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CONTENTS

Nutrients and antioxidants potential of star fruit (*Averrhoa carambola* L.)

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ABSTRACT: Star fruit (*Averrhoa carambola* L.), commonly known as the Golden Star, is a tropical fruit from the Oxalidaceae family, distinguished by its star-shaped cross-section and unique sweet-sour flavor. Traditionally used in Indian medicine as a cooling agent, it is valued for its nutritional and therapeutic benefits. However, no comprehensive studies were made in this fruit. Therefore, the nutritional composition, anti nutritional factors, and antioxidant potential of ripe star fruit was evaluated. The fruit showed a high moisture content (92.52%) and moderate acidity (0.32%), consistent with its juicy texture and tart taste. Proximate analysis revealed low levels of fat (0.28 g/100 g) and protein (0.56 g/100 g), along with moderate amounts of carbohydrates (6.49 g/100 g) and dietary fiber (3.25 g/100 g), indicating its suitability for low-calorie, fiber-rich diets. Mineral profiling identified potassium (119 mg/100 g) as the most abundant element, followed by phosphorus, calcium, sodium, and iron. Antinutritional factors were found in minimal concentrations, with oxalates at 7.53 mg/100 g, within acceptable limits for tropical fruits. Tannins (0.16 mg/100 g) and phytates (0.04 mg/100 g) were present in trace amounts, unlikely to affect nutrient bioavailability. Antioxidant activity was assessed using DPPH, ABTS, superoxide, and nitric oxide scavenging assays with IC_{50} values of 636 µg/mL, 662 µg/mL, 298 µg/mL, and 78 µg/mL, respectively. The findings highlight that star fruit is a nutritious and functional fruit with promising applications in health-conscious diets, and it can be used to develop nutraceutical and functional food products.

Keywords: Antioxidant, *Averrhoa Carambola*, star fruit

Averrhoa carambola, commonly known as a golden star or star fruit, is an attractive fruit of the family Oxalidaceae, cultivated in tropical and sub-tropical regions of the world (Narain *et al*., 2001). This tropical fruit is characterized by its star-like shape and a delightful combination of sweet and sour flavors (Kesavnath *et al*., 2015).

Star fruits are green and unripe during the early stages of growth, but they gradually turn yellow or light orange as they mature (Narain *et al*., 2001). Star fruits have a juicy flesh and feature five distinct longitudinal ridges or angles, offering a crunchy and crisp texture (Muthu *et al*.,2016).

Star fruit is rich in essential nutrients that contribute significantly to its health benefits. Star fruit is reportedly low in sugar and sodium and rich in phenolic compounds like epicatechin, vitamin C, proanthocyanidins, and carotenoids (Shui and Leong, 2004). Carotenes, vitamins, and acids were found in the ripe fruit of *Averrhoa carambola*, with high levels of vitamin C (25.8 mg/100 g fruit), tartaric acid (4.37 mg/100 g fruit) and vitamin B_2 (0.12 mg/100 g fruit) (Muthu *et al*., 2016). In their study, Manda *et al*. (2012) reported that 100g of star fruit offers 0.38g of protein, a minimal fat content of 0.08g, 9.38g of carbohydrates, and 0.90g of fiber. They also emphasized that it is an excellent source of potassium, copper, folate, and pantothenic acid. Star fruit is rich in natural antioxidants like L-ascorbic acid (Vitamin C) and Gallic acid, which are known to combat reactive oxidative species (ROS) (Moresco, 2012).

Star fruit has many medicinal uses and contains secondary metabolites with diverse organic activities (Kumar and Arora, 2016). Carambola has been reported to have beneficial antioxidant, inflammatory, anti-cancer, hypocholesterolaemic, and immunity-boosting properties. It also possesses various phytochemicals and minerals. (Lakmal *et al*., 2021). Silva and Sirasa (2018) found that *Averrhoa carambola* exhibits strong antioxidant properties, as FRAP and DPPH assays demonstrated. Kuntang *et al*. (2022) also noted that the high antioxidant activity of star fruit bio-extract makes it suitable for creating functional foods and cosmetic items. Traditional Indian medicine highlights the ripe fruits of star fruit as beneficial for addressing issues like hemorrhaging, fever, eczema, and diarrhoea.

