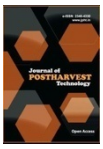

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RESEARCH ARTICLE

Sensory quality attributes of microwave vacuum concentrated pineapple juice

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ABSTRACT

Pineapple (*Ananas comosus* L.) is one of the commercially important fruit crops of India which is preferred by many people due to its pleasant aroma, flavor and refreshing sugar–acid balance. Concentration of pineapple juice is used to reduce the transportation, packaging and storage cost as well as to ensure off-time availability of juices. In this work, pineapple juice was concentrated by microwave vacuum evaporation process up to 50 brix. The sensory quality attributes of reconstituted pineapple juice was evaluated and compared with fresh pineapple juice and one of the packaged pineapple juices available commercially in the market. The sensory data were analyzed by using fuzzy logic to find out the relative importance of the quality attributes of pineapple juice samples in general, ranking of the pineapple juice samples and ranking of individual quality attributes of each of the pineapple juice samples tested. The results of fuzzy logic revealed that reconstituted pineapple juice was comparable with fresh pineapple juice in terms of sensory quality attributes taste, mouthfeel and colour on 6-point sensory scale. The aroma attribute of reconstituted pineapple juice was lower than the fresh pineapple juice on 6-point sensory scale. Microwave vacuum evaporation process used for concentration of pineapple juice was better option than thermal vacuum evaporation process.

Keywords: Pineapple juice, microwave vacuum evaporation, thermal vacuum evaporation, fuzzy logic, sensory quality

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INTRODUCTION

Pineapple (*Ananas comosus* L.) is a tropical or subtropical fruit belonging to Bromeliaceae family. Pineapple is one of the commercially important fruit crops of India. The pineapple varieties grown commercially in India are Kew, Giant Kew, Queen, Common Queen, Mauritius (NHB, 2017). India is the fourth largest producer of pineapple with an annual output of 1.96 million tonnes as against the total annual world production of 25.81 million tonnes (FAO, 2016). Pineapple contains considerable amounts of calcium, potassium, magnesium, phosphorous, iron, manganese, fiber, vitamin C and is low in fat and cholesterol (Khalid et al., 2016). It contains the protein digesting enzyme mixture called bromelain (Manzoor et al., 2016).

Fresh pineapple juice is preferred by many people due to its pleasant aroma, flavor and refreshing sugar–acid balance. The best storage conditions for pineapple fruits are 7-13˚C temperature and 80 or 90% relative humidity with proper ventilation

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conditions (Medina and Gárcia, 2005). At these conditions, pineapples can be stored up to 20 days. Pineapple stored below 7 ˚C results in chilling injuries. Pineapple fruits with crown may be kept at normal temperature under ventilation of fresh air for 10-15 days after harvesting (NHB, 2017).

Pineapples are converted into different processed products in order to increase its availability for longer time and to generate more profit. The processed pineapple products available in the market are pasteurized pineapple juice, concentrated pineapple juice, canned pineapple, dried pineapple and pineapple pulp (Medina and Gárcia, 2005). Concentration of fruit juices, a major unit operation in the fruit-processing industry, is used to reduce the transportation, packaging and storage cost as well as to ensure off-time availability of juices. This is especially true in the case of tropical fruit juices for which production region and consumption are normally far apart geographically. Concentrated fruit juice also ensures a longer storage life due to low water activity (Cassano et al., 2003). Concentration of fruit juices is of critical importance as it determines the quality of the final product such as flavor, color, aroma, appearance and mouthfeel (Maskan, 2006). In industries, fruit juices are concentrated using thermal evaporation process (multi-stage vacuum evaporation) (Jiao et al., 2004). Other methods of concentration like membrane concentration and freeze concentration processes produce better quality products than the vacuum concentration process but the adaptation of these processes for concentration of fruit juices in industries is limited due to various reasons (Cassano et al., 2004; Sánchez et al., 2011). Microwave vacuum concentration of fruit juices provides high evaporation rate and better product quality than the conventional method of concentration of fruit juices in rotary vacuum evaporator (Bozkir and Baysal, 2017; Naderi et al., 2016).

In the present work, pineapple juice was concentrated in microwave vacuum evaporation system up to 50 brix and its sensory quality was evaluated and compared with fresh pineapple juice and the packaged pineapple juice available commercially in the market. Prior to consumption, concentrated fruit juices are reconstituted by adding water and sugar (if required) so as to obtain the reconstituted juice equivalent to fresh juice. Hence concentrated pineapple juice obtained from microwave vacuum evaporation system was reconstituted, by adding water, up to 12 ˚Brix for the purpose of its sensory evaluation. Sensory quality attributes of reconstituted pineapple juice prepared in this project work were compared with those of the fresh pineapple juice and the packaged pineapple juice available commercially in the market.

