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Sensory analysis of bar samples prepared from mahua (*Madhuca longifolia*) flower syrup using fuzzy logic

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ABSTRACT

Five bar samples, including a control bar, prepared from different percentages of mahua flower syrup were investigated using fuzzy logic sensory analysis. These bar samples were ranked against each other: the quality attributes of the bars (colour, flavour, stickiness, overall acceptability and taste) were scored and the bars rated. A panel of 15 judges performed the sensory evaluation. Analysis indicated that taste, overall acceptability and flavour were the main quality attributes, while stickiness and colour were less important. Fuzzy logic sensory analysis determined that the bar with 100% replacement of sugar with mahua flower syrup was the most acceptable.

Keywords

Fuzzy logic sensory analysis

Mahua bar

Response surface methodology (RSM)

Overall acceptability

Introduction

In the last few years, herbal medicine has become increasingly popular in developing and developed countries because of its natural origins and fewer side effects. Mahua (*Madhuca longifolia*), a member of the *Sapotaceae* family, is a forest tree providing food, fodder and fuel [1–4]. This large evergreen tree is found in India, Sri Lanka and Nepal and produces edible flowers which have a high medicinal value and are used in ayurvedic medicine [5].

The edible flowers and fruits of the mahua tree are collected in March–May, thus providing employment during the leanest agricultural season in India. The nutrient content of the flower deteriorates during storage, and so juice is extracted from the fresh flowers and immediately processed to produce a liquid concentrate. This honey-like liquid sweetener is used for the preparation of bakery and confectionary goods (candy, biscuits and cakes) [4, 6, 7]. The sugar content of mahua flowers collected from different geographical regions ranges from 40% to 70% [5], indicating that these flowers could be used as a novel source of natural sweetener.

Although they are a rich and easy source of nutrition in rural areas, these flowers are not popular as a food, and only small quantities are consumed raw, cooked or fried in different parts of India [8]. Abhyankar and Narayana [9] described the preparation of sugar syrup from dry mahua flowers and its use as a sweetening agent in different food products. The hedonic test was then used to examine the colour, flavour, taste, texture and overall acceptability of these products, which were all found to be very acceptable. In other research, candy, biscuits and cakes were prepared using mahua concentrate as a liquid sweetener [7, 10]. In 2008, Patel and Naik [10] made a sauce from crushed fresh flowers after manually removing the stamens.

The aim of this study was to capitalize on the nutritional value of mahua flower by incorporating it into a fruit bar, with a view to future industrial application. We procured fresh mahua flowers from Allahabad, U.P., India. We had earlier analysed a mahua cupcake [7] prepared with mahua flower syrup used as a sweetening agent. In this paper, we examine mahua bars prepared with mahua flower pulp. The hedonic test was then used to study the colour, flavour, taste, texture and overall acceptability of the bars.

Consumer acceptability is one of the biggest challenges in product development. Therefore, the sensory test is used to predict consumer acceptability and the likely success of the product on the market. Data obtained on sensory attributes

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such as colour, smell, taste and mouth feel can be analyzed using fuzzy logic to remove the subjective element from ratings [11] and assess associations between independent variables (e.g., colour, flavour, appearance, taste and texture) and dependent variables (e.g., acceptance, rejection, ranking, and strong and weak attributes) [12, 13]. Fuzzy logic can also be used to rank food products [11]. The tool has been extensively employed for quality ranking based on the sensory evaluation of aromatic foods packed in starch-based films [14], drinks formulated from dahi (Indian yoghurt) [13], mango drinks [15], jam samples [16] and other food products [17].

In the present study, we develop a fuzzy comprehensive model based on the sensory score awarded by 15 judges to five samples of mahua bar containing different percentages of mahua syrup. This study demonstrates the usefulness of the developed fuzzy model for the optimization and ranking of bars with different ingredient ratios.

