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Rheological attributes of goat milk chhana and rasogolla

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Abstract
This investigation was conducted to evaluate the rheological attributes of goat milk rasogolla. Chhana was prepared from Surati goat milk (3.5% fat/8.5% MSNF). Nine batches rasogolla were prepared from chhana coagulated at three temperatures viz. 75, 80 and 85 ºC containing WPC-80 at 3 levels (i.e. 0, 0.25, 0.50 and 0.75% w/w of milk). It was observed that when rate of addition of WPC and coagulation increases the hardness of *chhana* also increased significantly ($P<0.05$). Chhana coagulated at 75 ºC containing no WPC, showed significantly ($P<0.05$) lowest level of chewiness in goat milk *chhana* among all other treatment. Hardness was lowest (5.83 N) when *rasogolla* was made from milk containing combination of 0.50% WPC and 80 ºC coagulation temperature. The significant ($P<0.05$) difference was found in cohesiveness, springiness, gumminess, chewiness and hardness between goat milk and cow milk *rasogolla*. The moisture and protein content of the goat milk *chhana* was significantly ($P<0.05$) higher than cow milk *chhana*. The moisture and protein content of the goat milk *rasogolla* was significantly ($P<0.05$) higher than cow milk *rasogolla*. The hardness of goat milk *rasogolla* was significantly ($P<0.05$) higher than cow milk *rasogolla*. Overall acceptability score of goat milk *chhana* and *rasogolla* was as good as *chhana* and *rasogolla* prepared from cow milk.

Keywords: goat milk, chhana, rasogolla, rheology, hardness

Introduction
Rasogolla is sweet syrupy dessert which is white in colour and is very popular in Indian subcontinent made from unripened heat and acid coagulated cottage cheese i.e. *chhana*. It is ping-pong ball size and has a spongy, chewy body and smooth texture. Traditionally, cow milk has been used exclusively for *chhana* preparation of *rasogolla* because of its excellent sensory attributes.

Goat milk is a nutritional and therapeutic food. Certain therapeutic properties in human nutrition, such as a better utilization of fat and mineral salts in individuals suffering from malabsorption syndrome, are attributed to goats' milk (Alferez *et al.*, 2001). Goat milk differs from cow or human milk in higher digestibility, distinct alkalinity, higher buffering capacity, and certain therapeutic values in medicine and human nutrition (Park, 1991) [28]. Goat milk fat contains significantly greater contents of short and medium chain length fatty acids (C4:0-C12:0) than cow milk fat (Chandan *et al.*, 1992; Haenlein, 1992) [9, 15]. Goat milk does not contain the protein agglutinin that promotes clustering of fat globules. The absence of clustering facilitates rapid digestion and absorption (Farah and Rüegg, 1991) [13].

Goat milk has been used to manufacture *chhana* and rasogolla (Jailkhani and De, 1980; Moorthy and Rao, 1982; Joshi *et al.*, 1991) [20, 26, 21]. The texture of *chhana* is widely recognized as one of the most important parameters in determining the quality and suitability for preparation of different sweets (Desai *et al*., 1992; Adhikari *et al*., 1993) [11, 2]. The texture of *chhana* is influenced by the quality of milk used and the coagulation procedure employed. Cone penetrometer has been used by several workers to study hardness of *chhana* (Aneja *et al.*, 1982) [5]. Desai *et al.* (1992, 1993) [11, 10] employed Instron TPA (Texture Profile Analysis) for characterization of market *chhana* and also compared the texture of buffalo milk *chhana* obtained by various process modifications. Sindhu and Patil (2004) [33] studied the effect of alteration of salt balance of cow milk on texture of *chhana* using Instron, Universal Testing machine and they found reduction in hardness, gumminess and chewiness with increase in level of added sodium dihydrogen phosphate. Desai *et al.* (1993) [10] reported that TPA could successfully be used to distinguish between sponge and normal types (small and large) of *rasogolla* sold in popular markets. Verma (1989) [38] replaced the cone assembly of the standard cone penetrometer with a dead weight assembly so as to measure the softness and springiness of *rasogolla* balls as affected by the moisture content of the *chhana* base and also to monitor the textural changes during storage.

Chakrabarti *et al.* (2001) [8] characterized the rheological properties (hardness, fracturability, adhesiveness, gumminess, chewiness, cohesiveness, springiness and resilience) and obtained a standard value for *rasogolla* (sponge and ordinary) using texture analyser and chemical composition of *rasogolla*. Karunanithy *et al*. (2006) [22] made a comparative study on quality and textural parameters of commercial and machine prepared *rasogolla* using TAHDI-Micro Stable System as texture analyzer. However, very scanty data is available on rheological aspects of goat milk chhana and rasogolla. Hence, this study was planned and conducted to evaluate the rheological attributes of goat milk *chhana* and rasogolla and to compare it with cow milk chhana and rasogolla respectively.

Materials and Methods

Fresh Surati goat milk was obtained from the livestock research station of the university. The fat and SNF content of the milk was varied from 3.5 to 4.2% and 8.5 to 8.7% respectively. WPC-80 was obtained from Charotar Casein Company, Malharpura, Nadiad, India, containing 80.3% protein. Citric acid, supplied by Loba-Chemical Pvt. Ltd., Mumbai, was used as a coagulant. Double Refined (DR) cane sugar of Madhur Brand, Shri Renuka Sugars Ltd., Karnataka was used.

