Process optimization for the development of easy-to-cook jackfruit bulbs

Chalani Akmeemana[*], Indira Wickramasinghe, Piyumi Chathurangi Wanniarachchi and Thisum Vithanage

Department of Food Science and Technology, Faculty of Applied Sciences,
University of Sri Jayewardenepura, Nugegoda, Sri Lanka

*Correspondence: chathurangichalani@sci.sjp.ac.lk, ⓘD ORCID: https://orcid.org/0000-0002-1832-085X

Abstract Overproduction of jackfruit (*Artocarpus heterophyllus*) in harvesting seasons and its short post-harvest shelf life make it an underutilized fruit species. The present study was conducted to analyze the feasibility of preparing processed jackfruit products to enhance utilization and reduce wastage. Jackfruit bulbs were cut into 4.5 cm ± 0.5 cm in length and 0.5 cm ± 0.3 cm in width pieces. The two-factor factorial technique was used as the experimental design when developing the products. As factors, the freezing operation and dipping treatment were considered. Hot water extracts of *A. heterophyllus* leaves and *Trachyspermum ammi* leaves were used as two dipping treatments and sensory evaluation tests were carried out to determine which dipping treatment is better. *T. ammi* dipping treatment had better sensory acceptance, and hence continued as the selected dipping method. The effect of freezing (-18 °C for 12 h), pre-cooking time, and rehydration on cooking time was also investigated. Frozen and non-dipped jackfruit bulb pieces had the highest sensory acceptance, hence its proximate composition, DPPH, total phenolic acid, and colourimetric values were determined. Moisture, ash, fat, crude protein and carbohydrate content of the frozen non-dipped jackfruit bulbs were 8.08 ± 0.28 %, 0.88 ± 0.01 %, 0.31 ± 0.03 %, 3.93 ± 0.06 %, 81.09 ± 0.54 % respectively. The colourimetric values (L*, a*, and b*) of the frozen non-dipped jackfruit bulbs were 79.40 ± 0.61, 1.87 ± 0.35, 25.43 ± 1.33, 25.50 ± 1.35 respectively. The results revealed that the freezing operation significantly (P<0.05) reduce the cooking time of jackfruit bulbs. Based on the sensory evaluation results, jackfruit bulbs that were frozen without dipping the *T. ammi* leaf extract were identified as having the best sensory acceptability. The final processed product possesses a good nutritional profile concerning the ash, fat, crude protein, carbohydrate, mineral content, DPPH and total phenolic acid content.

Keywords: Easy to cook food, jackfruit bulb, Proximate composition.

1 Introduction

Jackfruit, *Artocarpus heterophyllus* belongs to the family Moraceae and is mainly grown in tropical and sub-tropical regions (Vazhacharickal *et al.* 2015). A mature jackfruit tree often yields between 10 - 200 fruits every year. Normally it takes around three to seven months for the development of fruit for edible purposes. A cross-section of jackfruit when studied from outside to inside, it consists of an outer peel, rags, latex, bulb, core, seeds and arils. Jackfruit bulbs as well as seeds are the edible portions of the fruit (Akmeemana *et al.* 2022), accounting for 25% to 30% of the total weight (Baliga *et al.* 2011). There are two main types of jackfruit: one is firm, less sweet, and crispy, while the other is extremely soft, sweet-tasting, small, and fibrous (Swami *et al.* 2012). Jackfruit is a healthier source of calories because it does not contain any cholesterol or saturated fats (Goswami and Chacrabati 2016). Every part of the jackfruit tree can be utilized in a wide range of ways because of that there is no waste generated (Ranasinghe *et al.* 2019).

Every year, a huge post-harvest loss of jackfruit is reported due to a lack of knowledge on post-harvest technology, improperly organized marketing structures, having a smaller number of processing plants, poor demand in the local market, difficulty in initial processing steps, and rapid quality degradation of edible portion after removing from jackfruit peel (Vazhacharickal *et al.* 2015). Global acceptance of convenient instant food is increasing due to changing lifestyles, the need for convenience, an increase in the number of working professionals, and a growing inclination toward western culture. Low-caloric and highly nutritious instant food mixes are among the most preferred by consumers globally (Ajisha *et al.* 2018).

