International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(6): 1809-1816

Received: 22-09-2017
Accepted: 24-10-2017

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Physico-chemical characterization and fuzzy logic modeling of sensory evaluation for market *Ghewar*

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Abstract
Ghewar is a very popular traditional Indian sweet, commercially prepared during the festive seasons of "Rakshabandhan", "Teej" and "Makar Sankranti". To protect the traditional art of manufacturing and to make its presence worldwide physico-chemical and textural quality attributes were evaluated by collecting samples from the markets of Jodhpur, Ajmer, Sonepat and Jaipur cities. Similarly, the sensory scores of above market samples of *Ghewar* were analysed and ranked for their quality attributes with the help of fuzzy modeling. A team of eleven people familiar with product performed the sensory evaluation. Slight variations have been found in the method of manufacturing of product due to the local consumers' preference. Statistical analysis ($P \leq 0.05$) showed significant variation among the market samples for moisture, protein, fat, total ash, reducing sugar, free fatty acids, peroxide value, firmness, weight, thickness, diameter of a single sweet, water activity, L*, a* and b*. Among the screened market samples, the products from Jodhpur city were ranked as the most preferred samples. The quality attributes which affected the acceptability of samples were found to be colour & appearance, body & texture, sweetness and flavour in descending order of their significance.

Keywords: *Ghewar*, physico-chemical, sensory, market samples, fuzzy logic

Introduction
India is known for its age old traditions, cultures, festivals and social functions which involve consumption of different traditional sweets prepared by local *halwais*. Few of those sweets have high potential in global markets. This has escalated to understand the needs for protecting the knowledge and evaluating the technical aspects of bringing these regional cuisines to a global platform. *Ghewar* is one of those popular traditional sweets mostly made during the festive seasons of "Rakshabandhan", "Teej" and "Makar Sankranti". *Ghewar* is known for its matchless sweetness, unique colour and appearance, distinct texture and flavour. Traditionally this is prepared by deep frying of a thin batter in fat. The batter prepared by mixing *maida* in emulsified fat and adding water in that as per requirement. The emulsified fat is obtained by rubbing ice or mixing chilled water into liquefied fat. The final product has typical shape of a doughnut, crispy texture with the porous body and generally sweetened with concentrated sugar syrup (Saxena *et al*., 1996)[1]. This disc shape is generally obtained in round mold or in specially shaped frying pan and usually 8 to 10 inch in diameter. Fried *Ghewar* samples are often tiered by putting one above another to facilitate cooling, draining of fat and addition of sugar syrup on the top layer to make a mouth-watering delicacy. But in case of other similar kind of fried sweets like traditional *maida jalebi*, after frying the products are generally dipped into sugar syrup for sugar absorption (Chakkaravarthi *et al*., 2009)[2]. Some sweet makers prefer to add custard cream, cardamom powder and dry fruits-nuts on top of the layers of *Ghewar*. Production of this popular indigenous product confined to cottage industries of few specific regions. So, for large scale commercial production and to make its presence worldwide need was felt to analyse products from the markets of different regions. This will help to understand the trends of markets by characterizing the products using suitable techniques as reported for traditional products like *dodaburfi* (Chawla *et al*., 2011)[3], *thabdi* (Patel *et al*., 2012)[4], *halvasan* Patel *et al*., 2010)[5], *khoa jalebi* (Pagote and Jayaraj, 2012)[6], *kheer mohan* (Meena *et al*., 2014)[7] and *chhana jalebi* (Geetha *et al*., 2015)[8].
The decision for accepting or rejecting a food product is taken based on its sensory analysis which is generally characterized by vagueness and incorrectness.

During this subjective evaluation, the opinions oftenly come in linguistic form which is full of imprecision and confusion. Fuzzy logic is found to be a useful method for analysing such vague and ambiguous data to make final decisions on the acceptance, removal, grading of food with a conclusion on dominant and less important attributes also. In fuzzy modeling, relationships between dependent (acceptance, removal, grading, dominant and less important attributes of food etc.) and independent (colour and appearance, body and texture, sweetness and flavour etc.) variables are developed using linguistic variables (e.g. not satisfactory, good, excellent, etc.). This technique is useful for analysing data obtained from subjective (linguistic) as well as objective (accurate and precise) evaluation (Das, 2005[9]; Singh *et al*., 2012[10]; Meena *et al*., 2011[11]; Meena *et al*., 2016[12]; Chakraborty *et al*., 2013[13]; Hamr *et al*., 2017[14]; Routary and Mishra, 2012[15]).

The present investigation was carried out to evaluate various physico-chemical characteristics samples of *Ghewar* and fuzzy logic modeling of their sensory attributes for ranking them according to various quality characteristics.

