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Influence of incorporation of whey protein concentrate on the quality and yield of *Gulab jamun*

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Abstract
The present investigation was planned and conducted to study the influence of incorporation of WPC in milk on the quality and yield of *Gulab jamun*. Six batches of *khoa* were prepared by incorporating WPC in standardized milk (4.5% milk fat/ 8.5% MSNF) at different rates viz. 0.25 (K1), 0.50 (K2), 0.75 (K3), 1.00 (K4), 1.25 (K5) and 1.50 (K6) % w/w of milk. Control *khoa* (CK) was prepared without addition of WPC in milk. Six batches of *Gulab jamun* viz. G1, G2, G3, G4, G5 and G6 were prepared from experimental *khoa* samples K1, K2, K3, K4, K5 and K6 respectively, while control *Gulab jamun* (CG) was prepared from CK. The average yield of *khoa* samples prepared by addition of WPC in milk ranged from 21.32 to 27.29%. The addition of WPC in milk at different rates for preparation of *khoa* samples resulted in significant ($P<0.05$) increase in yield and moisture of *khoa*, while fat, and ash content decreased significantly ($P<0.05$). However, there was no significant ($P>0.05$) effect on protein content of *khoa*. Sugar absorption ratio, yield (g/100g *khoa*), moisture and protein content of experimental of *Gulab jamun* were affected significantly ($P<0.05$) while, fat, ash and total carbohydrate content were not affected significantly ($P>0.05$) at different rates of WPC in milk for preparation of experimental *Gulab jamun*. The highest mean scores of flavour 8.35, body and texture 8.18, colour and appearance 8.32 and overall acceptability 8.28 were obtained in experimental *Gulab jamun* G3 (0.75% WPC w/w of milk) compared to all other experimental sample as well as CG. Acceptable quality *Gulab jamun* could be prepared by addition of WPC in milk at the rate of 0.75 (% w/w of milk). The yield of the optimized *Gulab jamun* was found 33.51% higher than CG. The cost of 1.0 kg *Gulab jamun* (G3) was 14.36% less than control.

Keywords: Whey protein concentrate, WPC, *Gulab jamun*, traditional dairy product, *khoa*, sweetmeat

Introduction

India has emerged as the largest milk producing country of the world. Nearly 163.7 million metric tons milk was produced in year 2016-17 in India (Ratnam, 2018) [19]. Milk utilization pattern reveals that indigenous dairy products are India's largest selling and most profitable segment after liquid milk accounting for 50-55% of milk produced in the country (Modha *et al*., 2015) [16]. A significant proportion of milk has been used in India for preparing a wide variety of dairy delicacies an unending array of sweets and other specialties from different regions of the country. The market for traditional Indian milk products is very large, fast growing and is likely to increase at an annual growth rate of about 20% as compared to western dairy products, which varies from 5-10% (Vaghela *et al*., 2016) [26]. In India, different types of sweets/desserts are consumed and *Gulab jamun* is one of the most important sweets consumed throughout the country. *Gulab jamun* is a popular and favourite Indian sweet dish/dessert comprised of fried milk balls of golden brown colour in sweet syrup flavoured with cardamom seeds and rosewater or saffron which is served warm or cool (Singh *et al*., 2011) [24]. The gross chemical composition of *Gulab jamun* varies widely depending on numerous factors, such as composition and quality of *khoa*, proportion of ingredients and sugar syrup concentration, etc. The composition of *Gulab jamun*, on the drained weight basis, varies in the following range: 25 –35% moisture, 8.5 – 10.5% fat, 6 – 7.6% protein, 0.9 – 1.0% ash and 43 – 48% total carbohydrates (Minhas *et al*., 1985) [15].

Whey Protein Concentrate (WPC) is the cheapest and most common form of whey protein, a by-product of cheese or paneer production. WPCs are known to possess functional properties for various food applications. Various functional properties of WPC like gelation and water binding are affected by process conditions. Schmidt (1984) [20] stated that a moderate heat treatment (60-70 °C range) of whey proteins causes structural unfolding of protein and at higher temperatures depending on compositions factors, proteins aggregation occurs. The unfolding step of proteins involves molecular interaction like hydrogen and hydrophobic bonding, whereas aggregation step involves disulphides linkage and is mediated by calcium. Morr (1982) [17] also documented the effect of increased calcium on heat-induced aggregation of whey proteins. Calcium is the single most critical mineral component of whey that affects the denaturation and aggregation of proteins and general network structure. He stated that minimizing non-protein component (high protein WPC) improves gel-forming ability. Water binding property of WPC is important as it influences the body and texture of any food. Water binding is important in baked goods, meat products and processed foods where moisture retention is desirable.