Manufacture of goat milk *chhana*

Calculated quantity of WPC-80 at different rates viz. 0, 0.25, 0.50 and 0.75% w/w of Surati goat milk (3.5% milk fat/ 8.5% MSNF) were blended with lukewarm milk at about 40 °C, about 50 times its weight and allowed to hydrate completely for 30 min before mixing in milk. The milk was heated to 90 °C for 5 min and cooled to desired coagulation temperature (viz. 75, 80 or 85 °C). Coagulation was carried out using 1.0% citric acid solution until clear whey was obtained with constant stirring. Whey was immediately drained after coagulation. The coagulated mass was kept hanging in a muslin cloth for 20 min. The chhana samples were packed in polyethylene pouches and stored in the refrigerator until use. Cow milk chhana was prepared according to procedure outlined by Aneja *et al*. (2002) [4].

Manufacture of goat milk rasogolla: The goat *chhana* prepared as outlined above served as the base for preparation of *rasogolla*. Sugar solution (50°Bx) was used for cooking and soaking of *rasogolla* respectively. Boiling sugar solutions were clarified by adding a few ml of skim milk and boiling it for about 3 min and then straining it through a muslin cloth. The final concentration of the sugar syrup was measured with the help of a pocket refractometer (Hand Refractometer, Erma, Japan, range 28 to 62°Bx). C*hhana* was properly kneaded to a smooth paste before cutting it into small pieces of 10 to 12 g each. Each portion was rolled between palms to form balls of about 15 mm diameter. It was ensured that each ball had a smooth surface with no cracks. About 2 lit of freshly clarified 50° Brix sugar solution was brought to boil in a stainless-steel vessel (23 cm diameter and 23 cm depth). C*hhana* balls were gently dropped into the boiling sugar solution. The temperature of the boiling sugar syrup was between 105 to 107 °C. The heating was regulated to impart stable foam on the surface of the syrup during cooking. Balls were gently stirred with a perforated ladle every 5 min. Cooking of the balls was done in a closed vessel, except for the first 5 min of cooking which was done keeping the vessel open. During cooking, to compensate loss of water, about 30 to 40 ml of hot water (80 °C) was added intermittently at an interval of about 5 min so that concentration of the boiling syrup remained almost constant. A cooking time of about 15 min was required for complete texturization of *rasogolla* balls. After completion of cooking, heating was stopped and the *rasogolla* balls were transferred to the 40°Brix clarified hot (60 °C) sugar solution using a perforated ladle. The *rasogollas* were then allowed to cool to room temperature and soaking in sugar solution was done for overnight before sensory evaluation and sampling for chemical analysis.

Chemical analysis

Rasogolla sample for chemical analysis was prepared as per the method described in IS:4079,1967. *Rasogolla* samples were kept at 40 °C for 20 min before transferring on a sieve of about one square cm mesh such that all the *rasogollas* were in one layer. The syrup was then allowed to drain for 10 min in a container. The samples were crushed to a smooth, homogenous paste before subjecting for analysis. Moisture, fat and sucrose content of rasogolla was determined as per the method prescribed in IS:4079,1967. Protein in *rasogolla* was determined by semi-micro Kjeldahl method IS:4079-1967, using Kjel-plus digestion system (M/s Pelican Instruments, Chennai, Model-KES 20LVA DLS) and Kjel-plus semi-automatic distillation system (M/s Pelican Instruments, Chennai, Model- Distil M).

Instrumental Textural Analysis of *Chhana*

Compression testing of *chhana* samples was done with Lloyd Instrument, Hampshire, UK (Model No. 01/2962) using 5 KN load-cells which moved at a speed of 20 mm/min (Figure 3.3). The trigger was set at 10 gf, compressive and tensile load limit were 4900 N and 4000 N respectively. The *chhana* samples were taken for texture measurement after tempering the same at 10±1 °C for 1h. All the textural measurements were conducted in a room maintained at 23±1 °C temperature and 65±1% RH. Cubic samples of the experimental *chhana*, with edges of 2.00±0.06 cm, were placed in the compression support plate in such a manner that fibers were oriented perpendicular to the cylindrical compression anvil. The cubic samples were compressed up to 70% of their initial size.

Five cubic samples were used for each experimental *chhana* under study and the average value of these readings was reported. The textural characteristics of the *chhana* samples were directly displayed on the monitor of the computer as graph (Load vs. time i.e. Kgf vs. s) as well as derived values in tabular form.

Rheological properties of *rasogolla*

Five samples of each *rasogolla* were subjected to uniaxial compression to 70% of the initial sample height, using a Food Texture Analyzer of Lloyd Instruments LRX Plus material testing machine, England; fitted with 50 Newton (N) load cell. The force-distance curve was obtained for a two-bite deformation cycle employing a Cross Head speed of 20 mm/min, Trigger 10 gf and 70% compression of the samples to determine various textural attributes of *rasogolla* held for 1 h at 23±1 C and 55% relative humidity. 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 application software.

