ISSN: 1991-0037 (print), 2710-3285 (online)
SOUTH ASIAN JOURNAL OF AGRICULTURE
https://www.banglajol.info/index.php/SAJA
Agrotechnology Discipline, Khulna University
https://ku.ac.bd/discipline/at

OPEN ACCESS

South Asian J. Agric.

Research Article

Vol. 10, No. 1&2, 2024: 36-46

Title: Effects of Frying Temperature-Time Combination on Physicochemical, Bioactive Compounds Changes and Storage Life of Vacuum Fried Jackfruit Chips

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Article Info:

Received:
December 29, 2023

Accepted:
September 28, 2024

Keywords:
Jackfruit bulb, maturity index, vacuum fryer, vegetables oil, nutritional quality, shelf life

ABSTRACT

The aim of the study was to optimize the vacuum fried jackfruit chips processing to produce high quality jackfruit chips at suitable frying temperature and time. Jackfruit chips were prepared from matured khaja type jackfruit. The harvested matured jackfruit was cut into halves and separated the bulbs. The seed was removed and bulb was sliced into about 5 mm thickness and then packaged in high density polyethylene (HDPE) packet (~60 micron) and frozen at -18ºC for 24 - 48 hours. Then the frozen slices were fried instantly using BARI Vacuum Frying Machine at 100,110 and 120ºC for 5, 10, 15, 20 and 25 minutes, respectively. The fried chips were de-oiled using BARI De-oiling Machine at 1400 rpm for 3 minutes. Finally, the de-oiled chips were packaged in metalex foil (~50 micron) packet without nitrogen gas and sealed for storage at ambient temperature (26±2ºC, 75±5%RH). Then the changes of physicochemical properties with different frying temperature and time at one-month interval upto six months and consumer preference test was evaluated by expert sensory panelists. According to the sensory panelist, the best frying temperature and time combination was found 110ºC for 25 minutes and 120 ºC for 20 minutes where sensory scored 8.12 and 7.88, respectively. The study will generate the information to the food processors and product development sectors to find out proper ways and means of processing and production of good quality vacuum fried jackfruit chips and thus mitigate the postharvest losses by extending the shelf life and marketability.

DOI: https://doi.org/10.3329/saja.v10i1.80237

To cite this article: Chowdhury, M. G. F., Khan, M. H. H., Molla, M., Alam, M., Islam, R., & Shikder, M. F. H. (2024). Effects of frying temperature-time combination on physicochemical, bioactive compounds changes, and storage life of vacuum fried jackfruit chips. *South Asian Journal of Agriculture,* 10(1&2): 36-46.

INTRODUCTION

Jackfruit is dicotyledonous compound fruit of the jackfruit tree (*Artocapus heterophyllus*) which belongs to the family Moraceae and grow commonly in the tropical countries of the Southeast Asia. Bangladesh, Thailand, Indonesia, and Malaysia which are the top five producers of jackfruits in the world with a total production of approximately 3.11 million tons per year (Sidhu, 2012; Saxena et al., 2013). Its

interior consists of eye-catching orange-yellow color edible bulbs and each bulb consists of sweet flesh (sheath) that encloses a smooth, oval, light, brown seed (Golderberg, 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 and Bapat, 2010). Due to a low yield of edible portion (around 35% of whole fruit), transportation and storage of raw jackfruit is not particularly economical (Saxena et al., 2012). Different preservation/processing methods have been developed to preserve this multi-nutritional and perishable fruits. However, a large amount of jackfruits still get spoiled due to lack of proper preservation/processing technology, an integrated supply chain, and/or storage facilities during the peak seasons of harvest.

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

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

MATERIALS AND METHODS

Collection of fruit, processing and frying conditions

Physiologically matured khaja type Jackfruit was collected from the Cotton Research, Training and Seed Multiplication Farm, Sreepur, Gazipur to the packhouse of Postharvest Technology Division, BARI, Gazipur. Jackfruits were sorted out from any harvesting and transportation injured and cleaned by washing with potable water. After peeling and decoring, the jackfruit bulbs were separated. The internal seed was removed by cutting into halves by sharp knives and then sliced at 5 mm thickness. After that jackfruit slices were sealed in HDPE packets and frozen at -18ºC in deep fridge for 24-48 hrs. (Figure 1). One batch/kilogram of processed jackfruit slices was placed in the vessel and fried in 15 L of vegetable oil below atmospheric pressure. After vacuum frying, the fried jackfruit chips were de-oiled for 2 minutes at 1400 rpm using BARI de-oiled machine to remove the excess frying oil. After de-oiling, the fried jackfruit chips were cooled then added spices and packed in HDPE packet with proper sealing and stored at ambient temperature (26±2ºC and 75±5% RH). The treatments studied in this work were: (1) Jackfruit chips

were fried at three levels of frying temperature (100, 110 and 120ºC); (2) frying time at5 minutes intervals (5, 10, 15, 20 and 25 minutes). Shelf-life study with physicochemical properties changes were evaluated upto six (06) months at one month interval. The following steps were maintained to process the jackfruit for preparing quality VF jackfruit chips.