Dewani and Jayaprakasha (2002) [12] in their study found that use of whey protein concentrates (WPC) at 30% level yielded the *Gulab jamun* having superior sensory attributes than the control. In case of *Gulab jamun*, above 40% WPC level there was increase in granularity of the product, unnecessarily increase in the softness and beyond 50% level there was disintegration of balls during frying. Reported that an acceptable quality of *Gulab jamun* can be prepared using 10% WPC. Addition of WPC at 10% level can give highest sensory scores and overall acceptability than control. However, sugar syrup absorption decreased while oil uptake increased with increase in levels of WPC. However, no literature is available for utilization of WPC in milk for preparation of *Gulab jamun*. Therefore experiment was undertaken for utilizing WPC in milk for preparation of *Gulab jamun* and to develop the dairy product which is acceptable with high nutritional value. The present study was conducted with following objectives to optimize the rate of addition of whey protein concentrate (WPC) in milk for preparation of *Gulab jamun* and to evaluate the yield, physico-chemical, textural characteristics and sensory characteristics of *Gulab jamun*.

Materials and Methods

Fresh, raw milk (Cow and buffalo) received at Anubhav Dairy of SMC College was used as the base material for *khoa* manufacture. Refined cottonseed oil (Fortune) was used as frying media for preparation of *Gulab jamun*. *Maida* and *Suji* (Uttam, Shree Bhagvati Flour & Food Pvt. Ltd.) was used as binder for preparation of *Gulab jamun*. Good quality commercial grade cane sugar, procured from the local market of Anand was used for preparing sugar syrup. Cardamom and baking powder was obtained from the local market of Anand. WPC-80 having a protein content of 80.30% was obtained from Charotar Casein Company, Malharpura, Nadiad and Gujarat India.

Preparation of *Khoa*

The control *khoa* was prepared from fresh standardised milk. It employed heating in a jacketed kettle with constant manual stirring-cum-scraping, keeping steam pressure 0.5-1.0 kg / sq. cm. till it reached to a semi solid consistency. Experimental *khoa* was prepared as similar to that of control *khoa* with slight modifications. For preparing experimental *khoa* samples, calculated quantity of WPC-80 in milk at different rates viz. 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 (% w/w) of milk) was blended with lukewarm milk (~ 20 x its weight) at 35-40 °C. It was then blended with milk which was used for preparation of *khoa* according to the method given above. The major difference was different rates of addition of WPC 80 i.e. 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 (% w/w) of milk.

Preparation of *Gulab jamun*

The experimental and control *khoa* were used as base material for preparation of control and experimental *Gulab jamun*. WPC (0.00, 0.25, 0.50, 0.75, 1.00, 1.25, 1.50 (% w/w) of milk) was added to standardized milk (4.50% fat & 8.50% SNF) prior to *khoa* making. *Maida and* pre-soaked *suji* (both at 10% of *khoa)* was then added to *khoa* (60-70% TS) and to prepare *Gulab jamun* dough. Approximate 10 g balls were prepared manually before frying in refined cottonseed oil (130° C for 13 - 15 min). The fried *Gulab jamun* balls were kept for 5 min before dipping in hot (65° C) sugar syrup (60%) and kept for soaking overnight.

Analysis

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

The moisture content was determined by standard procedure using Mojonnier Milk Tester Model-D (Laboratory Manual, 1959) [14]. Fat content of *Gulab jamun* was determined as per the procedure described in AOAC (2002). Total nitrogen/protein content was determined by semi-microkjeldahl method AOAC (2002), 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). Ash content was determined by procedure described in BIS (ISI: 1479-1961). The pH of *Gulab jamun* was measured using Systronic digital pH meter, Model 335 using a homogenate prepared by diluting 20 g sample in 20 ml of glass distilled water was subjected to pH measurement. The acidity of *Gulab jamun* was determined by method described in BIS (IS: 1479-1962) for condensed milk. For measurement of water activity, the sample of *Gulab jamun* 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). Peroxide value was determined by the method as described in Indian Standard (IS: 1479-1961). Yield of *Gulab jamun* was calculated by taking weight of *Gulab jamun* after soaking, and it was expressed as g/100g *khoa*.

For measuring sugar syrup absorption ratio of *Gulab jamun* fried *Gulab jamun* 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. *Gulab jamun*, after removing from syrup was allowed to drain for 10 min. on wire gauge and then weighed. Weight of two *Gulab jamun* over initial weight was taken as the amount of sugar syrup absorbed by *Gulab jamun* and represented as sugar absorption ratio.

Five samples of each experimental *Gulab jamun* 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 *Gulab jamun* held for 1 h at 23±1 ^{0}C and 55% RH. The complete work of calculations of area under the force-distance curve, statistical analysis of data generated and their conversion into various textural attributes were carried out by direct transfer of the data to Lloyd Instruments NEXYGEN data analysis and applications software.

