of synthetic TANG health drink for better sustainability school going children.

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. Previous research has shown the different products viz. sapota jam, sapota marmalade, sapota candy etc. produced from sapota. Still now, sapota instant powder to make RTS drink as an alternative of TANG is meager in the country. Hence, the present study has undertaken to fortify and develop value added sapota powder to make instant sapota powder.

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 and drying of the 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 dried and the powder was prepared according to the Fig.1 and Fig.2.

Selection of firm ripe fruit
↓
Washing of fruit
↓
Preparation of fruit
(Removal of peel core and seed)
↓
Extraction of pulp
↓
Placing the pulp into perforated stainless steel tray
↓
Cabinet drying of the pulp at 60±1°C
↓
Grinding the dried powder
↓
Sieving through 60 mesh sieve
↓
Fortification of the dried powder
↓
Packing in aluminium foil laminated pouches
↓
Storing at a cool and dry place at room temperature

Fig 1: Process flow chart for sapota powder.

Fig.2. Extracted and fortified sapota pulp powder.

Fortification of sapota powder

Fortification was done with ascorbic acid and beta-carotene (Table 1) to enhance the nutritive value, improve taste, appearance or color and sweetness to replace nutrients lost during processing. Ascorbic acid and beta-carotene are added at the rate of 1000 mg per 10g of powder respectively.

Table 1. Fortification of sapota powder

Ingredients	Quantity			
	T_1	T_2	T_3	T_4
Sapota powder	10g	10g	10g	10g
Sugar	75g	75g	75g	75g
Salt	3g	3g	3g	3g
Water	100 ml	100 ml	100 ml	100 ml
Ascorbic acid	-	1.0 g	-	-
β-carotene	-	-	1.0 g	-
Ascorbic acid+ β-carotene	-	-	-	1.0 g+1.0 g

Sensory evaluation of RTS sapota powder

Sensory evaluation of fresh and fortified sapota powder was done by formatting taste testing panel. The taste-testing panel was consisted of ten judges. They were asked to evaluate color, flavor, appearance, sweetness and overall acceptability of the product.

Results and discussion

Proximate and nutritional composition of sapota pulp

The proximate and nutritional composition analysis of the sapota pulp 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 (Table 2). TSS is sufficiently presented in the sapota pulp. It is primarily represented by sugars, with acids and minerals contributing. Results revealed that sapota is the rich source of vitamin-C (72.42±1.01 mg/100 g), ß-carotene (27.82±0.41 mg/100 g) and Total carotenoid (39.21±0.20 mg/100 g). 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).

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

Parameter	Fresh sapota pulp	LSD
TSS (°B)	15.25±0.24	*
Vitamin-C (mg/100 g)	72.42±1.01	*
ß-carotene (mg/100 g)	27.82±0.41	*
Total carotenoid (mg/100 g)	39.21±0.20	*
Total sugar (%)	18.57±0.56	*
Reducing sugar (%)	5.43±0.47	*
Acidity (%)	0.63±0.02	*
pH	5.25±0.24	NS
Ash (%)	2.33±0.02	*
Moisture (%)	70.01±0.10	*

All values are means of triplicate determinations ± SD. * indicates significant result ($p<0.05$). NS means non-significant letter.

Drying time and temperature: The mechanical drying method took time 40±2 hours at the temperature of 60±1^{o}C.

Air flow rate, relative humidity and drying ratio: At 60±1^{o}C the air flow rate of mechanically dried sapota powder was 1.3-1.4 m/s. It was observed that the air flow rate was increased with the fluctuation of drying temperature. The relative humidity of the drying air and drying ratio was 40% and 4:1(Table 3).

Table 3. Air flow rate, relative humidity, drying ratio, drying time and temperature of sapota powder

Air flow rate (m/s)	Relative humidity (%)	Drying ratio	Drying time (hrs)	Drying temperature (^oC)
1.3-1.4	40	4:1	40±2	60±2^oC

Physicochemical and nutritional properties of the stored sapota powder

After fortification, the RTS powder has been stored at room temperature and refrigerated temperature (3 to 5^oC) for its further analysis on various physicochemical and nutritional changes. The marketable life and microbiological activities of the RTS powder is also under supervision.

Energy content

Statistically highly significant differences were observed among the fortified treatment of the sapota RTS powder (Table 4). The energy content was calculated as cal/g of the powder. The highest energy content was recorded as 406.67±3.97 cal/g and 415.83±3.05 cal/g by the fortified treatment T_2 and T_4 indicates that the sapota powder fortified by the L-ascorbic acid and combination of L-ascorbic acid and β-carotene contributed to gain high energy value of the sapota powder.

Table 4. Energy content of sapota RTS powder.

Treatment	Energy (Cal/g)
T_1	373.34±1.99c
T_2	406.67±3.97b
T_3	377.04±1.55c
T_4	415.83±3.05a

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

Sensory evaluation of the fortified RTS sapota powder

The score obtained for T_2 and T_4 by the expert judgment in terms of color, flavor, appearance, mouth feel, sweetness and overall acceptability was higher than others (Table 5). The lowest score in terms of color, flavor, appearance, mouth feel, sweetness and overall acceptability was found in control treatment T_1. Hence, T_1 was not liked by the panel of judges. On the other hand, the fortification with ascorbic acid and β-carotene combination contributed to achieve higher color, flavor, appearance and sweetness of the treatment T_4. Hence, the treated RTS sapota powder T_4 was accepted by the all judges of the panelist.

