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Sensory Studies of Safflower Seed Milkshake Analogue using Fuzzy Logic

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ABSTRACT

The fuzzy logic technique was used to evaluate the acceptability of the safflower seed milkshake analogue with the conventional bovine milkshake. The sensory evaluation of four different milkshake formulations *viz.,* T_1 = Bovine milk (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%), T_2 = Safflower seed extract (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%), T_3 = Bovine milk (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%), T_4 = Safflower seed extract (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%) was conducted. The sensory panel was comprised of semi-trained, individuals of 18-45 years age. Study found T_4 sample as more acceptable and taste as the most salient sensory parameter followed by mouth feel, flavour and colour in determining the acceptability of the milkshake.The experiment evident the potential of safflower seed to use as an ingredient in the production of milkshake analogues. This milkshake analogue prepared from safflower seed was acceptable and on par with a bovine milkshake. The industry can use safflower seed extracts like soya bean, peanut, almond, cashew and oat extracts to provide a variety of beverages. Consumer's demand for vegan, lactose-free or novel drinks could be met by this novel milkshake analogue from safflower seed.

Keywords : Milkshake, Plant based milk analogue, Safflower seed, Sensory evaluation, Fuzzy logic

MILKSHAKE is a beverage prepared by blending milk, flavourings, fruit syrup, whole fruit pulp, sweeteners, and ice cream. The globe news wire released a report on the Global Packaged Milkshake Industry stating the growth of milkshake sales at a CAGR of 5.9 per cent from 2020-27 (Report Linker 2021). The milkshake market is driven by a shift in consumer preferences from carbonated drinks to healthy and nutritious drinks. The product development in the beverage sector has changed from standard sugary formulations to functional beverages with added novel ingredients and the removal of undesirable components with satisfying tastes and prices (Tireki, 2021). Recent market research concerns about functional and newer beverage development indicate a faster growth phase. The trends may be due to the growing population, changing dietary patterns and increased consumer knowledge. (Chughtai *et al.,* 2022). Bovine milk allergies, lactose intolerance, calorie concerns, hypercholesterolemia incidence and the desire for vegetarianism seek consumers for bovine milk substitutes. Plant-based alternatives to bovine milk are favourable among developing countries due to their lesser cost. The increasing number of plant-based dairy analogues offer numerous options in the food and beverage industry for similar taste, flavour and functionality on par with conventional bovine milk. Dairy Alternatives Market Overview (2022) reported that the sales of dairy alternatives in the global market are estimated to increase at the rate of 14.7 per cent from 2022-32.

The plant-based dairy analogues have been reported to have an unacceptable beany flavour and this can be masked by the incorporation of fruits/spices. Fruits are a good source of bioactive components and the most suitable choice to incorporate into beverages. The Food Safety and Standards Authority of India (2011) defines a thermally processed beverage as an unfermented but fermentable product which is prepared from juice or pulp/puree or concentrated juice or pulp of sound mature fruit. The substances that may be added to fruit juice or pulp are water, peel oil, fruit essences or flavours, salt, sugar, inverted sugar, liquid glucose, milk and other ingredients appropriate to the product and processed by heat, in an appropriate manner, before or after being sealed in a container, to prevent spoilage.

The consumer acceptance or preference of any food significantly depends upon the sensory impressions it creates in one's mind. The sensory attributes like appearance, colour, flavour, taste, mouth feel and consistency were checked by vision, olfactory, and gustatory in milkshake. The sensory panel may comprise trained, semi-trained or untrained individuals to express their results with more subjectivity, ambiguity and vagueness (Martinez, 2007). Human evaluation of sensory attributes is inaccurate, imprecise and uncertain repeatability (Das, 2005 and Routray, W. and Mishra, H. N., 2012). Fuzzy logic is a statistical tool for concluding ambiguous and vague data. The Fuzzy modelling uses linguistic variables (e.g., not satisfactory, good, excellent) to develop the relationship between independent (*e.g.,* colour, flavour, taste, mouth-feel, convenience) and dependent (*e.g.,* acceptance, rejection, ranking, strong and weak attributes of food) variables (Das, 2005). The fuzzy techniques are helpful in ranking samples based on specific quality characteristics & quality attributes with clarity over the acceptance of the product and compare the usefulness of the sensory parameters (Kumar *et al.,* 2021).

Safflower (*Carthamus tinctorius* L.) is an annual oilseed crop belonging to the Asteraceae family. It is a xerophilous species native to Asia and the Mediterranean basin and grown in arid and semi-arid regions. It is a minor, underutilized oilseed crop. The safflower seeds contain 38 g of fat, 17.6 g of protein, 1.3 g of mono and disaccharides, 35.8 g of dietary fiber, 7.1 g of minerals *viz*., 687 mg of potassium, 78.2 mg of calcium, 353 mg of magnesium, 644 mg of phosphorus, 5 mg of iron, 1 mg of selenium & the total proportion of essential amino acids in safflower seeds as 15 - 22 per cent of protein content and 74.4 per cent biological value (Kutsenkova *et al*., 2020). The nutritional value of safflower oil is, in fact, like that of olive oil and for this reason, the species has gained importance in recent years as a result of human consumption in arid and semi-arid regions (Bella *et al*., 2019). Safflower seed extracts may be useful for lactose intolerant people and infants allergic to bovine milk as these seeds are rich in their chemical composition.

