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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(10): 2193-2199

www.thepharmajournal.com
Received: 08-08-2021
Accepted: 13-09-2021

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Application of fuzzy logic model for sensory analysis of pumpkin flour incorporated expanded snacks

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Abstract
The aim of the study is to develop pumpkin flesh flour incorporated expanded snacks with the best sensory quality using Fuzzy logic. Expanded snacks were prepared from rice and maize flour with varied barrel temperature, screw speed and quantity of pumpkin flour. Thirty experimental runs were performed and five best optimized samples were selected and subjected to organoleptic evaluation. Sensory scores for the selected samples and ranking of sensory attributes according to their influence on the sensory acceptability of the product were obtained from 10 semi-trained panel members using a five-point sensory scale. The obtained scores were analyzed using Fuzzy logic based on a triangular membership function and the samples were ranked based on the similarity values obtained on a six-point standard fuzzy scale. The sample T_5 was found to be more acceptable compared to other samples with a similarity value of 0.8867 under "Very Good" category of the fuzzy scale. Other samples were also ranked as "satisfactory" and above on the standard fuzzy scale. All the selected samples were ranked as satisfactory or above which shows that incorporation of pumpkin flour at all the five combinations of input parameters does not have an adverse effect on the sensory quality of the expanded snacks and hence can be used as strategy to promote marketing and consumption successfully.

Keywords: Expanded snacks, fuzzy logic, pumpkin flesh flour, sensory evaluation, similarity value

Introduction
Consumer preference plays a significant role in the success of a product in the market. Hence it is necessary to know the consumers' demands before developing a new product. The increasing awareness towards nutrition and health has resulted in consumers moving towards a healthy food style. Recent days have witnessed the increasing preferences of food products with higher nutrients and antioxidants rather than a tasty food product (Singh *et al*., 2018a) [13]. Pumpkins were found to confer pharmacological benefits such as anti-diabetic, anti-inflammation, anti-hypertension, anti-tumor, anti-hypercholesterolemia (Aamir *et al.*, 2017) [1]. But the usage of the fruit is limited by its seasonal availability. Hence it is necessary to figure out a technique that can facilitate year around availability of the fruit in processed form. Previous studies on development of food products incorporated with pumpkin powder had shown that the fruit powder is suitable for development of food products with high dietary fibre content (Cerniauskiene *et al.*, 2014) [2]. In this study, cereal-based expanded snacks incorporated with pumpkin flesh flour was developed and subjected to sensory evaluation.
Extrusion cooking is a high temperature short time process where the food material is subjected to a thermo mechanical process which involves kneading, shearing, heating and pressurizing for a very short time. This type of processing is used especially for corn, rice and wheat-based products (Delgado *et al.*, 2015) [4]. Since the process involves high temperature and pressure, it ensures sterilization of the product and short time processing ensures more retention of nutrients than other thermal processing methods. The resulting extrudate product contains a denser protein network which reduces the availability of starch to be cleaved by alpha-amylase and delays starch hydrolysis (Hoebler *et al.*, 1999) [6]. The quality of the final product in terms of physico-chemical and organoleptic properties greatly relies upon a number of parameters such as screw speed, feeder speed, barrel temperature, feed moisture and feed composition. The aim of this study is to arrive at an optimum product, in terms of organoleptic properties, from the selected extrudate food samples prepared using different combinations of temperature, screw speed and varying quantity of pumpkin flour.

