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Optimization and Quality Evaluation of a Ready-to-Serve Beverage from Papaya Fruit

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Abstract

The primary objective of the present investigation was to optimize papaya fruit (*C. papaya* L.) RTS beverage based on changes in TSS, titratable acidity, and overall acceptability. RSM (Response Surface Methodology) with a face-centered design was used for optimization. The papaya fruit RTS beverage was prepared with papaya fruit juice, sugar, and citric acid at three levels of combinations ranging from 10-18%, 10-14%, and 0.1-0.3%, respectively. The efforts were made to study the biochemical composition and sensory properties of the RTS beverage. The optimized values for papaya fruit RTS beverage were obtained for 18% fruit juice, 13.19% sugar, and 0.12% citric acid, based on the results obtained. It was optimized based on TSS, titratable acidity, and overall acceptability; i.e., TSS (14.59°Bx), titratable acidity 0.27% and overall acceptability 7.26 were found to be enhanced and improved as the concentration of juice was increased.

Keywords: Papaya fruit, total soluble solids, beverage, RSM, overall acceptability

1. Introduction

Papaya (*Carica papaya* L.) originates from tropical regions of the Americas but has since spread widely and is now cultivated in Asia, Africa, and other parts of the world. (Farina *et al.*, 2020) [2]. Papayas are kept for only 7 to 14 days after harvest. They are perishable, which makes it difficult to transport to far-off locations during peak season and earn a reasonable price for farmers. To prevent quality deterioration and increase shelf life, several researchers have developed post-harvest preservation methods that preserve high sensory and nutritional attributes. The fruit's shelf life has been increased through the investigation and use of several preservation techniques (Marpudi *et al.*, 2011) [6].

Papaya is a fruit with multiple therapeutic benefits, including antioxidant, antimicrobial, anticancer, and hepatoprotective properties. It contains several bioactive components that strengthen the immune system and act as natural antioxidants. The pulp of papaya has long been used in traditional medicine for healing wounds and treating burns, while the ripe fruit helps prevent conditions such as dysentery, various skin diseases, psoriasis, and ringworm. Papain, an enzyme present in papaya, aids in the digestion of proteins and supports a healthy digestive system. It is a nutritionally rich tropical fruit containing vitamins A, C, and E, essential minerals, and enzymes like papain and chymopapain. Every part of the plant—including the fruit, leaves, seeds, roots, and latex—holds medicinal importance and is used in both traditional and modern healthcare (Saeed, 2014) [9].

The amounts of fruit pulp, sugar, water, and acidulant employed in the formulation process have a significant impact on the quality of a papaya RTS beverage. Important factors for assessing the final beverage's quality include total soluble solids (TSS), acidity, pH, color, flavor, consistency, and general acceptability. In fruit beverage manufacturing, acidification is especially crucial since the right amount of acidity both helps to control microbial growth and adds to a desired taste. In a similar vein, heat treatment is necessary to attain microbiological stability and extend the processed beverage's shelf life. (FAO, 2001; Fellows, 2017) [1, 3].

The development of a papaya RTS beverage ultimately provides an effective approach for value addition and proper application of perishable papaya fruit, which is rich in nutrition. Optimization of juice concentration, TSS, and acidity is important to obtain a beverage with desired physicochemical characteristics and consumer acceptability. Therefore, the present

study was undertaken to optimize a ready-to-serve (RTS) beverage from papaya fruit and evaluate its physicochemical, nutritional, and sensory characteristics in order to identify an acceptable formulation with better quality.

2. Materials and Methods

The papaya fruits (*Carica papaya* L.) were uniform, firm, mature, and ripe, of the Red Lady variety. These fruits were procured from the Department of Horticulture, AAU, Anand, Gujarat. The papaya fruit RTS beverage was prepared according to the combinations given in Table 1. The selected and sorted papaya fruits were washed with tap water to remove soil and dust particles. The fruits were cut in half, the peel was removed manually, and the flesh was cut into small pieces with a stainless-steel knife. After cutting and seed removal, a thick mass of pulp was used to extract the juice. The extracted juice was filtered through muslin cloth and then centrifuged. Optimization of the papaya fruit RTS beverage was carried out using three different levels of fruit juice concentration (10-18%), sugar (10-14%), and citric acid (0.1-0.3%). The digital refractometer was used to measure TSS (Total Soluble Solids), and the beverage was stored in 100 mL PET (Polyethylene Terephthalate) bottles for further study.

