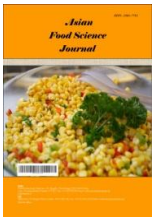

Asian Food Science Journal

14(3): 41-53, 2020; Article no.AFSJ.55262
ISSN: 2581-7752

Effect of Thermal Treatment on Physicochemical Stability and Antioxidant Properties of Locally Available Underutilized Star Fruit Juice

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Authors' contributions

This work was carried out in collaboration among all authors. Author JHS designed the study, managed the analyses of the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors WZ and MMH supervised this study. Author RSC checked the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2020/v14i330133
Editor(s):
(1) Dr. Amjad Iqbal, Abdul Wali Khan University Mardan, Pakistan.
Reviewers:
(1) Anna Rizzolo, Italy.
(2) Ye Liu, Beijing Technology and Business University, China.
(3) P. D. Sharma Rajendra Prasad, Central Agricultural University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55262

Original Research Article

Received 09 January 2020
Accepted 14 March 2020
Published 21 March 2020

ABSTRACT

Industrial processing of the fruit juice is responsible for the changes in some quality attributes. Thermal treatment is a most applicable operation for any processing and it affects the physicochemical and antioxidant properties of the juice. This study was conducted to observe the changes in some physical properties and the bioactive compounds of star fruit (*Averrhoa carambola* L.) juice during thermal treatment at 70°C, 80°C and 90°C for 10, 20, 30 and 40 min by a temperature-controlled water bath. During thermal treatment of the juice pH and browning index increased significantly *(P≤ 0.05)* with time and increasing temperature whereas the Cloud index of the juice decreased. No significant variation *(P≥ 0.05)* noticed in the case of total soluble solids. Color differences gradually increased in case of color parameter ΔL^* (0 to 7.83 ± 0.20) and negatively increased in case of Δa^* (0 to -7.33± 1.00). Irregular results observed for Δb^* and maximum difference (3.01±0.08) noticed at 90°C for 40 min. The highest overall color change (ΔE=

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11.04±0.76) observed when the juice treated at 90°C for 40 min. In consideration of the bioactive compounds, maximum ascorbic acid estimated (24.17±0.70mg/100ml) in fresh juice and with rising temperature and time it decreased. β-carotene also decreased significantly during heat treatment. The Total Polyphenol Content (TPC) found in fresh juice as (540.08±16.64 mg GAE/100 ml) and it was not changed in a regular manner with temperature change. Flavonoid content increased significantly *(P≤0.05)* when the juice was heat-treated at 70°C and 80°C while no significant change observed at 90°C. Maximum DPPH scavenging activity found in fresh juice (60.19±1.39%) and decreased to (53.83±1.43%) when 90°C temperature was applied for 40 min. This study may help to find out the nutritional value of locally available star fruit and physicochemical changes of this fruit juice during thermal processing.

Keywords: Star fruit juice; heat treatment; physical properties; bioactive compounds; physicochemical change.

1. INTRODUCTION

Averrhoa carambola L. is usually known as Star fruit. It is a popular tropical fruit having some potential health-promoting properties [1]. It is an underutilized fruit that is distributed in tropical and many subtropical regions such as Malaysia, Taiwan, Thailand, Israel, Florida, Brazil, Philippines, China, Australia, Indonesia, India, Bangladesh and other areas of the world with the same climatic conditions [2]. It is rich in natural antioxidants containing polyphenols and ascorbic acid which may reduce the chances of occurring cancer, inflammatory bowel disease, cardiovascular diseases, immune dysfunction, neural diseases, and aging [3]. This fruit was used in the treatment of different diseases like headaches, vomiting, cough, hangovers, and eczemas from many years ago because of its nutraceutical properties [4]. Star fruit has shown in vitro hypoglycemic effects because of its water-insoluble fiber fraction [5]. It is a popular fruit globally for its sweet-sour taste, nutritional composition and the presence of biologically active compounds that provide health benefits. According to the Bangladesh Bureau of Statistics (BBS), 14221 Metric Ton star fruit was produced in Bangladesh in 2016-2017 [6]. The fruit is highly perishable and most of the production of these fruits are destroyed by microbial activity. Processing of different value-added products from this fruit may be a way to reduce the wastage and it will help to increase the economic value of this fruit. Jam, squash, chutney or juice, etc. may be processed from this nutrient-rich fruit. High heat is needed to apply for any of these processing or to reduce the microbial load. In case of jam preparation, after mixing of pectin and sugar to a required level, the mixer is needed to heat at 104–105°C final boiling point and finally hot filling in a glass jar is also held at 85°C [7]. For fruit juice pasteurization, generally, 80-100°C temperature is used for reducing the microbial load [8]. pH, total soluble solid, color, browning index and cloud value are the important physicochemical parameter on which, the consumer acceptability depends. β-carotene, ascorbic acid, polyphenol, flavonoids are the important bioactive compounds that determine the nutritional and clinical value of the food product. This physical and the antioxidant properties of this fruit juice are changed during different types of product processing from this fruit. The star fruit is underutilized in Bangladesh and in former study jam and squash were prepared from the star fruit juice and the storage stability of that products were assessed. Moisture, TSS, pH, acidity, and ascorbic acid of that products were found to be stable during storage for 0 days to 3 months at 25-34°C, 10°C and 0°C [9]. The objectives of this present study were to observe the effect of heat treatment on some physical properties and some antioxidant compounds of star fruit juice.

