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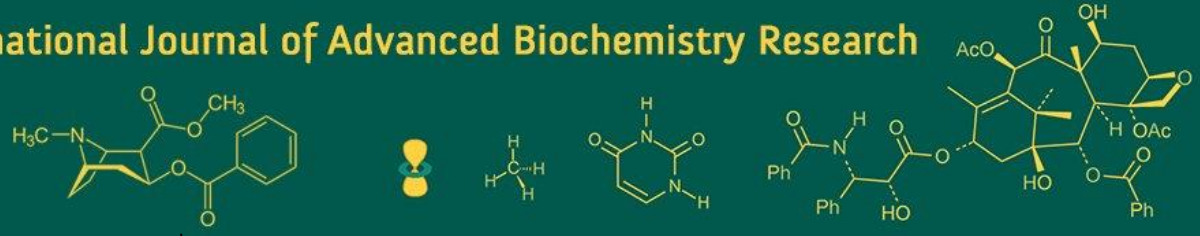

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Process optimization of *Gulabjamun* utilizing pearl millet (*Pennisetum glaucum* L.)

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Abstract
The present investigation was conducted to study the effect of admixing pearl millet (*Pennisetum glaucum*) with *maida* in five proportions viz. 25:75 (G1), 50:50 (G2), 75:25 (G3), 100:0 (G4) and 0:100 (control) at the rate of 20% of *khoa*. Optimization of the rate of addition of pearl millet flour for the preparation of *gulabjamun* was carried out based on sensory attributes. It was found from the present study that the *gulabjamun* with acceptable quality can be prepared by the addition of pearl millet: *maida* at the rate of 50:50 by 20% wt of *khoa*. The addition of various levels of pearl millet had a significant (p<0.05) effect on sensory attributes and rheological properties of *gulabjamun*. The fat, protein, ash, total solid and total carbohydrate content of *gulabjamun* increased significantly (p<0.05) with increased in the proportion of pearl millet flour. The addition of various rates of pearl millet had not significant effect on the acidity and pH of *gulabjamun.* The sugar syrup absorption increased significantly (p<0.05) with an increase in the proportion of pearl millet. In conclusion, the study was successful in formulating an acceptable quality of *gulabjamun* prepared by addition of Pearl millet: *Maida* in the ratio of 50:50, and the proportion was added @ 20% by wt of *khoa* as a binder which enhanced its overall acceptability.

Keywords: *Gulabjamun*, pearl millet, *bajra*, *Pennisetum glaucum*, Khoa

1. Introduction
India is immerged as major milk producing nation in the globe sharing 24% of the global milk production (Ministry of Fisheries, Animal Husbandry & Dairying, 2023) [14]. India has the world's highest production of milk and about 50-55% of its production is applied for manufacture of various traditional dairy products (Baladhiya *et al.*, 2020) [3]. Traditional dairy products have always been an integral element of India's socio-cultural life. Traditional dairy products are always offered to celebrate festivals, wedding ceremonies, inauguration of a new house, baby birth, getting a job and social occasions. Traditional dairy products have more acceptability and longer shelf life than milk. It is also considered that the conversion of milk into milk products is more gainful than the sale of milk. The most significant benefit of this segment is the huge consumer demand for the products.

Gulabjamun is a traditional Indian heat desiccated product in which *khoa* is a basic ingredient. In the category of traditional dairy products, *khoa* is in the paramount place. Dhap variety of *khoa* with 50 to 60% total solids is preferred for *gulabjamun* production. Traditionally, *gulabjamun* is made from dough containing mainly *maida* and *khoa*. This dough is formed into small round balls, which are deep-fried till golden to dark brown colour, soft and slightly spongy body. The product should have no lumps and rigid inner midst and have a consistent grainy structure. Soaking in sugar syrup is a key operation in the preparation of *gulabjamun*. Soaking of *gulabjamun* not only gives sweetness but also gives its typical texture.

Maida contains a protein called gluten that provides the flour with its pliability and thickness as well as the capacity to be kneaded and binds the dough together. The preparation of *gulabjamun* utilising *maida* as a binder is unsuitable for people who suffer from celiac disease. So, using pearl millet (*Pennisetum glaucum*) flour in place of *maida* or its combination is the best way to reduce or make it free from gluten in *gulabjamun.* Millets are the oldest food grains and they may have been the first cereal used for domestic purposes. Millet growing region decreases by dint of low recognized support for millet compared to wheat, rice and maize.