Sensory evaluation

For the organoleptic evaluation of *Gulab jamun*, 10 judges familiar with desirable attributes of *Gulab jamun* were selected. The *Gulab jamun* samples were evaluated using a 9 - point hedonic scale. The judges were also requested to give criticisms for each attribute of the samples. Control and experimental samples of *Gulab jamun* were evaluated at a temperature of 20±2 °C.

Microbiological analysis

Gulab jamun sample was analyzed for the standard Plate Count (SPC), Coliform count and Yeast and Mold count (YMC) by the methods as described in BIS(IS: 5550: 2005).

Statistical analysis

Completely randomized design (CRD) was used for data collected in this study.

Results and discussion

To decide the proximate rate of addition of WPC in milk, *Gulab jamun* was prepared according to the method described by Aneja *et al.*, (2002) [3]. Experimental *khoa* were prepared from milks which were incorporated with WPC at rate i.e. 0.00 (CK), 0.25 (K1), 0.50 (K2), 0.75 (K3), 1.00 (K4), 1.25 (K5) and 1.50 (K6) (% w/w) in milk. Seven batches of *Gulab jamun* were prepared from *khoa* made by addition of WPC at rate i.e. 0.00 (CG), 0.25 (G1), 0.50 (G2), 0.75 (G3), 1.00 (G4), 1.25 (G5) and 1.50 (G6) (% w/w) in milk. Control *Gulab jamun* (CG) was prepared using the same method without addition of WPC in milk.

Effect of addition of different rates of WPC in milk on yield of *khoa*

The average values of % yield of *khoa* made with different rates of addition of WPC in milk were presented in Table 1. The mean values of % yield of *khoa* varied from 20.52 (CK) to 27.29 (K6). The % yield of *khoa* increased progressively with increase in the rate of addition of WPC in milk. Among the experimental samples of *khoa*, sample K6 had the highest yield (27.29%). The tabulated values showed that incorporation of WPC in milk had significant (P<0.05) effect on % yield of experimental *khoa* compared to control except the experimental samples of *khoa* K1 and K2. Among the experimental samples of *khoa* K1, K2 and K3 were found to be statistically at par with each other, while K4, K5 and K6 differ significantly (P<0.05) from K1, K2, K3 and Control *khoa* sample. No data were reported in the literature on the effect of addition of WPC in milk on yield of *khoa* for comparison with yield of experimental *khoa*. From the above discussion, it could be concluded that the average values of yield of experimental samples of *khoa* was ranged from 21.32(K1) to 27.29 (K6) %. The addition WPC in milk greater than 0.75 % in had significant (P<0.05) increase in % yield of experimental *khoa* compared to control *khoa* (20.52%).

Table 1: Effect of addition of different rates of WPC on yield and composition of *khoa*

Treatments	Yield (%)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
CK	20.52 ± 1.07	33.73 ± 2.86	21.31 ± 0.93	20.86 ± 1.11	3.66 ± 0.19
K1	21.32 ± 1.39	35.77 ± 1.93	20.85 ± 1.05	19.36 ± 0.22	3.49 ± 0.25
K2	22.45 ± 1.62	37.60 ± 1.10	20.55 ± 1.01	18.71 ± 0.73	3.35 ± 0.06
K3	23.83 ± 1.63	39.74 ± 0.76	19.91 ± 0.51	17.63 ± 0.94	3.27 ± 0.06
K4	24.95 ± 1.57	41.75 ± 2.05	19.63 ± 1.90	16.46 ± 1.09	3.20 ± 0.04
K5	26.02 ± 1.59	42.89 ± 2.55	19.22 ± 0.32	15.75 ± 1.26	3.12 ± 0.02
K6	27.29 ± 1.54	44.47 ± 1.96	18.84 ± 0.33	14.53 ± 1.26	2.95 ± 0.05
SEm	0.87	1.16	0.58	0.58	0.07
CD(0.05)	2.63	3.52	NS	1.76	0.23
CV%	6.32	5.10	5.02	5.70	3.92
Each observation is a mean ± SD of three replicate experiments (n=3); NS = Non-significant at 5% level of significance.					

Effect of addition of different rates of WPC in milk on composition of *khoa*

The average values of % moisture content of *khoa* made with addition of different rates of WPC in milk presented in Table 1 reveals that the mean values of moisture content of *khoa* varied from 33.73 (CK) to 44.47 (K6) %. The moisture content of *khoa* increased progressively with increasing the rate of WPC in milk. Incorporation of WPC in milk had significant (P<0.05) increasing effect on % moisture content of experimental samples of *khoa* compared to control sample of *khoa*, however experimental samples of *khoa* K1 and K2 were found to be statistically at par. The increase in the moisture content of experimental *khoa* may be due to the denatured proteins in WPC which are essentially insoluble, but have very high water binding capacity (Short *et al.*, 1978) [22]. From the above discussion it could be said that the average values of moisture content of experimental samples of *khoa* were ranging from 35.77(K1) to 44.47(K6) %. The addition of WPC in milk higher than the level of 0.50 % had significant (P<0.05) increasing effect on % moisture content of experimental samples of *khoa* compared to control *khoa*.

