Evaluation of selected physico-chemical, colour and textural characteristics of market *Gulabjamun*

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Received: 12 May 2021 / Accepted: 10 October 2021 / Published online: 22 December 2021
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Abstract: *Gulabjamun* is one of the most popular traditional Indian dairy products. The various characteristics such as physico-chemical, colour and textural quality characteristics of six brands of *Gulabjamun* were investigated which plays important role in its marketing and consumer acceptance. The fat and unit-weight of market *Gulabjamun* were found statistically highly significantly different ($p<0.01$). The moisture content, percent absorbed sugar, GMD, sphericity of market *Gulabjamun* were found statistically highly significant ($p<0.001$). Apparent density was statistically significant ($p\leq 0.05$). The fat, moisture and percent absorbed sugar of market *Gulabjamun* were ranged between 6.47 ± 0.37 to $12.32\pm 1.19\%$, 40.51 ± 0.70 to $47.53\pm 0.42\%$ d.b. and 12.24 ± 0.25 to $37.65\pm 0.52\%$, respectively. The geometrical mean diameter, apparent density and unit-weight varied between 3.09 ± 0.01 to 3.60 ± 0.06 cm, 1.40 ± 0.05 to 1.84 ± 0.32 g/cm³ and 24.21 ± 0.29 to 44.40 ± 0.45 g, respectively. Colour characteristics i.e. L^* , a^* , b^* and browning index (BI) market *Gulabjamun* were found statistically highly significant ($p<0.001$). The variation in the values of L^* , a^* , b^* and browning index was observed to be between 34.70 ± 0.41 to 46.46 ± 0.55 , 3.92 ± 0.28 to 6.50 ± 0.39 , -2.30 ± 0.59 to 11.48 ± 0.48 , and 2.77 ± 1.33 to 36.98 ± 0.56 , respectively. The hardness, cohesiveness, gumminess, chewiness and resilience were found statistically highly significant ($p<0.001$) whereas springiness was found statistically non-significant ($p\geq 0.05$). The hardness, springiness, gumminess, chewiness, cohesiveness and resilience ranged between 3.36 ± 0.56 N to

10.71 ± 1.66 N, 0.52 ± 0.29 to 0.88 ± 0.12 , 0.86 ± 0.13 N to 2.14 ± 0.28 N, 0.44 ± 0.24 N to 1.88 ± 0.30 N, 0.18 ± 0.01 to 0.25 ± 0.01 and 0.24 ± 0.01 to 0.35 ± 0.02 , respectively. It was observed that the size of market *Gulabjamun* (3.09 ± 0.01 to 3.60 ± 0.06 cm) may be taken as 3.0-3.6 cm for development of process equipments for *Gulabjamun* manufacturing.

Keywords: Colour, *Gulabjamun*, Market, Sphericity, Texture

Introduction

India is the largest milk producing country in the world with about 19% contribution in total world milk production. The India's total milk production is estimated to have increased to 187.7 million tonne (MT) during year 2018-19 from 176.35 million tonnes during the year 2017-18 (NDDB, 2019). About half of total milk produced, is consumed in the liquid form and the remaining half is used for manufacturing of various milk products such as ghee, curd, butter, *khoa* and *khoa* based products, paneer, cheese, *chhana* and *chhana* based products, ice cream and milk powders. A traditional Indian dairy product (TIDP) refers to the products which are indigenous to India and some Asian countries such as Nepal, Bangladesh and Pakistan (Aneja et al. 2002). The various efforts towards its manufacturing including heat desiccation, heat coagulation, fermentation and use of different ingredients resulted into quality products and there are number of sweetmeats (TIDPs), their varieties and brands, available in the Indian market.