But at present to promote millets as a major component of food UN declares 2023 as the "International Year of Millets" (Kumari *et al*., 2023) [10]. In many nations, pearl millet (*Pennisetum glaucum*) has been recognised as a component of gluten-free cereals. In India, pearl millet is also known as "*bajra*". It is a major crop for poor farmers, especially the tribal people in India. Pearl millet is soothing and easy to digest.

The chemical composition of *gulabjamun* varies greatly based on variables including the type and quality of *khoa*, constituents and syrup concentration. *Gulabjamun* contains moisture, fat, protein, total carbohydrates and ash ranging from 25 to 35%, 9 to 11%, 6 to 7%, 48 to 52% and 0.9 to 2%, respectively.

2. Materials and Methods

Raw components like milk, *maida*, pearl millet, sugar and *ghee* were used in the experiment.

Milk received from the Mini Dairy plant of Sardarkrushinagar Dantiwada agricultural University for the study. Good quality *Maida* and Pearl millet which is free from stones, dust, insects and other impurities was procured from local market. Good quality sugar for preparation of sugar syrup and *ghee* is also procured from local market. The pearl millet flour had an average composition of 4.38% fat, 10.82% protein, 8.96% moisture and 2.13% Ash.

2.2 Preparation of *Khoa*

Khoa was made from fresh standardised milk. *Khoa* was produced using heat desiccation in an open, steam-jacketed stainless steel pan that was run at 0.75 kg/cm2 steam pressure while being constantly stirred and scraped. The procedure of heating and stirring was carried out until the end product achieved the necessary consistency (60-% TS). After removing *khoa* from the kettle, it was allowed to cool at ambient temperature before being utilized within 24 hours to make *gulabjamun*.

2.3 Preparation of *Gulabjamun*

Gulabjamun was developed using a method described by Ghosh *et al*. (1986) [7] with minor alterations. It involves proper blending of *khoa*, Pearl millet*/Maida* at different rate, baking powder and water (optional) to make homogenous and smooth dough. Small amount of water was added in case of dough is hard. The small balls formed from the dough were deep fried in *ghee* to golden brown colour and subsequently transferred to 60 °Brix sugar syrup maintained at about 65 °C.