Organoleptic evaluation of a food product is an essential element in the development of a new food product or modification of an existing food product, since the acceptance of a food product depends more upon the sensory quality. Sensory evaluation plays a crucial role that helps to develop and present to the consumers, a best product, which eventually leads to success of the product in the market (Lazim and Suriani, 2009) [8]. Hence, it is necessary to perform an organoleptic evaluation of the product to test its acceptability in the market. Organoleptic evaluation of a food product relies totally up on the perception of the individual, their likes and dislikes. Hence, the sensory scores which are obtained in linguistic forms for the product would always be more subjective and approximate rather than being precise. Decision made by a person in an uncertain phenomenon would always be imprecise and totally drawn on the person's store of knowledge, which is more ambigue and unreliable. To deal with an approximate data, fuzzy logic was introduced by Zadeh (1965) [16], where the limiting factor is precision and reliability. To deal with the sensory data, fuzzy logic model was developed by Chen, (1988) [3]. Later in 1991, Zhang and Litchfield, presented a comprehensive model for analysis of the sensory data, ranking of the food samples and thereby arriving at an optimum product in terms of sensory quality.

In fuzzy analysis, the samples are denoted by a series of elements and membership functions which are eventually defuzzified and presented as a single value called similarity value for ranking of the samples (Zimmerman, 1991) [18]. This value denotes the similarity of the samples' sensory quality with a corresponding sensory scale. For this, the sensory scores are subjected to a mathematical procedure involving triplets for the sensory attributes as well as the samples' sensory score (Shinde and Pardeshi, 2014) [11]. Fuzzy sets along with the membership functions are able to represent a sensory value concerned with the product, dismissing the uncertainty in the manual scores as they are fuzzy (Lazim and Suriani, 2009) [8]. A weighing subset with respect to the sensory attributes is included in the fuzzy analysis in order to evaluate based on the order of importance of the sensory attributes that contributes to the acceptability of the product. The intended purpose of fuzzy logic modelling is to get rid of the subjectivity in the sensory analysis (Singh *et al*., 2018b). In this study, fuzzy logic was used to arrive at the best product, in terms of sensory quality, out of five extrudate food samples with different combinations of temperature, screw speed and varying quantity of pumpkin flour. Fuzzy logic is a pathway for expression of human thinking and perception using a real number obtained by series of mathematical procedures (Jaya and Das, 2003) [7].

Fuzzy logic for analysis of sensory scores had been used previously for development of mahua flour syrup incorporated cup cakes (Singh *et al*., 2018a) [13], mahua flower syrup incorporated bar samples (Singh *et al*., 2018b) [14], mango drinks (Jaya and Das, 2003) [7], millet based composite flour bread (Singh *et al*., 2012) [12], seaweed coffee infusions (Yogesh and Prarabdh, (2018) [15], drinks formulated from Dahi powder (Routray and Mishra, 2011) [9], ready to eat expanded snacks (Deshmukh *et al*., 2018) [5], beetroot candy (Sana *et al*., 2016) [10] and various other food products.

Methodology

Pumpkin flesh flour incorporated extruded snack products were developed using different combinations of barrel temperature (heater 4 -126 to 145˚C; heater 3- 75 to 95 ˚C), screw speed (18 to 35 Hz) and pumpkin flour composition (10, 20 and 30%) which required thirty experimental runs. Five samples were selected based on higher retention of protein, lesser hardness and higher overall acceptability were selected using Response Surface Methodology. Pumpkin flour levels for all the selected samples were 20%. The process conditions for the selected samples are given in Table 1. The selected samples were then subjected to organoleptic evaluation by ten semi-trained panel members. The judges were instructed to give scores for Colour (C), Flavour (F), Texture (X), Taste (T), and Overall acceptability (O) of the samples based on a five-point sensory scale which indicates "Not Satisfactory", "Fair", "Medium", "Good" and "Excellent" with respect to each sensory attribute. Ranking for the sensory attributes with respect to the impact on the product's acceptability was also obtained from the same panel members based on a five-point scale indicating "Not important", "Somewhat important", "Important", "Highly important" and "Extremely important".