Gulabjamun is the fat deep fried and sugar soaked traditional dairy product popular throughout India. Traditionally, it is prepared by producing the homogeneous dough mass, by proper mixing and kneading of *Khoa*, *Maida*, and baking powder. *Maida* is used as binding agent which and it helps to prevent disintegration of *Gulabjamun* balls at time of frying. The balls prepared from dough are deep-fat fried in frying medium (ghee or refined vegetable oil) until a golden brown colour obtained and subsequently soaked into sugar syrup. Deep-fat frying is a very complex process. It is industrially important food processing operation which increases the acceptability of a food product. The fried food undergoes different properties changes like textural and chemical changes etc. The moisture and fat content of finished product significantly depends upon frying conditions

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such as frying time and frying temperature. In general, the desirable characteristics of *Gulabjamun* are brown colour, smooth and spherical shape, soft and slightly spongy body (free from lumps), uniform granular texture with pleasant cooked flavour (Vasava et al. 2018). There are mainly two key processes, which are very important in *Gulabjamun* production i.e. frying of *Gulabjamun* balls and its soaking in sugar syrup (after frying of balls). The deep fat frying and sugar soaking of *Gulabjamun* are most important with respect to its chemical, physical and textural properties.

The characteristics of market sample of various Indian dairy products have been reported by several researchers in published literature such as *paneer* (Rajorhia et al. 1984; Goyal et al. 2007; Desale et al. 2009; Godbole et al. 2013; Peter et al. 2015; Ranjan Naik et al. 2016), *Rasogolla* (Desai et al. 1993; Srinivasa et al. 2017), brown *peda* (Londhe and Pal, 2008), *Halvasan* (Patel et al. 2010), *Dodaburfi* (Chawla et al. 2011), *KhoaJalebi* (Jayaraj and Pagote, 2012), *Thabdi* (Patel et al. 2012), *kheer mohan* (Meena et al. 2014) and *Khoa-peda* (Singh et al. 2018). However, the characteristics of market sample of *Gulabjamun* are rarely or not reported in published literature.

The characteristics of any food are very important parameters for food processing operation, heat and mass transport processes, food transport and handling, and for design of process, modelling and optimization. It will be useful for designing particular equipment or determining the behaviour of the product during its handling. The present study was undertaken to investigate the selected physico-chemical, colour and textural characteristics of the different brands of market *Gulabjamun*.

Material and Methods

Collection of Market Gulabjamun Samples

The various brands of *Gulabjamun* are being manufactured in different parts of India. These are being marketed throughout India in small tin cans or other appropriate packaging materials. For present study, different brands of *Gulabjamun*, manufactured in Nagpur (Maharashtra), Bengaluru (Karnataka), Bikaner (Rajasthan), New Delhi regions along with Karnal (local market), were procured from Delhi and Karnal market. The market *Gulabjamun* samples of different brands were collected as fresh as available in the market. The market samples of *Gulabjamun* were designated as M1, M2, M3 and M4 for established brands in India whereas M5 and M6 for sample from local market of Karnal, Haryana, India.

Physico-Chemical characteristics

Some physico-chemical characteristics, such as fat, moisture, percent absorbed sugar, geometrical mean diameter (GMD), sphericity, apparent density and unit-weight, of *Gulabjamun* were determined.

Fat

Fat content of the samples was estimated using Mojonnier method (BIS, 1981). The fat in the samples was calculated by following equation:

$$\text{Fat (\%)} = \left(\frac{W_d - W}{W_s} \right) \times 100$$

Where, W_s is the weight of the material taken initially for the test (g), W_d is the weight of the dish with the material after drying (g), and W is the weight of the empty dish (g).

Moisture

The moisture content in samples was estimated by the gravimetric method (AOAC, 2005). Following expression was used for determination of moisture on dry basis (% d.b.): ‘ ‘

$$\text{Moisture (\% d.b.)} = \left(\frac{W_s - W_d}{W_d - W} \right) \times 100$$

Where, W_s is the initial weight of the dish with sample (g), W_d is the final weight of the dish with the sample after drying (g), and W is the weight of the empty dish (g).

Percent absorbed sugar

Initial weight of *Gulabjamun* was measured using digital weighing balance. *Gulabjamun* was then placed on a plate and 5 kg weight was applied on plate. After 5 min, the weight of pressed or final *Gulabjamun* was taken. Percentage of absorbed sugar syrup was calculated using following equation (Mohanta, 2014).

$$\text{Absorbed sugar (\%)} = \frac{W_1 - W_2}{W_1}$$

Where, W_1 is the weight of *Gulabjamun* (g) and W_2 is the weight of *Gulabjamun* after weight is applied (g).

