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Sensory evaluation of microwave assisted ultrasound treated soymilk beverage using fuzzy logic

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ABSTRACT

This study was centered to develop an acceptable quality of soymilk based flavoured beverage based on sensorial characterization. The beverage contains an array of health beneficial compounds such as phytosterols, isoflavones, and flavonoids. These compounds are attributed to prevention of osteoporosis, cancer, heart disease, and reduction of cholesterol. Moreover, this flavoured beverage is essential for vegan consumers and lactose intolerant than normal consumers. The sensory examination of nine soymilk based flavoured beverages (S1, S2, S3, S4, S5, S6, S7, S8, and S9) was done to maximize the acceptability. Lastly, ranking of the different samples according to their sensory qualities and also to rank attributes of general quality. After review of the sensory parameters collected from a jury of 26 jurors, the rating of flavored beverage samples based on soymilk was followed S2 > S9 > S1 > S4 > S8 > S7 > S6 > S5 > S3. The ranking for the attributes of general quality was Taste > Mouthfeel > After Taste > Color > Aroma.

1. Introduction

Plant-based milk alternatives are a growing phenomenon, which can serve as a cheap alternative to poor developing-country, economic community and in areas where cow milk supply is inadequate. One of the most common plant based milk is soymilk together with other plant milks (Jeng et al., 2010). It is an aqueous extract of soybean, was first prepared in China, 2000 years ago. It contains protein (50–65%) and fat (20–30% on dry basis) along with many bioactive compounds such as phytosterol and isoflavones (Jeng et al., 2010). Among vegans, the soymilk has become a potential substitute for dairy milk, with a wide array of health benefits such as reduced cholesterol levels and Protecting against cancer, cardiovascular disease and osteoporosis (Kwok and Niranjan, 1995; Oguntunde and Akintoye 1991; Poliseli-Scopel et al., 2013). The kind of most biologically active compounds present in soymilk is isoflavones such as Genistin. In addition, it is also a potential source of other phytochemicals which helps in reducing the cholesterol. The phytochemical attributed to the reduction of the cholesterol is phytosterols (Sethi et al., 2016). It is a milk analogue with high nutrition profile and health benefits with limited consumer acceptability due to its beany flavor and associated indigestion problem (Poliseli-Scopel et al., 2013). Commercially, soymilk is processed at high temperatures to inactivate enzymes and to reduce the microbial load which leads to loss of nutrients and burnt flavor in the final product. A sound quality milk has several applications in food process industry such as bakery and confections.

The obtained milk analogue could be used for the development of several different food products such as confectioneries, bread, and cake for the lactose intolerant community and consumers (Devi, 2012). The products available are such as the soymilk, Tofu, the yoghurts and various other kinds of fortified yoghurts with formulation of soymilk to increase the acceptability of the products. Initially, the study was conducted over the plain soymilk and correlation was established between the acceptability and physicochemical properties of the milk (Terhaag et al., 2013). In another study the changes in soymilk was studied over the period of

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storage and chemical composition (Achouri et al., 2007). Moreover, there are a number of yoghurts prepared from soymilk either in plain form or flavored and this product is the most attempted to succeed attributing the importance of consuming soymilk (Favaro Trindade et al., 2001). It was characterize using paired directional two-sided comparison test. The responses of this sample analysis influenced to consider mouthfeel as one of the major criteria for doing sensory analysis of the soymilk-based sample since it has less solid content compared to cowmilk based products. In addition, in another study of sensorial characterization of the yoghurt a 10-point scale set was used in order to evaluate the sourness, viscosity, sweetness, and beaniness. The responses of this study suggested to not keep viscosity as one the parameters for the sensorial characterization of the beverage due to insignificant effect and it was close to mouthfeel (Buono et al., 1990). Sensorial characterization of the products are of paramount importance, because ultimately it is the consumer who has to accept the product based upon it color, tase, aroma, mouthfeel, texture, and after taste.

One such statistical toll for sensory analysis is fuzzy logic technique. The implementation of fuzzy techniques helped in ranking of the all samples differently based on specific quality characteristics and quality attributes with clarity over the acceptance of the product and comparative usefulness of the same sensory attributes such as Taste, Mouthfeel, After Taste, Color, Aroma. Consequently, the improvement and further modifications in the formulation of products became so easy and important factors were easily controlled which were important for marketability (Jaya and Das, 2003). There are a number of products which had been analyzed by technique of fuzzy logic previously such as mango beverage and coffee (Lazim and Suriani, 2009; Jaya and Das, 2003). A number of studies had been already done for different non-alcoholic beverages for sensorial characterization using fuzzy logic approach such as drinks made from dahi powder, milk formulated with barberry juice, pulp of mango and litchi juice, probiotic whey beverages with orange powder flavor, and mango drinks (Routray & Mishra, 2012; Tahsiri et al., 2017; Kaushik et al., 2015; Faisal et al., 2017; Jaya & Das, 2003).

