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Research Article

Formulation and evaluation of solar-assisted tray dried *khoa* powder based gulabjamun mix

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Abstract

The present study was envisaged to utilize *khoa* powder prepared using solar assisted tray drying system in the formulation of gulabjamun mix by mixing *khoa* powder with maida in ration of 70:30 (m/m) and adding 0.5% baking powder. The formulation obtained from solar-assisted tray-dried *khoa* powders derived from full cream milk *khoa* and standardised milk *khoa* was assessed for its compositional and physical attributes, including bulk, tapped and particle density; porosity; Carr's index; Hausner ratio and angle of repose. Additionally, the colour attributes were evaluated and compared with skim milk powder based market sample of gulabjamum mix. Further, gulabjamuns were prepared using these formulations of gulabjamun mixes and evaluated for sensory, textural and colour attributes. Results of the study implied successful use of *khoa* powder obtained from solar assisted tray drying system in formulation of gulabjamun mix with comparable sensory acceptability of gulabjamuns (overall acceptability score: 7.37±0.03) with market based gulabjamun mix samples (7.46±0.08) on a 9-point hedonic scale.

Keywords: Browning index, Gulabjamun mix, Gulabjamun, *Khoa* powder, Porosity

Highlights

- The study indicates the variations in chemical composition, as well as the physical and engineering properties of various gulabjamun mixes
- Study highlights the comparative evaluation of sensory and textural attributes of gulabjamun samples made from different formulations of gulabjamun mixes
- The information provided in this study indicates suitability of tray dried *khoa* powder in formulation of gulabjamun mix

INTRODUCTION

Gulabjamun is a famous indigenous milk-based dessert in India. Dhap *khoa* having 40-45% moisture is a good choice for preparation of the gulabjamun. Preparation of gulabjamun is a lengthy and cumbersome process as it includes conversion of milk into *khoa*, which is then utilized for the preparation of gulabjamun by mixing with maida (refined wheat flour), baking powder and other optional ingredients followed conversion of mix into dough, portioning, ball making, frying and dipping of fried balls in the sugar syrup. Maida helps to prevent the breaking of gulabjamun balls during frying.

Researchers have attempted to add convenience in the making of gulabjamun by eliminating step of *khoa* making through the development of gulabjamun mix formulations. Such formulations generally are based on roller dried milk powder or spray dried milk powders (Aneja *et al*., 2002) as a source of milk solids. Roller dried milk powders based formulations are reported to yield better quality gulabjamun than the spray dried milk powder based formulations owing to the cooked flavour of roller dried milk powders (Thakur and Ramesh, 2015). However, such formulation lacks typical *khoa* taste. Vacuum tray dried *khoa* powder based gulabjamun mix was also developed by Yawale and Rao (2012). To ensure the availability of gulabjamun throughout the years, attempts were made to develop *khoa* powder mixture-based gulabjamun mix preparation (Rajorhia, 1989). However, traders prefer to use spray dried milk powder in gulabjamun mix formulations due to its easy availability, whereas, roller dried milk powders are less abundant in marketplace. In addition, roller drying and spray dryings systems are costly compared to tray drying systems. Advantages of tray driers are relatively simple to operate and maintain for small scale drying operations. Tray dried *khoa* powder was useful particularly in case of products that cannot be dried using spray or roller

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driers, i.e. from *khoa*-to-khoa powder. The present study aimed to utilise solar-assisted tray drying systems for the production of *khoa* powder derived from *khoa* obtained from full cream and standardised milks. *Khoa* powders thus obtained were used in gulabjamun mix formulations. The concept of solar -assisted in tray drying systems can significantly enhance the energy economy (Prasad *et al*., 2024).

MATERIALS AND METHODS

Khoa powder: *Khoa* powder was obtained through solar assisted tray drying system using *khoa* prepared from full-cream milk (FM *khoa*) and standardized milk (SM *khoa*) in tray dryer at 65°C up to equilibrium moisture content (Prasad *et al*., 2024). The weight of *khoa* mass (kg) was recorded until the two consecutive reading differences is less than 0.1 g, and considered as equilibrium moisture content reached.