Materials and methods

Mahua bar preparation

The study aimed to develop a mahua bar with the maximum possible amount of mahua syrup using response surface methodology (RSM), an optimization technique commonly used in food science. A total of 20 experiments were performed. Each experiment was carried out twice on two samples prepared independently. The bars were coded from MB1 to MB20. The flowchart for the preparation of the bars is as follows:

Weigh all ingredients

⇩

Pour the guava pulp and mahua juice into a pan

⇩

Add sugar

⇩

Heat with continuous stirring

⇩

Add pectin

⇩

Continuously stir

⇩

Add citric acid

⇩

Use a refractometer to determine 75°B

⇩

Spread on trays lined with butter

⇩

Cut into rectangles

Fuzzy analysis of sensory data for ranking mahua bars

Fuzzy logic is an important tool for analyzing vague and imprecise data and drawing conclusions regarding the acceptance, rejection, ranking, and strong and weak attributes of food. In fuzzy modelling, linguistic variables (e.g., not satisfactory, good, excellent, etc.) are used for developing relationships between independent (e.g., colour, flavour, texture, overall appearance, etc.) and dependent (e.g., acceptance, rejection, ranking, strong and weak attributes) variables [12, 13]. In fuzzy theory, a subject can be represented by fuzzy sets with a series of elements and their membership degrees compared to crisp sets [18]. Such fuzzy sets provide the mathematical methods that can represent the uncertainty of human expressions [19]. Fuzzy sets can be used for the analysis of sensory data instead of average scores to compare sample attributes [20, 21]. The developed fuzzy mathematical models perform remarkably well in the evaluation and ranking of food products [22]. The acceptance or rejection of food is ultimately based on sensory evaluation [23]. The sensory quality of food can be evaluated by estimating the opinion of the consumer [24, 25]. The main objective of this study was to evaluate the sensory scores of different mahua bar samples using fuzzy logic and grade the samples according to their sensory qualities.

Sensory evaluation of mahua bars

Four mahua bar samples with high overall acceptability scores were compared with a control bar using fuzzy logic. All five bars were formulated using RSM. The bars were coded as control, MB3, MB5, MB11 and MB15. MB3 contained 20.0 g guava pulp, 100 g mahua flower juice and 15 g sugar; MB5 contained 40.0 g guava pulp, 80 g mahua flower juice and 30 g sugar; MB11 contained 30.0 g guava pulp, 73 g mahua flower juice and 22.5 g sugar; and MB15 contained 30.0 g guava pulp, 90 g mahua flower juice and 22.5 g sugar.

Quality attributes selected for sensory evaluation

The quality attributes selected for sensory evaluation of the mahua bars were colour, flavour, stickiness, taste and overall acceptability. All 15 judges were familiar with the quality attributes of the samples before the actual sensory evaluation. They were advised to briefly sniff the samples twice before tasting them and scoring them first for flavour. They were also advised to rinse their mouth with water between testing consecutive samples [15]. Judges were instructed to select one of the fuzzy scale factors (‘poor’, ‘fair’, ‘medium’, 'good' or 'excellent') for each of the quality attributes and to rank the quality attributes as 'not important', 'somewhat important', 'important', 'highly important' and 'extremely important'. The observation data were then analyzed using fuzzy analysis of sensory scores. This method has been successfully applied for mango drinks [15], dahi powder [13], instant green tea powder [26] and bread prepared from millet-based composite flours [27].

The bar samples were ranked by using the triangular fuzzy membership distribution function, which has been explained in detail by Das [12]. Sensory scores for the samples were obtained from the fuzzy scores awarded by the judges, which were converted to triplets and used for the estimation of similarity values for ranking samples. Major steps in the fuzzy modelling of sensory evaluation included: (1) calculation of the overall sensory scores of samples in the form of triplets; (2) estimation of membership function on a standard fuzzy scale; (3) computation of the overall membership function (OMF) on a standard fuzzy scale; (4) estimation of similarity values and ranking of the bar samples; and (5) general quality attribute ranking of the bar samples.