Manilkara zapota, Sapodilla also known as sapota belongs to the Sapotaceae family. These are brown-coloured ranging from 5-10 cm diameter. India is a leading producer of fruit. Sapodilla fruits are a rich source of nutrients (sugars, ascorbic acids, protein, amino acids), minerals (potassium, calcium, and iron) and comprise bioactive compounds (ellagitannins, gallotannins, phenolic acids and flavonoids (anthocyanins and flavanols)). Punia *et al*., (2022) suggested that the nutritional profile of sapodilla fruit makes it a potential source of nutraceutical compounds. Banana fruit is one of the important staple foods in the world across different ethnicities and has been an extensively studied fruit for edible purposes. The pulp of banana fruit is rich in bioactive compounds like dietary fibre, low glycaemic carbohydrates, natural sugars, vitamins, minerals and antioxidants. Suriyamoorthy *et al*., (2022) reported that, these beneficial compounds are responsible for the proper functioning of the immune system and enhance the prevention of various diseases and metabolic disorders like cancer, diabetes and heart diseases. Hence, the current study was conducted to evaluate the sensory acceptance of fruit beverages from safflower seed extract in comparison to fruit beverage from bovine milk using fuzzy logic.

Material and Methods

Preparation of Safflower Seed Extract

The safflower seed extract was prepared as explained by Kashid *et al*., (2007). The cleaned, washed, de-husked safflower seeds were soaked in 0.05 per cent NaCl solution (1:5 Safflower seeds : 0.05 per cent NaCl Solution) for 10 hours. Safflower seeds were drained, washed using potable water and further soaked in boiling water for 10 min. Twice-soaked safflower seeds were ground by adding water (1:2 Safflower Seed : Water ratio) and filtered through a muslin cloth. The filtrate obtained was used in the preparation of safflower seed extract beverage.

Preparation of Fruit Pulp

Fruits *viz*., sapota and banana were washed, peeled, & ground in a mixer separately and filtered using a muslin cloth. The prepared sapota and banana pulp were packed separately in PET jars and stored in a refrigerator at - 4 °C until further use.

Preparation of Safflower Milkshake Analogue and Bovine Milkshake

The safflower milkshake analogue and bovine milkshake were prepared with 60 per cent safflower seed extract/ bovine milk as base and 30 per cent fruit pulp, 10 per cent sugar and 0.1 per cent of cardamom powder were added and mixed uniformly (Ubale *et al*., 2014). The experiment was conducted using following formulations *viz*.,

T_1 = Bovine milk (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

T_2 = Safflower seed extract (60%) + Banana pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

T_3 = Bovine milk (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

T_4 = Safflower seed extract (60%) + Sapota pulp (30%) + Sugar (10%) + Cardamom powder (0.1%)

The ingredients according to the formulation were mixed well and homogenized. The prepared milkshake analogue and milkshake were filled in a presterilized 200 ml glass bottle and pasteurized in boiling water for 20 min, further bottles were cooled in a water bath and stored at room temperature.

Sensory Evaluation of Safflower Milkshake Analogue and Bovine Milkshake using Fuzzy Logic

A panel of eleven judges who are non-beetle leaf chewers and non-smokers were selected in the age group between 21 and 40 years. The quality attributes colour, flavour, taste and mouthfeel of the milkshake sample were selected for the sensory evaluation. The judges were detailed about the quality attributes, score card (as shown in fig. 1) and method of scoring for the sensory evaluation. They were instructed to judge the samples quickly but not in hurry and to take two short sniffs of the samples before 'tasting' the sample and give the score for the 'Flavour and colour' first on the score card and rinse their mouth with water between tasting the consecutive samples (Ranganna, 1987). The ratings *viz.,* Excellent, Good, Medium, Fair and Not satisfactory were assigned as fuzzy scale factors and the judges were instructed to give a tick mark (✓) in the respective fuzzy, the scale factor for each of the quality attributes of the sample after evaluating the samples.

Sensory quality attributes of milkshake samples	Sensory scale factors				
	Not satisfactory	Fair	Medium	Good	Excellent
Color					
T1					
T2					
T3					
T4					
Flavor					
T1					
T2					
T3					
T4					
Taste					
T1					
T2					
T3					
T4					
Mouthfeel					
T1					
T2					
T3					
T4					
Quality attributes of milkshakes in general	Sensory scale factors				
	Not at all important	Somewhat important	Important	Highly important	Extremely important
Color					
Flavor					
Taste					
Mouthfeel					

Fig. 1: Fuzzy sensory score card (Das, 2005)

The milkshake samples were evaluated for their sensory attributes using the Fuzzy logic method referred to (Das, 2005; Jaya and Das, 2003; Routray and Mishra, 2012; and Kumar *et al.,* 2021). The sensory scores of beverage samples were collected from fuzzy score cards, which were used for the estimation of similarity values for ranking by converting them into triplets. The steps followed were: (1) Estimation of triplets for the sensory score of the milkshake sample; (2) Estimation of triplets for general sensory attributes of the milkshake sample; (3) Estimation of triplets for relative weightage of sensory attributes of milkshake samples; (4) Estimation of triplets for the overall sensory score of milkshake samples; (5) Estimation of values of the overall membership function of sensory scores of milkshake samples using the standard fuzzy scale; (6) Estimation of similarity values of milkshake samples and (7) The ranking of the general sensory attributes of milkshake samples.