In this study, the acceptability of the consumers and target group was analyze using fuzzy logic technique. The substitute to conventional milk was developed by the application of microwave and ultrasonication to counter the problem of beany flavor and problems associated with indigestion (Wang et al., 2008; Kakade et al., 1974). To make the milk more acceptable to the consumers a certain amount of flavor was added to the obtained soya milk as shown in Table 1.

2. Materials and methods

2.1. Soymilk extraction

Soybean (*Glycine* max., cv. JS-9305) was procured from the Indian Institute of Soybean Research, Indore, India. The soybeans were cleaned and stored at 4 °C in polypropylene containers until further processing and extraction of soymilk. Soymilk Extraction was done from split kernels and it was attributed to the rapid soaking of split grains. The sequential extraction was done using first microwave treatment where microwave treatment time was an independent variable, followed by ultrasonication with controlled ultrasonic treatment time and temperature as independent variable for extraction. Split soyabean kernels were soaked in the distilled water keeping the ratio of 1:5 (v/v) for soybean and water in Petri dish for a period of 4 h. Soaked beans were treated with microwave (Model: Intellocook; Make: LG, South Korea) in soaked condition with same water for 1, 2, 3, 4 and 5 min at optimized power level of 900 W according to the previous study (Amponsah & Nayak, 2016). Microwave treated soybean sample was ground in a household grinder (Model: Master Chef 3.0; Make: Bajaj, India) for 2 min at 1200 rpm. Additional water was added to obtain maximum recovery of soymilk until soybean to water ratio equals 1:7 (Khaleque, 1971). The ground sample mix was packed in LDPE and undergone ultrasound treatment in bath type ultrasonicator (Model: UD80-SH-3 l; Make: Takashi, Japan) with a constant frequency of 28 kHz for the exposure time of 30, 60 and 90 min at temperature 40, 50 and 60 °C to optimize the extraction of soymilk with highest percentage of protein (Preece et al., 2017; Amponsah & Nayak, 2016). The soymilk was filtered manually from ultrasonicated samples using a 2-layer of muslin cloth and stored at 4 °C until the beverage was prepared.

Table 1
formulation of the soymilk based flavored beverages for sensory evaluation.

Sl no.	Milk type (volume each sample 1 L)	Flavor (ml)	Sample No.
1.	Milk extracted from treated soybeans	5, 10 and 15	S1, S2, S3
2.	Commercial soymilk from supermarket	5. 10 and 15	S4, S5, S6
3.	Milk extracted from Raw soybeans	5, 10 and 15	S7, S8, S9

2.2. Materials required for preparation of beverage

Every time fresh soymilk was recovered after respective treatment and extraction from soybeans and was considered as the base ingredient needed for the preparation of beverage and standard food grade vanilla flavor (Faisal et al., 2017). The standard quality of soymilk was purchased from the close vicinity of super-market and was used for comparison with prepared one.

2.3. Equipments required

To prepare flavored beverages these are the following Equipments were used such as pH meter, microwave of domestic type, ultrasonicator bath type, low density polyethylene (LDPE) sealing machine, refrigerator, blender, electronic balance, thermometer and refractometer were made available in the laboratory. The physico-chemical properties of milk were tested such as total solid after normal oven drying at 60 °C, for overnight, protein percentage by Kjeldahl Method (K-360, Buchi, Switzerland), fat percentage by Gerber method, viscosity using Ostwald's viscometer, and color changes using CIE-LAB colorimeter (SpectroGuide, BYK, Germany).

2.4. Preparation of soymilk based flavored beverage

To prepare the soymilk-based flavored beverage one liter of fresh soymilk was extracted every time for the sensory. For final recovery and eradication of the any remaining solid and foreign particle, filtration was done with 2 layers of the muslin clothes. After that flavoring was done for each and every sample. Every sample consisted of one liter of the freshly extracted soya milk and certain amount of flavoring according to the combination shown in Table 1. Total nine samples were obtained for the sensory evaluation. Each semi-trained panelist was given appropriate time to judge the sample with utmost precision and difference. The sensory was planned while maintaining the proper hygienic and sound condition for the panelists to focus and analyze with best of their ability.

2.5. Obtaining sensory scores for the sample

A semi-trained panel of 26 members was screened and selected for the sensory evaluation of soymilk based flavored beverages. All the panelists were asked for their interest and willingness to participate in the sensory study on a regular basis. Proper guidelines and training about the product were given to all the panelists before the sensory evaluation. Panelists were punctual and in good health condition throughout the study. Several quality characteristics, terminologies, score sheets and methods of evaluation followed in the study were thoroughly explained to the panelists (Routray & Mishra, 2012). After each testing sample, panelists were instructed to take the puffed rice and then rinse their mouth with water to eliminate any residual effects. After the evaluation of each sample panelists were asked to give their preference by giving a tick (√) mark in the given fuzzy linguistic score sheet. Samples and quality attributes were assessed in this sheet as satisfactory, fair, medium, strong and excellent (Jaya and Das, 2003). In this study Excel 2016 (Microsoft Inc. 2016, United states) was used for all the calculation of sensory evaluation data of soymilk based flavored beverages using a fuzzy logic approach.

