KKU ENGINEERING JOURNAL 2016;43(S2):291-293 Research Article

KKU Engineering Journal

https://www.tci-thaijo.org/index.php/kkuenj/index

Fuzzy analytical modeling for sensory evaluation of water meal (*Wolffia arrhiza* (L.) Wimm.) - Rice cracker

Patareeya Lasunon* and Nipaporn Sengkhamparn

Faculty of Applied Science and Engineering, Khon Kaen University, Nong Khai Campus, Nong Khai,43000, Thailand.

Received April 2016
Accepted June 2016

Abstract

The sensory attributes (color, odor, flavor, crack and overall acceptance) of the developed water meal-rice cracker product with water meal at 1.5, 3, 5, 7 and 10% of rice were evaluated. The sensory evaluation data were analyzed with the fuzzy analytical modeling. The major steps were: (1) calculation sensory scores in the form of *Triplets Sensory Scales*; (2) determination of *Overall Sensory Score* for all quality characteristics of each samples in the form of triplets; and (3) computation of *Similarity Values* on standard fuzzy scale and ranking the samples. The results of fuzzy analysis showed that the sample 2 (3% water meal) was the best quality of water meal-rice cracker.

Keywords: Fuzzy logic, Sensory evaluation, Rice cracker, Water meal, Scilab program

1. Introduction

Water meal (*Wolffia arrhiza* (L.) Wimm.) is a flowering plant which has green or yellow-green thalli and floats at the surface of a smooth water such as ponds or lake [1]. It can be grow in the North and the North-eastern of Thailand and can be used as a fresh food and as an ingredient for home cooking. It contains high amount of protein is higher than meat or soybean [1]. Besides, it shows the antioxidant activity due to β-carotene and linderic acid contents [1]. It has been reported that it can be used as an ingredient for Water meal steamed fish with curry paste (Hor Mok), Water meal candle candy emerald (Kanom Teain Morakot), Water meal stuffed noodle rolls (Guay Teiw Lord) [2] and water meal leather [1].

Sticky rice cracker product (KhaoTaen) is a traditional Thai snack which is mainly made form sticky rice. The cooked sticky rice is mix with other ingredient such as water melon juice or other fruit juice, salt, sesame and coconut milk. Then, it is cut as a flat circle sheet and dried by sun dry or equipment. After that, the dried sheet is deep fried to get crispy texture. The fried sticky rice cracker can be added by concentrated coconut sugar or crispy pork or chili paste [3].

Fuzzy logic is capable technique to analyze the sensory evaluation data which are vague and imprecise. It is applied to decide about the vital characteristics of foodstuff like acceptability, elimination, ranking of superior and inferior attributes [4]. Because of human expressions on filling for foods are fuzzy rather than deterministic, then the fuzzy mathematical models were developed in the sensory evaluation of food products [5]. The fuzzy logic models were applied for evaluation of sensory quality of (a) bread prepared from millet-based composite flours [4], (b) tea liquor made out of dried CTC tea [6], (c) jam samples available in market [5] and (d) screened market samples of Kheer Mohan which is a chhana based sweet meat highly popular in eastern Rajasthan [7].

In this study, the water meal is used as an ingredient for making rice cracker product. The sensory characteristic of water meal-rice cracker were evaluated. The fuzzy analytical modeling were used to analyze the sensory data for ranking the water meal-rice cracker.

2. Materials and methods

2.1 Preparing of water meal-rice cracker

The water meals were cleaned and dried at 60ºC for 24 hrs. The Jasmine rice were mixed with dried water meal at 1.5, 3, 5, 7 and 10% of rice (sample 1,2,3,4 and 5, respectively) and then cooked by an automatic house-hold rice cooker. The starch solution were added to cooked water meal rice mixture and then were sheeted approximately 0.3-0.5 mm in thickness and rounds by using cookies mold. After that, the water meal rice sheet were sun dried and then deep fried.

2.2 Sensory evaluation

The water meal-rice cracker were prepared for sensory evaluation by 33 panelists. All sample were judge in 5 attributes including color, odor, flavor, crack and overall acceptance using a nine point hedonic scale. This sensory scores were separated into 5-point sensory scales, where hedonic scale with ‘‘1” equaling *Poor*, “2-3” equaling *Fair*, “4-5” equaling *Good*, “6-7” equaling *Very good* and “8-9” equaling *Excellent*.