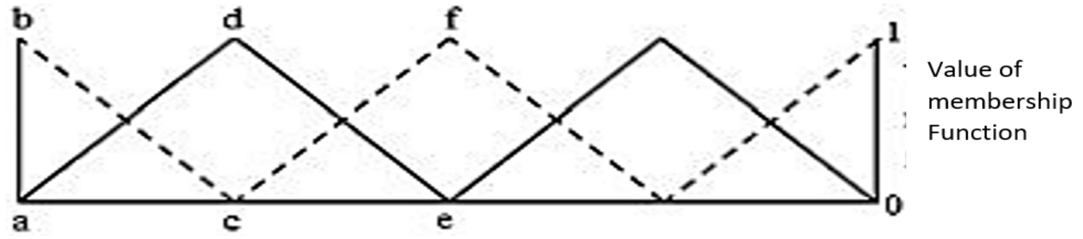
Table 1: Samples selected for organoleptic evaluation

Sample No.	Screw Temperature (Hz)	Heater 4 temperature (˚C)	Heater 3 temperature (˚C)	Pumpkin flour (%)
T_1	29.50	142.07	85.00	20
T_2	29.50	135.00	77.93	20
T_3	29.50	135.00	85.00	20
T_4	33.04	135.00	85.00	20
T_5	32.00	140.00	80.00	20

The fuzzy analysis for the obtained sensory scores was done as described by Shinde and Pardeshi, (2014) [11]: Singh *et al*., 2018a [13]; Singh *et al*., 2018b [14]. Fuzzy analysis involves a) calculation of sensory scores using triplets; b) Conversion of quality attribute ranks into triplet scores; c) Calculation of overall sensory scores for the samples; d) estimation of a triangular membership functions; e) Calculation of overall membership function; f) Calculation of similarity values for a 6-point scale which indicates "Not Satisfactory", "Fair", "Satisfactory", "Medium", "Good" and "Excellent"; g) ranking of samples based on the similarity values.

Triplets for the sensory scores and sensory attributes

The triplets are sets of three numbers in association with a triangular membership function. For the five-point sensory scale, the triplets were assigned based on a triangular membership function as shown in Fig 1.



Scale	0	25	50	75	100
category	Not satisfactory/ Not important	Fair/Somewhat important	Satisfactory/ Important	Good/Very Important	Excellent/ Extremely Important
Triplets	(0, 0, 25)	(25, 25, 25)	(50, 25, 25)	(75, 25, 25)	(100, 25, 25)

Fig 1: Triplets associated with the sensory scores and sensory attribute ranking

The triplets for the sensory scales and attributes were assigned as presented in Table 2. The value of the abscissa with respect to the membership function value 1 is indicated by the first number and the distance to the left and right of the first number for the membership value 0 is indicated by the second and third numbers respectively (Shinde and Pardeshi, 2014) [11].

Table 2: Triplets assigned for the sensory scales and attribute ranking

Ranking of samples	Ranking of sensory attribute	Triplets
Not Satisfactory	Not Important	(0,0,25)
Fair	Somewhat Important	(25,25,25)
Medium	Important	(50,25,25)
Good	Very Important	(75,25,25)
Excellent	Extremely Important	(100,25,0)

Results and Discussion

The fuzzy scores for the sensory evaluation of the extrudate samples are given in Table 3. The number in each column represents the number of panel members that have ranked corresponding sensory scale for the samples.

Table 3: Fuzzy scores of the extrudate samples

	Not Satisfactory	Fair	Medium	Good	Excellent
Colour					
T_1	3	4	3	0	0
T_2	1	4	3	2	0
T_3	2	1	3	4	0
T_4	0	0	2	2	6
T_5	0	0	0	2	8
Flavour					
T_1	4	4	2	0	0
T_2	1	5	4	0	0
T_3	0	2	3	5	0
T_4	0	0	2	1	7
T_5	0	0	0	2	8
Texture					
T_1	2	3	5	0	0
T_2	0	1	5	4	0
T_3	0	0	3	7	0
T_4	0	0	1	2	7
T_5	0	0	0	1	9
Taste					
T_1	1	4	3	2	0
T_2	0	2	6	2	0
T_3	0	2	3	5	0
T_4	0	0	1	4	5
T_5	0	0	0	1	9
Overall Acceptability					
T_1	3	2	5	0	0
T_2	0	1	6	3	0
T_3	0	1	3	6	0

