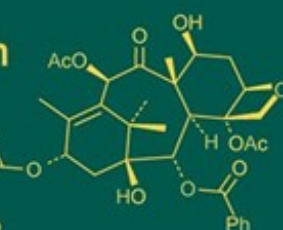
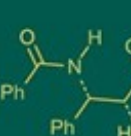
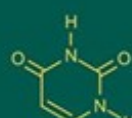


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Development and quality evaluation of star fruit (*Averrhoa carambola* L.) Ready-To-Serve blended with plum and pineapple

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ABSTRACT

The present investigation entitled "Development and quality evaluation of star fruit (*Averrhoa carambola* L.) Ready-To-Serve beverage blended with plum and pineapple" was conducted during 2025-26 at the Horticulture Processing Laboratory, Department of Fruit Science, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment was conducted to develop and evaluate blended RTS beverages prepared from star fruit, plum and pineapple juice. Seven treatments were evaluated in a Completely Randomized Design (CRD) with three replications, viz., T₀: 100% star fruit (control), T₁: 80% star fruit + 20% plum, T₂: 60% star fruit + 40% plum, T₃: 80% star fruit + 20% pineapple, T₄: 60% star fruit + 40% pineapple, T₅: 80% star fruit + 10% plum + 10% pineapple and T₆: 60% star fruit + 20% plum + 20% pineapple. The beverages were evaluated for physico-chemical, sensory and microbial characteristics at 15-day intervals up to 90 days of ambient storage. Among the treatments, T₆ exhibited the best overall performance in the freshly prepared beverage, recording total sugar (8.37%), reducing sugar (6.65%), non-reducing sugar (1.72%) and sugar:acid ratio (27.90), along with the highest sensory scores for colour and appearance (8.60), taste (9.00), flavour (9.00), aroma (8.90) and overall acceptability (8.80). The maximum ascorbic acid content (3.49 mg/100 ml) was recorded in T₄. During storage, TSS, titratable acidity, total sugar and reducing sugar increased, whereas ascorbic acid, TSS:acid ratio, sugar:acid ratio and sensory scores decreased. Microbial count increased from 0.00 to 0.53 x 10⁴ cfu/ml but remained within acceptable limits.

Keywords: Star fruit, Plum, Pineapple, Ready-To-Serve beverage, Blending

Introduction

Star fruit (*Averrhoa carambola* L.), commonly known as carambola, is an important tropical and subtropical fruit belonging to the family Oxalidaceae. The fruit is characterized by its distinctive star-shaped appearance when cut transversely and is valued for its refreshing taste and nutritional properties. It contains sugars, vitamin C, minerals and several bioactive compounds, including flavonoids and phenolic compounds, which contribute to its potential functional properties (Kumari *et al.*, 2024 [1], Lakmal *et al.*, 2021). In India, star fruit is considered a minor fruit crop and is commonly grown in home gardens and small orchards. Despite its nutritional and processing potential, its utilization as a value-added processed product remains comparatively limited (Mitra, 2014) [2].

Pineapple (*Ananas comosus* L.) is an important tropical fruit valued for its characteristic aroma, flavour and refreshing taste. It contains sugars, organic acids, vitamins and the proteolytic enzyme bromelain and is widely utilized for juice and other processed products. Its desirable flavour and balanced sugar-acid characteristics make pineapple juice suitable for blending with other fruit juices (Hossain *et al.*, 2015; Nath *et al.*, 2024) [3].

Plum (*Prunus* spp.) is a nutritionally valuable fruit containing sugars, organic acids, vitamins, minerals, pectin and bioactive compounds such as phenolics, anthocyanins and flavonoids. It is consumed fresh as well as processed into various value-added products. Incorporation of plum juice into blended beverages may contribute desirable flavour and nutritional attributes (Voca *et al.*, 2009; Zarlashgt and Ullah, 2023) [4, 5].

