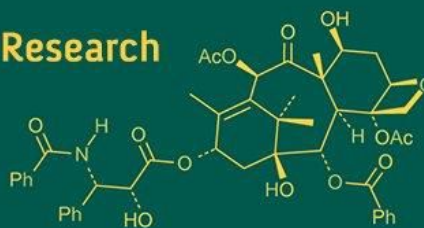
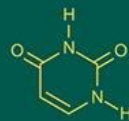
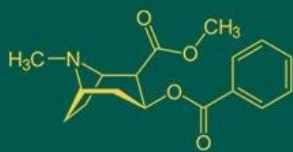


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Standardization of formulation and processing conditions for the development of ghee residue-based *Baal Mithai*

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Abstract

The byproducts generated during the processing of milk remained underutilized because of the lack of information and facilities in our country. Their appropriate use can improve the income of both milk producers and the processors. Like many other byproducts from the milk processing industry, the ghee residue (GR) obtained during ghee production is one of the valuable byproducts of ghee production units, which have been neglected in spite of their promising opportunity for further value addition. Therefore, in the present study, efforts were made to valorize GR by incorporating it into *Baal Mithai* (a traditional Indian sweet) formulation by replacing the khoa used in the traditional recipe. GR was collected from a local ghee processor and pretreated with different concentrations of sodium bicarbonate, and the 1.5% treatment was found to be the best on the basis of its yield and other quality attributes. Subsequently, a standardized *Baal Mithai* formulation was developed by replacing khoa with pretreated GR at the 60% level based on its quality parameters. This formulation showed highly acceptable texture, higher moisture and fat, and enhanced flavor and aftertaste. This study demonstrated the potentials of the GR using the formulation of traditional sweet *Baal Mithai* for their nutritional enhancement without affecting its acceptability.

Keywords: Ghee residue, *Baal Mithai*, optimization, sodium bicarbonate, physicochemical properties, sensory evaluation

Introduction

The burden on current food systems to feed a greater population has greatly risen as a result of rising global population. Therefore, the modern food enterprises are concentrating on a number of strategies to expand their production capacity due to limited food resources. One such strategy is the use of byproducts in various food applications. The food industry has traditionally placed a strong emphasis on finding a commercial use for the by-products due to their economic significance. Utilizing by-products helps the industry's economy by boosting production capacity, diversifying its product line, and reducing the strain on effluent treatment plants (ETPs) to reduce the organic load in the effluents before disposal. This is consistent with the European Union's (EU) action plan for the "circular economy," which includes a thorough strategy to reduce, reuse, recover, and recycle energy and nutrients (Faustino *et al.*, 2019)^[5].

India is the leader in the milk production scenario in the world. The production and processing of this huge amount of milk always generates a number of by-products like whey, buttermilk, skim milk, and ghee residue (GR) and derived by-products like caseins, caseinates, lactose, whey proteins (WP), etc. The high nutritive value of these dairy byproducts has prompted the researchers and the milk processors to find ways to utilize these byproducts efficiently (Rafiq and Rafiq, 2018)^[12]. Approximately 33% of India's annual milk supply is reportedly used to make ghee, according to published reports. Ghee residue makes up about 10% of the total ghee produced in our country. Ghee residue is a by-product of the dairy industry that is obtained by the ghee manufacturing process. Ghee residue has been reported as one of the largest by-products of the dairy industry (Janghu). According to reports, the majority of the GR obtained is discarded as waste due to a lack of knowledge about the quality characteristics of GR.

Current patterns and shifting consumer preferences suggest that classic products have a huge possibility for innovation and development. Among many traditional sweets available in our country, *Baal Mithai* is one of the important sweets preferred due to its characteristic flavor and texture (Aggarwal *et al.*, 2018) [1]. It is a heat-desiccated traditional dairy sweet that belongs to the Kumaon region of Uttarakhand. It is famous for its brown chocolate-like fudge prepared from roasted khoa and covered in white sugar balls. Ghee residue has good nutrients and energy, i.e., the fat, protein, lactose, and ash content. That's why it can be used as a very good substitute for khoa in *Baal Mithai* and can be incorporated in the making of *Baal Mithai* sweet without altering its sensorial properties. In the present study, we have standardized the formulation and the processing conditions for the development of ghee residue-based *Baal Mithai*.