*Corresponding author. Tel.:
Email address: Lpatar@hotmail.com
doi: 10.14456/kkuenj.2016.112

Table 1 Relative weightage of each attributes for water meal-rice cracker in general

Attributes	Sensory scale factors					Triplet Sensory Scales	Triplet weight
	Poor	Fair	Good	Very Good	Excellent		
Color	3	3	6	12	9	C = (65.9, 22.72, 18.18)	WC = (0.209, 0.072, 0.057)
Odor	1	2	6	19	5	O = (68.93, 24.24, 21.21)	WO = (0.218, 0.076, 0.067)
Flavor	1	2	14	10	6	F = (63.63, 24.24, 20.45)	WF = (0.201, 0.076, 0.064)
Crack	3	3	9	8	10	Cr = (64.39, 22.72, 17.42)	WCr = (0.204, 0.072, 0.055)
Overall	1	2	23	7	0	Al = (52.27, 24.24, 25)	Wal = (0.165, 0.076, 0.079)

Table 2 Triplet sensory scale of attributes in sample 1

Attributes	Sensory scale factors and Frequency					Triplet Sensory Scales
	Poor	Fair	Good	Very Good	Excellent	
Color	2	9	17	5	0	S1C = (43.93, 23.48, 25)
Odor	4	7	17	5	0	S1O = (42.42, 21.96, 25)
Flavor	5	14	9	4	1	S1F = (36.36, 21.21, 24.24)
Crack	2	12	14	5	0	S1Cr = (41.66, 23.48, 25)
Overall	1	10	13	9	0	S1Al = (47.72, 24.24, 25)

2.3 Fuzzy analytical modeling for sensory evaluation

The major steps of this model have been calculated in the following manner:

2.3.1 Triplets sensory scale

Triangular membership function distribution of 5-point sensory scales was denoted as Triplet (set of three numbers) viz. Poor(0,0,25) Fair(25,25,25) Good(50,25,25) Very good(75,25,25) and Excellent(100,25,0) [4,5,6,7]. The triplet sensory scale for each attributes were obtained by (i) sum the frequency sensory scales of each attributes; (ii) triplets related with sensory scales and (iii) number of panelists, as the following example.

For example; In sample 1 (1.5% water meal), the frequency of the color with 5-point sensory scales (poor to excellent), out of 33 panelists, were given by 2, 9, 17, 5 and 0 respectively. Then triplet sensory scale for the color, S1C, was calculated as follows,

$$\text{SIC} = \frac{2(0,0,25)+9(25,25,25)+17(50,25,25)+5(75,25,25)+0(100,25,0)}{33} = (43.93, 23.48, 25)$$

2.3.2 Overall sensory score

The relative weightage, , of attribute which is defined by the sample in general, was calculated as where, is the triplet sensory scale for attribute and is the sum of first digit of triplets sensory scale from all attributes. Therefore, we have the triplet relative weightage of each attributes for water meal-rice cracker in general as in Table 1.

Then overall sensory score of the samples can be calculated by integrating the triplet sensory scale with their relative weightage of attribute, by using triplet multiplication rule:

$$(a_1, a_2, a_3) \text{ x } (w_1, w_2, w_3) = (a_1 w_1, a_1 w_2 + a_2 w_1, a_1 w_3 + a_3 w_1) \quad \text{(Eq 1)}$$

For example; From the triplet sensory scale of attributes in sample 1 (Table 2), the overall sensory score, , could be obtained by using Eq.1 with the data given in Table 1 as the following,

$$S01 = (S1C \text{ x } WC) + (S10 \text{ x } W0) + (S1F \text{ x } WF) + (S1Cr \text{ x } WCr) + (S1Al \text{ x } WAl) = (42.242, 38.725, 38.687). \quad \text{(Eq 2)}$$

2.3.3 Similarity values on standard fuzzy scale

Standard fuzzy scale is used for distributing the overall sensory score, as triplet , among 6-point sensorial scale and named from to [4,5,6,7]. The values of membership functions to were taken as:

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).