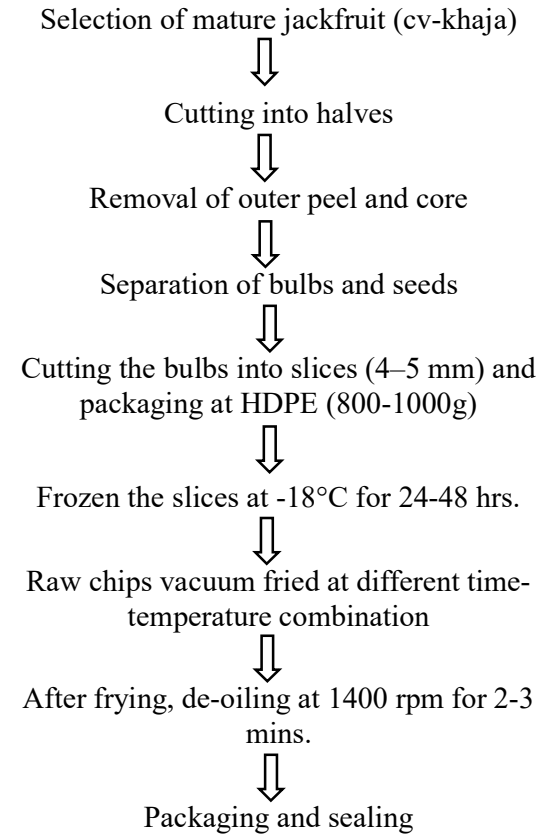

Figure 1. Diagram for the processing of vacuum fried jackfruit chips

Measurements of external appearance

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

Measurements of moisture content

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

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

Measurements of total carotenoids content

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

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. The mixture was then centrifuged, and the residue was retained. This extraction process was repeated several times by washing the residue with ethanol until the color was removed, as indicated by the anthrone reagent. Perchloric acid was added to the retained residue, followed by another

round of centrifugation. The resulting supernatant was collected and adjusted to a volume of 100 ml. To this solution, 4 ml of anthrone reagent was added, and the mixture was heated to boiling. After rapid cooling, the color intensity was measured at 630ηm using a UV-Spectrophotometer.

Sensory evaluation

The VF jackfruit chips products subjected to different frying temperature and time combinations for evaluating the changes in the sensory quality attributes. Few panel tests were performed at one month interval during storage period. Based on a 0-9 hedonic scale the highest response was marked and comments of the expert persons were documented for quality improvement as per the procedure of Molla et al. (2008). 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 duplicate as means ± standard deviation. One-way ANOVA with posthoc by Tukey Multiple Comparison Test was used to evaluation of the recorded data. The connotation was stated at the 95% confidence level. Statistical analysis and data processing were performed using software SPSS 17.0 (IBM INC., New York).

RESULTS AND DISCUSSION

Effects of appearance at different frying conditions and storage

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

The $a*$ value of the VF jackfruit chips was found to increase with the progress of frying duration at all the frying temperatures (Table 2). The a* value ranged from 2.16 to 4.94. The increase was very rapid at120°C compared to other frying temperatures. During storage, a* values started to increase in all treatments. After six months of storage, a* value ranged from 5.96 to 8.77. Significant alterations were observed at lower temperatures of 100°C for low frying time 5 min and 110°C for 10 min frying durations. Changes in $a*$ value indicated development of golden brown to dark brown color in jackfruit chips due to incomplete frying with higher moisture level that causes browning reactions, breakdown of the chemical compounds and fungal growth (Garayo and Moreira, 2002).

Moisture content changes at different frying conditions and storage

The moisture loss from the jackfruit bulbs under vacuum at different frying temperature and time is illustrated in Table 3. There were significant ($p \leq 0.05$) differences in moisture content in the VF jackfruit chips. From the observation, the result indicated that at each temperature frying at 5 and 10 minutes produced incomplete fried chips due to less crispiness. The moisture content of the jackfruit chips were ranges from 40.38% to 1.83% at 100°C for 5 minutes and 120°C for 25 minutes, respectively. Since the frying is

carried out under vacuum which decreases the boiling point of water, moisture removal was instant without much warm-up. After storage, the moisture content increased in each treatment ranges 3.25% to 44.11% due to the absorbance of moisture with microspores of the packaging materials. Since the frying was carried out under vacuum which decreased the boiling point of water, moisture removal was instant from jackfruit slices without much warm-up phase. The phenomenon is in accordance with the findings for vacuum fried potato chips (Yagua and Moreira, 2011).