Estimation of Triplets for the Sensory Score of the Score of Milkshake Samples

The triplets of sensory attributes, *i.e.,* colour, flavour, taste, and mouth feel of each milkshake sample were calculated using equation 1 with the triplets associated with the sensory scale using equation 1.

$$T_X(SA) = \frac{n_1(0\ 0\ 25)+n_2\ (25\ 25\ 25)+n_3(50\ 25\ 25)+n_4(75\ 25\ 25)+n_5(100\ 25\ 0)}{n_1+n_2+n_3+n_4+n_5} \quad \ldots.(1)$$

Where 'X' represents the treatment number, SA represents the sensory attribute of the treatment, n_1, n_2, n_3, n_4 and n_5 represent the sensory score associated with sensory scale factors, not satisfactory, fair, medium, good and excellent respectively of that sample.

Estimation of Triplets for General Sensory Attributes of Milkshake Samples

The triplets of the general sensory attributes colour, flavour, taste and mouthfeel of the milkshake sample were calculated using equation 2:

$$Q_{SA} = \frac{n_1(0\ 0\ 25)+n_2\ (25\ 25\ 25)+n_3(50\ 25\ 25)+n_4(75\ 25\ 25)+n_5(100\ 25\ 0)}{n_1+n_2+n_3+n_4+n_5} \quad \ldots.(2)$$

Where SA represents the sensory attribute of the milkshake sample and n_1, n_2, n_3, n_4 and n_5 represent the sensory score associated with sensory scale factors of the sensory attribute.

Estimation of Triplets for Relative Weightage of Sensory Attributes of Milkshake Samples

The triplets of the relative weightage of sensory attributes for each sample were determined using equation 3.

$$Q\ (SA)_{Rel} = \frac{Q_{SA}}{Q_{SUM}} \quad \ldots\ldots.(3)$$

Where SA represents the sensory attribute, Q_{SA} represents the triplets of the general sensory attribute of the milkshake sample; Q_{SUM} represents the sum of all first digits of the triplets of each sensory attribute of the milkshake sample.

Estimation of Triplets for the Overall Sensory Score of Milkshake Samples

The sensory scores of the milkshake samples are represented in the form of a triplet for each sensory attribute and these triplets of each sensory attribute are to be compiled to form a single triplet which will represent the overall sensory score of the milkshake sample. The overall sensory score of the milkshake sample in the form of a triplet is calculated using equation 4.

$$SO_X = T_X(C) \times Q(C)_{Rel} + T_X(F) \times Q(F)_{Rel} + T_X(T) \times Q(T)_{Rel} + T_X(MF) \times Q(MF)_{Rel} \quad \ldots\ldots.(4)$$

Where SO represents the overall sensory score of the milkshake sample, X represents the sample number, $T_X(C)$, $T_X(F)$, $T_X(T)$ and $T_X(MF)$ represents the triplet of sensory attributes 'Colour, Flavour, Taste and Mouthfeel' of that sample respectively and $Q(C)_{Rel,}$ $Q(F)_{Rel,}$ $Q(T)_{Rel,}$ and $Q(MF)_{Rel}$ represents the triplets of general relative weightage score of sensory attributes 'Colour, Flavour, Taste and Mouthfeel' respectively.

The multiplication of triplets of sensory attributes with triplets of the general relative weightage score of the sensory attribute was performed using equation 5.

$$(a, b, c) \times (d, e, f) = [(a \times d), (a \times e) + (d \times b)], [(a \times f) + (d \times c)] \quad \text{.....(5)}$$

Where a, b & c represents the triplets of sensory attributes and d, e & f represents the triplets of the general relative weightage score of the sensory attribute of sample.

Estimation of Values of Overall Membership Function of Sensory Scores of Milkshake Samples on the Standard Fuzzy Scale

The standard fuzzy scale for a 6-point sensory scale in a triangular distribution pattern is shown in fig. 2. In the fig. 2, the sensory scales *viz.,* Not satisfactory/ Not at all necessary, Fair/Somewhat necessary, Satisfactory/Necessary, Good/Important, Very good/ Essential and Excellent/Essential are marked as Fl, F2, F3, F4, F5 and F6 (Das, 2005). The value of the fuzzy membership function of each sensory scale is between a minimum and maximum value of 0 and 1, respectively (Sarkar *et al*., 2020). The values of the membership function of the sensory scale are defined by a set of 10 numbers as explained by Das (2005). The values of the membership function of the standard fuzzy scale are:

Fl = (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)

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)

The values of membership function (B_X) of the overall sensory score of milkshake samples were calculated in association with the standard fuzzy scale as given in fig. 3. For a given value of Y, B_X can be calculated using the following equation