The present study aimed to investigate the feasibility of using jackfruit bulbs to create an easy-to-cook novel food product, thereby effectively utilizing jackfruit bulbs thus reducing post-harvest losses. Furthermore, the objectives of the present study were (i) to examine the impact of *A. heterophyllus* and *Trachyspermum ammi* dipping treatments on sensory quality (ii) to determine the impact of pre-cook time, rehydration, and freezing on cooking time, and (iii) to analyze the proximate composition and antioxidant activity for the frozen-non-dipped jackfruit bulb treatment, which has the highest level of sensory acceptability.

2 Material and Methods

2.1 Raw materials and chemical ingredients

Jackfruit bulbs, *Artocarpus heterophyllus* and *Trachyspermum ammi* leaves were harvested from the Piliyandala area (6°48′31.8″N 79°57′10.1″E) in Sri Lanka. Chemical reagents chloroform, methanol, concentrated sulfuric acid, boric acid,

hydrochloric acid, Kjeldahl catalyst tablets, Kjeldahl indicator, Sodium Hydroxide, Phenol, Standard D Glucose, Phenolphthalein indicator were of the analytical grade.

2.2 Collecting of raw materials and initial processing

Jackfruit *A. heterophyllus* and *T. ammi* leaves harvested from the Piliyandala area in Sri Lanka were washed well using clean, running water. Jackfruit was cut and jackfruit bulbs were separated. Bulbs were stored in an airtight container and taken to the Food Science and Technology laboratory at the University of Sri Jayewardenepura, Sri Lanka. Jackfruit bulbs were cut into pieces (4.5 cm ± 0.5 cm length, 0.5 cm ± 0.3 cm width in size) and were stored at 4 °C temperature for further use.

2.3 Experimental design

A two-factor factorial design was used to develop four sample formulations statically (Table 1). The variables freezing (-18 °C for 12 h) and dipping (*T. ammi* hot water extract) were used as factors.

Table 1. Formulation of jackfruit bulbs for the two-factor factorial design.

Sample No.	Description
01	Non-frozen, non-dipped sample (Control sample)
02	Frozen, non-dipped sample
03	Non-frozen dipped sample
04	Frozen, dipped sample

2.4 Selection of the best dipping treatment

Preparation of hot water extracts

Hot water extracts of *T. ammi* leaves and *A. heterophyllus* leaves were prepared according to Fernando *et al.* 1991. In a shaking water bath, 200 g of each leaf material was placed in a beaker with 1000 ml of distilled and shaken for 3 hours at 100 °C until the final volume was reduced to 200 ml.

Dipping treatment of jackfruit pieces

To formulate three solutions with different concentrations, *A. heterophyllus* hot water extracts were diluted with distilled water by dilution factors of 1/10, 2/10, and 4/10. Similar series of solutions were prepared for *T. ammi* leaves extract using the same dilution factors mentioned above.

In each of the solutions prepared, 100 g of jackfruit bulb pieces were dipped for about 30 mins and were drained well. Then the drained jackfruit bulb pieces were dried in a dehydrator at 60 °C for 12 h.

Optimization of dipping treatment

Three sensory evaluation tests with 30 semi-trained panellists were used to select the best dipping treatment and concentration. The first sensory test was performed to determine which of the three concentrations of *A. heterophyllus* leaves solution-dipped jackfruit pieces provided the best sensory experience. The second sensory test was performed to determine the best sensory treatment among the three concentrations of *T. ammi* leaves solution-dipped jackfruit pieces. The selected concentration of *A. heterophyllus* leaves and *T. ammi* leaves dipped jackfruit bulb samples was used for the third sensory test to finalize the dipping treatment for the subsequent product development process.

