In India, about 7% of the total annual milk production is utilized for the manufacture of khoa, which is extensively used for the preparation of traditional milk sweets such as Gulabjamun, Peda, Burfi, Kalakand etc. Manufacture of these milk-based sweets at present depends upon the availability of khoa as a base material. It would be of immense value to find out the alternate sources of milk solids and therefore, a suitable technology for the manufacture of Gulabjamun mix and the sweets there from would help the dairy industry and traders alike.

Gulabjamun has been made in India for generations mainly in the home and confectionaries. At present, Gulabjamun is made in scattered pockets. The dairy plants have become highly technical and almost completely mechanized. The rigid health department regulations and standards, call for many type of specialized equipments. The process relating to manufacture of indigenous product like Gulabjamun which involve lot of labour and process steps yet to be attempted in a mechanized sector.

In preparing Gulabjamun, khoa, skim milk powder etc. can be used as a base material. Especially, khoa and skim milk powder based Gulabjamun are available in Indian market. There are three different colours of Gulabjamun available in the Indian market are black, brown and light brown. As per the market survey, brown colour Gulabjamun is the most acceptable one among the public.

Inspite of its high economic importance as an indigenous milk product, Gulabjamun has not received the attention it really deserves from the research workers. Recently a very few studies have been reported by Indian scientists on the method of production and quality of the product.
The related information has been reviewed under the following broad heading:

2.1 Technology of Gulabjamun production.

2.2 Heat and mass transfer in frying.

2.3 Dried milk products.

2.4 Recipe for Gulabjamun mix.

2.1 Technology of Gulabjamun production

2.1.1 Gulabjamun

Gill and De (1974) have described a recipe for small scale preparation of Gulabjamun using 300 gm Khoa, 35 gm maida, half tea spoon full baking powder, 1 kg sugar, 1 kg water and ½ kg ghee. They suggested that the balls should be kept pressed for sometimes in sugar syrup before allowing to float for 10-12 hrs at room temperature. No process control details such as temperature of frying or syrup concentration were given. The balls according to them should be fried until deep brown colour develops which appears to be inconsistent with the traditional method of Gulabjamun preparation. Therefore, the process needs to be standardized before its commercial exploitation.

Thompkinson and De (1981) also used stored cow and buffalo milk khoa powder (roller dried) for Gulabjamun making. The body and texture of Gulabjamun prepared from cow milk khoa powder were soft and spongy while those from buffalo milk khoa powder were hard and compact.

Deshmukh et al., (1993) studied the effect of homogenization of milk in the preparation of khoa on quality of the final Gulabjamun. Khoa made from unhomogenized and homogenized milk was blended with maida in the ratio 3:1,
baking powder was added at levels of 0, 0.02, 0.05, 0.08 and 0.11 per cent. Gulabjamun prepared from unhomogenized milk khoa with 0.08 per cent baking powder was the most acceptable product. Milk homogenization did not improve the quality of Gulabjamun.

2.1.1.1 Traditional method of Gulabjamun manufacture

Traditionally Gulabjamun is made from khoa, Rangi et al., (1985) standardized the recipe for Gulabjamun. They reported that using 80 per cent khoa and 20 per cent refined flour for dough preparation, moisture content of the dough was adjusted to 40 per cent and baking powder was added at the rate of 0.25 per cent to the raw mix. The same workers reported that Gulabjamun prepared from cow milk were not received well by the consumers because of hard texture.

2.1.1.2 Formulation of Gulabjamun mix powder

The desirable attributes of Gulabjamun are light brown colour, spherical shape, soft and spongy body with penetration value of around 150 (precision cone penetrometer, 300 AOCS cone), absence of lumps and hard core, uniform granular texture, mild cooked flavour, free from doughy feel, juiciness and optimum sweetness (Ghosh, 1983). Best quality Gulabjamun were obtained from SMP based mix consisting of 43.5 per cent SMP, 25.0 per cent semolina, 15 per cent butter fat, 1.5 per cent baking powder and 0.1 per cent cardamom (Ghosh et al., 1984). Replacing the part of maida with semolina in the mix powder eliminated the stickiness and doughiness.

Incorporation of semolina (15 per cent) improved the granularity, sponginess and softness of the sweet. The softness was further increased by adding 15 per cent butter fat. Baking powder was added to improve the texture quality of Gulabjamun. Higher amounts imparted soapy taste and extra porosity with big air cells in the balls. Cracking of balls during frying was another problem with excess baking powder.
Cardamom powder was added to mask the powdery flavour in the balls prepared from SMP (Ghosh et al., 1984).

Ghosh et al., (1986) have developed the formulations of Gulabjamun mix powder from both roller as well as spray dried skim milk. Sweets of highly uniform and acceptable quality can be prepared by both housewives and confectioners from these mixes. The shelf-life of these mixes in metalized laminate pouches are about 9 months at room temperature.