2. MATERIALS AND METHODS

2.1 Sample Preparation

Fresh and matured carambola were collected from the local market in Sylhet, Bangladesh. Primarily collected star-fruits were washed properly under running clean tap water. Then they were cut into small pieces (sizes around 3–4 cm) by steel cutter and the seeds were removed by hand. The sliced pieces were then crushed in a juicer (MJ-M176P, Japan). The juice was filtered with the help of muslin cloth in order to make the juice clearer. After filtration, the final juice was then transferred into several clean plastic bottles and stored in the laboratory freezer at -20°C temperature for further analysis [10].

2.2 Thermal Treatment of the Star Fruit Juice at Different Condition

The thermal treatment of star fruit juices was carried out with a temperature-controlled water bath. Twelve small beakers were cleaned with distilled water and then 20 ml of juice sample was poured in each of the beakers. They were sealed properly with aluminum foil paper thus no moisture can evaporate during thermal treatment. The samples were then treated at 70°C, 80°C and 90°C for 10, 20, 30 and 40 min, respectively. The samples were cooled immediately after the thermal treatment by keeping them in an ice bath and then TSS, pH, color change, browning index, cloud index, β-carotene, ascorbic acid, flavonoid content, total polyphenol content and DPPH scavenging activity of the treated samples were investigated [11].

2.3 Sample Extraction

Sample extraction was accomplished by using 80% acetone with a proportion of 1:10 (sample: solvent). The sample solvent mixtures were incubated in a shaking incubator (SI-200, Korea) by controlling 20°C for 90 min. After the incubation period, the crude extracts were centrifuged at 3,000 rpm (416G, Gyrozen, Korea) for 15 min and after that, they were filtered through Whatman filter paper No. 42. The aliquots were collected and stored below -22°C for farther analysis [10].

2.4 Determination of Physicochemical and Antioxidant Properties

2.4.1 Determination of juice content

The juice content was weighed and recorded in grams according to the procedure followed by Jamil et al. [12]. The percent juice content was calculated by using the following formula;

% Juice content = (Juice weight/ fruit weight) × 100

2.4.2 Determination of moisture and ash content

Moisture content and Ash content of star fruit were measured by the method described in AOAC [13].

2.4.3 Determination of total soluble solids

TSS of star fruit juice was measured by using Hand Refractometer (General REF103, China). Several drops of juice were used to determine the TSS content of the juice and it was expressed in the ºBrix unit [14].

2.4.4 Determination of pH

pH values of the star fruit juice samples (both fresh and treated) were measured by using a calibrated digital pH meter (Consort C5010, Belgium) at room temperature [14].

2.4.5 Color change

Color values of the fresh and heat-treated samples were measured by using a CIE colorimeter (PCE-CSM4). After calibration of the colorimeter, a fixed amount of star fruit juice was poured into the measuring cup which was then surrounded by black paper strip thus no light can pass from outside. In this method, L^* represents the lightness; a^* means the measure of red (positive values) and green color (negative values); b^* measures the yellow (positive value) or blue (negative values) colors. The color change of the samples was determined by comparing the values of the treated samples with L^*, a^*, b^* that of the fresh juice sample and expressed as ΔL^*, Δa^*, Δb^* and ΔE. The overall color change (ΔE) of the samples was calculated according to Santipanichwong and Suphantharika [15].

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

2.4.6 Cloud index

The cloud index was measured by a slight modification of the method described by Cruz-Cansino et al. [16]. Five ml of the star fruit Juice samples were centrifuged at 1026 *g* for 10 min at room temperature. The supernatant absorbance was measured at 660 nm using a UV-vis spectrophotometer (Model-1800, Shimadzu). Distilled water was used as a blank.

2.4.7 Browning index

The browning index was measured by a slight modification of the method described by Cruz-Cansino et al. [16]. Ten mL of star fruit juice was centrifuged at 1026 *g* for 10 min to remove coarse particles. To 5 mL of the resulting supernatant, 5 mL of ethyl alcohol was added and the centrifugation was repeated. The absorbance reading of the supernatant was taken at 420 nm using a UV-Vis spectrophotometer (Model-1800, Shimadzu).