MATERIALS AND METHODS

Preparation of score card for sensory evaluation

Quality attributes of pineapple juice selected for sensory evaluation were colour, aroma, taste, and mouthfeel. Fifteen judges, all non-smokers and non-beetle leaf chewers were selected based on good health, average sensitivity, interest in sensory evaluation, ability to concentrate and learn and familiarity with the pineapple juice. Judges were familiarized with the definition of quality attributes, scorecard and the method of scoring. Judging was done during 10:00 AM to 12:00 PM. They were asked to practice the scoring procedure according to the definition of each of the quality attributes before the actual test. They were asked to judge the samples quickly, but not in hurry and also to sense the aroma of the sample by sniffing the sample and enter the score for aroma first in the score card before 'testing'. They were advised to rinse their mouth with water between testing the consecutive samples. Pineapple juice purchased from the market was labeled as sample S_1, the pineapple juice obtained from reconstituting concentrated juice by the Microwave vacuum concentration was labeled as sample S_2 and the fresh pineapple juice was labeled as sample S_3. Judges were asked to give tick (✓) mark to the respective scale factor for each of quality

attributes mentioned in the scorecard. They were also asked to rank the quality attributes of pineapple juice in general, by giving tick (✓) mark to appropriate scale factors.

Five point sensory scales viz., Not satisfactory (NS), Fair (F), Medium (M), Good (G), Excellent (EX), were used for evaluation of pineapple juice samples. Judges were also asked to evaluate the relative importance of four quality attributes (viz., colour, flavour, taste and mouthfeel) on the five point sensory scale viz., Not at all important (NI), Somewhat important (SI), Important (I), Highly important (HI), and Extremely important (EI), for the pineapple juice in general.

The results were analyzed by using fuzzy logic to find out the relative importance of the quality attributes of pineapple juice samples in general, ranking of the two samples and ranking of individual quality attributes of each of the three samples tested.

Fuzzy comprehensive modeling of sensory scores

Fuzzy set theory was introduced by Zadeh (1965), which allows uncertain phenomena to be treated mathematically. Chen (1988) developed a fuzzy comprehensive model for analyzing sensory data. Ranking of three pineapple juice samples and their quality attributes was carried out using triangular fuzzy membership distribution function (Das, 2005). The values of triplets associated with triangular fuzzy membership distribution function for five-point sensory scale is represented in Fig. 1. In the triangular fuzzy membership distribution, sensory scales are represented by a set of three members called 'triplets' (Table 1 and Table 2). Sensory scores of pineapple juice samples and their quality attributes are converted into triplets, which were used for the estimation of similarity values needed for the ranking of samples.

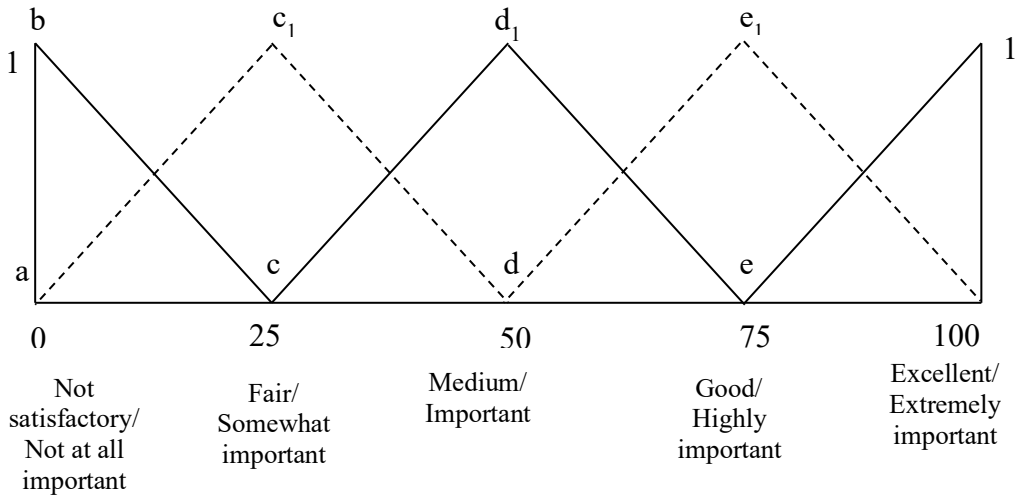

Fig. 1: Values of triplets associated with triangular fuzzy membership distribution function for five-point sensory scale

Table 1: Triplets associated with sensory scales for quality attributes of pineapple juices

Not satisfactory	Fair	Medium	Good	Excellent
0 0 25	25 25 25	50 25 25	75 25 25	100 25 0

Table 2: Triplets associated with sensory scales for relative importance of quality attributes of pineapple juices

Not at all important	Somewhat important	Important	Highly important	Extremely important
0 0 25	25 25 25	50 25 25	75 25 25	100 25 0