Materials and methods

Collection of *Ghewar* samples

Based on the consumer's response three preferred samples from the markets of each of four selected cities namely Jodhpur (S1), Ajmer (S2), Sonepat (S3) and Jaipur (S4) which are popular for this particular product were brought to the laboratory of National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Sonepat, Haryana in proper packed condition. Information regarding the traditional art of manufacturing, ingredients used, facilities available etc. were collected as per questionnaires prepared during personal visits to those cities. Samples were evaluated for physico-chemical parameters, textural and sensory attributes (Meena *et al*., 2014)[7].

Physico-chemical analysis

Market samples were mixed properly to distribute all components uniformly before analysis using pestle and mortar. Moisture content was determined using moisture analyser (Model No. MB 50C, max-50 g and accuracy-0.001g, Greifensee, Sweitzerland),), fat by Soxhlet extraction method, protein using Kjeldahl (Model No: SpeedDigester,K-439 and Kjelflex,K-360, Buchi, Switzerland), reducing sugar using volumetric (Lane-Eynon), total ash by standard gravimetric method. All the analysis was done as per the standard procedure suggested in AOAC (2005)[16]. Free fatty acids and peroxide value as per method suggested by Ranganna (2004)[17]. Colour values (L*, a*, b*) and water activity (aw) were determined using a hand chromameter at 25±1 ^{O} C (Model No.CR-400; Konica Minolta, Japan) and Aqua lab (make U.S.A.) respectively.

Texture Analyser, TA-XT2i (Stable Micro Systems, UK) which is equipped with a 25 kg load cell and calibrated with 5 kg standard dead weight was used for firmness of *Ghewar*. Before starting the test, the probe was calibrated to a distance of 50 mm. For this test, Warner - Bratzler blade (HDP/WBR; Warner Bratzler Rectangular notch blade) probe was used. The probe was brought close to the product surface. During analysis, probe travelled to a distance of 15 mm for cutting the product and returned to original position. This operation generated a force-time curve. The highest positive peak force from the force-time curve was taken as firmness of the product and expressed in terms of Newton (N). For morphological features, three *Ghewar* were randomly picked from each lot of most preferred samples and weights were measured using an electronic weighing balance (Model No. BSA224S-CW; max-220g and accuracy 0.0001g; Sartorius Group, Germany). Similarly, thickness and diameter were measured using a Vernier calipers, digital micrometer (Model No. 293-821, MDC-25SB, Mitutoyo, Japan; range-0-25 mm and accuracy 0.001mm) and metric scale.

Sensory evaluation through fuzzy logic

Eleven healthy judges, who were willing to do sensory evaluation, didn't have any habit of smoking or beetles leaves chewing and were familiar with *Ghewar*. They were selected from the faculty and research scholars of Department of Food Engineering and Department of Food Science and Technology, NIFTEM, Sonepat, Haryana. Experts were well acquainted with the quality attributes- colour & appearance, flavour, sweetness and body & texture which were selected for sensory analysis before actual evaluation. The four samples coded as S1, S2, S3 and S4 were served in proper packed condition at room temperature to the judges who were instructed to do the sensory evaluation rapidly but not in rush. It was suggested to use lukewarm water for rinsing of face after each evaluation. Judges were also directed to put a tick (√) against the correct scale factors namely poor, fair, good, very good and excellent for each quality attributes. Along with these, they were also asked to grade the quality attributes in general on the relative scale factors, viz. not at all important, somewhat important, important, highly important, and extremely important (Hamr *et al*., 2017[14]; Routary and Mishra, 2012[15]; Uprit and Mishra, 2002[18]; Jaya and Das, 2003[19]; Mukhopadhyay *et al*., 2013[20]; Giusti *et al*., 2008[21]; Sinija and Mishra, 2011[22]).

The major steps followed during fuzzy modeling of sensory scores are-

Calculation of overall sensory scores of all *Ghewar* samples in the form of triplets -

The first step for calculation of overall sensory scores is to find out "triplets" for sensory scores for each quality attributes such as SCA (colour & appearance), SF (flavour), SS (sweetness) and SBT (body and texture) using Eq.1 and Table 2. For example, in case of sample S1 and its colour & appearance attribute (CA), value of triplet, S1CA will be,

$$S1CA=\frac{(0(0\ 0\ 25)+1(25\ 25\ 25)+1(50\ 25\ 25)+5(75\ 25\ 25)+4(100\ 25\ 0)}{(0+1+1+5+4)} \quad \ldots\ldots (1)$$

Where, the numbers 0, 1, 1, 5, 4 on the numerator of the above equation are representing the number of judges (Table 2) who rated the *Ghewar* S1 as poor, fair, good, very good and excellent scores respectively. Triplets linked with these have been taken from Table 1.Fig. 1 depicts the distribution pattern of 5-point sensory scales. The first figure in triplet is designated as coordinate of abscissa at which the value of membership function is 1. Second and third number of the triplet denote the distance to left and right of the first number respectively where the membership function is zero. In Fig. 1,

triangle p q r indicates membership function of poor category; triangle p r_1 s indicates membership function of fair category, and so on (Das, 2005[9]; Meena *et al*., 2011[11]; Chakraborty *et al*., 2013[13]; Hamr *et al*., 2017[14];Sinija and Mishra, 2011[22]).

