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Effect of citric acid concentration on physico-chemical properties, bio-active compounds and sensory attributes of dried jackfruit bulb slices during storage

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Abstract

In today's fast-paced world, it is necessary to minimize losses by developing processing techniques for jackfruit. The study was conducted to prepare dried jackfruit bulb slices from mature jackfruit and the effect of citric acid concentration was also investigated. The sensory quality of jackfruit after frying was evaluated in terms of color, flavour, taste, texture, crispiness, oiliness and overall acceptability. Jackfruit (khaja variety) was collected, cleaned, peeled, scoped and the bulb was sliced into two equal parts. The bulb slices were dried in a cabinet dryer at 65±2°C for 8±1 hrs. Then, the dried jackfruit bulb slices were fried at 140±2°C for 2-3 mins. Analysis showed that there was a considerable effect of citric acid concentration on dried jackfruit bulb slices. After 90 days, moisture content was increased for all the dried samples. All three dried samples showed the same decreasing pattern for ash, pH, ascorbic acid and total carotenoid content. However, the lowest amount of ash (16.67%), ascorbic acid (70%) and total carotenoid content (36.57%) loss were observed in the 1% citric acid-treated sample at 90 days of storage compared with the others. After 90 days, comparatively higher lightness, b and browning value was found in the same sample. From the sensory analysis of fried samples, it was observed that the sample soaked with 1% citric acid obtained the highest score for overall acceptability (7.40±1.27) in the 9-point hedonic rating scale that was significantly different from the control sample (without treatment). In conclusion, citric acid-treated samples gave a better result than the untreated ones (Control) because citric acid acts as a preservative. It is recommended that a 1% citric acid-treated sample can be used industrially to produce quality dried jackfruit bulb slices.

1. Introduction

Jackfruit is a dicotyledonous compound fruit (*Artocarpus heterophyllus* L.) cultivates in several tropical countries of Southeast Asia and is predominantly abundant in India and Bangladesh. It is consumed not only as a fruit when ripe but also as a vegetable in the unripe stage (Mondal *et al*., 2016). The bulbs comprise the perianth segment of the fruit that is fleshy, fibrous and enriched with sugars (Rahman *et al*., 1999). In most of the jackfruit growing areas, poor people need to eat this fruit as a replacement for rice for at least one of their everyday meals, that is why Jackfruit is called "poor man's food". Its position next to mango in total acreage means second in annual production (10,37,877 metric tons in the fiscal year 2018-2019) amid the fruits grown in Bangladesh (BBS, 2019).

Jackfruit deteriorates quickly when ripens, so it is necessary to develop value-added products from the bulbs. It is incredibly rich in carbohydrates, vitamins and minerals, such as calcium and iron (Giraldo-Zuniga, 2006). Besides, fresh fruit is enriched with vitamin-A and flavonoid pigments such as carotene-ß, xanthin, lutein and cryptoxanthin-ß. Additionally, jackfruit is also a superior source of antioxidant in the form of vitamin C, which supplies about 13.7 mg or 23% of RDA (Swami *et al*., 2014). It contains a B-complex group of vitamins that is rare among fruits. Furthermore, jackfruit is known to alleviate diabetes, hypertension, dermatosis, cancer, asthma, coughs, acne, wounds, and diarrhea (Moke *et al*., 2017; Ilmi *et al*., 2020; Zubaydah *et al.,* 2021).

At present, consumers are looking for products that conserve their original characteristics to a large extent. In

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industrial requisites, this means developing operations reducing undesirable processing effects (Saguy and Karel, 1980). The actual recovery of bulbs or edible portions of a heavy and bulky jackfruit varies from 20% to 25% (Swami *et al*., 2014). A variety of products have been prepared from raw, tender and ripe fruits and seeds like nectar, jam, and curry in combination with other vegetables, dehydrated products (e.g., papad, pickles, bulbs, chips, jackfruit bar). Moreover, there is also a possibility for dehydrated crisps from jackfruit bulbs which could offer convenience to consumers (Saxena *et al*., 2012). Stabilized jackfruit curry was prepared from raw jackfruit is certainly known as Indian culinary preparations. Basically, the value-added products made from jackfruit are dependent on conventional processing methods like dehydration, freezing, and canning, leading to obstruction of the sensory properties basically compared to a multifarious preservation technique (Saxena *et al*., 2009).