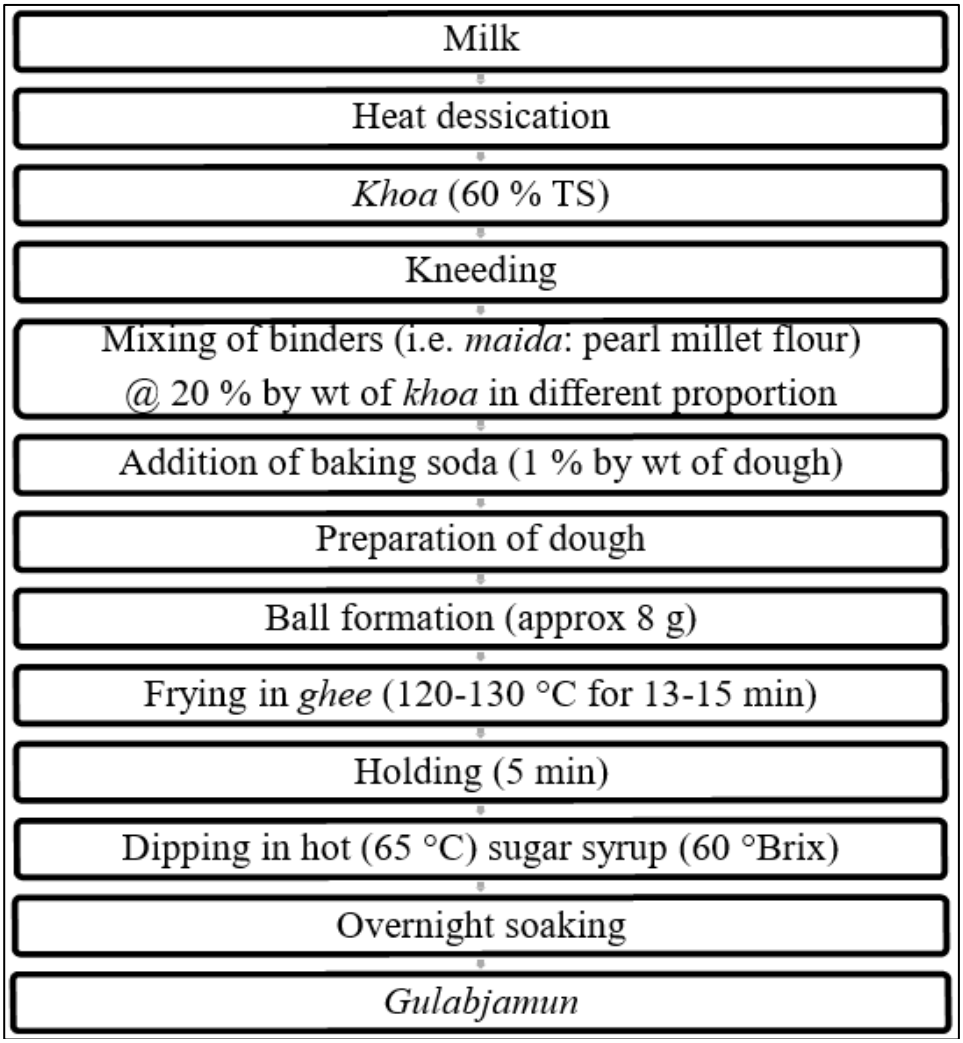

Fig 1: Flow diagram for manufacture of *gulabjamun*

2.4 Sensory evaluation

Sensory evaluation of control *gulabjamun* and experimental *gulabjamun* was done by eight semi-trained judges. The 9-point hedonic scale method was used to evaluate sensory perception. Judges were also asked to record their thoughts and observations for each quality listed on the scorecard.

2.5 Compositional and Physico-chemical analysis

A sugar syrup soaked *gulabjamun* was heated for 20 minutes at 40 °C. They were then left on a sieve with a mesh size of about one centimetre square for 10 minutes to let the sugar syrup drain. *Gulabjamun* was then divided into small pieces and thoroughly mixed to create a paste that used for various analysis. Fat content of *gulabjamun* was determined using the Gerber method as per the procedures described by Ladkani and Mulay (1974) [13]. The total protein content was determined by semi-micro Kjeldahl method mentioned in AOAC (2002) [2]. Total solids were estimated by the protocol described in Laboratory Manual (1959) [11]. The BIS (IS: 1479-1961) method for determining ash content was used for determination of ash content of *gulabjamun*. Total carbohydrate was derived by difference of sum total of the major constituents like moisture, protein, fat and ash from 100. The BIS (IS: 1166-1986) method for condensed milk measurement was used to determine the acidity of *gulabjamun*. The pH of *gulabjamun* was measured using digital pH meter. The method described by Patel (2020) [17] was used for the sugar syrup absorption of *gulabjamun*.

2.6 Rheological properties

Rheological properties viz. hardness, cohesiveness, gumminess, springiness and chewiness of *gulabjamun* was determine by using Food Texture Analyzer of Lloyd Instruments LRX Plus Material Testing Machine, which operates on the parallel plate uniaxial compression principle.

2.6.1 Statistical analysis

Statistical analysis of data obtained from various experiments during optimization was done by using statistical software SPSS with completely randomized design (CRD).

3. Results and Discussion

3.1 Selection of Rate of Pearl Millet for the Acceptable *Gulabjamun*

Pearl millet: *maida* ratios of 25:75, 50:50, 75:25 and 100:00 were tested as binders for *gulabjamun* production during the preliminary studies. During the frying process, *gulabjamun* made with less than 20% binder was disintegrated. Based on the preliminary studies, different proportions of pearl millet: *Maida* by 20% weight of *khoa* was selected for further study. Four different levels of pearl millet: *maida* at ratios of 25:75 (G1), 50:50 (G2), 75:25 (G3) and 100:0 (G4) along with control 0:100 (C) were used for the manufacture of *gulabjamun*. The compositional, physico-chemical, sensorial and rheological properties of each lot of *gulabjamun* were examined after each batch was manufactured using the technique shown in Figure 1. Selection of rate of pearl millet flour was optimised on the basis of sensory evalution.

