INTRODUCTION

Milk and milk based products have been a good source of nutrition to human health. Rasogolla is an Indian traditional dairy product, stored and served in sugar syrup. In size and shape it resembles a ping-pong ball. It is snow white in colour, possesses a spongy, chewy body and smooth texture. On all festive occasions it is widely accepted as most popular sweet and all ages of people like it.

Chhana is the base material from which rasogolla is prepared. Generally cow milk is preferred for preparation of rasogolla as the cow milk chhana is having soft body and smooth texture, which are suitable for rasogolla preparation[1,2]. For the preparation of chhana, milk is heated to its boiling temperature and cooled to 70ºC[3-5]. Coagulating agent like citric or lactic acid solution is added to the heated milk and mixed with gentle stirring using a ladle. The mixture is kept for some time for settling and coagulating milk solids. After the coagulation, whey is drained out; the coagulum is called as chhana. Composition of cow milk chhana is given in Table 1.

The traditional method of rasogolla preparation is shown in Figure 1. The first unit operation carried out on chhana for rasogolla preparation is the kneading of chhana to a smooth mass. Generally kneading is done manually by putting the chhana on a wooden plate. Tambat[6] reported rasogollas prepared with cow milk chhana with 3.5 to 4 percent fat and 2 to 4 percent maida levels on the weight basis of chhana were having good flavor and

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**Table 1.** Composition of chhana made from cow milk.

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Lactose (%)</th>
<th>Ash (%)</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>53.4</td>
<td>24.7</td>
<td>17.6</td>
<td>2.2</td>
<td>2.1</td>
<td>Shrinivasan and Anantakrishnan[8]</td>
</tr>
<tr>
<td>53.1</td>
<td>24.8</td>
<td>17.8</td>
<td>2.2</td>
<td>2.1</td>
<td>Kumar and Shrinivasan[7]</td>
</tr>
<tr>
<td>55.7</td>
<td>23.5</td>
<td>16.4</td>
<td>2.2</td>
<td>2.0</td>
<td>Sen and Rajorhia[6]</td>
</tr>
</tbody>
</table>

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The first unit operation carried out on chhana for rasogolla preparation is the kneading of chhana to a smooth mass. Generally kneading is done manually by putting the chhana on a wooden plate. Tambat[6] reported rasogollas prepared with cow milk chhana with 3.5 to 4 percent fat and 2 to 4 percent maida levels on the weight basis of chhana were having good flavor and
taste. De and Tambat \cite{10,11} reported that rasogolla prepared without refined wheat flour showed dull white color, cracks on outer surface, undesirable soft body and loose texture with sticky surface. Goel and Agrawal \cite{12} added sodium-bicarbonate during kneading of cow milk chhana and observed that the sugar absorption capacity was increased in the cooked chhana balls.

Figure 1. Process and material flow diagram for preparation of rasogolla.

About 8-10 g of kneaded chhana is taken, rolled between palms and ball is made. Care is taken not to have cracks on the surface of the ball. The balls are put in vigorously boiling sugar syrup of 50-60 percent concentration for about 15-20 minutes \cite{3,13,14}. During cooking a considerable amount of water evaporates and the concentration of sugar syrup increases. In order to avoid this increased concentration of sugar syrup, water is added to the boiling sugar syrup during cooking. After the cooking, balls are taken out of the boiling sugar syrup and soaked in sugar syrup having sugar concentration of about 40%, which is lower than that used for cooking \cite{13,15}. This process stabilizes the texture of rasogolla in terms of hardness, gumminess, springiness and chewiness. During the soaking period, equilibration of sugar syrup concentration within the rasogolla takes place. Rasogolla is stored and served in this sugar syrup.

The Bureau of Indian Standards has laid down the specification for canned rasogolla as shown in Table 2 \cite{16}.