In Ayurveda, the ripe fruit of star fruit is often viewed as a digestive aid and tonic. This plant's leaves, roots, flowers, and fruits also hold potential as nutritious supplements, suggesting a need for further research and development as functional foods or medicinal agents for promoting human health (Luan *et al*. 2021). In view of these, a study was conducted to analyse the antioxidants and nutrient properties of carambola fruits.

MATERIALS AND METHODS

Plant Material

Fresh star fruit (*Averrhoa carambola*) was harvested from the college orchard of the Department of Fruit Science, College of Agriculture, Vellanikkara. The fruits were carefully selected for their uniformity in size, ripeness, and free from any physical defects. Once collected, they were washed thoroughly to ensure the removal of any surface contaminants. The seeds were extracted, and the fruit was processed using a Sujata Multimix Mixer Grinder. The pulp was obtained by straining the blended fruit through fine muslin cloth to separate the juice.

Proximate nutrient composition determination

Moisture

A sample of 2 g was placed in pre-weighed moisture dishes and dried for eight hours at 60 °C in a hot air oven. The moisture content was calculated based on the weight loss observed (AOAC, 2023).

Acidity

The fruit's acidity was determined using Ranganna (1986). 10 ml of fruit extract was taken in a conical flask and diluted with 40 mL of distilled water. A few drops of 1% phenolphthalein indicator were added, and the solution was titrated with 0.1 N NaOH until a light pink color remained for 30 seconds, which indicated the endpoint. The titratable acidity was then calculated and expressed as a percentage citric acid equivalent using the formula:

$$\frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Volume made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample}}$$

Carbohydrates

The carbohydrate content was determined using the Anthrone method described by Sadasivam and Manickam (1992). The fruit pulp was hydrolyzed with 5 mL of 2.5 N HCl by boiling for three hours in a water bath. After cooling, the solution was neutralized with solid sodium carbonate until the effervescence stopped and the volume was made up to 100 ml and centrifuged. 0.1 ml of the supernatant was taken and diluted to a final volume of 1 ml. Subsequently, 4 ml of anthrone reagent was added to the solution. The mixture was heated for 8 minutes and quickly cooled. The mixture was heated for eight minutes before measuring their color intensity at 630 nm. The carbohydrate content was determined by comparing the absorbance of the sample to a glucose standard curve. The total carbohydrates were quantified and expressed as grams per 100 grams.

Protein

The protein content of star fruit was determined using the Kjeldahl method (AOAC,2023). The method is structured around three fundamental steps: digestion, distillation, and titration. During the digestion phase, one gram of pulp is added to a Kjeldahl digestion flask, followed by the addition of 10 to 15 ml of concentrated H_2SO_4 and one g of a Kjeldahl catalyst, which includes copper sulphate and potassium sulphate. In the distillation phase, the digested sample was moved to a distillation flask, and 10 mL of 40% NaOH was added to facilitate the release of ammonia gas. The distillate was collected in a receiver containing 2% boric acid and mixed indicators, then titrated against a 40% NaOH solution using a standard acid (0.2 N HCl). In the titration step, the ammonia-boric acid complex was titrated with 0.1 N HCl until the solution turned pink, indicating the endpoint. The total nitrogen content was calculated using the formula:

$$\text{Total Nitrogen (\%)} = \frac{(V1\text{-}V2) \times N \times 6.25}{\text{Sample Weight}}$$

Where V1 is the volume of the HCl sample, V2 is the volume of HCl for the blank, N is the normality of HCl and 6.25 is the atomic weight of nitrogen.