2.4.8 Determination of β-carotene content

β-carotene content was determined by following the procedure that was described by Joseph et al. with a slight modification [17]. A representative portion of the star fruit juice sample (1 ml) was accurately weighed in a glass test tube. Then 5 ml of chilled acetone was added to it and it was shaken for 15 min with occasional shaking at 4±1°C. The sample was vortexed at high speed for 10 min and finally centrifuged at 1370 *g* (Model-416G, Gyrozen, Korea) for 10 min. The supernatant was collected, and the precipitated compound was re-extracted with 5 ml of acetone by the centrifugation process described above. Whatman filter paper No. 42 was used to filtrate the supernatant. The absorbance of the extract was determined at 449 nm wavelength in a UV-Vis spectrophotometer (Model-1800, Shimadzu). The standard stock solution of β-carotene was prepared by dissolving 0.025 g β-carotene in 5ml of acetone.

Weight of β-Carotene in sample = $(\frac{W_2}{x} \times y)$ gm

Here, Weight of Sample = W_1; Weight of β-Carotene = W_2; Absorbance of standard β-Carotene = x; Absorbance of Sample = y.

2.4.9 Determination of ascorbic acid

Ascorbic acid was determined by the titrimetric method described by Ranganna and it is the most accepted method of all the titrimetric methods which is based on the reduction of 2,6-dichlorophenol-indophenol by ascorbic acid. 5 ml of sample was mixed with 3% HPO_3 and made up to volume 50 ml with HPO_3. Then it was filtered with filter paper. 10 ml of the HPO_3 extract of the sample was taken and titrated with the standard dye to the light pink endpoint which should be persisted for at least 15 seconds [18].

Ascorbic acid (mg/100 ml) =

$$\frac{Titre \times Dye\ factor \times Volume\ made\ up \times 100}{Aliquot\ of\ extract\ taken\ for\ estimation \times Weight\ of\ sample}$$

2.4.10 Determination of polyphenol content

The total phenolic content of the star fruit juice samples was measured by using the Folin-Ciocalteau assay by Slinkard and Singleton with slight modification. According to this study, 20µl of the extract and 1.58 ml of distilled water was taken in a test tube. Then, 100µl Folin-Ciocalteau reagent was also added. Mixed well and within 8 minutes, 300 µl of 20% sodium carbonate was added. The sample mixture was vortexed immediately and the tube was incubated in dark condition for 30 mins at 40°C. Blank was also prepared. After incubation of the blank and the sample, the absorbance was measured at 765 nm in a UV-Vis spectrophotometer (Model-1800, Shimadzu). The results were expressed in mg Gallic Acid Equivalent (mg GAE)/100g sample [19].

2.4.11 Determination of total flavonoid content

The aluminum tri-chloride method with slight modification was used to measure the total flavonoid content (TFC) of the star fruit juice. Briefly, 0.5 mL of the sample extract was mixed with 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminum tri-chloride, 0.1 mL of 1M potassium acetate and 2.8 mL of deionized water. After incubation at room temperature for 40 min, the absorbance of the mixture was measured at 415 nm against deionized water blank in a UV–Vis spectrophotometer (Model-1800, Shimadzu). Results were expressed as quercetin equivalent (mg QE)/100 mL of the sample [10].

2.4.12 Determination of radical scavenging activity by DPPH

The assessment of the Antioxidant activity was performed based on the inhibition of the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical by the juice extract [20]. For this analysis, 0.1 ml of sample extracts were added to 1.4 ml DPPH radical methanolic solution (0.1 Mm) and then the mixture was kept for 30 minutes. The whole process was performed in a dark condition. A blank solution was prepared by using 0.1 ml methanol in 1.4 ml of DPPH radical solution. The absorbance was measured at 517 nm by using a UV-Vis Spectrophotometer (Model-1800, Shimadzu). The results were calculated using the following equation:

Radical scavenging activity (%) = $\frac{A_o - A}{A_o}$ ×100%; Here, A_o is the absorbance of control blank, and A is the absorbance of the sample extract.

2.5 Statistical Analysis

Statistical analysis was conducted using excel-2013 and a one-way ANOVA test for multiple comparisons with XLSTAT 2014 software. P-

value ≤ 0.05 was regarded as statistically significant and it was measured by Duncan's multiple range test. Data were expressed as means ± standard deviation (SD) of three independent measurements.

3. RESULTS AND DISCUSSION

3.1 Moisture Content, Juice Content and Ash Content of Fresh Star Fruit

Star fruit is a nutrient-rich and highly perishable fruit that contains a high amount of moisture. The moisture content of this fruit was found 93.50 ± 0.22% in this present study. According to Manjula Shantaram et al. moisture content in greenish-yellow *Averrhoa carambola* was found about 94.22 ± 1.75% [21], which is near to the value that was found from our current study. According to another study of Narain et al., the moisture content of star fruit at their different ripening stage were found as in green stage (90.65 ± 0.58%); in half-ripe stage (90.32 ± 0.98%) and in the ripe condition (89.96 ± 0.39%) [22]. The moisture content of the star fruit may vary depending on their ripening stage and also variety to variety. From this current analysis of star fruit, it was determined that the percentage of juice content was 58.53 ± 0.55%. Therefore, it can be seen that the amount of the juice content in star fruit is much higher than the orange (39.13±0.14)%, sweet lime (32.46±0.17)%, lemon (30.26±0.12)% and grapes (24.13±0.26)% which was studied by Jamil et al. [12]. Ash content of the star fruit was found as 323.1 ± 6.35 mg/100gm fresh sample in this physical analysis which is in the range (260-400)mg/100 gm star fruit and about near to the value (336 ± 38)mg/100gm found in the study done by Narain et al. [22,23].