2.1.1.3 Characteristics of Gulabjamun

Adhikari (1993) studied heat induced structural changes that occur during the processing of khoa (a heat-desiccated Indian milk product) and Gulabjamun (a product obtained by frying khoa, admixed with starch, in clarified butter fat and subsequently soaked in 60 per cent sugar syrup) using SEM and TEM. Constant boiling of milk during khoa manufacture led to the formation of casein whey protein complexes, which coalesced gradually during boiling to form a fuzzy – agglomerated mass and finally precipitated as heat-induced milk gels, joined together by thick protein bridges. Further heat desiccations of this resulted in compaction of the protein agglomerates with reduction in void spaces and fat globules interspersed in between (i.e. khoa). Frying of khoa in clarified butter fat resulted in enlargement of the voids, producing a loose matrix having starch particles interlinked loosely with the agglomerated protein bodies and the clumped fat globules cemented in it (i.e. Gulabjamun). The laboratory and market Gulabjamun had significant structural similarities in fat and protein.

Adhikari et al., (1994) studied the interrelationship between texture, composition, and microstructure of khoa and Gulabjamuns made from buffalo’s milk. Instron hardness, gumminess, and chewiness were negatively correlated with moisture and fat contents, but positively correlated with protein, lactose, added carbohydrates ash and Ca.
contents for both khoa and Gulabjamuns. Cohesiveness was moderately influenced by composition, while no correlation was found between composition and springiness for both products. Significant interrelationships between hardness and cohesiveness and between gumminess and chewiness were observed.

2.1.1.3.1 Sensory characteristics

Sensory characteristics of Gulabjamun vary depending on the quality of ingredients and manufacturing conditions. Buffalo milk khoa is highly suitable for the preparation of Gulabjamun as it is soft, has loose body and smooth granular texture (Srinivasan and Anantakrishnan, 1964).

Ghosh et al., (1986) recommended that Gulabjamun should have following desirable quality attributes.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Desirable characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>light brown to dark brown</td>
</tr>
<tr>
<td>Smell</td>
<td>slightly cooked</td>
</tr>
<tr>
<td>Taste</td>
<td>sweet</td>
</tr>
<tr>
<td>Body</td>
<td>soft, slightly spongy, juicy</td>
</tr>
<tr>
<td>Texture</td>
<td>uniform, slightly granular</td>
</tr>
<tr>
<td>Shape</td>
<td>spherical to oval</td>
</tr>
</tbody>
</table>

Trisodium citrate was added at 0.05, or 0.8 per cent during kneading khoa (made from unconc. 40 or 50 per cent TS milk), together with 10 per cent suji (w/w), to give 9 different combinations. Addition of trisodium citrate generally resulted in Gulabjamun with more sugar absorption, greater springiness, increased flavour score, and better
body and texture. Products obtained from 40 per cent concentrate khoa plus trisodium citrates were softer than the others (Prajapati et al., 1990).

Prajapati et al., (1991) discussed the influence of khoa prepared from fresh or concentrated buffalo’s milk on quality of Gulabjamun (a khoa-based sweet). Gulabjamun prepared from khoa were evaluated for chemical composition, rheological properties and sensory quality. It is concluded that Gulabjamuns with equally good sensory and textural quality and similar composition can be made from khoa prepared from concentrated milk. Effects of incorporation of trisodium citrate in varying concentrations during khoa and dough making on the quality of Gulabjamun were studied. Composition, penetration value and springiness of Gulabjamuns were not affected significantly by the use of trisodium citrate, whereas flavour and sugar absorption characteristics improved significantly under similar conditions. Softness and sensory quality of Gulabjamun could be improved with the addition of 0.5 per cent trisodium citrate in milk during khoa manufacture (Prajapati et al., 1994).

2.1.1.3.2 Chemical and microbiological quality

With a view to assess the quality of market milk products available in Bombay, Sharma and Zariwala (1978) collected market samples of Gulabjamun and analysed them for different chemical constituents. The moisture percentage varied from 22.2 to 41.8, fat percentage from 5.0 to 8.0, protein percentage from 0.0 to 3.4, acidity percentage (lactic) from 0.06 per cent to 0.12, lactose percentage from 2.6 to 5.4 and sucrose percentage from 30.5 to 41.3. The wide variation in chemical composition indicated that the product is being prepared under uncontrolled conditions because no legal standards exist at present.

Minhas et al., (1985) studied the effect of mix formulations (containing 70, 80 and 90 per cent of khoa and 30, 20 and 10 per cent of wheat flour), frying temperatures (130,
140 and 150 °C) soaking time (2 and 4 hrs) on the chemical composition (protein, fat uptake, total carbohydrates, mineral and trace element content) of Gulabjamun. The proportion of khoa and flour in the formulation had a significant effect on chemical composition of Gulabjamun. Fat uptake decreased significantly, as frying temperature increased from 130 to 150 °C. Increased time of soaking in sugar syrup also decreased the fat content of Gulabjamun.

2.1.1.4 Shelf life of Gulabjamun and its base materials

No systematic studies have been conducted so far to evaluate the shelf life of Gulabjamun. However, Gulabjamun like all other indigenous dairy products suffers from a limited shelf life varying from 3 to 4 days under ordinary conditions of storage. Literature available on the shelf life of its raw materials is reviewed here.