Steps involved in fuzzy modeling of sensory evaluation of pineapple juice are given below:

i. Sum of sensory scores for quality attributes of pineapple juices

Sum of sensory scores corresponding to each of the sensory points on five-point sensory scale for the particular quality attributes of pineapple juice was calculated by counting the responses of judges at that sensory point for that particular quality attribute.

ii. Sum of sensory scores for relative importance of quality attributes of pineapple juices in general

Sum of sensory scores corresponding to each of the sensory points on five-point sensory scale for relative importance of the particular quality attributes of pineapple juice was calculated by counting the responses of judges at that sensory point for that particular quality attribute.

iii. Calculation of the triplets for sensory scores of the quality attributes of pineapple juices

The triplets for sensory scores of the quality attributes of pineapple juice were calculated from the triplets associated with the sensory scale for quality attributes, given in Table 1, and the sum of sensory scores for quality attributes and the total number of judges using the following equation:

$$S1C = \frac{\sum_{i=1}^{i=5}(sensory\ score)_i * (triplets)_i}{total\ no.of\ judges} \quad (1)$$

Where S1C is triplets for sensory scores of colour for sample 1, $(\text{sensory score})_i$ is sensory score at ith sensory point on sensory scale corresponding to colour for sample 1 and $(\text{triplets})_i$ is triplets associate with ith sensory point on five-point sensory scale. Similarly, S2C and S3C, triplets for sensory scores of colour for sample 2 and sample 3 respectively; S1A, S2A and S3A, triplets for sensory scores of aroma for sample 1, sample 2 and sample 3 respectively; S1T, S2T and S3T, triplets for sensory scores of taste for sample 1, sample 2 and sample 3 respectively; S1M, S2M and S3M, triplets for sensory scores of mouthfeel for sample 1, sample 2 and sample 3 respectively were calculated.

iv. Calculation of the triplets for sensory scores of relative importance of the quality attributes for pineapple juices

The triplets for sensory scores of relative importance of the quality attributes of pineapple juice were calculated from the triplets associated with the sensory scale for relative importance of quality attributes, given in Table 2, and the sum of sensory scores for relative importance of quality attributes and total number of judges using the following equation:

$$QC = \frac{\sum_{i=1}^{i=5}(sensory\ score)_i * (triplets)_i}{total\ no.of\ judges} \quad (2)$$

Where QC is triplets for sensory scores of colour in general for pineapple juice, $(\text{sensory score})_i$ is sensory score at ith sensory point on sensory scale for relative importance of quality attributes corresponding to colour and $(\text{triplets})_i$ is triplets associate with ith sensory point on five-point sensory scale for relative importance of quality attributes. Similarly, QA, QT and QM, triplets for sensory scores of aroma, taste and mouthfeel in general respectively were calculated.

v. **Calculation of triplets for relative weightage of quality attributes of pineapple juices**

The triplets of relative weightage of quality attributes of pineapple juice were calculated from the triplets of quality attributes in general using the following equations:

$$QC_{rel} = \frac{QC}{Q_{sum}}$$
$$QA_{rel} = \frac{QA}{Q_{sum}}$$
$$QT_{rel} = \frac{QT}{Q_{sum}} \quad (3)$$
$$QM_{rel} = \frac{QM}{Q_{sum}}$$

where

$$Q_{sum} = QC_f + QA_f + QT_f + QM_f \quad (4)$$

Where QC_{rel} ,$QF_{rel,}$ $QT_{rel,}$ and QM_{rel} are triplets corresponding to the relative weightage of colour, Aroma, taste and mouthfeel respectively of the pineapple juice and QC_f, QA_f, QT_f and QM_f are first digit of triplets QC, QA, QT and QM.

vi. **Calculation of triplets for overall sensory score of pineapple juices**

The triplets for overall sensory scores of pineapple juice samples were calculated from the triplets for quality attributes of sample and the triplets for the relative weightage of quality attributes using following equation:

$$SO1 = S1C \times QC_{rel} + S1A \times QA_{rel} + S1T \times QT_{rel} + S1M \times QM_{rel} \quad (5)$$

Where SO1 is triplets for overall sensory score of pineapple juice sample 1. Similarly, SO2 and SO3 the triplets for overall sensory score of pineapple juice sample 2 and sample 3 respectively were calculated. Each of the terms on right side of Eq.(5) represents a triplet. Following is the rule applied for multiplication of triplet (a b c) with triplet (d e f)

$$(a\ b\ c) * (d\ e\ f) = (a*d\quad a*e + d*b\quad a*f + d*c) \quad (6)$$

vii. Calculation of membership function of sensory scores on standard fuzzy scale