Table 2. BIS Specification for canned rasogolla.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Specifications</th>
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</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>45-55%</td>
</tr>
<tr>
<td>Milk fat</td>
<td>5%</td>
</tr>
<tr>
<td>Sucrose</td>
<td>45%</td>
</tr>
<tr>
<td>Protein</td>
<td>5%</td>
</tr>
<tr>
<td>Acidity of syrup, max</td>
<td>6.0*</td>
</tr>
<tr>
<td>Concentration of syrup, max</td>
<td>55 °Brix</td>
</tr>
<tr>
<td>Bacterial count, per gram, max</td>
<td>500</td>
</tr>
<tr>
<td>Coliform count, per gram</td>
<td>nil</td>
</tr>
</tbody>
</table>

Kneading of Chhana

Kneading is an important step in rasogolla manufacturing. It is a mixing and folding process in which rheological and textural properties of chhana are changed (Figures 2-4). Traditionally chhana is kneaded manually to a smoother mass for rasogolla preparation. Tarafdar \cite{17} kneaded chhana by using a disc grinder, similar to the one used for reducing particle size of granular solids. It had a rotating disc, which maintained a very small gap with another stationary disc. The rotating disc was an integral part of feed auger. When the screw and the disc were rotated, chhana mass could move from a feed hopper and was forced to come out through the space between two discs. The values of flow behaviour index (n), consistency coefficient (K) modified mixing index (M) and time of compression ($T_c$) of the mechanically kneaded chhana nearly stabilized at 89 cm/sec disc speed.

Ten Hove and Das \cite{3} prepared rasogolla by kneading the chhana in a disc grinder, the peripheral speed of the grinder was 0.89 m/s and balls were made from 10 g chhana lumps by rolling in between palms.
Karunanithy [4] developed a chhana kneader and ball former. The chhana kneader consisted of a kneading chamber, made up of Stainless Steel pipes and the rear end was welded with 6 mm thick Stainless Steel plate having provision to insert the rotor. The other end was closed with 6 mm thick Stainless Steel plate with bolt and nuts so as to fix the rotor with screw and spokes. Three different rotor models were fitted to kneading chamber. In model I, a screw of 25 mm pitch was fixed at both ends of the rotor shaft. Spokes were fixed in the rotor shaft in a helical pattern to facilitate simultaneous mixing and conveying. In model II, a star perforated plate was inserted after feed end screw in order to increase the shear/mixing rate. Spokes and screw were fixed on the hollow shaft and inserted inside the kneading chamber. Model III was a single spiral type flight of 225 mm length and 105 mm diameter.

Modified mixing index and uniformity of mixing index were better for model II, but model I with a peripheral speed of 93.46 cm/s was considered best based on the temperature rise, diameter expansion of chhana ball during cooking and sensory qualities of rasogolla (Figures 5-7). About 2.5 g chhana lumps were put on ball former and the oscillator was turned on. On oscillation, the lumps got transformed into the shape of balls in 15 min.

Cooking of Chhana Balls at Atmospheric Pressure

Bhattacharya and Des Raj [12] reported that strength and concentration of sugar syrup primarily depend on the desired sweetness and shelf-life of rasogolla. They used 40-65% sugar solution for the purpose of cooking and 40% sugar solution for soaking. With lower concentrations (40-45%), rasogolla was less sweet and not acceptable due to its hard body and slightly decomposed texture caused by cooking for a longer period than optimum. Above 60% the quality of rasogolla was inferior on account of browning, hard body, and less spongy texture of product, because the higher concentration of sugar elevated the boiling temperature of cooking syrup. Syrup with 55% concentration was most acceptable. De [18] recommended 30 °Brix concentration of
sugar syrup for cooking while no water was added to compensate for the evaporation loss. Goel [17], Kundu and De [18] and Bhattacharya and Des Raj [12] suggested that the strength of sugar syrup during cooking should be maintained between 50 and 60 °Brix.

Ten Hove and Das [3] prepared rasogolla with 45, 55, 60 and 65 °Brix sugar solutions. The diameter of the ball was measured using a Vernier caliper at an interval of 1 min. Initial diameter of the ball was 2.7 cm, while final diameter after 10 min cooking was 3.7 cm for all the sugar solutions. So, the volume expansion was 2.6 times as compared to chhana ball after 10 min cooking time. It was found that the influence of sugar syrup concentration on the volume expansion was negligible.

