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Optimization of Chayote–Mandarin Blended Beverage

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Chayote is an underutilized fruit with bland flavour and is available abundantly in Sikkim. To minimize post–harvest losses through value addition, an investigation was conducted to produce refreshing RTS beverage. The blending of mandarin juice was done to make it flavourful and one of the healthy alternatives for the consumers. The full factorial experimental design was followed to optimize chayote juice to mandarin juice and level of juice contents. The optimum composition from 15 experiments were decided based on quality of the juice i.e., colour, TSS, pH, titratable acidity, ascorbic acid, and sensory attributes. An ANOVA results confirmed that the process variables produced significant changes in TSS, pH, titratable acidity, and ascorbic acid. However, the highest values of dependent variables like TSS (16.27°Brix) were found for treatment T_4, pH (4.40) for treatment T_4, titratable acidity (1.08%) for treatment T_{12}, ascorbic acid (14.91mg/100g) for treatment T_9. The DMRT analysis also showed that treatments with different letters are significantly different. The sensory indices and ranking proved that the likeliness of beverage prepared in different treatment were different and no specific treatment had overall highest rating. Therefore, treatment with consistent perception for all attributes and high on ranking was considered the better. The treatment T_2, was therefore considered as optimum and was also confirmed with colour, TSS, pH, titratable acidity, and ascorbic acid values as well. Treatment T_2 was prepared by blending chayote with mandarin at 1:1 ratio and 10% juice content.

Keywords: Blended beverage, Chayote, Ready to drink, Sensory evaluation, Sikkim mandarin

Introduction

Chayote (*Sechium edule*) is an underutilized vegetable, belongs to the Cucurbitaceae family. Chayote fruits show wide morphological variability, ranging from smooth to slightly fibrous surfaces, often accompanied by vertical ridge like pattern. Their size can differ greatly, influenced not only by varietal traits but also by environmental and management factors such as topography, cultivation practices, and local climate. Typically, the fruits may extend up to about 26 cm in length and reach nearly 11 cm in width at their broadest point. Such variation leads to multiple fruit forms, including round, oval, sub–oval, and pear–shaped types. Some genotypes also possess soft spines on the surface. Although pale yellow varieties are commonly cultivated, the fruits occur in a spectrum of colours ranging from yellowish hues to deeper green tones.[1]

Chayote is low–calorie vegetable, supply in roughly 19 kcal per 100 g, and contains only a small amount of soluble sugars (around 1.6 g per 100 g). It also provides several key nutrients, including calcium, phosphorus, potassium, magnesium, and vitamin C (approximately 11–20 mg per 100 g).[2] Despite being rich in fibre, minerals, starch, vitamins, the fruit has relatively short storage life of 30 to 45 days under refrigerated condition i.e. at 7°C and 85–90% RH, because of its high moisture content.[3,4] Due to lower shelf–life of fresh chayote, it must be processed.[3] Traditionally, it is consumed as a vegetable in cooked form.

Fruit and vegetable juices are highly preferred beverages, attracting consumers from every age category. A fruit or vegetable juice is an unfermented, though fermentable, extract obtained from sound and mature produce using appropriate extraction methods, including mechanical processes. The product may be used in its pure form or diluted to form ready–to–serve beverage and must be preserved exclusively through physical means. It can appear either clear or cloudy, and the addition of sugars or acids is permitted when allowed under the relevant product standards.[5]

Juice blending, which consists of mixing multiple fruit and/or vegetable juices, is an effective scientific approach for enriching the product's vitamin, mineral,

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and overall nutritional composition, depending on the specific raw materials incorporated.[6] Sometimes, blending various fruit/vegetable juices is adopted as an approach to reduce production costs by partially substituting expensive or exotic fruits. It also helps in masking/moderating undesirable sensory attributes such as excessive acidity, astringency, or bitterness, while enhancing qualities like total soluble solids, flavour balance, and colour stability. Studies on blending of chayote and pineapple juice along with stevia as a sweetener[7], spiced chayote juice[8], chayote–sugar cane beverage[9], etc. were reported by the scientists. They showed that the blended chayote juice has significant acceptance amongst several age group.