3.2 Effect of Pearl Millet Flour on the Sensory Attributes of *Gulabjamun*

The consumption of dairy products is strongly correlated to the human senses, odour and taste. Sensory quality has most important for the market acceptance of any product. Effect of pearl millet flour on sensory attributes of *gulabjamun* was shown in Table 1.

Table 1: Effect of pearl millet flour on the sensory attributes of *gulabjamun*

Treatments	Flavour	Body & Texture	Colour & Appearance	Overall Acceptability
C	8.35a±0.11	8.25a±0.15	8.44a±0.12	8.35a±0.06
G1	7.86b±0.30	7.78ab±0.38	7.88b±0.28	7.84a±0.35
G2	7.74b±0.35	7.89ab±0.30	7.99ab±0.18	8.01a±0.18
G3	7.38b±0.37	7.25bc±0.47	7.19c±0.44	7.24b±0.42
G4	6.80c±0.40	6.81c±0.65	6.71c±0.55	6.76b±0.53
SEm	0.16	0.21	0.18	0.18
CD (0.05%)	0.49	0.64	0.53	0.53
CV (%)	4.22	5.59	4.62	4.62
Fisher's Least Significant Difference indicates that means with at least one letter common are not statistically significant. The figures placed after±represent Standard Deviation.				

The most crucial factor in determining whether a food will be accepted is its flavour. The flavour score of *gulabjamun* added with different rates of pearl millet, control scored highest (8.35) among all treatments followed by G1, G2, G3 and G4 were found to be 7.86, 7.74, 7.38 and 6.80, respectively. The flavour score of *gulabjamun* declined significantly (p<0.05) from 8.35 to 6.80 as the level of pearl millet addition increased, as shown in Table 1. Treatments G1, G2 and G3 were discovered to be statistically equivalent to one another among all treatments. Texture plays a key role in consumer's acceptance and market value of any food stuff. The range for body and texture score of *gulabjamun* was found to be 8.25 (C) to 6.81 (G4). Compared to other treatments, the body and texture score was found to be higher in the control (8.25) sample. It can be shown from Table 1 that with an increased in the rate of pearl millet flour in *gulabjamun*, there was a gradually decreased in the body and texture score of *gulabjamun* except for G1 and G2 from 8.25 to 6.81. Among all treatments, C, G1 and G2; G1, G2 and G3 were found to be statistically equivalent to one another, while G3 and G4 were also statistically not significantly differed. The body of *gulabjamun* was found slightly loose with increasing the level of pearl millet because pearl millet gives more porous *gulabjamun* than *maida*. Therefore, they absorb more *ghee* during frying and also absorb more sugar syrup. The most attractive feature of a food product is its colour and its appearance is another factor in how well-liked it is on the market. The scores for *gulabjamun's* colour and appearance ranged from 8.44 (C) to 6.71 (G4). It can be seen from the tabulated value that as the rate of pearl millet increased, there was a successive decreased in the colour and appearance score of *gulabjamun* except for G1 and G2 from 8.44 to 6.71. Among all treatments, G1 and G2, G3 and G4, C and G2 were found to be statistically at par with each other. The colour of pearl millet was darker than the colour of *maida*, so it was discovered that adding more pearl millet to *gulabjamun* caused colour to become slightly blackish. The incorporation of pearl millet flour had a significant (p<0.05) effect on the overall acceptability of *gulabjamun*. The

overall acceptability of control *gulabjamun* scored highest (8.35) among all treatments followed by G2, G1, G3 and G4 was found to be 8.01, 7.84, 7.24 and 6.76, respectively. As the amount of pearl millet increased, there was a progressively decreased in the overall acceptability score of *gulabjamun* except for G1 and G2 from 8.35 to 6.76. Among all treatments, G1, G2 and G3 were found statistically equivalent to each other, while G3 and G4 were also not significantly differed. From the above discussion on the effect of pearl millet flour on sensory score of *gulabjamun*, it could be concluded that the average sensory score of *gulabjamun* i.e. flavour, body and texture, colour and appearance and overall acceptance ranged from 8.35 to 6.80, 8.25 to 6.81, 8.44 to 6.71 and 8.35 to 6.76, respectively.