Sensory evaluation

Chhana and *rasogolla* samples were tempered to 25±2 °C before judging. During the assessment sessions 25 g of *chhana* and *rasogolla* (one ball) in petri dishes with lids were served for sensory evaluation and panellists were asked to evaluate the sample. The plates were labelled with three-digit codes. The order in which samples were presented was randomized across subjects. Subjects in one session assessed a maximum of 5 samples. The sensory panel (n=10) was composed of staff members and post graduate students working in the institution. The sensory attributes of the *chhana* as measured by the characteristics of the *chhana* which are flavour, body and texture, colour and appearance and overall acceptability were evaluated using the 9-point hedonic scale.

Statistical Analysis

The mean values generated from the analysis of duplicate samples of *rasogolla*, obtained in three replications were subjected to statistical analysis using completely randomized design (CRD) developed by Anand Agricultural University, Anand.

Results and Discussion

The results obtained on the rheological quality of goat milk *chhana* as affected by incorporation of varying levels of WPC and coagulation temperature measured in terms of hardness, cohesiveness, springiness, gumminess, chewiness, adhesiveness of goat milk *chhana* is presented in Table 1.

Hardness

Incorporation of WPC at different rates had significant (P<0.05) effect on hardness (N) of goat milk *chhana*. The data shown Table 1 shows that when level of WPC increased the hardness of *chhana* also increased significantly (P<0.05). *Chhana* made from milk incorporated with 0.75% WPC had significantly (P<0.05) higher hardness 32.68 compared to *chhana* prepared from milk incorporated with lower levels of WPC viz. 0, 0.25 and 0.5% (w/w of milk). When coagulation temperature increased the hardness was increased significantly (P<0.05). *Chhana* made using a higher temperature of coagulation viz. 85 °C had a higher value of hardness viz. 27.46 which was found to be significantly higher compared to *chhana* coagulated at lower temperatures viz. 75 °C and 80 °C. The lowest hardness was found in sample coagulated at 75ºC containing no WPC i.e. 10.46 N. In present investigation it was observed that when rate of addition of WPC and coagulation increases the hardness of *chhana* also increased significantly (P<0.05).
El-Salam (2015) [12] reported that soft cheese made with incorporation of WPC in milk had higher hardness compared to control prepared without incorporation of WPC. Solowiej *et al*. (2010) [35] also reported that addition of whey protein concentrates (WPC 35 and WPC 65) to processed cheese analogues produced harder cheeses than cheese analogues prepared without incorporation of WPC. Herrero and Requena (2006) [18] made yoghurt from goat milk with addition of WPC and they found that addition of WPC improves the textural quality (hardness, firmness) in yoghurt. The textural characteristics of cheese are mainly influence by its moisture, fat and protein content. Addition of WPC resulted in significantly higher protein content of *chhana*. It has been reported that high protein content in cheese is linked to higher values of hardness (Awad *et al*., 2001) [6]. Incorporation of WPC in goat milk lead to incorporation of whey protein into the pores of casein network of cheese matrix like fat globules which yielded a higher protein/fat ratio resulting in a compact and continuous areas of protein matrix (Lobato-Calleros *et al*., 2007) [24].
The increase in firmness by addition of WPC can be explained by the fact that protein aggregates, formed by the interaction between casein micelles and denatured whey proteins via intermolecular disulphide bonds, appear during the first steps of coagulation (Lucey *et al*., 1999) [25]. The addition of whey proteins to milk and the formation of aggregates by interaction with casein micelles created a more rigid gel structure in yoghurt, which increased when the proportion of whey protein was increased (Puvanenthiran *et al*., 2002) [31]. Goat's milk has slightly lower casein content than cow's milk, with a very low proportion or absence of αs1-casein, and a higher degree of casein micelle dispersion (Remeuf & Lenoir, 1986; Vegarud *et al*., 1999) [32, 37]. This could have partly contributed to the increase in hardness of goat milk *chhana*. Singh *et al*. (2013) [34] made *chhana* from buffalo milk and found that when coagulation temperature increases the hardness of *chhana* also increases. Thus, the results obtained in this study corroborates with that reported in literature. In other studies, replacing fat with WPC increased the hardness, cohesiveness, gumminess and chewiness values of soft cheese (El-Salam, 2015) [12]. In addition, using WPC increased the softness of Feta cheese (Tashakori *et al*., 2013) [36]. However, Henriques *et al.* (2013) [17] stated that hardness, chewiness and gumminess values were similar in control and treated cheese with whey protein. The difference in results could be attributed to the type and quality of WPC used and manufacturing conditions.

Cohesiveness

As seen in Table 1, addition of WPC had significant (P<0.05) effect on cohesiveness of goat milk *chhana*. Experimental samples of *chhana* incorporated with 0.75% WPC in milk had significantly (P<0.05) lower cohesiveness value than other treatments i.e. samples incorporated with 0, 0.25 and 0.5% WPC (w/w of milk). When coagulation temperature increased the cohesiveness value of decreased significantly (P<0.05).
The results obtained in this corroborates with those reported by Lobato-Calleros *et al.* (2007) [24] who reported that cohesiveness is negatively correlated with WPC level in soft cheese. With increase in level of WPC the cohesiveness of cheeses decreased. Othman (2008) [27] also reported that addition of WPC reduced the cohesiveness of low-fat soft cheese compared to cheese make without addition of WPC. Solowiej *et al*. (2010) [35] also reported that addition of WPC in processed cheese analogue resulted in decrease in cohesiveness.