Formulation of gulabjamun mix: *Khoa* powder based gulabjamun mix was formulated by mixing *khoa* powder and maidaa ratio of 70:30 (m/m) and adding 0.5% baking powder (Weikfield, Pune) and mixing properly. Maida (refined wheat flour) was procured locally and passed through in an 80 meshsieve size. Various formulations were coded as given below in Table 1.

Table 1. **Different types of gulabjamun mix sample codes and their description**

S.No.	GM Code	Description
1.	GM-FM	(70% KP-FM+30% maida) + 0.5% baking powder
3.	GM-SM	(70% KP-SM+30% maida) + 0.5% baking powder
5.	GM-M	Skim milk powder based gulabjamun mix (market sample)

GM: Gulabjamun mix, KP: *Khoa* powder, FM: Full cream milk, SM: Standardized milk

Chemical composition of gulabjaum mix: Moisture (gravimetric method), fat (Mojonnier method), protein (Kjeldahl method) and ash content of gulabjamun mix was estimated adopting procedures outlined in IS: SP:18 Part XI (1981). Whereas, total carbohydrate of was estimated using the difference method.

Physical and engineering properties of gulabjaum mix: Physical and engineering properties of gulabjamun mix i.e., angle of repose (Littlefield *et al*., 2011); bulk and tapped density (Salooja and Balachandran, 1988): particle density and porosity (Prasad *et al*., 2024); Carr's Index (Carr, 1965) and Hausner Ratio (Hausner, 1967) were determined. A water activity meter (Lab Swift-aw, Novasina) was used to determine the water activity (aw) of gulabjamun mix at 25°C.

Colour measurement of gulabjamuns mix: Colour coordinates (CIELAB L*, a*, and b*) of *khoa* powder and gulabjamun mix were obtained using Colour Flex EZ (Hunter Lab, USA). Whiteness Index (WI), Browning Index (BI) and Colour Difference ($\triangle$E) were done adopting methods described by Vargas *et al*. (2008); Erbay and Koca (2015) and, Fernandez-Avila *et al*. (2017), respectively.

Preparation of gulabjamun and evaluation of sensory and texture quality

In the present investigation, gulabjamun was made using different gulabjamun mixes, i.e., GJ-FM (gulabjamun made from GM-FM gulabjamun mix); GJ-SM (gulabjamun made from GM-SM gulabjamun mix); and GJ-Mgulabjamun (gulabjamun made from GM-M gulabjamun mix) and evaluated for sensory and textural properties.

Preparation of gulabjamun: Smooth dough was formed from various gulabjamun mix formulations by adding of warm water and kneading. The dough was held for 2-3 h to provide desired hydration. Dough was portioned and converted in smooth balls of approx. 8 g size. Balls were fried in sunflower oil at 130-135°C for 10-12 min or till golden brown colour and held for 5 minutes at ambient tem-perature. Fried gulabjamun balls were then soaked in sugar syrup (60% concentration) at 65°C for 3 hours (Aneja *et al*., 2002).

Sensory evaluation: Gulab-jamun samples were subjected for evaluation of sensory quality by 7 experienced panelists selected from the dairy faculty of the College of Dairy Science, Amreli. The judges gave scores to the samples for sensory attributes viz., colour and appearance, flavour, body and texture and overall acceptability were assessed using a 9-point hedonic scale.

Texture analysis of gulabjamun: A texture analyser (model TA. XT Plus, Stable Micro Systems Ltd., UK) was used for Texture Profile Analysis (TPA) of gulabjamun in this study. TPA was done for the product to analyse hardness, adhesiveness, springiness, cohesiveness and gumminess. A P50 cylindrical probe with 5 mm/s of pre-test, test and post-test speed; and 50% compression was taken for TPA analysis.

Statistical analysis: Data obtained were subjected to one way ANOVA test using SPSS (Ver. 20.0) followed by DMRT (Duncan's multiple range tests).

RESULTS

Chemical composition of gulabjamun mix: Table 2 depicts the gross chemical composition of gulabjamun mix samples. The gulabjamun mix made by *khoa* powder exhibited lower moisture content (%) as compared to ready-to-use gulabjamun mix, which could be due to differences in formulation ratios of initial components.