Goel [17], Kundu and De [18], De [19], Bhattacharya and Des Raj [12] and Chandan [20] reported the cooking time for atmospheric cooking of rasogolla ranging from 20-30 min. Bhattacharya and Des Raj [12] found that 25 to 30 min of cooking was optimum for good quality and acceptability of rasogolla. Heating for less than 25 min gave rasogolla of white colour with minimum loss of moisture and fat from the chhana balls, but they were not acceptable due to inadequate cooking of balls, less sponginess and poor taste. Excessive cooking above 30 min resulted in rasogolla of inferior quality in all respects viz., browning, excessive loss of moisture and fat from the rasogolla, hard body, decomposed texture and poor taste. Goel and Agrawal [11] prepared rasogollas from 6 g chhana balls and reported that cooking of rasogolla at 104 to 106 °C for 15 minute was adequate. They did not mention the cooking sugar syrup concentration but reported that the final concentration of sugar syrup was maintained at 40% by addition of water. The higher cooking temperature yielded product with hard body, with reduced springiness and darker colour of product. But in lower and shorter temperature range the product was soft and springy.

Soaking of Rasogolla in Sugar Syrup

After cooking is completed, the rasogollas are transferred to another vessel containing sugar syrup with a concentration lower than the cooking syrup. Kundu and De [18], Singh and Ray [21] kept rasogolla overnight at 40 °Brix concentration of sugar.
syrup for development of texture. Karunanithy [13] prepared rasogollas from 2.5 g chhana balls and stored rasogolla at 40 °Brix for 16 h at room temperature before analysis. Tambat [9] prepared chhana balls of 1-2 cm diameter and reported that rasogolla was required to be soaked in 40-45 °Brix for 4 h for texture stabilization. Goel and Agrawal [11] prepared rasogollas from chhana balls of 6 g weight and suggested to cool down the rasogolla in 40% sugar concentration under normal room temperature for 16 h for proper development of texture (Figures 8-11).

Figure 8. Sugar syrup preparation for cooking rasogolla

Figure 9. Chhana balls put in sugar syrup for cooking.

Figure 10. Rasogollas kept for soaking.

Figure 11. Rasogollas kept for sale.

Cooking chhana balls under pressure

Bhattacharya and Des Raj [22] cooked chhana balls under pressure inside a pressure cooker to overcome the difficulty of
maintaining proper concentration of sugar syrup during cooking of chhana balls in open pan boiling due to evaporation of water. They prepared chhana from cow milk, made balls and cooked the chhana balls under pressure. They found that a gauge pressure of 1 kg/cm², equivalent to saturation temperature of 121°C for water, required in pressure cooker was attained in about 13-15 min. This pressure was maintained for 1 to 7 min and then heating was stopped. After 10 min the pressure inside cooker was released slowly. It was found that rasogolla cooked in 50-55% sugar solution for 2-3 min under 1 kg/cm² pressure and then releasing the pressure after 10 min was more acceptable than that cooked for longer time whereas those cooked for 0 to 1 min remained uncooked.

**Texture of Rasogolla**

Ten Hove and Das [3] put the chhana balls in sugar syrup and a thermocouple was placed at the centre of the ball. The variation of temperature with time was read from a temperature indicator and noted at 0.5 min interval and diameter was measured using vernier caliper at 1 min interval. They found that though the centre of the rasogolla attained a maximum temperature after 6 min and the maximum volume expansion occurred after 10 min cooking time, the textural parameters of rasogolla like hardness, cohesiveness and springiness attained constant values after 20 min cooking in 55 ºBrix. It was found that cohesiveness increased during cooking, probably due to settling of the casein network in rasogolla. Springiness remained nearly constant. Gumminess and chewiness increased with time. Though the maximum volume expansion took place in 10 min, but cooking was to be continued for 20 min for getting proper texture of rasogolla.