Fig. 2 shows 'standard fuzzy scale' following triangular distribution pattern of 6-point sensory scale. The six points on fuzzy scale are represented as F1, F2, F3, F4, F5 and F6 corresponding to Not satisfactory/Not at all necessary, Fair/Somewhat necessary, Satisfactory/Necessary, Good/Important, Very good/Highly important, Excellent/Extremely Important respectively. The values of fuzzy membership function for each of the sensory points on fuzzy scale follow triangular distribution pattern with maximum and minimum values equal to 1 and 0 respectively. The maximum values of fuzzy membership function for each interval of 10, i.e. (10-0), (20-10), (30-20), (40-30), (50-40), (60-50), (70-60), (80-70), (90-80) and (100-90) on 'standard fuzzy scale' were opted as the values of membership function for particular sensory point (e.g. F1) based on its triangular distribution pattern on the fuzzy scale. Referring to the Fig. 2, the values of membership function for each of the six sensory points on fuzzy scale (viz., F1, F2, F3, F4, F5 and F6) are given in the form of row matrix having 10 elements as shown below:

$$F1 = (1, 0.5, 0, 0, 0, 0, 0, 0, 0, 0)$$
$$F2 = (0.5, 1, 1, 0.5, 0, 0, 0, 0, 0, 0)$$
$$F3 = (0, 0, 0.5, 1, 1, 0.5, 0, 0, 0, 0) \quad (7)$$

$$F4 = (0, 0, 0, 0, 0.5, 1, 1, 0.5, 0, 0)$$

$$F5 = (0, 0, 0, 0, 0, 0, 0.5, 1, 1, 0.5)$$

$$F6 = (0, 0, 0, 0, 0, 0, 0, 0, 0.5, 1)$$

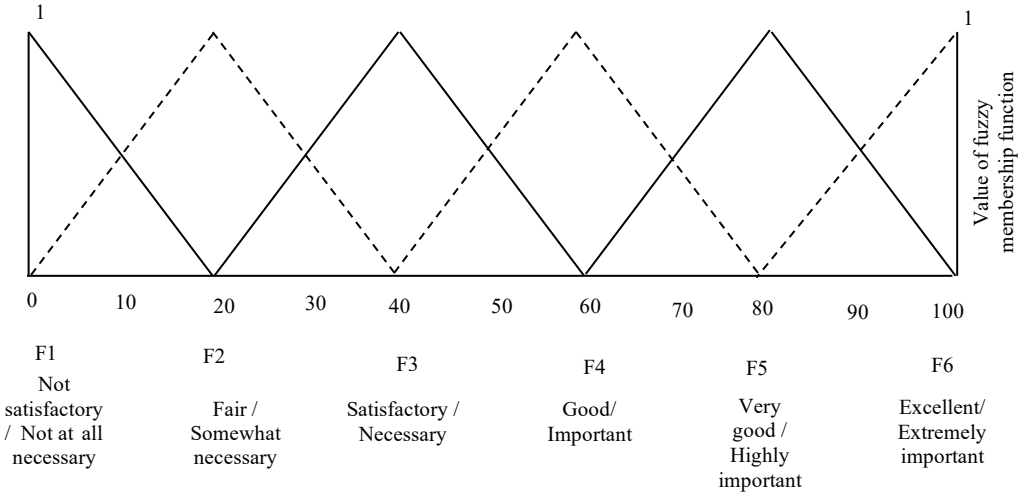

Fig. 2: Representation of standard fuzzy scale

viii. Calculation of overall membership function of sensory scores on standard fuzzy scale

The graphical representation of membership function for triplet (a b c) is shown in Fig. 3. The abscissa represents value corresponding to triplet and ordinate represents value of membership function for triplet (a b c). For a given value of x on the abscissa, value of membership function B_x can be expressed as equation (8),

$$B_x = \frac{x-(a-b)}{b} \quad \text{for (a-b)} < x < a$$

$$= \frac{(a+c)-x}{c} \quad \text{for } a < x < a + c \qquad (8)$$

$$= 0 \quad \text{for all other values of x}$$

The values of membership function B_x at x= 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 were evaluated using equation 8 for triplets of overall sensory scores of pineapple juice samples. The value of membership function of sensory scores of the sample on standard fuzzy scale is given by set of ten numbers, which are, maximum value of B_x at 0< x <10, maximum value of B_x at 10< x <20, maximum value of B_x at 20< x <30, maximum value of B_x at 30< x <40, maximum value of B_x at 40< x <50, maximum value of B_x at 50< x <60, maximum value of B_x at 60< x <70, maximum value of B_x at 70< x <80, maximum value of B_x at 80< x <90 and maximum value of B_x at 90< x <100. The overall membership functions of sensory scores of samples on standard fuzzy scale were represented by row matrix having 10 elements and denoted as B1, B2 and B3 for sample 1, sample 2 and sample3 respectively.

