International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 1840-1848

Received: 18-05-2018
Accepted: 26-06-2018

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Studies on rheological and sensory properties of gluten-free *Gulabjamun* during storage

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Abstract
The present investigation was planned to study the influence of different levels of sago (0.8, 0.9, 1.0 and 1.1 g/ 100g *khoa*) and potato starch (19, 20 and 21g/ 100g *khoa*) on rheological properties of gluten-free *gulabjamun*. Combination of guar gum: xanthan gum @ 0.05: 0.15% (w/w of *khoa*) resulted in the most desirable sensory attributes from amongst all the levels of hydrocolloids studied. The rheological properties of the standardized gluten-free *gulabjamun* were: hardness 3.82±0.083 N, springiness 8.017±0.10 mm, gumminess 1.40±0.01 N, cohesiveness 0.24±0.008, adhesiveness 0.16±0.013 Nmm and chewiness 7.73±0.10 Nmm. Changes in rheological and sensory properties of gluten-free *gulabjamun* packed in pre-sterilized polyethylene terephthalate (PET) bottles were monitored at refrigerated temperature (7±2 °C). Scores for all the sensory attributes decreased during the storage period and it was found that the product had a shelf life of 35 d. There was a significant ($P<0.05$) increase in hardness up to 21st d thereafter a decrease in hardness was observed. There was a significant ($P<0.05$) increase in cohesiveness and gumminess up to 7th d which decreased thereafter. There was a significant ($P<0.05$) increase in chewiness up to 7th d thereafter a decrease in chewiness was observed. There was a significant ($P<0.05$) decrease in adhesiveness up to 7th d thereafter increase in adhesiveness was observed. The springiness of gluten-free *gulabjamun* followed a non-linear pathway there was a significant ($P<0.05$) effect during storage period.

Keywords: Gluten-free, rheology, stabilizers, *gulabjamun*, sago, potato starch, guar gum

Introduction

Gulabjamun, a popular traditional Indian sweet. It has been made in India for generations mainly in the home and confectionaries. *Gulabjamun* is traditionally prepared from dhap variety of *khoa* by kneading with refined wheat flour (maida) which is used as a binding material. The gross chemical composition of *gulabjamun* varies widely depending on a number of factors, such as composition and quality of *khoa* used, type and proportion of ingredients and concentration of sugar syrup. The most liked product should have brown colour, smooth and spherical shape, soft and slightly spongy body, free from both lumps and hard central core, uniform granular texture, with cooked flavour and free from doughy feel and the sweet should be fully succulent with sugar syrup with optimum sweetness. The texture of *gulabjamun* is judged mainly on its sponginess and juiciness, with crumbliness and gumminess being the main negative attributes (Ghosh *et al*. 1986 and Patel *et al.* 1992) [9, 24]. Traditionally *gulabjamun* is prepared using maida (refined wheat flour) as a binding agent. Gluten is the protein present in wheat that holds the dough together and makes the flour pliable and thick and gives it the ability to be kneaded and to accept injected air. *Gulabjamun* which is prepared using maida as an ingredient is not suitable for people suffering from celiac disease for people who are fasting. In India sago, potato starch, shingada (water chestnut), makhana (lotus seeds) and amaranth are permitted during fasting. These ingredients are rich in starch and have good binding properties. Moreover, these ingredients are gluten-free.

In manufacture of gluten-free *gulabjamun*, wheat flour was replaced with sago and potato starch as binding agents, therefore the dough obtained did not have the desired pliability which is obtained when maida is used as binder. Since potato starch lacks protein and sago has very little protein i.e. 0.3%, they are not capable of forming typical porous structure of *gulabjamun* that imparts typical body and texture characteristics to *gulabjamun* and contributing the texture that wheat proteins develop. Moreover, sago and potato starch are different from wheat starch in terms of the size and shape of their granules, so their gelatinization properties, water absorption rate and swelling capacity are not the same.

Consequently, replacing part of the wheat flour with sago/potato starch changes the rheological properties of the dough drastically (Mukprasirt *et al.* 2000) [21].

Many food ingredients and additives can be used to improve the quality of fried foods, but hydrocolloids are the principle category of functional agents that have been widely used in literature (Varela and Fiszman, 2011) [32]. Hydrocolloids have been shown to influence the gelatinization of starches. It is well known that addition of hydrocolloids to starch suspensions causes a synergistic increase in viscosity (Liu *et al.* 2003) [20]. A combination of hydrocolloids (gums) is used in starch-based products to improve stability, modify texture, facilitate processing and improve its gelatinization and rheological properties (Kruger *et al.* 2003; Shi and BeMiller, 2002) [16, 25]. The use of such combinations was found in food products such as bakery and cereal products, fruit fillings, sauces, frozen foods, and confectionary products (Ward and Andon, 2002) [33]. In gluten-free dough, it is necessary to adjust recipes by adding xanthan gum and extra eggs to recipes to add the elasticity (Emerson, 2006) [8]. Use of hydrocolloids such as xanthan gum and methylcellulose gave good results in products in which wheat flour was replaced with other cereals such as rice flour (Mukprasirt *et al.* 2000 and 2001; Amboon *et al.* 2010) [21, 22, 2].

It was observed that when sago and potato starch were used as binders for preparation of gluten-free *gulabjamun*, the experimental products had a hard crust. This resulted in *gulabjamun* with incomplete sugar syrup absorption. The products had a hard central core with a very pasty interior and were found to lack in desirable sweetness and porosity. The absence of gluten in sago/ potato starch based dough entails a lower ability to provide desirable body and texture to the product, so to obtain dough with optimum properties, an agent that will give the formulation the required consistency needs to be added.