$$B_X = \frac{Y - (a-b)}{b} \quad \text{if } (a-b) < Y < a$$

$$= \frac{(a+c)\, Y}{c} \quad \text{if } a < Y < (a+c)$$

$$= 0 \text{ for all other values of Y} \quad \text{..... (6)}$$

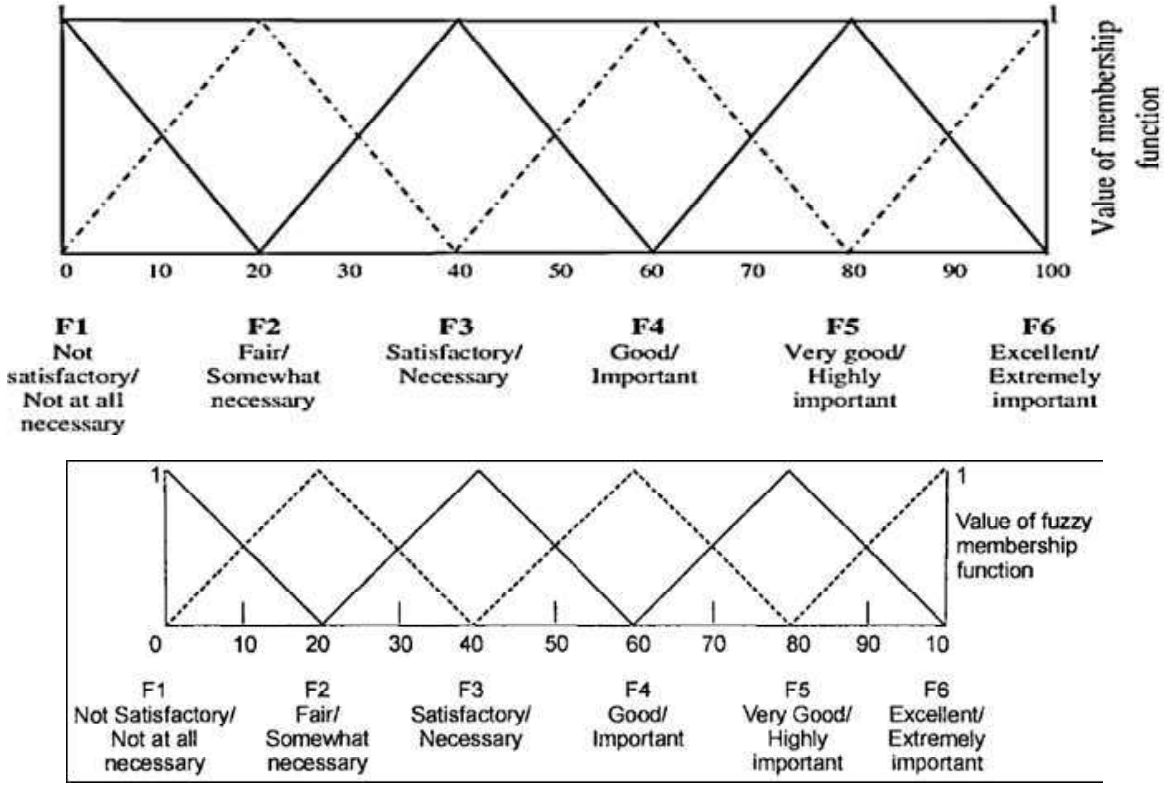

Fig. 2: Standard Fuzzy Scale (Das, 2005)

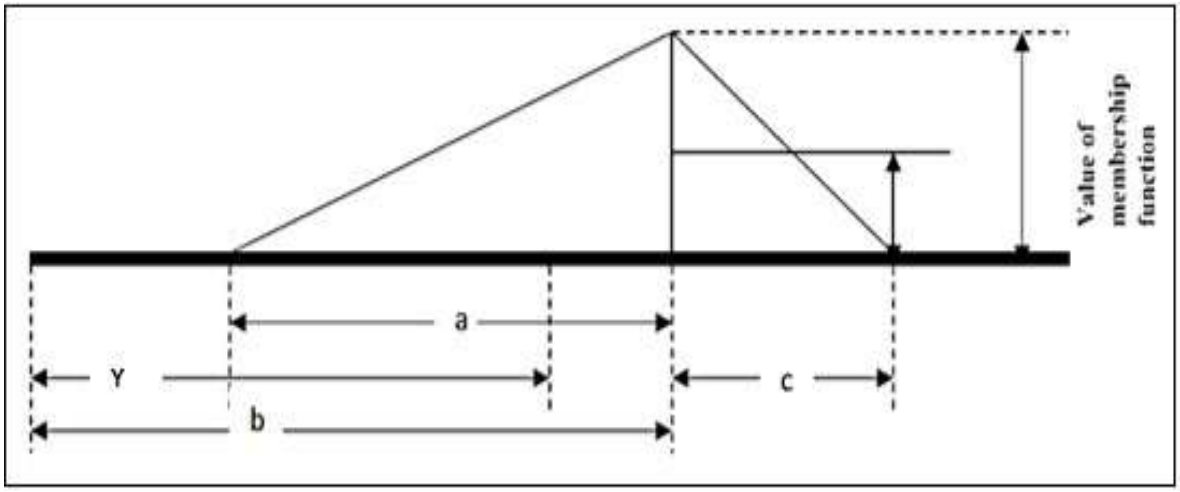

Fig. 3 : Representation of the triplet (a b c) and its membership function (Das, 2005)

Where,

B_X = Value of membership function of 'X' sample

Y = 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100

(a, b, c) = triplet values of the overall sensory score of samples

Estimation of Similarity Values of Milkshake Samples

To estimate the similarity values of milkshake samples, first the value of ($F_Z \times F_Z^1$), ($F_Z \times B_X^1$) and ($B_X \times B_X^1$) have to be calculated. The F_Z represents a matrix of 10 rows and 1 column with Z being the number of standard fuzzy scales. Similarly, B_X represents a matrix of 1 row and 10 columns with X being the number of samples. The values F_Z^1 and B_X^1 represent the transpose of matrices F_Z and B_X. The matrix multiplication was carried out as shown in fig. 4.