Materials and Methods

Ghee Residue (GR), was sourced from the Dairy Technology section of the Livestock Production Management Division, ICAR-IVRI, Izatnagar, Bareilly (U.P.), collected in low-density polyethylene (LDPE) and refrigerated at $4 \pm 2^\circ\text{C}$. The milk (mixed cow and buffalo milk) utilized for *khoa* preparation was pasteurized and collected from the same place. The analytical grade chemicals (HiMedia, Merck, Sigma-Aldrich) and ingredients like sugar, cardamom, and sodium bicarbonate were procured from the local market of Bareilly. The glassware and plastic wares was procured from standard farms (Tarson, Borosil) and the LDPE pouches (200 gauge) were purchased from local market.

Methods

To standardize the formulation of ghee residue incorporated *Baal Mithai*, in the preliminary trials a control *Baal Mithai* formulation was standardized.

Standardization of control *Baal Mithai*

The two major ingredients i.e. *khoa* and cane sugar, for *Baal Mithai* were selected based on the information from the traditional *Baal Mithai* processors in Bareilly city. The *khoa* and sugar were mixed in various ratios viz., 50:50, 60:40, 70:30 and 80:20 and cooked for 20 min at medium heat (177°C to 191°C) in iron made *kadhai*, with continuous stirring with iron made spatula. After proper cooking the *khoa* and sugar mix was getting separated from the utensil surface, was the indication of optimum cooking. The cooked mix was cooled in a rectangular stainless steel tray by patting the mix to a 1 cm thickness sheet, after rinsing the inner surface with greasing oil.

Pretreatment of GR and preparation of *khoa*

Unprocessed GR was collected from ghee processors in Bareilly city. After bringing to the laboratory the GR sample was treated with different levels of sodium bicarbonate solution in water. Solutions were prepared using 0.5 (T₁), 1 (T₂) and 1.5% (T₃) sodium bicarbonate in potable water. Then GR samples were weighted (100 g) in muslin cloth then tied and put in vessel containing sodium bicarbonate solution. Vessel was put on gas stove and solution was boiled 100°C for 20 min. After heat treatment muslin cloth with sample was hanged in air to remove excess water for 5 hour. Later muslin cloth was untied and treated GR was poured on stainless steel tray then weighted.

For the preparation of *khoa*, method described by Dua *et al.* (2018) [4], was followed by using the pasteurized milk (mixed cow and buffalo milk) collected from dairy technology section of the LPT Division. The milk was with a pH 6.55, specific gravity 1.027, fat 5.3%, SNF 8.1%. The steps are presented in Figure 1.

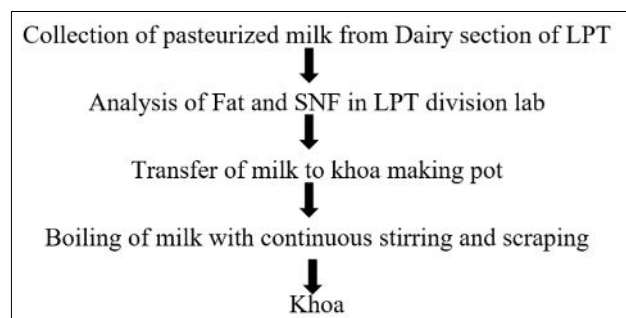


Fig 1: Preparation of khoa

GR Incorporation in *Baal Mithai* formulation

Pretreatment of the GR was standardized and the best one was selected based on its physicochemical and sensory parameters. Three group of *Baal Mithai* formulation was evaluated, T₁, T₂, and T₃. The major ingredient of *Baal Mithai*, GR was evaluated in three different levels viz., 50, 60 and 70%, and *khoa* was taken in 30, 20, and 10 %. Whereas, the cane sugar level was fixed at 20%. The weighted ingredients were mixed *Baal Mithai* prepared separately for three different formulations (Figure 2).