2.6. Steps involved in the application of fuzzy logic for analysis

The crucial processes for the examination of sensorial attributes are associated with the fuzzy modeling approach was as given below:

1. Cumulative sensorial computation scores in the form of triplets for the soymilk based flavoured beverage.
2. Membership function expression on a standard fuzzy scale;
3. Estimation of cumulative membership function and consistency characteristic parameters at regular fuzzy scale for soymilk-based flavoured beverage;
4. Rating of expectations of quality attributes for flavoured beverage dependent on soymilk in general;
5. Computing of similarity values and rating order for flavoured soy milk-based beverage.

2.6.1. Triangular fuzzy number and arithmetic operations

The triangular fuzzy membership function is a five-point sensory scale distribution system, as shown in Fig. 1a as input of the membership function. It reflects the linguistic terminology associated with corresponding sensory-scale triplet values such as poor/not satisfactory (0 0 25), 'fair/somewhat important (25 25 25),' 'good/important (50 25 25),' 'very good/highly important (75 25 25 25)' and 'excellent/extremely important' (100 25 0). The triangular fuzzy number is the triplet (a, b, c) to the sensory scale. The central value of a discrete set of a Fuzzy number is 'a' here. It denotes a point's y-coordinate on the coordinate plane where a membership function 's value is 'one.' Where 'b' and 'c' are left, and where the right spreads in the sensory scale distribution pattern where the membership function is zero' as mentioned in Fig. 1a.

2.7. Estimation of sensorial triplet scores of soymilks based flavored beverages and overall quality

The details of the sum of sensory scores, number of judges were recorded in sensory sheet. Triplets associated with the sensory scale were used to calculate the triplets of a specific quality attribute such as color, aroma, mouthfeel, taste, and after taste in each sample. For example, in sample 1 (one liter of soymilk and 5 ml of vanilla flavor), color attribute out of 26 panelists, 4 panelists comply with a satisfactory score, 4 panelists comply with a fair score, 3 panelists comply with medium, 14 panelists comply with a good score, and 1 panelist comply with an excellent score. Similarly, the process applicable to all the samples. Use Eq. (1) to calculate the triplets for sensory scores of a quality attribute (color) for any sample.

$$\text{Sxcolour} = \frac{n_1(0\ 0\ 25) + n_2(25\ 25\ 25) + n_3(50\ 25\ 25) + n_4(75\ 25\ 25) + n_5(100\ 25\ 0)}{n_1 + n_2 + n_3 + n_4 + n_5} \quad (1)$$

Here 'x' represents the sample number (1–9) n_1 to n_5 represents the scores of judges in the corresponding linguistic terms (i.e., n_1 judge corresponds to 'not satisfactory', n_2 judge corresponds to 'fair', n_3 judge corresponds to 'medium', n_4 judge corresponds to 'good' and n5 judge corresponds to 'excellent') associated with the corresponding triplets in the sensory scale. Similarly, sensory score for other quality attributes like aroma (Sx aroma), taste (Sx taste), mouthfeel (Sx mouthfeel), and after taste (Sx after taste) was estimated using Eq. (1), for all the nine samples. The relative weighting of each quality attribute was determined using triplets for sensory quality attribute scores and first value total of all quality attributes in triplets (a) i.e., Q_{sum} (Jaya and Das, 2003). The overall sensory score of the samples was calculated using the triplets for a sample sensory score and relative weights of each quality attribute, as indicated in the Eq. (2).

$$SO1 = SOC1 * Q_{Crel} + SOA1 * Q_{Arel} + SOT1 * Q_{Trel} + SOM1 * Q_{Mrel} + SOAT1 * Q_{ATrel} \quad (2)$$

Where C1 is the color-related triplets and QCrel denotes the triplets corresponding to the relative weighting of the consistency attributes of soy milk-based flavored drink. Similarly, A1, T1, M1, and AT1, is for aroma, taste, mouthfeel, and after taste. Similarly, the overall sensory scores of each sample will be calculated using Eq. (2). The triplet's multiplication for two triplets (a b c) and (d e f) is performed using Eq. (3) (Sarkar et al., 2020).

$$(abc) * (def) = (a * d \quad a * e + d * b \quad a * f + d * c) \quad (3)$$

2.8. Application of standard fuzzy scale for the estimation of membership function

A six-point scale (F1, F2, F3, F4, F5, and F6) with a set of ten numbers each as inputs in a triangular distribution pattern, as