Geometrical mean diameter (GMD):

The major, intermediate and minor dimensions of *Gulabjamun* samples were measured as A, B and C, respectively by using a digital vernier calliper (make: Mitutoyo; range: 0-150mm; least count: 0.1 cm). The size of the *Gulabjamun*, in terms of geometrical mean diameter (GMD), was computed using standard equation (Srinivasa et al. 2017; Barnwal et al. 2017):

$$\text{GMD} = (A \times B \times C)^{1/3}$$

Sphericity

Sphericity (Φ) may be referred as the ratio of GMD to the major linear dimension, i.e., length (A). It was computed using the following equation (Srinivasa et al. 2017; Barnwal et al. 2017):

$$\text{Sphericity}, \phi = \frac{\text{GMD}}{A} = \frac{(A \times B \times C)^{1/3}}{A}$$

Apparent density (ρ_{app})

The apparent density (ρ_{app}) of the market *Gulabjamun* sample was computed as mass per unit volume from the following equation:

$$\rho_{\text{app}} = \frac{W}{\left(\frac{4}{3} \pi R^3\right)}$$

Where W is the weight of *Gulabjamun* (g) and R is the radius ($0.5 \times \text{GMD}$) of *Gulabjamun* (cm).

Unit Weight of the *Gulabjamun*

A precision electronic balance (model: KERRO BL 3003; capacity: up to 300 g; least count: 0.001 g) was used to measure unit weight of the market *Gulabjamun* (Srinivasa et al. 2017).

Colour characteristics

The consumer acceptability of *Gulabjamun* is very important and it depends upon the crust colour of it. The colour of market samples *Gulabjamun* was measured using a computer based image analysis technique (Minz et al. 2018). The sample was transferred into wide petri-dish and images of sample were captured in colour desk instrument which was based on reflectance spectroscopy technique. The digital images were processed using Scilab program to compute colour values. This colour value was obtained in terms of lightness, "CIE L" ranging from zero (black) to 100 (white), "CIE a" ranging from +60 (red) to -60 (green) and "CIE b" ranging from +60 (yellow) to -60 (blue). The browning index (BI) value of *Gulabjamun* was calculated using by following relation (Srinivasa et al. 2017; Barnwal et al. 2017).

$$BI = \left[\frac{100 \times (x - 0.31)}{0.17} \right]$$

$$\text{Where, } x = \frac{(a^* + 1.75 \times L^*)}{(5.645 \times L^* + a^* - 3.012 \times b^*)}$$

Textural characteristics

Texture profile of *Gulabjamun* was determined by using texture analyser (TA-XT2i; M/s Stable micro systems; Software: Texture Expert Exceed, Version: 2.55), fitted with a 25 kg load cell and calibrated with 5 kg standard dead weight prior to use (Kumar et al. 2006). *Gulabjamun* was compressed twice in a reciprocating motion to obtain a two-bite texture profile curve using a double compression test. The various test parameters, used throughout the study, for whole, uncut *Gulabjamun* sample were P-75 compression probe, 1 mm/s probe pre-test speed, 0.5 mm/s test speed, 10 mm/s post-test speed, 7.5 mm distance (compression) and 25 ± 1 °C maintained sample temperature. The obtained texture profile curve (TPA) was used to determine the hardness, springiness, cohesiveness, gumminess, chewiness and resilience of the tested market *Gulabjamun* samples.

Statistical analysis

The experimental data for different characteristics such as physico-chemical, colour and textural characteristics were analysed statistically. The Analysis of Variance (ANOVA) for all various characteristics of market *Gulabjamun* were analyzed by SPSS (v. 15. 0) software and 2D-graphs of various characteristics were prepared by using Microsoft Excel-2007 software.