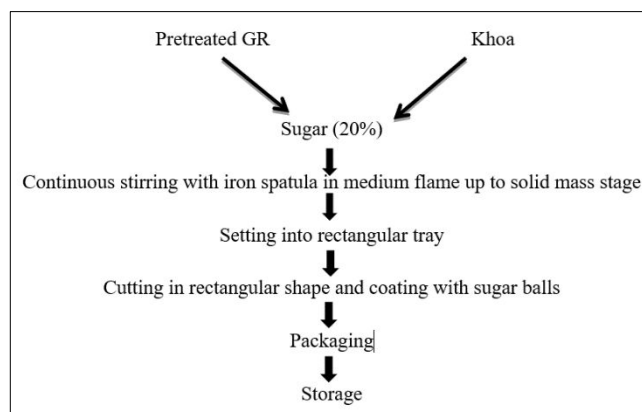


Fig 2: Preparation of *Baal Mithai*

For that dry iron *kadhai* was put on gas stove then *khoa* and cane sugar powder were poured in *kadhai* and roasted on medium heat (177°C to 191°C) for 7-8 min then pretreated GR was poured in *kadhai* containing *khoa* and sugar powder mix. All three ingredients again mixed by continuous scrapping by iron spatula on medium heat till the product start leaving surface of *kadhai*. Then product was taken into rectangular stainless steel tray for setting and cut into rectangular pieces of 2x1x1 cm. After cutting pieces were coated with sugar balls then packed in LDPE pouches.

Quality assessment of developed GR-based *Baal Mithai* pH

Measured with Aczet pH meter. The pH of the sample prepared was measured with the help of a digital pH meter. Before using it for estimation purposes, the electrode assembly of the pH meter was calibrated against standard buffer solutions of pH 7.0 and 4.0. A homogeneous sample

was prepared by diluting 5 g of the sample in 45 ml distilled water. The pH of the sample was determined by dipping the electrode into the spread sample at 25 °C (Trout *et al.*, 1992) [1].

Titrateable acidity

Titrateable acidity of the spread was determined as per IS: SP: 18, Part I (1981) [8]. To determine the acidity of the spread, 10g of the GR and GR based *Baal Mithai* sample was diluted with 40 ml of lukewarm distilled water and 3-4 drops of phenolphthalein indicator (0.5% in neutralized 50% ethyl alcohol) was added to the sample. The contents were properly mixed and titrated against standard N/10 NaOH solution. The acidity was expressed as per cent lactic acid (LA). The formula for calculation of acidity given below:

$$\text{Acidity (\%LA)} = \frac{9 \times A \times N}{W}$$

Where, A= volume of standard NaOH required for titration, N= normality of standard NaOH solution, W= weight of sample

Water activity (a_w)

Water activity (a_w) of GR based *Baal Mithai* was measured using a digital water activity meter (4TE Dew point water activity meter, aqua lab), where the samples were quickly transferred into plastic cups provided with instrument to prevent moisture gain and measured for water activity at 25 °C.

Moisture

Moisture content (%) was determined according to the method of AOAC (1995) [2]. The samples (5gm) were transferred to pre-weighed flat bottom stainless steel dish, which was again weighed. This was transferred to hot air oven at 102±1°C and kept for 16-18 h. The dried samples were placed in a desiccator having fused calcium chloride as desiccant. After cooling the dish was weighed. Moisture content was calculated by following formula:

$$\text{Moisture (\%)} = \frac{(\text{Weight of dish + sample}) - (\text{weight of dish + dried sample})}{(\text{Weight of dish + sample}) - (\text{Weight of empty dish})} \times 100$$

Crude Fat

Fat (%) content was determined using Soxhlet extraction unit as described by AOAC (1995) [2]. Moisture free ground samples were taken into fat free extraction thimble and placed in Soxhlet extractor. Then 150 ml of petroleum ether (Boiling point 60-80 °C) was poured into previously dried and weighed flask. Soxhlet extractor was fit with reflux condenser and to oil flask and placed on an electrically heated sand bath in order to boil the solvent gently. Extraction was carried out for approximately 16 h. Fat content was calculated by following formula:

Crude protein

For digestion, in a clean and dry Kjeldahl flask (500 mL), 5-10 boiling aids, nitrogen-free 4g catalyst mixture (Potassium sulphate and Copper sulphate in 9:1 ratio) and accurately weighted 1±0.1g sample (s) were taken. Any copper sulphate solution, K₂SO₄ or sample residues remaining on the neck of the flask was washed down by adding 10 mL of

concentrated H₂SO₄ (Strength: 95-98% m/m; nitrogen-free; density 1.84 g/mL). The blank tube was also placed containing 10 ml concentrated H₂SO₄ without sample as a control. This mixture was then gently mixed, followed by digestion at 420 °C till a clear solution was obtained.