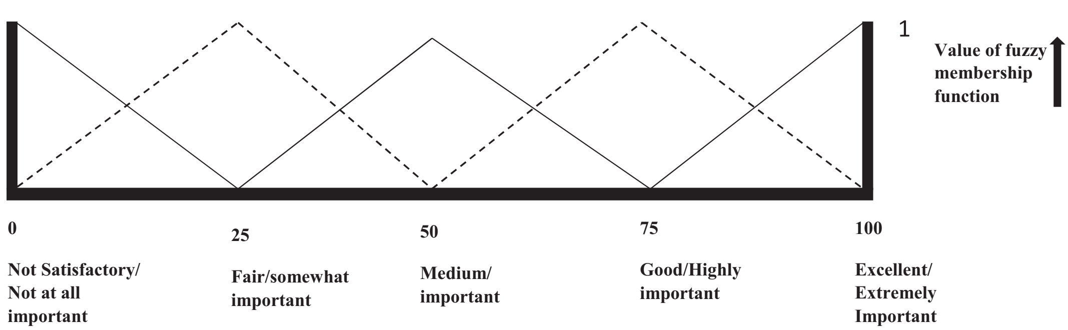

Fig. 1a. Representation of triangular membership function distribution pattern of sensory scales.

shown below, was used to calculate the membership function, and its use was attributed to the rapid convergence of results during fuzzification and defuzzification and easier to interpret (Routray & Mishra, 2012; Faisal et al., 2017). The values of the Fuzzy membership function in the triangular distribution pattern lie from a minimum value of 0 to a maximum value of 1 (Sarkar et al., 2020).

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)
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)

2.9. Calculation of overall membership function

The standardized fuzzy scale was associated with the overall quality of the soymilk based flavored beverage and expressed by a triplet as shown in the Fig. 1b as output of the triplet calculation. The graph indicates the membership function value is 'one' if the abscissa value is 'a,' the membership function value is 'zero' if the abscissa value is less than 'a − b' or greater than 'a + c'. The value of membership function Bi can be determined using the Eq. (4) for a given value of 'i' on the abscissa $Bi = \frac{i-(a-b)}{b}$ for $(a-b) < i < a$

$$Bi = \frac{(a+c)-i}{b} \quad \text{for} \quad a < i < (a+c)$$

$$Bi = 0 \quad \text{for} \quad i < (a-b) \text{ and } i > (a+c) \tag{4}$$

Bi's membership feature value was calculated at I = 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 for overall sensory quality of each soymilk dependent flavored beverage sample and quality attribute in general. The I value of each sample's membership function on the standard fuzzy scale was given by a set of 10 numbers starting from 0 < I < 10 to 90 < I < 100 with 10 intervals, whereby the maximum values of Bi occurred in the mentioned range of 'i'.

2.10. Estimation of similarity values and ranking of the soymilk based flavored beverage

The similarity data for every soymilk-based flavored beverage were calculated using the F and B values generally at the standard fuzzy scale obtained from each sample and quality attributes. The similarity values of each sample were expressed by the acronym 'Sm,' while the transposition of matrix F and B was expressed respectively by F′ and B′ and the estimation was done according to Eq. (5). The rule of matrix multiplication was followed for the calculation of similarity values of both samples and quality attributes (Routray & Mishra, 2012). After calculation, the similarity values were then compared among each other for maximum values to get better ranking. The ranking decreases with the decreasing value of similarity values.

$$S_m(F,B) = \frac{F \times B'}{\max(F \times F' \text{and} B \times B')} \tag{5}$$

3. Results and discussion

3.1. The results and analysis of the fuzzy modeling technique

The sensory evaluation is an uncertain phenomenon which leads to an incorrect human interpretation. The vagueness and uncertainty in the sensory data could be minimized mathematically using the fuzzy set theory. This theory converts the extent of vagueness in making perception to a mathematical integer by considering linguistic scores given by the judges and then converting into numerical values. The samples to be evaluated would be given to each judge, along with the fuzzy logic score sheet. All the judges mark their preference in linguistic terms, i.e., not satisfactory, fair, medium, good, and excellent. The score sheets were collected and checked for how many numbers of judges who gave their preference for not satisfactory over specific quality attributes. Similarly, the same process followed for fair, medium, good, and excellent.

3.2. Triplets for sensory scores of soymilks based flavored beverage and Judges' preference for the quality attributes

Maximum preference was given for medium, good and excellent in color, aroma, and taste attributes for all the samples. While in mouthfeel and after-taste (AT), the maximum preference was given for medium and good (Table 2). According to the judges' color, aroma, and taste could be the most influencing quality attributes in the case of soymilk based flavored beverage. The triplets for the sensory sample score were determined using the sensory score preferences given for every soymilk dependent flavored beverage sample and the triplets associated with the sensory score. Similarly, triplets for sensory scores of quality attributes were calculated using sensory scores given priority for quality attributes and the visual and auditory ratings linked triplets. Table 2 illustrates the triplets of sensory scores for all of the samples, whereas the triplets for the quality attribute are given in Table 3. Table 3 presents the judges' preferences for a sensory score of quality attributes, i.e. Colour, Aroma, Mouthfeel and After Taste. A maximum number of judges (20) gave preference in all the quality attributes for a very important and extremely important category. But the taste is the influencing factor among quality attributes since 13 judges gave preference for extremely important.