It was concluded from the sensory assessment of *gulabjamun* by eight semi-trained judges that the G2 sample of *gulabjamun* which contain pearl millet: *maida* @ 50:50 gave the most acceptable *gulabjamun* in terms of sensory quality.

3.3 Effect of Pearl Millet Flour on the Chemical Composition of *Gulabjamun*

Chemical composition has been very important aspect in term of the nutritional value of any product. Effect of pearl millet flour on chemical composition of *gulabjamun* was shown in Table 2.

Table 2: Effect of pearl millet flour on the chemical composition of *gulabjamun*

Treatments	Fat (%)	Protein (%)	Ash (%)	Total Solid (%)	Total Carbohydrate (%)
C	9.53e±0.17	6.26d±0.09	1.31e±0.06	66.26d±0.95	49.17c±0.82
G1	9.93d±0.22	6.38cd±0.10	1.54d±0.09	67.27d±0.77	49.42c±0.93
G2	10.48c±0.22	6.41bc±0.14	1.81c±0.03	68.63c±0.54	49.93bc±0.55
G3	10.88b±0.10	6.53ab±0.08	2.01b±0.06	69.92b±0.65	50.50b±0.65
G4	11.28a±0.17	6.63a±0.06	2.20a±0.08	71.85a±0.39	51.74a±0.46
SEm	0.09	0.05	0.03	0.34	0.35
CD (0.05%)	0.27	0.15	0.09	1.04	1.06
CV (%)	1.75	1.53	3.63	1.00	1.40
Fisher's Least Significant Difference indicates that means with at least one letter common are not statistically significant. The figures placed after±represent Standard Deviation. The total carbohydrates were determined by difference.					

The fat content of *gulabjamun* ranged from 9.53 (C) to 11.28% (G4). As the rate of adding pearl millet flour to *gulabjamun* increased, there was a significant (p<0.05) rise in the fat content of *gulabjamun* from 9.53 to 11.28% as the pearl millet flour contain higher fat compare to *maida*. Among all treatments, there was not any treatment found to be statistically at par with each other. The average protein content of *gulabjamun* varied from 6.26 (C) to 6.63% (G4). Table 2 demonstrated that the protein content of *gulabjamun* increased statistical significantly (p<0.05) from 6.26 to 6.63% with an increase in the rate of pearl millet flour addition. The protein content for C and G1; G1 and G2; G2 and G3; G3 and G4 were discovered to be statistically equivalent to one another among all treatments. The range for ash content of *gulabjamun* was found to be 1.31 (C) to 2.20% (G4). Compared to other treatments, ash content was found to be higher in G4 i.e. 2.20%. Data obtained from Table 2 shows that as the rate of pearl millet addition increased, there was a significant (p<0.05) increased in the ash content of *gulabjamun* from 1.31 to 2.20%. Among all treatments, there was not any treatment found to be statistically at par with each other. The average values of total solid content in *gulabjamun* ranged from 66.26 (C) to 71.85% (G4). Table 2 demonstrated that the total solid content of *gulabjamun* increased significantly (p<0.05) from 66.26 to 71.85% as the level of pearl millet addition increased. Among all treatments, C and G1 were found to be statistically at par with each other. The average total carbohydrate content of *gulabjamun* varied from 49.17 (C) to 51.74% (G4). Among all treatments, total carbohydrate content was found to be higher in G4 (51.74%). Table 2 provide evidence that the total carbohydrate content of *gulabjamun* significantly (p<0.05) increased from 49.17 to 51.74% as the rate at which pearl millet flour was added to the *gulabjamun* was increased. Among all treatments, G2 and G3 were discovered to be statistically equal, while C, G1 and G2 were also statistically non-significantly differed.

3.4 Effect of Pearl Millet Flour on the Physico-Chemical Properties of *Gulabjamun*

Physico-chemical properties have very vital role on shelf life of any product due to the microbiological quality of any product depend mainly on physico-chemical properties of product. The mean values of physico-chemical properties by different levels of addition of pearl millet flour in *gulabjamun* are narrated in Table 3.

