AATCC Review

13 November 2024: Received
31 January 2025: Revised
25 February 2025: Accepted
02 March 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Enhancing consumer's acceptability of Pomelo juice (*Citrus grandis Linn.*) through blending with sweet orange juice

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ABSTRACT

This study aimed to enhance the consumers' acceptability of pomelo fruit juice by reducing its bitterness by blending it with sweet orange juice. The study involved the extraction of pomelo and sweet orange juices and the preparation of their blends. The blends were prepared by adding sweet orange juice with pomelo juice in different proportions and compared with pure pomelo and pure sweet orange juices by sensory evaluation. The prepared blends were subjected to sensory evaluation using a hedonic scale. The sensory evaluation revealed that the blending ratio of 3:2 (pomelo: sweet orange), matched the overall consumers' acceptability to that of the sweet orange juice. Moreover, the prepared drinks were stored for 90 days to evaluate their shelf-life and changes in biochemical properties such as TSS, pH, total sugar, reducing sugar, non-reducing sugar, vitamin C, titratable acidity and the microbial counts were analyzed at intervals of 30 days. Some biochemical properties such as TSS, pH, total sugar and reducing sugar were noted to be increasing with storage duration. Whereas, other biochemical properties such as vitamin C, titrable acidity, and non-reducing sugar decreased with the increase in storage duration. The microbial counts were found to be within limits for consumption up to 90 days. This finding has resulted in a minimal processing technique that has potential to increase the utilization of the underutilized pomelo, in the form of fruit juice. Furthermore, the blends thus prepared were completely natural beverages that has the potential to compete heavily with synthetic drinks.

Keywords: *Blending, Sensory evaluation, Consumer acceptability, Shelf-life, Pomelo, Orange*

1. INTRODUCTION

Increasing demand for nutrition-rich foods has stimulated research to identify sources that are nourishing as well as economically viable [1]. Citrus fruits are well-known for their nutritional and pharmacological benefits. Among the various species of citrus fruits, the largest one and the underutilized is the Pomelo(*Citrus maxima*) [2]. Known for its rich nutrient profile, pomelo has the potential to support cardiovascular health, immunity, skin vitality, digestion, and weight management [3], [9]. The global production comes mainly from China which accounts for 52% of total global pomelo production [10]. Pomelo's edible part comprises around 50–55% of the fruit and its juice generally contains 7–11°B total soluble solids. Apart from being rich source of vitamin C (30–43 mg per 100 g), it contains other bioactive compounds like carotenoids, limonoids, and flavonoids that make it beneficial for health [11], [12]. Eating a quarter of a pomelo provides about 60 calories and over 100% of the daily recommended ascorbic acid [13].

Despite its nutrient-rich profile, pomelo utilization is limited especially in countries like India. The important factor that hinders its utilization is the conversion of limonoids present in pomelo juice to limonin which turns the juice bitter, shortly after extraction. Additionally, its processing is challenging because of its thick rind and tough membranes around its segments which are inedible [14 and 18]. The bitterness in pomelo juice not only affects consumer acceptability but also shortens the shelf life of the juice [19]. Thus, pomelo presents a unique opportunity if processed effectively [20], [22].

Studies indicate that combining juices from multiple fruits can yield products with better taste and nutrient profiles, particularly for acidic or bitter fruits [3]. Blending pomelo juice with other fruit juices can under mask its bitter taste, and improve its nutritional value [23]. Sweet orange (*Citrus sinensis*), which is a fusion between pomelo and mandarin, grown widely in India, provides a complementary sweetness and is favored in beverages due to its color, flavor, and high ascorbic acid content [24], [25].

In regions like Bihar, India, where pomelo production is high, limited post-harvest processing has led to its underutilization. Developing methods for blending pomelo with other fruits can enhance consumer acceptance and utilization of its nutritional benefits. This study thus focused on creating a palatable pomelo beverage with an extended shelf life by incorporating sweet orange juice. Expanding pomelo processing could lead to new value-added products, benefiting both consumers and producers by increasing fruit utilization and offering a healthy, natural alternative to synthetic beverages [26].

2. MATERIAL AND METHODS

2.1. Procurement of fruits and extraction of juice

The pomelo and orange fruits were procured from the local fruit market of Pusa, located in the neighborhood of the Dr. Rajendra Prasad Central Agricultural University, Samastipur, Bihar, India. After pre-processing cleaning, both fruits were manually peeled off using a knife (stainless steel).