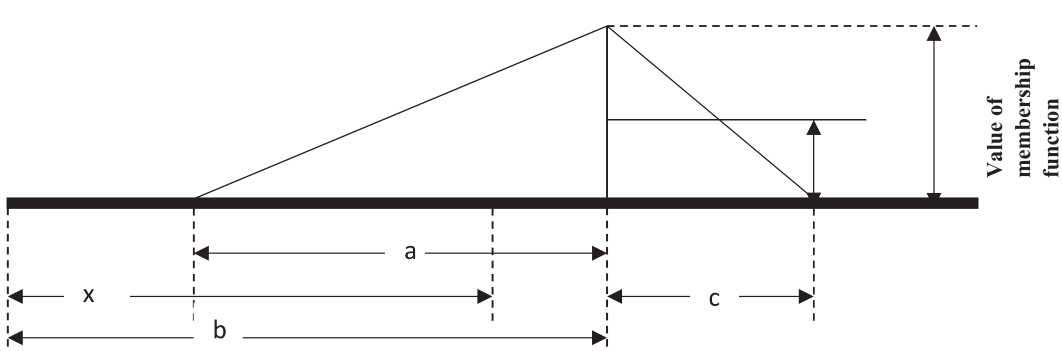

Fig. 1b. Representation of the triplet (a–c) along with their membership function.

Table 2
Sum of the number of judges with different preferences and triplets associated with the sensory scores for the quality attributes of soymilk based flavored beverage beverages.

Sensory quality attributes of beverages	NS	FR	MD	GD	EX	Triplets of the sensory scores			
Color									
S1	4	4	3	14	1	S1C	43.51	35.53	37.13
S2	0	0	3	9	14	S2C	69.16	49.51	37.46
S3	1	3	10	11	1	S3C	46.62	39.18	38.39
S4	2	5	7	11	1	S4C	43.51	37.09	37.13
S5	2	3	10	10	1	S5C	44.29	37.42	37.44
S6	0	4	11	9	2	S6C	47.40	40.29	37.93
S7	2	0	3	9	12	S7C	62.94	45.32	36.48
S8	2	5	5	14	0	S8C	44.29	37.42	38.22
S9	0	0	4	5	17	S9C	70.71	50.17	35.76
Aroma									
S1	0	1	5	14	6	S1A	65.92	46.60	37.40
S2	1	1	4	10	10	S2A	67.63	46.37	34.51
S3	4	7	9	6	0	S3A	36.81	32.42	33.58
S4	1	0	4	15	6	S4A	65.92	45.74	37.40
S5	4	9	8	5	0	S5A	34.24	31.48	32.79
S6	6	9	7	4	0	S6A	29.96	28.18	31.48
S7	0	0	7	14	5	S7A	65.06	46.28	38.00
S8	0	2	5	14	5	S8A	63.35	45.65	37.47
S9	0	1	3	14	8	S9A	69.34	47.86	36.74
Taste									
S1	1	0	6	15	4	S1T	82.69	53.31	37.42
S2	0	0	5	13	11	S2T	105.34	64.69	36.31
S3	11	1	10	2	1	S3T	35.11	26.47	32.49
S4	3	2	5	14	2	S4T	70.23	47.28	37.80
S5	13	8	4	1	0	S5T	21.52	21.23	32.70
S6	8	12	6	0	0	S6T	27.18	28.60	33.56
S7	0	4	6	12	4	S7T	77.02	52.73	36.56
S8	0	3	12	8	3	S8T	71.36	51.02	36.84
S9	0	2	4	11	9	S9T	89.48	56.50	32.78
Mouthfeel									
S1	0	2	7	14	2	S1M	68.67	48.61	38.71
S2	0	0	1	16	8	S2M	85.32	54.09	36.05
S3	7	6	8	3	1	S3M	36.41	30.71	32.81
S4	1	4	8	9	3	S4M	61.39	45.17	36.10
S5	7	7	7	3	1	S5M	35.37	30.37	32.58
S6	6	6	6	8	0	S6M	43.70	35.19	36.45
S7	0	2	8	11	5	S7M	73.88	51.36	37.75
S8	0	3	7	12	4	S8M	71.79	50.68	38.34
S9	1	1	4	12	6	S9M	71.79	47.56	34.18
After Taste									
S1	0	2	6	17	1	S1AT	65.20	46.01	37.66
S2	1	1	5	12	7	S2AT	81.86	53.67	36.08
S3	7	3	9	5	2	S3AT	38.74	32.20	34.32
S4	2	6	8	6	5	S4AT	60.26	43.82	37.11
S5	6	6	8	5	0	S5AT	33.86	30.12	33.88
S6	8	6	7	5	0	S6AT	37.06	33.07	34.85
S7	0	2	4	14	6	S7AT	69.73	48.92	37.20
S8	2	4	9	8	3	S8AT	62.70	46.19	37.72
S9	0	4	3	10	9	S9AT	75.33	50.52	34.86