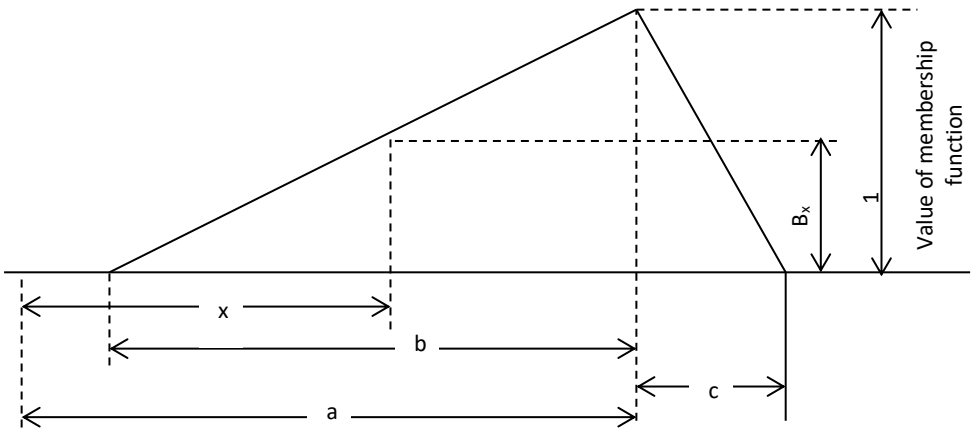

Fig. 3: Graphical representation of triplet (a b c) and its membership function

ix. Calculation of similarity values and the ranking of pineapple juice samples

After calculating the values of overall membership function of sensory scores of pineapple juice samples on standard fuzzy scale, these values were compared with the values of membership function for each of the six sensory points (F1, F2, F3, F4, F5 and F6) on standard fuzzy scale. The similarity values for each of the sample were calculated using equation given below:

$$S_m(F,B) = \frac{F \times B^T}{Max\,(F \times F^T \text{ and } B \times B^T)} \quad (9)$$

Where $S_m(F,B)$ is similarity value corresponding to sensory scale point F for sample having overall membership function B. The F^T and B^T are transpose of matrix F and B respectively. The similarity values $S_m(F1,B1)$, $S_m(F2,B1)$, $S_m(F3,B1)$, $S_m(F4,B1)$, $S_m(F5,B1)$ and $S_m(F6,B1)$ for sample 1; $S_m(F1,B2)$, $S_m(F2,B2)$, $S_m(F3,B2)$, $S_m(F4,B2)$, $S_m(F5,B2)$ and $S_m(F6,B2)$ for sample 2; $S_m(F1,B3)$, $S_m(F2,B3)$, $S_m(F3,B3)$, $S_m(F4,B3)$, $S_m(F5,B3)$ and $S_m(F6,B3)$ for sample 3 were calculated using Eq.(9). The pineapple juice sample having highest similarity values was ranked higher and pineapple juice sample having lower similarity values was ranked lower.

x. Calculation of quality attribute ranking of pineapple juice in general

Similar procedure as followed in earlier section 2.3 (vii, viii and ix) was used to calculate quality attribute ranking of pineapple juice in general. The values of membership function of sensory score for relative importance of quality attributes of pineapple juice were calculated from the triplets for sensory score of relative importance of quality attributes using Eq. (8) and denoted as BC, BA, BT and BM for colour, aroma, taste and mouthfeel respectively. Similarity values for each quality attributes in general were calculated from values of BC, BA, BT and BM and values of F1, F2, F3, F4, F5 and F6 using Eq.(9). The quality attribute having highest similarity values was ranked higher and quality attribute having lower similarity values was ranked lower.

xi. **Calculation of quality attribute ranking of individual pineapple samples**

Similar procedure as followed to evaluate the quality attribute ranking of pineapple juice in general was used to calculate quality attribute ranking of individual pineapple juice. Here, triplets for overall sensory scores for colour, aroma, taste and mouthfeel of sample 1 were calculated from triplets for overall sensory scores of pineapple juice in general using relative weightage for these quality attributes. For this, average sum (Q_{sum}) of first digit of triplets QC, QA, QT and QM was used.

The triplets of relative weightage of quality attributes of sample 1 were calculated from the triplets of quality attributes in general using the following equation:

$$QC1_{rel} = \frac{QC}{Q_{sum}}$$
$$QA1_{rel} = \frac{QA}{Q_{sum}}$$
$$QT1_{rel} = \frac{QT}{Q_{sum}} \quad (10)$$
$$QM1_{rel} = \frac{QM}{Q_{sum}}$$

Where,

$$\mathrm{Q_{sum}} = \frac{1}{4} * (\mathrm{QC_f} + \mathrm{QA_f} + \mathrm{QT_f} + \mathrm{QM_f}) \quad (11)$$

Where $QC1_{rel}$, $QF1_{rel}$, $QT1_{rel}$, and $QM1_{rel}$ are triplets corresponding to the relative weightage of colour, aroma, taste and mouthfeel respectively for the sample 1.