Citric acid is widely used as it is effective against microbial growth in food products and also gives the much-desired "clean label" (Theivendran *et al.,* 2006; Jin *et al*., 2010). It is a relatively weak acid, but it is one of the strongest acids which completely edible and shows a non-harmful effect on humans. For this reason, it is an ideal choice for many kinds of food preservation. Beyond its primary use as a preservative, citric acid has plentiful other uses in the food industry. It can even be used in food processing, as it is an efficient chelating agent and can hinder contamination by metallic ions.

Drying takes excess water away from the sample until it reaches equilibrium condition, permits early harvest as it minimizes product damage and loss (Bala, 1997). Besides, the drying process is essential for increasing the shelf-life and reduction in the volume of fruits and vegetables (Prakash *et al*., 2004). Dehydrated fruits and vegetables are normally used as either food products or constituents in the preparation of various foods. On the other hand, fried foodstuffs are liked by everybody and serve as a significant diet because of their distinctive flavour and texture. Additionally, fast processes like frying lead to a sterile and dry product with a comparatively longer shelf life (Maity *et al*., 2014). During the frying process, food is submerged in an oil bath at a temperature higher than the boiling point of water, and thus, the counter flow of water vapour and oil at the surface of the manufactured goods occurred (Bouchon and Pyle, 2004). Additionally, a fried product with a drying process produces safe food because drying is one of the established methods of storing food for later consumption.

Each year, a huge amount of Jackfruit, particularly obtained in the peak season (June-July) goes to waste due to a lack of appropriate postharvest knowledge throughout harvesting, transporting, and storing. Giraldo-Zuñiga *et al.* (2006) estimated the drying kinetics and Saxena *et al*. (2012) determined the Degradation Kinetics of Color and Total Carotenoids in Jackfruit Bulb Slices. Through these developments, it is possible to reduce the losses of matured jackfruit bulbs transforming them into products after minimal processing with high nutrition content. Considering the above discussion, the present study was undertaken to analyze the effect of citric acid concentration on physico-chemical properties and bio-active compounds of dried jackfruit bulb slices and to evaluate the sensory quality parameters of dried jackfruit bulb slices after frying.

2. Materials and methods

2.1 Sample preparation for drying

Fresh, mature and disease-free jackfruit was washed under tap water to get rid of dirt, sand and other adverse materials before use. The peel was detached by knife, the bulb was scooped and the seed was detached. Then, the bulbs were cut down into two equal pieces (7±0.51 mm thickness). After that, the samples were washed with 2% NaCl and blanched at 95^{o}C for 5 mins. Finally, three types of samples were prepared at room temperature and these were control (without treated jackfruit bulb slices), jackfruit bulb slices soaked with 0.5% citric acid solution and jackfruit bulb slices soaked with 1% citric acid solution. Both the treated samples were soaked for 10 mins at room temperature in citric acid solution. The prepared bulb slices were shown in Figure 1 (a, b and c) and those were used for further processing.

2.2 Drying process of jackfruit bulb slices

The samples were spread in a single layer (loading capacity 1 kg/m^2) on the trays in a cabinet dryer. The trays are made of mild steel, with a length of 0.74 m, width 0.74 m and depth of 0.1 m. All the bulbs utilized in this research were from the same batch. The samples were dried at 65±2°C. The temperature sensors (LM 35) were used to observe the temperature inside the drying chamber and the values were collected from the mini-LCD display. The drying time was about 8±1 hrs. Drying was continued until the final moisture content had reached a mass fraction of 8.94±0.71% (db). Three samples were prepared by using the cabinet drying method after being treated with citric acid and those are shown in Figure 1 (d, e and f).

2.3 Frying process of dried jackfruit bulb slices

The dried jackfruit bulb slices were immersed in an oil bath at a temperature of about 140±2°C for 2-3 mins then some spices were added for enhancing the taste.

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(a) Control (without treatment) before drying
(b) Soaked with 0.5% citric acid solution before drying
(c) Soaked with 1% citric acid solution before drying
(d) Control (without treatment) after drying
(e) Soaked with 0.5% citric acid solution after drying
(f) Soaked with 1% citric acid solution after drying
(g) Control (without treatment) after frying
(h) Soaked with 0.5% citric acid solution after frying
(i) Soaked with 1% citric acid solution after frying

Figure 1. Photographic views of treated and untreated jackfruit bulb slices before and after drying and finally after frying.