The mean values of protein content of different *khoa* as seen in Table 1 ranged from 18.84 (K6) to 21.31 (CK) %. The % protein content of all experimental of samples of *khoa* decreased progressively, but difference in % protein content was found to be non-significant (P>0.05) among experimental samples of *khoa* as well as control *khoa*. The decrease in % protein content of experimental sample of *khoa* with increased rate of WPC from 0.00 to 1.50% (w/w) of milk could be attributed to the higher moisture retention in the experimental samples *khoa* as compared to control sample of *khoa*. The protein content of experimental *khoa* decreased non-significantly (P>0.05) with increased rate of addition of WPC in milk. This may be attributed to addition of WPC in milk as it provides the protein and binds the moisture in the product.

The mean values of fat content of *khoa* varied from 14.53 (K6) to 20.86% (CK). It was observed that, the fat content of experimental samples of *khoa* decreased significantly

(P<0.05) compared to control sample of *khoa* except experimental sample of *khoa* K1. Among the experimental sample of *khoa*, K1 and K2 were found to be statistically (P>0.05) at par with each other, while K5 and K6 were also statistically non-significantly (P>0.05) differed. The decrease in fat content of experimental *khoa* could be ascribed to higher moisture content of such samples.

The mean values of ash content of *khoa* ranged from 2.95 (K6) to 3.66 (CK) %. It could be observed from Table 4.2 that with increase in the rate of WPC in milk the % ash content of product decreased progressively. The tabulated values for % ash content of experimental *khoa* prepared by addition of WPC in milk decreased significantly (P<0.05) compared to control, however % ash content of the experimental *khoa* K1 was found to be statistically at par (P>0.05) with that of control *khoa*. There was no data available for comparison of compositional aspects of *khoa* as affected by addition of WPC in milk at different rate.

Effect of addition of different rates of WPC in milk on sugar absorption ratio of *Gulab jamun*

The data obtained for sugar absorption ratio of *Gulab jamun* is presented in Table 2. The values of sugar absorption ratio of *Gulab jamun* were ranging from 1.87(CG) to 2.15(G3). The addition of WPC had significant effect (P<0.05) on sugar absorption ratio of experimental sample of *Gulab jamun* up to 0.75% level of WPC in milk. Thereafter the sugar absorption ratio of experimental *Gulab jamun* decreased significantly (P<0.05) with increase in rate of addition of WPC above level of 0.75%. However, sugar absorption ratio of experimental *Gulab jamun* sample G5 and G6 was statistically at par with each other. At higher level of WPC (0.75%) addition in milk, the sugar absorption ratio decreased due to decrease in porosity of *Gulab jamun* balls. No data were available in literature for comparison of sugar absorption ratio of experimental *Gulab jamun.*

Yield of *Gulab jamun* (g/ 100g *khoa*)

The data obtained for yield of *Gulab jamun* were presented in Table 2 reveals that the values of yield of *Gulab jamun* were ranging from 244.03(CG) to 280.57(G3) g/100g *khoa*. The yield of experimental samples of *Gulab jamun* increased significantly (P<0.05) up to 0.75% level of WPC in milk as compared to control *Gulab jamun*. Addition of WPC in milk higher than 0.75% rate resulted in decreasing non-significant (P>0.05) trend of yield of experimental *Gulab jamun*. Vaja (2012) [27] reported similar trend for yield of experimental *Gulab jamun* sample prepared from *khoa* using different blends of SCBM and whey.

Table 2: Effect of addition of different rates of WPC in milk on yield and sugar absorption ratio of *gulabjamun*

Treatments	Yield of *gulabjamun* (g/ 100g *khoa*)	Sugar absorption Ratio
CG	244.03 ± 5.98	1.87 ± 0.04
G1	254.47 ± 3.91	1.95 ± 0.03
G2	263.61 ± 6.49	2.02 ± 0.04
G3	280.57 ± 8.15	2.15 ± 0.06
G4	268.83 ± 6.90	2.05 ± 0.05
G5	257.08 ± 5.98	1.97 ± 0.04
G6	254.47 ± 7.26	1.94 ± 0.07
SEm	3.75	0.03
CD(0.05)	11.38	0.09
CV%	2.50	2.48

Each observation is a mean ± SD of three replicate experiments (n=3); NS = Non-significant at 5% level of significance.