Blending of fruit juices provides an effective approach for combining desirable sensory and nutritional characteristics of different fruits. In particular, blending star fruit juice with pineapple and plum juices may help develop a beverage with improved flavour, taste and overall acceptability while providing an opportunity for value addition and better utilization of star fruit. Ready-To-Serve (RTS) beverages offer a convenient form of fruit utilization and have considerable potential for the development of value-added fruit products.

However, information on the standardization of suitable blending ratios of star fruit, plum and pineapple juices and their quality changes during ambient storage is limited. Therefore, the present investigation entitled "Development and quality evaluation of star fruit (*Averrhoa carambola* L.) Ready-To-Serve beverage blended with plum and pineapple" was undertaken to standardize suitable blending ratios and evaluate the physico-chemical, sensory and microbial quality of the developed RTS beverage during ambient storage, along with its economic feasibility.

Materials and Methods

Fully mature, healthy and disease-free star fruit, plum and pineapple fruits were procured from the local market of Raipur, Chhattisgarh. Fruits were selected for uniform size, colour and maturity and washed thoroughly with potable water before processing. Sugar, citric acid, potassium metabisulphite (KMS) or sodium benzoate were used as additives and preservatives in RTS beverage preparation.

The fruits were washed, peeled and cut into small pieces. Juice was extracted separately using a mixer grinder/juice extractor and filtered through a muslin cloth. Seven treatment combinations were prepared by blending star fruit juice with plum and pineapple juice in different proportions. The treatments consisted of T₀: 100% star fruit (control), T₁: 80% star fruit + 20% plum, T₂: 60% star fruit + 40% plum, T₃: 80% star fruit + 20% pineapple, T₄: 60% star fruit + 40% pineapple, T₅: 80% star fruit + 10% plum + 10% pineapple and T₆: 60% star fruit + 20% plum + 20% pineapple. Sugar syrup was prepared and adjusted to 10°Brix, while citric acid was added to maintain 0.3% titratable acidity. The juice blend was mixed with the syrup, cooled to room temperature and preservatives (KMS or sodium benzoate) were added according to the treatment. The RTS beverage was filled into pre-sterilized 200 mL glass bottles, sealed with crown caps, and pasteurized in hot water (below 100 °C for 20 minutes). The bottles were cooled and stored at ambient room temperature for 90 days.

Chemical parameters (TSS, titratable acidity, ascorbic acid, TSS: acid ratio, total sugar, reducing sugar, non-reducing sugar and sugar: acid ratio), sensory evaluation and microbiological analysis were recorded at 15-day intervals during the storage period.

Results and discussion

Chemical changes during storage of blended star fruit RTS

The storage behaviour of the selected blended RTS, T₆ (Star fruit: Plum: Pineapple = 60:20:20), was evaluated at 15-day intervals up to 90 days under ambient storage conditions. The changes in chemical parameters, namely TSS, titratable acidity, ascorbic acid, TSS:acid ratio, total sugar, reducing sugar, non-reducing sugar and sugar:acid ratio, are presented in Table 1 and illustrated in Fig. 1. All the chemical parameters showed significant changes with the advancement of the storage period.

Total soluble solids (TSS)

TSS increased significantly from 10.00 to 11.17 °Brix during 90 days of storage. The gradual increase was attributed to the hydrolysis of polysaccharides and pectic substances into soluble sugars. Similar increases in TSS during storage have been reported in RTS beverages by Bhatt *et al.* (2022) [6] and Pillai *et al.* (2024) [7].

Titrateable acidity

Titrateable acidity increased significantly from 0.30% to 0.85% during storage. The increase may be due to the formation of organic acids through carbohydrate degradation and other biochemical reactions. Similar findings were reported by Sarkar and Bulu (20 17) and Chandra *et al.* (2018) [8].