3.2 Effect of Thermal Treatment Condition on the pH and Total Soluble Solids of the Star Fruit Juice

The pH of the fruit juice is a very important parameter that indicates the level of acidity of the juice beverage. From this study, it was found that the star fruit juice is highly acidic because of its low pH. The pH value at the different thermal treatment conditions of the juice are shown in Fig. 1.

In our recent study, the pH value of fresh star fruit juice was found as 2.56 ± 0.01. It is more or less similar to the findings reported by Narain et al., who were found the pH value for the green mature star fruit and half-ripe star fruit as 2.40 ± 0.23 and 2.71 ± 0.33, respectively [22]. From the statistical analysis, it was found that with increasing temperature and time, the pH values were increased significantly *(P ≤0.05)*. Organic acids of star fruit juice may destroy during heat treatment and ultimately it affects the pH value of the juice. A similar type of result was found from the study on the effect of heat treatment on *Morinda citrifolia* extract [14]. The TSS of the star fruit juice was measured at different heat treatment conditions. The treatment conditions did not produce any effect on the values of TSS. Both the raw juice and heat-treated juice samples showed the TSS value of 6.8 ºBrix. About the same effects were shown earlier by different researchers on their works on different fruit juices [24]. Only a little increase in TSS has happened and it was estimated as 7.0 ºBrix when the juice was heat-treated at 90°C for 30-40 min. This increase in TSS may result from the degradation of pectic substances into soluble solids due to prolonged heating.

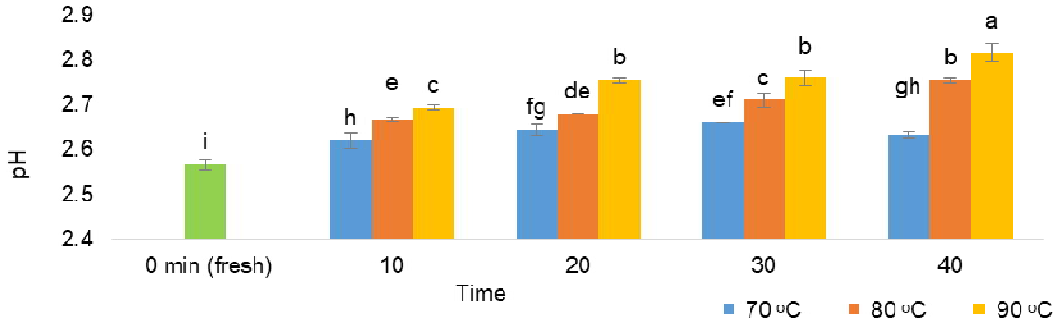

Fig. 1. The effect of thermal treatment condition on pH of star fruit juice
Values with the same superscripts within the samples indicate no significant difference (P ≤ 0.05)

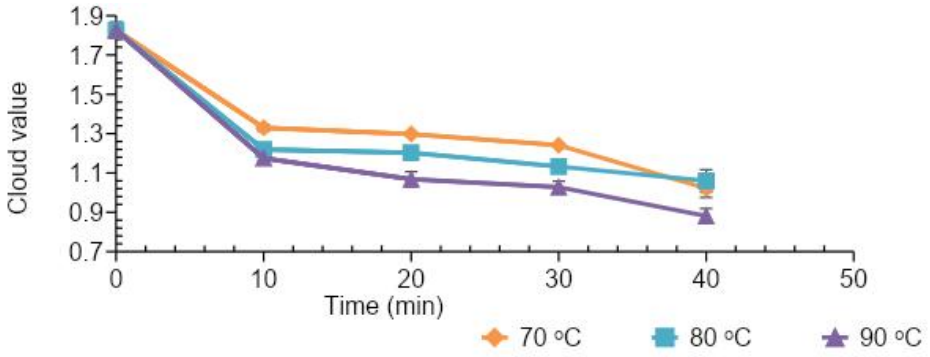

Fig. 2. The effect of thermal treatment condition on the cloud value of star fruit juice
The data are presented as the mean ± standard deviation (n=3)