2.5 Analysis of the effect of pre-cooking time, frozen operation, and rehydration for the cooking time

To check whether the freezing, rehydration, and precooking processes affect the cooking time of the dehydrated jackfruit pieces, 15 ± 3 g samples were precooked at one-minute intervals for up to 15 minutes. Pre-cooked samples were dried in a dehydrator for 12 h at 60 °C. To demonstrate the effect of the freezing operation on the cooking time of jackfruit bulbs, another 15 samples of 15 g $\pm$ 3 g of jackfruit pieces were pre-cooked from 1 min to 15 min separately at the one-minute interval and were frozen at -18 °C for 12 h. Frozen samples were thawed for 15 mins and dried in a dehydrator for 12 h at 60 °C. Each dehydrated sample was divided into two sets. The first group was boiled in 250 ml of distilled water (100 °C) until the desired softness was obtained. The second group was prepared after soaking the jackfruit pieces in distilled water for 10 min and boiling (100 °C) them in 250ml of distilled water until they reached the desired softness. The samples were tested for softness by pressing them between the fingers and thumb (Sethi *et al.* 2014).

2.6 Final sensory evaluation

Using a five-point hedonic scale rating with 30 semi-trained panelists, the final sensory evaluation test was conducted for four samples created using a two-factor factorial design. Before serving the samples for sensory analysis, they were rehydrated for 10 minutes in distilled water and boiled for 2 minutes at 100 °C to achieve the desired cooking quality. Data analysis was carried out using SPSS statistical software version 24.0, and the sample with the best sensory acceptability was identified by using the Friedman test.

2.7 Proximate composition analysis

The AOAC (Association of Analytical Communities) official method 2000 was used to determine the moisture, ash, and crude protein content. The fat content was analyzed according to (Sanchez-Machado *et al.* 2004) with slight modifications. Initially, 2:1 chloroform: methanol solution was used to extract lipids included in the samples. Then, 2 g of the sample (already dried, grounded) was weighed into a centrifuge tube. Under the fume hood, 14 ml of the initially prepared solution mixture was added into the centrifuge tube and the centrifuge tube was closed. Tubes were vortexed for 2 min in a vortex mixer. Then the content of the tube was filtered through Whatman No. 41 paper. The residue was re-extracted by using 5 ml of the solvent mixture and vortexed for 30 s. Then the extract was filtered through Whatman No. 41 paper. The filtrates were allowed to dry under the fume hood. When drying was completed, the final residue was measured and taken as the total lipid content of the sample.

2.8 Analysis of total carbohydrate content

Total carbohydrate content was measured by the Dubois method (Dubois *et al.* 1956) with slight modifications. Initially, a beaker was placed on an analytical balance and approximately 100 mg of grounded jackfruit bulb sample powder was transferred into the beaker. Then, 50 ml of 2 M HCl solution was added to the beaker. The mixture was boiled at 100 °C for about 2 h in a water bath. After that beaker was taken out from the hot water bath and neutralized with 50 ml of 2 M NaOH. Then the mixture was filtered by using Whatman filter paper. A test tube was filled with 0.5 ml of filtrate and 0.5 ml of 20% phenol. Afterwards, 2.5 ml of Conc. H_2SO_4 acid was added rapidly. Then the mixtures of solutions were kept at room temperature for 30 min. The absorbance was measured at 490 nm by using a UV Mini Spectrophotometer. Blank solutions were prepared by using distilled water without jackfruit bulb samples. The amount of sugar in the sample was found with the help of the D-Glucose reference curve. The same procedure used to prepare the D-Glucose standard curve was used to test D-Glucose solutions at concentrations of 1, 0.5, 0.25, 0.125, 0.0625, 0.03125, and 0.015625 mg/ml. Triplicate solutions were used to minimize the errors in the results.

2.9 Analysis of the mineral content (AAS method)

Sample preparation for metal analysis using the Atomic Absorption Spectrometer was done as per guidelines provided in the AOAC official method (AOAC 2000).

2.10 Determination of titratable acidity for Jackfruit bulbs

The titratable acidity (TA) was determined according to Jagadeesh *et al.* 2007 with some modifications. Accordingly, 5 g of sample was measured using an analytical

balance and transferred to a vortex tube. Then 100 ml of distilled water was added to the tube and the tube was vortexed for 5 min. After that, the mixture was filtered through Whatman 41 filter paper and 10 ml of the filtered sample was transferred into a conical flask. As an indicator 4 drops of phenolphthalein were added. The mixture was titrated against 0.1 N NaOH until the pink colour endpoint was reached, and TA% was calculated as follows:

$$TA\% = \frac{\text{Normality of NaOH} * \text{Volume of NaOH} * 192.124}{3 * \text{Weight of the sample}}$$

2.11 Determination of antioxidant properties of jackfruit bulbs

The dried jackfruit bulb sample was mixed with methanol at 1:40 (g/ml). The sample mixture was allowed to stand at room temperature for 6 h in a shaker and filtered through Whatman 41 filter paper. The above mixture was used for the phytochemical composition analysis.