**Microstructure of Rasogolla**

Rasogollas were prepared with cow, buffalo and mixed milk for the study of microstructure of the rasogolla by Adhikari [14]. However, the proportion of cow and buffalo milk in the mixed milk was not mentioned by the author. For preparation of rasogolla, cow milk with 4% fat and 9.6% SNF, buffalo milk with 5% fat and 9% SNF and mixed milk with 5% fat and 9% SNF was used. The milk was boiled for 3 min and cooled at room temperature. It was then coagulated by 1% citric acid. The mixture was kept for 15 min before straining. The mixture was dipped in distilled water bath at 50 ºC and was washed for 3 times. The chhana was pressed to 42-48% solid content. Wheat flour 2%, baking powder 0.05% and cardamom flavor 1% in solution form were added to chhana and kneading was done. Chhana balls of 1.5 cm diameter weighing 15-16 g were prepared and cooked for 15-16 min in 60-62% boiling sugar syrup. Then the cooked rasogollas were transferred to 40% sugar syrup and analyzed after 12 h of soaking. From the Scanning electron microscopic study, they found that cow milk rasogolla showed a loose, porous protein matrix with coalesced casein micelles forming a thread like structure. Buffalo milk rasogolla had agglomerated casein micelles which were large, compact and formed a scale or layer type structure. Mixed milk rasogolla was having combination of both type structures. Light microscopic investigation showed that cow milk rasogolla had smooth, small oval shaped pores, while buffalo milk rasogolla had rough edged irregularly shaped large pores and mixed milk rasogolla had a heterogeneous structure.

They studied the microstructure of cow, buffalo, mixed milk rasogolla and market rasogolla and found that the pore size of rasogolla prepared by cow milk varied from 0.8-1 mm, buffalo milk from 0.9-1.9 mm, mixed milk from 0.8-1.8 mm and market rasogolla from 0.7-1.25 mm (Figures 12-14).

**Variability in Rasogolla Quality**

The quality of rasogolla primarily depends on the quality of chhana, initial moisture content of chhana and the chhana quality depends on many factors such as type of milk, type and amount of acid used for making chhana etc.

**Types of Milk**

Cow, goat and buffalo milk can be used for rasogolla making. De and Ray [1] and Joshi [23] observed that chhana produced from cow milk had a soft body, smooth texture, and light yellow color more suitable for rasogolla preparation than buffalo milk chhana, which was coarse, granular and hard. Rao [2] reported that crossbred cow's milk having 4% fat resulted in the best quality chhana for rasogolla making. Haque [24] prepared rasogolla with cow milk, buffalo milk and mixed milk (cow milk 50% and buffalo milk 50%). They reported that rasogolla prepared from the cow milk got the highest organoleptic score and the rasogolla
prepared from the mixed milk chhana were also nearly similar to the cow milk rasogolla. Cow milk chhana was soft and buffalo milk chhana was hard in texture. Lower than 4% fat in cow milk resulted in hard body and coarse texture of chhana while higher fat level resulted in the greasy surface. Bhattacharya and Des Raj [12,22] used cow milk with 3-4% fat for preparation of rasogolla. Bhargava [25] tried rasogolla preparation with goat milk having 1, 2, 3, 4, 5, 6% fat. They reported that goat milk having 3-4% fat gave round, soft and spongy rasogolla of acceptable quality. Iyer [26] found that dilution of buffalo milk with 25% water and addition of 0.05% sodium citrate prior to boiling the milk, improved the quality of chhana for making rasogolla. It was found from the observations that cow milk with 4 percent fat was best for preparation of rasogolla as it made rasogolla soft and spongy with highest organoleptic score in comparison to those prepared from other milk.