2.1.1.4.1 Shelf life of khoa

Various scientists have tried to improve the shelf life of khoa using appropriate packaging materials. Shelf life of khoa is improved when it is packaged in butter paper (De and Ray, 1953 and Jalil et al., 1973). Decreasing the initial moisture content of khoa also improves its shelf life (Rudreshappa and De, 1971 and Deshmukh et al., 1993). This will deteriorate the colour and texture of khoa.

In a comparative study, Kumar et al., (1975) observed that four-ply laminates (paper/poly/aluminium/poly) afforded maximum protection to khoa followed in descending order by 3-ply packs, 2-ply packs, polyethylene bags and parchment paper. Khoa has better keeping quality at low temperature (Rao et al., 1977).

Sharma and Zariwala (1978) reported that packaging material does not contribute significantly to the microbial contamination.

On the contrary, Rajorhia and Srinivasan (1975) reported that packages carry high incidence of microbial contamination.
2.1.1.4.2 Shelf life of khoa powder

Khoa powder has long keeping quality by virtue of its low moisture content. Patel and De (1979) reported that gas packed buffalo khoa powder kept well for 75 days at 37 + 1 °C and for 105 days at room temperature (16 to 30 °C) while air-packed products stored at room temperature showed storage life of 90 days.

Thompkinson and De (1981) observed that cow khoa powder stored for 120 days could still be used for the preparation of acceptable quality of Gulabjamun whereas fair quality Gulabjamuns could be made from buffalo khoa powder stored for 75 days at room temperature (16 to 30 °C).

2.1.1.5 Conditions of frying

Frying is one of the key parameter in the manufacture of Gulabjamun. Commonly used frying media is either vanaspati (hydrogenated fat) or ghee, preferably cow ghee. The balls should be neither over fried nor under fried. Colour should be light to medium brown.

Selvanayagan (1983) reported that frying temperature of 140 °C, ball diameter 3 cm, ball weight 15 g and frying time of 7 min were optimum.

According to Ghosh et al., (1984) the frying at 125 °C – 130 °C for 15 min was optimum, frying at lower temperature resulted into improper cooking, fragile texture and light brown colour. Above 130 °C, case hardening of balls took place, which prevented the heat to penetrate into the centre. High temperature of frying also results in deep brown colour, which is an undesirable attribute. However, higher temperatures have also been employed.

Rangi et al., (1985) suggested that the deep fat frying of Gulabjamun at 130 °C for 15 min gave Gulabjamun with excellent appearance (golden brown colour), texture and overall acceptability. The higher frying temperature of 150 °C resulted in crust
formation, which inhibited the syrup penetration into the Gulabjamun, adversely affecting the quality.

2.1.1.6 Preparation of sugar syrup

Dissolve one kilogram of sugar in one kilogram of water, and boil the solution till a two-string-consistency syrup is obtained.

De (1980) recommended that during this process, add four table spoonfuls of milk and ladle out the scum to obtain clear syrup. Keep this in a container so that a minimum depth of about 10 centimeter of syrup is obtained. Gulabjamun is a milk-based sweet prepared by blending khoa, refined wheat flour, baking powder and small amount of water to form a smooth dough, balls of which are deep-fat fried in ghee or refined vegetable oil before soaking in sugar syrup. In this study models capable of predicting the quality of Gulabjamun prepared using cane sugar and a sugar substitute, sorbitol were developed using response surface methodology (RSM) and applied to determine the optimum processing conditions. Box – behnken design was used to consider 3 independent variables, namely concentration (0B) of the syrup, its temperature and time of soaking, each at 3 different levels. The dependent variable measured for each treatment was a sensory score for overall quality, taken as a combination of the sensory impact of colour, appearance, texture, mouth feel, taste and aroma. According to RSM, the optimum score for overall quality attained for Gulabjamun prepared with cane sugar was 7.7, obtained at processing conditions of 51⁰B syrup, 54⁰C and 4 hrs. Soaking, whereas for Gulabjamun prepared with sorbitol, a maximum overall quality score of 8.0 was obtained at processing conditions of 54⁰B syrup, 65⁰C and 3 hrs soaking. These processing conditions were found to correlate with those of experimental conditions (Ramakrishna et al., 2004).
2.1.1.7 Dipping in sugar syrup

2.1.1.7.1 Sugar syrup concentration

Sugar, as a preservative is well known in the food industry. In liquid form, it is suitable to yeast growth in the concentration range of about 66 per cent and above.

Srinivasan and Anantakrishnan (1964) explained that syrup concentration is likely to influence physico-chemical quality of Gulabjamun. The desired form of the product is dependent on the syrup concentration in which it is dipped and stored. They suggested the 60 per cent concentration was the most desirable.

Ghosh et al., (1984) suggested that syrup concentration of 60 percent was optimum. The syrup distribution in the balls was uniform with optimum sweetness and soft texture.

Rangi et al., (1985) reported that fried Gulabjamun balls soaked in sugar syrup concentration of 50 per cent were rated excellent on sensory score.

Rao (2000) studied the diffusion of sucrose in Gulabjamun balls under nine different set of conditions i.e., three different sugar syrup concentration of 60 per cent, 70 per cent and 80 per cent (w/v) and three different temperatures viz., 60°C, 70°C and 80°C and calculated the diffusion coefficients for sugar into Gulabjamun prepared from the equation of Crank (1975).