Fat content of GM-FM (27.35%), GM-SM (23.15%), and GM-M (17.76%) were significantly (P<0.05) different from each other. The gulabjamun mix formulated with *khoa* powder had significantly higher fat content (%) compared to market gulabjamun mix. The protein content (%) of the experimental gulabjamun mix of GM-FM (17.76%) and GM-M (17.74%) were statistically at par with each other and significantly (P<0.05) differed from GM-FM (19.36%). In the case of carbohydrate content, GM-FM (45.03%) and GM-SM (47.38%) were statistically at par with each other and significantly (P<0.05) differed from GM-M (54.06%). The ash content (%) of the experimental gulabjamun mix of GM-M (4.02%), GM-FM (4.24%), and GM-SM (4.50%) were statistically (P<0.05) different from each other.

Table 2. Chemical compositions of gulabjamun mix

GM	Moisture (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Ash (%)
GM-FM	5.62±0.07^{a}	27.35±0.10^{c}	17.76±0.03^{a}	45.03±0.08^{a}	4.24±0.01^{b}
GM-SM	5.60±0.09^{a}	23.15±0.06^{b}	19.36±0.03^{b}	47.38±0.12^{a}	4.50±0.02^{c}
GM-M	7.42±0.15^{b}	17.76±0.45^{a}	17.74±0.56^{a}	53.06±0.25^{b}	4.02±0.06^{a}

Results are expressed as mean±SE (n = 5), $^{a-c}$ different superscripts differ significantly within column (p< 0.05).

Table 3. Physical and engineering properties of gulabjamun mixes

Parameters	GM-FM	GM-SM	GM-M
BD (kg/m^3)	477±3^{a}	540±2^{b}	475±3^{a}
TD (kg/m^3)	761±5^{a}	826±1^{b}	778±6^{a}
PD (kg/m^3)	1241±2^{a}	1267±3^{a}	1408±4^{b}
Porosity, ε (%)	61.60±0.27^{b}	57.40±0.15^{a}	66.27±0.21^{c}
CI (%)	37.39±0.15^{b}	34.60±0.64^{a}	38.91±0.07^{c}
HR	1.60±0.01^{b}	1.53±0.2^{a}	1.64±0.00^{c}
Angle of repose, θr (°)	45.59±0.19^{b}	44.75±0.21^{a}	45.15±0.07^{ab}
Water activity (a_w)	0.381±0.002^{b}	0.378±0.00^{b}	0.333±0.00^{a}

Results are expressed as mean±SE (n = 5), a-c different superscripts differ significantly within rows (p< 0.05).

Physical and engineering properties of gulabjamun mix: Physical and engineering properties of gulabjamun mix i.e. bulk density (BD), tapped density (TD), particle density (PD), porosity (%), Carr's index (CI), Hausner ratio (HR), Angle of repose and water activity (a_w) are shown in Table 3.

The bulk density of SM-*khoa* powder-based gulabjamun mix (540 kg/m^3) was significantly higher (p<0.05) than that of FM-*khoa* powder-based gulabjamun mix (477 kg/m^3). In the case of tapped density values for gulabjamun mix, GM-FM (761 kg/m^3) and GM-M (778 kg/m^3) were statistically at par. In the case of particle density of gulabjamun mix, GM-FM (1241 kg/m^3) and GM-SM (1267 kg/m^3) were found statistically at par with each other and significantly (P<0.05) differed from GM-M (1408 kg/m^3). The porosity (%) of gulabjamun mix for GM-FM (61.60%), GM-SM (57.40%), and GM-M (66.27%) were statistically (P<0.05) different from each other. The Carr's index (% CI) of gulabjamun mix samples for GM-FM (37.39%), GM-SM-(34.60%), and GM-M (38.91%) were statistically (P<0.05) different from each other. The Hausner ratio (HR) for GM-FM (1.60), GM-SM (1.53), and GM-M (1.64) gulabjamun mix samples were statistically (P<0.05) different from each other. The angle of repose (θr) for gulabjamun mix samples was GM-FM (45.59°) > GM-M (45.15°) > GM-SM (44.75°).

Table 4. Colour and colour indices of different types of gulabjamun mix

Colour parameters	GM-FM	GM-SM	GM-M
L*	81.92±0.46^{a}	83.23±0.44^{ab}	86.37±0.05^{b}
a*	-0.34±0.07^{b}	-0.43±0.11^{b}	-1.01±0.02^{a}
b*	20.96±0.77^{b}	19.78±0.59^{a}	21.21±0.12^{b}
WI	72.31±0.86^{a}	74.05±0.70^{b}	74.77±0.13^{b}
BI	28.58±1.47^{b}	26.14±1.15^{a}	26.59±0.22^{a}

Results are expressed as Mean±SE (n = 5), $^{a-c}$ different superscripts differ significantly within row (p< 0.05).