For distillation, the digested sample was cooled to room temperature, and 40 ml of distilled water was added in each tube including blank sample. The whole content was thoroughly mixed to ensure the complete dissolving of any crystals and cooled to room temperature. The 10 mL of this solution was transferred to an empty Kjeldahl tube, and immediately Kjeldahl flask was connected to the distillation apparatus. Next, a flask containing boric acid was connected to the condenser outlet. Next, boric acid solution (40 g boric acid was dissolved in hot water and made up to 1 L containing 3 mL of methyl red-bromocresol green indicator) and NaOH (40% w/v) solution lines were connected. Finally, the blank was prepared by replacing the sample with 25 mL boric acid (4%) with 2 drops each of indicators (Methyl red and Bromocresol green).

For titration, the collected distillate was removed from the distillation assembly and titrated against 0.1N hydrochloric acid. The appearance of slight violet colour indicated the endpoint. In addition, the titer volume was noted. The protein content was calculated using the following equation:

$$\% \text{ Nitrogen (N)} = \frac{14.01 \times (\text{ml of sample titre} - \text{ml of blank titre}) \times N}{\text{Sample weight (gm)}}$$

N = Normality of H₂SO₄

% Protein = 6.38 x %N

Total ash content

The ash content in the formulated GR based *Baal Mithai* and treated GR was estimated using the method outlined in AOAC (1995) [2]. Two to three grams of the spread sample weighed accurately in a previously weighed silica crucible. The sample was completely charred on an electric heater and then kept in a muffle furnace (550±10 °C) for 2-3 hours (till grey ash resulted). The crucible containing the ash was kept in a desiccator and weighed. The ash content was determined by using following formula:

$$\text{Total Ash (\%)} = \frac{W_1 - W}{W_2 - W} \times 100$$

Where, W = wt. in g of crucible, W₁ = wt. in g of crucible containing ash, W₂ = wt. in g of crucible with the sample taken for the test.

Total carbohydrate content

Total carbohydrate content of spread was determined by difference method.

Texture profile analysis (TPA)

Various rheological properties such as hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness were studied using texture analyser TAXT2in (Stable microsystem, Godalming, surrey, UK) fitted with a 25 kg load cell. Samples of cylindrical shape of height 1 cm

were subjected to mono axial compression of 80% of the initial sample height which was already tempered at 25 °C. The force distance curve was obtained for dual bite compression cycle employing a cross head speed of 2.5 mm/sec. The test conditions were maintained as under:

Test Mode	:	TPA
Pre-test Speed	:	5 mm/sec
Test Speed	:	2.5 mm/sec
Post-test Speed	:	2.5 mm/sec
Trigger Type	:	Auto
Strain	:	80%
Probe	:	P75
Temperature	:	25°C

Sensory evaluation

The sensory analysis of GR based *Baal Mithai* was performed on 9-point hedonic scale as per method given by Keeton (1983) [9]. Semi-trained taste panel consisting of scientists and Post graduate students LPT division were

involved in conducting the sensory evaluation of product. Sensory evaluation was conducted around 3:30 to 4:00 pm every time.

Statistical analysis

Three sets of trials were conducted taking duplicates in each set for each parameter, totaling six observations (n=6). Statistical analysis was done using IBM®SPSS® 27.0 software and Statistical significance was assessed at the 5% level as per Snedecor and Cochran (1980) [14].

Results and Discussion

Optimization of processing conditions for *Baal Mithai*

On the basis of various physicochemical and sensory quality parameters the control *Baal Mithai* was adjudged best with the formulation with 80% Khoa and 20% cane sugar powder. The data of quality parameters of developed *Baal Mithai* is presented in Table 1.