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DOI: https://doi.org/10.21276/AATCCReview.2025.13.01.511

The segments, seeds, and juice vesicles of the fruits were manually separated. The juice vesicles obtained were fed to a classic hand-operated juicer. The juices of both the fruits were prepared separately and the juicer was properly washed before use to prevent mixing and contamination during juicing. The extracted juices were filtered using a muslin cloth for the removal of the fibrous part.

2.2 Blending of juices

The filtered pomelo and orange juice were added in different proportions and blended with a hand beater. Three different blends were prepared having Orange: Pomelo ratio of 40:60 (T1), 30:70 (T2), 25:75 (T3) (Figure 1). Two other samples of pure pomelo juice (T0) and pure sweet orange juice (T4) were considered for the comparative evaluation.The blended drinks were added with sugar for TSS calibration, citric acid as acidity regulator and KMS as the preservative[27].

Figure 1. Different juice prepared, T0:Pure pomelo, T1:Orange:Pomelo blend (40:60), T2:Orange:Pomelo blend(75:25), T3:Orange:Pomelo blend(70:30), T4:Pure orange

2.3 Sensoryevaluation

Sensory evaluation of blended juice samples was done by 20 panelists of both genders (aged between 20 and 30 years), selected from the Department of Processing and Food Engineering of Dr. Rajendra Prasad Central Agricultural University. The panelists were explained the nature of the experiment without disclosing the identity of the samples. Panelists were provided with a glass of water and instructed to rinse their mouths between samples. They were given written instructions and asked to evaluate the products for acceptability based on their colour, taste, flavour, mouthfeel, and overall acceptability using a nine-point hedonic scale (1 = dislike extremely to 9 = like extremely) accordingly [28].

2.4 Storage studies

The blended juice samples were preserved by pasteurizing at a temperature of 80°C for 3 minutes[29], and filled in 200 mL pre-sterilized glass bottles. The bottles were crown corked immediately after pouring the juice samples into them and stored at the temperature of 5°C.[30]The samples were stored for 90 days and changes in physicochemical properties and microbial counts were evaluated at an interval of 30 days.

2.5 Laboratory analysis

The physicochemical parameters including total soluble solids, vitamin C, titratable acidity, total sugars, reducing sugars, and non-reducing sugars were determined by A.O.A.C. (1984) methods [31]. Microbiological analysis was carried out accordingly [32].

2.6 Statistical analysis

All experiments were carried out in triplicate and results of the physicochemical, sensory quality, and microbial count were statistically analyzed by analysis of variance (ANOVA) and means were compared by Duncan's multiple-test using SAS Version 9.1. Differences between the means at the 5% level were considered significant.

3. RESULTS AND DISCUSSION

3.1 Sensory properties of pure pomelo and orange juices and their different blends

The sensory scores of the blended pure juice samples in terms of colour, taste, flavour, mouthfeel, and overall acceptability at different times of evaluation are given in Appendix 1. A comparative representation of the sensory properties is shown in Figure 1. In the following figure, the inner-most line denotes the minimum score and the outer-most line denotes the maximum score, for each property. It can be observed that pure pomelo juice (T0) has the minimum score for almost all properties except colour. This shows that the colour of the pure pomelo juice is appealing, whereas, other sensory properties such as taste, flavor, mouthfeel, and overall acceptability were not so appealing. This can be attributed to the bitterness of the pure pomelo juice. As observed from the graph shown, pure orange juice (T4) has the maximum score for almost every sensory parameter, which can be attributed to the sweetness of the pure orange juice. However, the line representing sample T1 is not visible at all, except for the flavor where it is somewhat visible, above the line representing sample T4 (pure orange). This is so because this blend (T1) matches the pure orange juice in every sensory parameter. Moreover, its flavor has even improved slightly compared to pure orange juice (T0). The graph shows that other two blends (T2 & T3) have sensory properties greater than pure pomelo but less than pure orange. Among these two blends (T2 & T3), the line representing T2 is towards the outer side, whereas, the line representing T3 is towards the inner side. This shows that T2 has better sensory properties than T3. Thus, it can be concluded that the increasing concentration of orange juice has significantly improved the sensory properties of the blended juice. The sensory scores of all the samples were considered acceptable till the end of 90th day of storage. The sensory evaluation results have been found in accordance with [12].