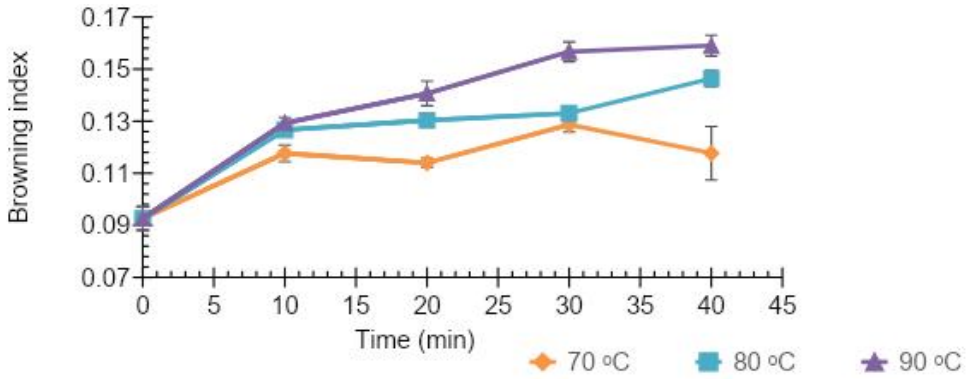

Fig. 3. The effect of thermal treatment condition on the browning index of star fruit juice
The data are presented as the mean ± standard deviation (n=3)

3.3 Effect of Thermal Treatment Condition on Cloud Index

The cloud value of a juice has an impact on the color and flavor. Various compounds like- lipids, pectin, cellulose, and protein contribute to the cloud value of a juice [25,26]. Cloud stability is an important visual quality parameter for the ultimate acceptance of consumers. From this present study, it was revealed that the cloudiness of the star fruit juice gradually decreased during thermal treatment. The cloudiness of the star fruit juice at different heat treatment condition that was found from the analysis are shown in Fig. 2.

In high-temperature holding conditions, most of the suspended particles precipitated out from the juice. So with the increasing temperature, the cloudiness of the juice gradually decreased. From this study cloudiness for the fresh juice was found maximum and it was 1.825± 0.04. The lowest value of the juice sample was found when it was heat-treated at 90°C for 40 min and the value was 0.881±0.03.

3.4 Effect of Thermal Treatment Condition on Browning Index

From the physicochemical analysis, the browning index of the star fruit juice was found to be increased with rising temperature and time. The result of different time-dependent heat treatment conditions is presented in Fig. 3.

Browning index of fresh star fruit juice was 0.092 and after heating the juice at 90°C for 40 min it becomes 0.159. Browning rate was significantly lower in the case of low-temperature thermal treatment conditions. The breakage of carotenoid pigments, ascorbic acid breakdown, Maillard reaction and caramelization due to temperature effect may be responsible for the variations in the browning index of the juice [27,28]. During the breakdown reactions, reactive carbonyls groups are produced which can act as a precursor for browning. Production of furfural compounds during the degradation of ascorbic acid also responsible for browning [28,29].

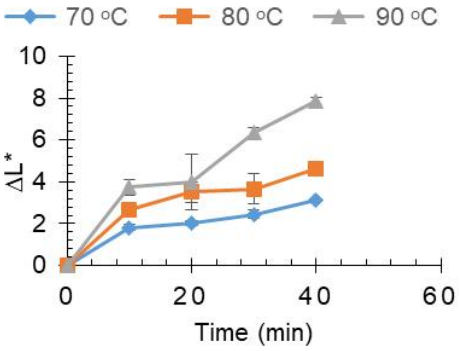

Fig. 4a. Changes in ΔL^* with thermal treatment

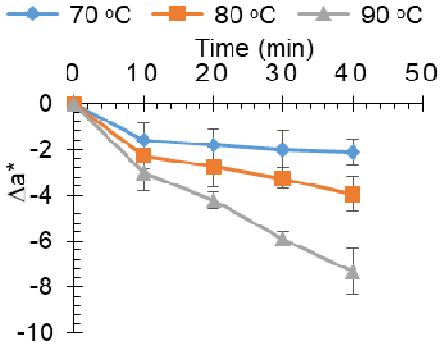

Fig. 4b. Changes in Δa^* with thermal treatment

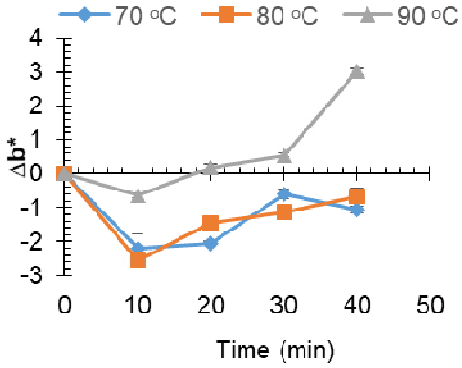

Fig. 4c. Changes in Δb^* with thermal treatment

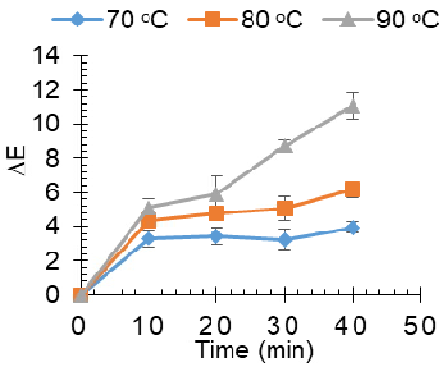

Fig. 4d. Changes in ΔE with thermal treatment

Fig. 4. The effect of thermal treatment condition on the color of star fruit juice
The data are presented as the mean ± standard deviation (n=3)