2.1 Sugar and Citric Acid

Sugar and citric acid were procured from the retail market of Anand, Gujarat.

2.2 Packaging Materials

Polyethylene terephthalate (PET) bottles having a capacity of 100 mL were purchased from M/s Axar Blow Plast, GIDC, Anand, Gujarat.

2.3 Total soluble solids (TSS)

TSS of papaya fruit pulp, extracted juice, and beverage was measured using an Atago RX-7000x refractometer

2.4 Titratable acidity as per cent citric acid

Ten grams of fruit sample was collected, mixed with 200 ml of distilled water and transferred to a 250 ml volumetric flask. One hundred milliliters of that aliquot were collected in a conical flask and titrated with 0.1 N NaOH using phenolphthalein as an indicator. The% titratable acidity was estimated using the formula provided (Ranganna, 2007).^[8]

$$\text{Titratable acidity (\%)} = \frac{T \times N \times V \times E}{1000}$$

Aliquote volume

Where,

T = Titre value (ml)

N = Normality of NaOH

V = Volume made up (ml)

E = Equivalent weight of citric acid

2.5 Overall acceptability

Sensory evaluation was carried out based on a 9-point hedonic scale, and overall acceptability was calculated.

2.6 Statistical Analysis

The data obtained on various characteristics were analyzed using a central composite design in the Response Surface category in Design Expert software (version 13).

3. Results and Discussion

Table 1 presents the results pertaining to the optimization of papaya fruit juice beverage and its effect on TSS, titratable acidity, and overall acceptability.

3.1 Effect of Different Levels of Fruit Juice, Sugar and Citric Acid on TSS of Papaya Fruit RTS Beverage

Total soluble solids (TSS) represent the concentration of dissolved solids present in a solution and are commonly determined using a refract meter. The data presented in Table 1 indicated that the TSS content of the papaya fruit RTS beverage formulated with varying levels of fruit juice, sugar, and citric acid ranged from 13.25 to 15.35 °Brix. The highest TSS value of 15.35 °Brix was recorded in the treatment containing 18% papaya fruit juice, 14% sugar, and 0.3% citric acid. In contrast, the lowest TSS value of 13.25 °Brix was observed in the beverage prepared with 10% papaya fruit juice, 10% sugar, and 0.1% citric acid. The increase in TSS observed with higher levels of fruit juice and sugar may be attributed to the greater contribution of soluble sugars and other water-soluble solids from these ingredients. From the Response surface analysis shown in Table 2, it could be seen that the concentration of fruit juice, sugar, and citric acid significantly affected the Total soluble Solids (TSS) content of papaya RTS beverage. The quadratic model for TSS was highly significant with $F = 38.68$ and $p < 0.0001$, suggesting that the model is a good representation of the relationship between the independent variables and the response. The interaction term AB (juice $\times$ sugar) was statistically significant ($F = 5.41$, $p = 0.0423$), indicating that the effect of juice and sugar on TSS is not just additive, but synergistic, meaning the combined effect is greater than the sum of its individual components (Fig 1). The observed variation in TSS with variations in fruit juice and sugar concentration is in line with earlier research showing that the final TSS of RTS drinks was impacted by formulation composition, namely the amount of added sugar and fruit-derived soluble solids (Singh *et al.*, 2012).^[13] A similar result for an increase in TSS content of dragon fruit juice while preparing a ready-to-serve beverage was observed (Ghorband and Joshi, 2023)^[4]. Similar TSS values have been reported in papaya-based RTS beverages, with Panghal *et al.* (2017)^[7] reporting approximately 14.98 °Brix in papaya RTS and Sindumathi *et al.* (2017)^[10] reporting 15 °Brix in papaya-mango RTS beverage

3.2 Effect of various levels of fruit juice, sugar and citric acid on titratable acidity of papaya fruit RTS beverage

The present investigation showed that citric acid concentration was the most important factor influencing the titratable acidity of papaya RTS. In contrast, sugar and fruit juice had comparatively small but statistically significant effects. The quadratic model for TA was highly significant ($F = 27.67$, $p < 0.0001$) with a non-significant lack of fit ($F = 0.4381$, $p = 0.8069$), indicating the model is reliable and valid for predicting acidity within the experimental domain (Table 3). Titratable acidity ranged from 0.22 to 0.35. The highest titratable acidity value of 0.35 was recorded in the treatment containing 18% papaya fruit juice, 14% sugar, and 0.3% citric acid. In contrast, the lowest value of 0.22 was observed in the beverage prepared with 10% papaya fruit juice, 10% sugar, and 0.1% citric acid (Table 1). The ANOVA results are reflected in this visual pattern (Figure 2), with citric acid being the strongest contributor to TA, while juice was the closest to a linear increase. The points of