Results and Discussion

Physico-chemical characteristics of market *Gulabjamun* samples

The fat content of market *Gulabjamun* samples (M1, M2, M3, M4, M5 and M6) were found statistically highly significantly different ($p < 0.01$) with each other (Table 1). It varied from $6.47 \pm 0.37\%$ (M3) to $12.32 \pm 1.19\%$ (M6). The fat content of *Gulabjamun* on drained weight basis was reported as about 10% (Aneja et al. 2002). The variation in fat content of *Gulabjamun*, prepared using khoa of Buffalo milk blending with sweet corn milk, was found to be 10.26-14.98% (Patil et al. 2017). The market *Gulabjamun* samples M5 and M6 were observed to be in nearly this range whereas M1, M2, M3 and M4 had lesser fat content. Minhas et al. (1985) reported that the fat content range 9.9 to 16.7% of *Gulabjamun* (prepared by different formulations mix, different frying temperature range and different soaking time range) was more than the fat content of studied market *Gulabjamun*. The moisture content of studied market *Gulabjamun* samples were found statistically highly significant ($p < 0.001$) among each other (Table 2). The moisture content of samples M3, M4, and M5 were statistically at par with each other. The moisture content of M3, M5 and M6 were statistically at par with each other whereas that of M1, M3, M4 and M6 was statistically different with each other (Figure 1). It varied from 40.51 ± 0.70 %d.b. (M6) to 47.53 ± 0.42 %d.b. (M2). The variation of moisture content of *Gulabjamun*, prepared by using different

Fig. 1 Moisture, percent absorbed sugar, unit-weight and L^* values of Market *Gulabjamun*

Table 1 Fat, apparent density, b^* , browning Index and hardness of Market *Gulabjamun*

Market <i>Gulabjamun</i>	Fat (%)	Apparent density (g/cm ³)	b^*	Browning Index	Hardness (N)
M1	8.53 ^{cd} ±0.43	1.56 ^a ±0.04	3.17 ^a ±0.09	17.52 ^a ±0.80	5.78 ^{bc} ±0.28
M2	9.59 ^{bc} ±0.27	1.84 ^a ±0.32	5.63 ^b ±0.27	26.21 ^b ±1.32	7.15 ^{ab} ±0.38
M3	6.47 ^c ±0.37	1.57 ^a ±0.03	11.48 ^a ±0.48	36.98 ^a ±0.56	10.71 ^a ±1.66
M4	7.63 ^{de} ±0.35	1.84 ^a ±0.24	5.39 ^b ±0.02	24.53 ^b ±1.63	9.95 ^a ±1.63
M5	10.29 ^b ±0.37	1.40 ^a ±0.05	-2.30 ^d ±0.59	2.77 ^d ±1.33	7.61 ^{ab} ±2.22
M6	12.32 ^a ±1.19	1.83 ^a ±0.07	2.57 ^c ±0.34	20.09 ^c ±0.80	3.36 ^c ±0.56
ANOVA for fat, apparent density, b^* , browning Index and hardness of Market <i>Gulabjamun</i>					
DF	5	5	5	5	5
SS	64.285	0.519	307.255	1918.404	109.474
MS	12.857	0.104	64.451	383.681	21.895
F-Value	36.782	3.479	471.250	295.914	11.958
Prob	<0.0001***	0.036*	<0.0001***	<0.0001***	<0.0001***

Mean values with the same superscript are not significantly different; * $p \leq 0.05$; *** $p \leq 0.001$; $n=3$

level of *Khoa* and *Paneer*, were 35.07-37.50 % (Singh et al. 2019), which is slightly lower as compared to moisture content of studied market *Gulabjamun*. The percent absorbed sugar in *Gulabjamun* of market samples were found statistically highly significant ($p < 0.001$) with sample type (Table 2) and their values (Figure 1) ranged between 12.24±0.25 % (M1) to 37.65±0.52% (M3). The percent absorbed sugar of M1, M4 and M5 were statistically at par with each other whereas M2, M3 and M6 were not statistically at par with each other. The fat, moisture and percent absorbed sugar were found maximum for M6, M3 and M1, respectively whereas minimum for M2, M6 and M3, respectively (Table 1, Figure 1).