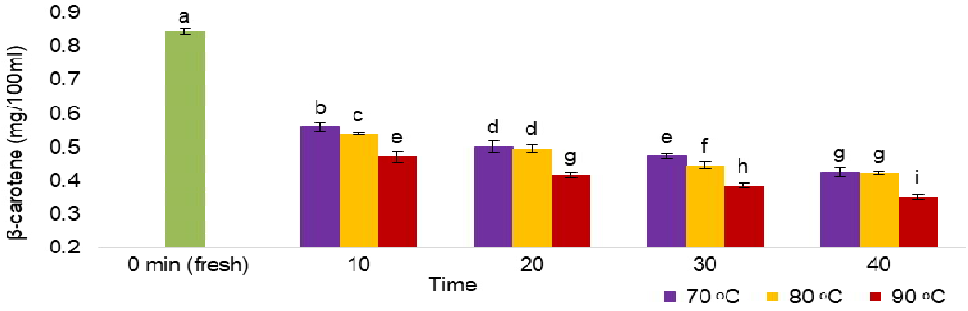

Fig. 5. The effect of thermal treatment condition on β-carotene content of star fruit juice
Values with the same superscripts within the samples indicate no significant difference (P ≤0.05)

3.5 Effect of Thermal Treatment Condition on Color Change

The thermal treatment condition is responsible for the color change of star fruit juice. Processing affected the color properties of the samples depending on the sample type and processing method and susceptibility of the natural pigments present in juice samples to the degree and time of their exposure to temperature [10]. L^* value of the fresh star fruit juice was 30.87±0.61, a^* value of the fresh juice was 1.82±0.13 and b^*

value of the juice was 21.02±0.05. These three parameters were found to change during different heat treatment condition which is responsible for the overall color change of the juice. From this study, it was revealed that the lightness of the star fruit juice ΔL^* value was increased with the temperature and the heat treatment time. On the other hand, Δa^* value of the juice was decreased which indicates that the reddish color of the juice gradually decreases with time and temperature and turns into greenish. The overall color change occurred significantly *(P≤0.05)* in the case of heat treatment and it was dependent on both the time and temperature of the heat treatment condition.

3.6 Effect of Thermal Treatment Condition on Retention of β-carotene

In this study, the effect of thermal treatment on the β-carotene content of the juice was determined and the values are presented in Fig. 5.

The result was found as the β-carotene content of the juice gradually decreased with the rising temperature and time. In fresh juice the value was maximum and it was (0.84±0.009 mg/100mL) and the lowest value was found when it was treated at 90°C for 40 min (0.35±0.007 mg/100mL). A similar result was found in the case of banana pumpkin puree where the beta carotene content of the purees was gradually decreased with temperature and time [11]. In another study of Ishiwu Charles N. et al., the β-carotene content of tomato was found to decrease 15.7 ±0.01 mg/100 mL (raw) to 15.2±0.01 mg/100 mL(2 min boiled) and 5.7±0.140 mg/100 ml (30 min boiled) which determines the sharp decrease in β- carotene content of the samples as heat treatment time increased [30]. Fig. 5 confirms that β-carotene is a heat-sensitive compound and could be more available in fresh star fruit juice than the processed juice and its degradation depends on both temperature and time of thermal treatment.

3.7 Effect of Thermal Treatment Condition on Ascorbic Acid Content of Star Fruit Juice

From this physicochemical analysis of star fruit juice, the ascorbic acid content in fresh star fruit juice was found as 24.17 ± 0.70 mg/100 ml juice. Our result was more or less similar to the findings reported by Nayak et al. [24], who were found the ascorbic acid content of 24.8 ± 0.71 mg/100 mL in the start fruit juice. Fig. 6 illustrates the changes in the ascorbic acid content of star fruit juice with increasing temperature and time during thermal treatment.

The ascorbic acid was found to decrease much sharply in the case of 90ºC temperature and the value decreased from 24.17 ± 0.70 (fresh) to 9.832±0.00 mg/100ml (heat-treated at 90ºC for 40 min). A similar type of result can be seen in the case of pomegranate juice where the ascorbic acid was decreased with the rising temperature and this degradation follows the first-order reaction kinetics [31]. The degradation of ascorbic acid was found to be increased and it was influenced by the method of heating, temperature, and heat treatment time [30,32]. For the higher retention of ascorbic acid, the processing of star fruit juice must be at a lower temperature due to the heat sensitivity of the ascorbic acid.

3.8 Effect of Thermal Treatment Condition on Total Polyphenol Content of Star Fruit Juice

From this study, it was found that the phenolic content of fresh star fruit juice may be increased or decreased depending on the temperature and responding time. Fig. 7 illustrates the variation of the polyphenol content of star fruit juice with different heat treatment conditions.