The value of membership function of overall sensory score on standard fuzzy scale were determined by a set of 10 numbers, which were the maximum values of in the 10 intervals from 0 to 100 in the mentioned range of . This values can be estimated in Eq.3,

$$B_x = \begin{cases} 1 & ; \quad x = a \\ \dfrac{x-(a-b)}{b} & ; \quad (a-b) < x < a \\ \dfrac{(a+c)-x}{c} & ; \quad a < x < (a+c) \\ 0 & ; \quad otherwise \end{cases} \quad \text{(Eq 3)}$$

For example; the overall sensory score in sample 1 (shown in Eq.2), SO1=(42.242, 38.725, 38.687), by using Eq.3 with these values at x = 0, 10,…..100 the result was establish as,

$B1_x$ = (0.1674, 0.4256, 0.6838, 0.9421, 1, 0.7995, 0.5410, 0.2825, 0.0240, 0) (Eq.4)

After calculating B_x, their values were compared with the corresponding standard fuzzy scale to were calculated as follows,

$$S_m(F_i) = \frac{F_i \times B_x^T}{\text{maximum of } \left(F_i \times F_i^T \text{ and } B_x \times B_x^T\right)}, \; i = 1,2,\ldots,6 \quad \text{(Eq 5)}$$

Through the use of Eq.5, the values of F_1 to F_6 and B_x were used to determine *Similarity Values* of the sample i.e.

Table 3 Sensory data of the water meal-rice cracker samples

Attributes	Sensory scale factors and Frequency					Triplet Sensory Scales	Overall Score
	Poor	Fair	Good	Very Good	Excellent		
Color	2	9	17	5	0	S1C = (43.93, 23.48, 25)	
Odor	4	7	17	5	0	S1O = (42.42, 21.96, 25)	**Sample1 (1.5%)**
Flavor	5	14	9	4	1	S1F = (36.36, 21.21, 24.24)	
Crack	2	12	14	5	0	S1Cr = (41.66, 23.48, 25)	SO1 = (42.242, 38.725, 38.687)
Overall	1	10	13	9	0	S1Al = (47.72, 24.24, 25)	
Color	2	5	7	7	12	S2C = (66.66, 23.48, 15.9)	
Odor	4	3	17	7	2	S2O = (50, 21.96, 23.48)	**Sample2 (3%)**
Flavor	6	2	11	9	5	S2F = (53.78, 20.45, 21.21)	
Crack	1	3	9	13	7	S2Cr = (67.96, 24.21, 19.53)	SO2 = (59.052, 44.378, 39.098)
Overall	5	3	9	10	6	S2Al = (56.81, 21.21, 20.45)	
Color	3	11	12	6	1	S3C = (43.18, 22.72, 24.24)	
Odor	0	11	12	9	1	S3O = (50, 25, 24.24)	**Sample3 (5%)**
Flavor	1	11	11	9	1	S3F = (48.48, 24.24, 24.24)	
Crack	0	5	9	11	8	S3Cr = (66.66, 25, 18.93)	SO3 = (53.181, 44.414, 40.535)
Overall	0	3	16	13	1	S3Al = (59.09, 25, 24.24)	
Color	4	8	14	5	2	S4C = (44.69, 21.96, 23.48)	
Odor	5	12	7	5	4	S4O = (43.18, 21.21, 21.96)	**Sample4 (7%)**
Flavor	2	10	12	6	3	S4F = (48.48, 23.48, 22.72)	
Crack	0	4	9	16	4	S4Cr = (65.15, 25, 21.96)	SO4 = (51.068, 42.207, 39.186)
Overall	2	7	9	12	3	S4Al = (55.3, 23.48, 22.72)	
Color	6	12	13	0	2	S5C = (34.84, 20.45, 23.48)	
Odor	5	8	15	4	1	S5O = (40.9, 21.21, 24.24)	**Sample5 (10%)**
Flavor	2	9	12	5	5	S5F = (51.51, 23.48, 21.21)	
Crack	0	7	9	11	6	S5Cr = (62.12, 25, 20.45)	SO5 = (49.007, 41.253, 38.113)
Overall	2	3	17	4	7	S5Al = (58.33, 23.48, 19.69)	

