Consortium for Educational Communication

Module on

Cheese And Paneer

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Text

1. Introduction

Cheese is a solid food made from the milk of cows, goats, sheep and other mammals. Cheese is made by coagulating milk. This is accomplished by first acidification with a bacterial culture and then employing an enzyme, rennet (or rennet substitutes) to coagulate the milk to “curds and whey.” The precise bacteria and processing of the curd play a role in defining the texture and flavor of most cheeses. Some cheeses also feature moulds, either on the outer rind or throughout. There are hundreds of types of cheese produced all over the world. Different styles and flavors of cheese are the result of using milk from various mammals or with different butterfat contents, employing particular species of bacteria and moulds, and varying the length of aging and other processing treatments. Other factors include animal diet and the addition of flavouring agents such as herbs, spices or wood smoke. Whether the milk is pasteurized may also affect the flavor. The yellow to red colouring of many cheeses is a result of adding annatto. Cheeses are eaten both on their own and cooked as part of various dishes; most cheeses melt when heated. For a few cheeses, the milk is curdled by adding acids such as vinegar or lemon juice. Most cheeses, however, are acidified to a lesser degree by bacteria, which turn milk sugars into lactic acid, followed by the addition of rennet to complete the curdling.

Rennet is an enzyme mixture traditionally obtained from the stomach lining of young cattle. Vegetarian alternatives to rennet are available; most are produced by fermentation of the fungus *Mucor miehei*, but others have been extracted from various species of the *Cynara* thistle family.

Cheese has served as a hedge against famine and is a good travel food. It is valuable for its portability, long life, and high content of fat, protein, calcium, and phosphorus. Cheese is a more compact form of nutrition and has a longer shelf life than the milk from which it is made.

2. History

Cheese is an ancient food whose origins predate recorded history. There is no conclusive evidence indicating where cheese making originated, either in Europe, Central Asia or the Middle East, but the practice had spread within Europe prior to Roman times and, according to Pliny the Elder, had become a sophisticated enterprise by the time the Roman Empire came into being. Proposed dates for the origin of cheesemaking range from around 8000 BC (when sheep were first domesticated) to around 3000 BC. The first cheese may have been made by people in the Middle East or by nomadic Turkic tribes in Central Asia. Since animal skins and inflated internal organs have, since ancient times, provided storage vessels for a range of foodstuffs, it is probable that the process of cheese making was discovered accidentally by storing milk in a container made from the stomach of an animal, resulting in the milk being turned to curd and whey by the rennet from the stomach. Cheesemaking may also have begun independent of this by the pressing and salting of curdled milk in order to preserve it. Observation that the effect of making milk in an animal stomach gave more solid and better-textured curds, may have led to the deliberate addition of rennet. The earliest archaeological evidence of cheesemaking has been found in Egyptian tomb murals, dating to about 2000 BC. The earliest cheeses were likely to have been quite sour and salty, similar in texture to rustic cottage cheese or feta, a crumbly, flavourful Greek cheese. Cheese produced in Europe, where climates are cooler than the Middle East, required less aggressive salting for preservation. In conditions of less salt and acidity, the cheese became a suitable environment for a variety of beneficial microbes and molds, which are what give aged cheeses their pronounced and interesting flavors.

3. Definition

Codex Alimentarius, FAO/WHO, standard No 6, defines cheese as:

"Cheese is the fresh or ripened solid or semi-solid product in which the whey protein/ casein ratio does not exceed that of milk, obtained:

a) "By coagulating (wholly or partly) the following raw materials: milk, skimmed milk, partly skimmed milk, cream, whey cream, or buttermilk, through the action of rennet or other suitable coagulating agents, and by partially draining the whey resulting from such coagulation".

b) "By pressing techniques involving coagulation of milk and/or materials obtained from milk which give an end product which has similar physical, chemical and organoleptic characteristics as the product systemized under classification of cheese".

4. World production and consumption

Worldwide cheese is a major agricultural product. According to FAO united nation, 2011, over 20 million metric tonnes of cheese are produced worldwide. Largest producer of cheese is US, which accounts for 30% of world production, followed by Germany and France. Table1 demonstrates the world's top consumers, producers and exporters

Table 1. Consumption, production and export trend of the world according to FAO USA, 2011.

Top Producers	Top Exporters	Top Consumers
United States	Germany	France
Germany	France	Iceland
France	Netherlands	Greece
Italy	Italy	Germany
Netherlands	Denmark	Finland

5. Classification of cheese

Cheeses are classified on the basis of a series of parameters which include:

a) Type of milk employed

b) Fat content

c) Moisture content

d) Duration of ripening

e) Curing characteristics

f) Technology adopted during cheese making and temperature of curd processing

g) Denomination

Fig 1 gives the natural cheeses classified according to the maturation agent used and firmness.