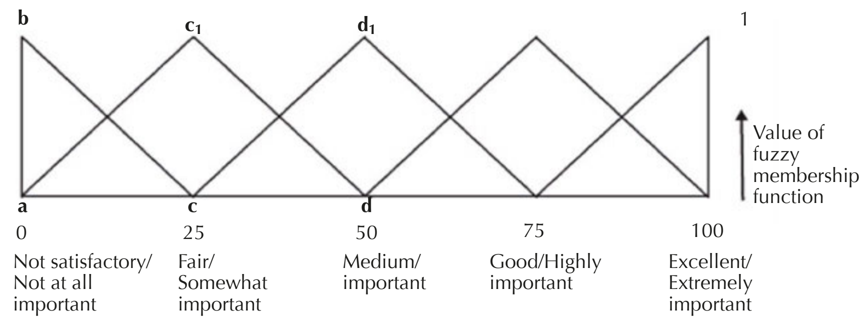

Figure 1 - Triplets associated with the triangular membership distribution function for five-point sensory scales

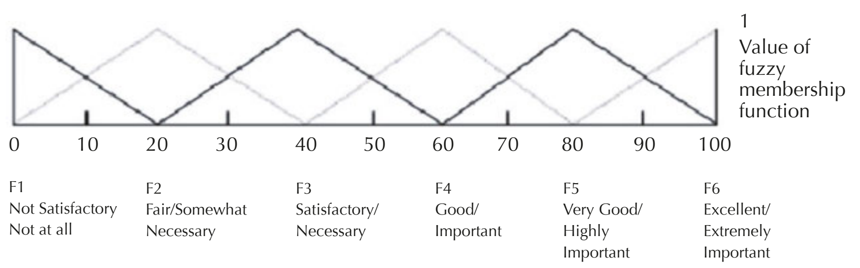

Figure 2 - Standard fuzzy scales for membership functions

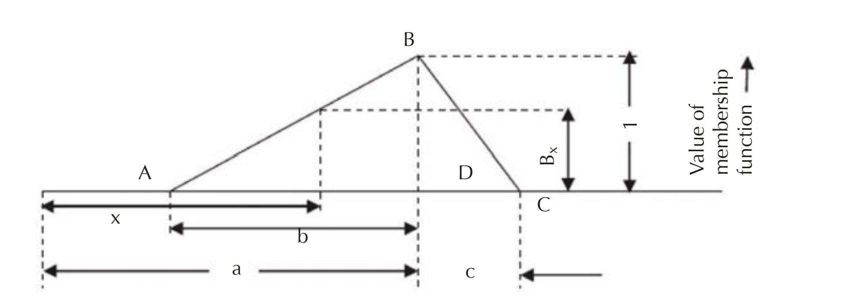

Figure 3 - Graphical representation of triplet (a, b, c) and its membership funcion

1

$$S2C = \frac{0\,(0\ 0\ 25) + 0\,(25\ 25\ 25) + 1\,(50\ 25\ 25) + 12\,(75\ 25\ 25) + 2\,(100\ 25\ 0)}{(0 + 0 + 1 + 12 + 2)} = (76.67\ 25\ 21.67)$$

2

$$SO1 = S1C \times QC_{rel} + S1F \times QF_{rel} + S1S \times QS_{rel} + S1O \times QO_{rel} + S1T \times QT_{rel}$$

3

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

Triplets associated with sensory scales

A set of three numbers known as a 'triplet' is used to represent the triangular membership function distribution pattern of sensory scales and the distribution pattern of five-point sensory scales. They consist of 'not satisfactory/not at all important (0,0,25)', 'fair/somewhat important (25,25,25)', 'medium/important (50,25,25)', 'good/highly important (75,25,25)' and 'excellent/extremely important (100,25,0)' (Fig. 1). The three numbers in brackets are the triplets, where the first number of the triplet denotes the coordinate of the abscissa where the value of the membership function is 1 (Figs. 1–3), and the second and third numbers of the triplet designate the distance to the left and right, respectively, of the first number, where the membership function is 0 [13]. For example, in Fig. 1, triangle a b c represents the membership function for the 'not satisfactory/not at all important' category, and triangle a c1 d represents the distribution function for the 'fair/somewhat important' category.

Triplets for sensory scores and overall quality of bar samples

For a particular sample, the triplet corresponding to a specific quality attribute (colour, flavour, etc.) can be obtained from the sum of the sensory scores, triplets associated with the sensory scale, and the number of judges selecting a score (Table 1). For example, the triplet for the sensory score for the colour of MB3, where one of the 15 judges gave a ‘medium’ score, 12 gave a ‘good’ score and two gave an ‘excellent’ score, is calculated as shown in Eq. 1.