Colour and colour indices of gulabjamun mix: Colour coordinates (L*, a*, b*) as well as the colour indices i.e., whiteness and browning index of gulabjamun mix are presented in Table 4.

Table 5. Sensory attributes of gulabjamun made by different types of gulabjamun mix

GJ Types	Flavour	Body and Texture	Colour and Appearance	Overall acceptability
GJ-FM	7.66±0.06^{b}	7.39±0.07^{b}	7.33±0.52^{b}	7.37±0.03^{b}
GJ-SM	7.59±0.06^{b}	6.73±0.07^{a}	6.81±0.06^{a}	6.99±0.06^{a}
GJ-M	7.19±0.06^{a}	8.07±0.07^{c}	7.33±0.07^{b}	7.46±0.08^{b}

Data are expressed as mean±SE (n = 7), $^{a\text{-}c}$ different superscripts differ significantly within the column (p< 0.05).

Table 6. Textural properties of gulabjamun made using different gulabjamun mix

Texture Property	GJ-FM	GJ-SM	GJ-M
Hardness(g)	2651±62^{b}	3446±136^{c}	1917±32^{a}
Adhesiveness (g)	-111.7±3.2^{b}	-126.4±3.28^{a}	-37.5±1.34^{c}
Springiness (s)	0.334±0.01^{a}	0.413±0.014^{b}	0.749±0.009^{c}
Cohesiveness	0.418±0.002^{b}	0.335±0.007^{a}	0.624±0.002^{c}
Gumminess (g)	1107.8±24.5^{a}	1149.9±27.4^{ab}	1195.7±19.8^{b}
Chewiness (g. s)	370.5±12.9^{a}	475.9±26.0^{b}	894.6±9.9^{c}

Results are expressed as Mean±SE (n = 5), $^{a\text{-}c}$different superscripts differ significantly within row (p< 0.05).

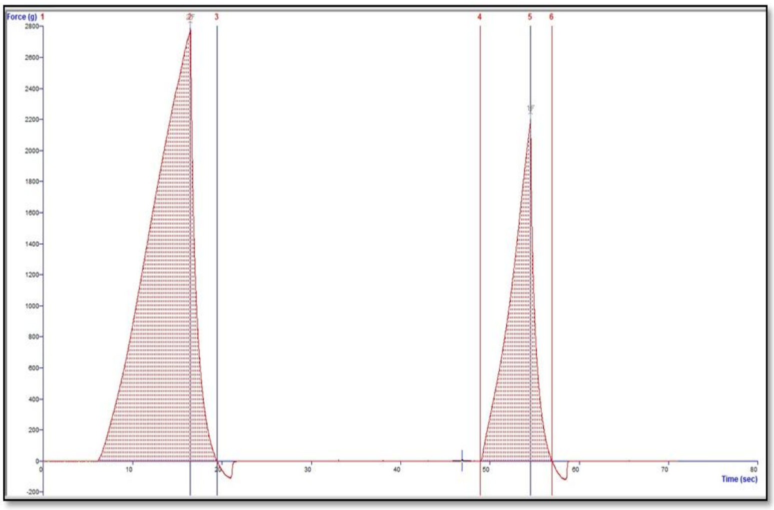

Fig. 1. A typical texture profile of gulabjamun

Lightness (L*) values of SM-*khoa* powder-based gulabjamun mix (83.23±0.44) were slightly higher than those of FM-*khoa* powder-based gulabjamun mix (81.92±0.46). The a* values for gulabjamun mix GM-FM (-0.34±0.07) and GM-SM (-0.43±0.11) were statistically at par with each other and were significantly (P<0.05) differed from GM-M (-1.01±0.02). The b* parameter indicates positive values for yellowish colours and negative values for bluish colours. The order of b* values for gulabjamun mix is GM-SM (19.78) < GM-FM (20.96) < GM-M (21.21).