2.4 Shelf-life determination

Dried jackfruit bulb slices were packaged in polypropylene bags and stored at room temperature (25±2°C). The shelf life was studied by analyzing different physico-chemical properties and bio-active compounds of dried jackfruit bulb slices. The properties were analyzed at every 45 days interval.

2.5 Determination of physico-chemical properties and bio-active compounds of dried jackfruit bulb slices

2.5.1 Moisture and ash content

Moisture and ash content was analyzed using the Association of Official Analytical Chemists (AOAC, 2005) method.

2.5.2 pH

A laboratory digital pH meter (HI 2211, Hanna Instruments, Romania) was used to measure the pH of dried jackfruit bulb slices by standard procedure (Ranganna, 2009). After meshing the samples with the help of mortar and pastel, distilled water was added to them to prepare juice. First of all, calibration was carried out through buffer solution (pH-4 and pH-7). After that, the electrode was dipped into the juice and the automatic reading was recorded.

2.5.3 Total soluble solid

The products meshed into a mortar and juice was prepared by the addition of distilled water. After that, a drop of juice was placed on the prism of the Refractometer (model: PDR-45 and brand: Biobase) and the percentage of total soluble solids was recorded from direct reading. Temperature correction was made as described by Ranaganna (2009).

2.5.4 Color

The surface color of the dried jackfruit bulb slices was measured using a colorimeter (High-Quality Colorimeter, BCM-200). Three parameters L value [lightness, ranging from zero (black) to 100 (white)], a value [ranging from +60 (red) to -60 (green)] and b value

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[ranging from +60 (yellow) to -60 (blue)] were estimated to determine the color properties. Then, the browning value was calculated by the following formula (1) and (2) (Supapvanich *et al*., 2020).

$$Browning\ value = 100 \times \frac{X - 0.31}{0.172} \quad (1)$$

where X = (a+1.75 L)/(5.645L+a-3.012b) (2)

2.5.5 Ascorbic acid

Ascorbic acid (Vitamin C) was determined by using the titration method according to Ranganna (2009). Around 10 g sample was thoroughly mixed with 100 mL of 3% HPO_3 and filtered through a Whatman no. 42 filter paper. Titration of the filtered sample was carried out with the dye solution which was made of 200 mL with 50 mg of the sodium salt of 2,6-dichlorophenol indophenol, 42 mg of sodium bicarbonate and distilled water. The endpoint of titration was indicated by the appearance of pink color. In a titration method, using the same procedure dye factor was estimated with known ascorbic acid. Ascorbic acid (Vitamin-C) was calculated by the subsequent equation (3).

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up}}{\text{Volume of filtrate taken} \times \text{weight of sample}} \times 100 \quad (3)$$

2.5.6 Total carotenoid content

Total carotenoid content was analyzed according to Carvalho *et al*. (2010). About 2 g of sample and 25 mL of acetone were added into a test tube. Then vortex was carried out for 10 mins and filtered using a Whatman No. 41. After that, the mixture was poured into a separator funnel containing 30 mL of petroleum spirit and 5 mL of distilled water. Then a pinch of anhydrous sodium sulfite (Na_2SO_3) was added. The upper layer was collected and the lower portion was discarded (aqueous phase). The discard portion was reused with petroleum spirit and the color portion was collected. The total volume of the colored portion was measured, and absorbance was read at 450 nm using a spectrophotometer (UV 1800 shaanxi, china) against a blank sample. The total carotenoid content was determined using the following formula (4):

$$\text{Carotenoid Content } (\mu g/g) = \frac{A * V}{A^{1\%} 1\,cm \times P(g)} \times 10^4 \quad (4)$$

Where A = Absorbance at 450 nm, V = Total extract volume (mL), P = Sample weight (g) and $A^{1\%}1_{cm}$ = 2592 (β-carotene extraction coefficient in petroleum spirit)

2.5.7 Sensory evaluation

Sensory evaluation of the three fried jackfruit bulb slices that were controlled (without treatment), soaked with 0.5% citric acid solution and soaked with 1% citric acid solution was conducted as described by Iwe (2002) by the panel of judges to the product. The sensory quality attributes of the samples were color, flavor, texture, taste, crispiness, oiliness and overall acceptability. In the questionnaire introduced to the panelists, they were cordially requested to observe and taste the samples as coded with the sample provided and grade them on the basis of a 9-point hedonic scale presenting least acceptable to most acceptable in all features. They were also provided with drinkable water to rinse their mouth after evaluating each sample to verify taste interference.