Similar values were obtained for each quality attribute (colour, flavour, stickiness, overall acceptability and taste) of all five samples. The control bar was sample 1, MB3 was sample 2, MB6 was sample 3, MB11 was sample 4, and MB15 was sample 5. The triplets for the sensory scores of quality attributes were also calculated from the weights given by the judges to the quality attributes (Table 2). The triplets for the overall sensory scores of samples were obtained by multiplying the triplet for the sensory score for each quality attribute by the triplet for the relative weight of that particular attribute, and the sum of the resultant triplet values for all attributes was taken. For example, the overall sensory score in the form of the triplet for sample 1 (i.e., the control bar) is given by Eq. 2, where S1C, S1F, S1S, S1O and S1T represent the triplets corresponding to the colour, flavour, stickiness, overall acceptability and taste, respectively, of the first sample, and QC_{rel}, QF_{rel}, QS_{rel}, QO_{rel} and QT_{rel} denote the triplets corresponding to the relative weight of the quality attributes of samples in general. Using similar equations, the overall scores for all five samples were calculated. The rule applied for the multiplication of triplet (a b c) by triplet (d e f) is given by Eq. 3.

4

F1 = {1, 0.5, 0, 0, 0, 0, 0, 0, 0, 0} for ‘not satisfactory/not at all’
F2 = {0.5, 1, 1, 0.5, 0, 0, 0, 0, 0, 0} for ‘fair/somewhat necessary’
F3 = {0, 0, 0.5, 1, 1, 0.5, 0, 0, 0, 0} for ‘satisfactory/necessary’
F4 = {0, 0, 0, 0, 0.5, 1, 1, 0.5, 0, 0} for ‘good/important’
F5 = {0, 0, 0, 0, 0, 0, 0.5, 1, 1, 0.5} for ‘very good/highly important’
F6 = {0, 0, 0, 0, 0, 0, 0, 0, 0.5, 1} for ‘excellent/extremely important’

5

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

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

$$B_x = 0 \quad \text{for } x < (a - b) \text{ or } x > (a + c)$$

6

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

Membership function for a standard fuzzy scale

Figure 2 shows the triangular distribution pattern of a six-point sensory scale, which is referred to as a standard fuzzy scale. The symbols F1, F2, F3, F4, F5 and F6 represent sensory scales. The membership function of each sensory scale follows a triangular distribution pattern where the maximum value of the membership function is 1. The values of the membership functions of F1, F2, F3, F4, F5 and F6 are defined by a set of 10 numbers as shown in Eq. 4.

OMF of sensory scores on a standard fuzzy logic scale

Figure 3 is a graphical representation of the membership function of a triplet (a, b, c). The figure shows that for a triplet (a, b, c), when the value of the abscissa is a, the value of the membership function is 1, and when it is less than a–b or greater than a+c, the value is 0. For a given value of x on the abscissa, the value of the membership function B_x can be expressed as shown in Eq. 5.

For each of the samples and its triplets, the value of the membership function B_x at x=0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 can be obtained from Eq. 5. This membership function value of samples on a standard fuzzy scale will be given as a set of 10 numbers which are (maximum value of B_x in the interval $0<x<10$), (maximum value of B_x in the interval $10<x<20$), (maximum value of B_x in the interval $20<x<30$), (maximum value of B_x in the interval $30<x<40$), (maximum value of B_x in the interval $40<x<50$), (maximum value of B_x in the interval $50<x<60$), (maximum value of B_x in the interval $60<x<70$), (maximum value of B_x in the interval $70<x<80$), (maximum value of B_x in the interval $80<x<90$), and (maximum value of B_x in the interval $90<x<100$).

Similarity values and ranking of mahua samples

After the OMF (B’s) for the overall quality of all five samples was obtained, the similarity values for each sample were calculated using Eq. 6, where S_m is the similarity value for the sample/quality attribute under consideration, and B^T and F^T denote the transpose of matrices B and F, respectively. Using the rules of matrix multiplication, the values of S_m are calculated. Thus, for the first sample, 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) were calculated. The similarity values under the six categories were compared to determine the highest similarity value of each sample. The category corresponding to the highest similarity value of a sample was considered as that most responsible for the sample quality. For example, if out of these six similarity values for the second sample, S_m (F4, B2) has the highest value, then the overall quality of that sample was regarded as 'good' because the six-point standard membership function F4 falls in the 'good/important' category. Using a similar procedure, the overall quality of each sample was defined. The obtained overall qualities of the samples as calculated above were combined in order to rank all five samples.