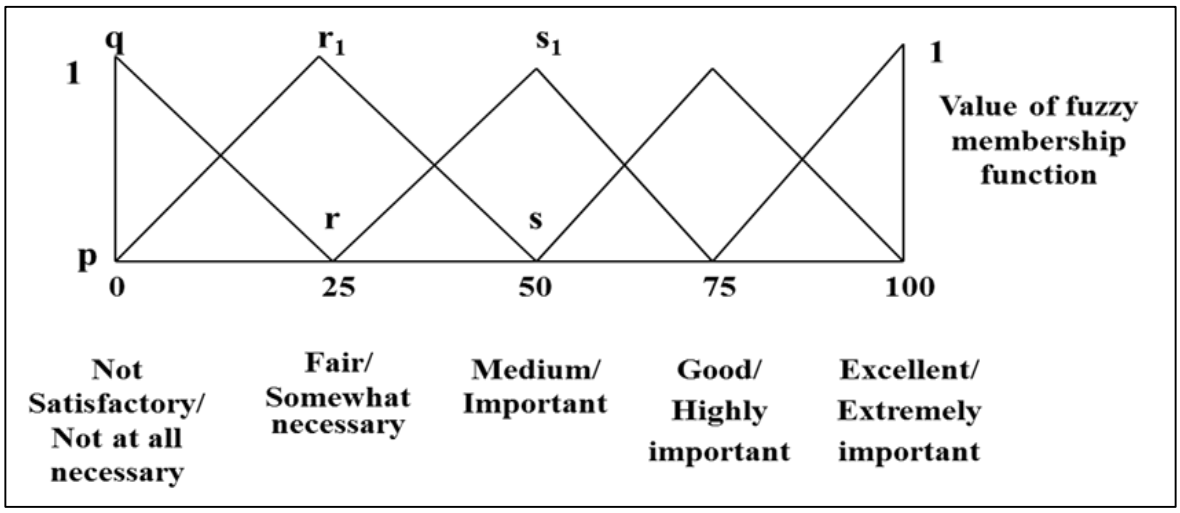

Fig 1: Triplets linked with triangular membership function of 5-point sensory scale (Das, 2005[9]; Meena *et al*., 2011[11])

Table 1: Triplets related with 5-point sensory scale

Poor	Fair	Good	Very good	Excellent
0 0 25	25 25 25	50 25 25	75 25 25	100 25 0

After these the triplets for each quality attributes like QCA (colour & appearance), QF (flavour), QS (sweetness) and QBT (body & texture) were calculated in general using Eq.1, sensory scores given in Table 3 and sets of triplets given in Table 1. Triplet related with overall sensory scores of each *Ghewar* sample was calculated using following Eq. 2 (Das, 2005[9]; Sinija and Mishra, 2011[22]).For S1, the overall sensory score was determined by:

$$SO1 = S1CA \times QCArel + S1F \times QFrel + S1S \times QSrel + S1BT \times QBTrel \ldots\ldots\ldots (2)$$

Where, S1CA, S1F, S1S, and S1BT are representing the triplet values of sensory scores of colour & appearance, flavour, sweetness and body & texture of S1 and QCA_{rel}, QF_{rel}, QS_{rel}, and QBT_{rel} are the triplets related with the relative weightage of different quality attributes of *Ghewar* as mentioned earlier. The similar method was followed for the determination of the overall scores for all samples. The product of multiplication of a triplet (p q r) with another triplet (l m n) was calculated according to the Eq. 3 (Das, 2005[9]; Meena *et al*., 2011[11]; Sinija and Mishra, 2011[22]):

$$(p\ q\ r) \times (l\ m\ n) = (p \times l\ p \times m + l \times q\ p \times n + l \times r) \ldots\ldots\ldots (3)$$

Table 2: Judges' preference for specific quality characteristics of *Ghewar* samples and triplets related with sensory scores

Sensory quality characteristics of *Ghewar* samples	Poor	Fair	Good	Very Good	Excellent	Sensory scores triplet
Colour and appearance (CA)						
S1	0	1	1	5	4	S1CA=(77.2725.0015.91)
S2	0	1	4	4	2	S2CA=(65.9125.0020.45)
S3	0	3	5	3	0	S3CA=(50.0025.0025.00)
S4	0	1	3	4	3	S4CA=(70.4525.0018.18)
Flavour (F)						
S1	0	2	3	3	3	S1F=(65.9125.0018.18)
S2	0	1	5	3	2	S2F=(63.6425.0020.45)
S3	0	4	4	3	0	S3F=(47.7325.0025.00)
S4	0	1	5	4	1	S4F=(61.3625.0022.73)
Sweetness (S)						
S1	0	1	1	4	5	S1S=(79.5425.0013.63)
S2	0	1	2	5	3	S2S=(72.7225.0018.18)
S3	0	2	6	3	0	S3S=(52.2725.0025.00)
S4	0	1	1	5	4	S4S=(77.2725.0015.91)
Body & Texture (BT)						
S1	0	1	1	5	4	S1BT=(77.2725.0015.91)
S2	0	2	3	6	0	S2BT=(59.1025.0025.00)
S3	0	2	2	7	0	S3BT=(61.3625.0025.00)
S4	0	0	2	6	3	S4BT=(77.2725.0018.18)