Texture is a very essential sensory parameter. It can influence the quality of the final product with respect to shelf life, consumer acceptance as well as processing and handling ability. Certain traditional foods exist wherein texture determines the acceptability of food instead of flavor. Textural attributes of any product needs to be studied thoroughly in order to assess its mechanical behavior during mastication and swallowing. It is also important to know about the rheology of the product so that equipment can be designed in accordance to its behavior under different conditions. Product quality prediction is feasible if rheological data is available under pre-determined manufacturing conditions. Replacing maida with gluten-free ingredietnts like sago and potato starch while preparing gluten free gulabjamun introduces an additional ingredient in the matrix of casein and milk fat. Rheological changes are expected in the developed product. Keeping in view the above facts, this investigation was planned to determine the effect of composition on the rheological characteristics of developed product during storage.

Materials and Methods

Fresh, raw mixed (cow and buffalo) milk was used as the base material for manufacture of *khoa*. The average fat % of the milk was 5.3±0.2 and average MSNF content was 8.6±0.05%. Sago and potato starch powder were procured from local market at Anand, Gujarat. The approximate composition of the sago was 11% moisture, 0.4% total ash, 0.10% acid insoluble ash, 98% starch, 0.30% protein, 0.20% crude fibre; by weight, 100 ppm sulphur dioxide and 4.5-7 pH of aqueous extract, and the approximate composition of potato starch was 18% moisture, 0.1% crude protein, 0.1% crude fat, 0.1% crude fibre, 0.3% crude ash, 78.3% starch and 81.5% carbohydrate; levels/kg. Guar gum and xanthan gum were obtained from Hi Media Laboratories Pvt Ltd., Mumbai. Good quality commercial grade cane sugar of 'Madhur' brand was used for preparing sugar syrup. Refined vegetable oil/Anand cottonseed oil (Anand Regional Co-operative oilseeds growers' Union Ltd. Ahmedabad) was used as frying medium in gluten-free *gulabjamun* preparation.

Caramel flavour was prepared in the laboratory by burning 300g sugar on direct flame in a clean and dry stainless steel vessel. After caramelization was completed (as indicated by a dark brown colour) heating was stopped and 100ml water was added and the ingredients were mixed thoroughly. The mixture was cooled and stored in a clean and dry glass bottle until use. Cardamom was procured from local market at Anand, Gujarat.

Preparation of *Khoa*

Khoa was prepared using standardized milk (4.5% milk fat and 8.5% MSNF) by heat desiccation in a steam jacketed stainless steel open pan operated at 0.75 kg/cm^2 steam pressure with continuous manual stirring and scrapping. The process of heating stirring was continued till the product acquired desired consistency (60-65% TS). At this stage caramel flavour was added @ 1 ml/100g *khoa* and blended thoroughly in the hot mass. The finished product was subsequently transferred to enamel trays, worked till pat formation stage. The samples were kept at room temperature (25 to 30 °C) for 18-20 h and packaged in sanitized polyethylene pouches. The pouches were then stored at refrigerated temperature (4±2 °C) till use. The approximate composition of *khoa* was 32.00±0.53% moisture, 16.92±0.24% protein, 21.00±0.42% fat and 3.50±0.14% ash.

Control (C) *gulabjamun* was prepared using the method reported by Aneja *et al*. (2002) [3] using maida (refined wheat flour) as a binding agent.

Process for manufacture of Gluten-Free *Gulabjamun*

For manufacture of gluten-free *gulabjamun*, sago paste and potato starch paste were prepared as described below:

Sago beads were subjected to dry grinding in a mixer (sieving through 80 mesh size sieve) to obtain sago powder (10g). Addition of (4 X the weight of sago) water (45 °C). The paste was then soaked for one hour and Heating to 90 °C for 2-3 min to obtain sago paste. To obtain potato starch paste, potato starch powder (20g) was mixing with calculated amount of hydrocolloids as shown in Table 1 and equal amount of water (45 °C) was added to form a paste. Heating to 70-75 °C for 3-4 min with continuous stirring to obtain potato starch paste.

Dhap *khoa* (prepared from 4.5/8.5% fat/SNF milk) was blended with the sago paste (1.0 g/100 g *khoa*) and potato starch/hydrocolloid paste (20 g/100g *khoa*; guar gum @ 0.05, xanthan gum @ 0.15g/100g *khoa*) and cardamom powder @ 0.1g/100g *khoa*. The mixture was kneaded to obtain dough. The dough was kept at room temperature (28-32 °C) for 1.5 h for proper resting. The dough was then portioned into balls of approximate 10 g each and subjected to deep frying in cottonseed oil at 125 to 130 °C for 10 to 12 min. The balls were kept at room temperature (28-32 °C) for 5 min after frying and then soaked in sugar syrup (62.5 °Brix) at 60 C for 1 h followed by filling in pre-sterilized PET bottles. The product was stored in 7±2 °C.

Compositional Analysis: *Gulabjamun* soaked in sugar syrup were tempered at 40 °C for 20 min. They were then kept on a sieve of about one square cm mesh to allow the sugar syrup to drain for 10 min. The gluten-free *gulabjamun* were then cut into small pieces and mixed thoroughly to form a paste, which was then tested separately for different chemical constituents.