Fat

The total fat content was determined using the Soxhlet extraction method described by AOAC

(2023). In this method, 5 g of dried sample was placed in a thimble and inserted into the Soxhlet extractor. A pre-weighed extraction flask with 150–200 mL of petroleum ether was connected to the apparatus. The apparatus was heated, causing the solvent to evaporate, condense, and wash the sample multiple times, extracting the fat over 6–8 hours. After extraction, the solvent was removed by evaporation using a rotary evaporator. The extraction flask was then placed in a desiccator to remove any remaining moisture before being weighed again. The change in weight from before to after extraction reflected the total fat content, calculated using the formula:

$$\text{Total Fat (\%)} = \frac{\textit{weight of the fat extracted}}{\textit{weight of the sample}} \times 100$$

Fibre

The crude fiber was estimated using Sadasivam and Manickam's method (1992). 2 g of dried sample was first boiled with 1.25% H_2SO_4 for 30 minutes, then filtered and washed. The residue was then boiled with 1.25% NaOH for 30 minutes, followed by another filtration and washing**.** After a second filtration, the residue was washed with hot water, ethanol, and acetone to remove impurities. The residue obtained was transferred to an ashing dish and dried at 130°C for 2 hours. Once dried, the dish was cooled in a desiccator, reweighed, and recorded. The residue was ignited in a muffle furnace at 600°C for 30 minutes, cooled gain in the desiccator, and reweighed. The percentage of crude fiber was calculated using the formula:

$$\frac{\textit{Weight of dried residue -Weight of ash}}{\textit{Weight of sample}} \times 100$$

Beta carotene

Beta carotene was estimated using the method suggested by Srivastava and Kumar (2014). 5 g of sample was extracted using 10 to 15 mL of acetone and a few anhydrous sodium sulfate crystals. The supernatant was carefully decanted, and 10 to 15 mL of petroleum ether was added, mixed thoroughly, and left undisturbed for layer separation. The upper layer was then transferred to a 100 mL volumetric flask and diluted to 100 mL with petroleum ether. The color intensity was measured using a spectrophotometer at 452 nm, and the beta-carotene content was expressed in µg per 100 g of the sample.

Vitamin C

The vitamin C content of star fruit was estimated using the method suggested by Sadasivam and Manickam (1992). One g of the sample was homogenized with 10 mL of 4% oxalic acid and filtered. The extract was titrated with 2,6-dichlorophenol indophenol (DCPIP) dye until a pink color appeared. The vitamin C content was determined based on a standard ascorbic acid curve and expressed in mg per 100 g sample.

Total ash

The ash content of star fruit was analyzed using the method given by ISI (1980). A five-gram sample was weighed into a crucible and ignited in a muffle furnace at 550–600°C for 5 to 6 hours until complete incineration. The crucible was then cooled in a desiccator to room temperature and weighed. The resulting ash content was calculated as a percentage of the initial sample weight, representing the total mineral residue in the sample.

$$\text{\% Ash} = \frac{w1 - w2}{w1} \times 100$$

Where W_1 (Initial weight) refers to the combined weight of the crucible and the sample before ashing, W2 (Final weight) refers to the combined weight of the crucible and the ash after incineration.

Mineral Determination

Calcium and Iron

The calcium and iron content in star fruit was assessed using the AOAC (2023) method. One gram of the dried sample was digested using 10 mL of concentrated nitric acid and 5 mL of perchloric acid heated until a clear solution formed. After cooling, the digested mixture was diluted to 50 mL with deionized water and filtered. The concentrations of calcium and iron were determined using an atomic absorption spectrophotometer (AAS), with calcium measured at 422.7 nm and iron at 248.3 nm. The results were compared to a standard calibration curve, and the mineral content was reported in mg per 100 g of the sample.

Sodium, Potassium and Phosphorous

The sodium, potassium, and phosphorus content of star fruit was determined using the AOAC (2023). One g dried sample was digested with 10 mL of concentrated nitric acid (HNO_3) and 5 mL of perchloric acid ($HClO_4$) by heating until a clear solution was formed. After digestion, the sample was cooled, diluted to 50 mL with deionized water, and filtered. The sodium and potassium levels were analyzed using a flame photometer, with sodium detected at 589 nm and potassium at 766 nm, using standard solutions for calibration. The phosphorus content was determined by adding ammonium molybdate reagent and ascorbic acid, which resulted in a blue phosphomolybdate complex, measured at 660 nm using a UV-Vis spectrophotometer. The mineral concentrations were calculated based on standard calibration curves and expressed in mg per 100 g sample.