Table 3: Judges' total preference for specific quality characteristics of *Ghewar* in general and the triplets related with those scores

Quality characteristics	NI	SI	I	HI	EI	Sensory scores triplet	Triplets for relative weightage
Colour and Appearance	0	0	2	6	3	QCA= (77.2725.0018.18)	QCA_{rel}=(0.25560.08270.0601)
Flavour	0	1	5	4	1	QF= (61.3625.0022.73)	QF_{rel}= (0.20300.08270.0752)
Sweetness	0	0	3	5	3	QS= (75.0025.0018.18)	QS_{rel}= (0.24810.08270.0601)
Body & texture	0	0	1	3	7	QBT= (88.6425.009.09)	QBT_{rel}= (0.29320.08270.0301)

QCA- triplet for colour & appearance, QF - triplet for flavour, QS - triplet for sweetness and QBT - triplet for body & texture; NI- not at all important, SI- somewhat important, I- important, HI- highly important, EI- extremely important; QCA_{rel}, QF_{re}, QS_{rel}, QBT_{rel} are triplet for relative weightage of quality attributes colour & appearance, flavour, sweetness and body & texture.

Calculation of overall membership functions (OMFs) for *Ghewar* samples on standard fuzzy scale-

Fig. 2 illustrates the triangular distribution pattern for 6-point sensorial scale (named as F1, F2, F3, F4, F5 and F6) which is commonly known as standard fuzzy scale. Membership function for every sensorial scale follows triangular distribution pattern in which the values of membership functions varies from 0 to 1 and represented by a set of 10 numbers as shown below.

$$\left.\begin{aligned} F1 &= (1, 0.5, 0, 0, 0, 0, 0, 0, 0, 0) \\ F2 &= (0.5, 1, 1, 0.5, 0, 0, 0, 0, 0, 0) \\ F3 &= (0, 0, 0.5, 1, 1, 0.5, 0, 0, 0, 0) \\ F4 &= (0, 0, 0, 0, 0.5, 1, 1, 0.5, 0, 0) \\ F5 &= (0, 0, 0, 0, 0, 0, 0.5, 1, 1, 0.5) \\ F6 &= (0, 0, 0, 0, 0, 0, 0, 0, 0, 5, 1) \end{aligned}\right\} \quad \ldots\ldots\ldots (4)$$

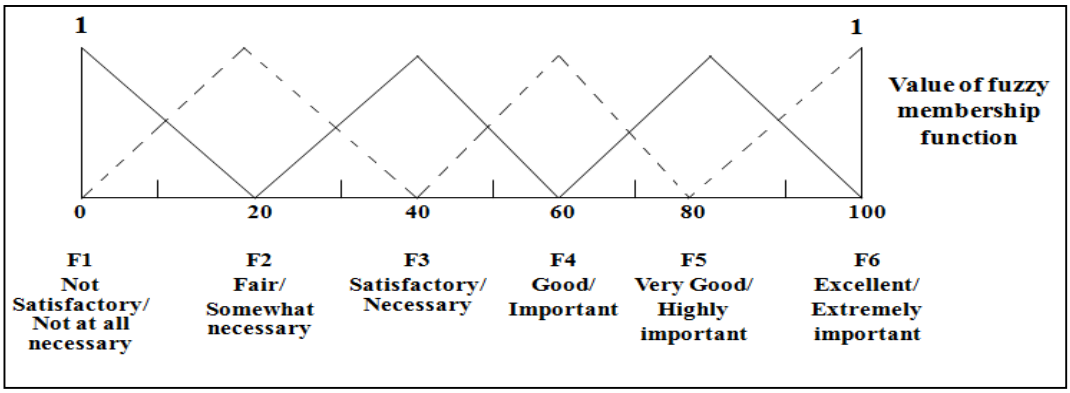

Fig 2: Standard fuzzy scale (Das, 2005[9]; Meena *et al*., 2011[11])

The membership function of a particular triplet (a b c) was shown graphically in Fig. 3. The value of membership function is 1 when the value of abscissa is a or 0 when the value of abscissa is greater than (a + c) or less than (a - c). Bx is the value of fuzzy membership function (Sinija and Mishra, 2011[22]) which can be estimated for each sample at x = 0,10,20,30,40,50,60,70,80,90 and100 using Eq. 5. So, the values of Bx will be found in the form of a set of ten numbers.