Ascorbic acid

Ascorbic acid decreased significantly from 17.70 to 12.73 mg/100 ml over the storage period. The reduction was mainly due to oxidative degradation of vitamin C during storage. These results agree with

Goswami *et al.* (2019) [9] and Santos *et al.* (2021) [10]. Ascorbic Acid (mg/100g)

TSS:Acid ratio

The TSS:Acid ratio decreased significantly from 33.33 to 13.14 during storage. Although TSS increased slightly, the faster increase in acidity resulted in a lower ratio, indicating a gradual decline in sweetness-acidity balance. Similar finding were reported by Sarkar and Bulu (20 17) and Chandra *et al.* (2018) [8].

Total sugar

Total sugar increased significantly from 8.37% to 9.27% after 90 days. This increase may be attributed to the conversion of complex carbohydrates into simple sugars during storage. Similar observations were reported by Sarkar *et al.* (2017) [11] and Pillai *et al.* (2024) [7].

Reducing sugar

Reducing sugar increased significantly from 6.65% at 0 days to 7.43% after 90 days of storage. The increase in reducing sugar may be attributed to the hydrolysis of non-reducing sugar, particularly sucrose, into reducing sugar during storage. Similar finding were reported by Sarkar *et al.* (2017) [11] and Pillai *et al.* (2024) [7].

Non-reducing sugar

Non-reducing sugar decreased significantly from 1.72% to 1.22% during storage, likely due to the hydrolysis of sucrose into reducing sugars. Similar trends were reported by Sarkar and Bulu (20 17) and Pillai *et al.* (2024) [7].

Sugar:Acid ratio

Sugar:Acid ratio declined significantly from 27.90 to 10.91 over 90 days of storage. The increase in titratable acidity was greater than the increase in total sugar, resulting in a reduced sugar:acid ratio and changes in beverage taste during storage. Similar findings were reported by Sarkar *et al.* (2017) [11] and Chandra *et al.* (2018) [8].

Sensory parameters of blended star fruit RTS during storage

The sensory quality of the selected blended RTS, T₆ (Star fruit: Plum: Pineapple = 60:20:20), was evaluated at 15-day intervals up to 90 days under ambient storage conditions. The observations are presented in Table 2 and illustrated in Fig. 2.

Colour and appearance

Colour and appearance scores decreased significantly from 8.60 at 0 days to 4.35 after 90 days of storage. The decline may be attributed to pigment degradation, non-enzymatic browning and oxidative reactions during storage. Similar findings were reported by Bhatt *et al.* (2022) [6] and Pillai *et al.* (2024) [7].

Taste

Taste scores decreased significantly from 9.00 to 4.00 during storage. The reduction in taste may be due to changes in sugar-acid balance, loss of freshness and development of slight off-flavours during storage. Similar observations were reported by Sarkar and Bulu (20 17) and Sackey *et al.* (2017) [12].

Flavour

Flavour scores declined significantly from 9.00 at 0 days to 4.12 after 90 days of storage. The decrease may be attributed to the loss of volatile flavour compounds and oxidative changes during storage. Similar findings were reported by Sarkar and Bulu (20 17) and Sackey *et al.* (2017) [12].

Aroma

Aroma scores decreased significantly from 8.90 to 4.13 during storage. The decline may be due to the gradual loss of volatile aromatic compounds and oxidative deterioration during storage. Similar results were reported by Sarkar *et al.* (2017) [11] and Sackey *et al.* (2017) [12].

Overall acceptability

Overall acceptability decreased significantly from 8.80 at 0 days to 4.05 after 90 days of storage. The gradual decline may be attributed to the combined reduction in colour, taste, flavour and aroma during storage. Similar findings were reported by Bhatt *et al.* (2022) [6] and Sackey *et al.* (2017) [12].

C. Microbial activity in blended star fruit RTS during storage

The microbial quality of the selected blended RTS, T_6 (Star fruit: Plum: Pineapple = 60:20:20), was evaluated at 15-day intervals up to 90 days under ambient storage conditions. The observations are presented in Table 3 and illustrated in Fig. 3. The microbial colony count increased significantly with the advancement of storage period.