Estimation of antinutritional composition

Oxalate

The oxalate content of star fruit was analyzed using the procedure suggested by Marderosin *et al*. (1979). A 2 g sample was mixed with 190 mL distilled water and 10 mL 6N HCl, boiled in a water bath, diluted, and filtered. The precipitate was washed in between to make the volume about 125 ml, and 3-4 drops of methyl red was added to the filtrate, followed by concentrated ammonia till the solution turned to faint yellow. The mixture was then heated to 90–100°C, filtered using No. 41 filter paper, and rinsed thoroughly to remove impurities.10 mL of 5% calcium chloride solution was added, and the mixture was left undisturbed for 24 hours to allow precipitation. The resulting precipitate was collected on Whatman No. 41 filter paper and thoroughly washed with hot water to remove residual calcium ions. Diluted sulfuric acid (H_2SO_4, 1:4) was added until the precipitate was dissolved entirely, and the solution was warmed to 70°C. The oxalate content was quantified by titrating the solution with N/20 potassium permanganate until a stable endpoint was reached.

Tannin

The tannin content in star fruit was estimated using the method described by Ranganna (1986). One gram sample was extracted with 50 mL of distilled water by heating at 80°C for 30 minutes with occasional shaking. The extract was then cooled, filtered into a 100 mL volumetric flask, and diluted to volume. For analysis, 1 mL of the extract was mixed with 2.5 mL of Folin-Denis reagent and 2.5 mL of 20% sodium carbonate solution, allowing the mixture to stand for 30 minutes. The absorbance was measured at 760 nm using a UV-Vis spectrophotometer, with tannic acid as the standard for calibration. The tannin content was expressed as mg tannic acid equivalent per 100 g sample.

Phytates

The phytate content in star fruit was estimated using the method described by Sadasivam and Manickam (1992). Two grams of the fruit sample were extracted using 0.2N hydrochloric acid with continuous shaking for a specified duration. The extract was filtered, and a ferric chloride solution was added to form a ferric-phytate complex. The precipitate was thoroughly washed, dissolved in an acidic medium, and heated to ensure complete dissolution. The absorbance of the solution was measured at 465 nm using a spectrophotometer, and the phytic acid content was quantified using a standard calibration curve. The final values were reported as mg per 100 g of the sample.

Antioxidant assays

DPPH Radical scavenging assay

The DPPH radical scavenging assay, as described by Prieto *et al*. (1999), is a widely used method for evaluating antioxidant activity. In this method, a DPPH solution is prepared in methanol or ethanol, typically at a concentration of 0.1 mM or 0.2 mM, and kept in the dark to prevent degradation. The antioxidant sample is then prepared at different concentrations in methanol. To initiate the reaction, 1 mL of the DPPH solution is mixed with 1 mL of the sample solution, while a control and a blank are also prepared. The mixture is then incubated in darkness at room temperature for 30 minutes, allowing the antioxidants to interact with the DPPH radicals. Following incubation, the absorbance is recorded at 517 nm using a UV-Vis

spectrophotometer. The percentage of DPPH radical inhibition is determined using the formula:

$$\% \text{ Inhibition} = \frac{A \text{ control} - A \text{ sample}}{A \text{ control}} \times 00$$

where: $A_{control}$ is the absorbance of the DPPH solution without the sample. A_{sample} is the absorbance of the solution with the sample.

ABTS radical scavenging assay

The ABTS radical scavenging assay, outlined by Re *et al*. (1999), is a commonly employed technique for assessing antioxidant activity. In this method, the ABTS radical is produced by reacting an ABTS solution with an oxidizing agent, specifically potassium persulfate. Usually, a 7 mM ABTS solution is combined with 2.45 mM potassium persulfate and left to incubate in the dark at room temperature for 12 to 16 hours, forming ABTS. After 6 minutes, the absorbance was recorded at 734 nm. The ability to scavenge free radicals was determined using the equation below and represented as the percentage of ABTS radical inhibition compared to the blank.

$$\% \text{ Inhibition} = \frac{A \text{ control} - A \text{ sample}}{A \text{ control}} \times 100$$

$A_{control}$ and A_{sample} refer to the absorbance measurements of ABTS radicals in the PBS buffer and the sample extracts, respectively.