2.1.1.7.2 Duration of Dipping

Time of soaking of fried balls in sugar syrup also affects the sweetness of Gulabjamun.

Ghosh et al., (1984) recommended the overnight soaking in 60° Brix syrup at 70°C. Higher concentration of syrup resulted in excessive sweetness. Dilute syrup did not impart adequate sweetness to Gulabjamun.

Rangi et al., (1985) suggested four hours of soaking in 50 °Brix solutions at 70°C.
Rajorhia (1989) stated that by increasing the sugar syrup temperature to 80°C, the absorption property of the balls improved.

Gulhati et al., (1992) advocated the dipping of Gulabjamun balls at 60°C Brix in hot sugar syrup for 4 hrs. Whereas, Saxena et al., (1996) suggested the soaking of Gulabjamuns in sugar syrup of 60 °Brix concentration for overnight at room temperature. Rajorhia (2000-01) suggested the equal proportions (on weight basis) of water and sugar are boiled till a syrup of about 60 per cent concentration is obtained.

2.1.2 Khoa

Khoa, an important indigenous product prepared by partial desiccation of milk, is used as a base material in preparation of variety of popular milk sweets viz., burfi, peda, Gulabjamun and kalakand. It is also known as khoya, khova, kava or mava. It is made by heating, evaporating and desiccation of milk at atmospheric pressure accompanied with continuous stirring until dough like consistency is achieved. Standards laid down by BIS (IS No.4883-1980) for three khoa varieties are given in the table 2.1.

Table 2.1. BIS specifications of different types of khoa

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Khoa type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dhap</td>
</tr>
<tr>
<td>TS (%) min</td>
<td>55</td>
</tr>
<tr>
<td>Fat (% dmb) min</td>
<td>37</td>
</tr>
<tr>
<td>Protein (% dmb) min</td>
<td>37</td>
</tr>
<tr>
<td>Ash (%dmb) max</td>
<td>6</td>
</tr>
<tr>
<td>Titrable acidity (% LA) max</td>
<td>0.6</td>
</tr>
<tr>
<td>End uses</td>
<td>Gulabjamun</td>
</tr>
</tbody>
</table>
Srinivasan and Gyanendra (1982) evaluated that mean composition of cow milk khoa, buffalo milk khoa and fresh market khoa was:

<table>
<thead>
<tr>
<th>Component</th>
<th>Cow Milk Khoa</th>
<th>Buffalo Milk Khoa</th>
<th>Fresh Market Khoa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>30.9</td>
<td>22.3</td>
<td>28.4</td>
</tr>
<tr>
<td>Fat</td>
<td>22.0</td>
<td>32.2</td>
<td>24.6</td>
</tr>
<tr>
<td>Protein</td>
<td>19.1</td>
<td>17.7</td>
<td>19.0</td>
</tr>
<tr>
<td>Ash</td>
<td>3.7</td>
<td>3.7</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Desirable characteristics of khoa refers to typically milk – cooked flavour, similar to that perceived from boiled milk and are free from any objectionable or abnormal flavour, possessing uniform and slightly granular texture (Dharampal and Gupta, 1984).

Rajorhia et al., (1990) reported that khoa sample prepared from buffalo milk and slightly sour milk (up to 20 per cent acidity) had similar sensory and rheological properties. Sour milk having greater than 0.25 per cent acidity resulted in acidic order and large grain formation in khoa.

Goyal and Srinivasan (1990) suggested khoa samples were packed in 3 types of pasteurized flexible packages or MST cellulose film middle and stored at 37 °C at foil inner (150 gauge LDPE) packages were tested for bursting strength using a pneumatic burst tester before filling and after emptying after 0, 5, 10 and 15 days of storage.

Boghra and Mathur (1991) analysed for minerals from forty samples of khoa collected from 5 different shops of Karnal city. A noticeable difference in magnesium, phosphorus and zinc content for calcium among shops was observed. The nutritional quality of milk proteins was evaluated at different stages during the preparation of khoa from buffaloe’s milk. Khoa was prepared by heating buffaloe’s milk (5 per cent fat) with steam (100-1050°C) at 1406 kg/cm pressure. Samples were analysed for
moisture, fat, protein, lactose and lysine content at initial, intermediate (Dhap) and final stages of khoa preparation. Results suggested that nutritional value of milk proteins does not decrease during khoa preparation (Sapre and Deodhar, 1991). The indigenous milk products of India are classified broadly into condensed (khoa, burfi, Gulabjamun, peda etc.), cultured and acid precipitated (paneer, chhana, sandesh, rasogolla) product. Technological innovations in khoa, shrikhand and Gulabjamun manufacture and development in equipment for manufacture of ghee and other indigenous milk product are described with the acid of flow charts and details of equipment design (Punjrath, 1991).

Gothwal and Bhavanadasan (1992) khoa was prepared from buffaloes and cow’s milk and evaluated for browning as where samples of sterilized milk (with or without added cane sugar), condensed milk and skim milk powder. Results were given in graphs and tables. Khoa prepared from buffalo milk had higher levels of TS and browning than that prepared from cow milk. Effects of storage at 5-30 °C on browning of khoa were also determined and at all temperature browning increased more in cow’s milk than buffaloes milk khoa lower temperature.