Starch content changes at different frying conditions and storage

There were significant differences observed in starch content in the jackfruit chips fried at different temperature and time. During frying starch became gelatinized due to heating and the products become crisp in nature. The starch content ranges from 15.91% to 17.88% after frying. Jackfruit bulbs fried at lower temperature for shorter time (100°C for 10 minutes) caused higher starch content (17.88%) due to incomplete frying but it decayed drastically up to 13.24% during six months' storage. During storage, starch started broken down ranged from 10.15% to 13.25% by converting into sugar. The starch content in the jackfruit chips is illustrated in the Figure as line diagram in Figure 2. Starch content of potato tubers determined the texture of processed product and positively correlated with the dry matter (Uppal, 1999).

Total carotenoid content changes at different frying conditions and storage

The yellow color of jackfruit chips was due to the presence of carotenoids which were found to degrade during frying. Total carotenoid content were degraded after frying. The carotenoids content ranged from 5.62 to 6.57 mg/100g after frying. Jackfruit bulbs fried at lower temperature lower time caused higher starch content but it decayed drastically 4.08mg/100gduring six months storage. The total carotenoids content in the jackfruit chips is illustrated in the Figure as bar diagram in Figure 3. The carotenoid molecule has a characteristic conjugated polyene which is highly susceptible to degradation due to oxidation (Boon et al., 2010). Further, carotenoid was reported to be deteriorated by several researchers during thermal processing depending on the type of raw material and the temperature involved in processing (Ahmed et al., 2002; Koca et al., 2007).

Sensory evaluation at different frying conditions and storage

Vacuum fried jackfruit chips were assessed for sensory acceptability in terms of appearance, taste, flavor, crispiness, oiliness and overall acceptability. The sensory score for jackfruit color was rated high during chips frying at higher temperature with time. It was observed that yellow flesh turned into golden yellow during vacuum frying. Jackfruit chips fried at higher temperature 120°C with longer frying time (over 25 min) ensure lower the sensory score due to over frying and undesirable surface browning of the slices, which occurred caramelization of sugar. Higher frying temperature exhibited crispiness faster. In case of sensory evaluation, the highest overall acceptability 6.56 and 6.15 were observed in the treatments of 110°C for 25 min and120°C for 20 min, respectively (Table 5). In the experimentation, temperatures 100°C, 110°C and 120°Cfor 5, 10 and 15 minutes were belonged to sensory score under 5 (Neither like or dislike) for the development of the VF jackfruit chips due to incomplete frying and less crispiness (Table 5).

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

Treatments		Lightness (L*) value			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	5	59.17±0.41f	47.69±0.49f	46.41±0.50f	44.77±0.47d
	10	62.63±0.65bc	55.23±0.94de	48.39±0.65f	45.23±0.03d
	15	64.98±0.26ab	63.19±0.34ab	57.81±0.41bcd	54.36±0.15bc
	20	67.48±0.95a	62.29±0.68ab	57.98±0.66bcd	54.07±0.13bc
	25	62.44±0.73ab	62.46±0.06ab	60.14±0.77abc	58.53±0.49ab
110°C	5	56.76±0.51ef	52.34±0.42e	47.52±0.27f	44.14±1.57d
	10	62.52±0.57bc	52.26±0.82e	46.46±0.39f	48.27±1.17cd
	15	63.96±0.32ab	61.19±0.68abc	56.83±0.54cd	55.55±0.56b
	20	63.34±0.06ab	60.49±0.48bc	58.11±0.20bcd	55.89±0.60b
	25	62.95±0.40bc	62.35±1.01ab	61.46±0.84ab	60.05±0.05ab
120°C	5	60.37±0.87cd	57.96±0.21cd	52.56±0.62e	45.86±0.08d
	10	65.05±0.34ab	61.84±1.06ab	57.64±0.92cd	55.18±0.03b
	15	66.23±0.50a	63.97±1.73a	62.40±0.10a	62.53±0.29a
	20	65.38±0.06ab	63.22±0.93ab	63.81±0.48a	59.56±0.40ab
	25	57.89±0.09de	56.62±0.54d	55.74±0.64de	54.85±0.15bc