Superoxide and hydroxyl scavenging activity

The superoxide and hydroxyl radical scavenging activity is based on the method described by Beauchamp and Fridovich (1971). In this process, the reaction mixture generally includes 50 mM phosphate buffer, 0.1 mM EDTA, 0.1 mM xanthine, 0.025 mM NBT, and xanthine oxidase. A test sample or a standard antioxidant, like ascorbic acid or quercetin, is added, and the mixture is incubated at room temperature for 10 to 20 minutes. The absorbance is subsequently measured at 560 nm with a UV-Vis spectrophotometer. The percentage inhibition of superoxide radicals is calculated using the formula:

$$\% \text{ Inhibition} = \frac{A \text{ control} - A \text{ sample}}{A \text{ control}} \times 100$$

where $A_{control}$ is the absorbance of the reaction mixture without the sample, and A_{sample} is the absorbance in the presence of the antioxidant.

Nitric oxide scavenging activity

The nitric oxide (NO) scavenging activity assay, as described by Marcocci *et al*. (1994). In this method, sodium nitroprusside acts as a nitric oxide donor, leading to the spontaneous generation of NO in an aqueous solution. The standard reaction mixture comprises 10 mM SNP in phosphate-buffered saline mixed with the test sample at different concentrations. The solution is incubated at room temperature for 150 minutes while exposed to light to enhance nitric oxide production. After the incubation phase, an equal volume of Griess reagent, —a combination of 1% sulfanilamide in 5% phosphoric acid and 0.1% N-(1-naphthyl) ethylenediamine dihydrochloride is added to the reaction mixture. The nitrite formed reacts with the Griess reagent, creating a purple azo dye and its absorbance is measured at 540 nm using a UV-Vis spectrophotometer. The percentage of nitric oxide scavenging activity is calculated using the formula:

$$\% \text{ Inhibition} = \frac{A \text{ control} - A \text{ sample}}{A \text{ control}} \times 100$$

where $A_{control}$ is the absorbance of the reaction mixture without the sample, and A_{sample} is the absorbance in the presence of the antioxidant.

RESULTS AND DISCUSSION

Physico-chemical analysis

Different physico-chemical like Moisture, acidity, carbohydrates, protein, fat, fiber, beta carotene, vitamin C, and total ash of star fruit are presented in Table 1. The moisture content of the ripe star fruit in this study was 92.52%, notably higher than the 85.1% reported by Edem *et al.* (2008). Interestingly, our results are more comparable to the 92.5% moisture content recorded by Edem *et al*. (2008) for unripe star fruit. The possible variations might be due to cultivar differences, growing conditions, or ripening stages at the time of analysis. The high moisture content in the ripe samples emphasizes the fruit's perishable nature. It reinforces the necessity

for diligent post-harvest practices and proper storage conditions to mitigate the chances of deterioration. The titratable acidity of the star fruit was measured at 0.32%, indicating a moderately acidic nature that contributes to the fruit's characteristic tart flavor. This value is similar to the findings of Basena *et al*. (2019), which reported titratable acidity levels of 0.26% in ripe star fruits and 0.39% in half-ripe fruits, indicating the significance of fruit maturity on acidity. The slight differences noted across studies could be attributed to variations in cultivar, climatic factors, and post-harvest management.

The carbohydrate content of star fruit was determined to be 6.49 g/100 g, consistent with the 6.73 g/100 g reported by the USDA. However, Gautam *et al*. (2024) reported a significantly higher total carbohydrate content of 9.65% in star fruit, indicating that variations may arise from differences in ripeness.

The protein and fat levels of star fruit in this study were observed at 0.56 g/100 g and 0.28 g/100 g, respectively. These findings align closely with USDA data, which indicates that fresh star fruit contains 1.04 g/100 g of protein and 0.33 g/100 g of fat. On the other hand, Narain *et al*. (2001) showed a lower protein value of 0.45 g/100 g for star fruit. The observed protein and fat content variations across studies may be influenced by factors such as cultivar type, maturity stage, climatic and soil conditions.