Table 3: Effect of pearl millet flour on the physico-chemical properties of *gulabjamun*

Treatments	Acidity (% LA)	pH	Sugar Syrup Absorption (g/100 g)
C	0.31b±0.01	6.66a±0.09	130.15d±1.40
G1	0.32ab±0.01	6.61a±0.06	132.70c±0.81
G2	0.32ab±0.01	6.59a±0.06	133.60bc±0.66
G3	0.32a±0.01	6.57a±0.05	134.48b±1.18
G4	0.33a±0.01	6.58a±0.02	136.55a±1.08
SEm	0.01	0.03	0.53
CD (0.05%)	NS	NS	1.59
CV (%)	2.59	0.90	0.79
Fisher's Least Significant Difference indicates that means with at least one letter common are not statistically significant. The figures placed after±represent Standard Deviation.			

The addition of different rates of pearl millet flour had not any statistically significant impact on the acidity of *gulabjamun*. The acidity of *gulabjamun* added with five various proportions of pearl millet: *maida* i.e. 25:75 (G1), 50:50 (G2), 75:25 (G3), 100:0 (G4) and 0:100 (C) were found to be 0.32, 0.32, 0.32, 0.33 and 0.31% LA, respectively. Statistics revealed that the treatment G1, G2, G3 and G4 were at par with each other, while C, G1 and G2 also statistically non-significantly differed. According to the tabulated data and relevant statistical analysis, the pH of *gulabjamun* did not varied statistical significantly when pearl millet flour was added at various rates. The pH of *gulabjamun* varied in a small range from 6.57 (G3) to 6.66 (G1). Data obtained from Table 3 showed that as the rate of pearl millet increased, there was not any specific trend was observed in the pH of *gulabjamun*. Statistics revealed that all treatments were comparable to one another. The production of *gulabjamun* involves several steps, one of which is the soaking of *gulabjamun* balls in sugar syrup. It promotes sugar syrup absorption, which raises *gulabjamun's* weight and sweetness. The average results for the sugar syrup absorption of *gulabjamun* produced with various amounts of pearl millet flour addition are narrated in Table 3. The addition of varied rates of pearl millet flour significantly (p<0.05) affects the *gulabjamun's* capacity to absorb sugar syrup. The average values for sugar syrup absorption of *gulabjamun* varied from 130.15 to 136.55 g/100 g. The sugar syrup absorption was found to be higher in G4 (136.55 g/100 g) as compared to other treatments. Table 3 demonstrated that the rate at which pearl millet flour was added to *gulabjamun* increased, there was a significant (p<0.05) increased in the amount of sugar syrup that the *gulabjamun* absorbed from 130.15 to 136.55 g/100 g. Among all treatments, G1 and G2 were found to be statistically at par with each other, while G2 and G3 were also statistically non-significantly differed.

3.5 Effect of Pearl Millet Flour on the Rheological Properties of *Gulabjamun*

The sensory characteristics and overall quality of *gulabjamun* are significantly influenced by a rheological property of *gulabjamun*. The type of raw material utilized, its composition and the manufacturing procedure used all have a considerable impact on the textural appearance of *gulabjamun*. Hardness, cohesiveness, chewiness, gumminess and springiness were the characteristics taken into consideration for *gulabjamun's* rheological appearance. Effect of pearl millet flour on chemical composition of *gulabjamun* was shown in Table 4.

Table 4: Effect of pearl millet flour on the rheological properties of *gulabjamun*

Treatment	Hardness (N)	Cohesiveness	Gumminess (N)	Springiness (mm)	Chewiness (Nmm)
C	8.93a±0.29	0.30ab±0.03	2.63a±0.13	6.49c±0.34	17.07bc±1.31
G1	8.31ab±0.59	0.25c±0.02	2.07b±0.28	7.17bc±0.65	14.90c±2.95
G2	9.00a±0.52	0.31a±0.00	2.79a±0.19	7.21b±0.54	20.00a±0.25
G3	8.08b±0.30	0.27bc±0.03	2.16b±0.17	8.08a±0.47	17.48ab±1.77
G4	7.36c±0.23	0.29ab±0.02	2.10b±0.11	6.97bc±0.18	14.62c±0.86
SEm	0.23	0.01	0.09	0.23	0.85
CD (0.05%)	0.70	0.03	0.28	0.70	2.56
CV (%)	5.60	7.77	7.85	6.49	10.09
Fisher's Least Significant Difference indicates that means with at least one letter common are not statistically significant. The figures placed after±represent Standard Deviation.					