The total polyphenol content for fresh star fruit juice is 540.08±16.64 mg GAE/100 mL; this value is comparable to that of Nayak et al. [24], which is (6.03 ± 0.32 mg GAE/mL). This variation is due to the difference in the variety of the cultivar, the environment and the soil condition. From this study, it was found that the TPC of star fruit juice may decrease or increase with the heat treatment condition. The amount of TPC was found to be increased to the highest value when the juice was heat-treated at 70°C for only 10 min and it was found to be decreased to the lowest value (443.42±5.77 mg GAE /100 ml) when the juice was heat-treated at 90°C for 40 min. According to Azzouzi et al., the value of the total polyphenols of pasteurized orange juice varies from 46.3 to 58.3 GAE/100mL and there is a significant increase in the polyphenols content of the juice treated at 88°C temperature for 15 seconds [33]. In another contradicting study, [34] observed a dramatic loss of phenolic content on convectional and organic grown food as a result of thermal treatment. According to [31] heat treatment on the pomegranate juice affected the

total polyphenol content of the juice and it was decreased gradually with rising temperature. Contradictory results were found by the researchers in the different studies on the effects of heat treatment conditions on the total phenolic content. In some studies, the result was found to increase in the phenolic content and in other studies, it was found to decrease. In this study, it was an attempt to simulate the actual heat treatment conditions for star fruit juice.

3.9 Changes in Flavonoid Content of Star Fruit Juice during Thermal Treatment

Flavonoid is an important health-promoting component of fruit juice. In mild heat treatment of star fruit juice, it was found to increase the flavonoid content. But this is not a uniform change with different heat treatment conditions. Flavonoid content of fresh juice was examined as 2.56 ± 0.40 mg QE/100 ml. The values were significantly changed *(P≤0.05)* with different heat treatment conditions. In the case of the heating at 70°C for 20 min, the flavonoid content found as a maximum (6.51±0.40 mg QE/100 ml). Our results are consistent with the result of a temperature-dependent study on the shiitake mushroom where the flavonoid content found to increase during heating up to a certain temperature by Choi et al. [35]. From the study of another author, it was found that the flavonoid content significantly increased in the apple juice during heating up to 70°C [36]. Heat treatment of star fruit juice at 70°C and 80°C results in a significant *(P≤0.05)* increase in flavonoid content but not such a significant change in the case of 90°C.

3.10 Effect of Thermal Treatment Condition on DPPH Scavenging Activity of Star Fruit Juice

Fig. 9 illustrates the changes of DPPH scavenging activity according to the heat treatment conditions.

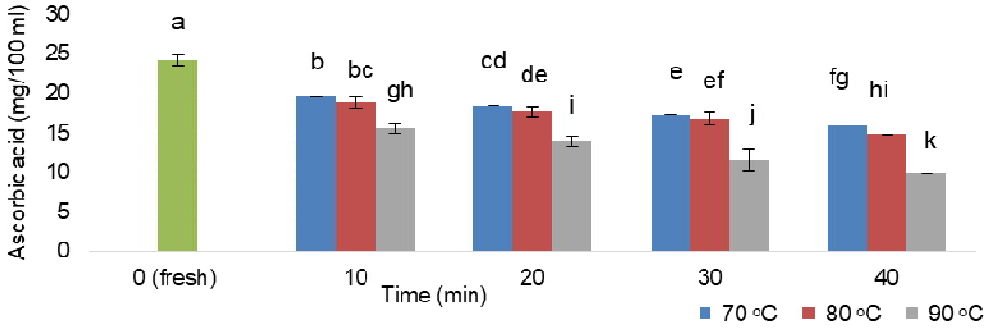

Fig. 6. The effect of thermal treatment condition on ascorbic acid content of star fruit juice
Values with the same superscripts within the samples indicate no significant difference (P ≤0.05)

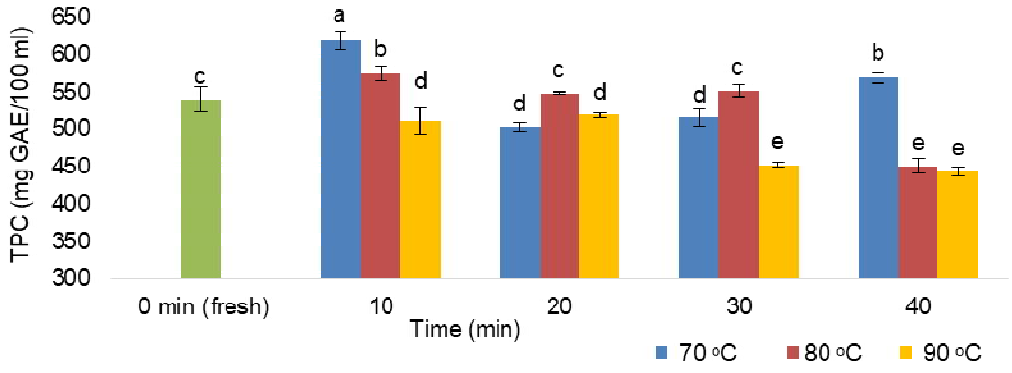

Fig. 7. The effect of thermal treatment condition on the total polyphenol content of star fruit juice
Values with the same superscripts within the samples indicate no significant difference (P ≤ 0.05)