Sensory quality of gulabjamun: The sensory parameter chosen to assess the quality of gulabjamun was flavour, body and texture (B&T), colour and appearance (C&A) and overall acceptability (OA) score. The average sensory scores of different attributes are presented in Table 5.

The flavor values for gulabjamun GJ-FM (7.66±0.06) and GJ-SM (7.59±0.06) were statistically at par with each other and were significantly (P<0.05) differed from GJ-M (7.19±0.06). The body and texture (B &T) score was statistically (p< 0.05) different with each other for GJ-FM, GJ-SM, and GJ-M gulabjamun samples. The colour and appearance (C&A) were statistically at par with each other for GJ-FM and GJ-M in the gulabjamun samples. The overall acceptability for gulabjamun GJ-FM (7.37±0.03) and GJ-M (7.46±0.08) were statistically at par with each other and were significantly (P<0.05) differed from GJ-SM (6.99±0.06).

Textural properties of gulabjamun made by gulabjamun mix: Textural characteristics of gulabjamun made by different types of gulabjamun mix are presented in Table 6.

The hardness (g) of GJ-FM (2651±62 g), GJ-SM (3446±136 g), and GJ-M (1917±32 g) were statistically different (P<0.05) from each other. The adhesiveness (g) of GJ-FM (-111.7 g), GJ-SM (-126.42 g), and GJ-M (-37.5 g) were statistically different (P<0.05) from each other. The springiness (g) of GJ-FM, GJ-SM and GJ-M were statistically different (P<0.05). Cohesiveness is the ratio of the area of the second bite to the first bite. Gulabjamun GJ-M sample had the highest value of the cohesiveness, i.e., 0.624. Texture profile analysis (TPA) curve of gulabjamun is given in Fig. 1. The cohesiveness for GJ-SM (0.335), GJ-FM (0.418), and GJ-M (0.624) gulabjamun samples were statistically significantly (P<0.05) different from each other.

DISCUSSION

Chemical composition of gulabjamun mix: The chemical composition of gulabjamun mix largely depends on the choice of ingredients used in the formulation. Some formulations use SMP as a source of milk solids, whereas the fat content is adjusted using vegetable oil or ghee. It is difficult to differentiate whether the difference in the experimental gulabjamun mix and the manual gulabjamun mix is only due to the form, such as maida, fat source in different ratios. The findings of Ghosh *et al.* (1984) supported our observations and reported that the moisture (%) and protein (%) of the market gulabjamun mix in the range of 6 to 8% and 17 to 19%, respectively. According to Kushwaha *et al.* (2018), the ready-to-use gulabjamun mix contained an average of 8.60% moisture, 13.75% fat, 20.50% protein, and 4.0% ash. All varieties of *khoa* powder-based gulabjamun mix were in accordance with IS 12220-1987, which suggested a maximum of 8% moisture, a minimum of 15% total protein, a minimum of 15% fat (dry basis), and a maximum of 60% carbohydrate in instant gulabjamun mix.

Physical and engineering properties of gulabjamun mix: The bulk density of gulabjamun mix depends on moisture content, the quantity of interstitial air between powder particles, and the shape, size, and size distribution of the particles themselves. Literature on the bulk density of gulabjamun mix is limited. Szulc *et al.* (2016) reported that the mean bulk density and tapped density of WMP were 461 kg/m^3 and 541 kg/m^3, respectively. Particle density depends mainly on the composition of the gulabjamun mix because it defines the product mass density. Westergaard (1994) reported that particle density (kg/m^3) of WMP, nonfat milk solid, and spray dried whey powder were 1280, 1520, and 1580 kg/m^3, respectively.

The porosity of the *khoa* powder-based gulabjamun mix was lower than that of the SMP-based gulabjamun mix, due to the fact that the the fact that the porosity of *khoa* powder was lower than skim milk powder (SMP). Mettler (1980) reported that the porosity of spray-dried WMP and SMP was 74 and 57%, respectively. The compressibility index assesses the ability to lower the volume of the gulabjamun mix. The Hausner ratio (HR) represents the ratio of tap bulk density to bulk density. Powders having a Hausner ratio of less than 1.25 are easily fluidized, but powders having a ratio of more than 1.4 showed by showed difficulties in the fluidization process (Geldart *et al.*, 1984). SM-*khoa* powder-based gulabjamun mix had a higher Hausner ratio compared to FM-*khoa* powder-based gulabjamun mix; therefore, SM-*khoa* powder-based gulabjamun mix could be considered less fluidized. Ilari and Mekkaoui (2005) reported that the Hausner ratio of whole milk powder was 1.59.