Springiness

Chhana prepared from milk containing 0.75% WPC had significantly (P<0.05) higher springiness compared to experimental samples of *chhana* prepared from milk incorporated with lower levels of WPC i.e. 0, 0.25 and 0.5% WPC (w/w of milk). The interaction effect of level of WPC and coagulation temperature showed significant (P<0.05) effect on springiness. *Chhana* made from milk incorporated with 0.75% WPC had significantly (*P*<0.05) higher springiness 5.79 compared to *chhana* prepared from milk incorporated with lower levels of WPC viz. 0, 0.25 and 0.5% (w/w of milk). When coagulation temperature increased the springiness was increased significantly (*P*<0.05).

The results obtained in this study are in contrast with those reported by Hanafy *et al.* (2016) [6] who stated that addition of WPC in non-fat fresh soft cheese prepared by acid coagulation did not have any significant effect on springiness of cheeses. These differences may be due to the type and properties of WPC used and the level of addition as well as manufacturing procedures used. The higher springiness seen in samples containing higher levels of WPC and coagulated at higher temperature i.e. 85 °C could be in part attributed to the decrease cohesiveness and gumminess (Table 1) of samples incorporated with higher levels of WPC and coagulated at higher temperatures i.e. 85 °C.

Gumminess

A significant (*P*<0.05) lower level of gumminess was observed in experimental samples prepared without addition of WPC compared to samples containing WPC. Observed data indicated that there was significant (*P*<0.05) increase in gumminess when samples were coagulated at 80 °C and 85 °C compared to samples coagulated at 75 °C.

The results are in agreement with those of Othman (2008) [27], who found that addition of WPC to milk increase the gumminess of low-fat soft cheese comparing to low fat control. Hanafy *et al.* (2016) [6] reported that non-fat soft fresh Cheese made from skim milk powder milk treated with 2% WPC (w/w of milk) had highest gumminess and chewiness values, while adding a higher concentration of WPC (4 and 6%) significantly decreased values of these parameters. The difference in results could be attributed to the type and quality of WPC used and manufacturing conditions. Thus, the results obtained in this part of the study are in agreement with those reported in literature.

Chewiness

The data presented in Table 1 shows that chewiness (Nmm) of goat milk *chhana* shows that there was a significant (*P*<0.05) increase in chewiness *chhana* when level of WPC increases. Coagulation temperature had a significant (*P*<0.05) effect on chewiness of *chhana*. Chewiness of samples of *chhana* prepared using 85 °C had significantly (*P*<0.05) higher chewiness which was found at par with 80 °C. Chhana coagulated at 75 °C containing no WPC, showed significantly (*P*<0.05) lowest level of chewiness in goat milk *chhana* among all other treatment. Chewiness as described earlier is a product of hardness, cohesiveness and springiness (H X C X S). Hence, the factors responsible for the observed increases in these values with increase in C/F ratio could also be considered responsible for change in chewiness of the product made by the modified method.

Adhesiveness

The values of adhesiveness depicted in Table 1 suggest that there was a significant effect of varied levels of WPC and coagulation temperature on adhesiveness, of goat milk *chhana*. A significant (*P*<0.05) lower level of adhesiveness was found in samples devoid of WPC. Whereas the adhesiveness of samples prepared from milk incorporated with 0.75% WPC and 0.50% WPC (i.e. 1.29 N, 1.27 N respectively) were found to be at par (*P*>0.05) with each other. An increasing trend of adhesiveness with rising coagulation temperature was noticed. A significantly (*P*<0.05) higher value of adhesiveness i.e. 2.10 N mm was recorded for samples coagulated at 85 °C compared to the other two temperatures studied i.e. 75 and 80 °C.

The results obtained are in agreement with those of Hanafy *et al.* (2016) [6] who reported that adhesiveness values of non-fat fresh cheese made from skim milk powder gradually increased with increase in level of addition of WPC.

Rheological properties of *rasogolla*

The results obtained pertaining to rheological/textural profile of *rasogolla* is presented in Table 2.

Hardness

It can be observed from Table 2 with increase in level of WPC the hardness of *rasogolla* decreased significantly (*P*<0.05) up to 0.50% level of addition of WPC in *chhana* milk. Beyond that a significant (*P*<0.05) increase in hardness was noticed. R*asogolla* made from *chhana* containing 0.50% WPC had significantly (*P*<0.05) lower hardness values compare to other level of WPC studied i.e. 0, 0.25 and 0.75%. As seen in Table 2, coagulation temperature had significant (*P*<0.05) effect on the hardness values of goat milk *rasogolla*. *Rasogolla* made from *chhana* coagulated at 80 ºC had significantly (*P*<0.05) lower hardness compared to *rasogolla* samples made from *chhana* coagulated at 75 and 85 ºC. The values presented in Table 2 reveal that hardness was lowest (5.83 N) when *rasogolla* was made from milk containing combination of 0.50% WPC and 80 ºC coagulation temperature.