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

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

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

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

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

Treatments		Moisture (%)			
Temperature	Time (min)	Initial	2 months	4 months	6 months
100°C	5	40.83±1.91a	41.18±0.18a	42.17±0.15a	44.11±0.10a
	10	8.11±0.59d	10.24±0.31d	10.60±0.24c	11.81±0.13d
	15	3.61±0.23ef	4.34±0.18f	5.02±0.02e	5.96±0.06f
	20	2.69±0.03ef	2.84±0.02g	3.28±0.14f	3.73±0.06h
	25	2.60±0.08ef	2.87±0.01g	3.19±0.00fg	3.70±0.01h
110°C	5	27.18±0.31b	27.15±0.94b	29.46±0.18b	29.78±0.18b
	10	6.39±0.37d	8.55±0.32e	8.62±0.05c	8.95±0.05e
	15	3.09±0.09ef	4.59±0.13f	5.84±0.04d	5.96±0.03f
	20	2.73±0.10ef	2.92±0.03g	3.29±0.09f	3.71±0.02h
	25	1.88±0.06f	2.42±0.02g	2.92±0.03g	3.25±0.05i
120°C	5	18.88±1.13c	21.51±0.43c	22.34±0.14b	22.71±0.16c
	10	4.19±0.09e	4.70±0.25f	5.64±0.12d	6.04±0.28f
	15	3.08±0.13ef	4.20±0.02f	4.93±0.04e	5.32±0.02g
	20	2.29±0.16f	2.64±0.04g	3.08±0.04fg	3.42±0.14i
	25	1.83±0.04f	2.32±0.05g	2.88±0.01g	3.41±0.07i

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

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

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

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

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

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

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

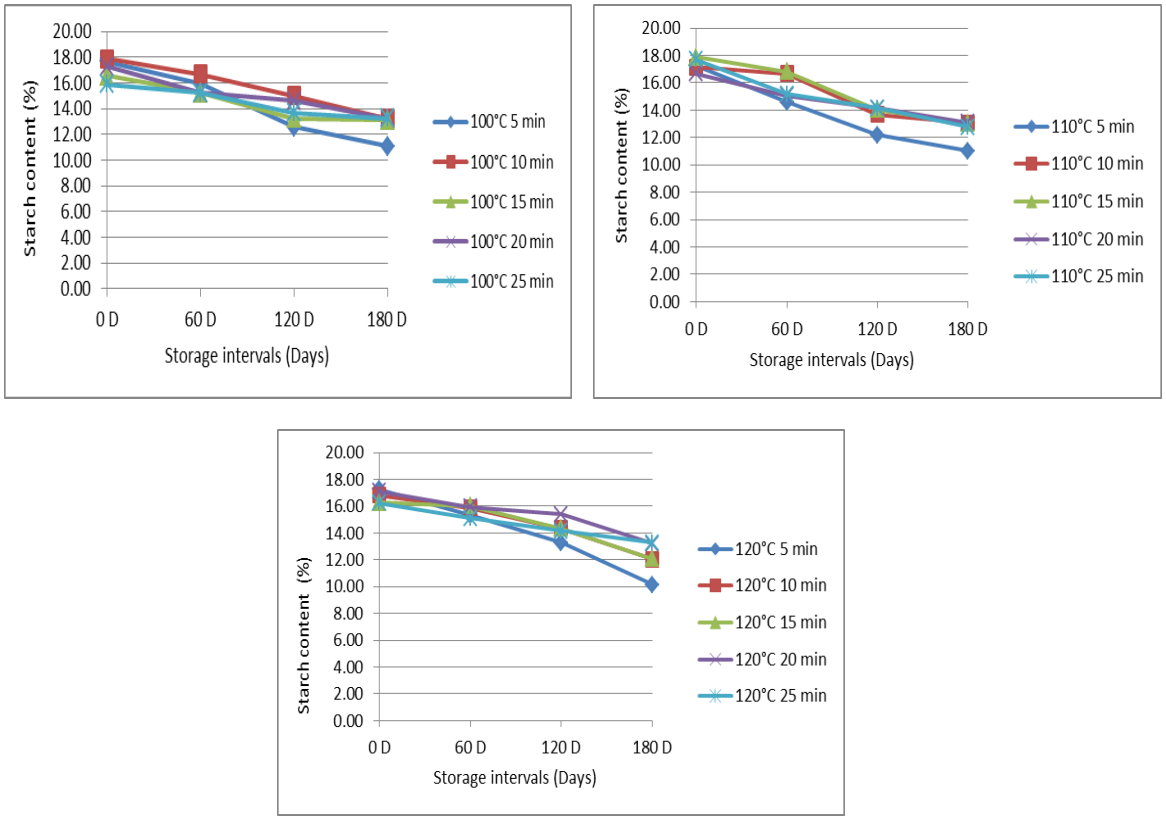

Figure 2. Effect of frying temperature-time on starch content (%) of VF jackfruit chips during 6 months of storage at ambient condition