Total nitrogen/protein content was determined by semi-microkjeldahl method AOAC (2002b), using Kjel-plus digestion system (Model-KPS 006L, M/s.Pelican Instruments, Chennai) and Kjel-plus semi-automatic distillation system (Model- Distil M, M/s. Pelican Instruments, Chennai). Fat content of *gulabjamun* was determined as per the procedure described in AOAC (2002b). Ash content was determined by procedure described in BIS (ISI: 1479-1961). The total solids content was determined by standard procedure using Mojonnier Milk Tester Model-D (Laboratory Manual, 1959). Total carbohydrate was derived by difference of sum total of the major constituents like moisture, protein, fat and ash from 100. The acidity of gluten-free *gulabjamun* and sugar syrup was determined by method described in BIS (IS: 1479-1962) for condensed milk. The pH of *gulabjamun* was measured using Systronic digital pH meter, Model 335. The method described by Franklin and Sharpe (1963) for cheese was used. The homogenate prepared by diluting 20g sample in 20ml of glass distilled water was subjected to pH measurement. For the water activity measurement, the sample of *gulabjamun* tempered at 25 °C temperature, was measured using Rotronic Hygroskop Model: Hygrolab-3 (M/s. Rotronicag, Switzerland) connected to a sensing element (AW-DIO) with a measuring range of 0-100% relative humidity (RH). The method prescribed by Deeth *et al*. (1975) was used to estimate the FFA content of burfi. Peroxide value was determined by the method as described in Indian Standard: 1479 (Part II-1961). The soluble nitrogen content of gulabjamun sample was determined by the procedure outlined by Kosikowski (1982) using three grams of sample.

For measuring the sugar syrup absorption, fried *gulabjamun* balls (two for each treatment) with known weight was transferred to 50 ml beaker containing sugar syrup, and allowed to soak for overnight at room temperature. *Gulabjamun*, after removing from syrup was allowed to drain for 10 min. on wire gauge and then weighed. Increase in weight of two *gulabjamun* over initial weight was taken as the amount of sugar syrup absorbed by *gulabjamun* and represented as percentage absorption of sugar syrup.

Texture profile Analysis: Five samples of each experimental *gulabjamun* were subjected to uniaxial compression to 50% of the initial sample height, using a Food Texture Analyzer of Lloyd Instruments LRX Plus material testing machine, England; fitted with 0-500 kg load cell. The force-distance curve obtained for a two-bite deformation cycle employing a Cross Head speed of 20 mm/min, Trigger 10 gf and 40% Compression of the samples to determine various textural attributes of *gulabjamun* held for 1 h at 23±1 °C and 55% RH.

Sensory Evaluation: The sensory panel was composed of staff members and post graduate students working in the institution. Judges who were familiar with desirable attributes of *gulabjamun* were selected. The selection criterion was that subjects had to be regular consumer's of typical dairy sweets as well as their similar behavior between sensory evaluation sessions. The samples were subjected to sensory evaluation as described in using a 9-point hedonic scale scorecard as suggested by Stone and Sidel (2004). The judges were also requested to note down their observations/ comments for each attribute specified in the score card. The gluten-free *gulabjamun* were tempered to 35±2 ^{0}C for judging. Samples were served in odour free plastic cups covered with plastic lid. The samples were labeled with random three-digit code. The order of presentation of the samples was randomized across subjects.

Shelf Life Studies: Gluten-free *gulabjamun,* which was prepared using a combination of binders (*viz.* sago and potato starch), was packed in composite polyethylene terephthalate PET bottles (sterilized using a solution of 150 ppm available chlorine solution for 10 min at 35 °C). The experimental samples were studied for the storage related changes. The samples packed in PET bottles were kept at refrigerated temperature (7±2 °C). The compositional, physico-chemical, rheological, sensory and microbial properties of fresh and stored samples of gluten-free *gulabjamun* were monitored at predetermined time interval after every 7th d. Stored *gluten-free gulabjamun* was rejected on basis of sensory evaluation as well as visible yeast and mold growth on the surface.

Statistical analysis: Statistical analysis of data was carried out as per Steel and Torrie (1980) using completely randomized design.

Results and Discussion

Preliminary trials were conducted using several hydrocolloids *viz.* sodium alginate, pectin, carrageenan, guar gum and xanthan gum. Four levels of hydrocolloids (Table 1) were selected based on preliminary studies. To select the most suitable hydrocolloids in gluten-free *gulabjamun,* five batches of *gulabjamun* was prepared using pre-treated sago and potato starch as described above. The calculated level of hydrocolloids were added along with the soaking water used for pre-treatment of potato starch before subjecting to gelatinization, Gluten-free *gulabjamun* was prepared according to procedure described in above. Control (C) was prepared using maida as binder according to the procedure described by Aneja *et al*. (2002) [3] without incorporation of any hydrocolloids. All the experimental products and control were subjected to sensory evaluation by a panel of 10 judges using a 9-point hedonic scale scorecard at a temperature of 35±2 ^{0}C. Three replications were conducted. The effect of selected hydrocolloids and their combinations on acceptability of *gluten-free gulabjamun* are presented in Table 1.

Table 1: Effect of selected hydrocolloids and their combinations on acceptability of *gluten-free gulabjamun*

Hydrocolloids (% by wt. of *khoa*)	Sensory Attributes			
	Flavour	Body And texture	Colour and appearance	Overall acceptability
Control	++++	++++	++++	++++
Guar gum (0.1%)	+	+	++	+
Xanthan gum (0.1%)	+	-	+	+
Guar gum: xanthan gum (0.05%: 0.05%)	+	+	+	+
Guar gum: xanthan gum (0.05%: 0.15%)	+	+++	++	+++
Guar gum: xanthan gum (0.15%: 0.05%)	+	+	+	+

++++ Highlyacceptable
+++ Acceptable
++ Moderately acceptable
+ Slightly acceptable
- Not acceptable