Therefore, the problem of bland taste and high pH in the chayote juice was addressed during present investigation by blending it with another fruit juice. To blend fruit juice, Sikkim mandarin (*Citrus reticulata* Blanco) was selected. Sikkim mandarins known for its pleasant flavour, appealing taste, and attractive juice colour. Kishore *et al*.[10] has reported highest total soluble solids of about 12.0°Brix, lowest titratable acidity of 1.34%, maximum TSS–to–acid ratio of 7.98. It also contains notable levels of reducing sugar, total sugar, and sugar–to–acid ratio of 6.20%, 9.49%, and 5.63, respectively. Its juice is refreshing with sweet–acid taste, appealing colour and nutritious due to its ascorbic acid content. Its availability and quality made it one of the best selections for blending with chayote juice.

Materials and Methods

The study was carried out in the Department of Processing and Food Engineering at the College of Agricultural Engineering and Post Harvest Technology, Ranipool, Sikkim – 737 135 during the year 2021–2022. The material used, the methods and procedures followed are discussed under following sub–headings.

Raw Materials

Fresh chayote (light green coloured) and local mandarin were purchased from the weekly market at Ranipool, Sikkim. Analytical–grade chemicals and other materials required for juice blending and quality evaluation were sourced from the laboratory facilities of the department.

Preparation of Blended Chayote and Mandarin Beverage

Well matured chayote and mandarin fruits were picked and washed followed by peeling using hand peeler. The core of chayote was removed using corer while the flesh is split into halves and fed into fruit juicer (USHA cold press juicer, CPJ–3625, made in India), separately. The both the juices were then strained through double layered muslin cloth to avoid any solids to enter extract. The cleaned juices were stored in a container which is then immediately kept for chilling in refrigerator before further quality evaluation.

Blended RTS beverages were prepared using different ratio of the extracted chayote and mandarin juice. However, the final TSS of the blended beverages was fixed at 12°Brix as per FSSAI guidelines. Hence, following mass balance and solid balance equations (1 and 2) were used to find quantities of chayote juice, mandarin juice, sugar, and water.

Mass balance:

$$\text{Quantity of RTS Beverage (g)} = CJ+MJ+S+W \quad \ldots (1)$$

where, CJ = Weight of chayote juice, g
MJ = weight of mandarin juice, g
S = weight of sugar, g
W = Weight of water, g

Solid balance

$$(RTS)\times(TSS_{RTS})=(CJ)\times(TSS_{CJ})+(MJ)\times(TSS_{MJ})+(S) \quad \ldots (2)$$

The sugar is dissolved in required quantity of water as per the experimental design and syrup was prepared. This syrup was added to the blended fruits juice (chayote and mandarin juice). The mixture was then blended using blender for proper mixing of all ingredients. The prepared RTS beverage was heat treated (pasteurized) and were then filled into the pre–sterilized glass bottles. The sterilization was carried out at 121°C in an autoclave (Indo Scientific & Surgicals, India) for 15 minutes at the pressure of 103.42 kPa. The filled bottles were sealed airtight using caps and capping was done manually. The prepared samples were analysed for chemical and sensory qualities. The complete process flowchart for manufacture of the blended chayote mandarin beverage is given in Fig. 1.

Experimental Design

The full factorial experimental design was used to decide all possible combinations of levels for all factors, randomly.[9] During the present study, the fruit juice content of blended beverages was varied between 10 and 18% and the ratio of chayote juice to mandarin juice was varied between 2:3,1:1 and 3:2.