**Figure 13.** Scanning Electron Micrograph of buffalo milk rasogolla (20µm).

**Figure 14.** Scanning Electron Micrograph of Mixed milk Rasogolla (20µm).

**Type and Amount of Acid Used for Making Chhana**

Rao [2], Gajendran [27], Singh and Ray [22] found that good quality rasogolla could be made with chhana coagulated by citric acid. Rao [3] reported that 3.5 g citric acid per kg of cow milk was required for producing best quality chhana for rasogolla making. Soni [28] reported that 1.25 g citric acid per liter of buffalo milk was needed to produce good quality chhana for rasogolla. Bhattacharya and Des Raj [12,22] used 0.8% hot citric acid solution for coagulation of cow milk for preparation of rasogolla. Tarafdar [16] used 2% citric acid solution at the rate of 100-125 ml per lit of cow milk. Ten Hove and Das [3] used 1.5% citric acid solution at the rate of 250ml per liter of cow milk for coagulation and preparation of rasogolla. Ravichandra [29] found hardness of rasogolla was influenced maximum by fat content of the milk, followed by acidity of milk acid mixture, SNF of milk and moisture content of chhana. Rasogolla of desired hardness can be prepared with cow milk of 3.3% fat and 8% SNF, coagulated with citric acid at 0.4% lactic acid level of milk acid mixture and 58% chhana ball moisture content. Karunanithy [4] used 2% citric acid for coagulation of cow milk at the rate of 125 ml/lit of milk for preparation of rasogolla. Mahanta [30], Shrinivasan and Anantakrisnan [6], Gera [31] suggested that sour whey could be used for production of soft quality chhana suitable for rasogolla making. Citric acid is used by most of the investigators for preparation of chhana for rasogolla making.

**Initial Moisture Content of Chhana**

Bhattacharya and Des Raj [15] prepared rasogolla with chhana having initial moisture content of 40, 45, 50, 55, 58, 60 and 65% and reported about 55-58% moisture in chhana to be optimum for preparation of good quality rasogolla having round shape, soft body, and maximum spongy texture for atmospheric cooking. Moisture content below 50% gave rasogolla harder body, grainy and less spongy texture and at 60% and above the body of rasogolla was soft but the shape was flattened and texture was slightly decomposed.

Bhattacharya and Des Raj [22] prepared rasogolla in pressure cooker with chhana having 45, 48, 50, 55, 60, 62, 65% moisture content and found that better quality rasogollas were produced at 50-60% moisture content of chhana. Rasogollas made with chhana containing moisture below 50% were less acceptable due to hard body and grainy sensation during chewing despite having spongy texture. Chhana containing moisture above 60% yielded very soft rasogolla with broken texture and irregular sized bigger cavities.
Repeated Use of Same Syrup for Cooking of Rasogolla

Bhattacharya and Des Raj [12] used same sugar syrup for cooking four batches of rasogolla one after another. They reported that sugar syrup used up to the second time for cooking, gave rasogolla of acceptable quality. Use of sugar syrup after second time gave inferior quality rasogolla with brown color. After second time the sugar syrup intensified and led to rasogolla of inferior color and fat lost from chhana during cooking accumulated in the sugar syrup, resulting in a greasy surface in the rasogolla.

Mechanization of Rasogolla Making

Rasogolla production is largely confined to cottage and small-scale industry in India. Its production depends on the age-old practice, which is cumbersome, time consuming, labor intensive and makes it difficult to attain high quality standards. The products are handled manually during the course of their preparation, packaging and storage. In traditional method of preparation it is impossible to meet the large scale demand. For meeting the increased demand of rasogolla, maintenance of quality standards is necessary. It must be produced in a continuous manner using machines (Figures 15-17).

![Figure 15. Rasogolla cooker developed at IIT Kharagpur for cooking rasogolla under atmospheric pressure.](image1)

![Figure 16. Rasogolla Cooker developed at IIT Kharagpur.](image2)

![Figure 17. Rasogolla cooker developed at IIT Kharagpur.](image3)

Production of rasogolla was reported to be increasing at the rate of about 67 percent per year [32]. The increased demand calls for greater opportunity in the organized dairy sectors of the country to modernize rasogolla production. Traditional milk products have a good market abroad. Entrepreneurs in Europe, North America, and Australia look for manufacturing them [33].