Effect of addition of different rates of WPC in milk on composition of *Gulab jamun*

As seen in Table 3, the moisture content of experimental *Gulab jamun* G2 (32.86), G3 (34.05) and G4 (33.55) were significantly (P<0.05) higher as compared control *Gulab jamun* moisture content (30.53%). The increase in moisture content of *Gulab jamun* is attributed to higher sugar absorption ratio of experimental *Gulab jamun* (Table 2). The experimental sample G3 had significantly (P<0.05) higher moisture content compared to control and G6. The moisture content of experimental *Gulab jamun* was higher than those reported by Nalawade (2014). Average protein content of different *Gulab jamun* was found in range of 8.43(G3) to 9.55(CG) %. The protein content was higher in G1 (9.11%) compared to all other experimental *Gulab jamun*. Addition of WPC at different rate had significant (P<0.05) effect on protein content of *Gulab jamun*. The protein content of experimental *Gulab jamun* sample (G3) was lowest compared to all other experimental samples as well as control *Gulab jamun*. The protein content of *Gulab jamun* indicated that with increase in the rate of addition of WPC, the protein content of *Gulab jamun* decreased simultaneously up to 0.75% level of WPC. The decrease in % protein content of *Gulab jamun* with increased rate of addition of WPC is attributed to the higher moisture retention of *Gulab jamun*. As the rate of addition of WPC increased above 0.75%, there was non-significant (P>0.05) decrease in protein content of *Gulab jamun*. The protein content of experimental *Gulab jamun* fulfilled the requirement for protein content specified by the BIS (IS:11602:1986) and was comparable with those described by Chaudhari (2016) [9], Vaja (2012) [27], Ghube *et al.*, (2015) [13], Adhikari *et al.*, (1994) [2] and Thakar *et al.*, (1994) [25].

The fat content of the experimental *Gulab jamun* samples were found to be non-significantly (p>0.05) decreased with increased rate of addition of WPC up to 0.75%. The fat content was higher in control *Gulab jamun* (10.56%) as compared to all other treatments while the values of fat content of all experimental *Gulab jamun* in case of G1, G2, G3, G4, G5 and G6 were statistically at par with each other. The fat content of experimental *Gulab jamun* was fulfilled the requirement for fat content specified by the BIS (IS:11602: 1986) and was comparable with those reported by Chaudhari (2016) [9], Vaja (2012) [27], Singh *et al.*,(2011) [24], Deshmukh *et al.*,(1993) [10], Adhikari *et al.*, (1994) [2], and Thakar *et al.*, (1994) [25]. The addition of different rate of WPC in milk had non-significant (P>0.05) effect on ash and total carbohydrate content of experimental sample of *Gulab jamun*.

Table 3: Effect of addition of different rates of WPC (% w/w in milk) on composition of *gulab jamun*

Treatments	Moisture (%)	Protein (%)	Fatm (%)	Ash (%)	Carbohydrate (%)
CG	30.53 ± 0.90	9.55 ± 0.23	10.56 ± 0.97	1.42 ± 0.09	47.77 ± 1.50
G1	31.91 ± 1.04	9.11 ± 0.21	10.26 ± 0.98	1.37 ± 0.06	47.37 ± 1.09
G2	32.86 ± 1.15	8.82 ± 0.15	10.12 ± 0.88	1.32 ± 0.06	46.91 ± 0.82
G3	34.05 ± 1.16	8.43 ± 0.45	9.52 ± 1.02	1.27 ± 0.05	46.49 ± 1.50
G4	33.55 ± 1.13	8.65 ± 0.32	10.16 ± 0.44	1.29 ± 0.06	46.50 ± 0.98
G5	32.42 ± 1.37	8.87 ± 0.35	10.23 ± 0.43	1.32 ± 0.08	47.18 ± 1.17
G6	31.86 ± 1.68	8.92 ± 0.34	10.41 ± 0.41	1.39 ± 0.04	47.43 ± 1.68
SEm	0.71	0.18	0.45	0.04	0.74
CD(0.05)	2.14	0.54	NS	NS	NS
CV%	3.77	3.47	7.66	5.06	2.73
Each observation is a mean ± SD of three replicate experiments (n=3); NS = Non-significant at 5% level of significance.					

Effect of addition of different rates of WPC in milk on physico-chemical properties of *Gulab jamun*

It can be seen from Table 4 that the addition of different rate of WPC in milk had non-significant (P>0.05) effect on the pH of experimental *Gulab jamun*. The control sample of *Gulab jamun* had higher pH value compared to all other experimental *Gulab jamun* samples. The pH of experimental *Gulab jamun* samples obtained in present study was found in range of 6.44(G6) to 6.47(G1) pH of *Gulab jamun* which was comparable to those reported by Vaja (2012) [27]. The average value for titratable acidity of *Gulab jamun* ranged from 0.313(CG) to 0.354(G6) % LA. There was progressive increase in acidity of experimental samples of *Gulab jamun* with increase in rate of addition of WPC in milk, however the increasing effect on titratable acidity of experimental *Gulab jamun* was found to be non-significant (P>0.05). The value of titratable acidity for experimental *Gulab jamun* was comparable to those reported by Vaja (2012) [27].