T_4	0	0	2	2	6
T_5	0	0	0	1	9

Fuzzy scores for the sensory attributes ranking are given in Table 4. The number in each column represents the number of panel members that have ranked the sensory attribute with the corresponding sensory scale. As far as the extrudate samples are concerned, texture is the major contributor to acceptability of the product since any changes to texture such as moisture absorption or increased hardness may lead to unappealing mouthfeel. This was also evident in the previous study conducted by Deshmukh *et al.*, 2018 [5]. The ranking of the sensory attributes by the panel members also evinced this statement, where more importance was given to texture followed by taste of the extrudates.

Table 4: Sensory attribute ranking with respect to extrudate product

	NI	SI	M	VI	EI
Colour	0	1	4	3	2
Texture	0	0	0	1	9
Taste	0	0	0	2	8
Flavour	0	0	2	2	6
Overall acceptability	0	1	1	3	5

Calculation of triplets for sensory score and sensory attributes

The sensory scores in the form of triplets for each attribute of the sample was calculated using the eqn. 1.

$$T_i = \frac{\sum(N_1 \text{ x triplet}))}{\text{Total no.of panel members}} \text{ ... Eqn. 1}$$

Where, N_1 is the number of panel members corresponding to the attribute and sensory scale and i is the sample number.

For instance, the triplet score for the sample T_1 that corresponds to color can be calculated as,

$$T_1C = \frac{3(0,0,25)+4(25,25,25)+3(50,25,25)+0(75,25,25)+0(100,25,0)}{10} = (25,17.5,25)$$

Similarly, the triplet scores for all the samples with respect to each sensory attribute were calculated and the triplets are given in Table 5.

Table 5: Triplets for sensory scores of the extrudate samples

	Colour	Texture	Taste	Flavour	Overall Acceptability
T_1	(25, 17.5, 25)	(32.5, 20, 25)	(40, 22.5, 25)	(20, 15, 25)	(30, 17.5, 25)
T_2	(40, 22.5, 25)	(57.5, 25, 25)	(50, 25, 25)	(32.5, 22.5, 25)	(55, 25, 25)
T_3	(47.5, 20, 25)	(67.5, 25, 25)	(57.5, 25, 25)	(57.5, 25, 25)	(62.5, 25, 25)
T_4	(85, 25, 10)	(90, 25, 7.5)	(85, 25, 12.5)	(87.5, 25, 7.5)	(85, 25, 10)
T_5	(95, 25, 5)	(97.5, 25, 2.5)	(97.5, 25, 2.5)	(95, 25, 5)	(97.5, 25, 2.5)

Triplets for sensory attributes

The triplets for each sensory attribute were calculated using Eqn. 2.

$$Q = \frac{\sum(N_2 \text{ x triplet})}{\text{Total no.of panel members}} \text{ ...Eqn.2}$$

Where N_2 is the number of panel members in the corresponding ranking scale of the attribute.
Therefore, triplets for color of the product were calculated as,

$$QC = \frac{0(0,0,25)+1(25,25,25)+4(50,25,25)+3(75,25,25)+2(100,25,0)}{10} = (65, 25, 20)$$