2.5.8 Statistical analysis

Single-factor CRD design was employed for this experiment and the data were analyzed using the statistical software SPSS (IBM/version 22). The factor was a formulation of fried jackfruit bulb slices treated with 0%, 0.5% and 1% citric acid solution. The means of the responses color, flavor, taste, texture, crispiness, oiliness and overall acceptability of fried jackfruit bulb slices were compared by Duncan's Multiple Range Test (DMRT). Both the ANOVA and DMRT analyses were performed at a 5% level of significance.

3. Results and discussion

3.1 Physico-chemical properties and bio-active compounds of dried jackfruit bulb slices

3.1.1 Effect of citric acid concentration on physico-chemical properties of dried jackfruit bulb slices during storage

The average moisture content of fresh jackfruit bulb slices was estimated to be around 320.17% (db). The moisture content of dried Jackfruit bulb slices (without treatment, soaked with 0.5% citric acid solution and soaked with 1% citric acid solution) was presented in Figure 2 (a). Maximum moisture content was observed in dried Jackfruit bulb slices treated with 1% citric acid (9.65%) as compared to the control sample (8.93%) and Jackfruit treated with 0.5% citric acid (8.23%) sample at the storage starting day in dry basis. Although Jackfruit bulb slices soaked with 1% citric acid solution gave higher moisture content at 0 days, after 90 days lower moisture content (10.86%) was obtained by the same sample. Few amounts of moisture were absorbed by jackfruit bulb slices soaked with 1% citric acid solution within 90 days compared with the others. Again, the moisture content of dried Jackfruit bulb slices slightly increased after 45 days even after 90 days. Many physical changes such as cell wall collapse and shrinkage are the main determinant of textural properties in foods which occurred due to moisture transfer and induce stresses inside food materials (Prachayawarakorn *et al*., 2008).

Fresh jackfruit bulb slices were subjected to ash determination and 0.86±0.02% ash was observed. Figure

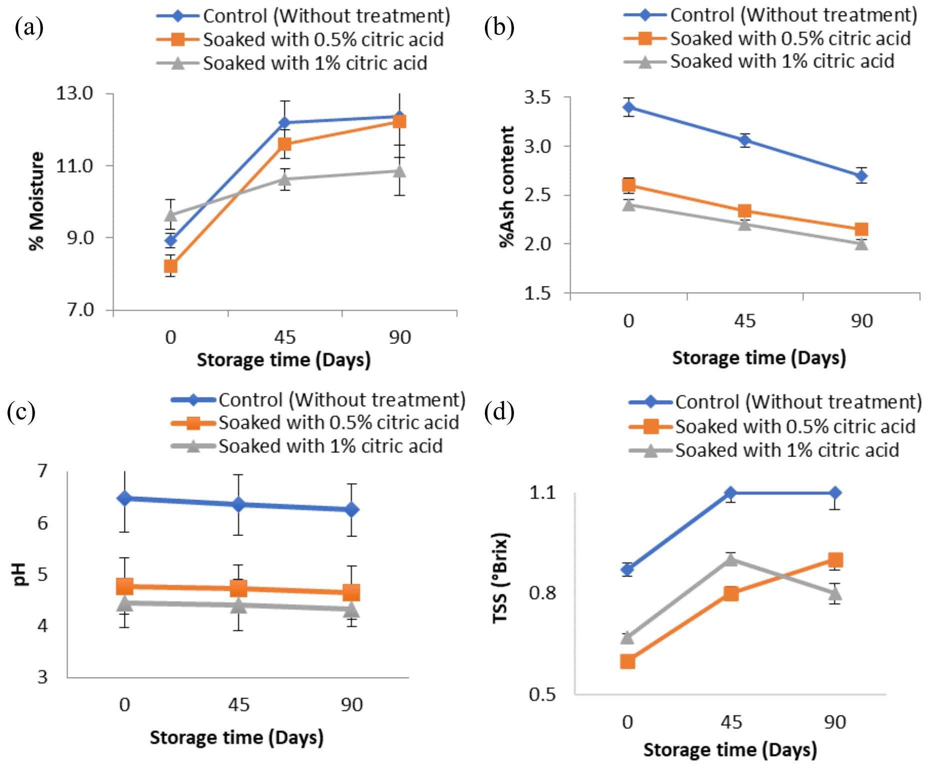

Figure 2. Effect of citric acid concentration on physico-chemical properties in dried jackfruit bulb slices during storage: (a) moisture content, (b) ash content, (c), pH and (d) TSS.