Table 5. Sensory evaluation of fortified RTS sapota powder

Treatment	Color	Flavor	Appearance	Mouth feel	Sweetness	Overall acceptability
T_1	$5.10\pm0.0.99^b$	5.20 ± 1.03^c	4.90 ± 1.19^c	5.30 ± 0.82^d	6.20 ± 1.03^b	5.72 ± 0.66^c
T_2	8.00 ± 0.66^a	7.70 ± 0.48^{ab}	8.10 ± 0.56^a	7.50 ± 0.53^b	7.90 ± 0.56^a	7.84 ± 0.27^a
T_3	5.43 ± 0.814^b	6.80 ± 1.03^b	6.60 ± 0.96^b	6.50 ± 0.97^c	7.70 ± 1.63^a	6.30 ± 0.63^b
T_4	8.38 ± 0.32^a	8.20 ± 1.03^a	8.30 ± 0.95^a	8.40 ± 0.52^a	8.10 ± 0.96^a	8.19 ± 0.38^a

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

Microbial count

Table 6 shows the microbial count of the fortified RTS sapota powder inter 30 days' interval of storage. No microorganism was observed initially due to the high dried powder was used for the enumeration. After 120 days of storage, no aspergillus, shijella and e-coli was detected in the treated RTS sapota powder. But after 150 days (5 months), few aspergillus, Shijella and E-coli was detected but they were acceptable limit. Further storage studies and microbial count is under supervised.

Table 6. Microbial counts of the fortified RTS sapota powder

Treatments	Microbial counts (storage periods)				
	30 Day	60 Day	90 Day	120 Day	150 Day
			Aspergillus (cfu/g)		
T_1	ND	ND	ND	ND	3.1×10^3
T_2	ND	ND	ND	ND	$2.3x\ 10^3$
T_3	ND	ND	ND	ND	$2.6x\ 10^3$
T_4	ND	ND	ND	ND	1.5×10^3
			Shijella (cfu/g)		
T_1	ND	ND	ND	ND	2.3×10^7
T_2	ND	ND	ND	ND	1.4×10^7
T_3	ND	ND	ND	ND	1.2×10^7
T_4	ND	ND	ND	ND	1.1×10^7
			E-coli (cfu/g)		
T_1	ND	ND	ND	ND	1.0×10^3
T_2	ND	ND	ND	ND	0.3×10^3
T_3	ND	ND	ND	ND	0.5×10^3
T_4	ND	ND	ND	ND	0.3×10^3

ND= Not Detected

Conclusion

The RTS sapota powder fortified using L-ascorbic acid and β-carotene. All the fortified powdered were then incorporated to analyze their physicochemical, nutritional and energy value. The fortified products were microbiologically and sensory evaluated by the microbial count and formation of judgment panelist. The microbiological reports confirm that all the fortified powder was acceptable limit up to 150 days (5 months) of storage. The fortified treatment T_2 and T_4 was more acceptable by the panelist of the sensory attributes. The fortified RTS sapota powder could be used as an alternative to synthetic TANG drinks Therefore; it could be recommended as a health drink for better sustainability in the country market. Further research should be continued to develop mini pack and Food X-ray for more confirmation to use as ready to serve (RTS) drink powder for school going children.

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Additional works performed by the division (2021-2022)

SL No.	Date	Name of Institute/ Person	Name of Sample	No. of Sample	No. of Parameter
01.	15.07.2021	Entomology Division, BARI	Mango	07	08
02.	31.08.2021	TCRC, BARI	Potato	16	07
03.	12.09.2021	BSMRAU Student	Mango	03	06
04.	12.09.2021	Hoimonty Barua, PhD Student	Guava	36	06
05.	27.09.2021	Pahartali, Chottogram, Student	Guava, Anola, Pomelo	13	08
06.	28.09.2021	SAU, Dhaka	Biscuit	06	02
07.	31.10.2021	TCRC, BARI	Taro Root	03	07
08.	02.11.2021	TCRC, BARI	Aroids	02	03
09.	22.11.2020	HRC, BARI, Gazipur	Pomelo	02	06
10.	13.03.2022	RARS, Akbarpur	Jackfruit	03	05
11.	13.03.2022	SSD, BARI, Gazipur	Cauliflower	12	03
12.	29.03.2022	Agronomy Division, BARI	Tomato	05	01
13.	29.03.2022	TCRC, BARI	Cassava	06	08
14.	29.03.2022	TCRC, BARI	Potato Leaf	17	05
15.	05.04.2022	TCRC, BARI	Potato	02	05
16.	07.04.2022	TCRC, BARI	Sweet Potato	08	10
17.	11.04.2022	TCRC, BARI	Sweet Potato	09	10
18.	11.04.2022	TCRC, BARI	Stolon	10	05
19.	12.04.2022	RARS, Jamalpur	Tomato	05	05
20.	24.04.2022	HRC, BARI	Jackfruit	02	06
21.	24.04.2022	SSD, BARI	Bitter Gourd	10	02
22.	12.05.2022	ARS, Khulshi, BARI	Star Gooseberry	03	06
23.	25.06.2022	ARS, Ramgar, Khagrachari	Egg Fruit	02	08
			Total number of sample analyzed		**182**