EX, excellent; FR, fair; GD, good; MD, medium; NS, not satisfactory; S1, sample 1; S2, sample 2; S3, sample 3; S4, sample 4; S5-Sample 5; S6- Sample 6; S7- Sample 7; S8-Sample 8; S9-Sample 9. S1C, triplet associated with the quality attribute color of sample 1; S2C, triplet associated with the quality attribute color of sample 2; S3C, triplet associated with the quality attribute color of sample 3; S4C, triplet associated with the quality attribute color of sample 4; S5C, triplet associated with the quality attribute color of sample 5; S6C, triplet associated with the quality attribute color of sample 6; S7C, triplet associated with the quality attribute color of sample 7; S8C, triplet associated with the quality attribute color of sample 8; S9C, triplet associated with the quality attribute color of sample 9; S1A-S9A, triplets associated with the quality attribute Aroma of sample 1 to sample 9; S1T-S9T, triplets associated with the quality attribute Taste of sample 1 to Sample 9; S1M-S9M, triplets associated with the quality attribute mouthfeel of sample 1 to sample 9; S1AT-S9AT, triplets associated with the quality attribute after taste of sample 1 to sample 9.

3.3. Triplets for sensory scores of quality attributes and relative weightage

The triplets for the overall sensory scores of flavored drinks based on soy milk were measured using their triplets for sensory scores and the relative weighting of quality attributes is also shown in Table 3. The relative weight triplets of each quality attribute were determined using Qsum, i.e. the sum of the triplets' first term for the quality attributes' sensory score (56.73, 62.50, 82.69, 75.96 and 73.07) as demonstrated in Table 3. While the triplets of sensory scores were determined for quality characteristics using the triplets associated with the sensory scores and preferences given by judges for all the quality attributes (Table 3). For example, the priority provided by jurors during the first key characteristic (color) is not at all important, somewhat important, very important, and extremely important were 1, 4, 10, 9, and 2, respectively. The first term of triplets corresponding to the linguistic terms, i.e., not at all important (0), somewhat important (25), important (50), highly important (75) and extremely important (100) were calculated in accordance with Eq. (1) to get triplets of quality attributes (56.73 24.038 23.07). The triplets only for sensory characteristics scores of the S1 (SO1) samples were determined as per Eq. (2), and exhibited in Eqs. (6) and (3).

Table 3
Sum of the number of judges with different preferences, triplets associated with scores and the relative weightage for quality attributes of the soymilk based flavored beverages samples in general.

Quality attributes	NI	SI	IM	HI	EI		triplets for sensory scores				Triplets for relative weightage		
color	1	4	10	9	2	QC	56.73	24.03	23.07	QCrel	18.910	0.23	0.22
aroma	2	3	7	8	6	QA	62.50	23.07	19.23	QArel	20.83	0.22	0.18
taste	0	1	3	9	13	QT	82.69	25.00	12.50	QTrel	27.56	0.20	0.10
mouthfeel	0	1	6	10	9	QM	75.96	25.00	16.34	QMrel	25.32	0.21	0.13
after taste	0	2	6	10	8	QAT	73.07	25.00	17.30	QATrel	24.35	0.21	0.15

Where, NI-Not at All Important; SI-Somewhat Important; IM- Important; HI-highly Important; EI-Extremely Important; QC, triplet for sensory score of quality attribute color; QA, triplet for sensory score of quality attribute Aroma; QT, triplet for sensory score of quality attribute Taste; QM, triplet for sensory score of quality attribute mouthfeel; QAT, triplet for sensory score of quality attribute After Taste; QCrel, triplet for relative weightage of quality attribute color; QArel, triplet for relative weightage of quality attribute Aroma; QTrel, triplet for relative weightage of quality attribute Taste; QMrel, triplet for relative weightage of quality attribute mouthfeel; QATrel, triplet for relative weightage of quality attribute After taste.

$$\begin{aligned} SO1 = & (85.00\ \ 25.00\ \ 10.00) * (0.23\ \ 0.08\ \ 0.06) \\ & + (80.00\ \ 25.00\ \ 16.67) * (0.29\ \ 0.08\ \ 0.03) \\ & + (83.33\ \ 25.00\ \ 11.67) * (0.27\ \ 0.08\ \ 0.04) \\ & + (83.33\ \ 25.00\ \ 13.33) * (0.22\ \ 0.08\ \ 0.05) \end{aligned} \tag{6}$$

Triplets for the total sensory scores of the samples S2 (SO2), S3 (SO3) and S4 (SO4) were determined in the same way as shown below:

SO1 = (41.14 43.01 33.39)
SO2 = (51.54 51.39 35.02)
SO3 = (23.94 28.32 27.60)
SO4 = (37.86 40.48 32.42)
SO5 = (20.75 25.94 26.69)
SO6 = (22.84 28.56 27.75)
SO7 = (43.63 45.73 34.08)
SO8 = (39.45 42.55 33.11)
SO9 = (47.15 47.90 33.45)

3.4. Overall membership functions of sensory scores on standard fuzzy scale

The measurements of soya milk samples' total membership functions and quality attributes in general were determined using the triplets for the overall sensory sample scores and quality attributes. The triplets (a b c) for all the samples and quality attributes were used for calculation at 0–100 for in accordance with Eq. (4). For example, in sample 1, the triplets (41.14 43.01 33.39) were used to calculate 'B' value of sample 1 at every level from 0 to 90. Table 4 shows metrics of the cumulative membership features of all the samples and consistency attributes.

$$B1 = (0,\ 0,\ 0,\ 0.16,\ 0.36,\ 0.56,\ 0.75,\ 0.95,\ 1.00,\ 0.74) \tag{7}$$

$$B2 = (0,\ 0,\ 0.048,\ 0.236,\ 0.425,\ 0.613,\ 0.802,\ 0.990,\ 0.990,\ 0.738)$$

$$B3 = (0.085\ \ 0.392\ \ 0.699\ \ 0.994\ \ 0.994\ \ 0.703\ \ 0.412\ \ 0.120\ \ 0\ \ 0)$$

$$B4 = (0,\ 0.089,\ 0.315,\ 0.542,\ 0.768,\ 0.994,\ 0.994,\ 0.73,\ 0.464,\ 0.194)$$

$$B5 = (0.178,\ 0.486,\ 0.794,\ 0.903,\ 0.903,\ 0.616,\ 0.328,\ 0.040,\ 0,\ 0)$$

$$B6 = (0.178,\ 0.486,\ 0.794,\ 0.903,\ 0.903,\ 0.616,\ 0.328,\ 0.040,\ 0,\ 0)$$

$$B7 = (0,\ 0,\ 0.172,\ 0.374,\ 0.576,\ 0.778,\ 0.979,\ 0.979,\ 0.759,\ 0.491)$$

$$B8 = (0,\ 0.086,\ 0.305,\ 0.523,\ 0.742,\ 0.961,\ 0.961,\ 0.78,\ 0.514,\ 0.248)$$

$$B9 = (0,\ 0,\ 0.105,\ 0.301,\ 0.498,\ 0.695,\ 0.892,\ 0.892,\ 0.870,\ 0.584)$$

3.5. Similarity values and ranking of the quality attributes and samples

The similarity values (0–1) help in finding the best sample and quality attribute based on the ranking. The highest similarity value among all the nine samples in excellent criteria gets the top priority and chosen as the best sample. If two samples fall into same category, then the highest similarity score will be given preference and declared as the best sample. Similarly, same approach was followed for other samples and quality attributes and presented in the Table 5a and Table 5b, respectively. The calculation of the similarity values depends on the membership functions and F values (F1 to F6). In soymilk based flavored beverages samples, the sample (S1, S2, S3, S4, S5, S6, S7, S8, and S9) 2 and sample 9 falls under excellent category with high similarity scores of 0.577 and 0.553, respectively. Sample 2 with 0.577 was given preference according to the similarity ranking rules (Jaya and Das, 2003). Sample 1, 4, 7 and 8 falls under good category with 0.699, 0.575, 0.523 and 0.570, respectively. The sample 3, 5 and 6 falls under medium category with 0.626, 0.628 and 0.629, respectively. The samples were like following, S1-treated soybean with 5 ml of flavor in 1 L, S2- treated soybean with 10 ml of flavor in 1 L, S3- treated soybean with 15 ml of flavor in 1 L, S4- commercially available milk with 5 ml of flavor, S5- commercially available milk with 10 ml of flavor, S6- commercially available milk with 15 ml of flavor, S7- Raw soybean milk with 5 ml of flavor, S8- Raw soybean milk with 10 ml of flavor,

Table 4
Values of overall membership function of the soymilk based flavored beverages samples.

Overall membership function	Values									
B1	0	0.01	0.23	0.44	0.65	0.87	0.89	0.895	0.63	0.37
B2	0	0	0.04	0.23	0.42	0.61	0.80	0.990	0.99	0.73
B3	0.08	0.39	0.69	0.99	0.99	0.70	0.41	0.120	0	0
B4	0	0.08	0.31	0.54	0.76	0.99	0.99	0.73	0.46	0.19
B5	0.17	0.48	0.79	0.90	0.90	0.61	0.32	0.040	0	0
B6	0.17	0.48	0.79	0.90	0.90	0.61	0.32	0.040	0	0
B7	0	0	0.17	0.37	0.57	0.77	0.97	0.979	0.75	0.49
B8	0	0.08	0.30	0.52	0.74	0.96	0.96	0.78	0.51	0.24
B9	0	0	0.10	0.30	0.49	0.69	0.89	0.892	0.87	0.58