2(b) represents the ash content of three dried jackfruit bulb slices. From Figure 2(b), maximum ash content was observed for the control sample (3.4%) as compared to the Jackfruit treated with 0.5% (2.6%) and 1% (2.4%) citric acid at 0 days. A percentage of 20.59%, 17.31% and 16.67% ash loss were observed in the control, 0.5% and 1% citric acid-treated samples respectively. The samples showed a similar decreasing trend after 45 and 90 days. The ash content decreases depending on the increase of the moisture difference (MD). With the increasing amount of moisture difference (MD), there is little or no change in getting ash (Caliskan and Dirim, 2013).

Around 6.29±0.01% pH value was observed for fresh jackfruit bulb slices. The pH content of dried Jackfruit bulb slices (without treatment, soaked with 0.5% citric acid solution and soaked with 1% citric acid solution) was shown in Figure 2(c). pH value was maximum in the control (untreated) sample (6.47) as compared to the Jackfruit treated with 0.5% (4.77) and 1% (4.44) citric acid at zero-day. It is the effect of pre-treatment with citric acid. pH value decreases with the increasing percentage of citric acid. The pH values presented the same decreasing pattern as ash with time. The difference in pH was found due to the different moisture contents and also from the buffering action of citric acid that prevents the pH values to decrease with the concentration of organic acids (Jorge *et al.,* 2014).

The average TSS (Total soluble solid) content of fresh jackfruit bulb slices was found to be around 0.15° Bx. The TSS (Total soluble solid) content in dried Jackfruit bulb slices (without treatment, soaked with 0.5% citric acid and soaked with 1% citric acid) was presented in Figure 2(d). The highest TSS (Total soluble solid) was observed in the dried Jackfruit of the control sample (0.87°Bx) as compared to the treated samples. TSS found for 0.5% and 1% citric acid was (0.6°Bx) and (0.67°Bx), respectively at zero-day. Although the lowest TSS was observed for jackfruit bulb slices soaked with 0.5% citric acid solution at storage starting the day after 90 days the lowest TSS was found for Jackfruit bulb slices soaked with 1% citric acid solution. An increase in the TSS (Total soluble solid) content of dried Jackfruit bulb slices is related to changes in the cellular wall, particularly the pectic substances and hemicellulose associated with changes in the firmness of fruits (Giovannoni, 2004).

3.1.2 Effect of citric acid on color parameters in dried jackfruit bulb slices during storage

The color properties such as L, a, b and browning values in dried Jackfruit bulb slices (without treatment, soaked with 0.5% citric acid solution and soaked with 1% citric acid solution) were presented in Figure 3. A declined L, b and browning value and inclined value of both treated samples along with the control sample was observed over the storage period. Both treated samples obviously maintained high L, b and browning values for up to 90 days. However, at 0-day sample treated with 0.5% citric acid showed a higher L, b and browning value, but, after 90 days sample treated with 1% citric