$$\left.\begin{aligned} Bx &= \frac{x-(a-b)}{b} && \text{for } (a-b) < x < a \\ Bx &= \frac{(a+c)-x}{c} && \text{for } a < x < (a+c) \\ Bx &= 0 && \text{for } x < (a-b) \text{ and } x > (a+c) \end{aligned}\right\} \quad \ldots..(5)$$

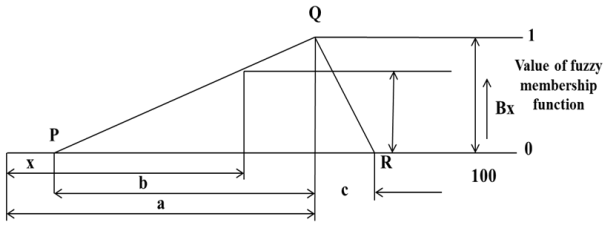

Fig 3: Graphical illustration of a triplet (a, b, c) for overall sensory score along with its membership function (Das, 2005[9])

Assessment of similarity values and ranking of *Ghewar* samples and ranking of various quality characteristics of *Ghewar* samples in general

After calculating B values (Eq. 5), similarity values of each sample were calculated using Eq.as below-

$$Sm(F, B) = \frac{F \times B'}{\text{Maximum } (F \times F' \text{ and } B \times B')} \quad \ldots\ldots\ldots (6)$$

Where, Sm= similarity value of any sample

F′= transpose of matrix F

B′= transpose of matrix B

After determining similarity values i.e. Sm (F1, B1) to Sm (F6, B1) for S1, the highest similarity value was obtained through comparison of all similarity values of that particular sample. After the determination of overall qualities of all four samples, following the same process, they were ranked on the basis of highest similarity value. The similarity values of *Ghewar* samples in general and individual quality attributes were calculated from standard fuzzy scale, triplets associated with quality characteristics in general and triplets linked with overall sensory scores of each quality attributes.

Statistical and fuzzy logic analysis

Statistical significance of the data obtained for the market samples of *Ghewar* was analysed employing one way ANOVA using SPSS software (version 16.0, USA).Critical differences were determined for statistical significance between treatments as suggested by Sundararaj *et al*.(1972)[23]. The mean differences were calculated using the Post Hoc-Duncan test ($P \leq 0.05$). Fuzzy logic analysis of the experimental sensory data in the present investigation was determined using a mathematical program Matlab™ (version, 2010) (Das, 2005[9]).

Results and Discussion

Physico-chemical attributes of *Ghewar*

Variations in all constituents of market *Ghewar* (i.e. moisture, protein, fat, total ash, starch, reducing sugar, free fatty acids and peroxide value) were statistically significant ($P \leq 0.05$) as presented in Table 4. Moisture content of *Ghewar* samples ranged from 14.08 (S4)-19.48% (S3), protein 4.23 (S3)-7.98% (S4), fat 33.67 (S3)-44.90% (S1), total ash 0.07 (S4)-0.53% (S3), reducing sugar 24.19 (S4)-32.93 % (S3), free fatty acids 0.13(S1)-0.23%(S2) and peroxide value 4.00 (S4)-8.00 (S2) milli equiv O_2/kg oil. It was observed that the compositional

variation are quite close to *Ghewar* prepared in laboratory as reported by Saxena *et al*. (1996)[1]. This difference in chemical composition of *Ghewar* samples collected from different shops may be attributed to the following reasons-1) types of raw ingredients used; 2) manufacturing practices and frying conditions; 3) the difference in the concentration and amount of sugar syrup added to *Ghewar* during soaking and time duration for which *Ghewar* was soaked in this sugar syrup as per the consumer's preference. The colour of market samples varied from golden yellow at the surface and light brown at the bottom to cream colour at the surface with golden brown at the bottom. However, dark brown and deep yellow colour *Ghewar* also found popular in the market. L*, a* and b* (colour) values of *Ghewar* samples ranged from 25.93 (S5)-58.24 (S4), 13.13 (S2)-15.99 (S4) and 12.70 (S4)-30.35 (S5), respectively. The difference in colour may be due to the extent of product frying in fat, temperature of frying, number of cycles for which that fat was used for frying, addition of food colour like- saffron, soaking of the product in sugar syrup and concentration of sugar syrup. The variation in soaking conditions and storage conditions were may be responsible for variation in water activity of *Ghewar* samples which was ranging from 0.71 (S4)-0.79 (S3) as shown in Table 5a.

All the markets samples had a typical disc like shape but varying weight, diameter, thickness and firmness distinguished one from another. Average values of firmness, weight, diameter, thickness of the *Ghewar* from different cities are presented in Table 5b. The average ranges for firmness of the *Ghewar* samples were 8.19-25.20 N. Maximum firmness (25.20 N) was observed in samples from S4 while least (8.19 N) in samples collected from S2. Statistical analysis showed that the firmness values of S4 samples were significantly higher ($P \leq 0.05$). The samples collected from S1 were observed to have the highest diameter (20.10 cm), whereas S4 samples had least (7.50 cm). The thickness of *Ghewar* was significantly different ($P \leq 0.05$) from each other and varied 1.90 cm (S2) – 3.50 cm (S1). Weight per piece of market samples varied from 74 (S3) - 508 g (S1).