Similarly, triplets for other sensory attributes were also calculated and the values are as follows.
QX = (97.5, 25, 2.5)
QT = (95, 25, 5)
QF = (85, 25. 10)
QO = (80, 25, 12.5) …Eqn. 3
In order to bring resultant overall triplets in the range between 0 and 100, the triplets for the sensory attributes were reduced by $1/Q_{sum}$, where Q_{sum} is the sum of the first values of triplet in Eqn. 3.
Q_{sum} = 65 + 97.5 + 95 + 85 + 80
Q_{sum} =422.5
The relative weightage for the sensory attributes is given in Eqn 4.
QC_{rel} = (0.1538, 0.0592, 0.0473)
QX_{rel} = (0.2308, 0.0592, 0.0059)
QT_{rel} = (0.2249, 0.0592, 0.0118)
QF_{rel} = (0.2012, 0.0592, 0.0237)
QO_{rel} = (0.1893, 0.0592, 0.0296) ...Eqn. 4

The overall sensory score (OT) for the samples were calculated using Eqn 5.
$OT_i = T_iC*Qcr_{el} + T_iX*QX_{rel} + T_iT*QT_{rel} + T_iF*QF_{rel} + T_iO*QO_{rel}$
…Eqn. 5

For multiplication triplets, a rule-based approach was used as given in Eqn6

(a, b, c) * (x, y, z) = (a*x, (a*y)+(b*x), (a*z)+(c*x)) ...Eqn. 6
The overall sensory scores for the samples are given in Table 6.

Table 6: Overall sensory score triplets for the extrudate samples

Samples	Triplet Scores		
OT_1	**30.04438**	**27.42604**	**28.21006**
OT_2	47.61834	38.01775	30.22189
OT_3	59.21598	41.53846	31.53846
OT_4	86.6568	50.59172	19.63018
OT_5	96.61243	53.5503	14.74852

Membership functions associated with sensory scores

The five-point sensory scale was then converted into a six-point standard fuzzy scale denoted by F1, F2, F3, F4, F5, F6 to indicate “Not Satisfactory”, “Fair”, “Satisfactory”, “Good”, “Very Good” and “Excellent”. This membership function is a set of 10 numbers based on a triangular membership pattern as shown in Fig 2.