The similarity values (S_m) of the milkshake sample were obtained by comparing the values of the membership function of the milkshake sample (B_X) and the values of the standard fuzzy scale (F_1 to F_6). These values were calculated using the following equation :

$$S_m (F_Z B_X) = \frac{(F_Z \times B_X^1)}{\text{Maximum of } (F_Z^1 \times F_Z^1) \text{ and } (B_X^1 \times B_X^1)} \quad \ldots\ldots(7)$$

$$\begin{pmatrix} R_1 & R_2 & R_3 & R_4 & R_5 & R_6 & R_7 & R_8 & R_9 & R_{10} \end{pmatrix} X \begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \\ C_{10} \end{pmatrix} = \begin{pmatrix} (R_1 X C_1) + (R_2 X C_2) + (R_3 X C_3) + \\ (R_4 X C_4) + (R_5 X C_5) + (R_6 X C_6) + \\ (R_7 X C_7) + (R_8 X C_8) + (R_9 X C_9) + \\ (R_{10} X C_{10}) \end{pmatrix}$$

Fig. 4: Matrix multiplication

The similarity values for sample 1 Sm (F_1 B_1), Sm (F_2 B_1), Sm (F_3 B_1), Sm (F_4 B_1), Sm (F_5 B_1) and Sm (F_6 B_1) were calculated using equation 7. Similarly, the similarity values of all samples were calculated. Referring to the similarity values, the milkshake samples were ranked by locating the sensory factor with the highest similarity value. The milkshake sample that exhibited the highest similarity value on the superior sensory scale was ranked highest.

The Ranking of the General Sensory Attributes of Milkshake Samples

The ranking of the general sensory attributes of the milkshake sample was done by calculating the similarity values of the general sensory attributes of the milkshake sample. These values were calculated similarly with the similarity values of the milkshake sample using equation 8.

$$S_m (F_Z Q_{SA}) = \frac{(F_Z \times B^1_{SA})}{\text{Maximum of } (F_Z \times F^1_Z) \text{ and } (B_{SA} \times B^1_{SA})} \quad \ldots..(8)$$

Where B_{SA} is a matrix of 1 row and 10 columns of the quality attributes and B^1_{SA} is the transpose of the matrix. The sensory attribute with the highest value on the superior scale was ranked highest.

Results and Discussion

The safflower milkshake analogue and bovine milkshake were prepared as explained and given for

Table 1

Sensory score for sensory attributes and triplet values of milkshake samples

Sensory attribute	Not satisfactory	Fair	Medium	Good	Excellent	Triplets for the sensory score			
							a	b	c
Sample T_1									
Colour	0	0	0	5	6	T_1C	88.64	25.00	11.36
Flavour	0	0	1	6	4	T_1F	81.82	25.00	15.91
Taste	0	0	1	5	5	T_1T	84.09	25.00	13.64
Mouthfeel	0	0	0	6	5	T_1M	86.36	25.00	13.64
Sample T_2									
Colour	0	0	0	3	8	T_2C	93.18	25.00	6.82
Flavour	0	0	1	5	5	T_2F	84.09	25.00	13.64
Taste	0	0	0	3	8	T_2T	93.18	25.00	6.82
Mouthfeel	0	0	0	5	6	T_2M	88.64	25.00	11.36
Sample T_3									
Colour	0	0	1	8	2	T_3C	77.27	25.00	20.45
Flavour	0	0	1	5	5	T_3F	84.09	25.00	13.64
Taste	0	0	0	6	5	T_3T	86.36	25.00	13.64
Mouthfeel	0	0	0	9	2	T_3MF	79.55	25.00	20.45
Sample T_4									
Colour	0	0	0	6	5	T_4C	86.36	25.00	13.64
Flavour	0	0	0	3	8	T_4F	93.18	25.00	6.82
Taste	0	0	0	3	8	T_4T	93.18	25.00	6.82
Mouthfeel	0	0	0	6	5	T_4M	86.36	25.00	13.64

T_1: Bovine Milk (60%) + Banana Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_2: Safflower seed extract (60%) + Banana Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_3: Bovine Milk (60%) + Sapota Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_4: Safflower seed extract (60%) + Sapota Pulp (30%) + Sugar (10%) + Cardamom Powder (0.1%); T_1C, T_1F, T_1T, and T_1M represent triplets associated with sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_1; T_2C, T_2F, T_2T, and T_2M represents triplets associated with sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_2; T_3C, T_3F, T_3T, and T_3M represents triplets associated with sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_3, and T_4C, T_4F, T_4T, and T_4M represents triplets associated sensory attribute Colour, Flavour, Taste, and Mouthfeel respectively for sample T_4

TABLE 2

Sensory score for general sensory attributes and triplet values of general sensory attributes and relative weightage of sensory attributes of milkshake samples

Quality attributes in general	NI	SI	I	HI	EI	Triplets for the general sensory attributes				Triplets for relative weightage of sensory attributes			
							a	b	c		a	b	c
Colour	0	0	3	4	4	Q_C	77.27	25.00	15.91	QC_{Rel}	0.2267	0.0733	0.0467
Flavour	0	0	1	5	5	Q_F	84.09	25.00	13.64	QF_{Rel}	0.2467	0.0733	0.0400
Taste	0	0	0	1	10	Q_T	97.73	25.00	2.27	QT_{Rel}	0.2867	0.0733	0.0067
Mouthfeel	0	0	2	4	5	Q_M	81.82	25.00	13.64	QM_{Rel}	0.2400	0.0733	0.0400

NI: Not at all important, SI: Somewhat important, I: Important, HI: Highly important, EI: Extremely important, Q_C, Q_F, Q_T, and Q_M represent the triplet for the sensory score of Colour, Flavour, Taste, and Mouthfeel respectively; QC_{Rel}, QF_{Rel}, QT_{Rel}, and QM_{Rel} represent the triplet for relative weightage of Colour, Flavour, Taste, and Mouthfeel respectively.

sensory evaluation to eleven judges using fuzzy score cards. The score cards after evaluation were collected and the preferences of the judges were summed and tabulated in Table 1 and Table 2 for milkshake samples and general quality attributes of milkshake, respectively.