Boghra and Mathur (1996) analysed the samples taken at various stages of khoa preparation from buffalo and cow milk. It showed gradual and marked decrease in moisture content (Approx. 33 per cent) between milk and coagulation stage, about 15 per cent at intermediate (I and II) and about 4 to 55 between simulating dhap and final khoa from both species. This results in simultaneous 4 to 6 folds in protein, fats, lactose and milk salts.

According to (PFA, 2002) khoa is the product obtained from cow, buffalo, goat or sheep milk/milk solids or a combination thereof by rapid drying. The fat content shall not be less than 30 per cent on dry weight basis of the finished product. It may contain citric acid not more than 0.1 per cent by weight. It shall be free from added starch,
added sugar and added colouring matter. Three main varieties of khoa are prepared in rural areas namely Pindi, Dhap and Danedar, which differ in terms of quality, texture, composition and their final use.

2.1.2.1 Method of khoa making

Several mechanized methods have been developed for the manufacture of khoa by different workers from time to time.

**Banerjee et al., (1968)** developed the first semi-continuous khoa – making machine, which was further modified by **Rajorhia and Srinivasan (1975)**. The equipment consisted of scraped surface heat exchanger and two open semi jacketed pans with reciprocating spring-loaded scrapers. The machine had several problems including poor quality of finished product.

**Sawhney et al., (1987)** mechanized the traditional batch process by providing jacketed shallow open pan with a swinging hanger type scraper for stirring during the desiccation process. In this equipment, the jacket is filled with water up to two third of its height and is placed over the furnace. Steam is generated in the jacket and its temperature and pressure are controlled by adjusting the safety valve, which is provided to adjust the water steam pressure in the jacket in a range from 0 - 4 kg/cm². The equipment is developed for the manufacture of khoa under rural conditions.

**More (1987)** designed batch type semi mechanized scraped surface heat exchanger. It consists of jacketed drum with vapour exhaust and scraper assembly. The scraper assembly comprises of spring loaded blades, rubber boots and a central shaft. In each batch, 4 kg of milk is used. Both these mechanized units are of batch type and unsuitable for commercial production of khoa.
Dharampal and Cheryan (1987) tried membrane processes for pre concentration of milk using reverse osmosis process followed by desiccation in open vats or SSHE. Cow milk concentrated to 2.5 fold by RO process was successfully used. Such process offers an attractive energy saving in the initial concentration of milk. The quality of khoa made by the membrane process was found to be identical to the conventionally prepared product.

Agrawala et al., (1987) developed a mechanized conical process vat for preparation of khoa. This equipment consists of spring-loaded blades and stainless steel conical vat with cone angle 60 and steam jacket partitioned into 4 sections. A positive displacement screw pump is connected at the outlet of the vat for recirculation and spreading of the product over heat transfer surface. An inclined scraped surface heat exchanger (ISSHE) was developed at National dairy Development Board for continuous manufacture of khoa (Punjrath et al., 1990). Concentrated milk of 42 to 45 per cent total solids is used as feed. Inclination of ISSHE permits formation of a pool of boiling milk critical to formation desirable grains and simulation of cooked flavour in khoa similar to that achieved in traditional process. This system has been most widely adopted by organized dairies.

Rajorhia et al., (1991) evaluated the performance of four mechanized systems of khoa making viz. ISSHE, convap-contherm, roller dried and conical vat methods with regards to physico-chemical characteristics, sensory properties and operational features. Khoa made from ISSHE was found to be the best of all the other mechanized system and it was comparable to khoa made by traditional method. The contherm – convap scraped surface heat exchanger system developed by Alfa – Laval has also been used for the manufacture of khoa but it produced sticky and lumpy product with inconsistent flow.
Patel et al., (1992) prepared khoa using two different set of concentration conditions using two different method of manufacture from buffalo milk standardized at fat : SNF ratio 0.6 (TS 15 per cent). In first method the milk was boiled vigorously to achieve partial concentration (approximately 1:2) followed by spreading and scraping of concentrate on the hot surface of kettle till the finished product was obtained. The other method stimulated the traditional method in a way that milk was allowed to simmer to partial concentration (approximately 1:3) until coagulated mass was noticed. The coagulated mass was concentrated under low heat conditions to study the effect of concentration condition on texture profile of khoa. Lower granulation with higher smoothness was observed in khoa prepared by second method. Dhap khoa (37 – 45 per cent moisture) was more cohesive than Pindi (28-35 per cent).