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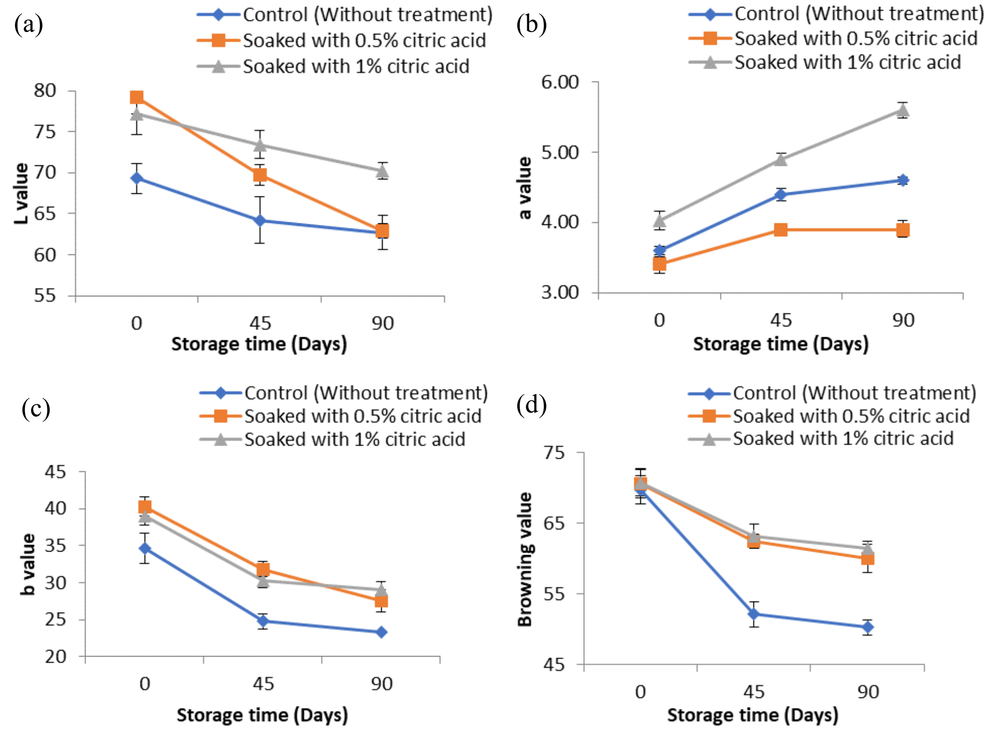

Figure 3. Effect of different treatment on color parameters in dried jackfruit bulb slices during storage: (a) L value, (b) a value, (c), b value and (d) browning value.

acid revealed a higher L, b and browning value. On the other hand, the value for the 0.5% citric acid-treated sample was lower than the 1% citric acid-treated sample and control one. The total color variation mainly occurred due to the effect of temperature on carbohydrates, proteins, and vitamins, and then these phenomena affect color degradation in fresh food (Hawlader *et al*., 2006).

3.1.3 Effect of citric acid on bioactive compounds of dried jackfruit bulb slices during storage

Ascorbic acid (vitamin-C) content in dried Jackfruit bulb slices (without treatment, soaked with 0.5% citric acid solution and soaked with 1% citric acid solution) was presented in Figure 4(a). Figure 4(a) exhibited that dried Jackfruit treated with 1% citric acid (14.2 mg/100 g) obtained higher ascorbic acid (vitamin-C) content than the control sample (13.4 mg/100 g) and Jackfruit treated with 0.5% citric acid (13.5 mg/100 g) at zero-day. Due to the pretreatment before drying more ascorbic acid content was preserved by citric acid-treated samples. Jackfruit bulb slices soaked with 1% citric acid solution gave the highest ascorbic acid content at 0 days, 45 days and 90 days. It is also clear that a minimum loss of ascorbic acid content (9.94 mg/100 g) was obtained by the same sample. Again, the ascorbic acid content of dried Jackfruit bulb slices decreased gradually after 45 days and 90 days. The decrease in vitamin C might be due to the temperature, light, heat, pH and oxidation as described by (Alam *et al.,* 2009). However, the ascorbic acid (vitamin C) content of fresh jackfruit bulb slices was found to be around 8.7±0.97 mg/100 g.

The average total carotenoid content of fresh jackfruit bulb slices was found at 4.5±0.3 µg/g. From Figure 4(b), the highest total carotenoid content was observed in dried Jackfruit bulb slices treated with 1% citric acid at 6.7 µg/g as compared to the control 5.1 µg/g and 0.5% citric acid-treated sample (5.4 µg/g) at zero-day. Saxena *et al*. (2012) reported 0.12 µg/g total