The angle of repose (θr) for gulabjamun mix samples was GM-FM (45.59°) > GM-M (45.15°)> GM-SM (44.75°). A lower angle of repose indicates better free-flowing property; therefore, SM-*khoa* powder-based gulabjamun mix had better free flowing property as compared to FM-*khoa* powder-based gulabjamun mix. Walstra *et al.* (1999) stated that the angle of repose for WMP and SMP was 46.5° and 46°, respectively. The water activity (a_w) for GM-FM (0.381) and GM-SM (0.378) gulabjamun mix samples were statistically at par with each other and significantly ($P<0.05$) differed from GM-M (0.333). According to Pugliese *et al.* (2017), SMP's water activity ranged from 0.237 to 0.303, while that of WMP ranged from 0.249 to 0.329.

Colour and colour indexes of gulabjamun mix: Lightness (L*) values of SM-*khoa* powder-based gulabjamun mix (83.23±0.44) were slightly higher than those of FM-*khoa* powder-based gulabjamun mix (81.92±0.46) due to the FM-*khoa* powder-based gulabjamun mix having a higher fat content than the SM-*khoa* powder-based gulabjamun mix, which supports fat if the L* is higher. Market-based gulabjamun mix had a higher L* value (86.37±0.05) compared to *khoa* powder-based gulabjamun mix due to the L* value of skim milk powder being higher than *khoa* powder. According to Nanua *et al.* (2000), whole milk powder L* value was 95.96. According to Milovanovic *et al.* (2020), buffalo milk powder colour coordinates (L*, a*, b*) buffalo milk powder were 87.9±3.6, -3.56±0.4, and 8.8±6.5, respectively.

The WI of GM-M (74.77) and GM-SM(74.05) were statistically at par ($p<0.05$) and GM-FM (72.31) differs for each other. The mean of BI for GM-M (26.59) and GM-SM (26.14) gulabjamun mixes were statistically at par with each other and significantly ($P<0.05$) differed from GM-FM (28.58) gulabjamun mixes. BI of the SM-*khoa* powder-based gulabjamun mix was lower than the FM-*khoa* powder-based gulabjamun mix, due to the difference in the initial composition ofraw material. Al-Hilphy *et al.* (2021) reported that colour measurement systems were considered crucial in assessing food product acceptability and quality. Adekunte *et al.* (2010) divided perceivable colour differences into three categories: highly distinct (△E>3), distinct (1.5<△E<3), and small differences (1.5<△E). The average colour difference (△E) of *khoa* powder-based gulabjamun mix and SMP-based gulabjamun mix was calculated to 4.53 (GM-FM-E) and showed highly distinct total differences between *khoa* powder-based gulabjamun mix and SMP-based market gulabjamun mix.

Sensory quality of gulabjamun: Sensory attributes play a vital role in deciding the acceptability of the product. The quality of gulabjamun was brown, with a smooth and spherical shape, a soft and slightly spongy body, no lumps or hard central core, a cooked flavour, and thoroughly saturated with sugar syrup for optimum sweetness. The flavour score of *khoa* powder-based gulabjamun was found to be higher than market gulabjamun mix-based gulabjamun due to the higher percentage of milk solids in *khoa* powder-based gulabjamun. Body and texture scores of *khoa* powder-based gulabjamun were lower than SMP-gulabjamun mix-based gulabjamun (GJ-M), due to less cohesive force between the particle and non-uniform particle size distribution of *khoa* powder. The colour and appearance (C&A) were statistically at par with each other for GJ-FM and GJ-M in the gulabjamun samples. Colour and appearance scores of FM *khoa* powder (FM-GJ)-based gulabjamun were higher than SM *khoa* powder-based gulabjamun (GJ-SM), due to the higher percentage of milk fat in FM *khoa* powder-based gulabjamun. The overall acceptability score (OA) of FM *khoa* powder-based gulabjamun was higher than SM *khoa* powder-based gulabjamun. Patel *et al.* (2020) reported that flavour, body & texture, colour & appearance, and overall acceptability scores of gulabjamun made from *khoa* and maida (80:20) were obtained 7.33, 7.51, 7.41, and 7.24, respectively; the result reported was in agreement with the current study. The result obtained for the overall acceptability of the gulabjamun was close to the findings of Dewani and Jayprakasa (2002), who studied the effect of the addition of whey protein concentrated and reported an overall acceptability score for the gulabjamun ranging from 6.50 to 8.16.