Kishore and Dodeja (1999) used both buffalo milk and concentrated milk for khoa making using SSHE. Capacity of plant was in the range of 36-40 kg/hr. for buffalo milk and 115 – 125 kg/hr for concentrated milk with total solids content of 36 per cent. The khoa prepared from buffalo milk was having better flavour, body and texture compared to khoa made from concentrated milk. The lower sensory score for concentrated milk khoa was due to high pastiness and textured defects found in khoa. Traditionally khoa is prepared by taking four liters of milk and boiling it in an open pan accompanied with vigorous agitation. In final stage of process pan is removed from the fire and khoa is worked with ladle (Rajorhia, 2002). Batch variation in quality of product is due to varying temperature profile over the heat transfer surface of the pan and the uncontrolled heat input. In organized dairies, double jacketed stainless steel kettles with or without an inbuilt scraper have replaced karahi (Rajorhia, 2002). Steam is circulated in the jacket. This provides a non-smoky heating medium and uniform heating by regulating the steam pressure with the help of a steam control valve, khoa produced by this method is usually granular unless it is properly mashed. A continuous khoa – making machine was evaluated for heat transfer
behaviour during manufacture of khoa. The machine consisted of 3 individual scraped surface heat exchangers (SSHE) equipped with a Teflon coated spring loaded rotor-scaper assembly. The overall heat transfer coefficient, steam and product side film heat transfer coefficient were determined under various operating conditions of the SSHE. Quality attributes of khoa prepared under different conditions were also evaluated. It is suggested that the graphical method used in this study to determine steam side film heat transfer coefficient using nusselt theory and heat flux equivalent concept was quite simple to use in jacketed SSHE (Bhadania et al., 2004).

2.1.2.2 Texture of khoa

Various workers have used the milk with different fat and SNF content for khoa making.

Miyani et al., (1990) studied the influence of fat: SNF ratio of milk on rheological and organoleptic quality of khoa. Rheological properties of khoa such as hardness, cohesiveness, brittleness, gumminess, springiness and chewiness showed a declining trend with increase in fat: SNF ratio. They found that a fat: SNF ratio of 0.5 (total solids 15 per cent) resulted in the product with the most desirable organoleptic quality.

Rajorhia et al., (1990) studied the effect of composition on texture of khoa prepared from buffalo milk. Khoa with varying total solids (56.23 – 71.95 per cent) fat (20.8 – 28 per cent) and protein (14.92 – 18.87 per cent) was evaluated. It was observed that with varying extent of heat treatment to milk during khoa preparation, WDP (water dispersible protein) varied from 8.54 - 28.7 per cent. They observed that crumbliness in khoa increased with increasing total solids, fat and protein and decreased with increase in WDP. Firmness increased with total solids, fat and protein and decreased with increased in WDP. On the contrary, stickiness increased with increased WDP.
Gupta et al., (1990) also observed that increase in total solids resulted in increased hardness and it was suggested that higher WDP content resulted in smaller amount of protein of the total protein to transfer to solid network, which results in lower strength of network giving less hard khoa. It was also observed that cohesiveness of khoa tended to decline with increasing total solids, fat and protein. Khoa samples prepared from buffaloe’s fresh and slightly sour milk (up to 0.20 per cent acidity) had similar sensory and rheological properties. Sour milk having >0.25 per cent acidity resulted in acidic odour and large grain formation in khoa. Such samples showed max. Hardness, springiness, gumminess and chewiness. Neutralization of sour milk with 20 per cent sodium bicarbonate solution improved the flavour and smoothened the texture of khoa (Rajorhia et al., 1990). Texture of khoa made from buffaloe’s milk using a steam kettle was assessed and compared to khoa obtained by traditional processing. The steam kettle process yielded a product that was significantly harder, springier, gummier and chewier but less adhesive than that from the simulated traditional process. Sensory evaluation revealed that firmness and chewiness were higher for traditionally processed khoa. Khoa made by the steam kettle process was more desirable with respect to texture, having greater smoothness and less crumbliness. High moisture khoa (Dhap) was softer and smoother and less gummy and chewy than low-moisture khoa (Pindi). Interactions of processing with moisture and milk acidity were statistically non-significant for all texture parameters except chewiness (Patel et al., 1992). Cow’s milk khoa is generally unacceptable due to its smooth and pasty body, sandy texture and salty taste. Potential development of a desirable grainy texture in cow’s milk khoa was investigated with the addition of whey protein concentrate (WPC). Khoa, containing WPC showed improved sensory properties over the control khoa and compared well with commercial khoa. A lower T.S. content in WPC – containing khoa was necessary to counteract the adverse effect of WPC on instron texture parameters. It is concluded that a good quality khoa with reduced TS content
can be prepared by incorporating 5 per cent WPC into cow’s milk khoa during preparation. This method enables acceptable khoa to be manufactured in places where buffaloe’s milk is not available (Patel et al., 1993).

2.1.2.3 Storage of khoa

Sorption isotherms for khoa prepared from cow’s and buffalo’s milk and 3 local market khoa were of typical Gulabjamun mix oil type and showed a steep rise above 45 per cent RH. Desorption occurred in all 3 types of khoa samples at all RH standard (11 – 92 per cent). Equilibrium moisture contents of <17, <12 and <21 per cent, respectively for khoa from cow’s milk, buffaloe’s milk and the market, corresponding to about 54 per cent RH, were considered safe to avoid mould growth, but at these moisture levels khoa samples were hard. At RH > 55 per cent, Khoa developed mould growth (Goyal and Srinivasan, 1989). The effectiveness of antimicrobial agents (hisaplin and potassium sorbet) and commonly available packaging materials (aluminium foil, polyethylene and parchment paper) on microbial quality of khoa during storage at 37 and 5°C was studied. Results showed that counts of mesophilic aerobes, yeast and fungi in khoa were reduced by the incorporation of 0.30 per cent potassium sorbet.