Triplets for sensory scores of relative importance of quality attributes of sample 1 are given by multiplication of triplets for sensory scores of sample 1 and triplets corresponding to the relative weightage of quality attributes for the sample 1 as given below:

$$C1 = S1C \circ QC1_{rel}$$
$$A1 = S1A \circ QA1_{rel} \quad (12)$$
$$T1 = S1T \circ QT1_{rel}$$
$$M1 = S1M \circ QM1_{rel}$$

Where C1, A1, T1 and M1 are triplets for sensory scores of relative importance of colour, aroma, taste and mouthfeel of sample 1. These triplets were converted into membership function of sensory score for relative importance of quality attributes of sample 1 using Eq. 8 and denoted as BC1, BA1, BT1 and BM1 for colour, aroma, taste and mouthfeel respectively. Further, these values of membership function were converted into similarity values using Eq. 9 and comparison was done to find out the higher and lower ranks of quality attributes of sample 1. The same process was followed for other samples to rank their quality attributes.

RESULTS AND DISCUSSION

The sensory evaluation of concentrated pineapple juice, obtained from the microwave-assisted vacuum concentration process was done after reconstituting it. The sensory analysis of reconstituted pineapple juice, fresh pineapple juice and a commercial brand of pineapple juice available in the market was done using fuzzy logic. The results of the fuzzy logic are presented here.

Triplets of overall sensory scores of pineapple juice samples

The sum of the responses obtained for pineapple juice samples by fifteen judges are shown in Table 3 for sensory scores of quality attributes of pineapple juice samples and in Table 4 for sensory scores of relative importance of quality attributes of pineapple juice in general. The triplets associated with the sensory scores for quality attributes of pineapple juice samples were calculated using Eq. (1) and are presented in Table 5.

Table 3: Sum of sensory scores of quality attributes of pineapple juice samples

Sensory quality attributes for pineapple juice samples	Samples	Sensory scores				
		NS	F	M	GD	EX
Colour	S_1	0	0	9	4	2
	S_2	0	0	2	10	3
	S_3	0	0	3	7	5
Aroma	S_1	0	4	6	5	0
	S_2	0	0	4	8	3
	S_3	0	0	1	6	8
Taste	S_1	0	3	6	5	1
	S_2	0	0	5	7	3
	S_3	0	0	3	5	7
Mouthfeel	S_1	0	0	3	8	4
	S_2	0	0	3	9	3
	S_3	0	0	4	5	6

Table 4: Sum of sensory scores for relative importance of quality attributes of pineapple juice in general

Quality attributes of pineapple juice samples in general	Sensory scores				
	NI	SI	I	HI	EI
Colour	0	0	10	3	2
Aroma	0	0	3	10	2
Taste	0	0	1	3	11
Mouthfeel	0	0	2	9	4

The triplets for sensory scores of relative importance of the quality attributes (colour, aroma, flavor and mouthfeel) of pineapple juice in general were calculated using Eq. (2) and are presented in Table 6. The triplets of relative weightage of quality attributes of pineapple juice were calculated from the triplets of quality attributes of pineapple juice in general using Eq. (3) and are presented in Table 6.

Table 5: Triplets for sensory scores of the quality attributes of the pineapple juice

Sensory quality attributes for pineapple juice samples	Triplets for sensory scores
Colour	S1C =(63.33 25.00 21.67)
	S2C=(76.67 25.00 20.00)
	S3C=(78.33 25.00 16.67)
Aroma	S1A=(51.67 25.00 25.00)
	S2A=(73.33 25.00 20.00)
	S3A=(86.66 25.00 11.67)
Taste	S1T=(56.67 25.00 23.33)
	S2T=(71.67 25.00 20.00)
	S3T=(81.67 25.00 13.33)
Mouthfeel	S1M=(76.67 25.00 18.33)
	S2M=(75.00 25.00 20.00)
	S3M=(78.33 25.00 15.00)

Table 6: Triplets for sensory scores of relative importance of the quality attributes of pineapple juice in general

Quality attributes of pineapple juice in general	Triplets for sensory scores	Triplets for relative weightage
Colour	QC=(61.67 25.00 21.67)	QC_{rel}=(0.20 0.08 0.07)
Aroma	QA=(73.33 25.00 21.67)	QA_{rel}=(0.24 0.08 0.07)
Taste	QT=(91.67 25.00 06.66)	QT_{rel}=(0.30 0.08 0.02)
Mouthfeel	QM=(78.33 25.00 18.33)	QM_{rel}=(0.26 0.08 0.06)
	Q_{SUM} = 305.00	

The triplets for overall sensory scores of pineapple juice samples were calculated from the triplets for quality attributes of sample and the triplets for the relative weightage of quality attributes using Eq. (5). The triplets for overall sensory scores of the three pineapple juice samples are presented below.