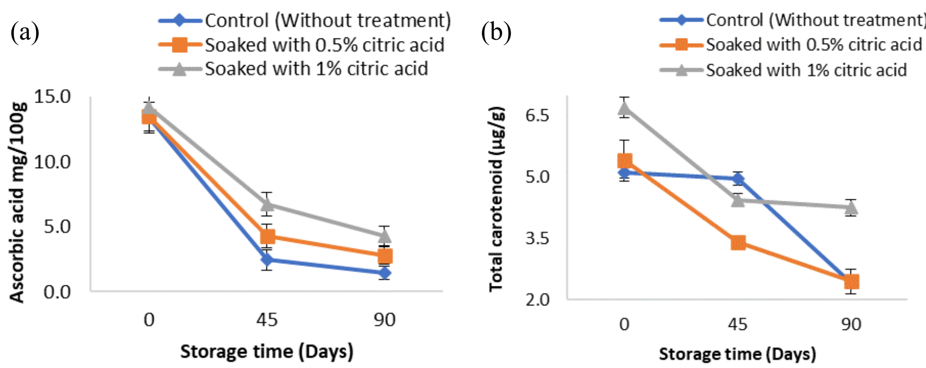

Figure 4. Effect of citric acid on bioactive compounds of dried jackfruit bulb slices during storage: (a) ascorbic acid and (b) total carotenoid.

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Table 1. Effect of citric acid concentration on mean sensory score of fried jackfruit bulb slices.

Sample (fried jackfruit bulb slices)	Color	Flavor	Taste	Texture	Crispiness	Oiliness	Overall acceptability
Control (without treatment)	6.50±1.00[b]	6.70±138[a]	6.95±1.32[a]	6.80±1.32[a]	6.70±1.17[a]	6.55±1.19[a]	6.55±1.19[b]
Soaked with 0.5% citric acid solution	7.60±0.75[a]	7.15±1.09[a]	7.55±0.76[a]	7.40±0.88[a]	7.05±0.88[a]	6.55±0.95[a]	7.05±1.05[ab]
Soaked with 1% citric acid solution	7.55±1.19[a]	7.00±0.97[a]	7.50±1.00[a]	7.35±1.18[a]	7.00±1.19[a]	7.15±0.95[a]	7.40±1.27[a]

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p \le 0.05$).

carotenoid in dried jackfruit after drying at 60°C which is far lower than the values found by this research. Pretreatment with citric acid before drying is the main reason behind the higher carotenoid content in citric acid -treated samples than in the untreated control one. Jackfruit bulb slices soaked with 1% citric acid solution gave the highest total carotenoid content at 0 day and after 90 days. Lower loss (2.45±0.30 µg/g) of carotenoid content was revealed by the sample soaked with 1% citric acid. Kramer (1997) has described that the carotenoid content decreased with time because carotenoids could easily oxidize in the presence of oxygen, light and temperature.

3.2 Sensory evaluation of fried jackfruit bulb slices

The dried jackfruit bulb slices were then fried and three pictures are shown in Figure 1 (g, h and i).

Sensory analysis results revealed that there were significant ($p \le 0.05$) differences in color and overall acceptability among the control and sample treated with 1% citric acid. From Table 1, it was also observed that in flavor, taste, texture, crispiness, and oiliness there was no significant difference among the samples. Fried jackfruit bulb slices soaked with 1% (7.55±1.19) and 0.5% (7.60±0.75) citric acid solution were significantly different from the control (6.50±1.00) for color. However, between the treated samples there was no significant difference at 5% level of significance. As shown in Table 1, the sample treated with 1% citric acid obtained the highest score for overall acceptability (7.40±1.27) and the sample treated with 0.5% citric acid secured the second position (7.05±1.05). Although Jackfruit bulb slices soaked with 0.5% citric acid solution was not significantly different from the control and the other treated sample, a noticeable difference was detected between the control and 1 % citric acid-treated sample. Thus, it is clear that the sample soaked with 1% citric acid was highly acceptable than the other two samples.

4. Conclusion

Considering the perspective, a huge amount of jackfruit losses in Bangladesh in the peak season, this research work was carried out to prepare and preserve the original characteristics of jackfruit as much as possible. With the increase in storage time, there was an increase in moisture content, TSS and a decrease in ash, pH, ascorbic acid and total carotenoid content for the dried jackfruit bulb slices soaked with 1% citric acid. Minimum variation was observed for all the physico-chemical properties of the same sample that is Jackfruit bulb slices soaked with 1% citric acid solution. In the storage periods, superior color properties were retained by the 1% citric acid-treated sample. Finally, the sample named jackfruit bulb slices soaked with 1% citric acid solution was more acceptable than the others. This study demonstrated that the addition of citric acid in jackfruit certainly affects the quality attributes. The findings of this present study will facilitate the development of commercial processing techniques for the effective utilization of matured jackfruit for manufacturing dried and fried jackfruit.

Conflict of interest

The authors declare no conflict of interest.

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