From Table 1, it can be observed that with respect to the sample T_1 the colour, flavour, taste and mouth feel were preferred as Excellent, Good, Good/Excellent and Good, respectively, by most judges. The highest number of judges preferred the colour and taste of the sample T_2 as excellent. The highest number of judges ranked the colour, flavour, taste and mouthfeel of sample T_3 as Good, Good/Excellent, Good and Good, respectively. The Flavour and taste of sample T_4 were preferred as Excellent whereas the colour and mouthfeel were preferred as Good by the highest number of judges.

The sensory score preferences were used to calculate the triplet values for the milkshake samples and the general quality attributes of the milkshake using equation 1 and tabulated in Table 1 and Table 2, respectively.

The triplets for relative weightage of sensory attributes (QC_{Rel}, QF_{Rel}, QT_{Rel} and QM_{Rel}) were calculated using triplets for the sensory score, in general, using equation 3. Where in Q_{SUM} = 340.91, which is the sum of all first digits of triplets for the general sensory score and tabulated in Table 2.

Triplets for the Overall Sensory Score of Milkshake Samples

The triplets for the overall sensory score of milkshake samples were calculated using the values of triplets for the sensory score of milkshake samples and the triplets of relative weightage of the general sensory attributes of the milkshake sample using equation 4 and referring equation 6.

The triplets for the overall sensory score of the sample T_1 can be calculated as follows :

$$SO_1 = T_1C \times QC_{Rel} + T_1F \times QF_{Rel} + T_1T \times QT_{Rel} + T_1MF \times QMF_{Rel}$$

Triplet a $(88.64 \times 0.2267) + (81.82 \times 0.2467) + (84.09 \times 0.2867) + (86.36 \times 0.2400) = 85.1058$

Triplet b $[(88.64 \times 0.0733) + (25 \times 0.2467)] + [(81.82 \times 0.0733) + (25 \times 0.2467)] + [(84.09 \times 0.0733) + (25 \times 0.2867)] + [(86.36 \times 0.0733) + (25 \times 0.2400)] = 49.9999$

Triplet c $[(88.64 \times 0.0467) + (11.36 \times 0.2267)] + [(81.82 \times 0.0400) + (15.91 \times 0.2467)] + [(84.09 \times 0.0067) + (13.64 \times 0.2867)] + [(86.36 \times 0.0400) + (13.64 \times 0.2400)] = 25.1060$

Similarly, the triplets for the overall sensory scores for the remaining milkshake samples were calculated and tabulated in Table 3.

TABLE 3

Triplets for the overall sensory score of milkshake samples

Milkshake samples	A	b	c
SO_1	85.1058	49.9999	25.1060
SO_2	89.8482	51.3332	21.4696
SO_3	82.1058	48.9999	27.5454
SO_4	89.9998	51.3332	21.8333

SO_1, SO_2, SO_3 & SO_4 represent the triplet of the overall sensory score of milkshake sample, T_1, T_2, T_3, and T_4, respectively

Overall Membership Function for Sensory Scores of the Milkshake Sample on the Standard Fuzzy Scale

The values of the overall membership function B_1, B_2, B_3 and B_4 for milkshake samples on the standard fuzzy scale were calculated using equation 6 for a value of X varying from 0 to 100. The overall membership function for the T_1 beverage sample using the triplet values of overall sensory score SO_1 can be calculated as shown in Table 4.

From the above table, it can be observed that the value of B_1 satisfies the first condition of Equation 6 when the value of X is 40, 50, 60, 70 and 80, the second condition when the value of X is 90 and 100. Furthermore, the value of B_1 is zero when the value of X is 0, 10, 20 and 30 as per the third condition of equation 6. It can also be noted that when the value of X is $80 < X < 90$, the value of B_1 is 1, thus the values of the overall membership function B_1 for sample T_1 are as follows

$B_1 =$ 0.0000, 0.0000, 0.0000, 0.0000, 0.0979, 0.2979, 0.4979, 0.6979, 0.8979, 1.0000, 0.8051

Similarly, the values of B_2, B_3, and B_4 were calculated and tabulated in Table 5 in the form of matrix.

The similarity values of the milkshake samples were calculated using the values of the overall member ship function (B_1 to B_4) and the values of the standard fuzzy scale (F_1 to F_6) were considered as a matrix of order (1 × 10) and (10 × 1) respectively and the transpose of these matrices were formed as B_1^1 to B_4^1 and F_1^1 to F_6^1. The matrix multiplication was carried out as shown in fig. 4 and the values of ($F_Z \times F_Z^1$), ($F_Z \times B_X^1$) and ($B_X \times B_X^1$) were calculated as given in Table 5.

TABLE 4

Calculation for overall membership function of T_1 beverage sample

a	b	C	a-b	Y	a	(Y-(a-b)) /b	a	Y	a+c	((a+c)-Y) /c
85.1058	49.9999	25.1060	35.1060	0	85.1058	-0.7021	85.1058	0	110.2118	4.3899
85.1058	49.9999	25.1060	35.1060	10	85.1058	-0.5021	85.1058	10	110.2118	3.9915
85.1058	49.9999	25.1060	35.1060	20	85.1058	-0.3021	85.1058	20	110.2118	3.5932
85.1058	49.9999	25.1060	35.1060	30	85.1058	-0.1021	85.1058	30	110.2118	3.1949
85.1058	49.9999	25.1060	35.1060	40	85.1058	0.0979	85.1058	40	110.2118	2.7966
85.1058	49.9999	25.1060	35.1060	50	85.1058	0.2979	85.1058	50	110.2118	2.3983
85.1058	49.9999	25.1060	35.1060	60	85.1058	0.4979	85.1058	60	110.2118	2.0000
85.1058	49.9999	25.1060	35.1060	70	85.1058	0.6979	85.1058	70	110.2118	1.6017
85.1058	49.9999	25.1060	35.1060	80	85.1058	0.8979	85.1058	80	110.2118	1.2034
85.1058	49.9999	25.1060	35.1060	90	85.1058	1.0979	85.1058	90	110.2118	0.8051
85.1058	49.9999	25.1060	35.1060	100	85.1058	1.2979	85.1058	100	110.2118	0.4067