The data obtained for water activity of *Gulab jamun* are presented in Table.4. The values of water activity of experimental samples of *Gulab jamun* were ranging from 0.894 to 0.908. The increase in rate of addition of WPC in milk had shown non-significant (P>0.05) decreasing trend in the water activity of experimental *Gulab jamun*. The value of water activity for experimental *Gulab jamun* was comparable to those reported by Vaja (2012) [27], but higher than that of reported by Sharma and Zariwala (1978) [21].

Table 4: Effect of addition of different rates of WPC in milk on physico-chemical properties of *gulabjamun*

Treatments	pH	Acidity (% LA)	a_w
CG	6.48 ± 0.29	0.313 ± 0.017	0.908 ± 0.025
G1	6.47 ± 0.23	0.321 ± 0.026	0.906 ± 0.230
G2	6.47 ± 0.24	0.325 ± 0.024	0.904 ± 0.016
G3	6.47 ± 0.22	0.328 ± 0.008	0.902 ± 0.017
G4	6.45 ± 0.26	0.335 ± 0.031	0.898 ± 0.018
G5	6.45 ± 0.24	0.341 ± 0.011	0.895 ± 0.021
G6	6.44 ± 0.31	0.354 ± 0.038	0.894 ± 0.026
SEm	0.15	0.014	0.012
CD(0.05)	NS	NS	NS
CV%	4.02	7.45	2.40
Each observation is a mean ± SD of three replicate experiments (n=3); NS = Non-significant at 5% level of significance.			

Effect of addition of different rate of WPC in milk on rheological properties of *Gulab jamun*

The average value of hardness of *Gulab jamun* was ranging from 7.07(G3) to 10.26(G6) N as seen in Table 5. As increase in rate of addition of WPC in milk increased the hardness of experimental *Gulab jamun* sample decreased simultaneously up to addition of 0.75% WPC in milk, while above 0.75% WPC in milk increased the hardness of experimental *Gulab jamun* sample. The hardness of experimental *Gulab jamun* sample G4 (8.36 N) and G5 (9.51N) was statistically (P>0.05) at par with each other, while the hardness of experimental *Gulab jamun* sample G5 (9.51N) and G6 (10.26N) were statistically (P>0.05) at par with each other. The hardness of experimental *Gulab jamun* G3 sample was lower among all experimental and control *Gulab jamun*. The values observed for hardness of experimental *Gulab jamun* samples were comparable to those reported by Vaja (2012) [27] (3.941 N to 2.774), Chaudhari (2016) [9] (5.10 to 8.16 N). The average value of Cohesiveness of *Gulab jamun* was ranging from 0.18 (G3) to 0.32 (G6) as presented in Table 5. The addition of different rate of WPC in milk had a significant effect (P<0.05) on cohesiveness of experimental *Gulab jamun*. The cohesiveness of experimental *Gulab jamun* decreased significantly (P<0.05) with increase in rate of addition of WPC in milk up to 0.75%. Among the entire experimental sample G3 had lowest (0.18) cohesiveness value compared to other samples except G2 sample. Singh and co-workers (2009) [23] examined the texture profile of *Gulab jamun* made by use of soy flour and reported that cohesiveness increased with increase in the level of soy flour. Adhikari (1993) [1] described the textural characteristic of *khoa* and *Gulab jamun* made from cow milk and reported that cohesiveness of laboratory and market *Gulab jamun* sample was 0.35 and 0.39. Yawale and Rao (2012) [28] studied textural profile analysis of effect of maida level in *khoa* powder *Gulab jamun* mix, and reported the cohesiveness range from 0.25 to 0.30. Vaja (2012) [27] and Chaudhari (2016) [9] reported that cohesiveness of *Gulab jamun* ranged from 0.110 to 0.165 and from 0.18 to 0.25, respectively.

Incorporation of different rate of WPC in milk has a significant effect (P<0.05) on springiness of experimental *Gulab jamun*. The springiness of experimental *Gulab jamun* increased significantly (P<0.05) with increased in rate of addition of WPC in milk up to 0.75%. Adhikari (1993) [2] who studied the textural characteristic of *khoa* and *Gulab jamun* made from cow milk reported that springiness of laboratory and market *Gulab jamun* sample was 3.60 and 3.40. Yawale and Rao (2012) [28] examined textural profile analysis of effect of maida level in *khoa* powder *Gulab jamun* mix and mentioned that the increase the level of maida increased the springiness of *Gulab jamun*. Vaja (2012) [27] and Chaudhari (2016) [9] mentioned that springiness of *Gulab jamun* ranged from 6.404 to 7.071 mm and from 6.64 to 8.19 mm, respectively.