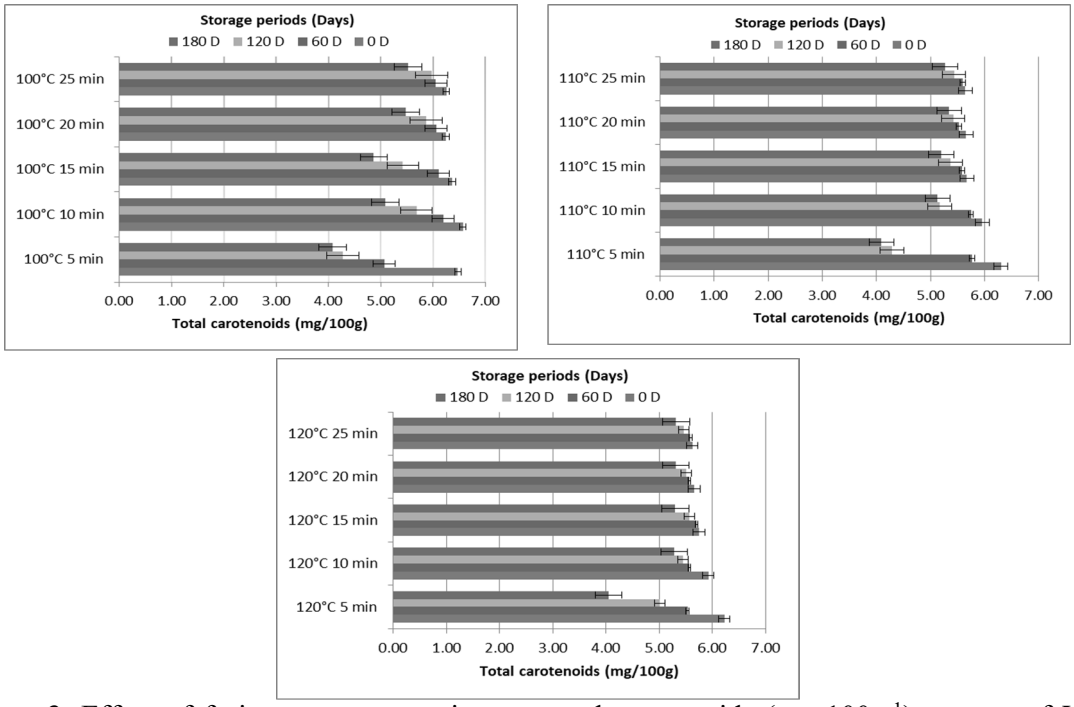

Figure 3. Effect of frying temperature-time on total carotenoids (mg $100g^{-1}$) content of VF jackfruit chips during 6 months of storage at ambient condition

CONCLUSION

The main purpose of the experiment was to optimize the VF jackfruit chips processing protocol to produce export-oriented jackfruit chips at suitable frying temperature and time combination with shelf life study for six months in metalex foil packet at ambient temperature. Proper processing and pretreatments are mandatory to develop quality products. Jackfruit bulbs are needed to slice at about 5 mm thickness to make it chips form with attractive slick shape. The jackfruit bulbs must be frozen at -18°C for 24-48 hours as a pre-treatment to get the crispy and crunchy products with longer shelf life. It can be concluded that suitable frying temperature-time combination is an important issue for quality VF chips products considering organoleptic properties. According to the sensory panelists on the basis of appearance, texture, flavor, crispiness, oiliness and overall acceptability, the suitable frying temperature-time combination was found 110ºC for 25 minutes and 120ºC for 20 minutes where sensory scored 8.12 and 7.88, respectively. After 06 months of storage, each treatment scored 6.56 and 6.15, respectively. Without suitable packaging materials, products quality attributes mainly texture and appearance were greatly affected. If nitrogen flash with foil pack is used for storing chips, the quality will be retained for longer time. This technology will add value in agro-processing industry for producing quality VF jackfruit chips and will assist to reduce postharvest loss of jackfruit of our country. The economic analysis will be conducted for further study.

Competing interest

The authors affirm that there isn't any conflict of interest with this article's publishing.

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 study. 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 (Project ID#099) and Krishi Gobeshona Foundation (KGF) for intensive research and demonstration among the stakeholders under BKGET fund (ID#TF 65-C/19).

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