TABLE 5

The values of the overall membership function and the values of the standard fuzzy scale in the form of matrix

The values of the overall membership function and the values of the standard fuzzy scale in form of Matrix										
B_1	0.0000	0.0000	0.0000	0.0979	0.2979	0.4979	0.6979	0.8979	1.0000	0.8051
B_2	0.0000	0.0000	0.0000	0.0289	0.2237	0.4185	0.6133	0.8082	1.0000	0.9929
B_3	0.0000	0.0000	0.0000	0.1407	0.3448	0.5489	0.7529	0.9570	1.0000	0.7134
B_4	0.0000	0.0000	0.0000	0.0260	0.2208	0.4156	0.6104	0.8052	1.0000	0.5420
F_1	1	0.5	0	0	0	0	0	0	0	0
F_2	0.5	1	1	0.5	0	0	0	0	0	0
F_3	0	0	0.5	1	1	0.5	0	0	0	0
F_4	0	0	0	0	0.5	1	1	0.5	0	0
F_5	0	0	0	0	0	0	0.5	1	1	0.5
F_6	0	0	0	0	0	0	0	0	0.5	1

Transpose of the Matrix									
B_1^1	B_2^1	B_3^1	B_4^1	F_1^1	F_2^1	F_3^1	F_4^1	F_5^1	F_6^1
0.0000	0.0000	0.0000	0.0000	1	0.5	0	0	0	0
0.0000	0.0000	0.0000	0.0000	0.5	1	0	0	0	0
0.0000	0.0000	0.0000	0.0000	0	1	0.5	0	0	0
0.0979	0.0289	0.1407	0.0260	0	0.5	1	0	0	0
0.2979	0.2237	0.3448	0.2208	0	0	1	0.5	0	0
0.4979	0.4185	0.5489	0.4156	0	0	0.5	1	0	0
0.6979	0.6133	0.7529	0.6104	0	0	0	1	0.5	0
0.8979	0.8082	0.9570	0.8052	0	0	0	0.5	1	0
1.0000	1.0000	1.0000	1.0000	0	0	0	0	1	0.5
0.8051	0.9929	0.7134	0.5420	0	0	0	0	0.5	1

The values of $(F_Z \times F_Z^1)$, $(F_Z \times B_X^1)$, and $(B_X \times B_X^1)$											
$F_1*B_1^1$	0.0000	$F_1*B_2^1$	0.0000	$F_1*B_3^1$	0.0000	$F_1*B_4^1$	0.0000	$F_1*F_1^1$	1.2500	$B_1*B_1^1$	3.2875
$F_2*B_1^1$	0.0489	$F_2*B_2^1$	0.0145	$F_2*B_3^1$	0.0703	$F_2*B_4^1$	0.0130	$F_2*F_2^1$	2.5000	$B_2*B_2^1$	3.2413
$F_3*B_1^1$	0.6447	$F_3*B_2^1$	0.4619	$F_3*B_3^1$	0.7599	$F_3*B_4^1$	0.4546	$F_3*F_3^1$	2.5000	$B_3*B_3^1$	3.4317
$F_4*B_1^1$	1.7936	$F_4*B_2^1$	1.5478	$F_4*B_3^1$	1.9527	$F_4*B_4^1$	1.5390	$F_4*F_4^1$	2.5000	$B_4*B_4^1$	2.5368
$F_5*B_1^1$	2.6493	$F_5*B_2^1$	2.6113	$F_5*B_3^1$	2.6902	$F_5*B_4^1$	2.3814	$F_5*F_5^1$	2.5000		
$F_6*B_1^1$	1.3051	$F_6*B_2^1$	1.4929	$F_6*B_3^1$	1.2134	$F_6*B_4^1$	1.0420	$F_6*F_6^1$	1.2500		

B_1, B_2, B_3 & B_4 represent the triplet of the overall membership function for samples T_1, T_2, T_3, and T_4, respectively; F_1 to F_6 values of the standard fuzzy scale

Using the above values of $(F_Z \times F_Z^1)$, $(F_Z \times B_X^1)$, and $(B_X \times B_X^1)$ the similarity values of milkshake samples with respect to the scale factor were calculated using equation 7.

The similarity values for sample 1 can be calculated as follows :

S_m (F_1 B_1)

Not satisfactory, F1

$$\frac{(F_1 \times B_1^1)}{\text{Maximum of } (F_1 \times F_1^1) \text{ and } (B_1 \times B_1^1)} \quad \frac{0.0000}{3.2875} \quad \textbf{0.0000}$$

S_m (F_2 B_1)

Fair, F2

$$\frac{(F_2 \times B_1^1)}{\text{Maximum of } (F_2 \times F_2^1) \text{ and } (B_1 \times B_1^1)} \quad \frac{0.0489}{3.2875} \quad \textbf{0.0149}$$

S_m (F_3 B_1)

Satisfactory, F3

$$\frac{(F_3 \times B_1^1)}{\text{Maximum of } (F_3 \times F_3^1) \text{ and } (B_1 \times B_1^1)} \quad \frac{0.6447}{3.2875} \quad \textbf{0.1961}$$