The GMD of Market *Gulabjamun* samples were found statistically highly significant ($p < 0.001$) with sample type (Table 2) and the values (Figure 2) varied from 3.09±0.01 cm (M1) to 3.60±0.06 cm (M6). The GMD of samples M1, M3, M4 and M5 were statistically at par with each other whereas that of M2 and M6 was statistically at par with each other (Figure 2). The variation in diameter of market *Rasogolla* was 2.7±0.0 to 3.9±0.1 cm (Srinivasa et al. 2017),

which was similar to the GMD of market *Gulabjamun*. The sphericity of market *Gulabjamun* samples were found statistically highly significant ($p < 0.001$) with sample type (Table 2) and it varied (Figure 3) from 0.94 (M1) to 0.97 (M6). The sphericity of market *Gulabjamun* samples M1, M2, M3 and M4 were statistically at par with each other whereas M1 was statistically different with M5 and M6 samples (Figure 3). The sphericity of *Gulabjamun* may depend on frying temperature of the balls and at lower temperature; balls obtain soft crust which may not retain its shape (spherical). The sphericity of any food near unity (1.00) may be considered as a spherical product for modelling of heat and transfer processes occurring during product production. The apparent density of studied market *Gulabjamun* samples ranged from 1.40±0.05 g/cm³ (1 g/cm³ = 1000 kg/m³) to 1.84±0.32 g/cm³ i.e. M5 (minimum) to M2 (maximum), respectively (Table 1). It was statistically significant ($p \leq 0.05$) with sample type (Table 1). Franklin et al. (2013) found that the average apparent densities of conventionally fried *Gulabjamun* at different temperatures i.e. 125, 135 and 145°C were 0.827, 0.808 and 0.775 g/cm³, respectively. The unit-weight of market *Gulabjamun* samples were found

Fig. 2 Geometric mean diameter (GMD) and *a** values of Market *Gulabjamun*

Table 2 ANOVA for some physical and colour characteristics of Market *Gulabjamun*

Market <i>Gulabjamun</i>	Moisture (%)	Percentage Absorbed sugar (%)	GMD (cm)	Sphericity (cm)	<i>L*</i> (fraction)	<i>a*</i>
DF	5	5	5	5	5	5
SS	105.188	1454.819	0.440	0.002	290.118	16.630
MS	21.040	290.964	0.088	0.000	58.024	3.326
F-Value	96.016	1016.290	7.328	4.498	282.659	20.137
Prob	<0.0001***	<0.0001***	<0.01**	0.015*	<0.0001***	<0.0001***

Mean values with the same superscript are not significantly different; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$; $n = 3$

Fig. 3 Sphericity, springiness, gumminess, and chewiness of Market *Gulabjamun*

statistically highly significant ($p \leq 0.01$) with sample type (Table 3) and their values (Figure 1) varied from 24.21 ± 0.29 g (M1) to 44.40 ± 0.45 g (M6). The unit-weight of *Gulabjamun* sample M1 and M5 were found statistically at par with each other whereas that of M2 and M4 was statistically at par with each other (Figure 1). The samples M3 and M6 were statistically different with each other.

Colour characteristics of market *Gulabjamun*

The colour parameters of market samples *Gulabjamun* were studied using image analysis. Colour characteristics i.e. L^* and a^* (Table 2), b^* and browning index (Table 1) of studied market *Gulabjamun* samples were found statistically highly significant ($p < 0.001$) with sample type (Table 3). The values of L^* (Figure 1) ranged (minimum to maximum) between 34.70 ± 0.41 (M1) to 46.46 ± 0.55 (M3). The a^* values ranged (minimum to maximum) between 3.92 ± 0.28 (M1) to 6.50 ± 0.39 (M2). The values of b^* and

Fig. 4 Cohesiveness and resilience of Market *Gulabjamun* **Table 3** ANOVA for some textural characteristics and unit weight of Market *Gulabjamun*

Market <i>Gulabjamun</i>	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)	Resilience	Unit- weight (g)
DF	5	5	5	5	5	5
SS	0.292	0.007	3.308	3.497	0.20	1242.454
MS	0.058	0.001	0.662	0.699	0.004	207.076
F-Value	2.070	24.407	12.260	10.700	29.584	330.459
Prob	0.140 ^{NS}	<0.0001***	<0.0001***	<0.0001***	<0.0001***	<0.01**