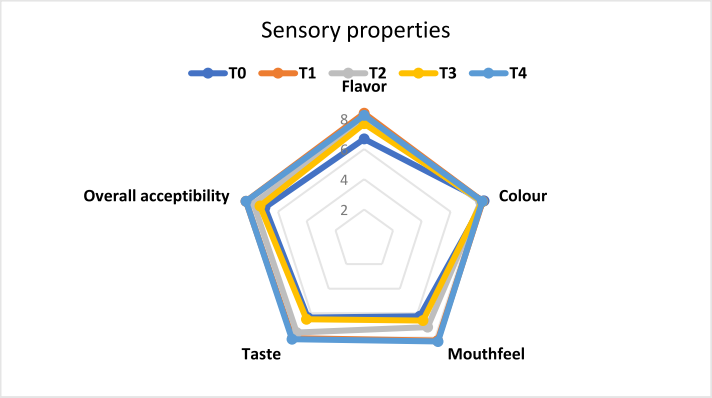

Fig 2. Comparison of sensory properties of blended and pure juice samples.

3.2 Effect of storage duration on the physicochemical parameters of blended RTS drinks

3.2.1Total Soluble Solids (°B)

The total soluble solids values for all samples at different storage times are given in Table 1. The total soluble solids of juice samples were calibrated to a constant value of 45 °Brix at the time of preparation. The result showed that the TSS of all samples increased with storage duration. The total change in TSS varied from 3.50 % to 5.55 % at the end of 90 days of storage. The increasing trend of TSS might be due to the formation of simpler compounds by hydrolysis of polysaccharides such as pectin and starch. Similar observations have been noticed by[13 and 33].

3.2.2 pH

The pH increased with an increase in storage duration and the pH of different samples differed significantly. At the beginning (day 0), the two most acidic samples(T1 & T2) had a pH of 3.32 and the least acidic sample was T3 with a pH of 3.44. ThepH showed an increasing trend during the period of storage as at the end of 90 days, sample T1 was the most acidic with pH of 3.46 and T3 was least acidic with having pH of 3.58. The increase in pH ranged from 3.54 % to 5.12 % at the end of 90 days (Table 1). This might be possible due to the decrease in acidity with the passage of time. A similar trend has been reported in the preparation of pomelo juice[12].

3.2.3 Vitamin C/Ascorbic Acid (mg/100ml)

A decreasing trend of vitamin C with an increase in storage duration was observed. The decrease was significant with duration of storage and there was a significant difference in the samples as well. The highest amount of vitamin C content on 0^{th} day was present in sample T4 with 45.34 mg/ml and the lowest amount of vitamin C was observed in sample T1 with its content of 40.34 mg/ml(Table 1). The reduction of the ascorbic acid was found to be ranging from 23.97 % to 27.55 %. Vitamin C is one of the most sensitive biochemical parameters which is liable to losses. The samples of juices showed a decrease in their trend all over the duration of storage. The declination might be due to the effect of storage temperature and the catalytic action of fructose. Analogous observations of a decrease in the content of vitamin C have been reported [34],[36].

3.2.4 Titrable Acidity (%)

Thetitrable acidity of all samples at the time of preparation and different storage times is given in Table 1. At0^{th} day, the maximum titrable acidity was found in T0 (1.12) i.e., pure pomelo juice and the least was in T4 (1.01) i.e., pure orange juice.

However, no significant difference was observed in the titratable acidity of blends T1(1.10) & T3(1.10), while the titratable acidity of blend T2 (1.03) differed significantly. On 30^{th} day, the change in titratable acidity of T2 and T3 was found to be significant whereas it was non-significant for T0, T1, & T4. On 60^{th} day, a significant change was observed in T2, T3, & T4, and non-significant change was observed in T0 and T1. At the end of 90^{th} day, a significant change was noted in all juice samples. Overall, the trend of change in titratable acidity was decreasing with increase in storage duration. However, the change was minimal and varied from 2.68 % to 10 %. Literature suggests that a decrease in acidity is a normal phenomenon in the presence of sugars during storage duration and depends on the concentration level of sugars in the products. Similar findings have been reported [28] , [37].