Table 4: Chemical composition of *Ghewar* collected from different markets

Sample	Moisture (%)	Protein (%)	Fat (%)	Total ash (%)	Reducing sugar (%)	Free fatty acids (%)	Peroxide Value (milli equiv. O_2/kg oil)
Range	14.08-19.48	4.23-7.98	33.67-44.90	0.07-0.53	24.19-32.93	0.13-0.23	4.00-8.00
S1	15.33±0.61^{a}	6.24±0.32^{b}	43.37±1.41^{a}	0.10±0.02^{b}	28.22±0.84^{b}	0.14±0.01^{c}	4.67±0.58^{c}
S2	17.64±0.54^{b}	5.26±0.58^{c}	40.70±0.98^{b}	0.12±0.03^{b}	31.35±0.71^{a}	0.21±0.02^{a}	7.67±0.58^{a}
S3	18.62±0.75^{b}	4.39±0.18^{d}	34.50±0.86^{c}	0.49±0.06^{a}	32.29±0.62^{a}	0.15±0.01^{c}	6.33±0.58^{b}
S4	14.49±0.54^{a}	7.55±0.38^{a}	40.30±0.40^{b}	0.11±0.04^{b}	26.28±0.51^{c}	0.18±0.01^{b}	4.67±0.58^{c}

(n=3, mean ± SD); S1, S2, S3 and S4 are *Ghewar* samples from four different retail markets

Means with different superscripts within a column for a particular parameter differ significantly ($P \leq 0.05$).

Table 5a: Physical characteristics (colour and water activity) of *Ghewar* collected from different markets

	L*	a*	b*	Water activity (a_w)
Range	25.93-58.24	9.11-14.76	14.64-30.35	0.71-0.79
S1	56.34±0.90^{a}	11.38±0.41^{b}	25.52±0.46^{b}	0.75±0.01^{a}
S2	46.16±1.02^{c}	13.99±0.82^{a}	16.73±0.54^{c}	0.77±0.01^{a}
S3	50.59±2.06^{b}	10.77±0.64^{bc}	15.25±0.61^{d}	0.78±0.01^{a}
S4	26.32±0.43^{d}	9.86±0.65^{c}	29.53±0.94^{a}	0.75±0.02^{a}

(n=3, mean ± SD); S1, S2, S3 and S4 are *Ghewar* samples from four different retail markets

Means with different superscripts within a column for a particular parameter differ significantly ($P \leq 0.05$).

Table 5b: Physical characteristics (morphological and textural) of *Ghewar* collected from different markets

	Weight (g)	Diameter (cm)	Thickness (cm)	Firmness (N)
Range	74.00-508.00	7.50-20.10	1.90-3.50	8.19-25.20
S1	505.33±2.52^{a}	19.23±1.10^{a}	3.40±0.10^{a}	18.88±2.90^{b}
S2	104.67±3.06^{c}	12.97±0.15^{b}	1.97±0.06^{c}	9.51±1.18^{d}
S3	77.00±1.73^{d}	10.07±0.12^{d}	2.13±0.15^{c}	13.10±0.88^{c}
S4	253.33±1.53^{b}	11.27±0.25^{c}	3.03±0.06^{b}	23.26±1.69^{a}

(n=3, mean ± SD); S1, S2, S3 and S4 are *Ghewar* samples from four different retail markets

Means with different superscripts within a column for a particular parameter differ significantly ($P \leq 0.05$).

Sensory analysis using fuzzy logic

The sensory analysis data for the selected market samples of *Ghewar viz.*, S1 to S4 were presented in Table 2.Using the sensory analysis data and triplets associated with the sensory scores presented in Table 1, the sensory score triplets were calculated through Eq.1. In the present study, several sensory scores like "not at all important (NI), somewhat important (SI) etc. were considered for the quality attributes in general and the triplets related with sensory scores of quality attributes *viz.*, flavour, body and texture, etc. of *Ghewar* samples in general were also determined in the same way as the sensory scores were earlier determined for *Ghewar* samples. Table 3 represents the sensory scores for the quality criteria of *Ghewar* in general, their associated triplets and relative weightage of the concerned quality attributes. Overall sensorial scores of all the *Ghewar* samples were found using Eq. 2. Multiplication process of triplets as described in Eq.4 was used to multiply the related triplet values of the sensory scores of *Ghewar* samples and their corresponding relative weightage of quality attributes i.e. triplets for overall sensory scores (OSS) of S1 denoted by SO1 was calculated as:

$$SO1 = (77.27\ \ 25.00\ \ 15.91) \times (0.2556\ \ 0.0827\ \ 0.0601) + (65.91\ \ 25.00\ \ 18.18) \times (0.2030\ \ 0.0827\ \ 0.0752) + (79.54\ \ 25.00\ \ 13.63) \times (0.2481\ \ 0.0827\ \ 0.0601) + (77.27\ \ 25.00\ \ 15.91) \times (0.2932\ \ 0.0827\ \ 0.0301) \quad \ldots\ldots\ldots\ldots (7)$$