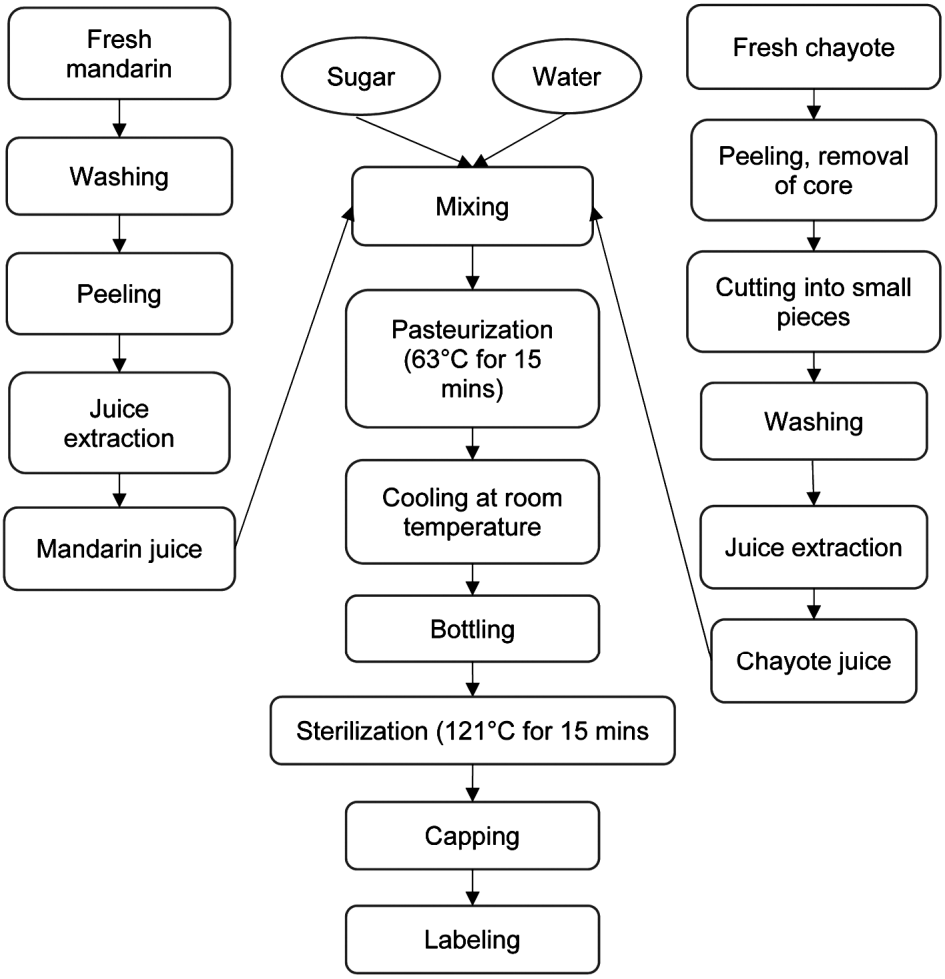

Fig. 1 — Process flow chart for chayote–mandarin blended beverage

Table 1 — Effect of juice content and ratio of blends on quality of blended beverage

Treatment	Juice content (%)	Chayote : Mandarin	TSS, °Brix	pH	Titratable acidity, %	Ascorbic acid, mg/100g
T_1	10	3:2	12.47^{de}	4.37^{h}	0.64^{d}	11.62^{bc}
T_2	10	1:1	12.73^{f}	4.23^{f}	0.74^{ef}	11.73^{cde}
T_3	10	2:3	12.23^{bc}	4.23^{f}	0.70^{e}	8.91^{a}
T_4	12	3:2	16.27^{j}	4.40^{h}	0.44^{a}	8.84^{a}
T_5	12	1:1	15.40^{i}	4.18^{ef}	0.51^{b}	11.72^{cde}
T_6	12	2:3	14.63^{h}	4.03^{c}	0.55^{c}	11.68^{cd}
T_7	14	3:2	13.93^{g}	4.23f	0.62^{cd}	14.70^{g}
T_8	14	1:1	12.50^{de}	4.10^{d}	0.75^{ef}	11.82^{e}
T_9	14	2:3	12.33^{cd}	4.00^{c}	0.71^{e}	14.91^{h}
T_{10}	16	3:2	11.67^{a}	4.13^{de}	0.75^{ef}	11.76^{de}
T_{11}	16	1:1	12.30^{bcd}	3.90^{b}	0.83^{f}	14.81^{h}
T_{12}	16	2:3	12.60^{ef}	3.80^{a}	1.08^{h}	11.93^{f}
T_{13}	18	3:2	12.10^{b}	4.30^{g}	0.63^{cd}	11.71^{cde}
T_{14}	18	1:1	12.77^{f}	4.10^{d}	0.83^{f}	11.66^{cd}
T_{15}	18	2:3	12.20^{bc}	3.93^{b}	0.95^{g}	11.55^{b}
F value (treatments)			338.69	83.64	701.57	9235.74
F value (Interaction)			72.76	8.13	152.30	7790.86
CV			0.97	0.80	1.50	0.27
CD (5%)			0.21	0.06	0.018	0.05