Use of guar gum @ 0.1% resulted in a product with hard body whereas use of xanthan gum @ 0.1% resulted in a product with very soft body. As the proportion of guar gum in the blend increased *viz.* product containing guar gum: xanthan gum (0.15: 0.05%) the hardness of *gulabjamun* increased resulting in a product with hard body which lacked complete sugar syrup absorption and a hard central core. This result is consistent with those of Shi and Be Miller (2002) [25], who suggested that the greatly decreased peak viscosity when negatively charged gums were added to potato starch was due to the repulsion between phosphate groups on potato starch and the negative charges on the gum molecules. Lee *et al.* (2002) [19] reported that xanthan gum (negatively charged) reduced the paste viscosity of sweet potato starch significantly, possibly through strong network formation with starch, whereas guar gum (neutral gum) increased the viscosity. In general, the literature studies the action of one or more hydrocolloids and describes their effects, but without stating the reason for the choice or attempting to describe the relationship between the chemical composition or structure of the different gums and their different effects in the fried products (Varela and Fiszman, 2011) [32].
These results are also in corroboration with Casas *et al.* (2000) [5] who reported that mixtures of xanthan and guar gum showed a higher combined viscosity than that occurring in each separate gum. This synergistic interaction was affected by the gum ratio in the mixture and dissolution temperature of both gums. The intermolecular interaction between xanthan and guar gum and the synergy increase of viscosity have already been described in literature (Tako and Nakamura, 1984 and 1985; Khouryieh *et al.* 2006) [29, 30, 14].
Amongst these hydrocolloids guar gum and xanthan gum when used in combination gave promising results. It can be seen from Table 1 addition of guar gum: xanthan gum @ 0.05: 0.15% (w/w of *khoa*) resulted in the most desirable sensory attributes from amongst all the levels of hydrocolloids studied. Hence, it was decided to add guar gum: xanthan gum @ 0.05: 0.15% (w/w of *khoa*) in the formulation. In order to optimize the level of sago and potato starch, potato starch and sago were incorporated in *gulabjamun* at selected levels. Potato starch and sago were added at the rate of (19, 20 and 21% w/w of *khoa*) and (0.8, 0.9, 1.0 and 1.1% w/w of *khoa*), respectively.

Effect of addition of different levels of potato starch and sago on rheological properties of gluten-free *Gulabjamun*
The effect of addition of different levels of potato starch and sago on rheological properties of gluten-free *gulabjamun viz.* hardness, chewiness, gumminess, adhesiveness, springiness and cohesiveness content is presented in Table 2.

Hardness
The data presented in Table 2 shows how the average values for hardness of gluten-free *gulabjamun* was affected by incorporation of potato starch and sago at different level of addition. The average values for hardness for different samples of gluten-free *gulabjamun* were found to vary from 3.13 (P3S1) to 4.60 (P2S4). Addition of potato starch as well as sago had a significant ($P<0.05$) effect on the hardness values (N) of gluten-free *gulabjamun*. All the interactions between potato starch and sago had significant ($P<0.05$) effect on the hardness of gluten-free *gulabjamun*. The values presented in Table 4.16 reveal that hardness was lowest (3.13 N) when gluten-free *gulabjamun* was made from dough containing combination of 21% potato starch and 0.8% sago (P3S1).
In the present investigation it was found that the experimental samples could be attributed to more softness of gluten-free *gulabjamun* prepared with sago and potato starch due to more retention of moisture. The increase in moisture retention could in part be ascribed to the water binding ability of proteins. The reduction in hardness in experimental samples of gluten-free *gulabjamun* could partly be attributed to development of typical rheological characteristics in gluten-free *gulabjamun* containing sago. The increase in hardness can also be partly attributed to addition of potato starch.
These results corroborate with those reported by Patel *et al*. (1992) [24] who reported that the hardness of market samples of *gulabjamun* ranged from 4.89 to 15.80 N. Adhikari *et al.* (1994) [1] reported that the hardness of market sample of *gulabjamun* was 11.60±1.35 N, whereas, the hardness of laboratory sample of *gulabjamun* was 9.80±1.10 N. Chaudhary (2016) [6] reported that the average values of hardness of *gulabjamun* made from different rate *moraiyo* was ranging from 5.10 to 8.16 N. Yawale and Rao (2012) [34] investigated textural profile analysis of effect of maida level in *khoa* powder *gulabjamun* mix and reported the hardness, which ranged from 2.65 to 4.90 and 2.75 to 4.81 N, respectively.
The results obtained in the present study corroborates with those obtained by Chaudhary (2016) [6] and Yawale and Rao (2012) [34]. However, the results obtained in the present investigation with respect to hardness of *gulabjamun* are lower than those reported by Patel *et al*. (1992) [24] and Adhikari *et al*. (1994) [1].
The differences in hardness value of gluten-free *gulabjamun* as affected by use of different binders for manufacturing of *gulabjamun.* However, published data on hardness of gluten-free *gulabjamun* as affected by addition of sago and potato starch are not available for comparison.

Chewiness
Chewiness is the energy required to masticate a food to a state ready for swallowing. It is a product of hardness (N), springiness (mm) and cohesiveness (Larmoda, 1976) [18]. The data presented in Table 4.17 are the average values for chewiness of gluten-free *gulabjamun* made with different treatment combinations. The average values for chewiness for different samples of gluten-free *gulabjamun* were found to vary from 5.02 (P1S3) to 11.93 Nmm (P2S2).
Addition of potato starch as well as sago had a significant ($P<0.05$) effect on the chewiness values of gluten-free *gulabjamun*. The interactions between potato starch and sago had statistically significant ($P<0.05$) effect on chewiness values. The chewiness value was the highest (20.14 Nmm) when gluten-free *gulabjamun* was made from dough containing 20% potato starch and 1.1% sago. In addition, value of chewiness is indirectly proportional to level of binders used. The results observed in the present study corroborates with those reported in literature. Patel *et al*.

(1992) [24] studied the textural characteristics of market sample of *gulabjamun* and reported that the chewiness of the *gulabjamun* samples ranged from 1.17 to 14.21 Nmm. Adhikari *et al*. (1994) [1] reported that the chewiness of market sample of *gulabjamun* was found to be 18.71±5.12 Nmm, whereas, the chewiness of laboratory sample of *gulabjamun* was 12.35±4.12 Nmm. Thus, in the present study chewiness of *gulabjamun* prepared using potato starch and sago as binders was within the range reported in the literature.