Similarly, the triplets related with overall sensory scores for the remaining three samples were also calculated and given below.

$$\left.\begin{aligned} SO1 &= (75.52\ \ 49.06\ \ 32.50) \\ SO2 &= (65.13\ \ 46.62\ \ 36.12) \\ SO3 &= (52.90\ \ 42.26\ \ 36.37) \\ SO4 &= (72.30\ \ 48.68\ \ 34.36) \end{aligned}\right\} \quad \ldots\ldots\ldots (8)$$

Determination of Overall Membership Functions of Sensory Scores on Standard Fuzzy Scale

Eq.5 was used for the calculation of the values of OMF (Bx) of sensory scores of the samples on standard fuzzy scale. The triplets for overall sensory scores of S1 i.e. SO1=75.5249.0632.50 was used in this calculation. It was considered from the triplet that a=75.52, b=49.06, and c=32.50. Finally, using Eq.5 and values of a, b, c, the values of Bx at x=0, 10…100 were obtained as B1= (0 0 0.0722 0.2760 0.4798 0.6837 0.8875 1.000 0.8622 0.5545). Similarly, OMFs of the remaining three samples i.e. SO2, SO3 and SO4 were also determined and given in Table 6.

Table 6: Overall membership function values of various samples

Overall Membership Function	Values									
B1	0.0000	0.0000	0.0722	0.2760	0.4798	0.6837	0.8875	1.0000	0.8622	0.5545
B2	0.0000	0.0320	0.2465	0.4610	0.6755	0.8900	1.0000	0.8652	0.5883	0.3115
B3	0.0000	0.2215	0.4581	0.6947	0.9314	1.0000	0.8048	0.5298	0.2549	0.0000
B4	0.0000	0.0000	0.1311	0.3365	0.5419	0.7473	0.9528	1.0000	0.7759	0.4849

Determination of Similarity values of prepared *Ghewar* samples with their Ranking

The similarity values of *Ghewar* samples were determined using Eq. 6 where denominators and numerator were calculated through the process of matrix multiplication using the values of OMF of sensory scores and membership function of standard fuzzy scales. For *Ghewar* sample S1-F1×B1', F1×F1', and B1×B1' were calculated and values were put into Eq. 6 where Highest value among F1×F1' and B1×B1' was selected as denominator while F1×B1' was selected as numerator of the equation. The similarity value under F1 (not satisfactory) is estimated as 0. Likely, similarity values under remaining categories i.e. F2, F3, F4, F5 and F6 were determined for S1. Similarity values for remaining three samples for different scale factors were also determined and shown in Table 7.

From Table 7 it is clear that the highest similarity values for S1 and S4 fall under the category 'very good', i.e., (0.7141) and 0.6693 respectively. Similarly, the highest similarity values for S2 and S3 fall under the category 'good', i.e., 0.7162 and 0.7038 respectively. The ranking of all samples were carried out after the comparison of maximum similarity values of all samples as S1 > S4 > S3 > S2. Thus, it was clear that *Ghewar* samples obtained from the local market of Jodhpur city and Jaipur city were of higher quality than another two market samples as these *Ghewar* samples have the highest score than other *Ghewar* samples.

Table 7: Similarity values of *Ghewar* samples with ranking

Sensory scales	S1	S2	S3	S4
Not at all satisfactory, F1	0	0.0043	0.0307	0
Fair, F2	0.0581	0.1370	0.2851	0.0803
Satisfactory, F3	0.3134	0.4590	0.6538	0.3535
Good, F4	0.6389	0.7162	0.7038	0.6629
Very Good, F5	0.7141	0.5679	0.3295	0.6693
Excellent, F6	0.2724	0.1631	0.0354	0.2342
Ranking	I	III	IV	II

Bold-faced texts highlight highest similarity values.

Quality ranking of *Ghewar* in general

The ranking of different *Ghewar* samples was also done based on the similarity values of the quality characteristics in general for different scale factors. In order to find the similarity values first the triplets for sensory scores of the quality characteristics in general were used to determine the values of OMF. Rest of the procedures are same to determine the similarity values using Eq. 6. The similarity values for all the quality attributes of *Ghewar* were presented in Table 8.

Table 8: Similarity values of all quality attributes of *Ghewar* in general

Sensory Scales	Colour and appearance	Flavour	Sweetness	Body and Texture
Not at all necessary, F1	0	0	0	0
Somewhat necessary,F2	0	0.0277	0	0
Necessary, F3	0.0618	0.4426	0.0800	0
Important, F4	0.6074	0.9615	0.6800	0.2326
Highly important, F5	0.9417	0.4943	0.8820	0.8827
Extremely important, F6	0.2899	0.0342	0.2258	0.6093
Ranking	I	IV	III	II

Bold-faced texts highlight highest similarity values.