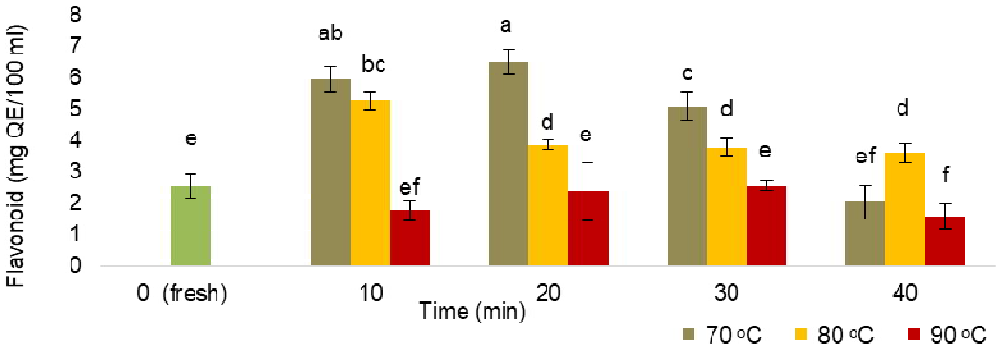

Fig. 8. The effect of thermal treatment condition on the total flavonoid content of star fruit juice

Values with the same superscripts within the samples indicate no significant difference (P ≤0.05)

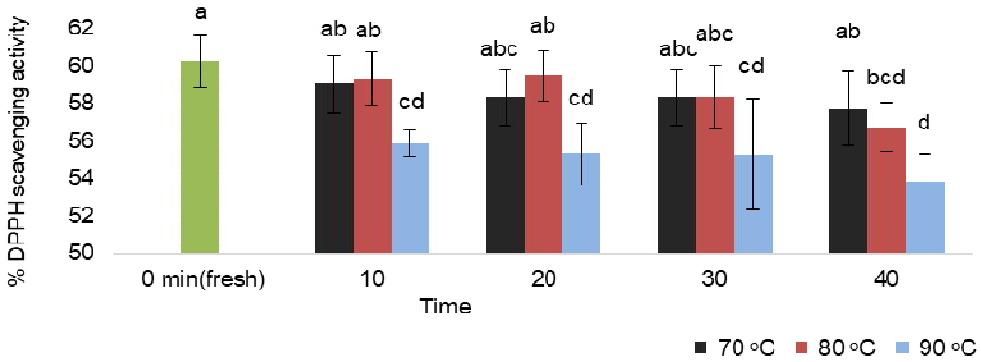

Fig. 9. The effect of thermal treatment condition on %DPPH scavenging activity of star fruit juice

Values with the same superscripts within the samples indicate no significant difference (P≤0.05)

Antioxidant activity determines the nutritional and medicinal value of star fruit. Antioxidant activity of the fresh star fruit juice (60.19±1.39%) obtained in our present study. It turns out that the antioxidant activity of this underutilized star fruit is near to the antioxidant activity of lemon (63%), orange (61%) and higher than the grapefruits (58%), mandarin (52%), tomato (10%) and guava (3%) those found in the other study [37]. From this present study, it revealed that antioxidant scavenging activity was highest in the fresh juice and decreased during thermal treatment but it also remains unchanged in some heat treatment conditions. Heat treatment at 70°C for 40 min results in a loss of antioxidant activity. In the case of 80°C (20 min) heat treatment, the DPPH scavenging activity increased and again decreased with increasing time. The more significant loss *(P≤0.05)* held in heat treatment at 90 °C temperature. The lowest value of antioxidant scavenging activity estimated as 53.83±1.43% when the star fruit juice was treated at 90°C for 40 min. Our results are compatible with the findings of Ali et al. who found that fresh fruits contain the highest antioxidant activity and the processing of juices at high temperature are responsible for the decrease in the antioxidant activity [37]. In the study of other researchers it also observed that thermal treatments at 75°C and 100°C resulted in decreases in anti-DPPH radical activity of raw juices of spinach, 'komatsuna' and 'chingensai' to 55–65% [38].

4. CONCLUSION

β-carotene and ascorbic acid degradation were in regular trend and this affects the total antioxidant activity of the juice. From this study, it was found that ascorbic acid degradation is much higher at 90°C than 70°C and 80°C. TPC was also decreased more significantly in the case of 90°C and the change of TPC was not in a regular trend. Flavonoid content increased significantly *(P≤0.05)* when the juice was heat-treated at 70°C and 80°C but no significant

change was observed at 90°C. Changes of β-carotene, ascorbic acid and TPC results in the ultimate antioxidant capacity of the heat-treated star fruit juice. The findings from our work could predict the optimal processing conditions that minimize the degradation of bioactive compounds in star fruit juice. Therefore, the star fruit could be utilized in the processing of different value-added products which may create a good chance of fruit manufacturing and a good source of economy in Bangladesh as well.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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