design are close to the fitted plane, which also shows a good fit of the model. From the above results, it can be observed that the fruit juice, sugar, and citric acid levels significantly affected the titratable acidity of papaya RTS beverage. (Fig 2). The results obtained agree with studies on fruit RTS and nectar formulations, which reported that citric acid concentration has a pronounced effect on titratable acidity because added citric acid directly increases the acid content of the beverage. In comparison, variations in pulp/juice and sugar concentrations may produce smaller changes in acidity, depending on the inherent organic acid content of the fruit and the dilution effect of the formulation. (Sharma, 2020; Bartholomew & Sinclair, 2022)^[12, 11].

3.3 Effect of various levels of fruit juice, sugar, and citric acid on Overall acceptability of papaya fruit RTS beverage

Overall acceptability was observed during sensory evaluation using a 9-point hedonic scale. It ranged from 6.25 to 7.40. The maximum overall acceptability value of 7.40 was recorded in the treatment containing 14% papaya fruit juice, 12% sugar, and 0.2% citric acid. In contrast, the minimum value of 6.25 was observed in the beverage prepared with 14% papaya fruit juice, 12% sugar, and 0.3% citric acid (Table 1). The sensory evaluation overall acceptability score of papaya RTS was significantly affected

by the independent variables studied, with the quadratic model highly significant ($F = 12.09$, $p = 0.0003$), while the lack of fit was non-significant ($F = 0.0574$, $p = 0.9965$), which means that the model is highly significant and can be reliably used to predict the consumer acceptability of papaya RTS within the studied range (Table 4). The response surface design (Fig 3) for papaya RTS showed that fruit juice, sugar, and citric acid concentrations play unique and complementary roles in controlling the three important quality attributes investigated - total soluble solids (TSS), titratable acidity (TA), and overall acceptability (OA). The fruit juice and sugar concentrations had the most significant linear effects, in addition to an interaction between the two, closely followed by a curvilinear (quadratic) effect, which were largely expected because the concentrations of these substrates, which contribute directly to the soluble solids in the beverage, had the largest effects on TSS. The obtained results for overall acceptability were in close agreement with RTS beverage prepared by dragon fruit juice at varying proportions of fruit juice, sugar, and citric acid (Ghorband and Joshi 2023).^[4] The study evaluated papaya RTS using a 9-point hedonic scale, considering colour and appearance, flavour, taste, and mouthfeel. Sensory scores of 6 or above out of 9 were found to be acceptable, making it particularly useful for interpreting your overall acceptability results. (Jain, *et al.* (2015)^[5].

Table 1: Optimization of the process for preparing RTS beverage from papaya fruit juice

Run	Factor 1 A: Juice (%)	Factor 2 B: Sugar (%)	Factor 3 C: Citric acid (%)	Response 1 TSS (°Bx)	Response 2 Titratable Acidity (%)	Response 3 Overall acceptability
1	14	12	0.2	13.79	0.27	7.10
2	14	10	0.2	13.75	0.27	7.22
3	18	10	0.3	14.33	0.33	6.45
4	14	12	0.2	13.82	0.26	7.25
5	18	10	0.1	14.12	0.23	7.17
6	14	12	0.1	13.82	0.23	7.13
7	14	12	0.2	13.88	0.29	7.35
8	10	10	0.1	13.25	0.22	7.10
9	10	14	0.3	13.95	0.34	6.35
10	18	14	0.1	14.85	0.29	7.26
11	10	14	0.1	13.75	0.24	7.05
12	10	12	0.2	13.65	0.28	7.18
13	14	12	0.3	13.87	0.31	6.25
14	14	12	0.2	13.97	0.28	7.40
15	14	12	0.2	13.72	0.26	6.95
16	18	14	0.3	15.35	0.35	6.50
17	10	10	0.3	13.45	0.32	6.30
18	18	12	0.2	14.6	0.29	7.28
19	14	14	0.2	14.45	0.3	7.25
20	14	12	0.2	13.7	0.27	6.9

Table 2: ANOVA table for the effect of fruit juice, sugar, and citric acid on TSS of papaya RTS beverage