DPPH radical scavenging activity

The free radical activity of the jackfruit bulb sample was measured by DPPH following the method of (Gunathilake and Ranaweera 2016) with some modifications. Hence, 6.309 mg DPPH was dissolved in 100 ml of methanol solution. Next, 2 ml of DPPH methanol solution and 2 ml of the diluted solution were transferred into a test tube by using a micro pipet. The solutions were mixed for 1 min by using a vortex mixer. Afterwards, the mixture was kept in a dark place for 30 min and the absorbance was measured at 517 nm. Absorbance was calculated by using the following equitation.

$$\% \text{ of inhibition} = \frac{(\text{A control} - \text{A sample})}{A\ control} * 100$$

where A control equals to absorbance of the pure DPPH methanol solution.

Total phenolic content

Total phenolic content was measured according to the Folin – Ciocalteu reagent assay method described by Lim *et al.* 2002 with some modifications. 2.5 ml of Folin – Ciocalteu reagent was mixed with 25 ml of distilled water. The final solution was diluted up to 10 folds and allowed to stand at room temperature for 5 min. Then l ml of methanol extracted sample and 5 ml of Folin – Ciocalteu reagent was added to a test tube. The solutions were allowed to stand for 10 min at room temperature. Then, 4 ml of 7.5% sodium carbonate solution was added and the mixture was mixed thoroughly. The solutions were kept for 30 min in a dark place at room temperature. Absorbance was measured at 765 nm. The standard curve of Gallic acid was used to compare the absorbance reading. Nine different concentrations (10, 20, 30, 40, 50, 60, 70, 80, and 90 mg/l) of Gallic acid solutions were made from 1000 mg/l stock solution. The

standard curve was constructed from regression analysis using the software MINITAB (R17). TPC was expressed as Gallic acid equivalent in mg/l of jackfruit bulb extract.

2.12 Color values for easy-to-cook jackfruit bulb pieces

L*, a*, and b* values of dehydrated jackfruit bulb samples were measured by using a chronometer (Lovibond® LC100). L* reflects brightness ranging from black to white, a* denotes green to red values, and b* represents blue to yellow values. Colour values were taken as replicates (n=3) on different areas of the sample.

2.13 Data analysis

The collected data were analyzed using Minitab 17 statistical software with a 95% confidence interval using One-way ANOVA. The Friedman test was used to analyze the sensory evaluation data at a 95% confidence interval using SPSS software.

3 Results and Discussion

In the present study, a new product formulation was developed using a two-factor factorial design. As factors, freezing and dipping variables were used. Hot water extracts of *A. heterophyllus* and *T. ammi* leaves were used as dipping variables. A sensory test range was carried out to determine the best dipping treatment and concentration. Hot water extract from the leaves of *A. heterophyllus* was occupied because of its antioxidant properties, (Loizzo *et al.* 2010) whereas hot water extract from the leaves of *T. ammi* was used because it acts as a digestive stimulant by promoting the enzyme reactions that are responsible for bile secretion, digestion, or both. (Prakash *et al*. 2009) The jackfruit bulb pieces were precooked before dehydrating because it takes considerably more time for the developed product to achieve the desired cooking quality without precooking. The cooking time evaluation test was conducted to determine the pre-cooked time. The biochemical analysis was performed on the sample that was perceived as the most acceptable sensory sample.