Table 1: Physicochemical and sensory parameters of control *Baal Mithai*

Parameters	C ₁	C ₂	C ₃	C ₄	p value
Physicochemical Parameters					
pH	6.86±0.09 ^a	6.79±0.08 ^{ab}	6.62±0.09 ^{ab}	6.47±0.07 ^b	0.018
aw	0.72±0.01	0.74±0.01	0.75±0.015	0.77±0.01	0.09
Titrate acidity	0.37±0.01 ^b	0.4±0.02 ^b	0.43±0.02 ^b	0.48±0.01 ^a	0.00
Moisture	12.1±0.35 ^c	13.08±0.29 ^c	14.28±0.21 ^b	15.23±0.27 ^a	0.00
Crude fat	17.87±0.15 ^c	18.43±0.12 ^c	19.27±0.2 ^b	20.45±0.23 ^a	0.00
Crude protein	15.68±0.14 ^c	16.57±0.17 ^b	17.02±0.1 ^b	18.14±0.2 ^a	0.00
Total Ash	2.08±0.02 ^b	2.34±0.08 ^b	2.54±0.21 ^{ab}	2.88±0.1 ^a	0.02
Total Carbohydrate	52.24±0.31 ^d	49.6±0.46 ^c	46.89±0.27 ^b	43.29±0.39 ^a	0.00
Sensory Attributes					
Color & Appearance	7.035±0.06 ^b	7.28±0.06 ^{bc}	7.46±0.11 ^{ab}	7.68±0.15 ^a	0.002
Flavor	7.19±0.17 ^c	7.39±0.12 ^{bc}	7.5±0.14 ^{ab}	7.68±0.16 ^a	0.17
Texture	7.07±0.09 ^b	7.25±0.08 ^{ab}	7.28±0.08 ^{ab}	7.5±0.14 ^a	0.054
Milk flavor intensity	7.036±0.1 ^b	7.25±0.08 ^{ab}	7.4±0.12 ^{ab}	7.57±0.15 ^a	0.021
Aftertaste	7.25±0.13	7.46±0.12	7.56±0.12	7.78±0.19	0.101
Overall Acceptability	7.07±0.07 ^b	7.18±0.13 ^b	7.36±0.07 ^{ab}	7.6±0.12 ^a	0.006

Mean±SE with different superscripts in a row differ significantly (p<0.05), n=6 (physicochemical parameters), n=21 (Sensory parameters), C₁- *Baal Mithai* with 50% khoa, C₂- *Baal Mithai* with 60%khoa, C₃- *Baal Mithai* with 70%khoa, C₄- *Baal Mithai* with 80% khoa

Significant differences (p<0.05) were observed across the samples in pH, titratable acidity, and water activity (aw). The pH value decreased progressively with increasing khoa content, which may be attributed to the increased concentration of milk solids and inherent acidity of khoa. Titratable acidity, on the other hand, increased significantly with higher khoa levels. Water activity increased slightly with higher khoa content, possibly due to lower sugar concentrations, which naturally bind free water and thereby reduce aw.

A consistent trend was observed wherein increasing the proportion of khoa led to significant increases in moisture, crude fat, protein, and total ash content. The highest values for all these parameters were recorded in C₄ (80% khoa), aligning with findings from Patil *et al.* (2015) [10] in *burfi* enriched with dried date, in which increasing the percentage of khoa among treatments resulted in a significant increase (p < 0.05) in moisture, protein, fat, and total ash.

Sensory scores for color, flavor, texture, milk flavor intensity (MFI), aftertaste, and overall acceptability (OA) showed a clear preference for C₄, which had the highest khoa content. This could be due to a more appealing soft texture and balanced sweetness. The increase in overall

acceptability in C₄ underscores the consumer preference for less sugary and more milky confections.

Pretreatment of GR and its quality assessment

On the basis of the various physicochemical and sensory quality parameters of the sodium bicarbonate, the pretreatment process of GR was selected. It was observed that the 1.5% sodium bicarbonate-treated GR showed better (p < 0.05) attributes than the other two levels of sodium bicarbonate treatments (Table 2). The sodium bicarbonate-treated GR (T1, T2, & T3) was compared with the untreated GR for all the quality parameters.