The maximum and minimum levels of percent juice content and ratio of blended juice were decided based on reviewed literatures and the experimental trials. Total fifteen (15) experiments were designed and performed, and each experiment was replicated three times to minimize experimental error. The treatments/experiments were named as T_1, T_2, …., T_{15} as denoted in Table 1.

Quality Evaluation of Developed Beverage

Each blended juice sample was analysed for TSS, titratable acidity, pH, ascorbic acid, colour, and sensory properties.

The colour analysis was performed using a handheld chromameter (CR–400, Konica Minolta, Tokyo, Japan), holding the sensing head directly on the sample holding cell/cup. Before measurements, the chromameter was standardized with a white calibration plate (CR–A43). The colour of samples was measured using CIE illuminator C as light source and recorded in terms of L^*, a^*, and b^*values. Where L* represents lightness (0–100), a* represents red to green (+ to –) and b* represents yellow to blue (+ to –). The colour characteristics of the juice were quantified by calculating chroma (C*) and hue angle (h°). Chroma, representing the colour intensity, was calculated using the equation:

$$Croma = \sqrt{(a^*)^2+(b^*)^2}$$

Whereas, the hue angle indicates the type of colour and measured using following expression:

$$h^\circ = \tan^{-1}\left(\frac{b^*}{a^*}\right)$$

The TSS content of the blended beverage was determined using a digital handheld refractometer (Pal–α, ATAGO Co Ltd., Tokyo, made in Japan).[11] The pH of blended juice samples was measured using calibrated digital pH meter (EUTECH) as recommended by Ranganna.[12] Total titratable acidity of samples was measured by titrating the juice with 0.1 N sodium hydroxide using phenolphthalein as an indicator and the results were expressed as percent acidity.[12] The following formula was used for estimation of titratable acidity of the beverages in terms of percent anhydrous citric acid. The equivalent weight of citric acid used in the formula is 64.04 or mill equivalent weight of citric acid i.e., 0.006404.

$$\text{Titratable Acidity (\%)} = \frac{V_{NaOH}\times N_{NaOH}\times \text{ Equivalent weight of citric acid}\times 100}{V_{sample}} \quad \ldots (3)$$

where, V_{NaOH} = Volume of NAOH used (mL), N_{NaOH} = Normality of NaOH, Equivalent weight of citric acid = 64.04 and V_{sample} = Volume of sample titrated (mL)

The vitamin C content of blended chayote–mandarin RTS samples was measured using modified method of Adebayo[13] and calculated using given formula as ascorbic acid (mg/100g).

$$\text{Ascorbic acid } (mg/100g) = \frac{0.5}{V_1}\times\frac{V_2}{5}\times\frac{200}{\text{Weight of sample}}\times 100 \quad \ldots (4)$$

where, V_1 = Volume of dye consumed by 0.5 mg of standard ascorbic acid (mL), V_2 = Volume of dye consumed by 5 mL of test sample (mL), 0.5 = Ascorbic acid (standard) (mg) taken for titration, 200 = Corresponds to total volume of the extract (mL), 100 = Ascorbic acid content/100 g of the sample, 5 = Weight of sample taken for extraction (g) and 5 = Volume of the test sample taken for titration (mL)