Rehman and Salariya (2006) concluded that synthetic antioxidants inhibited the development of rancidity during storage of khoa. Therefore, storage life of khoa can easily be extended for 30 days by the addition of BHA and BHT.

2.1.3 Wheat flour

Wheat flour is a mixture of complex substances like starch, proteins, fats, minerals, vitamins etc. Some powerful enzymes of proteolytic types are also present. Maida is the product obtained by roller milling of cleaned, hard or soft wheat or its blends and bottling. Maida is graded as high gluten (HG), medium gluten (MG) and low gluten
(LG) types. The requirement of gluten content in maida for bread and biscuit is kept at a minimum of 10 per cent whereas for sweets and domestic preparations, the gluten content should be between 7-10 per cent (IS: 1009 - 1968).

Maida contains about:

72 – 75% - starch

12 – 14% - Moisture

7 – 13% - Protein

0.4 – 0.7% - Ash

and small amount of natural sugar, fats, enzymes and other organic components. For long periods of conservation, wheat flour should be stored in a closed atmosphere (Bellenger and Godon, 1972). Under this condition flour acidity increases owing to the accumulation of linoleic and linolenic acids which are slowly oxidized, reduction of disulphide groups is slow and there is little increase in sulphydryl, groups thereby decreasing the solubility of gluten protein. The change in baking strength is only minor. The ability of flour to swell in cold water or milk and form dough depends principally on the gluten present. Starch does not swell in cold water (Gill and De, 1974). Effects of addition of refined wheat flour (maida) and sugar on browning and physico chemical properties of cow’s and buffalo’s milk, pooled milk samples, khoa and khoa-based dairy products (burfi, kalakand, milk cake, Gulabjamun, milk peda) were studied. Addition of maida at an 8 per cent level increased the browning index by 20-22 per cent during heat treatment in both cow’s and buffalo’s milk. Addition of maida at 10 per cent increased the browning index by 13 per cent in burfi, kalakand and milk peda and by 18 per cent in milk cake. Milk samples containing added sugar levels of 6, 8 and 10 per cent and sterilized at 1.05 kg/cm² for 15 min, showed no
browning, although prolonged heating caused intense browning as compared to samples with no added sugar. Addition of sugar at 15-35 per cent (based on the wt. of khoa) produced less browning in burfi and kalakand than when sugar was added at 4 per cent. Different mix formulations were found to alter protein, fat and total carbohydrate contents of Gulabjamun. The frying temperature of Gulabjamun had a significant effect of fat uptake. Higher TS levels tend to increase browning in khoa and khoa – based sweets (Gothwal and Shukla, 1995). The addition of a heated and dried suspension of starch and gluten to the food products would enrich the protein content ranging from 5 to 50 per cent. It is claimed that maida is suitable for use in processing canned foods, since as a thickening agent the water carrying ability of the thickener is not so extensively reduced in the cooking operation as when starch alone is used (Gothwal and Shukla, 1995).

Londhe et al., (2000) studied the effect of incorporating different binder flours including shingada (water chestnut), maida (wheat flour) and sago (cassava) in khoa on the quality of the resulting Gulabjamun produced was studied colour and appearance scores were affected by the basic colour differences in the binder materials. Maida was snow white, sago flour was chalky white and shingada was pinkish. Thus, Gulabjamun containing maida had the most acceptable colour. Sago-containing Gulabjamun had lower flavour acceptability compared with that containing maida, but was found to be better than shingada combinations. In terms of texture, maida-containing Gulabjamun generally had superior texture followed by shingada flour. Overall acceptability of Gulabjamun containing maida was superior compared with that containing sago and shingada flour. It was concluded that Gulabjamun containing maida (10 per cent) was superior in terms of all sensory attributes considered, compared with the other flours.
2.1.4 Frying media

Most of the researchers have recommended frying of Gulabjamun balls at 130 °C for 15 min but used various sources of fat such as vanaspati and ghee (Rangi et al., 1985; Rajorhia, 1989; Aneja, 1992 and Ghosh et al., 1984) suggested frying of Gulabjamun balls in a steam jacketed kettle in hydrogenated oil at 125 – 130 °C for 15 min and subsequently soaking in 60 per cent hot sugar syrup at 60 °C for 2 hr.

2.2 Heat and Mass transfer in frying

The balls made from mix are fried in ghee in a shallow pan to immerse the balls completely during frying.

2.2.1 Frying techniques

Hallstrom (Sweden, 1980) reported that there are technically four different methods of frying available.

2.2.1.1 Contact frying (conduction via solid surface)

Heat is transferred from solid mater in direct contact with the product possibly via a very thin film of fat. As the product is not geometrically as plane as the pan plate, the film of fat varies in thickness, as well as local air or vapour bubbles being present. This gives a variation in the temperature of the product surface resulting in a characteristic appearance and colour. Heating normally is from one side only, but equipment for simultaneous two-side frying is available. The heat source is normally electricity but steam and gas are potential sources.
2.2.1.2 Deep fat frying (conduction via a liquid)

The product is transported through a hot liquid and all parts of the surface gain the same heat treatment and thus gets the same colour. The heat source may be electricity, steam or gas.