Microbial colony count ($\times 10^4$ CFU/ml)

No microbial colonies (0.00×10^4 CFU/ml) were observed at 0 and 15 days of storage, indicating the effectiveness of pasteurization and hygienic processing during product preparation. Microbial growth was first detected at 30 days (0.19×10^4 CFU/ml) and increased gradually to 0.27, 0.36, 0.45 and 0.53×10^4 CFU/ml at 45, 60, 75 and 90 days, respectively.

The gradual increase in microbial colony count may be attributed to the multiplication of surviving microorganisms, utilization of available nutrients and a gradual reduction in preservative effectiveness during prolonged storage. However, the microbial count remained comparatively low throughout the storage period, indicating satisfactory microbiological quality of the RTS beverage under ambient storage conditions. Similar findings were reported by Sharma *et al.* (2018) and Kumar *et al.* (2017).

Table 1. Effect of storage duration on chemical parameters of blended star fruit RTS (best treatment) under ambient conditions.

Days of Storage	TSS CBrix	Titration acid-ity (%)	Ascorbic acid (mg/100 ml)	TSS: Acid ratio	Total sugar (%)	Reducing sugar (%)	Non - reducing sugar (%)	Sugar: acid ratio
0 days	10.00erg	0.30fg	3.22a	33.33a	8.37defg	6.65g	1.72a	27.9a
15 days	10.13def	0.32ef	3.08ab	31.66b	8.46cdef	6.97f	1.49b	26.44b
30 days	10.37cde	0.35e	2.93bc	31.12bc	8.57bcde	7.29de	1.28c	24.49c
45 days	10.60bcd	0.48d	2.72d	29.71cd	8.69bcd	7.56cd	1.13d	18.10d
60 days	10.83abc	0.56c	2.51e	28.46de	8.76abc	7.82c	0.94e	15.64e
75 days	10.94ab	0.72b	2.33f	27.28ef	8.84ab	8.11b	0.73r	12.28f
90 days	11.17a	0.85a	2.10g	25.00g	9.10a	8.50a	0.56g	10.71g
SE (m)	0.16	0.01	0.04	0.53	0.12	0.09	0.01	0.30
±								
C.D. at 5%	0.48	0.03	0.11	1.62	0.35	0.28	0.04	0.93

Table 2. Effect of storage duration on sensory parameters of blended star fruit RTS (best treatment) under ambient conditions

DAS	Colour and appearance	Taste	Flavor	Aroma	Overall acceptability
0 days	8.60a	9.00a	9.00a	8.90a	8.80a
15 days	8.57ab	8.7Qrab	8.93ab	8.82ab	8.75ab
30 days	8.30abc	8.54bc	8.73abc	8.41c	8.49c
45 days	7.12d	7.19d	7.67d	7.02d	7.25d
60 days	6.72e	6.83de	6.10e	6.68de	6.58e
75 days	5.35f	5.21f	5.10f	5.09f	5.18f
90 days	4.35g	4.00g	4.12g	4.10g	4.05g
SE _m ±	0.12	0.13	0.11	0.12	0.08
C.D. at 5%	0.35	0.39	0.33	0.37	0.24

Table 3. Effect of storage duration on microbial analyses of blended star fruit RTS under ambient condition.

Notations	Days of Storage	Microbial colony count ($\times 10^4$) cfu/ml
Do	0 days	or
Dt	15 days	or
Dz	30 days	0.19e
D ₃	45 days	0.27d
D ₄	60 days	0.36c
D ₅	75 days	0.45b
D ₆	90 days	0.533
	SE _m ±	0.03
	C.D.	0.08

Note:

DAS: Days after storage: The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means