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4.53	9	0.5028	38.68	< 0.0001	significant
A-Juice	2.70	1	2.70	208.04	< 0.0001	
B-Sugar	1.19	1	1.19	91.58	< 0.0001	
C-Citric acid	0.1346	1	0.1346	10.35	0.0092	
AB	0.0703	1	0.0703	5.41	0.0423	
AC	0.0120	1	0.0120	0.9242	0.3590	
BC	0.0105	1	0.0105	0.8088	0.3896	
A ²	0.1080	1	0.1080	8.31	0.0163	
B ²	0.0825	1	0.0825	6.35	0.0304	
C ²	0.0184	1	0.0184	1.42	0.2615	
Residual	0.1300	10	0.0130			
Lack of Fit	0.0788	5	0.0158	1.54	0.3231	not significant
Pure Error	0.0511	5	0.0102			
Cor Total	4.66	19				

Table 3: ANOVA table for the effect of sugar, acid, and fruit juice on the titratable acidity of papaya RTS beverage

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.0245	9	0.0027	27.67	< 0.0001	significant
A-juice	0.0008	1	0.0008	8.24	0.0166	
B-sugar	0.0022	1	0.0022	22.90	0.0007	
C-citric acid	0.0194	1	0.0194	197.00	< 0.0001	
AB	0.0002	1	0.0002	2.04	0.1842	
AC	0.0002	1	0.0002	2.04	0.1842	
BC	0.0002	1	0.0002	2.04	0.1842	
A ²	0.0003	1	0.0003	3.33	0.0980	
B ²	0.0003	1	0.0003	3.33	0.0980	
C ²	0.0000	1	0.0000	0.4683	0.5093	
Residual	0.0010	10	0.0001			
Lack of Fit	0.0003	5	0.0001	0.4381	0.8069	not significant
Pure Error	0.0007	5	0.0001			
Cor Total	0.0255	19				

Table 4: ANOVA table of the effect of sugar, acid, and fruit Juice on the overall acceptability of papaya RTS beverage

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	2.50	9	0.2775	12.09	0.0003	significant
A-Juice	0.0462	1	0.0462	2.01	0.1862	
B-Sugar	0.0029	1	0.0029	0.1259	0.7301	
C-Citric acid	1.49	1	1.49	64.91	< 0.0001	
AB	0.0025	1	0.0025	0.1067	0.7506	
AC	0.0000	1	0.0000	0.0022	0.9637	
BC	0.0004	1	0.0004	0.0196	0.8914	
A ²	0.0063	1	0.0063	0.2729	0.6128	
B ²	0.0076	1	0.0076	0.3331	0.5766	
C ²	0.6664	1	0.6664	29.03	0.0003	
Residual	0.2295	10	0.0230			
Lack of Fit	0.0125	5	0.0025	0.0574	0.9965	not significant
Pure Error	0.2171	5	0.0434			
Cor Total	2.73	19				

Table 5: The optimum solution for the optimized dragon fruit RTS beverage

Parameters	Optimum value
Papaya fruit juice (%)	18
Sugar (%)	13.19
Citric acid (%)	0.12

Table 6: Responses for optimized dragon fruit RTS beverage

Parameters	Mean
TSS (⁰ Bx)	14.59 ± 0.11
Titratable acidity (%)	0.272 ± 0.009
Overall acceptability	7.264 ± 0.15

Each value is a replication of the three observations.

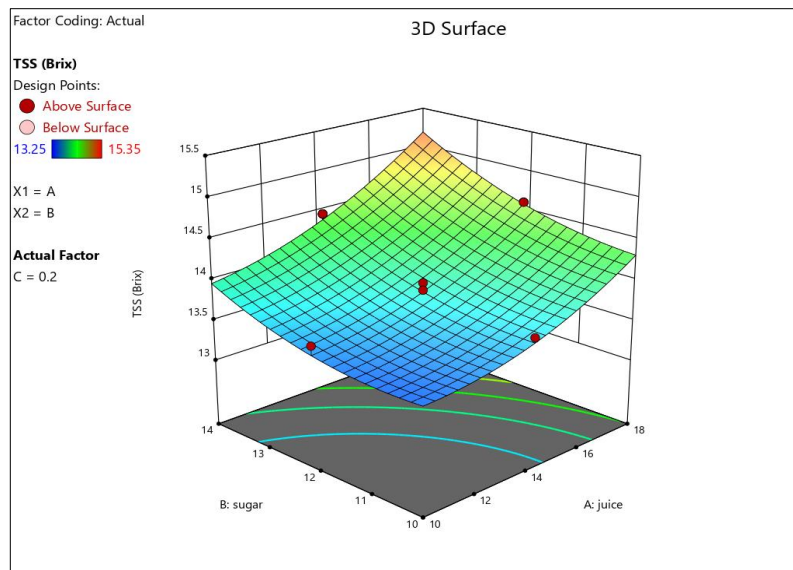


Fig 1: Surface Plot of the effect of fruit juice, sugar, and citric acid on TSS of papaya RTS beverage