3.1 Sensory evaluation for optimization of dipping treatment of Jackfruit bulb

Figure 1 illustrates the radar charts used to get an insight into the best sensory quality sample, from the two basic dipping treatments using *A. heterophyllus* and *T. ammi* leaves extracts applied to jackfruit bulbs. According to Figure 1, the sample code-100, i.e., jackfruit bulb pieces dipped in 1/10 dilution factor of *A. heterophyllus* leaves hot water extract, and the sample Code-500, i.e., jackfruit bulb pieces dipped in 2/10 dilution factor of *T. ammi* leaves hot water extract was selected from the dilution factor

series based on the results of sensory evaluation tests. The jackfruit bulb pieces dipped in a 2/10 dilution factor of *T. ammi* leaves hot water extract was the best sensory quality sample in terms of appearance, texture, odour, taste, and overall acceptability, according to the results of the sensory evaluation tests conducted for the above-selected samples (code 100 and code 500).
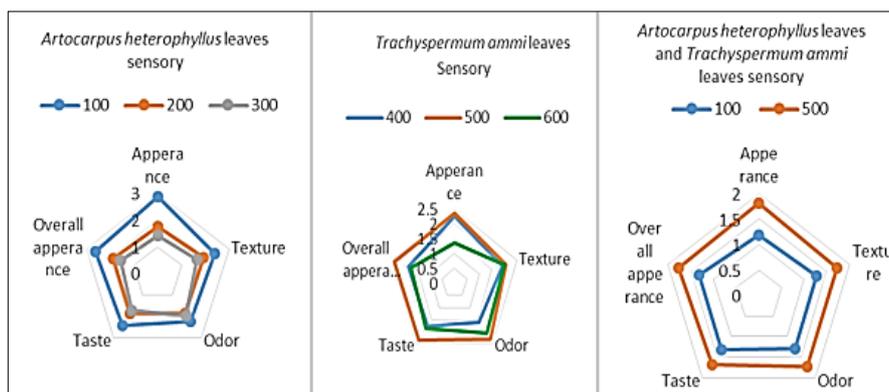

Fig 1. Optimization of the sensory treatments in jackfruit bulbs.
(Note: The codes 100, 200, and 300 represent 1/10, 2/10 and 4/10 dilution factors of hot water extract of *A. heterophyllus* leaves, respectively. Similarly, 400, 500, and 600 represent 1/10, 2/10 and 4/10 dilution factors of hot water extract of *T. ammi* leaves, respectively.)

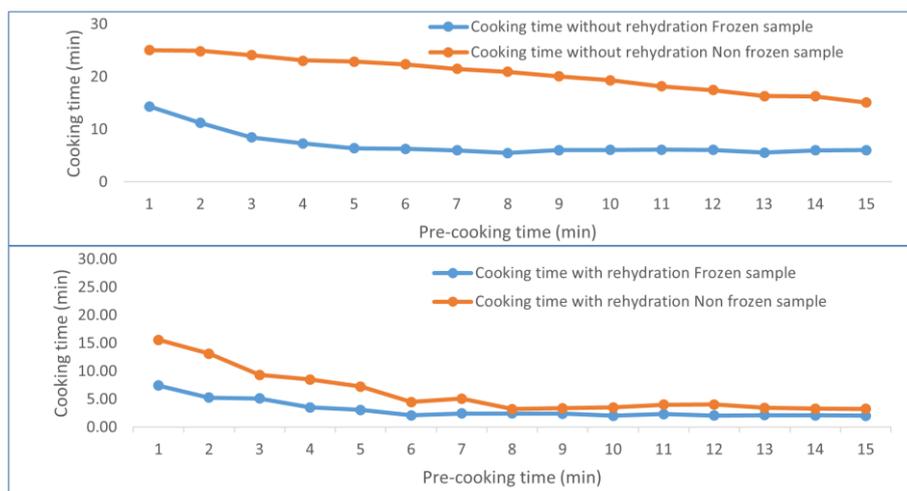## 3.2 Evaluation of cooking time

Fig 2. The effect of cooking time on rehydration, freezing, and pre-cooked time

According to Figure 2, with the optimization of the pre-cooking time of jackfruit bulb pieces, the frozen treatment has reduced the cooking time of the processed jackfruit bulbs. According to the results, 6 min pre-cooking, and 10 min rehydration was selected to reduce the final cooking time of the developed sample. According to Kuna A *et al*. (2019), the frozen operation reduced the cooking time significantly in the red gram dhal. When the pre-cooked time increased, the cooking time was reduced accordingly. According to Ghadge *et al.* (2008), the pre-cooking and freezing operation reduced the cooking time of the instant whole legume.