Textural properties of gulabjamun made by gulabjamun mix: The hardness of gulabjamun depends upon various factors, including moisture content, porosity, and composition of gulabjamun mix. Sukre *et al.* (2021) reported the hardness of market gulabjamun in the range of 3.36 N to 10.71 N. Patel *et al. (*2020) reported that hardness (N) of gulabjamun made from *khoa* and maida (80:20) was obtained at 11.34 N. Yawale and Rao (2012) studied the textural properties of gulabjamun made by *khoa* powder gulabjamun mix and reported that the hardness ranged from 2.65 to 4.90 kg (force), which showed similar agreement with our observations in range of 1.917 to 2.651 kg force. Adhesiveness is interrelated to sensory stickiness and measured by a negative peak. Gulabjamun made by SMP-based gulabjmun mix (0.749 seconds) was found to have the highest springiness. Yawale and Rao (2012) reported that decreasing the addition of maida decreased the springiness of gulabjamun. Sukre *et al.* (2021) reported that the springiness value of *khoa* powder-based gulabjamun (0.52 seconds) was lower than SMP-based gulabjamun (0.88 seconds), which shows similar results with current findings. Patel *et al.* (2020) reported that the cohesiveness of gulabjamun made from *khoa* and maida (80:20) was obtained at 0.40; the results were in support with the present investigation. Yawale and Rao (2012) reported that cohesiveness ranged from 0.25 to 0.30 for gulabjamun made by *khoa* powder-based gulabjamun mix; that result is lower than the findings of the current investigation. Gumminess is related to hardness and cohesiveness and is calculated by the product of these two parameters. Sukre *et al.* (2021) reported gumminess of market gulabjamun samples in the range of 0.86 to 2.14 N. Patel *et al. (*2020) reported that gumminess (N) of gulabjamun made from *khoa* and maida (80:20) was 4.70 N. Current investigation found that GJ-M gulabjamun (1195.7 g) had the highest gumminess and had the highest percentage of added refined wheat flour compared to experimental samples. Chewiness is calculated by the product of gumminess (hardness x cohesiveness) and springiness. The chewiness for GJ-FM (370.5 g/s), GJ-SM (475.9 g/s), and GJ-M (894.7 g/s) gulabjamun samples were statistically ($P<0.05$) different from each other. Yawale and Rao (2012) studied the effect of maida level in *khoa* powder-based gulabjamun mix and reported chewiness of gulabjamun increases with increased level of maida.

The aim of the study was to check the suitability *khoa* powder made by solar-assisted tray dryer in the formulation of gulabjamun mix. The flavour score of *khoa* powder based gulabjamuns was found to be higher than that of samples prepared using skim milk powder based gulabjamun mix market samples. However, market based mix formulation yielded better body and texture scores. In terms of overall acceptability full cream milk based *khoa* powder yielded better scores than standardized milk based *khoa* powder based gulabjamun mix samples. Acceptable quality gulabjamun mix can formulated using full cream based *khoa* powder obtained from tray drying process. The study proposes a unique approach for producing *khoa* powder in gulabjamun mix formulations using solar-assisted tray drying. It contributes to the existing corpus of knowledge about dairy-based dessert formulations.

Conflict of interest: The author declares no conflicts of interest pertaining to this research study.

Author's contribution: SP: Tested the samples, wrote the first version of the article, collected and organized the data, and played a pivotal role in crafting the original draft of the article; BPS: Provided valuable expertise in designing the research plan and offered continuous guidance throughout the study; KKA: Played a key role in interpreting the data for the article, evaluating the entire study comprehensively, conducted the final editing to ensure the article's; TH: Supervised chemical analysis of the samples, editing of manuscript.

Data availability statement: All the data supporting the research findings have been presented in this paper. The corresponding author is willing to provide the raw data upon reasonable request.

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