Sensory Evaluation

The 9–point hedonic scale was used evaluate perception of blended beverage samples.[14] The 9–degree hedonic scale had boundary indications: 'like extremely' [9] – 'dislike extremely' [1]. The sensory perceptual attributes like, appearance especially colour, flavour–taste, texture–consistency, texture–mouth feel, aroma–odour and overall acceptability. A panel of thirty untrained members (of the age group 20 – 45) from both genders were participated in the evaluation of coded blended juice samples taken in 30 mL transparent glass containers. The judges were given pallet cleanser (puffed rice) in between two samples to rinse their mouth. Furthermore, the sensory index was calculated for each attribute as per method described by Madhu.[15] The indices were calculated using following formula to interpret the results obtained:

$$\text{Sensory Index (\%)} = \frac{\begin{array}{c}(9X_1)+(8X_2)+(7X_3)+\\(6X_4)+(5X_5)+(4X_6)+\\(3X_7)+(2X_8)+(X_9)\end{array}}{9(X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9)}\times 100$$

where, $X_1$to X_9 represent the number of panellists assigning scores from 9 to 1, respectively.

Optimization of the Blended Chayote–Mandarin RTS

Optimization of process variables *viz*., fruit juice content and ratio of chayote juice to mandarin juice

was carried out based on desirable quality parameter. Highest sensory scores, high overall acceptability and ascorbic acid content were desirable characters used during deciding optimum composition. The experimental data collected during the study were statistically analysed using Analysis of Variance (ANOVA) under a Completely Randomized Design (CRD). Differences among treatment means were evaluated, and significance was determined based on the critical difference (CD) at the 5% probability level.

Results and Discussion

The TSS of chayote juice was 3.80 ± 0.5°Brix, whereas it was 11.06 ± 0.3°Brix for mandarin juice. The pH of chayote juice was 6.57 ± 0.04, whereas pH of mandarin juice was 3.90 ± 0.26. The average acidity of chayote juice was 0.96±0.04, whereas 1.04 ± 0.10 for mandarin juice.

The chayote–mandarin blended beverage was prepared as per experimental design explained in Materials and Methods. Developed beverages were evaluated for the quality parameters (dependent variables) *viz*., colour, TSS, pH, titratable acidity (with respect to citric acid), ascorbic acid and sensory attributes.

Statistical analysis determined the significance of independent parameters (fruit juice content and chayote: mandarin ratio) on the response variables (TSS, pH, titratable acidity, ascorbic acid content and colour) (Table 1). The statistical analysis using ANOVA showed that the juice content and chayote to mandarin ratio significantly affected TSS (%), pH, titratable acidity, ascorbic acid. The indices of sensory attributes and colour properties were also showed significant variation for different treatments.

TSS of Blended Beverage

The TSS of the developed blended beverages corresponds to 12°Brix as set prior to development of beverages. This was within the acceptable quality standards for RTS beverages (not less than 10%) according to FSSAI. The TSS was highest (16°Brix) when the juice content (%) was 12% and chayote to mandarin ratio was 3:2. Results from the DMRT demonstrated statistically significant differences among the treatments. These variations are represented in the table by assigning different superscript letters. Same letters showed non–significance between treatments whereas different letters showed the significant difference.

The TSS is the inherent character of the raw material used; however, its blending and heat treatment may affect the overall characteristics. The TSS represent the sugar content of the juice, with highest TSS, the sweetness of the juice was increased. The variation in TSS may also be observed due to longer pasteurization time and higher temperatures.[8] The rise in TSS may be attributed to the hydrolysis of sucrose into glucose and fructose as well as the breakdown of polysaccharides into simple sugars. A similar pattern was reported by Sogi *et al*.[16] in *Kinnow* RTS beverage and squash. The change in TSS during storage has also been associated with the conversion of complex carbohydrates into simple sugars.[17] Comparable observations were noted by Deka *et al*.[18] and Chaurasiya *et al*.[19] In the present study, statistical evaluation revealed that TSS values of Lime–based RTS formulations varied significantly across treatments.