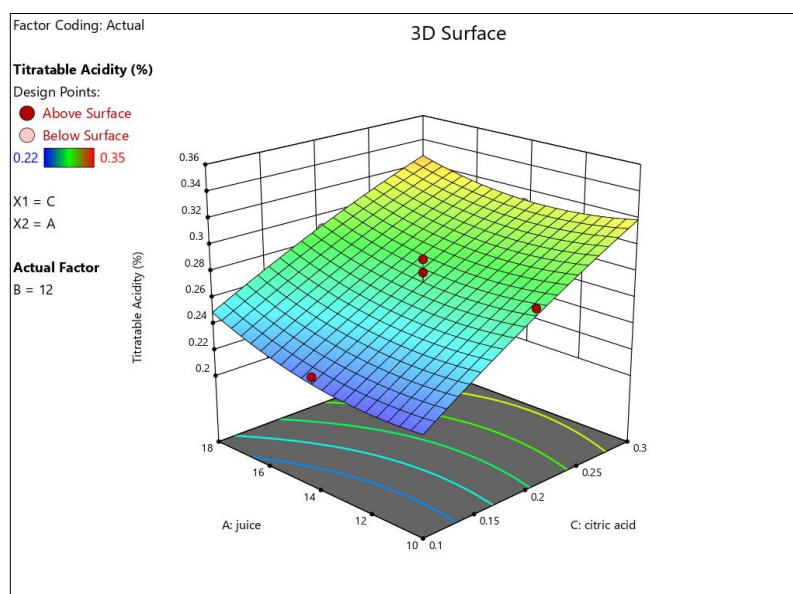


Fig 2: Surface plot of the effect of sugar, acid, and fruit juice on titratable acidity of papaya RTS beverage

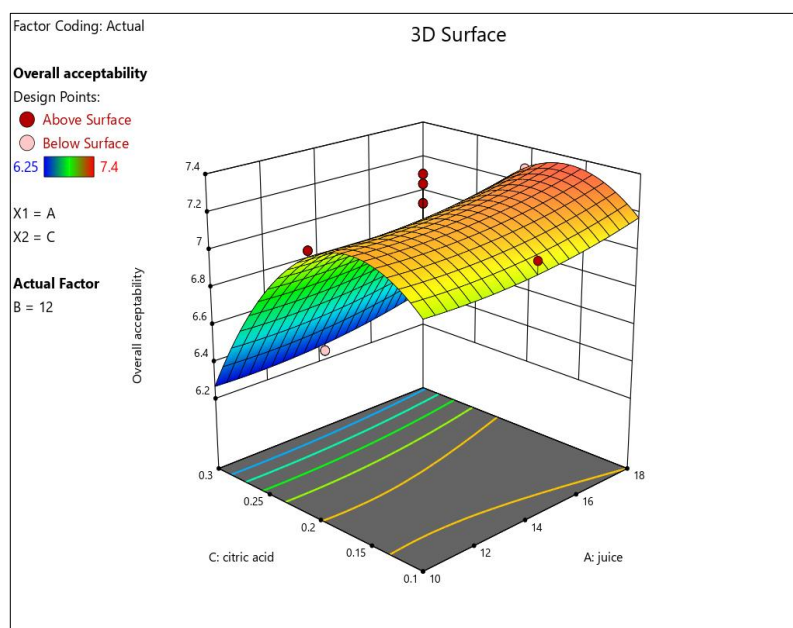


Fig 3: Surface plot of the effect of sugar, acid, and fruit juice on overall acceptability of papaya RTS

4. Conclusion

The nutritious papaya fruit RTS drink was made with papaya fruit juice, sugar, and citric acid. It was safe for consumption as there was no artificial color or flavor added. The results above showed that the papaya fruit RTS beverage was prepared using 18% fruit juice, sugar 13.19% and citric acid 0.12%. Thus, the beverage was optimized based on sensory evaluation (overall acceptability) and quality parameters. Increased concentration of fruit juice resulted in an increase in TSS and overall acceptability of papaya fruit RTS beverage.

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