The dietary fiber level of 3.25 g per 100 g is marginally more significant than the 2.8 g per 100 g documented by the USDA, but it falls short of the 10% found in unripe fruits, as noted by Edem *et al*. (2008). This suggests that fiber content may decrease as the fruit ripens.

The beta-carotene content in star fruit was measured at 1724.96 µg/100 g, highlighting its role as a valuable source of provitamin A. Muthu *et al*. (2016) indicated that ripe star fruits contain carotene in amounts from 3 to 550 µg per 100 g. The higher levels of beta-carotene observed in this study suggest a significant capacity for contributing to vitamin A levels and providing antioxidant activity, essential for vision, immune health, and skin integrity.

The vitamin C content of star fruit in this study was 25.5 mg per 100 g. This result is closely aligned with earlier research findings. Muthu *et al*. (2016) noted a vitamin C concentration of 25.8 mg per 100 g in mature star fruits. Similarly, Edem *et al*. (2008) reported ascorbic acid levels of 23 mg per 100 ml in unripe star fruit and 4.6 mg per 100 ml in ripe fruit. Factors such as the ripeness of the fruit, agricultural practices, and environmental conditions may account for the variations in vitamin C content observed across different studies.

The total ash content of the star fruit was 0.36, indicating the total mineral residue present in the fruit after combustion. The results of this study align closely with the observations made by Kumar and Arora (2016), who found that the ash content in star fruit varied between 0.26% and 0.40%. The value obtained in the present study falls well within this range.

Mineral estimation

The mineral content of ripe star fruit (*Averrhoa carambola*) revealed the presence of essential macro and micro elements in this study (Table 2). The calcium content (4.66 mg/100 g) observed in this study is consistent with values reported by Narain *et al*. (2001), who reported a calcium concentration of 4.83 mg/100 g in ripe star fruit, which varies based on the fruit's cultivar and maturity.

The phosphorus concentration identified in this study was 28.4 mg/100 g, significantly greater than 19 mg/100 g for ripe fruits and 21 mg/100 g for half-ripe fruits, as reported by Basena *et al*. (2019). The differences in phosphorus content could be attributed to factors such as fruit variety, soil nutrient levels, and the stage of maturity at harvest.

The sodium content of ripe star fruit was 2.6 mg/ 100 g, indicating a relatively low level of this

Table 1: Physico-chemical properties of Star fruit per 100g

Proximate Composition	Concentration
Moisture (%)	92.52
Acidity (N)	0.32
Carbohydrates (g)	6.49
Protein (g)	0.56
Fat (g)	0.28
Fibre (g)	3.25
Beta carotene (µg)	1724.96
Vitamin C (mg)	25.5
Total ash (%)	0.36

mineral. This is slightly less than the sodium concentrations observed by Muthu *et al*. (2016), which ranged from 3.8 to 3.85 mg/100 g. Also, sodium levels in fruits are commonly influenced by environmental conditions, such as soil salinity and irrigation methods, which can vary significantly across different cultivation areas.

The potassium content of ripe star fruit was recorded at 119 mg/100 g. This value is slightly below the 133 mg/100 g reported by Kumar and Arora (2016). The differences in potassium levels could be attributed to factors like cultivar variations, soil potassium availability, and geographical conditions. The iron content in this study was determined to be 0.39 mg/100 g, within the range of 0.34 to 0.45 mg/100 g, as noted by Muthu *et al*. (2016) in their analysis of star fruit. Similarly, Basena *et al*. (2019) observed iron levels of 0.43 mg/100 g in half-ripe fruits and 0.40 mg/100 g in ripe fruits, which closely aligns with the current results.

Anti-nutritional Factors

Anti-nutritional components including oxalates, tannins, and phytates were presented in Table 3.

The oxalate concentration in star fruit is 7.53 mg/100 g. This value aligns with observations by Ferrara (2018), who reported that oxalate levels in *Averrhoa carambola* vary significantly between varieties. Ferrara (2018) indicates a notable difference in oxalate content between sweet and sour fruit, with sour varieties having levels as high as 7 mg/g, while sweet varieties tend to have much lower concentrations.