Gumminess

The mean values of gumminess of *gulabjamun* were ranging from 0.72 (P1S3) to 2.32 N (P2S4) as the minimum and maximum values respectively. Addition of potato starch as well as sago had a significant (P<0.05) effect on the gumminess (N) of gluten-free *gulabjamun*. The interactions between potato starch and sago had statistically significant (P<0.05) effect on gumminess values.

Amongst the different treatments studied, gumminess of *gulabjamun* made from P1S3 was statistically lower. The value for gumminess of *gulabjamun* was found to be significant and positively correlated with flavour, body and texture and overall acceptability scores of *gulabjamun*. Thus, the results observed in the present study corroborates with those reported in literature. Patel *et al*. (1992) [24] studied the textural characteristics of market sample of *gulabjamun*. The authors reported the gumminess of the *gulabjamun* samples ranged from 0.38 to 2.05 N. Adhikari *et al.* (1994) [1] investigated interrelationship among texture, composition and microstructure of buffalo milk *khoa* and *gulabjamun*. The gumminess of market sample of *gulabjamun* was found to be 5.45±1.62 N, whereas, the gumminess of laboratory sample of *gulabjamun* was 3.43±1.36 N. Singh *et al.* (2009) [26] studied the texture profile of *gulabjamun* made with the soy flour, and reported that gumminess increased with increase in the level of soy flour. Ghube *et al.* (2015) [10] examined the textural characteristic of *gulabjamun* made from *khoa* blended with wheat bran and reported that gumminess decreased with increase in the rate of wheat bran. Adhikari (1993) investigated the textural characteristic of *khoa* and *gulabjamun* made from cow milk reported that gumminess of laboratory and market sample *gulabjamun* was 0.35 and 0.39 N. Yawale and Rao (2012) [34] studied textural profile analysis of effect of maida level in *khoa* powder *gulabjamun* mix and reported the gumminess ranged from 0.25 to 0.30 N. Chaudhary (2016) [6] reported that the average gumminess of experimental *gulabjamun* was ranged from 0.93 to 2.11 N.

Adhesiveness

Adhesiveness is the work necessary to overcome the attractive forces between the surface of the sample and the other materials with which the sample comes in contact. It is the negative force area for the first bite curve (Larmoda, 1976) [18]. The data presented in Table 4.19 are the average values for adhesiveness of gluten-free *gulabjamun* made with different treatment combinations. The average values for adhesiveness for different samples of *gluten-free gulabjamun* were found to vary from 0.10 (P1S3) to 0.34 (P2S2). It can be seen from data that addition of potato starch as well as has a significant effect (P<0.05) on adhesiveness of *gulabjamun*. Addition of potato starch reduces stickiness of the *gulabjamun* which is more in case when *gulabjamun* prepared solely from sago. Moreover, adhesiveness was having negative correlation with sensory attributes of *gulabjamun*. The interactions between potato starch and sago had statistically significant (P<0.05) effect on chewiness values. This correlation suggests that with the increase in adhesiveness (i.e. stickiness), the sensory scores for body and texture as well as overall acceptability decreases.

Thus, the results observed in the present study corroborates with those reported in literature. Patel *et al*. (1992) [24] studied the textural characteristics of market sample of *gulabjamun*. The authors reported the adhesiveness of the *gulabjamun* samples ranged from 0.39 to 1.43 Nmm. Adhikari *et al*. (1994) [1] investigated interrelationship among texture, composition and microstructure of buffalo milk *khoa* and *gulabjamun*. The adhesiveness of market sample of *gulabjamun* was found to be 0.60±0.08 Nmm, whereas the adhesiveness of laboratory sample of *gulabjamun* was 0.50±0.06 Nmm.

Springiness

Springiness refers to the height that the sample recovers between the first and second compression on removal of the deformation forces (Larmoda, 1976) [18]. The data presented in Table 4.20 are the average values for springiness of gluten-free *gulabjamun* made with different treatment combinations. The average values of springiness of gluten-free *gulabjamun* were ranging from 7.19 mm (P1S3) to 8.91 (P2S2) being the lowest and highest values respectively. Addition of potato starch as well as sago had a significant (P<0.05) effect on the springiness (mm) of gluten-free *gulabjamun*. The interactions between potato starch and sago had statistically non-significant (P>0.05) effect on springiness values. The values of springiness of *gulabjamun* was found to be significant (P<0.05) and positively correlated with sugar syrup absorption of *gulabjamun*. The results observed in the present study corroborates with those reported in literature. Yawale and Rao (2012) [34] examined textural profile analysis of effect of maida level in *khoa* powder *gulabjamun* mix and mentioned that the increase the level of maida increased the springiness of *gulabjamun*. Chaudhary (2016) [6] reported that the average springiness of experimental *gulabjamun* was ranged from 6.64 to 8.19 mm. Patel *et al*. (1992) [24] studied the textural characteristics of market sample of *gulabjamun*. The authors reported the springiness of the *gulabjamun* samples ranged from 2.79 to 7.88 mm. Adhikari *et al*. (1994) [1] investigated interrelationship among texture, composition and microstructure of buffalo milk *khoa* and *gulabjamun*. The springiness of market sample of *gulabjamun* was found to be 3.40±0.30 mm, whereas, the springiness of laboratory sample of *gulabjamun* was 3.60±0.45 mm.