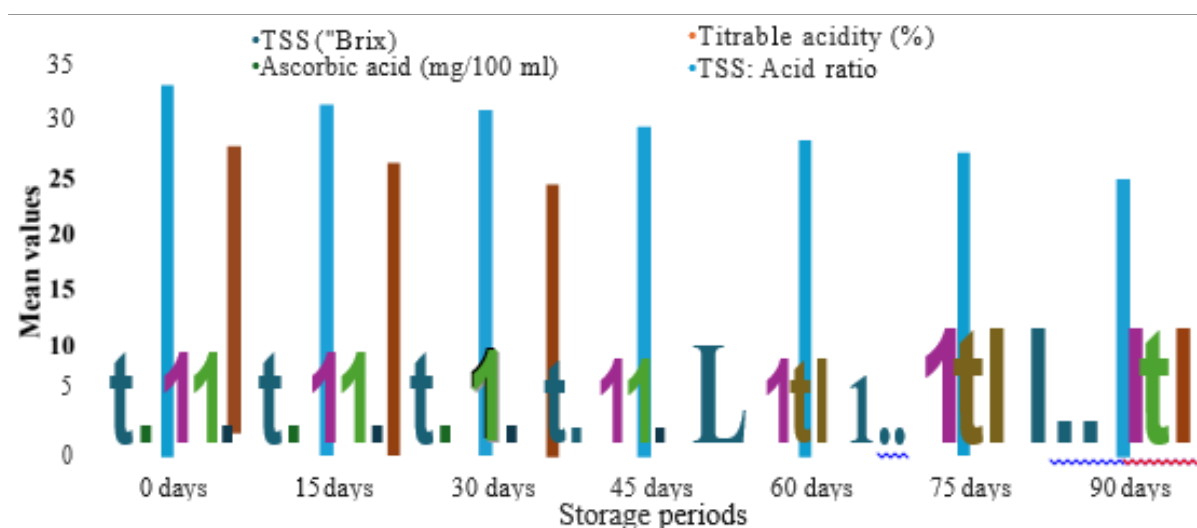


Figure 1. Effect of storage duration on chemical parameters of blended star fruit RTS (best treatment) under ambient conditions

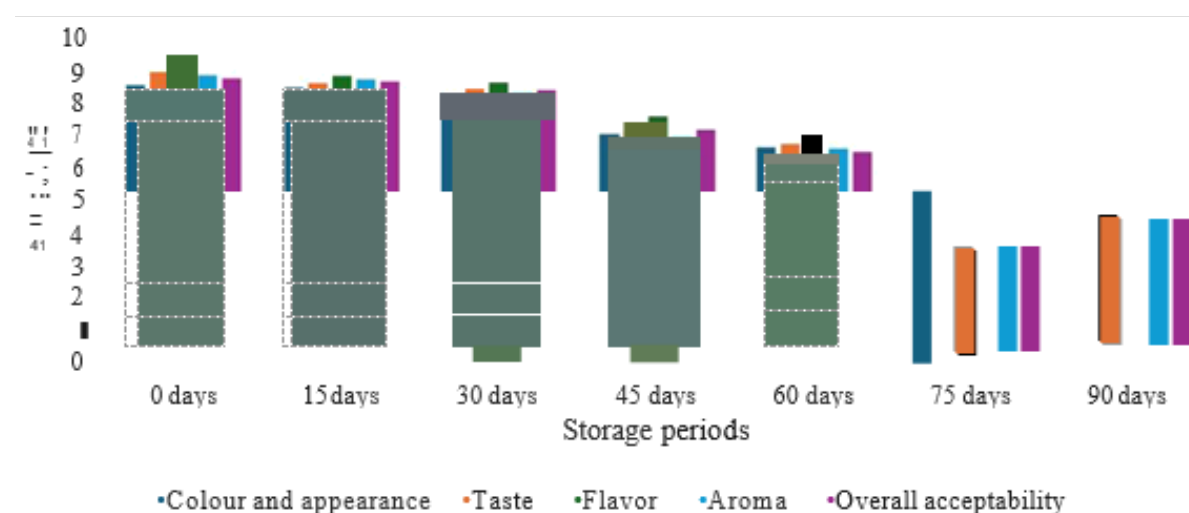


Figure 2. Effect of storage duration on sensory parameters of blended star fruit RTS (best treatment) under ambient condition.