Published data on hardness of *rasogolla* as affected by addition of WPC (w/w) of goat milk and coagulation temperature were not available for comparison. Patel (2017) [29] prepared *rasogolla* from mixed milk with addition of WPC and reported that addition of WPC in milk reduced that hardness of *rasogolla* up to a certain level i.e. 0.75% WPC in *chhana* milk. The average values of hardness of *rasogolla* made from mixed milk was 8.33 to 10.97 N. Desai *et al*. (1993) [10] reported that the overall textural quality of *Rasogolla* was significantly (*P*<0.05) correlated with moisture. Hardness of *Rasogolla* also influenced by moisture content and this type of comments was reported by Kumar *et al*. (1997) [23]. There was a positive correlation (0.508) between the moisture and hardness of *rasogolla*.

The amount of fat, type and concentration of cooking and soaking syrup with their interaction effects might be responsible for the observed difference in hardness. It is observed that when moisture content is decreased the hardness of *rasogolla* was increased this view is also in agreement with the results reported by Adhikari *et al.* (1992) [2]; Desai *et al.* (1993) [10]; Gupta *et al*., (1993) [14]; Hove and Das (1995) [19] and Patil (2005) [30]. Thus, the results obtained in our study corroborates with those reported in literature.

Cohesiveness

Rasogolla made from *chhana* prepared from milk incorporated with 0.50% WPC had significantly (*P*<0.05) lower cohesiveness compared to *chhana* prepared from 0 and 0.25% WPC. Cohesiveness of *Rasogollas* made from *chhana* prepared from milk incorporated with 0.50% WPC was at par (*P*>0.05) with samples prepared from 0.75% WPC. *Rasogolla* made from goat milk *chhana* at different level of coagulation temperature had significant (*P*<0.05) effect on cohesiveness of goat milk *rasogolla*. *Rasogolla* made from *chhana* which was coagulated at 80 ºC had significantly (*P*<0.05) lower cohesiveness compared to samples coagulated at 75 ºC. Cohesiveness of *Rasogolla* samples made from *chhana* which was coagulated at 80 ºC was at par with samples made at 85 ºC coagulation temperature. Rasogolla prepared using a combination of 0.50% WPC and 80 ºC coagulation had significantly (*P*<0.05) lower cohesive values compared to all the other treatment combinations.

Data on cohesiveness of goat milk *rasogolla* as affected by addition of WPC and coagulation are not available for comparison. According to report available in literature the cohesiveness value of *Rasogolla* varies from 0.54 to 0.95 (Desai *et al.*, 1993; Hove and Das, 1995; Patil, 2005) [10, 19, 30]. The results obtained during the study on cohesiveness of *rasogolla* are found to be within the range of these values. Patel (2017) [29] made *rasogolla* from mixed milk with addition of WPC in milk and reported that addition WPC milk during *chhana* making decrease the cohesiveness of *rasogolla*. Thus, the results obtained for goat milk *rasogolla* corroborates with those reported in literature.

Springiness

It is evident from the Table 2 that goat milk *rasogolla* made from *chhana* with addition of WPC had significant (*P*<0.05) effect on the springiness of goat milk *rasogolla*. R*asogolla* made from goat milk *chhana* containing 0.50% WPC had significantly (*P*<0.05) higher springiness i.e. 6.32 mm compare to goat milk *chhana* containing other levels of WPC i.e. 0, 0.25 and 0.75%. R*asogolla* made from goat milk *chhana* coagulated at 80 ºC had significantly (*P*<0.05) higher springiness 6.03 mm than other level of coagulation temperature i.e. 75 and 85 ºC. The data presented in Table 2 shows that the *rasogolla* sample R8 made which was from *chhana* prepared using a combination of 0.50% WPC and 80 ºC coagulation temperature had significantly (*P*<0.05) higher springiness i.e. 7.60 mm compared to all the other treatment combinations.

The springiness of *rasogolla* observed for the experimental as well as control samples was well above 3.82 to 5.0 mm as reported by Adhikari *et al*. (1992) [2] and Karunanithy *et al*. (2006) [22] but lower than 8.2 to 9.0 mm as reported by Desai *et al*. (1993) [10] and Hove and Das, (1995) [19]. The springiness of *chhana* increased markedly during cooking as a result of the development of a porous, ragged and uneven protein matrix structure. The greater the porosity, the higher was the absorption of sugar syrup (resulting in increased juiciness) (Adhikari *et al*., 1992) [2]. The greater the porosity, the higher is the absorption of sugar syrup and it was achieved in present investigation up to 0.50% level of addition of WPC thereafter there was a sharp decrease in sugar absorption ratio. This could be attributed to increase in hardness of chhana with higher rate of addition of WPC. Patel (2017) [29] made *rasogolla* from mixed milk with addition of WPC in milk and reported that addition WPC milk during chhana making increase the springiness of *rasogolla*.

Gumminess

The data shown in Table 2 reveal that gumminess (N) values of goat milk *rasogolla* containing WPC 0.50% were significantly (*P*<0.05) lower gumminess i.e. 4.58 N than other level of WPC. Addition of WPC significantly decrease the gumminess up to certain level i.e. 0.5% level of addition of WPC thereafter there was a significant (*P*<0.05) increase in gumminess with 0.75 level of addition of WPC in *chhana* milk. Similarly, *rasogolla* made from different level of coagulation temperature had significant (*P*<0.05) effect on gumminess of goat milk *rasogolla*. *Rasogolla* made from *chhana* which is coagulated at 80 ºC had significantly (*P*<0.05) lower gumminess i.e. 4.38 N compared to other coagulation temperatures studied viz. 75 and 85 ºC. Rasogolla made from combination of 0.50% WPC and 80 ºC coagulation temperature had significantly (*P*<0.05) lower gumminess i.e. 2.88 compared to all the other treatment combinations.