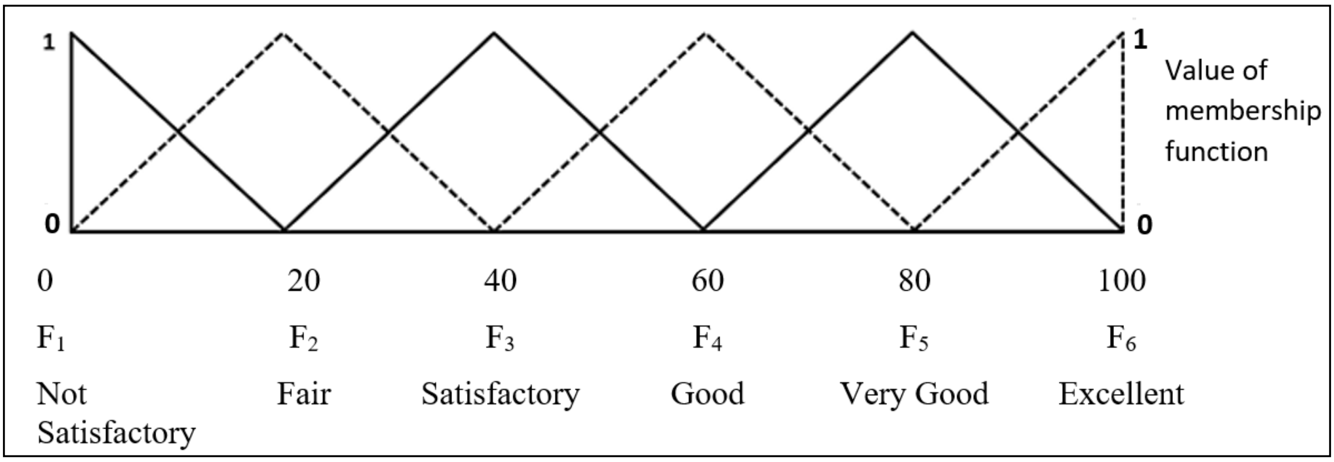


Fig 2: Standard fuzzy scale of triangular membership function

The values of the membership function can be described as follows:
(maximum membership value of B_x in $0<x<10$, maximum membership value of B_x in $10<x<20$,maximum membership value of B_x in $20<x<30$,maximum membership value of B_x in $30<x<40$,maximum membership value of B_x in $40<x<50$,maximum membership value of B_x in $50<x<60$,maximum membership value of B_x in $60<x<70$,maximum membership value of B_x in $70<x<80$,maximum membership value of B_x in $80<x<90$,maximum membership value of B_x in $90<x<100$).
The membership functions associated with the sensory scales F_1 to F_6 is given in Eqn. 7.

$F_1 = (1, 0.5, 0, 0, 0, 0, 0, 0, 0, 0)$
$F_2 = (0.5, 1, 1, 0.5, 0, 0, 0, 0, 0, 0)$
$F_3 = (0, 0, 0.5, 1, 1, 0.5, 0, 0, 0, 0)$
$F_4 = (0, 0, 0, 0, 0.5, 1, 1, 0.5, 0, 0)$
$F_5 = (0, 0, 0, 0, 0, 0, 0.5, 1, 1, 0.5)$
$F_6 = (0, 0, 0, 0, 0, 0, 0, 0, 0.5, 1)$ …Eqn. 7

Membership function associated with samples

The membership function of the samples is a set of 10 numbers calculated based on the graphical representation of the overall triplet scores (a, b, c) as shown in Fig 3.

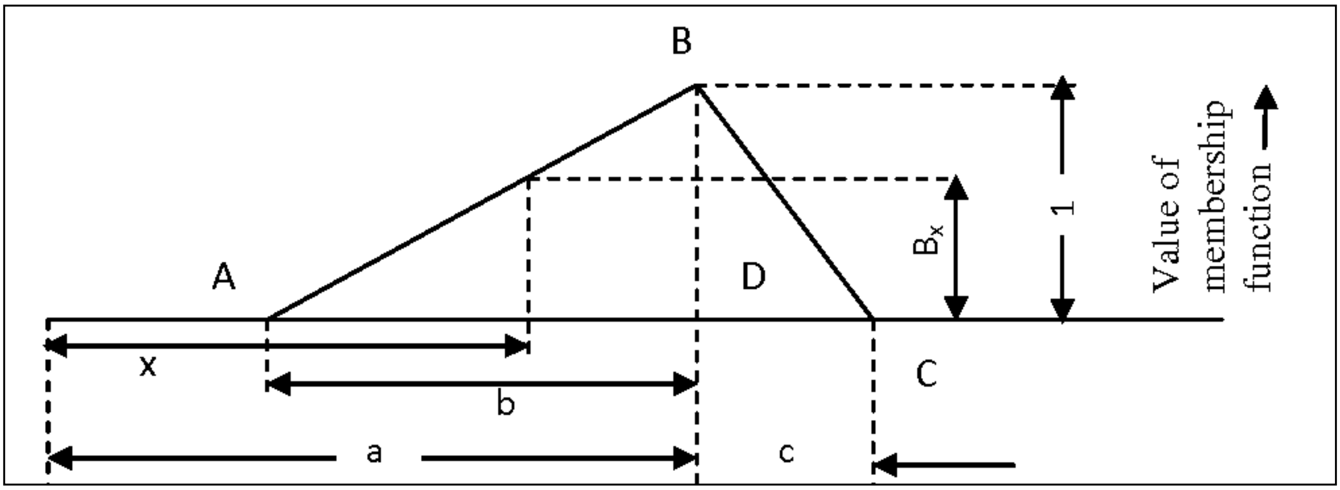


Fig 3: Graphical representation of the overall triplet scores and their association with the membership function values

From fig, when the value of abscissa is a, then the value of membership function is 1 and the membership value is zero when the value of abscissa exceeds (a+c) or falls below (a-b). For a given value of x, the value of B_x was calculated using the Eqn8. thus, for x=0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 are calculated for all the samples and presented in Table 7.