The most pronounced effect was on pH, which increased from 4.33 in the control to 6.94 in the 1.5% bicarbonate treatment (T-3). It also showed increased moisture and total ash content and decreased fat and protein, attributed to washing and leaching effects during treatment. The results were similar to the pH value of ghee residue reported by Sangita (2021) [13] and Gill (2021) [6].

The T3 scored significantly higher (p < 0.05) in terms of flavor and aftertaste, indicating a successful neutralization of off-flavors and enhanced palatability. This observation is supported by prior studies on the incorporation of treated GR in various dairy products.

Table 2: Physicochemical and sensory parameters treated and untreated GR

Parameters	C	T ₁	T ₂	T ₃	p-value
Physicochemical Parameters					
pH	4.33±0.14 ^d	5.17±0.07 ^c	5.851±0.09 ^b	6.94±0.12 ^a	0.00
Moisture	10.71±0.88 ^d	56.77±1.022 ^c	59.52±0.96 ^b	61.04±0.8 ^a	0.00
Crude fat	41.67±1.28 ^a	21±0.5 ^b	19.57±0.55 ^c	18.36±0.42 ^c	0.00
Crude protein	19.14±1.07 ^a	15.07±0.79 ^b	13.28±0.88 ^b	10.94±0.69 ^c	0.00
Total Ash	4.81±0.4 ^a	2.67±0.17 ^c	3.60±0.19 ^b	4.68±0.23 ^a	0.00
Total Carbohydrate	23.45±1.25 ^a	5.31±0.66 ^b	4.01±0.67 ^b	5.01±0.19 ^b	0.00
Sensory Parameters					
Color & Appearance	6.14±0.10 ^c	6.39±0.09 ^b	6.75±0.18 ^{ab}	6.5±0.12 ^a	1.36
Flavor	4.67±0.14	6.62±0.14	6.6±0.13	7.32±0.14	0.00
Texture	5.18±0.17	6.97±0.15	7.07±0.16	7.36±0.21	0.33
Milk flavor intensity	6.36±0.16	5.88±0.14	5.86±0.14	5.88±0.24	0.05
Aftertaste	4.6±0.18 ^b	6.39±0.13 ^a	7±0.19 ^a	7.07±0.17 ^a	0.00
Overall Acceptability	4.86±0.15 ^b	6.39±0.13 ^a	6.75±0.20 ^a	7.17±0.20 ^a	0.00

Mean±SE with different superscripts in a row differ significantly (p<0.05), n=6 (physicochemical parameters, n=21 (Sensory parameters), C- Control (Untreated ghee residue, T₁- ghee residue treated with 0.5% Sodium bicarbonate, T₂- treated with 1% Sodium bicarbonate, T₃- treated with 1.5% Sodium bicarbonate.

Standardized formulation of GR-based *Baal Mithai* and its quality assessment

On the basis of the various physicochemical, sensory and texture profile analysis, the combination of 60% pretreated GR and 20 khoa and 20% cane sugar powder (T₂) was adjudged optimum to formulate the standardized GR-based

Baal Mithai formulation. All the quality attributes found to differ significantly (p<0.05) among all the formulations i.e. control (no GR, 80% khoa+20% sugar), T₁ (50% GR+30% khoa+20 sugar), T₂ (60% GR+20% khoa+20 sugar), and T₃ (70% GR+10% khoa+20 sugar).

Table 3: Physicochemical, texture profile and sensory parameters of GR-based *Baal Mithai*