Cohesiveness

Cohesiveness refers to the extent to which a material can be deformed before it ruptures (Larmoda, 1976) [18]. The data presented in Table 4.21 are the average values for cohesiveness of gluten-free *gulabjamun* made with different treatment combinations. The average values for cohesiveness for different samples of gluten-free *gulabjamun* were found to vary from 0.17 (P1S3) to 0.34 (P3S4). Addition of potato starch as well as sago had a significant (P<0.05) effect on the cohesiveness of gluten-free *gulabjamun*. The interactions between potato starch and sago had statistically non-significant (P>0.05) effect on cohesiveness values. The results observed in the present study corroborates with those reported in literature. Singh *et al.* (2009) [26] examined the texture profile of *gulabjamun* made with the soy flour and reported that cohesiveness increased with increase in the level of soy flour. Adhikari (1993) described the textural characteristic of *khoa* and *gulabjamun* made from cow milk and reported that cohesiveness of laboratory and market sample *gulabjamun* was 0.35 and 0.39. Yawale and Rao (2012) [34] studied textural profile analysis of effect of maida level in *khoa* powder *gulabjamun* mix, and reported the cohesiveness ranged from 0.25 to 0.30. Chaudhary (2016) [6] reported that the averages of cohesiveness experimental *gulabjamun* were ranged from 0.18 to 0.25.

Table 2: Influence of varied levels of potato starch and sago on rheological properties of gluten-free *gulabjamun*

Potato starch (P) (% by wt. of khoa)	Sago (S) (% by wt. of khoa)				Average For Potato starch
	0.8	0.9	1.0	1.1	
	Hardness (N)				
19	3.40±0.26	3.16±0.35	3.17±0.26	3.43±0.15	3.29
20	3.96±0.21	4.43±0.29	3.90±1.14	4.60±0.46	4.22
21	3.13±0.15	3.36±0.06	3.56±0.12	4.30±0.10	3.59
Average For Sago	3.50	3.65	3.54	4.11	
	CD (0.05) P= 0.34; S= 0.39; PxS = NS				
	Chewiness (Nmm)				
19	7.22±0.11	8.32±0.11	5.02±0.14	9.43±0.10	7.50
20	9.53±0.35	11.93±0.38	7.73±0.10	8.06±0.06	9.31
21	7.37±0.18	8.46±0.24	5.75±0.21	9.54±0.09	7.78
Average For Sago	8.04	9.57	6.17	9.01	
	CD (0.05) P= 0.17; S= 0.19; PxS = 0.33				
	Gumminess (N)				
19	0.86±0.04	0.94±0.03	0.72±0.08	1.23±0.07	0.94
20	1.64±0.09	1.95±0.15	1.41±0.09	2.32±0.07	1.83
21	1.03±0.09	1.19±0.10	0.77±0.02	1.43±0.04	1.10
Average For Sago	1.18	1.36	0.97	1.66	
	CD (0.05) P= 0.066; S= 0.077; PxS = 0.130				
	Adhesiveness (Nmm)				
19	0.13±0.06	0.13±0.02	0.10±0.01	0.24±0.05	0.15
20	0.16±0.06	0.34±0.07	0.16±0.05	0.29±0.02	0.24
21	0.19±0.05	0.29±0.08	0.12±0.03	0.31±0.04	0.23
Average For Sago	0.16	0.25	0.13	0.28	
	CD (0.05) P= 0.040; S= 0.046; PxS = 0.080				
	Springiness (mm)				
19	7.80±0.12	7.92±0.11	7.19±0.13	7.56±0.21	7.62
20	8.81±0.12	8.91±0.07	8.00±0.13	8.57±0.13	8.57
21	8.14±0.04	7.91±0.12	7.33±0.03	7.59±0.30	7.74
Average For Sago	8.25	8.25	7.51	7.90	
	CD (0.05) P= 0.119; S= 0.138; PxS = NS				
	Cohesiveness				
19	0.23±0.04	0.23±0.02	0.17±0.03	0.25±0.04	0.22
20	0.27±0.02	0.28±0.03	0.25±0.03	0.32±0.03	0.28
21	0.26±0.03	0.27±0.02	0.23±0.03	0.34±0.05	0.27
Average For Sago	0.25	0.26	0.22	0.30	
	CD (0.05) P= 0.025; S= 0.029; PxS = NS				

* Each observation is mean ±SD of 3 replications. P = Potato starch, S = Sago

Effect of Storage on on Rheological Properties of Gluten-free *Gulabjamun*

Changes in rheological properties during processing or on storage of gluten-free *gulabjamun* can be considered a serious problem. The changes in rheological properties of gluten-free *gulabjamun* have a direct bearing on the acceptance of the product, which signifies its importance. Looking to this, the changes in rheological parameters of gluten-free *gulabjamun* during storage were studied and the results referring to hardness, cohesiveness, gumminess, chewiness, adhesiveness and springiness are depicted in Table 4.32.

Hardness: As seen in Table 3 during storage of gluten-free *gulabjamun* at refrigerated temperature, there was a significant (P<0.05) increase in hardness up to 21st d thereafter decrease. The hardness of freshly prepared gluten-free *gulabjamun* increased from 3.90±0.02 (0th d) to 5.92±0.04 (21st d) N; thereafter decreased to 4.86±0.05 N on 35th d of storage. The increase in hardness of samples of gluten-free *gulabjamun* during storage could be attributed to the decrease in moisture content in gluten-free *gulabjamun*. The observed increase in hardness during storage of product might be a result of decrease in sugar syrup penetration after certain time period. This is well supported by sugar syrup absorption. This increase might be due to the decrease in fat content, and reduction in moisture content (Gulhati *et al*. 1992) [11].

Vaja (2012) [31] studied the effect of storage on hardness of *gulabjamun* prepared from sweet cream butter milk khoa and maida as binders. He reported that the hardness increased significantly (P<0.05) from 4.226 (0th d) to 5.969 (28th d) N during storage at refrigeration temperature (7±2 °C). Thus, the results obtained in the present investigations corroborates with those reported in literature.