2.2.1.3 Convection oven frying (convection via a gas)

Generally the gas is air more or less moisturized. Steam superheated steam and even pressurized steam would be applicable but are so far not used.

2.2.1.4 Heat Radiation

This implies a non-touching method by means of electromagnetic heating example infra red radiation. The heat source is electricity or gas.

2.2.2 Heat transfer to the product

There are two major methods for transferring the heat to the product in frying technique, given as below:

2.2.2.1 Contact frying

Direct contact between the pan and the product implies very high heat transfer coefficients. As mentioned previously, the surface of the product is not plain. Further a film of fat may in some cases conduct the heat. Disappearing water (vapour phase) needs channels in the product surface. These circumstances reduce the average heat transfer coefficient. The reduction also depends on for instance the pressure in double sided belt fryers.
2.3 Dried milk products

The keeping quality of milk powders has been subject of many researchers in recent years. Deterioration of dried milk during storage involves principally in flavour, colour and reconstitution properties. The composition and quality of milk, handling and processing procedures, metallic contamination, packaging methods and storage conditions influence these changes.

2.3.1 Problems of storage

Change in moisture: The keeping quality of milk powder is related to its moisture content (Hall and Hedrick, 1971). Higher the moisture content of the product, lower will be the keeping quality. Lactose and protein cause the greatest effect on the moisture equilibrium. Chandet (1966) reported that the optimum moisture content for maximum storage stability is around 4.5%.

Berlin et al. (1968) studied the mechanism of water absorption by dehydrated milk powder, casein absorbs water initially at low relative pressure but as the pressure approaches to 0.5 p/p₀, and the lactose glass becomes the principal water-absorbing site.

2.3.2 Flavour changes: The off-flavour, which develops in dairy products as a result of oxidative deterioration and collectively, referred to as “oxidized flavour”.

Mutzelburg (1982) reported that flavour defects in milk products are caused by heating, exposure to light, enzyme (lipolysis, proteolysis) and oxidation of the products.

Bassette and Keeney (1960) described the cereal type flavour in dried skim milk to a homologous series of saturated aldehyde resulting from lipid oxidation in conjunction with products of the browning reaction.
2.3.3 **Free fat**: The presence of free fat in milk powder influences its oxidative deterioration and other physico-chemical properties.

*Buma (1971)* found that free fat is perhaps correlated directly with solubility of the powder and inversely with its dispersibility. The free fat content of whole milk powder decreases considerably. He weighed little amount of dried milk in a vessel with a screen bottom, after which the vessel was slowly lowered into a container holding petroleum ether. Milk fat was extracted from the surface of the dried milk particles; and free fat was expressed as a percent of the total fat content in the sample.

### 2.4 Recipe for Gulabjamun mix

Literature regarding the composition of ready-to-use Gulabjamun mix is scanty, as the formulation is a trade secret. Despite this, efforts have been made by some researchers to standardize the formulation of Gulabjamun mix.

*Ghosh et al. (1984, 1986)* reported the following recipe for ready-to-use Gulabjamun mix.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Quantity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skim-milk powder (Roller dried)</td>
<td>43.4</td>
</tr>
<tr>
<td>Maida</td>
<td>25.0</td>
</tr>
<tr>
<td>Suji</td>
<td>15.0</td>
</tr>
<tr>
<td>Butter oil</td>
<td>15.0</td>
</tr>
<tr>
<td>Baking powder</td>
<td>1.50</td>
</tr>
<tr>
<td>Cardamom powder</td>
<td>0.10</td>
</tr>
</tbody>
</table>
2.4.1 Chemical composition of Gulabjamun mix: The gross chemical composition of the Gulabjamun mix from SMP and WMP bases in terms of % fat, protein, ash and carbohydrates as given by Ghosh et al. (1984) is shown below:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>SMP base</th>
<th>WMP base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>8.44</td>
<td>8.20</td>
</tr>
<tr>
<td>Fat</td>
<td>15.03</td>
<td>15.10</td>
</tr>
<tr>
<td>Total protein</td>
<td>19.45</td>
<td>19.07</td>
</tr>
<tr>
<td>Total ash</td>
<td>3.89</td>
<td>3.93</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>53.19</td>
<td>3.70</td>
</tr>
</tbody>
</table>

(By difference)

2.4.2 Preparation of Gulabjamun: One kg of Gulabjamun mix was kneaded with 500 ml of potable water to form smooth dough. The consistency of dough was such that when rolled into small balls (12 g weight and 2.7 cm dia) did not show any signs of surface cracks (Ghosh et al., 1984).

The ‘Amul’ brand Gulabjamun mix from the Gujarat co-operative Milk Marketing Federation Ltd., has prescribed the following preparation procedure:

Hundred grams of ready-to-use Gulabjamun mix was mixed with 40 ml of water. The mix was gently kneaded into smooth dough and kept aside for 5 min. Dough was shaped in round Jamuns. The balls were deep fried in refined oil or ghee until golden brown colour is attained. Balls were then soaked in hot sugar syrup.