Kumar [34] developed a screw conveyor for kneading of chhana and portioning of the chhana to lumps of 10 g each. The lumps were made to fall on a spinning disc having a stationary disc above, which formed the chhana lumps to spherical shape.
Karunanithy [4] developed a chhana kneader having feed hopper, rotor, kneading chamber, outlet, reduction gear box and motor. Three different rotor models were fitted to kneading chamber. In model I, a screw of 25 mm pitch was fixed at both ends of the rotor shaft. Spokes were fixed in the rotor shaft in a helical pattern to facilitate simultaneous mixing and conveying. In model II a star perforated plate was inserted after feed end screw in order to increase the shear/mixing rate. Spokes and screw were fixed on the hollow shaft and inserted inside the kneading chamber. Model III was a single spiral type flight of 225 mm length and 105 mm diameter. It was found that the rotor model I fitted to the kneader having a screw of 25 mm pitch fixed at both ends of the rotor shaft with speed of 93.46 cm/s was considered as the best based on the temperature rise, diameter expansion of chhana balls during cooking and sensory qualities of rasogolla.

Karunanithy [5] developed ball former by using an oscillating tray. The kneaded chhana was manually portioned to lumps of 2.5 g. About 150 lumps were transferred to ball former for making spherical balls. After placing these lumps, the oscillator was turned on. On oscillation, the lumps got transformed into shape of balls and time required for formation was 15 min. The ball former was operated at 200 and 250 strokes/min (n), stroke length (L) of 5 and 10 cm with 0 and 5% slope (S) of ball forming surface having SS plain, SS perforated (1 mm dia and 1.5 mm pitch) and acrylic sheet. It was found that based on the sphericity of chhana balls and its retention in rasogolla, chhana ball can be successfully made from the chhana at 200 strokes/min and 5 cm stroke length and with 0% slope in SS plain surface.

Karunanithy [13] used chhana kneader and ball former as described above for preparation of rasogolla. The chhana balls were cooked in sugar syrup of 50 °Brix for 15 min and the temperature of boiling sugar syrup ranged between 105 to 110°C. The product was kept in 40 °Brix sugar syrup for 16 h. From the quality parameters study, they found that percentage of absorbed sugar syrup, porosity, expressible juice, volume expansion and overall acceptability was better for the chhana kneaded at 93.46 cm/s speed and balls formed at 200 strokes/min and 5 cm stroke length for SS plain surface with 0% slope. Porosity of rasogolla decreased with increase of stroke length and slope of ball forming unit.

Karunanithy [35] compared the quality parameters of rasogolla prepared from mechanically kneaded chhana with market samples and control. The control samples were prepared by manual kneading and forming balls by rolling in between the palms. The market rasogollas were collected from sweet shop in Coimbatore and Bangalore. They examined parameters such as porosity, expressible juice, colour, sensory scores and chemical composition of the samples. The percentage of absorbed sugar syrup, porosity, expressible juice and volume expansion were higher for the chhana kneaded in machine with balls formed at 200 strokes/min., and 5 cm stroke length for SS plain surface with 0% slope and comparable with control. Porosity and expressible juice was within the range of market samples. The hardness, colour, and overall acceptability were better for rasogollas prepared with machine kneaded chhana and machine formed balls and comparable with market samples and control samples i.e. chhana balls prepared by manual kneading and rolling.

CONCLUSION

Rasogolla is an Indian dairy product having good popularity abroad too. In recent years the marketing of rasogolla in cans has become a profitable business. Different brands of canned rasogolla are available in market. Mechanized production of rasogolla is very much needed as the demand is increasing. Only continuous chhana kneading and ball forming unit is developed but no work is done on continuous cooking machine. Development of a continuous cooking machine can facilitate continuous production of rasogolla. As pressure cooking has the potential to curtail the cooking time substantially, further work needs to be undertaken for facilitating its utilization with improved efficiency.

ACKNOWLEDGEMENT

Prof H. Das has been actively associated with the preparation of this paper till its finalization. Unfortunately he passed away on 22nd May, 2011 and is no more with us. His contribution is gratefully acknowledged.

REFERENCES