The gumminess of experimental *Gulab jamun* G3 (1.11N) was lower compared to gumminess of all other experimental *Gulab jamun* as well as control *Gulab jamun*, however the values of gumminess of experimental *Gulab jamun* G3 was statistically at par with that of experimental *Gulab jamun* G2(1.20N). The values of gumminess of experimental *Gulab jamun* G4, G5 and G6 were statistically at par with each other. The data obtained for gumminess of experimental *Gulab jamun* was comparable to those reported by Vaja (2012) [27] and Chaudhari (2016) [9] from 0.471 to 0.472 N, and 0.93 to 2.11 N respectively. As the rate of addition of WPC in milk increased, the values of chewiness of experimental *Gulab jamun* decreased significantly (*P*<0.05) from 9.46 (G1) to 6.64 (G3) Nmm. Rate of addition of WPC in milk above 0.75% increased significantly (*P*<0.05) the values of chewiness of experimental *Gulab jamun.* Among all experimental G3 (6.65Nmm) had significantly (*P*<0.05) lower value of chewiness. Adhikari (1993) [1] examined the textural characteristics of *khoa* and *Gulab jamun* made from cow milk and reported that chewiness of laboratory and market *Gulab jamun* sample was 3.60 and 3.40 Nmm. Yawale and Rao (2012) [28] studied textural profile analysis of effect of *maida* level in *khoa* powder *Gulab jamun* mix and reported that the increase in the level of *maida* increased the chewiness of *Gulab jamun*.

Table 5: Effect addition of different rate of WPC in milk on rheological characteristics of *gulab jamun*

Treatments	**Rheological characteristics**				
	Hardness (N)	**Cohesiveness**	**Springiness (mm)**	**Gumminess (N)**	**Chewiness (Nmm)**
CG	9.38 ± 0.58	0.26 ± 0.01	4.25 ± 0.25	1.46 ± 0.11	9.65 ± 0.28
G1	8.61 ± 0.89	0.25 ± 0.07	4.62 ± 0.31	1.35 ± 0.16	9.46 ± 0.32
G2	7.31 ± 0.90	0.21 ± 0.03	5.74 ± 0.14	1.20 ± 0.13	7.61 ± 0.34
G3	7.07 ± 0.44	0.18 ± 0.01	6.50 ± 0.18	1.11 ± 0.09	6.65 ± 0.23
G4	8.36 ± 0.99	0.22 ± 0.01	6.08 ± 0.46	1.48 ± 0.17	8.47 ± 0.34
G5	9.51 ± 0.47	0.28 ± 0.01	5.36 ± 0.34	1.59 ± 0.14	9.47 ± 0.42
G6	10.26 ± 0.45	0.32 ± 0.01	5.37 ± 0.33	1.71 ± 0.14	10.27 ± 0.36
SEm	0.41	0.01	0.16	0.08	0.19
CD(0.05)	1.25	0.03	0.49	0.24	0.58
CV%	8.27	6.88	4.96	9.74	3.81
Each observation is a mean ± SD of three replicate experiments (n=3); NS = Non-significant at 5% level of significance.					

Effect of addition of different rates of WPC in milk on sensory attributes of *Gulab jamun*

The data obtained for sensory score of *Gulab jamun* is presented in Table. 6 and the comments of Judges on sensory characteristics of *Gulab jamun* are presented in Table 7. The average flavour score of *Gulab jamun* ranged from 7.44 to 8.35. The highest flavour score was (8.35) observed in experimental sample G3. The flavour score of experimental G3 sample has statistically (*P*<0.05) higher than all other experimental sample as well as control *Gulab jamun*. As the rate of addition of WPC in milk increased higher than 0.75%, the flavour score decreased non-significantly (*P*>0.05) from 7.72(G4) to 7.58(G6). Addition of different rate of WPC in milk had significant (*P*<0.05) improving effect on flavour score of experimental samples of *Gulab jamun* upto 0.75% rate of addition of WPC in milk. All the experimental samples of *Gulab jamun* had higher flavour score than control sample.