Similarity values for quality attribute ranking of mahua bar samples in general

The same method as described previously was used to rank the quality attributes of samples in general and of samples individually. Using the overall sensory scores as triplets of the five quality attributes (colour, flavour, stickiness, overall acceptability and taste) and the six membership functions on standard fuzzy scales (F's), the similarity values for each of the quality attributes were calculated. Comparison of the similarity values for each of the five quality criteria (colour, flavour, stickiness, overall acceptability and taste) revealed the highest similarity value category. The category ('not at all necessary', 'somewhat important', 'necessary', 'important', 'highly important' and 'extremely important') corresponding to the highest similarity value was regarded as the best quality criterion for mahua bar samples in general. The ranking of the quality attributes of mahua bar samples in general was then determined based on the order of the highest similarity values and the corresponding category of the five quality attributes. We developed an Excel program for fuzzy logic evaluation of sensory data for the entire analysis.

Results and discussion

Fuzzy analysis of sensory data for quality evaluation and ranking of bar samples

Table 1 shows the sensory scores for the bars prepared from the juice of fresh mahua flowers (samples MB3, MB6, MB11

Sensory quality attributes	Poor	Fair	Medium	Good	Excellent	Triplets for sensory scores		
Colour								
Control	0	0	1	12	2	76.67	25	21.67
MB3	0	0	1	12	2	76.67	25	21.67
MB6	0	3	2	10	0	61.67	25	25
MB11	0	1	1	13	0	70	25	25
MB15	0	0	1	11	3	78.33	25	20
Flavour								
Control	0	0	0	13	2	78.33	25	21.67
MB3	0	4	3	8	0	56.67	25	25
MB6	0	2	3	10	0	63.33	25	25
MB11	0	0	3	11	1	71.67	25	23.33
MB15	0	0	0	11	4	81.67	25	18.33
Stickiness								
Control	0	0	2	12	1	73.33	25	23.33
MB3	0	3	2	10	0	61.67	25	25
MB6	0	3	5	7	0	56.67	25	25
MB11	0	0	3	11	1	71.67	25	23.33
MB15	0	0	1	12	2	76.67	25	21.67
Overall acceptability								
Control	0	0	0	14	1	76.67	25	23.33
MB3	0	3	2	10	0	61.67	25	25
MB6	0	1	6	7	1	63.33	25	23.33
MB11	0	2	1	12	0	66.67	25	25
MB15	0	0	0	13	2	78.33	25	21.67
Taste								
Control	0	1	1	12	1	71.67	25	23.33
MB3	0	2	3	10	0	63.33	25	25
MB6	0	1	4	10	0	65	25	25
MB11	0	0	0	13	2	78.33	25	21.67
MB15	0	0	0	14	1	76.67	25	23.33

Table 1 - Judges' preferences and triplets associated with the sensory scores for the quality attributes of bar samples

Quality attributes	Not important	Somewhat important	Important	Highly important	Extremely important	Triplets for sensory scores			Triplets for relative weights		
Colour	1	3	9	2	0	45	23.33	25	0.1304	0.0676	0.0725
Flavour	0	2	3	8	2	66.67	25	21.67	0.1932	0.0725	0.0628
Stickiness	0	0	5	7	3	71.67	25	20	0.2077	0.0725	0.0580
Overall acceptability	0	0	4	5	6	78.33	25	15	0.22705	0.0725	0.0435
Taste	0	0	2	6	7	83.33	25	13.33	0.2416	0.0725	0.0387