$$SO1 = (61.95\ \ 45.36\ \ 36.13)$$

$$SO2 = (73.93\ \ 49.32\ \ 36.13) \quad (13)$$

$$SO3 = (81.34\ \ 51.64\ \ 32.25)$$

Overall membership function of sensory scores on standard fuzzy scale

The values of overall membership function of sensory score of pineapple juice samples on standard fuzzy scale, B_x at x= 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 were evaluated using equation (8) for triplets of overall sensory scores of pineapple juice samples. The overall membership functions of sensory scores of sample 1, sample 2 and sample3 on standard fuzzy scale are given below and denoted as B1, B2 and B3 respectively.

$$B1 = (0.00\ \ 0.08\ \ 0.30\ \ 0.52\ \ 0.74\ \ 0.85\ \ 0.96\ \ 0.78\ \ 0.50\ \ 0.22)$$

$$B2 = (0.00\ \ 0.00\ \ 0.11\ \ 0.31\ \ 0.51\ 0.72\ \ 0.90\ \ 0.92\ \ 0.83\ \ 0.56) \quad (14)$$

$$B3 = (0.00\ \ 0.00\ \ 0.01\ \ 0.20\ \ 0.39\ \ 0.59\ \ 0.78\ \ 0.86\ \ 0.97\ \ 0.73)$$

Similarity values of pineapple juice samples and their ranking

After calculating the values of overall membership function of sensory scores of pineapple juice samples on standard fuzzy scale, these values were compared with the values of membership function for each of the six sensory points (F1, F2, F3, F4, F5 and F6) on standard fuzzy scale and similarity values for each sample were calculated using Eq. (9). The similarity values obtained for all three pineapple juice samples are presented in Table 7:

Table 7: Similarity values for the three pineapple juice samples

Sensory scales	Sample 1	Sample 2	Sample 3
Not Satisfactory, F1	0.0109	0.0000	0.0000
Fair, F2	0.1825	0.0745	0.0313
Satisfactory, F3	0.5299	0.3485	0.2634
Good, F4	**0.7443**	0.6560	0.5911
Very Good, F5	0.5421	**0.6987**	**0.7681**
Excellent, F6	0.1375	0.2754	0.3611
Ranking	III	II	I

It was evident from the Table 7 that highest similarity values for sample 1, sample 2 and sample 3 were 0.7443 under the sensory scale of 'Good', 0.6987 under the sensory scale of 'Very good' and 0.7681 under the sensory scale of 'Very good' respectively on 6-point sensory scale. The pineapple juice samples were ranked according to the highest similarity values on 6-point sensory scale. Following this rule, the overall sensory qualities of sample 1, sample 2 and sample 3 were considered 'Good', 'Very good'

and 'Very good' respectively. The sample 2 and sample 3 were under the category of 'Very good'. However, sample 3 was ranked higher because it had similarity value higher than the sample 2. Thus, the order of ranking of pineapple juice samples on 6- point sensory scale was found as given below:

Sample 3 (Very good) > Sample 2 (Very good) > Sample 1 (good)

Thus, it can be concluded that reconstituted pineapple juice (sample 2) made from the pineapple juice concentrate, obtained by the process of microwave vacuum concentration, was higher in terms of sensory quality attributes than the pineapple juice taken from the market (sample 1). The sensory quality attributes of reconstituted pineapple juice (sample 2) were comparable with fresh pineapple juice (sample 3) because reconstituted pineapple juice and fresh pineapple juice were in same category of 'Very good', whereas sensory quality attributes of sample 1 were in the category of 'Good' on 6-point sensory scale.

Quality attribute ranking of pineapple juice samples in general

The similarity values of the quality attributes of pineapple juice in general were calculated from the values of membership function of sensory score for relative importance of quality attributes of pineapple juice in general and the values of membership function for each of the 6-points sensory scale using Eq. (9). The similarity values of the quality attributes of pineapple juice in general are presented in the Table 8.

Table 8: Similarity values of the quality attributes of pineapple juice in general

Sensory scales	Color	Aroma	Taste	Mouthfeel
Not at all necessary	0.0000	0.0000	0.0000	0.0000
Somewhat necessary	0.0000	0.0000	0.0000	0.0000
Necessary	0.1600	0.1200	0.0000	0.0267
Important	**0.7364**	0.6667	0.1600	0.4570
Highly important	0.4944	**0.8164**	0.6667	**0.8437**
Extremely important	0.0488	0.3661	**0.8043**	0.4329
Ranking	IV	III	I	II

The highest similarity values for colour, aroma, taste and mouthfeel of pineapple juice were 0.7364 under the sensory scale of 'Important', 0.8164 under the sensory scale of 'Highly Important', 0.8043 under the sensory scale of 'Extremely important' and 0.8437 under the sensory scale of 'Highly important' respectively on 6-point sensory scale as shown in Table 8. Thus, the order of ranking of quality attributes of pineapple juice in general was as given below:

Taste (Extremely important) > Mouthfeel (Highly important) > Aroma (Highly important) > Colour (Important)

Quality factor ranking of individual pineapple juice samples

The procedure of finding out the similarity values of quality attributes of individual pineapple juice samples is described in section 2.3 (xi). The similarity values of quality attributes of individual pineapple juice samples are presented in Table 9.