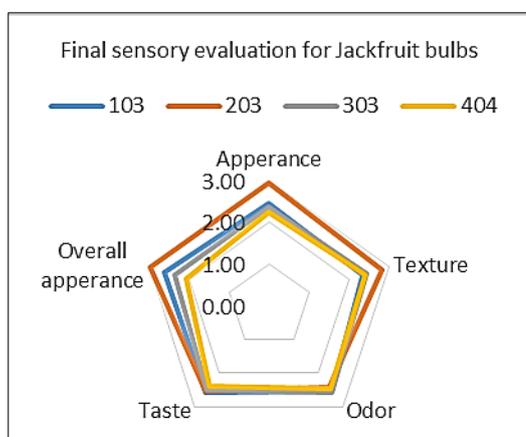### 3.3 Final sensory evaluation

Fig 3. Radar chart for the sensory evaluation of the final processed jackfruit bulb samples. (The codes 103, 203, 303 and 403 represent non-frozen and non-dipped samples, frozen and non-dipped samples, non-frozen and dipped samples, and frozen and dipped samples respectively).

According to the radar chart (Figure 3), the sample containing frozen jackfruit bulbs, without *T. ammi* leaves hot water extract was the best sensory quality sample concerning the appearance, texture, odour, taste and overall acceptability.

3.4 Proximate composition

The proximate composition of the best sensory-acceptable sample (the frozen jackfruit sample without *T. ammi* leaves hot water extract) is given in Table 2.

Moisture content

Opkala (2010) reported that 5 mins steamed blanched, 0.1% sodium sulfate treated, 55 °C dried jackfruit bulb flour contains 15.19 ± 0.01 % moisture content. Similarly, Yi *et al.* (2016) reported the influence of pre-drying treatments on the physicochemical

and organoleptic properties of explosion puff dried jackfruit chips. According to a study at 65 °C hot air-dried jackfruit bulb pieces contained 6.13 ± 0.12 % moisture content. The results of the current study showed 8.08 ± 0.28 % moisture content at 60 °C and which is less than the moisture content of the dried jackfruit bulbs at 55 °C and greater than the dried jackfruit bulbs at 65 °C.

Table 2: Proximate composition of the jackfruit sample with the best sensory quality.

Variable	Value
Moisture	8.08 ± 0.28 %
Ash	0.88 ± 0.01%
Total Fat	0.31 ± 0.03%
Crude Protein	3.93 ± 0.06%
Total Carbohydrate	81.09 ± 0.54%

[Data presented as mean ± S.D. (n = 3)

Ash content

Goswami *et al.* (2011) stated that the biochemical parameters of fresh jackfruit bulbs changed according to the growing area and the ash content of fresh jackfruit bulbs can be ranged from 1.11 to 0.70%. The current study demonstrated 0.88 ± 0.01% ash content which is comparable to Goswami *et al.* (2011).

Fat content

Opkala (2010) reported that 5 mins of steamed blanched, 0.1 % sodium sulfate treated, 55 °C dried jackfruit bulb flour contains 0.20 ± 0.04 % fat content. However, according to the variety, growing region (Goswami *et al.* 2011), and maturity stage (Maheswari and Valsan 2020), the biochemical parameters of jackfruit can vary. Ranasinghe *et al.* (2019) reported that the fat content of young jackfruit can vary between 0.1 and 0.6 % while the fat content of ripened jackfruit can vary between 0.1 and 0.4 %. The present study reported 0.31 ± 0.03 % fat content and it was in the range of the above studies.

Crude protein content

Maheswari and Valsan (2020) stated that the crude protein content of jackfruit can vary from 1.61 ± 0.02 % to 4.36 ± 0.06 % depending on the maturity stage of the jackfruit bulbs. The current study reported 3.93 ± 0.06 % of crude protein content and it complies with the above range reported in the previous study.

3.5 Mineral content analysis

Maheswari and Valsan (2020) further reported 44.67 ± 0.50 % of Calcium to be present in raw mature jackfruit bulbs while Ranasinghe *et al*. (2019) reported 2.0 - 41.0 % of Sodium content to be available in raw jackfruit bulbs. The mineral composition of the

best sensory-acceptable sample with respective to Na, Ca, Mg, K, and P is given in Table 3.