Table 4 Similarity values of water meal-rice cracker samples

Scale ranking	Similarity values of water meal-rice cracker				
	S1 (1.5%)	S2 (3%)	S3 (5%)	S4 (7%)	S5 (10%)
F1: Not satisfactory	0.1063	0.0157	0.0405	0.0424	0.0551
F2: Fair	0.4653	0.1964	0.2880	0.3061	0.3404
F3: Satisfactory	**0.7504**	0.5335	0.6227	0.6572	**0.6889**
F4: Good	0.5541	**0.7152**	**0.6800**	**0.6719**	0.6541
F5: Very Good	0.1613	0.4647	0.3639	0.3117	0.2692
F6: Excellent	0.0034	0.1153	0.0685	0.0367	0.0254

for sample 1 with the value of membership function on standard fuzzy scale $B1_x$ (shown in Eq.4), the similarity value under F_1 (not satisfactory) is estimated as $S_m(F_1) = \frac{F_1 \times B1_x^T}{maximum\ of\ (F_1 \times F_1^T\ and\ B1_x \times B1_X^T)} = 0.1063$ Likewise, similarity value under remaining F_2 to F_6 were obtained for sample 1. The ranking of different water meal-rice cracker samples were carried out through the estimation of similarity values for all the quality characteristic. Finally, the quality of each sample was determined by the maximum similarity values of that sample.

3. Results and discussion

A program in Scilab 5.5.2 was developed for calculation of all above fuzzy modeling steps. In this study, the frequency of each sensory scales, the triplets associated with sensory scale and the overall sensory scores of water meal-rice cracker samples show in Table 3.

So, the similarity values for samples of water meal-rice cracker have been shown in Table 4.

From Table 4, the maximum similarity values for five samples were 0.7504 (Satisfactory) for *S*1, 0.7152 (Good) for *S*2, 0.6800 (Good) for *S*3, 0.6719 (Good) for *S*4 and 0.6889 (Satisfactory) for *S*5. To see that, there are three samples under the same category 'Good' but the similarity values of *S*2 has highest score than *S*3 and *S*4. So, it was clear that *S*2 is the best quality. Therefore, the ranking of water meal-rice cracker samples were carried out after the comparison of maximum similarity values of all samples as *S*2 (Good) > *S*3 (Good) > *S*4 (Good) > *S*1 (Satisfactory) > *S*5 (Satisfactory).

4. Conclusions

The different samples of water meal-rice cracker were proposed to sensory evaluation out of 33 panelists. The technique of fuzzy analytical modeling was applied to analyze the sensory evaluation data. It was used to decide the ranking of water meal-rice cracker samples. The result showed that the sample *S*2 ranked first and followed by samples *S*3**,** *S*4**,** *S*1 and *S*5, respectively.

5. References

[1] Deepanya W. Development of products water meal (*Wolffia arrhiza* (L.) Wimm.) leather [research report]. Phetchabun :Food Science and Technology, Phetchabun Rajabhat University; 2012.

[2] Uttama – Ang S. Development of water meal (*wolffia arrhiza*(L) wimm) recipes for community and commercial utilization [research report]. Phetchabun: Phetchabun Rajabhat University; 2012.

[3] Thai community product standard. Thai community product standard No. 36/2554. Sticky rice cracker products (KhaoTaen). Bangkok: Thai Industrial Standards Institute; 2011. [InThai].

[4] Singh KP, Mishra A, Mishra HN. Fuzzy analysis of sensory attributes of bread prepared from millet-based composite flours. LWT-Food Sci Technol 2012;48:276-282.

[5] Shinde KJ, Pardeshi IL. Fuzzy logic model for sensory evaluation of commercially available jam samples. JREF 2014;1:78-84.

[6] Debjani C, Das S, Das H. Aggregation of sensory data using fuzzy logic for sensory quality evaluation of food. J Food Sci Technol 2013;50:1088-1096.

[7] Meena GS, Gupta VK, Khetra Y,Raghu HV, Parmar PT. Fuzzy logic (similarity analysis) modeling for sensory evaluation of market samples of Kheer Mohan. Indian J Dairy Sci 2015;68:326-333.