Table 5a
Similarity values of the soymilk based flavored beverages and their ranking.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Satisfactory	0.002	0.209	0.278	0.219	0.311	0.311	0.206	0.221	0.221
Fair	0.123	0.139	0.485	0.246	0.559	0.559	0.177	0.245	0.167
Medium	0.436	0.208	0.625	0.412	0.628	0.629	0.294	0.403	0.265
Good	0.699	0.445	0.389	0.575	0.354	0.354	0.523	0.569	0.504
Excellent	0.585	0.577	0.076	0.376	0.051	0.051	0.510	0.403	0.552
Ranking	III	I	IX	IV	VIII	VII	VI	V	II

Table 5b
Similarity value of the quality attributes in general.

	Color	Aroma	Taste	Mouthfeel	After taste
Not at All Important	0	0.314	0.331	0.347	0.319
Somewhat Important	0.060	0.161	0.165	0.173	0.159
Important	0.602	0.292	0.015	0.062	0.100
Highly Important	0.961	0.728	0.341	0.522	0.584
Extremely Important	0.337	0.360	0.742	0.683	0.615
Ranking	IV	V	I	II	III

and S9- Raw soybean milk with 15 ml of flavor. Therefore, the order of preference among samples were shown as S2 (excellent) > S9 (excellent) > S1 (good) > S4 (good) > S8 (good) > S7 (good) > S3 (medium) > S6 (medium) > S5 (medium).

The major difference obtained was the effect of microwave and ultrasonic treatments on the quality and acceptance of the samples, sample S2 was observed to be excellent based on all parameters because there was no oxidation and off-flavor was noted. The complete destruction of lipoxygenase by microwave and ultrasonication treatment assisted in obtaining a better-quality milk. The increase in degree of acceptability was obtained by the further addition of the artificial flavor to maintain a uniformity among samples. As it is known that the quality characteristics are the function of the particular type of food. Thus, color, aroma, taste, mouthfeel, and after taste were selected for soymilk based flavored beverage to quantify the quality attributes.

Implementation of various measurement criteria and scale was needed to recognize the similarity values after essentially rating the beverage 's content attributes. The main goal was to achieve the rating for the different samples and standard attributes. Only the membership function for quality attributes was determined in the same way viz. color (C), Aroma (A), Taste (T), Mouthfeel (M) and After taste (AT) were calculated. The appropriate conclusion withdrawn after relative comparison between the similarity values was observed that Taste (0.7422) was "highly important" in case of soymilk based flavored beverage and also can be considered as the most important factor amongst all because of the prevalent issues of soymilk drinks and other products for its beany and off-flavor, so, it was an appropriate finding for development of the soymilk drinks and other beverages. Both mouthfeel and after taste were also found to be in the category of "extremely important" but similarity value of mouthfeel (0.6832) and for After Taste was found (0.6151) to be less than taste. So, it was an excellent finding considering the importance of mouthfeel and after taste of the product and it was observed that after taste of the product was excellent. Therefore, as analysis revealed the second and third most important factor was observed to be mouthfeel and taste, which was also physically appropriate because when a consumer takes beverage, mouthfeel and taste are the two major criteria to like the product.

Similarly, it was applicable for the soymilk beverage too. Since, microwave and ultrasonication were sufficient enough treatment to inhibit any off-flavor or beany flavor production, aroma was noted to be just a "necessary" parameter for the beverage. Finally, the order of the preference of quality attributes was illustrated as Taste > Mouthfeel > After Taste > Color > Aroma. In general, from the conclusion withdrawn, it can be stated that since there is range for significance of the quality attributes, each and every quality parameter could be referred as imperative sensorial characteristics. The findings showed that taste is the essential quality attribute for soy milk, followed by mouthfeel after sample, color and flavor as reflected in Table 5b.

4. Conclusion

This study was focused to analyze the sensorial properties of a functional and healthy product using soymilk as base ingredient using fuzzy logic analysis. Moreover, it is a potential alternative to milk beverages which is suitable for vegans and lactose intolerants. In addition, it was organoleptically acceptable beverage containing functional ingredients like flavonoids and isoflavones. The soymilk-based beverages with added artificial flavor had been through olfactory examination to declare the potency of being a suitable replacement. Hence, averagely three sample were analyzed from the same combination to eradicate any misjudgment by application of fuzzy systems and programs. After this investigation, the data unveiled that, soymilk based flavored beverage sample S2 which was prepared by extraction of soymilk after pretreatment of soybeans by microwave and ultrasonication produced the superior soymilk-based beverage and that was followed by sample S9; consequently, S1 in third rank and S4 in fourth position. Whereas, S3 was the least acceptable sample attributed to the highest addition of flavor. In general, Taste > Mouthfeel > After Taste > Colour > Aroma, was observed as the rating of the soymilk based flavored beverage.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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