Table 2 - Judges' preferences and triplets for bar quality attributes

and MB15) and a control bar prepared using only guava pulp and sugar. Sensorial data and triplets related to the sensory scores presented in Table 1, were used to calculate sensory score triplets using Eq. 1. In the present study, several sensory scores (e.g., 'not at all important', 'somewhat important', etc.) were considered for the quality attributes in general, while the triplets related to the sensory scores of quality attributes (colour, flavour, stickiness, overall acceptability and taste) of bar samples in general were also determined in the same way as the sensory scores for mahua bar samples (Table 1). Table 2 shows the sensory scores and their associated triplets responsible for the qualities of mahua bar samples in general and with weighting. Equation 1 was used to estimate the overall sensory scores of each sample. The multiplication pattern of triplets as given by Eq. 3 was used to multiply the related triplet values of the sensorial scores obtained for samples and their corresponding relative weight of quality attributes, that is, triplets for the overall sensory scores of sample 1 (SO1) were calculated as:

SO1 = (76.66 25.00 21.66) × (0.130 0.067 0.072)
+ (73.33 25.00 23.33) × (0.193 0.072 0.062)
+ (78.33 25.00 21.666) × (0.207 0.072 0.057)
+ (76.66 25.00 23.33) × (0.227 0.072 0.043)
+ (71.66 25.00 23.33) × (0.241 0.072 0.038).

B1	0	0	0.1317	0.3242	0.5168	0.7094	0.902	1	0.8874	0.6582
B2	0	0.0995	0.3086	0.5178	0.7269	0.9360	1	0.8363	0.6003	0.3644
B3	0	0.1067	0.3187	0.5307	0.7428	0.9548	1	0.8110	0.5707	0.3304
B4	0	0	0.1719	0.3694	0.5670	0.7645	0.9620	1	0.8130	0.5814
B5	0	0	0.0901	0.2788	0.4674	0.6561	0.8448	1	0.9586	0.7251

Table 3 - Overall membership function values of bar samples

Similarly, the triplets related to overall sensory scores for samples MB3 (SO2), MB6 (SO3), MB11 (SO4) and MB15 (SO5) were also determined and are presented below:

SO1 = 75.088 51.924 43.623
SO2 = 63.059 47.818 42.383
SO3 =62.133 47.165 41.618
SO4 = 71.924 50.628 43.180
SO5 =78.228 53.003 42.826.

Scale factor	Control	MB3	MB6	MB11	MB15
Not satisfactory, F1	0	0.0125	0.0135	0	0
Fair, F2	0.0748	0.1680	0.1749	0.0892	0.0589
Satisfactory, F3	0.3213	0.4703	0.4835	0.3515	0.2875
Good, F4	**0.6035**	**0.6845**	**0.6915**	0.6281	0.5740
Very good, F5	0.6793	0.5337	0.5182	**0.6468**	**0.7047**
Excellent, F6	0.2806	0.1674	0.1559	0.2472	0.3094
Ranking	II	V	IV	III	I

Table 4 - Similarity values of the mahua bar samples and their ranking (the highest value in a column is shown in bold)

Scale factor	Colour	Flavour	Stickiness	Overall acceptability	Taste
Not important	0	0	0	0	0
Somewhat important	0.3153	0	0	0	0
Necessary	**0.9092**	0.2	0.0667	0	0
Important	0.6254	**0.8492**	0.6267	0.3067	0.08
Highly important	0.0736	0.6923	**0.7967**	**0.8533**	0.66
Extremely important	0	0.0850	0.1879	0.3489	**0.7092**
Ranking	V	IV	III	II	I

Table 5 - Similarity values and ranking of quality attributes of the mahua bars (the highest value in a column is shown in bold)

OMFs of sensory scores on a standard fuzzy scale

Six-point sensory scales ('not satisfactory/not at all necessary', etc.) called 'standard fuzzy scales' and denoted F1, F2, etc., were used to determine sensory scores. The membership function values for the standard fuzzy scale are shown in Eq. 4. Equation 5 was used to calculate the values of the OMF of the sensory scores of the samples on a standard fuzzy scale, for example, the triplets for the overall sensory scores of sample 1 (SO1) were calculated as (75.088 51.924 43.623), that is, a=75.088, b=51.924 and c=43.623. Using the same equation with these values, 10 values of B_x for 0<x<10, 10<x<20, 20<x<30,…,90<x<100 comes out as B1=(0 0 0.137 0.3242 0.5168 0.7094 0.9020 1.000 0.8874 0.6582). The OMFs of the remaining four samples of SO2 (B2), SO3 (B3), SO4 (B4) and SO5 (B5) were also determined and are given in Table 3.