Cohesiveness: During storage of gluten-free *gulabjamun* at refrigerated temperature, there was a significant (P<0.05) increase in cohesiveness up to 7th d thereafter decrease (Table 3). The cohesiveness of freshly prepared gluten-free *gulabjamun* increased from 0.17±0.02 (0th d) to 0.20±0.03 (7th d) and thereafter, decreased to 0.14±0.02 on the 35th d of storage. The observed changes in cohesiveness during storage might be as a result of degradation of proteins.

Vaja (2012) [31] studied the effect of storage on cohesiveness of *gulabjamun* prepared from sweet cream butter milk khoa and maida as binders. He reported that the cohesiveness significantly affected (P<0.05) by the treatment and storage period refrigeration temperature from 0.116 (0th d) to 0.193

(28th d) during the storage at refrigeration temperature (7±2 °C).

Gumminess: During storage of gluten-free *gulabjamun* at refrigerated temperature, there was a significant (*P*<0.05) increase in gumminess up to 7th d thereafter decrease. The gumminess of freshly prepared gluten-free *gulabjamun* increased from 1.09±0.11 (0th d) to 1.47±0.05 (7th d) and thereafter, decreased to 1.02±0.03 on the 35th d of storage. The order of increase in gumminess value of gluten-free *gulabjamun* after 35th d of storage at refrigeration had not shown any adverse effect on organoleptic acceptability of the product. Vaja (2012) [31] studied the effect of storage on gumminess of *gulabjamun* prepared from sweet cream butter milk khoa and maida as binders. He reported that the gumminess values for fresh *gulabjamun* were 6.410 N which decreased significantly to 5.693 N after 28th d of storage at refrigeration temperature (7±2 °C).

Chewiness: The acceptability of gluten-free *gulabjamun* is also determined by the chewiness. Any change induced during processing and manufacturing of *gulabjamun* will be therefore, critical from product quality point of view. The effect of period of storage at refrigerated temperature on the chewiness of gluten-free *gulabjamun* is depicted in the Table 3 indicated that during storage of gluten-free *gulabjamun* at refrigerated temperature, there was a significant (*P*<0.05) increase in chewiness up to 7th d thereafter decrease. The chewiness of freshly prepared gluten-free *gulabjamun* increased from 7.73±0.10 (0th d) to 11.24±0.09 (7th d) and thereafter, decreased to 8.25±0.09 on the 35th d of storage. Vaja (2012) [31] studied the effect of storage on chewiness of *gulabjamun* prepared from sweet cream butter milk khoa and maida as binders. He reported that the chewiness values for fresh *gulabjamun* were 3.081 which decreased significantly to 7.951 N after 28th d of storage at refrigeration temperature (7±2 °C).

Adhesiveness: The effect of period of storage at refrigerated temperature on the adhesiveness of gluten-free *gulabjamun* is depicted in the Table 3 reveal that freshly prepared gluten-free *gulabjamun* had adhesiveness value of 0.23±0.09 which was decreased significantly to 0.19±0.02 Nmm on 7th d of storage, then after it increased to 0.40±0.01 Nmm on 35th d of storage at refrigeration temperature (7±2 °C). An erratic behaviour in adhesiveness of gluten-free *gulabjamun* stored at refrigeration temperature was noticed during storage. Vaja (2012) [31] studied the effect of storage on adhesiveness of *gulabjamun* prepared from sweet cream butter milk khoa and maida as binders. He reported that *gulabjamun* stored at refrigeration temperature, adhesiveness values increased from 0.250 to 1.729 Nmm after 28th d of storage at refrigeration temperature (7±2 °C).

Springiness: Dairy products like gluten-free *gulabjamun* are more liked when they are soft and spongy in nature and hence this property is of great importance for the acceptability of the product. So, to assess the extent of the effect of storage on springiness of *gluten-free gulabjamun* samples after production and during storage was determined and the results obtained are tabulated in Table 4.32 for storage at 7±2 ^{0}C. Gluten-free *gulabjamun* showed non-linear pattern for springiness during storage at refrigeration temperature. The springiness value was 7.17±0.08 mm on 0th d and 7.01±0.09 mm on 35th d of storage at refrigeration temperature (7±2 ^{0}C). Vaja (2012) [31] studied the effect of storage on springiness of *gulabjamun* prepared from sweet cream butter milk khoa and maida as binders. He reported that *gulabjamun* stored at refrigeration temperature, springiness of fresh *gulabjamun* were 6.410 which decreased significantly to 5.693 mm after 28th d of storage at refrigeration temperature (7±2 ^{0}C).

Table 3: Effect of storage period on rheological properties of gluten-free *gulabjamun* at refrigerated temperature (7±2 ^{0}C)

Attributes	Storage period (d)						S. Em.	C.D. (0.05)	C.V. (%)
	0	7	14	21	28	35			
Hardness (N)	3.90±0.02	4.60±0.10	5.33±0.09	5.92±0.04	5.70±0.10	4.86±0.05	0.04	0.13	1.49
Cohesiveness	0.17±0.02	0.20±0.03	0.15±0.02	0.15±0.02	0.14±0.02	0.14±0.02	0.01	NS	15.07
Gumminess (N)	1.09±0.11	1.47±0.05	1.45±0.07	1.45±0.05	1.22±0.04	1.02±0.03	0.04	0.12	5.22
Chewiness (N mm)	7.73±0.10	11.24±0.09	10.24±0.10	10.07±0.12	9.26±0.09	8.25±0.09	0.05	0.16	0.95
Adhesiveness (N mm)	0.23±0.09	0.19±0.02	0.21±0.03	0.24±0.07	0.37±0.02	0.40±0.01	0.03	0.10	19.47
Springiness (mm)	7.17±0.08	7.59±0.04	7.17±0.08	7.20±0.10	7.10±0.10	7.01±0.09	0.05	0.15	1.16