S_m (F_4 B_1)

Good, F4

$$\frac{(F_4 \times B_1^1)}{\text{Maximum of } (F_4 \times F_4^1) \text{ and } (B_1 \times B_1^1)} \quad \frac{1.7936}{3.2875} \quad \textbf{0.5456}$$

S_m (F_5 B_1)

Very good, F5

$$\frac{(F_5 \times B_1^1)}{\text{Maximum of } (F_5 \times F_1^1) \text{ and } (B_1 \times B_1^1)} \quad \frac{2.6493}{3.2875} \quad \textbf{0.8059}$$

S_m (F_6 B_1)

Excellent, F6

$$\frac{(F_6 \times B_1^1)}{\text{Maximum of } (F_6 \times F_6^1) \text{ and } (B_1 \times B_1^1)} \quad \frac{1.3051}{3.2875} \quad \textbf{0.3970}$$

Similarly, the similarity values associated with other milkshake samples were calculated and tabulated in Table 6.

TABLE 6

The similarity values of milkshake samples

Scale Factor	Sample T_1	Sample T_2	Sample T_3	Sample T_4
Not satisfactory, F_1	0.0000	0.0000	0.0000	0.0000
Fair, F_2	0.0149	0.0045	0.0205	0.0051
Satisfactory, F_3	0.1961	0.1425	0.2214	0.1792
Medium, F_4	0.5456	0.4775	0.5690	0.6067
Good, F_5	0.8059	0.8056	0.7839	0.9387
Excellent, F_6	0.3970	0.4606	0.3536	0.4107

From Table 6, it can be observed that for sample T_1 the similarity values (Sm) are 0.0000, 0.0149, 0.1961, 0.5456, 0.8059 and 0.3970 with respect to scale factors Not satisfactory, Fair, Satisfactory, Medium, Good and Excellent respectively. Since the similarity value associated with the scale factor 'GOOD' is the highest, the overall quality of the sample T_1 is considered as 'GOOD'. Exercising the same analogy, the overall quality of samples T_2, T_3, and T_4 can be considered 'GOOD'.

As the values of all milkshake samples are associated with the scale factor 'GOOD', the sample with the maximum score should be ranked highest. Thus, the order of ranking for milkshake samples will be :

Sample T_4 (GOOD) > Sample T_1 (GOOD) > Sample T_2 (GOOD) > Sample T_3 (GOOD)

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TABLE 7

The overall membership function for general quality attributes of the milkshake samples

B_C	0.0000	0.0000	0.0000	0.0000	0.0000	0.3091	0.7091	1.0000	0.8286	0.2000
B_F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0364	0.4364	0.8364	1.0000	0.5667
B_T	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2909	0.6909	1.0000
B_M	0.0000	0.0000	0.0000	0.0000	0.0000	0.1273	0.5273	0.9273	1.0000	0.4000

$B_{C,}$ $B_{F,}$ B_T & B_M represents the triplet of the overall membership function for general quality attributes of the milkshake sample

Overall Membership Function for General Sensory Scores of the Milkshake Sample on the Standard Fuzzy Scale

The values of the overall membership function for general sensory attributes of the milkshake sample on the standard fuzzy scale were calculated similarly to the overall membership function of sensory scores of the beverage samples using the triplets of general quality attributes of the beverage sample and the triplets of the standard fuzzy scale referring equation 6 and tabulated in Table 7.

The Similarity Values for General Sensory Attributes of Milkshake Samples

The similarity values for general sensory attributes of milkshake samples were estimated using values of the overall membership function for general sensory attributes of milkshake samples similar to the similarity values of the milkshake samples.

Using the values of ($FZ \times F^1Z$), ($FZ \times B^1X$) and ($BX \times B^1X$) the similarity values of general sensory attributes of the milkshake sample with respect to the scale factor were calculated using equation 7 similarly to that of the similarity values of the beverage samples and tabulated in Table 8.

TABLE 8

The similarity values of general sensory attributes of milkshake samples

Scale Factor	Colour	Flavour	Taste	Mouth-feel
Not at all necessary, F_1	0.0000	0.0000	0.0000	0.0000
Somewhat necessary, F_2	0.0000	0.0000	0.0000	0.0000
Necessary, F_3	0.0618	0.0073	0.0000	0.0255
Important, F_4	0.6073	0.3564	0.0582	0.4473
Highly important, F_5	0.9132	0.9352	0.5927	0.9564
Extremely important, F_6	0.2642	0.4821	0.8614	0.3889

From Table 8, the highest similarity value associated with supreme scale factor can be observed for the sensory attribute 'Taste' associated with the scale factor 'Extremely important' (0.8614), followed by Sensory attributes Mouthfeel, Flavour and Colour which are associated with scale factor Highly important with similarity values 0.9564, 0.9352 and 0.9132 respectively. Thus, the general sensory attributes of the milkshake sample can be ranked in the order as follows.

TASTE (Extremely Important) > MOUTHFEEL (Highly important) > FLAVOUR (Highly Important) > COLOUR (Highly Important)

The current study ranks taste as the most salient sensory aspect compared to mouth feel, flavour and colour in determining the acceptability of the milkshake used in this experiment. Among the two milkshakes and their analogues compared in this experiment employing fuzzy logic, the safflower milkshake analogue with sapota pulp is the most acceptable. The study suggests safflower seed extract as a potential choice over bovine milk for use in the beverage processing industry to fulfil the needs of consumers with lactose intolerance and a vegan mindset.

Declaration of interest : There is no conflict of interest in this study.

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