The similarity values of bar samples were calculated using the values of membership functions (F's) of the standard fuzzy scale and the OMF (B's) values of sensory scores. Equation 6 was used to calculate similarity values. For instance, for sample 1 whose OMF on the standard fuzzy scale is B1 (Table 3), in order to determine the similarity value under the category 'not at all important (F1)', $F1\times B1^T$, $F1\times F1^T$ and $B1\times B1^T$ were calculated by applying the rules of matrix multiplication. The maximum value among $F1\times F1^T$ and $B1\times B1^T$ was taken as the denominator, the value of $F1\times B1^T$ was taken as the numerator of Eq. 6, and the similarity value under F1 (not satisfactory) is found to be 0.00. Likewise, the similarity values in the other categories of F2 (fair), F3 (satisfactory), F4 (good), F5 (very good) and F6 (excellent) were obtained for sample 1. A bar sample was ranked by combining the highest similarity value with the particular category ('not at all important', 'somewhat important', 'necessary', 'important', 'highly important', 'extremely important') in which the largest similarity value belongs.

The similarity values for all four samples and the control sample under different scale factors are presented in Table 4. It can be seen from this table that for sample MB15, the highest similarity value lies in the category 'very good', that is, 0.7047, followed by the control sample with similarity value 0.6793 and sample MB11 (0.6468) in the same category. For samples MB6 and MB3, highest similarity values (0.6915) and (0.6845) were obtained under the category 'good'. Samples were ranked after the maximum similarity values of all samples were compared, giving the order sample MB15 > control sample > sample MB11 > sample MB6 > sample MB3, where samples MB15, MB3, MB11 and MB6 were prepared using response surface design, and the control bar contained sugar and guava pulp. Thus, results indicate that bars optimized using RSM are preferred by fuzzy logic, and replacement of sugar with mahua flower juice is acceptable by fuzzy logic sensory analysis.

Quality ranking of bars in general

Different bar samples were ranked by estimating the similarity values of the quality attributes in general for different scale factors. In order to calculate the similarity values, Eq. 4 was used to obtain the membership function values of F1, F2, F3, F4, F5 and F6. The OMFs (B's) for the sensory scores of the quality factors were also determined using the above method. The requisite values in Eq. 6 were obtained by using the OMF values for colour (B1), flavour (B2), stickiness (B3), overall acceptability (B4) and taste (B5), and the values of F1, F2, F3, F4, F5 and F6.

Table 5 shows similarity values for all quality attributes of the bars. A comparison of values revealed that the highest similarity value for taste (0.7092) was obtained in the 'extremely important' category followed by overall acceptability (0.8533) and stickiness (0.7967), respectively, which are in the 'highly important category', and are considered very important for bars in general. This is followed by flavour (0.8492) in the 'important' category and then colour (0.9092) in the 'necessary' category. Based on their quality attributes in general, the attributes contributing to liking mahua bar samples were in the order taste > overall acceptability > stickiness > flavour > colour. Colour and appearance have previously been reported to be the least important quality attributes in other food products [28–30], which emphasizes the importance of this sort of study, where the conclusion cannot be drawn by mere observation.

Conclusion

Modelling sensory evaluation data using fuzzy logic showed that all samples are satisfactory or above, with sample MB15 being the best and likely to be highly acceptable in the market. Sample MB15 was followed in the ranking by the control bar, MB11, MB6 and MB5.The important quality attributes for a mahua bar sample are in the order taste > overall acceptability > stickiness > flavour > colour. Finally, the present work indicates that mahua flowers can be used as a natural, renewable, organic source of liquid sweetener. Sucrose in fruit bar products can be successfully replaced with mahua juice, resulting in a reduction in calories. The information obtained in this study may be helpful in the formulation of other mahua products. Finally, we conclude that all the sensory factors are important as their categorization ranges from necessary to extremely important.

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Human and animal rights

This article does not contain any studies with human or animal subjects performed by the any of the authors.

Conflict of interest statement

All authors declare that they have no conflict of interest.

Informed consent statement

This article does not contain any studies with human subjects.

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