3.2.5 Total Sugar (%), reducing sugar (%) and non-reducing sugar (%)

Total sugar, reducing sugar, and non-reducing sugar contents of all samples at different storage time are given in Table 1. The total sugar and reducing sugar of all the samples were observed to be increasing with an increase in storage duration. On 0^{th} day, the maximum total sugar was observed in T4 (34.57), and the minimum total sugar was found in sample T0(30.34), whereas, the maximum reducing sugar was observed inT4 (1.12) and the minimum reducing sugar was found in T0 (0.81). At the end of the 90^{th} day, the maximum amount of total sugar was found in sample T3 (35.01) and the least was observed in T0 (31.11), whereas, the maximum reducing sugar was found in T1 (2.23%) and the minimum reduction sugar was found in T0 (1.78%). The total change in total sugar varied from 0.98 % to 2.43 % and the change in reducing sugar ranged from 83.93% to 125.25 %. However, the non-reducing sugar was observed to be decreasing with an increase in storage duration. The total percentage change in non-reducing sugar ranged from 0.67 % to 1.79 %. On 0^{th} day, the maximum non-reducing sugar was observed in T4(33.45), and the minimum was observed in T0 (29.53). The increase in total sugar and reducing sugar might be due to the hydrolysis of polysaccharides which increased the soluble solids content. Whereas, a decrease in non-reducing sugar might have been observed due to the inversion of non-reducing sugars to reducing sugars in the presence of acids [37], [38].

Table 1. Variations of physico-chemical parameters of different juice blends during storage.

Parameters	Sample codes	Storage duration (Day)			
		0	30	60	90
TSS (°B)	T0	45	45.06^{c}	45.99^{a}	47.56^{a}
	T1	45	45.08^{bc}	45.56^{d}	46.69^{e}
	T2	45	45.18^{a}	45.89^{b}	47.23^{d}
	T3	45	45.01^{c}	45.65^{c}	47.34^{c}
	T4	45	45.14^{ab}	45.32^{e}	47.45^{b}
pH	T0	3.34^{bc}	3.38^{b}	3.42^{bc}	3.49^{b}
	T1	3.32^{c}	3.37^{b}	3.41^{c}	3.46^{b}
	T2	3.32^{c}	3.35^{b}	3.41^{c}	3.49^{b}
	T3	3.44a	3.46^{a}	3.51^{a}	3.58^{a}
	T4	3.39^{ab}	3.40^{b}	3.47^{ab}	3.51^{b}
Vitamin C (mg/100ml)	T0	40.67^{d}	36.54^{c}	32.32^{c}	31.17^{c}
	T1	40.98^{d}	35.45^{d}	32.67^{c}	31.11^{c}
	T2	42.34^{c}	38.43^{b}	36.32^{a}	32.21^{b}
	T3	44.32^{b}	38.97^{a}	35.51^{b}	32.11^{b}
	T4	45.34^{a}	39.21^{a}	36.20^{a}	33.43^{a}
Titratable Acidity (%)	T0	1.12^{a}	1.12^{a}	1.09^{a}	1.01^{ab}
	T1	1.10^{a}	1.09^{ab}	1.09^{a}	1.05^{a}
	T2	1.03^{b}	1.01^{c}	0.99^{b}	0.97^{b}
	T3	1.10^{a}	1.05^{bc}	1.03^{b}	0.99^{b}
	T4	1.01^{b}	1.01^{c}	0.98^{b}	0.96^{b}

Total Sugar (%)	T0	30.7^{c}	31.5^{b}	31.3^{c}	31.4c
	T1	32.1^{b}	32.4^{b}	32.5^{b}	32.9^{b}
	T2	31.2^{bc}	31.58^{b}	32.1^{bc}	32.8^{b}
	T3	34.3^{a}	34.3^{a}	34.6^{a}	35.0^{a}
	T4	34.3^{a}	34.8^{a}	34.8^{a}	34.5^{a}
Reducing Sugar (%)	T0	0.98^{a}	1.36^{ab}	1.56^{b}	2.03^{b}
	T1	1.02^{a}	1.38^{ab}	1.76^{ab}	2.23^{ab}
	T2	1.01^{a}	1.27^{b}	1.87^{a}	2.16^{ab}
	T3	1.01^{a}	1.23^{b}	1.78^{a}	2.23^{a}
	T4	1.07^{a}	1.50^{a}	1.85^{a}	2.05^{ab}
Non-reducing Sugar (%)	T0	30.2^{c}	30.3b^{c}	29.4^{c}	29.2^{c}
	T1	31.4^{b}	31.0^{b}	30.7^{b}	30.5^{b}
	T2	30.3^{c}	29.7^{c}	29.6^{c}	29.5^{c}
	T3	33.2^{a}	33.0^{a}	32.8^{a}	32.8^{a}
	T4	33.0^{a}	33.3^{a}	33.0^{a}	32.8^{a}