$B_x = \frac{x-(a-b)}{c}$, For $(a-b)<x<a$

$B_x = \frac{(a+c)-x}{c}$, For $a<x<(a+c)$

$B_x = 0$, For other values of x …Eqn. 8

Table 7: Membership function values for the extrudate samples

	Membership Function Values									
B_1	0.269148	0.633765	0.998382	1	0.64709	0.292606	0	0	0	0
B_2	0.010506	0.273541	0.536576	0.799611	1	0.921194	0.590308	0.259422	0	0
B_3	0	0.055912	0.296652	0.537393	0.778134	1	0.975141	0.658068	0.340994	0.023921
B_4	0	0	0	0.077778	0.275439	0.473099	0.67076	0.868421	1	0.829691
B_5	0	0	0	0	0.129558	0.316298	0.503039	0.689779	0.876519	1

Calculation of similarity values

Ranking of the extrudate samples was done using the similarity values calculated by the Eqn. 9.

$$S_M(B, F) = \frac{F*B^T}{\text{Maximum of }(F*F^T, B*B^T)} \quad \text{...Eqn. 9}$$

$S_M(B, F)$ corresponds to the similarity value of the sample, B is the membership function of the sample, F is the membership function for the corresponding sensory scale, F^T and B^T are the transpose matrices of F and B respectively. The calculation of S_M follows matrix multiplication. Thus, the similarity values for the samples were calculated and presented in Table 8. The category of the sensory scale under which the sample holds the highest similarity value denotes the overall sensory quality of the corresponding sample.

Table 8: Similarity values for the extrudate samples and their sensory scale

	Similarity values					
	F1	**F2**	**F3**	**F4**	**F5**	**F6**
T_1	0.1970	0.7619	0.7706	0.2071	0.0000	0.0000
T_2	0.0451	0.3720	0.7740	0.6555	0.1698	0.0000
T_3	0.0080	0.1782	0.5633	0.7725	0.4299	0.0558
T_4	0.0000	0.0122	0.1844	0.5365	0.8188	0.4158
T_5	0.0000	0.0000	0.1101	0.4702	0.8867	0.5502

Hence, based on the similarity values, the samples can be ranked as T_5 (Very good) > T_4 (Very good) > T_3 (Good) > T_2 (Satisfactory) > T_1 (Satisfactory). T_4 and T_5 have discretely obtained the highest similarity values under F_5 i.e., "Very Good" sensory scale. However, the similarity value was highest for T_5 compared to T_4 and hence T_5 was regarded as the sample with the best sensory quality among the five extrudate samples. The accuracy of prediction of sensory quality of the samples using fuzzy logic is more when compared to manual method. This is due to the fact that fuzzy logic analyses the sensory score of the samples according to the order of importance of the sensory attribute with respect to the type of product. This minimizes the weightage reduced in the overall sensory score of a sample due to an unimportant sensory attribute, for instance, colour in case of expanded products.

Conclusion

Fuzzy logic modelling of the extrudate samples had shown that T_5i.e., the sample prepared with screw speed at 32 Hz, heater 3 at 80˚C, heater 4 at 140˚C and 20% pumpkin incorporation is the best sample in terms of sensory quality and hence can be highly acceptable followed by T_4, T_3, T_2, and T_1. Texture was ranked as the important sensory attributes followed by taste with respect to extrudate products as ranked by the panel members. All the samples with pumpkin powder incorporation were ranked as satisfactory or higher. This shows that pumpkin powder, varied screw speed and barrel temperature (heater 3 and 4) does not have an adverse effect on the sensory quality of the extrudate product. Therefore, successful incorporation of cereal flour with pumpkin flesh flour can be possible without affecting the sensory acceptability of the product while also ensuring progression in terms of nutritive value of the product.

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