The published data on gumminess of goat milk *rasogolla* as affected by addition of WPC and coagulation are not available for comparison, however the recorded gumminess of experimental *rasogolla* was in accordance within the range reported by Desai *et al.* (1993) [10] i.e. 2.98 to 4.69 N, and Adhikari *et al*. (1992) [2] i.e. 3.62 N for *rasogolla* prepared from cow milk, but higher than those reported by Karunanithy *et al*. (2006) [22] i.e. who reported gumminess values in the range of 0.76 N for *rasogolla* prepared from cow milk. Patel (2017) [29] made *rasogolla* from mixed milk with addition of WPC in milk and reported that addition WPC milk during *chhana* making decrease the gumminess of *rasogolla*. Thus, the results are in accordance with those reported in literature.

Chewiness

The data shown in Table 2 reveal that chewiness (Nmm) values of goat milk *rasogolla* samples containing WPC 0.50% were significantly (*P*<0.05) lower than samples incorporated with other levels of WPC i.e. 0, 0.25 and 0.75%. Addition of WPC was significantly decreasing the chewiness up to 0.50% level of addition of WPC. Thereafter, with further increase in level of WPC there was a significant (*P*<0.05) increase in chewiness of *rasogolla*. As seen in Table 2 experimental *rasogolla* made from *chhana* prepared using different level of coagulation temperature had significant (*P*<0.05) effect on chewiness of goat milk *rasogolla*. *Rasogolla* made from *chhana* coagulated at 80 ºC had significantly (*P*<0.05) lower chewiness i.e. 22.85 N.mm compared to other coagulation temperature. Rasogolla which was made from combination of 0.50% WPC and 80 ºC coagulation temperature had significantly (*P*<0.05) lower chewiness 16.66 Nmm than all the other experimental samples.

Patel (2017) [29] made *rasogolla* from mixed milk with addition of WPC in milk and reported that addition WPC milk during *chhana* making decrease the chewiness of *rasogolla*. The published data on cohesiveness of goat milk *rasogolla* as affected by addition of WPC and coagulation are not available for comparison, The recorded values of chewiness for control and experimental *Rasogolla* were higher than the values (5.80 to 18.00 Nmm) reported by Adhikari *et al*. (1992) [2]; Patil, (2005) [30] and Karunanithy *et al*. (2006) [22], while lower than 42 to 68 Nmm as reported by Desai *et al*. (1993) [10]. These differences could be due to type of milk used and manufacturing parameters.

Adhesiveness

There was a progressive decrease in adhesiveness (N) values of goat milk *rasogolla* as the level of WPC increased from 0 to 0.75%. This effect was found to be significant (*P*<0.05) for at all levels of WPC studied viz. 0.0, 0.25, 0.50% and 0.75%. Experimental *rasogollas* made from *chhana* containing 0.75% WPC had significantly (*P*<0.05) lower average adhesiveness values i.e. 0.054 N compared to lower levels of WPC.

Rasogolla sample made from *chhana* coagulated at 80 ºC had significantly (P<0.05) lower adhesiveness 0.053 N values compared to *rasogolla* made from *chhana* coagulated at other temperatures i.e. 75 and 85 ºC. The data presented in the Table 2 show that the adhesiveness was the lowest i.e. 0. 042 N when *rasogolla* made from *chhana* milk containing 0.50% WPC and 80 ºC coagulation temperature (C8).

The comparison of the developed goat milk chhana and *rasogolla* vis-à-vis a *rasogolla* prepared from cow milk *chhana and rasogolla* was done with respect to certain compositional, rheological and sensory properties.

Comparison of goat milk *chhana* with cow milk *chhana*

*Goat milk chhana*and cow milk chhana were compared for its compositional, rheological and sensory attributes using two sample T test two sample assuming equal or unequal variances and the results are presented in Table 3. It can be seen from the Table 3 that the FDM content of the developed goat milk *chhana* was less than 50% on DMB. Therefore, according to FSSAI standards for *chhana* it can be classified as medium fat *chhana*. A comparison of goat milk *chhana* with cow milk *chhana* reveals that goat milk *chhana* had significantly lower (P<0.05) FDM compared to cow milk *chhana*. As seen from the Table 3 the hardness of goat milk *chhana* was significantly (P<0.05) higher than cow milk *chhana*. No significant (P>0.05) difference was found in cohesiveness, springiness, gumminess, chewiness and adhesiveness between both the types of *chhana*. There was an improvement in all the rheological properties except hardness of the developed goat milk *chhana* compared product prepared without addition of WPC.