Parameters	C	T ₁	T ₂	T ₃	p value
Physicochemical Parameters					
pH	6.13±0.03 ^b	6.29±0.06 ^b	6.68±0.09 ^a	6.83±0.14 ^a	0.00
a _w	0.74±0.01 ^b	0.78±0.01 ^b	0.79±0.01 ^a	0.81±0.01 ^a	0.00
TA	0.48±0.01 ^a	0.38±0.01 ^b	0.37±0.01 ^b	0.35±0.01 ^b	0.00
Moisture	11.72±0.20 ^c	11.91±0.13 ^c	18.57±0.44 ^b	21.45±0.36 ^a	0.00
Crude fat	19.42±0.29 ^d	21.74±0.23 ^c	24.02±0.37 ^b	26.19±0.74 ^a	0.00
Crude protein	17.97±0.26	18.83±0.57	19.48±1.12	19.61±1.56	0.656
Total Ash	2.89±0.10 ^a	2.07±0.09 ^b	2.57±0.23 ^{ab}	2.95±0.26 ^a	0.014
Total CHO	47.98±0.52 ^a	45.42±0.71 ^a	35.35±1.60 ^b	29.79±1.68 ^c	0.00
Texture profile analysis					
Hardness	7082.83±73.98 ^a	6346.09±120.5 ^b	4891.23±49.24 ^c	3972.83±94.09 ^d	0.00
Adhesive	-140.64±2.07 ^a	-128.76±14.33 ^a	-207.44±6.25 ^b	-291.86±14.68	0.00
Springiness	0.26±0.005 ^a	0.1±0.01 ^{bc}	0.08±0.003 ^c	0.11±0.002 ^b	0.00
Cohesive	0.23±0.01 ^a	0.12±0.001 ^d	0.19±0.004 ^c	0.2±0.001 ^b	0.00
Gumminess	1671.42±33.82 ^a	682.79±24.86 ^c	788.19±9.29 ^{bc}	689.82±21.93 ^c	0.00
Chewiness	437.37±16.94 ^a	81.64±3.28 ^b	71.45±3.81 ^b	70.82±5.27 ^b	0.00
Sensory Parameters					
Color & Appearance	6.71±0.16	7.07±0.14	7.21±0.19	7.03±0.16	0.202
Flavor	7.12±0.09	7.36±0.15	7.57±0.16	7.43±0.14	0.175
Texture	7.14±0.1	7.03±0.14	7.32±0.09	7.07±0.12	0.319
Milk flavor intensity	7.36±0.23	7.13±0.13	7.03±0.17	6.99±0.15	0.467
Aftertaste	7.21±0.11 ^b	7.25±0.08 ^b	7.75±0.12 ^a	7.07±0.1 ^b	0.001
Overall Acceptability	7.03±0.06	7.06±0.14	7.32±0.09	7.07±0.12	0.244

Mean±SE with different superscripts in a row differ significantly (p<0.05), n=6 (physicochemical parameters, n=21 (Sensory parameters), C- Control (*Baal Mithai* with no ghee residue), T₁- *Baal Mithai* with 50% GR, T₂- *Baal Mithai* with 60% GR, T₃- *Baal Mithai* with 70% GR

The incorporation of GR in *Baal Mithai* led to a significant increase (p<0.05) in pH and a_w across treatments. This was in contrast with the control, where higher khoa content retained more acidity and lower a_w. A corresponding decrease in titratable acidity was also observed, highlighting the buffering capacity of the pretreatment of GR.

Samples T₂ and T₃ had higher (p<0.05) moisture and fat contents. Protein levels increased modestly (p > 0.05). Ash content increased in T₃, consistent with mineral content retained post-treatment. Carbohydrate levels declined as GR content increased, likely due to the lower sugar-to-khoa

ratio in *Baal Mithai*. Prasad *et al.* (2012) ^[11] reported a similar trend in *burfi* by incorporation of GR, and Hirpara *et al.* (2020) ^[7] also reported similar results in GR-incorporated *thabdi*.

The addition of GR significantly (p < 0.05) affected the texture profile of *Baal Mithai*. Hardness dropped from 7082.83 g in the control to 3972.83 g in T₃. Similar downward trends were observed in adhesiveness, gumminess, and chewiness, suggesting that GR incorporation softened the product, enhancing its chewability. Springiness and cohesiveness also decreased,

indicating a less rigid internal matrix. The decreasing hardness and chewiness in *burfi* with increasing levels of GR has also been stated by Chaudhary (2017)^[3].

T₂ (60% GR) scored highest in aftertaste and overall acceptability, suggesting it provided the best balance of flavor and texture. While T₃ had a softer texture, its sensory scores declined slightly, indicating a potential over-softening and loss of characteristic product structure. These results align with Hirpara *et al.* (2020)^[7], who found that in ghee residue added to *thabdi*, an increase in the rate of incorporation of GR to the product increased the score of sensory attributes up to a limit; after that, the addition of GR caused a decrease in the sensory score.