Mean values with the same superscript are not significantly different; NS=non-significant; ** $p \leq 0.01$; *** $p \leq 0.001$; $n=3$

browning index ranged (minimum to maximum) between -2.30 ± 0.59 (M5) to 11.48 ± 0.48 (M3), and 2.77 ± 1.33 (M5) to 36.98 ± 0.56 (M3), respectively (Table 1). The L^* values were found statistically at par with each other (Figure 1) for market *Gulabjamun* samples (i) M2 and M4 (ii) M5 and M6, and (iii) M1 and M6. The M3 sample showed maximum L^* value. It was reported that lightness value (L^*) of *Gulabjamun* Balls depends upon frying temperature of *Gulabjamun* Balls (deep fat frying). Lightness value (L^*) of the *Gulabjamun* Balls (deep fat frying) was ranged from 23.48 to 79.86 which was decreased gradually with increasing frying time (Kumar et al. 2006). In case of a^* values of market *Gulabjamun* samples, the M2, M3, M4 and M6 were found statically at par with each other whereas samples M1 and M5 also found statically at par with each other (Figure 2). The b^* values and browning index were found statistically at par with each other for (i) M1 and M6, and (ii) M2 and M4 (Table 1) in market *Gulabjamun* samples.

Textural characteristics of market *Gulabjamun*

The hardness, cohesiveness, gumminess, chewiness and resilience were found statistically highly significant ($p < 0.001$) whereas springiness was found statistically non-significant ($p \geq 0.05$) with sample type (Tables 1 and 3). The values for hardness (Table 1) ranged (minimum to maximum) between 3.36 ± 0.56 N (M6) to 10.71 ± 1.66 N (M3). The values for springiness, gumminess and chewiness ranged (minimum to

maximum) between, 0.52 ± 0.29 (M6) to 0.88 ± 0.12 (M4), 0.86 ± 0.13 N (M6) to 2.14 ± 0.28 N (M4) and 0.44 ± 0.24 N (M6) to 1.88 ± 0.30 N (M4), respectively (Figure 3). The values for cohesiveness and resilience ranged (minimum to maximum) between, 0.18 ± 0.01 (M3) to 0.25 ± 0.01 (M6), and 0.24 ± 0.01 (M3) to 0.35 ± 0.02 (M6), respectively (Figure 4). The hardness was found statistically at par with each other for market *Gulabjamun* samples (i) M3, M4 and M5 (ii) M1, M2, and M5, and (iii) M1 and M6 (Table 1). In market *Gulabjamun* samples, the cohesiveness and resilience were found statistically at par with each other for (i) M1, M2, M4, and M5, and (ii) M2 and M3 (Figure 4). For market *Gulabjamun* samples, the gumminess was found statistically at par with each other for (i) M2, M3, M4, and M5 (ii) M1, M2 and M5, and (iii) M1 and M6 (Figure 3). The chewiness was observed statistically at par with each other for market *Gulabjamun* samples for (i) M1, M2, M3, and M5 (ii) (i) M1, M2, M5, and M6, and (i) M3 and M4 (Figure 3). Aneja et al. (2002) reported that the hardness (N), springiness (mm), cohesiveness, gumminess (N), chewiness (N.mm) of *Gulabjamun* as 14.09 N, 7.88 mm, 0.123, 1.75 N, and 14.21 N.mm, respectively. So, the hardness, springiness, cohesiveness and chewiness of *Gulabjamun* were found less than market sample of *Gulabjamun*.

Therefore, there was statistically significant difference was observed in the characteristics of selected brands of market *Gulabjamun* samples which may be due to the variations in

various steps at processing, packaging, storage and distribution stages of studied market *Gulabjamun* samples.

Conclusions

The various quality characteristics i.e. physico-chemical, colour and textural characteristics of six brands of *Gulabjamun* were determined and statistical analysis was carried out. The fat and unit-weight of market *Gulabjamun* were found statistically highly significantly different. The moisture content, percent absorbed sugar, GMD, sphericity of studied market *Gulabjamun* samples were found statistically highly significant. Apparent density was statistically significant. The hardness, cohesiveness, gumminess, chewiness and resilience were found statistically highly significant whereas springiness was found statistically non-significant ($p>0.05$). The size of market *Gulabjamun* (3.09 ± 0.01 to 3.60 ± 0.06 cm) may be taken as 3.0-3.6 cm for development of process equipments for *Gulabjamun* production.

Acknowledgement

The authors acknowledge fellowship and infrastructure received from ICAR-NDRI, Karnal to carry out the research work.

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