Comparison of goat milk *rasogolla* with cow milk *rasogolla*

The average values of the chemical composition of the developed goat milk *rasogolla* and cow milk *rasogolla* are collated in Table 4. The goat milk *rasogolla* met the requirement of BIS standards for *rasogolla* (IS: 4079-1967) with respect to moisture, fat, protein and sucrose content. A comparison of goat milk *rasogolla* with cow milk *rasogolla* reveals that goat milk *rasogolla* had significantly (P<0.05) lower fat content compared to cow milk *rasogolla*. The protein content of the goat milk *rasogolla* was significantly (P<0.05) higher than cow milk *rasogolla*. The higher protein content can be attributed to the differences in fat: MSNF ratio of both the milks. The hardness of goat milk *rasogolla* was significantly (P<0.05) higher than cow milk *rasogolla*. The average taste and smell score and colour and appearance score of goat milk *rasogolla* was significantly (P<0.05) lower than the cow milk *rasogolla*. The reduction in taste and smell of goat milk *rasogolla* was because of the slight goaty flavour. However, the average taste and smell score was 7.89 and 7.77 indicating that the product was “like moderately” to “liked very much” with respect to taste and smell. Trials taken during the study showed that addition of rose water as flavouring resulted in masking of the goaty flavour. As revealed by the statistical analysis in the table the body and texture score and overall acceptability score of goat milk *rasogolla* and cow milk *rasogolla* were statistically alike (P>0.05). The overall acceptability score of goat milk *rasogolla* was found to be at par (P>0.05) with cow milk *rasogolla*. Thus, goat milk *rasogolla* can be considered in same group of products as cow milk *rasogolla* based on the sensory scores.

Table 1: Influence of levels of WPC and coagulation temperature on rheological attributes of *chhana*

Level of addition of WPC (%w/w of milk)	**Coagulation Temperature °C**			**Average for WPC**
	75 °C	**80 °C**	**85 °C**	
Hardness, N				
0	10.46±0.37	13.28±0.33	16.45±0.30	13.4
0.25	19.18±0.32	20.54±0.26	23.65±0.24	21.12
0.50	22.44±0.30	28.05±0.27	31.03±0.24	27.17
0.75	26.99±0.32	32.33±0.28	38.72±0.25	32.68
Average for coagulation temperature	19.77	23.55	27.46	
CD 0.05: W=1.38; T= 1.20; WXT = 2.40				
Cohesiveness				
0	0.37±0.02	0.33±0.01	0.30±0.20	0.33
0.25	0.32±0.01	0.30±0.02	0.28±0.16	0.30
0.50	0.29±0.01	0.22±0.12	0.26±0.30	0.25
0.75	0.28±0.02	0.26±0.01	0.23±0.20	0.19
Average for coagulation temperature	0.31	0.27	0.28	
CD 0.05: W=0.026; T= 0.025; WXT = NS				
Springiness, mm				
0	2.43±0.33	3.52±0.25	3.66±0.31	3.20
0.25	2.97±0.29	3.84±0.11	4.7±0.27	3.84
0.50	4.20±0.01	7.54±0.25	5.46±0.35	5.73
0.75	4.56±0.25	6.33±0.17	6.48±0.40	5.79
Average for coagulation temperature	4.03	4.81	5.07	
CD 0.05: W=0.31; T= 0.27; WXT = 0.54				
Gumminess, N				
0	3.96±0.64	4.44±0.26	4.98±1.10	4.46
0.25	6.25±0.38	6.21±0.36	6.32±0.90	6.26
0.50	5.84±1.2	6.54±0.50	8.05±0.60	6.81
0.75	7.58±0.71	7.71±0.10	9.14±1.6	8.14
Average for coagulation temperature	5.91	6.22	7.12	
CD 0.05: W=0.56; T= 0.64; WXT = NS				
Chewiness, Nmm				
0	9.50±0.56	15.45±0.75	18.22±2.28	14.39

0.25	18.56±1.63	23.66±0.57	29.89±2.40	24.03
0.50	24.58±2.6	46.10±2.69	44.12±1.96	38.26
0.75	34.57±3.10	49.10±2.50	59.30±3.03	47.65
Average for coagulation temperature	21.78	33.57	37.88	
CD 0.05: W=3.21; T= 3.71; WXT = 6.43				
Adhesiveness, N				
0	0.27±0.02	1.3±0.11	1.14±0.03	0.90
0.25	0.33±0.05	1.03±0.04	3.34±0.28	1.14
0.50	0.44±0.04	0.84±0.09	2.14±0.18	1.27
0.75	0.74±0.03	1.28±0.14	1.79±0.08	1.29
Average for coagulation temperature	0.44	1.12	2.10	
CD 0.05: W=0.14; T= 0.12; WXT = 0.24				

Table 2: Influence of levels of WPC and coagulation temperature onrheological attributes of *rasogolla*