pH of Blended Beverage

The acidity of the blended beverage, influenced by available hydrogen ions and juice's buffering capacity, is an important quality attribute. It plays significant role not only to flavour balance but also to the microbial and physiochemical stability of the blended beverage. Since chayote juice and mandarin juice have different pH values, their ratio and quantity in blended beverage might have played role in change of pH of the beverages. The higher pH values of chayote are also a reason behind its blending with mandarin. The pH of developed blended beverages ranged between 3.8–4.3 for different treatments. No definite trend in the pH variation with fruit juice content could be observed. Furthermore, FSSAI has not given any guideline for specific pH values of the blended beverages.

Titratable Acidity of Blended Beverage

The Titratable Acidity (TA) of the developed blended beverages was varied between 0.44 and 1.08% citric acid for different treatments. It was increased with decrease in chayote juice content in the blend over mandarin juice content because of the low acidity of chayote juice. However, the titratable acidity of the developed blended beverages was above par with the maximum acceptable limits (0.2–0.3) for RTS beverages as per FSSAI standards. However, the results are below par and in the range for juice of fruits and vegetables as per FSSAI standards. The results are far below than the titratable acidity (1.36%) of blended juice of pineapple, orange, and carrot.

Ascorbic Acid of Blended Beverage

The concentration of ascorbic acid in the blended chayote–mandarin RTS showed a significant response to variation in the juice content and to the blending ratio between chayote and mandarin juice. The ascorbic acid is an inherent character of a raw material which may be varietal character and varied as per horticultural practices. However, the blending of two different juices had significantly changed the ascorbic acid in the sample blend. The result showed that the final product has ascorbic acid in the range from 8.84 to 14.91%. The highest ascorbic acid value was observed for 2:3 blend ratio and 14% juice content.

Colour of Blended Beverage

Though there is change in the lightness value (L*), a specific trend was not observed among experimental samples, however the lowest L* was observed for 2:3 blend of mandarin to chayote juice and 12% juice content (Table 2). It may be due to darker colour of mandarin juice compared to transparent colour of chayote juice. The other colour parameters like a* and b*, including Chroma showed the similar results as that of L*. However, negative relation was found for hue angle that the hue angle reduced with increase in juice content. The standard deviation for the average colour values was calculated and found that there was significant difference amongst treatment.

Sensory Quality of Blended Beverage

The acceptability of blended beverages was assessed by serving 15 sensory panellists (untrained). Based on flavour index It was observed that the panellists rated high (82.96%) to the beverage with high amount of mandarin juice. The high colour

Table 2 — Effect of juice content and ratio of blends on colour attributes

Juice content (%)	Chayote: Mandarin	Colour				
		L*	a*	b*	Hue angle	Chroma
10	3:2	34.90	−0.90	6.14	98.34	6.21
10	1:1	36.14	−0.85	7.59	96.39	7.64
10	2:3	33.66	−0.84	7.54	96.36	7.59
12	3:2	35.83	−1.01	9.02	96.39	9.08
12	1:1	33.74	−0.67	8.34	94.59	8.37
12	2:3	32.07	−1.36	5.70	103.42	5.86
14	3:2	36.59	−0.85	8.69	95.59	8.73
14	1:1	33.64	−0.53	6.82	94.44	6.84
14	2:3	34.92	−0.24	9.18	91.50	9.18
16	3:2	35.13	−1.34	8.16	99.33	8.27
16	1:1	34.56	−0.70	9.39	94.26	9.42
16	2:3	35.21	−0.33	10.35	91.83	10.36
18	3:2	38.04	−1.00	9.95	95.74	10.00
18	1:1	37.53	−0.54	10.79	92.87	10.80
18	2:3	36.30	−0.01	10.76	90.05	10.76

Table 3 — Effect of juice content and ratio of blend son sensory attributes of blended beverage