Each observation is a mean ± SD of three replicate experiments (n=3)

Effect of Storage on Sensory Attributes of Gluten-free *Gulabjamun*

The data on the sensory quality of gluten-free *gulabjamun* referring to flavour, body and texture, colour, appearance and overall acceptability after a storage period 35 d at refrigeration temperature (7±2 °C) are depicted in Table 4. The mean value presented revealed that flavour score of gluten-free *gulabjamun* was significantly (*P*<0.05) reduced during the storage period. During storage of gluten-free *gulabjamun*, flavour score up to 35th d was noticed and thereafter the product became unacceptable due to visible mold growth. The decrease in flavour score could be attributed to slight loss of freshness, which is essential with any food product. In fresh product, the compounds formed during browning reactions are responsible for the typical flavour of the product, but as storage period progresses, the chemical reactions disturbed the delicate balance of the compounds. However, the observed decrease in body and texture score of gluten-free *gulabjamun* during storage of product at refrigeration temperature might be a result of various chemical and microbial changes. The decline in score at refrigeration temperature could be mainly attributed to the gradual increase in hardness, cohesiveness and chewiness which resulted into a harder and chewier product.

It can be seen from Table 4 that body and texture score of gluten-free *gulabjamun* was significantly (*P*<0.05) influenced by the storage period at refrigeration temperature (7±2 °C). As observed from the Table 4, the body and texture score decreased during storage period at refrigerated temperature. During storage of gluten-free *gulabjamun* the body and texture score decreased significantly from 8.13±0.06 on 0th d to 6.57±0.12 on the 35th d of storage. The product became dry, hard, sandy and brittle which might be ascribed to the loss of moisture and possibly due to crystallization of added sugar at refrigerated temperature. This is because of dynamic structural and conformational changes, which may or may not be dependent on changes in moisture content (Navajeevan and Rao, 2005) [23]. The drop in score at refrigeration temperature could be mainly attributed to the gradual increase in hardness and gumminess which resulted into a harder and gummier product. It can be seen from Table 4 that there was a gradual increase in textural parameters such as hardness and gumminess up to the 21st d of storage, thereafter further decrease in body and texture score of gluten-free *gulabjamun* might be a result of various chemical and microbial changes.

The mean values obtained for colour and appearance scores reveals that colour and appearance score of gluten-free *gulabjamun* significantly (P<0.05) decreased during the storage period. During storage of gluten-free *gulabjamun* at refrigerated temperature, decreased in colour and appearance score from 8.46±0.05 on 0th d to 7.50±0.10 on the 35th d of storage was observed. The drop in scores during storage of gluten-free *gulabjamun* can be attributed to microbial, chemical and textural changes in the product. Moreover in the present study, evaporation of moisture during storage might have aggravated the appearance of the gluten-free *gulabjamun* as presence of moisture enlivens the appearance of the product by reflecting incident light.

The overall acceptability score of gluten-free *gulabjamun* during storage at refrigeration temperature was found to decrease with the increase in storage period. Fresh gluten-free *gulabjamun* had an overall acceptability score of 8.20±0.15; these values for overall acceptability were decreased significantly to 6.10±0.10 after 35th d of storage. Table 4 indicate that storage period had a significant effect (P<0.05) on overall acceptability score of gluten-free *gulabjamun* stored at refrigeration temperature. The overall acceptability scores of gluten-free *gulabjamun* was statistically different (P<0.05) from each other and the mean scores at 0, 7, 14, 21, 28 and 35 days of storage were statistically different from each other. However, the product was still acceptable by judges on sensory basis. Thus, the samples were still acceptable after 35 d of storage at refrigeration temperature. The observed decline in overall acceptability of gluten-free *gulabjamun* could partly attributed to development of change in flavour owing to development of flat, insipid taste with slight souring tinge, body and texture scores due to increase in rheological properties like hardness, chewiness and cohesiveness and also decrease in colour and appearance to some extent, in gluten-free *gulabjamun* during storage. Therefore, it can be concluded that the total score or in turn the organoleptic attributes of the product follows the trend that was evident in individual attributes of gluten-free *gulabjamun*.

Table 4: Effect of storage period on sensory properties of gluten-free *gulabjamun* at refrigerated temperature (7±2 ^{0}C)

Attributes	Storage period (d)						S.Em.	C.D. (0.05)	C.V. (%)
	0	7	14	21	28	35			
Flavour	8.23±0.06	7.77±0.06	7.23±0.06	6.77±0.06	6.43±0.06	6.13±0.06	0.03	0.10	0.81
Body and Texture	8.13±0.06	7.87±0.06	7.47±0.06	7.23±0.06	6.87±0.06	6.57±0.12	0.04	0.13	0.96
Colour and Appearance	8.46±0.05	8.27±0.06	8.07±0.06	7.87±0.06	7.73±0.06	7.50±0.10	0.04	0.12	0.83
Overall acceptability	8.20±0.15	7.67±0.06	7.13±0.06	6.73±0.06	6.33±0.06	6.10±0.10	0.04	0.13	1.06

Each observation is a mean ± SD of three replicate experiments (n=3)

Conclusion

Thus, it can be concluded that gluten-free gulabjamun has a shelf life of 35 d under refrigeration temperature (7± 2 °C) when packed in pre-sterilized polyethylene terephthalate (PET) bottles. During storage there was a significant (P<0.05) increase in hardness up to 21st d thereafter a decrease in hardness was observed. There was a significant (P<0.05) increase in cohesiveness and gumminess up to 7th d which decreased thereafter. There was a significant (P<0.05) increase in chewiness up to 7th d thereafter a decrease in chewiness was observed.

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