Level of addition of WPC (%w/w of milk)	Coagulation Temperature (°C)			Average for WPC
	75 °C	80 °C	85 °C	
Hardness, N				
0	13.46±0.41	8.70±0.21	13.36±0.45	11.84
0.25	9.60±0.43	6.86±0.32	11.77±0.26	9.41
0.50	8.50±0.40	5.83±0.17	8.03±0.12	7.45
0.75	10.50±0.41	8.47±0.39	10.45±0.40	9.80
Average for coagulation temperature	10.51	7.47	10.90	
CD 0.05: W=0.36; T= 0.41; WXT = 0.72				
Cohesiveness				
0	0.85±0.03	0.65±0.03	0.65±0.02	0.71
0.25	0.80±0.01	0.57±0.02	0.56±0.03	0.64
0.50	0.76±0.01	0.40±0.02	0.54±0.03	0.56
0.75	0.70±0.02	0.58±0.02	0.59±0.02	0.62
Average for coagulation temperature	0.77	0.55	0.58	
CD 0.05: W=0.02; T= 0.03; WXT = 0.05				
Springiness, mm				
0	5.10±0.32	5.46±0.41	4.80±0.16	5.12
0.25	5.40±0.33	5.80±0.16	5.53±0.33	5.57
0.50	5.70±0.12	7.60±0.16	5.66±0.49	6.32
0.75	4.83±0.17	5.26±0.24	5.4±0.33	5.16
Average for coagulation temperature	5.25	6.03	5.34	
CD 0.05: W=0.30; T= 0.35; WXT = 0.61				
Gumminess, N				
0	11.46±0.82	5.72±0.43	8.70±0.61	8.63
0.25	7.68±0.41	3.92±0.38	6.64±0.60	6.08
0.50	6.49±0.40	2.88±0.27	4.36±0.22	4.58
0.75	7.38±0.28	4.98±0.44	6.17±0.46	6.18
Average for coagulation temperature	8.25	4.38	6.47	
CD 0.05: W=0.48; T= 0.56; WXT = 0.97				
Chewiness, Nmm				
0	58.68±5.0	29.31±4.07	39.32±4.35	42.44
0.25	41.55±4.25	21.31±3.33	36.90±5.30	33.25
0.50	37.50±3.19	16.66±1.92	24.69±2.18	26.28
0.75	35.72±2.48	24.12±2.89	33.87±4.39	31.23
Average for coagulation temperature	43.36	22.85	33.69	
CD 0.05: W=4.12; T= 4.76; WXT = 4.20				
Adhesiveness, N				
0	0.086±0.04	0.062±0.02	0.076±0.03	0.075
0.25	0.076±0.03	0.058±0.03	0.065±0.04	0.066
0.50	0.070±0.04	0.042±0.02	0.056±0.03	0.056
0.75	0.065±0.010	0.048±0.01	0.047±0.04	0.054
Average for coagulation temperature	0.074	0.053	0.061	
CD 0.05: W=0.03; T= 0.04; WXT = 0.06				

Table 3: Comparison of compositional, rheological and sensory attributes of goat milk *chhana* and cow milk *chhana*

Parameter	Goat Milk chhana	Cow Milk chhana	t-stat	P Value
Moisture, %	54.37	52.12	1.81*	0.016
FDM, % DMB	48.43	51.82	6.27*	0.003
Hardness, N	28.05	16.44	12.04**	0.001
Cohesiveness, Nmm	0.22	0.20	NS	0.07
Springiness, mm	7.54	8.08	NS	0.37
Gumminess, N	6.54	5.288	NS	0.15

Chewiness, Nmm	46.10	46.57	NS	0.07
Adhesiveness, m^2	0.84	0.75	NS	0.14

Note: Values are average of seven readings
* t-values found significant difference at 5% level of significance
** t-values found significant difference at 1% level of significance

Table 4: Comparison of compositional, rheological and sensory attributes of goat milk *rasogolla* and cow milk *rasogolla*

Parameter	Goat Milk rasogolla	Cow milk rasogolla	t-stat	P value
Sugar absorption ratio	2.63	2.68	NS	0.64
Moisture, %	50.07	43.67	28.72**	0.002
Protein, %	7.04	6.96	NS	0.75
Fat, %	6.44	9.35	15.97**	0.003
Sucrose, %	35.73	37.66	NS	0.30
Hardness, N	5.83	5.03	6.71*	0.04
Cohesiveness, Nmm	0.40	0.37	2.30**	0.001
Springiness, mm	7.60	10.83	25.21**	$2.2x10^{-10}$
Gumminess, N	2.33	1.86	3.02*	0.04
Chewiness, Nmm	16.66	15.63	9.44*	0.03
Adhesiveness, m^2	0.042	0.035	NS	0.86
Colour & Appearance score	7.90	8.13	2.92*	0.009
Taste score	7.94	8.47	5.81**	0.004
Smell score	7.77	8.16	3.20*	0.03
Body & Texture score	7.98	8.14	NS	0.08
Overall acceptability score	7.93	8.05	NS	0.31

Note: Values are average of seven readings; Sensory scores obtained on 9-point hedonic scale
* t-values found significant difference at 5% level of significance
** t-values found significant difference at 1% level of significance
NS = Non-significant

Conclusion

No significant (*P*>0.05) difference was found in cohesiveness, springiness, gumminess, chewiness and adhesiveness between both the types of *chhana*, however the hardness of goat milk *chhana* was significantly (*P*<0.01) higher than cow milk *rasogolla*. There was no significant (*P*>0.05) difference between sugar absorption ratio, protein content, sucrose content, adhesiveness, body and texture score and overall acceptability score between goat milk and cow milk *rasogolla*. Hardness, Gumminess and chewiness was significantly (*P*<0.05) higher in goat milk *rasogolla* compared to cow milk *rasogolla*. Fat content, springiness and taste score was significantly (*P*<0.01) lower in goat milk *rasogolla* compared to cow milk *rasogolla*. Hardness, gumminess of goat milk *rasogolla* was significantly (*P*<0.05) higher compared to cow milk *rasogolla*.

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