Table 9: Similarity values and ranking of quality attributes of individual pineapple juice samples

Sensory scales	Sample 1				Sample 2				Sample 3			
	C	A	T	M	C	A	T	M	C	A	T	M
Not Satisfactory, F1	0.04	0.06	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Fair, F2	0.35	0.42	0.12	0.06	0.12	0.11	0.02	0.06	0.18	0.03	0.00	0.04
Satisfactory, F3	0.69	**0.85**	0.44	0.29	0.44	0.47	0.25	0.33	0.48	0.28	0.13	0.28
Good, F4	**0.80**	0.66	**0.71**	0.58	**0.84**	**0.81**	0.64	0.62	**0.81**	0.67	0.49	0.60
Very Good, F5	0.36	0.27	0.62	**0.85**	0.69	0.64	**0.85**	**0.78**	0.69	**0.83**	**0.90**	**0.77**
Excellent, F6	0.03	0.04	0.18	0.41	0.19	0.18	0.38	0.36	0.18	0.34	0.55	0.37
Ranking	II	IV	III	I	III	IV	I	II	IV	II	I	III

It was evident from Table 9 that highest similarity values for colour, aroma, taste and mouthfeel of sample 1 were under sensory scale of 'Good' (0.80), 'Satisfactory' (0.85), 'Good' (0.71) and 'Very good' (0.85) respectively. Similarly, the highest similarity values for colour, aroma, taste and mouthfeel of sample 2 were under sensory scale of 'Good' (0.84), 'Good' (0.81), 'Very good' (0.85) and 'Very good' (0.78) respectively. Further, the highest similarity values for colour, aroma, taste and mouthfeel of sample 3 were under sensory scale of 'Good' (0.81), 'Very good' (0.83), 'Very good' (0.90) and 'Very good' (0.77) respectively. On comparing the similarity values of quality attributes of individual pineapple juice samples, ranking of quality attributes of individual sample was for:

Sample 1 Mouthfeel (Very good) > Colour (Good) > Taste (Good) > Aroma (Satisfactory)

Sample 2 Taste (Very good) > Mouthfeel (Very good) > Colour (Good) > Aroma (Good)

Sample 3 Taste (Very good) > Aroma (Very good) > Mouthfeel (Very good) > Colour (Good)

The similarity value for taste of sample 2 and sample 3 were under the category of 'Very good' which was ranked first under 'Extremely important' quality attributes of pineapple juice in general. The quality attribute, taste, of pineapple juice of sample 2 and sample 3 was comparable, whereas it was under the category of 'Good' for sample 1.

The similarity values for mouthfeel of sample 1, sample 2 and sample 3 were under the category of 'Very good' which was ranked second under 'Highly important' quality attribute of pineapple juice in general. All three samples were comparable in terms of mouthfeel on 6-point sensory scale.

The similarity value for aroma of sample 1, sample 2 and sample 3 were under the category of 'satisfactory', 'Good' and 'Very good' respectively. The quality attribute, aroma, of pineapple juice was ranked third under 'Highly important' quality attributes of pineapple juice in general. The fresh pineapple juice (sample 3) was better in aroma attribute than the reconstituted pineapple juice (sample 2) and commercially available pineapple juice (sample 1). The reconstituted pineapple juice (sample 2) was better in aroma attribute than commercially available pineapple juice (sample 1).

The similarity values for colour of sample 1, sample 2 and sample 3 were under the category of 'Good' which was ranked fourth under 'Important' quality attributes of pineapple juice in general. All three samples were comparable in terms of colour on 6-point sensory scale.

CONCLUSIONS

The sensory quality attributes of reconstituted pineapple juice (sample 2) were comparable with that of fresh pineapple juice (sample 3) because reconstituted pineapple juice and fresh pineapple juice were in same category of 'Very good', whereas sensory quality attributes of sample 1 were in the category of 'Good' on 6-point sensory scale. It can be concluded that reconstituted pineapple juice (sample 2) was comparable with fresh pineapple juice (sample 3) in terms of sensory quality attributes taste, mouthfeel and colour on 6-point sensory scale. The aroma attribute of reconstituted pineapple juice was lower than the fresh pineapple juice on 6-point sensory scale. Microwave vacuum evaporation process used for concentration of pineapple juice was better option than thermal vacuum evaporation process.

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