The amount of pearl millet flour used had a significant (p<0.05) impact on the hardness of *gulabjamun*. The mean score for the hardness of *gulabjamun* varied from 7.36 N (G4) to 9.00 N (G2). It can be seen from the tabulated values that as the rate of addition of pearl millet flour increased, the hardness of *gulabjamun* was significantly (p<0.05) decreased except G2 sample of *gulabjamun*. It was revealed from the tabulated values that sample G1 and G3 were statistically equivalent to one another, while sample C, G1 and G2 were also statistically non-significantly differed. The average values for the cohesiveness of *gulabjamun* varied from 0.25 (G1) to 0.31 (G2). Data obtained from Table 4 showed that as the level of addition of pearl millet increased, there was not any specific trend was observed in the cohesiveness of *gulabjamun*. Statistics revealed that among all treatments, samples C, G2 and G4; C, G3 and G4 were comparable to one another and samples G1 and G3 were also equivalent. The gumminess of *gulabjamun* varied from 2.07 N (G1) to 2.79 N (G2). Among the different treatments studied, gumminess was found to be higher in G2 (2.79 N) sample as compared to other treatments. Table 4 showed that there was not any noticeable trend found for the gumminess of *gulabjamun* as the level of pearl millet addition increased. The tabulated values showed that sample C and sample G2 were statistically comparable to each other, while samples G1, G3 and G4 were also statistically non-significantly different. The springiness of *gulabjamun* varied from 6.49 mm (C) to 8.08 mm (G3). It can be shown from Table 4 that except G4 sample of *gulabjamun*, there was a statistically significant (p<0.05) rise in the springiness of *gulabjamun* with an increased in the rate of addition of pearl millet flour. The values of springiness for C, G1, G4 and G1, G2, G4 were discovered to be statistically equivalent among all treatments. The inclusion of pearl millet flour at varying rates significantly (p<0.05) impacted the chewiness of *gulabjamun*. The mean values for the chewiness of *gulabjamun* varied from 14.62 Nmm (G4) to 20.00 Nmm (G2). Table 4 showed that there was not any noticeable trend found for the chewiness of *gulabjamun* as the level of pearl millet addition increased. It is revealed from the tabulated values that sample C and G3; G2 and G3 were statistically at par with one another, while sample C, G1 and G4 also did not differ statistically. The rheological properties of *gulabjamun* varied noticeably with the type of milk utilized for the development of *khoa* for the production of *gulabjamun.* The rheological properties of *gulabjamun* are also affected by the proportion of different ingredients like *khoa*, *maida*, pearl millet and baking soda. The amount of water used for the preparation of dough also influences the rheological properties of *gulabjamun* (Lad, 2016) [12]. Thus, differences in rheological properties of *gulabjamun* prepared from various levels of addition of pearl millet flour

as well as the values stated in the literature may be attributed to such reasons.

Published data on proximate composition, physico-chemical attributes, rheological property and sensory attributes of *gulabjamun* affected by addition of pearl millet (*bajra*) are not available for comparison; however the values observed in the present study are very close to those reported by Patel *et al*. (2020) [17], Rathava *et al.* (2018) [21], Vasava *et al.* (2018) [23], Patil *et al.* (2017) [20], Lad (2016) [12], Chaudhari (2016) [6], Kardule (2015) [8], Nalawade (2014) [15], Patil (2014) [19], Krishnaveni (2010) [9], Singh *et al*. (2009) [22], Adhikari (1993) [1] and Patel *et al*. (1992) [16].

After completion of compositional analysis, physico-chemical analysis, sensory attributes and rheological properties of all treatment's *gulabjamun*, it was concluded based on the sensory evaluation that the G2 (pearl millet and *maida* @ 50:50) sample of *gulabjamun* was selected as optimized product for further storage studies, cost calculations and consumer acceptance trial.

4. Conclusion

It can be concluded on the basis of sensory evaluation of this investigation that a proportion of pearl millet: *Maida* @ 50:50 by 20% weight of *khoa* was most appropriate for development of *gulabjamun*. This developed *gulabjamun* contained pearl millet (*bajra*) flour which provides better nutrition value and also reduce gluten content of the final product which is essential for person who have celiac diseases. So, it is a reasonably well balanced food with functional properties that have been show to provide some medicinal benefits.

5. References

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