The similarity value of colour and appearance (0.9417) was observed to be highest followed by values of body and texture (0.8827) and sweetness (0.8820) through their comparison so they were considered as highly important quality attributes for *Ghewar* in general, while flavour (0.9615) was rated as an important attribute only. In general, the likeliness towards *Ghewar* samples based on their quality attributes was colour and appearance > body and texture > sweetness > flavour. This study showed that the major quality attributes for *Ghewar* are colour and appearance, body and texture, sweetness and flavour being the least important quality attribute.

Triplet values related with all quality attributes of individual samples and their relative weightage were used for the quality characteristic ranking of individual *Ghewar* samples employing the method as mentioned earlier. The results for all *Ghewar* samples (S1, S2, S3 and S4) are shown in Table 9.

Table 9: Similarity values for quality characteristics of each *Ghewar* sample

Scale factors	Colour and appearance	Flavour	Sweetness	Body and Texture
S1				
Not at all satisfactory, F1	0	0.0289	0	0
Fair, F2	0.0428	0.2793	0.0437	0.0194

Satisfactory, F3	0.2692	0.6569	0.2727	0.2072
Good, F4	0.5812	0.7181	0.5873	0.5302
Very Good, F5	0.7306	0.3300	0.7331	0.7864
Excellent, F6	0.3137	0.0332	0.3097	0.4059
S2				
Not at all satisfactory, F1	0	0.0326	0	0.0039
Fair, F2	0.1116	0.2891	0.0817	0.1324
Satisfactory, F3	0.4187	0.6736	0.3535	0.4474
Good, F4	0.6947	0.6945	0.6582	0.7116
Very Good, F5	0.6031	0.3006	0.6654	0.5807
Excellent, F6	0.1889	0.0289	0.2358	0.1681
S3				
Not at all satisfactory, F1	0.0416	0.1589	0.0346	0
Fair, F2	0.3085	0.6079	0.2966	0.1054
Satisfactory, F3	0.6661	0.7976	0.6598	0.4014
Good, F4	0.6773	0.4112	0.6885	0.6857
Very Good, F5	0.3012	0.0464	0.3157	0.6167
Excellent, F6	0.0314	0	0.0339	0.1945
S4				
Not at all satisfactory, F1	0	0.0415	0	0
Fair, F2	0.0827	0.3185	0.0566	0.0192
Satisfactory, F3	0.3553	0.6861	0.3014	0.2060
Good, F4	0.6591	0.6681	0.6152	0.5272
Very Good, F5	0.6633	0.2725	0.7162	0.7836
Excellent, F6	0.2339	0.0249	0.2884	0.4068

Bold-faced texts highlight highest similarity values.

From Table 9, It was observed that the similarity value of S1 for body and texture under 'very good' category' (i.e. 0.7864) is maximum. This was followed by sweetness (very good, 0.7331), colour and appearance (very good, 0.7306); flavour (good, 0.7181). So it became clear that body and texture is the strongest quality attribute of S1 while flavour is the weakest hence improving the flavour of the *Ghewar* can increase its marketability. Thus, quality attribute ranking of individual sample was obtained and shown in Table 10.

Table 10: Ranking of quality attributes for samples

Sample	Ranking of quality attributes
S1	Body and texture (very good) > Sweetness (very good)> Colour and appearance (very good) > Flavour (good
S2	Sweetness (very good)> Body and texture (good)> Colour and appearance (good)> Flavour (good)
S3	Sweetness (good)> Body and texture (good)> Colour and appearance (good)> Flavour (satisfactory)
S4	Body and texture (very good) > Sweetness (very good) > Colour and appearance (very good) > Flavour (good)

Conclusion

Although *Ghewar* is considered traditional sweet of Rajasthan, but it is very popular and has a very wide market in Northern India and abroad. Samples procured from market of different cities of northern India showed wide variations in their physico-chemical and textural attributes. Statistical analysis revealed that *Ghewar* procured from the market of Jodhpur city (S1) had good honeycomb structure and soft body, pleasant taste with moderate sweetness. Results obtained during the present investigation are of vital importance to protect the age old traditional knowledge and to add a new item in the organized food processing sector with uniform quality and improved safety. Employing fuzzy logic modeling on the sensory evaluation data, it was observed that the *Ghewar* samples from the local market of Jodhpur city and Jaipur city ranked first and second, followed by samples from Ajmer and Sonepat on third and last place on the basis of quality attributes of these samples. Vital quality attributes of *Ghewar* sample in general were sequenced as: Colour and appearance > body and texture > sweetness>flavour. Colour and appearance, body and texture and sweetness were the strongest attributes for all the samples. In contrast, for all other samples flavour was determined as the weakest attribute.

Acknowledgement

The economic assistance and other facilities provided by National Institute of Food Technology Entrepreneurship and Management (NIFTEM) are thankfully acknowledged for conducting the project work.

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