The tannin content in ripe star fruit was 0.16 mg/100 g, indicating a low concentration of this anti nutritional element. This finding is consistent with the earlier research by Narain *et al*. (2001), who reported a tannin level of 0.14 mg/100 g in ripe star fruit.

The phytate content of star fruit was 0.04 mg per 100 grams, indicating a very low concentration of this anti-nutritional factor. Phytates are recognized for their ability to bind essential minerals, which may hinder their bioavailability. However, the low concentration found in this study suggests that the intake of star fruit is unlikely to influence mineral absorption negatively.

Table 2: Mineral composition of Star fruit per 100g

Minerals (mg/100g)	Concentration
Calcium	4.66
Phosphorous	28.4
Sodium	2.6
Potassium	119
Iron	0.39

Antioxidant determination

The antioxidant properties of star fruit were assessed through four distinct assays: the DPPH radical scavenging assay, the ABTS radical scavenging assay, the superoxide and hydroxyl scavenging activity, and the nitric oxide scavenging activity as shown in Table 4.

The DPPH radical scavenging assay (IC_{50} value) of star fruit was 636 µg/mL (0.636 mg/mL), indicating moderate free radical scavenging effectiveness. This is compared to the findings of Zainudin *et al*. (2012), who reported an IC_{50} value of 1.31 ± 0.53 mg/mL for star fruit extract. This study reveals a lower IC_{50} value, indicating that the star fruit sample utilized in our research exhibited more antioxidant activity. ABTS radical scavenging assay, yielding an IC_{50} value of 662 µg/mL, which reflects moderate antioxidant activity. Singhatong *et al*. (2019) documented an ABTS radical scavenging activity of 722.71 ± 12.25 µg GAE/g extract in sweet-type star fruit.

The superoxide radical scavenging assay produced an IC_{50} value of 298 µg/mL, suggesting that the fruit extract has a moderately high ability to neutralize superoxide radicals. However, there is limited comparative data available regarding the superoxide

Table 3: Anti-nutritional factors of Star fruit per 100g

Anti nutritional composition	Concentration(mg/100g)
Oxalate	7.53
Tannins	0.16
Phytates	0.04

Table 4: Antioxidant assay of star fruit

Antioxidant assay	IC_{50}
DPPH assay	636 µg/mL
ABTS assay	662 µg/mL
Superoxide hydroxyl scavenging activity	298 µg/mL
Nitric oxide scavenging activity	78 µg/mL

scavenging activity of star fruit.

The star fruit was found to have comparatively high nitric oxide activity with an IC_{50} value of 78 µg/mL. This is in line with the observation of Singhatong *et al*. (2019), who reported high nitric oxide scavenging activity with IC_{50} value of 27.18 µg/mL.

The findings in this study suggest that the star fruit extracts possess a moderate antioxidant potential. This variation might be influenced by several factors, including the maturity of the fruit, the solvents used for extraction, the geographical origin, or the concentration of phenolic compounds and other bioactive materials present in the fruit.

CONCLUSION

The present study comprehensively evaluates the nutritional composition and antioxidant potential of ripe star fruits (*Averrhoa carambola* L). our finding showed that the star fruit is a hydrating, low-calorie fruit known for its juicy texture and mildly tart flavor. It could be a valuable source of essential nutrients, particularly vitamin C and beta-carotene, contributing to its antioxidant potential. Its low fat and protein content, moderate carbohydrates, and dietary fiber highlight its role as a healthy fruit choice. Star fruit is a nutrient-dense fruit rich in essential micronutrients, particularly potassium, which supports cardiovascular health and electrolyte balance. At the same time, its low sodium content makes it an excellent choice for those managing hypertension. This unique mineral profile, combined with its vitamins and phytochemicals, underscores the fruit's significant health benefits. Starfruit is a healthy and safe option with notable antioxidant benefits, making it an essential component of health-focused diets and a strong contender for developing nutraceuticals and functional foods. Its abundant phytochemical composition highlights its promise as a natural source of dietary antioxidants.

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