Conclusion

The present study focused on optimizing the formulation and processing conditions for the development of *Baal Mithai* by using GR as a nutrient-rich, valuable ingredient. Initially, different combinations of khoa and sugar were evaluated to establish the control formulation. Among the tested variants, the formulation containing 80% khoa and 20% cane sugar powder exhibited superior physicochemical and sensory qualities. This formulation demonstrated the highest moisture, fat, protein, and ash content, coupled with enhanced sensory scores, indicating that a higher khoa proportion contributed positively to both nutritional and sensory attributes. In the subsequent phase, pre-treatment of GR by using sodium bicarbonate at 1.5% showed the most desirable changes, including a significant increase in pH and moisture, a reduction in fat and protein due to the reduction of fat, and improved sensory attributes like flavor and aftertaste. The final phase involved developing the GR-based *Baal Mithai* by substituting khoa with the pre-treated GR at a 60% level, with 20% khoa and 20% sugar. This formulation showed favorable physicochemical properties, including increased moisture and fat content, decreased titratable acidity and carbohydrate levels, and a balanced texture profile. In addition, this formulation scored highest for aftertaste and overall acceptability during sensory evaluation. Thus, the study concludes that incorporating GR at a 60% substitution level offers an optimal balance of texture, nutrition, and consumer acceptability, providing a sustainable approach for by-product utilization in traditional Indian sweet *Baal Mithai*.

References

- Aggarwal D, Raju PN, Alam T, Sabikhi L, Arora B. Advances in processing of heat desiccated traditional dairy foods of Indian sub-continent and their marketing potential. *Food Nutrition Journal*. 2018;3:172.
- AOAC. Official method of analysis. 16th ed. Washington (USA): Association of Official Analytical Chemists; 1995.
- Chaudhary B. Study on the influence of incorporation of ghee residue on quality of Burfi [M.Tech. thesis]. Anand (India): SMC College of Dairy Science, Anand Agricultural University; 2017.
- Dua S, Kumar S, Kaur S, Ganai AW, Khursheed I. Chemical and sensory attributes of ghee residue burfi supplemented with corn flour. *Journal of Pharmacognosy and Phytochemistry*. 2018;7:3818-3822.
- Faustino M, Veiga M, Sousa P, Costa EM, Silva S, Pintado M. Agro-food byproducts as a new source of natural food additives. *Molecules*. 2019;24(6):1056.
- Gill A. Production and characterization of Ghee residue powder [Masters dissertation]. Karnal (India): National Dairy Research Institute; 2021.
- Hirpara P, Prajapati JP, Mehta BM, Pinto SV. Development of Thabdi milk sweets of Gujarat State, India utilizing Ghee residue as an ingredient. *Journal of Applied and Natural Science*. 2020;12(4).
- Indian Standards Institution. ISI Handbook of food analysis Part XI, Dairy products. New Delhi (India): Bureau of Indian Standards, Manak Bhavan; 1981. Report No.: IS:SP:18.
- Keeton JT. Effect of fat or sodium chloride or phosphate level on the chemical, sensory properties of pork patties. *Journal of Food Science*. 1983;48:878-881.
- Patil RV, Sawant PJ, Sawant DN, Todkar SR. Physicochemical analysis and sensory evaluation of burfi enriched with dried date. *Journal of Animal Research*. 2015;5(1):131-134.
- Prasad R, Daniel M, Tiwari D. Utilization of ghee residue for the preparation of chocolate Burfi. *Bhartiya Krishi Anusandhan Patrika*. 2012;27(3):175-178.
- Rafiq SM, Rafiq SI. Milk by-products utilization. In: *Current issues and challenges in the dairy industry*. London: IntechOpen; 2019.
- Sangita. Production and characterization of skim milk admixed ghee residue powder [Masters dissertation]. Karnal (India): National Dairy Research Institute; 2021.
- Snedecor GW, Cochran WG. Statistical methods. Calcutta (India): Oxford and IBH Publishing Co.; 1980.
- Trout ES, Hunt MC, Johnson DE, Claus JR, Kastner CL, Krompt DH. Characteristics of low fat ground beef containing texture modifying ingredients. *Journal of Food Science*. 1992;57:19-24.