Table 3: Mineral content of the jackfruit sample with the best sensory quality.

Mineral Type	Na	Ca	Mg	K	P
Concentration (mg/100g)	8.47 ± 0.04	43.88 ± 0.25	61.49 ± 0.47	709.65 ± 0.46	48.76 ± 0.21

[Data presented as mean ± S.D. (n = 3)]

3.6 Titratable acidity

Titratable acidity of jackfruit sample with the best sensory acceptability, i.e. frozen without dipping in *T. ammi* leaves extract was 0.29 ± 0.01 % (mean ± SD; n = 3). Yi *et al.* (2016) reported 0.30 ± 0.02 % titratable acidity in dehydrated jackfruit bulbs at 65 °C. Yi, Wang *et al.* (2016) reported 0.38 ± 0.04 % titratable acidity for freeze-dried jackfruit bulb pieces. Results of the current study were much lower compared to those. According to the (Opkala 2010) study, 0.81 ± 0.28 % titratable acidity was reported in jackfruit bulb flour made out of 5 min steamed blanched, 0.1 % sodium sulfate treated and 55 °C dried in a conventional hot-air drier. The variations may be due to the variety, growing condition and maturity stage of the jackfruit.

3.7 Antioxidant properties of easy-to-cook jackfruit bulb

DPPH (1-1-diphenyl 1-2-picrylhydrazyl) radical scavenging activity assay

Jagtap *et al.* (2010) reported that radical scavenging activity for the ethanolic extract of raw jackfruit bulb concentration ranged from 1, 2, 3, 4, and 5 mg/ml was in between 55% and 65%. The obtained value in this study ($38.43 \pm 0.12\%$) was less than the previously reported values, and it may be due to heating of the bulbs at 100 °C for 6 mins and dehydration at 60 °C.

Total Phenolic Content

Yi, Zhou *et al.* (2016) stated that the total phenolic content of hot air-dried jackfruit bulb was 0.84 ± 0.06 (mg GAE / g). According to (Yi, Zhou *et al.* 2016) the total phenolic content of the fresh jackfruit bulb was 1.8 ± 0.1 (mg GAE / g) and after freeze-drying, it was decreased up to 1.6 ± 0.1 mg GAE / g. According to the (Jagtap *et al.* 2010) study, the total phenolic content of the fresh jackfruit bulbs was 0.46 ± 0.014 mg GAE/ g. The value obtained for phenolic content in the present study ($0.38 \pm 0.04\%$) is lower than the above-reported values. This may be due to the pre-cooking of the bulbs for 6 mins at 100 °C, frozen treatment, thawing for 15 mins and drying treatment carried out at 60 °C.

3.8 Colour values of easy-to-cook jackfruit bulb

Table 4 indicates the colourimetric values of the best sensory-acceptable jackfruit bulb sample.

Table 4. Colour values of best sensory quality sample.

L^*	a^*	b^*	c^*
79.40 ± 0.61	1.87 ± 0.35	25.43 ± 1.33	25.50 ± 1.35

* Data presented as mean ± S.D. (n = 3)

The L* value is a measure of the lightness of the product colour. It ranges from 100 to 0. a* and b* values indicate the redness/greenness and yellowness/blueness respectively (Swami *et al.* 2016).

4 Conclusions

Four different formulations were developed by jackfruit bulbs following a two-factor factorial design, dipping or non-dipping and frozen or non-frozen as the variables. Among the three sensory tests conducted, the best sensory quality sample concerning appearance, texture, odour, taste and overall acceptability was the 2/10 dilution factor of hot water extract of *T. ammi* leaves dipped jackfruit bulb pieces sample. The results revealed that the frozen operation, pre-cooked time and rehydration significantly reduce the cooking time of jackfruit bulbs. To reduce the final cooking time of the developed product, 6 minutes of pre-cooking and 10 minutes of rehydration were selected based on the results of the cooking time evaluation. Final sensory evaluation indicates frozen non-dipped sample as the most sensory-acceptable sample. Furthermore, the final processed product possesses a good nutritional profile concerning the ash, fat, crude protein, carbohydrate, mineral content, DPPH and total phenolic acid content.

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