Juice content (%)	Chayote: Mandarin	Sensory analysis index (%)					
		Flavour/ Taste	Appearance/ Colour	Texture/ Mouthfeel	Aroma/ Odour	Texture/ Consistency	Overall Acceptability
10	3:2	74.07	75.19	74.44	75.56	76.30	80.37
10	1:1	78.52	79.26	79.26	75.56	78.52	80.74
10	2:3	76.30	73.33	76.67	72.96	78.89	84.44
12	3:2	75.93	75.19	74.44	72.22	76.67	77.04
12	1:1	80.00	78.52	82.96	77.78	75.19	77.78
12	2:3	78.15	81.48	77.04	83.70	69.63	82.22
14	3:2	77.41	75.56	73.70	67.41	78.89	75.19
14	1:1	69.63	76.30	82.22	71.11	77.04	74.07
14	2:3	71.48	79.26	74.44	75.19	75.93	71.11
16	3:2	78.15	81.11	81.48	72.22	72.96	71.11
16	1:1	74.07	77.41	80.00	71.11	77.41	77.78
16	2:3	75.19	75.19	74.44	81.48	77.04	82.22
18	3:2	82.96	75.93	77.04	68.52	73.70	74.44
18	1:1	80.37	79.63	76.30	75.56	74.44	75.19
18	2:3	77.04	83.33	76.67	80.74	83.33	78.89

indices were observed for high juice content in the developed beverages. However, no definite effect was observed for CJ:MJ on colour scores. The aroma indices showed that the blended beverages with higher amount of chayote juice were not much preferred by the panellists, however the scores were not significantly different. The texture was measure for two attributes like mouth feel and consistency. The data related to perception of mouth feel and consistency was converted in the index (Table 3). The mouth feel scores were higher with equal chayote juice to mandarin juice ratio i.e., 1:1. This shows that the panellists liked the developed blended beverage where there was equal amount of chayote juice and mandarin juice. Moreover, index for consistency showed that the panellists also liked the consistency of the developed blended beverage with equal amount of chayote to mandarin juice. All the compositions were accepted by the panellist. Nevertheless, an increase in the total juice content was associated with a reduction in the overall acceptability index. In contrast, treatments enriched with mandarin juice exhibited relatively superior acceptability ratings.

Optimization of Blended Beverage

The objective was to achieve highest acceptance rating on sensory attributes, highest ascorbic acid and TSS, acidity and juice content as per mandatory guidelines of FSSAI regulation. Analysis using the full factorial design followed by DMRT showed that the treatments differed significantly with respect to TSS, pH, titratable acidity, and ascorbic acid. The sensory scores did not show a treatment with highest scores for all sensory attributes, although highest scores were obtained for flavour (Taste) attribute in T_{13}, appearance in T_{15}, Aroma in T_6, Texture (mouthfeel) in T_5, Texture (consistency) in T_{15} and overall acceptability in T_{12}. Considering this, ranking was done for all index percentage and the results showed that the Treatment T_2 (1:1 chayote: mandarin, 10% juice content) had rank 3rd or 4th for all attributes and had consistent rating as well. Thus, the treatment may be considered as optimum subjected to minimum requirement of quality as per FSSAI.

Conclusions

Chayote, an underutilized fruit can be converted into juice. The study showed that the chayote – mandarin blended beverage can be one of the value–added products with wide acceptability. The performance of treatment T_2 was consistent for all sensory attributes and had TSS of about 12.73°Brix, pH of 4.23 and titratable acidity of 0.74%. Those results were at par with FSSAI regulation. Also, the treatment had significantly high ascorbic acid content (11.73 mg / 100 g). Therefore, the treatment T_2 was considered as optimum treatment. Findings from ANOVA, supported by DMRT, confirmed that the process variables significantly affected the response parameters, including TSS, pH, titratable acidity, and ascorbic acid. In future, shelf-life evaluation of blended beverage may be estimated and may be converted into powder by foam-mat drying or spray drying technologies. Though, diversity of chayote fruit is advantageous, availability of one variety in quantity is limited for processing and value addition.

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