3.2.6 Colour

The variation in colour values of different samples at different storage duration is given in Table 2. The colour was found to be degrading with an increasing number of days. The observation showed that the L* values increased for all the samples while b* values decreased at the end of 90 days. a* values for T4 and T2 increased while for all other samples decreased during the storage period. As we know the fact that L represents the darkness-to-lightness ratio, the observation of L* showed that the darkest juice prepared was T0 and the lightest coloured juice was sample T1. The juice was becoming lighter in colour with the passage of time. The reason might be the enzymatic activity of the fruit juices which leads to colour degradation upon storage [39].

Table 2. Observed Data (L*, a*, b*) for Colour of Prepared Juice Samples

Sample Codes	Storage duration (Days)			
	0	30	60	90
L* **Values**				
T0	47.7	48.2	48.5	49.3
T1	52.5	53.8	54.6	57.1
T2	51.4	52.1	53.4	54.9
T3	51.2	52.3	54.1	55.3
T4	51.1	51.8	52.3	53.5
a* **Values**				
T0	18.5	16.3	13.2	10.8
T1	13.1	11.7	10.9	9.4
T2	11.9	12.4	12.6	13.7
T3	14.4	12	11.5	9.6
T4	7.5	7.9	8.3	9
b* **Values**				
T0	38.8	36.1	33.4	30.2
T1	59.1	57.4	52.4	51.8
T2	58	54.2	48.6	43.5
T3	58.1	55.6	50.2	47.4
T4	57.4	55.1	49.8	47.7

3.3 Effect of storage duration on the microbial count of different juice blends

The results of microbial analysis showed no detection of microbes in any sample till 60 days of storage. There was microbial detection in samples T3 and T4, at the end of 90 days of storage. However, it was negligible, within the acceptable level (less than 2.00 CFU per mL), and safe for consumption. Thus, it can be concluded that all the samples were safe for consumption till 90 days of storage. This might be due to the effectiveness of the pasteurization and refrigerated (5 °C) storage condition. The results have been found in accordance with [32 and 40].

4. CONCLUSION

This study demonstrates that blending pomelo juice with orange juice can be a promising approach to overcome the bitterness and low consumer acceptability associated with pomelo juice. blend 60:40 (T1) had sensory attributes on par with the orange juice, making it as acceptable as pure orange juice. by leveraging the natural compatibility of pomelo and sweet orange, this blending strategy offers a sustainable solution for underutilized pomelo fruit. Value addition of underutilized fruits in this way can bridge the gap between agricultural surplus and consumer demand. Future research could explore scaling production, incorporating advanced preservation techniques, and assessing market feasibility to maximize the commercial potential of this product.

Acknowledgments

The authors, therefore, gratefully acknowledge Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India for technical support.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix - I

Average sensory scores of prepared juice samples

Days	Sample	Flavour	Colour	Mouthfeel	Taste	Overall acceptability
0	T0	6.67	8.34	6.26	6.36	6.90
	T1	8.37	8.25	8.25	8.05	8.23
	T2	7.93	8.11	7.15	7.59	7.695
	T3	7.68	8.21	6.61	6.51	7.25
	T4	8.23	8.22	8.32	8.13	8.22
30	T0	6.17	8.05	6.05	6.09	6.59
	T1	8.31	7.97	8.03	7.86	8.04
	T2	7.72	7.85	6.89	7.08	7.38
	T3	7.46	7.91	6.01	6.22	6.90
	T4	7.91	7.93	8.01	7.89	7.93
60	T0	6.03	7.61	5.77	5.79	6.30
	T1	8.23	7.32	7.87	7.56	7.74
	T2	7.32	7.23	6.59	6.78	6.98
	T3	7.03	7.33	5.73	5.93	6.50
	T4	7.41	7.24	7.84	7.57	7.51
90	T0	5.67	7.11	5.27	5.18	5.80
	T1	7.93	6.73	7.47	7.17	7.32
	T2	6.89	6.62	6.13	6.27	6.47
	T3	6.61	6.61	5.23	5.33	5.94
	T4	6.33	6.53	7.44	7.13	6.85

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