The body and texture score of experimental *Gulab jamun* increased from 7.51 (G1) to 8.18 (G3). The body and texture score of G3was significantly (*P*<0.05) higher G5, G6 and CG. Thus, addition of different rate of WPC in milk had significant (*P*<0.05) improving effect on body and texture score of experimental samples of *Gulab jamun* upto 0.75% rate of addition of WPC in milk. No any significant (*P*>0.05) difference was observed for colour and appearance scores of experimental *Gulab jamun* and control sample, though experimental *Gulab jamun* had higher colour and appearance score than control sample. Among all experimental sample of *Gulab jamun*, G3 (8.28) showed highest scores for colour and appearance. The experimental sample *Gulab jamun* G3 (8.28) sample had significantly (*P*<0.05) higher overall acceptability score among all the treatments as well as control sample. The experimental *Gulab jamun* samples G1, G2, G4, and G5 had overall acceptability score were at par with each other, while the G6 had statistically (*P*<0.05) lower overall acceptability score. Addition of different rate of WPC in milk had significant (*P*<0.05) improving effect on overall acceptability score of experimental *Gulab jamun* upto 0.75% rate of addition of WPC in milk. It can be concluded that experimental sample of *Gulab jamun* (G3*)* prepared by incorporation of at the rate of 0.75% WPC in milk yielded the most acceptable product in terms of sensory attributes.

Table 6: Effect of addition of different rates of WPC in milk on Sensory score of *gulab jamun*

Treatments	**Sensory score (out of 9.00)**			
	Flavour	**Body and Texture**	**Colour and Appearance**	**Overall Acceptability**
CG	7.44 ± 0.17	7.26 ± 0.48	7.64 ± 0.18	7.45 ± 0.19
G1	7.46 ± 0.27	7.51 ± 0.50	8.18 ± 0.57	7.71 ± 0.25
G2	7.83 ± 0.29	7.81 ± 0.71	7.88 ± 0.49	7.84 ± 0.27
G3	8.35 ± 0.26	8.18 ± 0.09	8.32 ± 0.44	8.28 ± 0.22
G4	7.72 ± 0.37	7.77 ± 0.11	7.88 ± 0.31	7.79 ± 0.18
G5	7.66 ± 0.09	7.11 ± 0.48	7.75 ± 0.08	7.50 ± 0.21
G6	7.58 ± 0.06	6.81 ± 0.43	7.66 ± 0.74	7.35 ± 0.18
SEm	0.13	0.26	0.26	0.126
CD(0.05)	0.41	0.79	NS	0.38
CV%	2.99	6.02	5.77	2.84
Each observation is a mean ± SD of three replicate experiments (n=3); NS = Non-significant at 5% level of significance.				

Table 7: Comments of Judges on sensory characteristics of *gulabjamun*

Treatments	Comments
CG	Slightly hard body, less porosity, coarse texture.
G1	Slightly hard and spongy, less porous and less coarse texture.
G2	Slight soft and spongy, porosity not uniform.
G3	Soft, spongy, succulent, good porous texture, pleasant with moderate sweetness, smooth glossy surface.
G4	Slight hard, less spongy, less porous and granular texture, less succulent.
G5	Hard, coarse, granular texture, less succulent, less sweetness.
G6	Hard, coarse, granular texture, less succulent, less sweetness.
Note: All experimental samples as well as control *gulabjamun* had golden yellowish colour and round shape	

Estimation of cost of production of optimized *Gulab jamun*

The raw material required for production of 1 kg *Gulab jamun* was 238.3 g *khoa*, 512 g sugar,23.83 g maida, 23.83 g suji, 7.50 g WPC and 1000 g refined cottonseed oil(3 times use). Thus, the total production cost of *Gulab jamun* was found to be 101.19 Rs. per kg on drain weight basis. The each *Gulab jamun* pack consists of 50:50 of *Gulab jamun* balls: sugar syrup so the cost of 1 kg of *Gulab jamun* pack would be 75.67 Rs. as seen in Table 8.

Thus, it can be concluded from the present investigation that, good quality *Gulab jamun* can be prepared by addition of WPC (at the rate of 0.75% w/w of milk) in milk used for *khoa* making. The yield of the *Gulab jamun* containing WPC was 33.51% higher than control and the cost of 1 kg *Gulab jamun* (containing 500 g *Gulab jamun* & 500 g soaking syrup) was 14.36% lower than control *Gulab jamun*.

Table 8: Estimated cost of raw materials required for 1.00 kg of optimized *gulab jamun*

Ingredients	Rate (`Rs./Kg)	Control		G3	
		Quantity (g)	Cost (Rs.)	Quantity (g)	Cost (`Rs.)
Milk	48	1000	48	1000	48
Maida(10% *khoa*)	60	20.52	1.23	23.83	1.43
Suji(10% *khoa*)	50	20.52	1.03	23.83	1.19
Sugar (50%)	32	361.50	11.57	512	16.40
Refined Vegetable oil (3times Use)	80	1000	26.67	1000	26.67
WPC (0.75% of Milk)	750	-	-	7.50	7.50
Raw material cost			80.50		101.19
Yield of *gulabjamun* (g/kg of milk)	-	500.77	-	668.60	-
Cost of 1kg *gulabjamun* (contain 500g *gulabjamun* & 500g soaking syrup)		Rs. 88.36		Rs. 75.67	

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