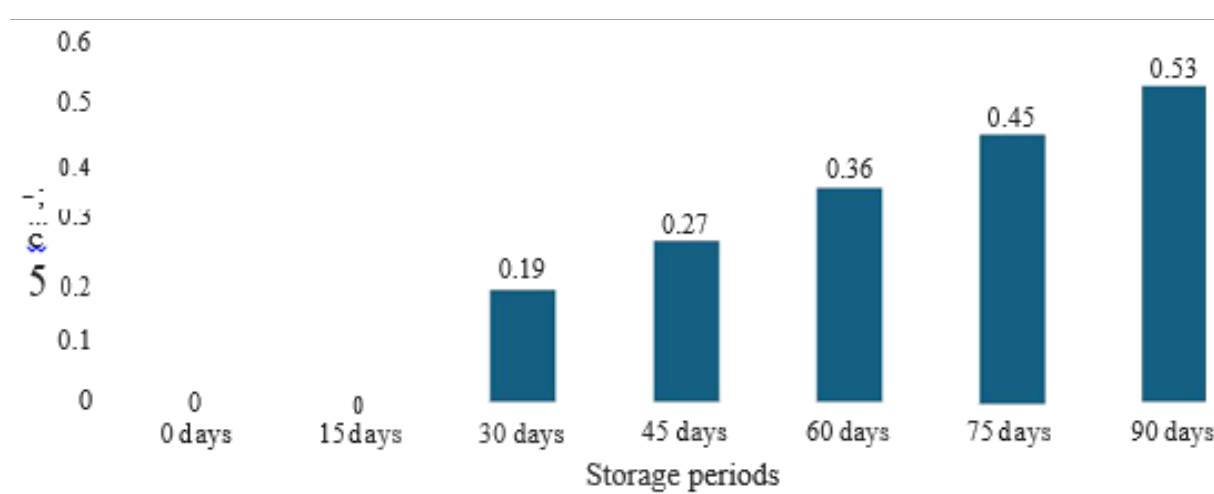


Figure 3. Effect of storage duration on microbial analyses of blended star fruit RTS under ambient condition.

Conclusion

The following conclusions can be drawn on the basis of the results obtained from the present investigation entitled "Development and quality evaluation of star fruit (*Averrhoa carambola* L.) Ready-To-Serve blended with plum and pineapple."

1. The present investigation showed that the optimum blending ratio for the preparation of star fruit RTS beverage was Treatment T_6 (60% Star fruit + 20% Plum + 20% Pineapple), followed by Treatment T_4 (60% Star fruit juice + 40% Pineapple), based on overall quality and performance.
2. During the 90-day storage period, TSS, total sugar and reducing sugar increased, whereas non-reducing sugar, ascorbic acid and TSS: Acid ratio decreased. Titratable acidity increased gradually during storage.
3. Microbial growth was observed after 30 days of storage and at 90 days the microbial count exceeded the permissible limit prescribed by FSSAI, indicating reduced microbial stability during extended storage.
4. Treatment T_6 recorded the highest Benefit: Cost ratio, followed by Treatment T_4 , demonstrating superior economic feasibility among all treatments.
5. Based on physicochemical characteristics, microbial quality, sensory evaluation and economic analysis, Treatment T_6 is recommended as the optimum formulation for the preparation of a high-quality, consumer acceptable and economically viable star fruit RTS beverage, followed by Treatment T_4 as the next best formulation.
6. Based on overall physico-chemical parameters, sensory attributes and storage stability, Treatment T_6 [Star fruit: Plum: Pineapple (60:20:20)] is recommended as the most suitable recipe for commercial preparation of blended RTS of star fruit.

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