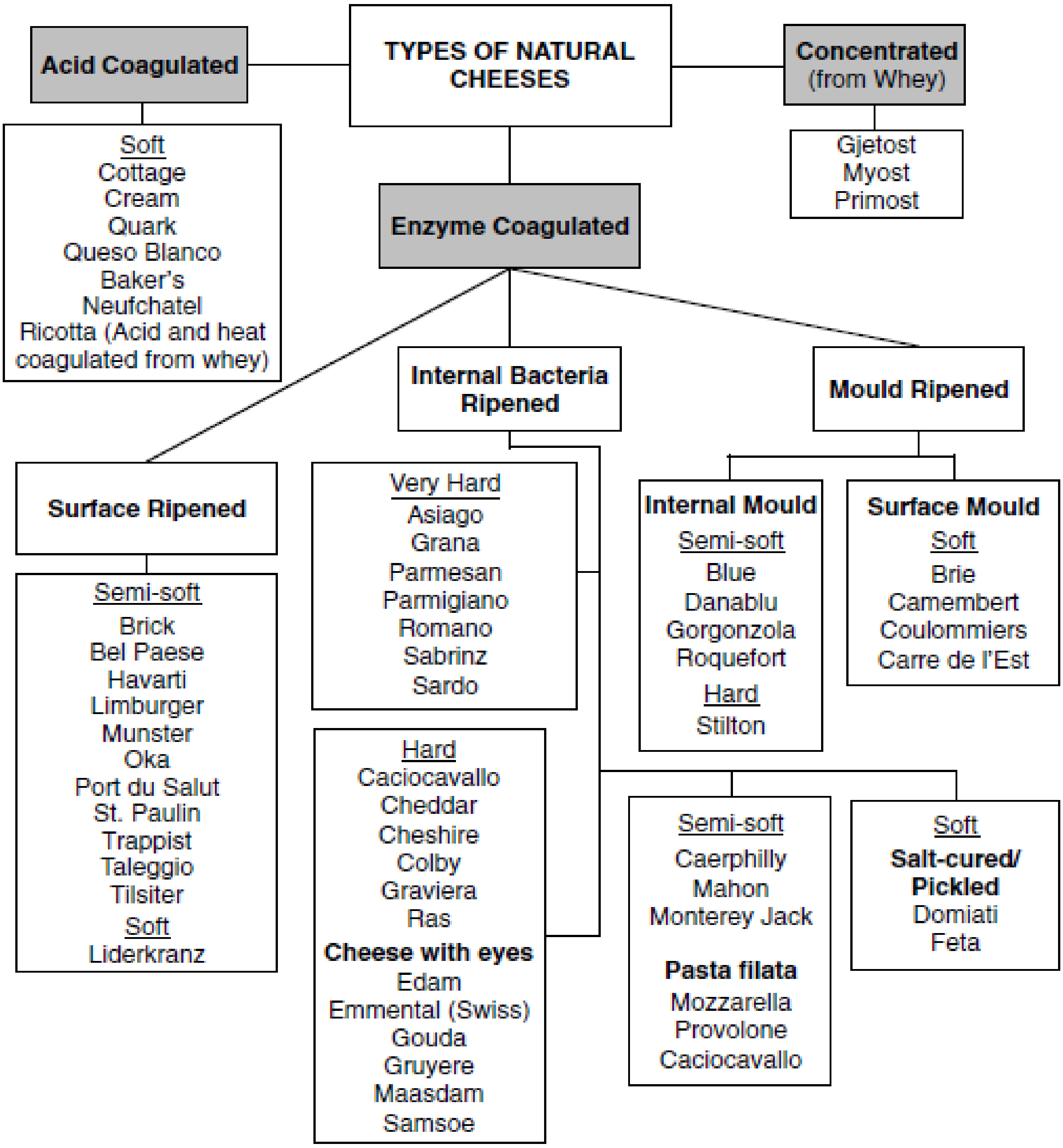

Fig.1. Natural cheeses classified according to the maturation agent used and firmness.

5.1 Classification on the basis of type of employed milk:

Some cheeses are categorized by the source of the milk used to produce them. While most of the world's commercially available cheese is made from cows' milk, many parts of the world also produce cheese from goats, buffalos and sheep, well-known examples being; cow milk cheeses: e.g., cheddar cheese, ewe's milk cheeses: caciotta cheese, roquefort cheese, buffalo milk cheeses: e.g., mozzarella cheese, goat milk cheeses: e.g., caciotta cheese. For cheeses not produced from cow milk, indication of the species is mandatory.

5.2 Classification on the basis of fat content

On the basis of fat content on dry basis (FDB), cheeses are classified as; High fat (> 60% FDB), e.g., Robiola, Tillagio, etc., full fat (45-60% FDB), e.g., Montasio, Rachera, cheddar etc, medium fat (25-45% FDB) e.g., Parmesan, Grana, etc, low fat (10-25% FDB) e.g., Emmenthal, skim (< 10% FDB), any kind.

5.3 Classification on the basis of moisture content

Categorizing cheeses by moisture content is generally accepted classification given in FAO/WHO standard No A6. The moisture content controls the cheese hardness and on that basis cheeses are classified as follows:

- **Fresh cheese**

The fresh cheese is not aged, has a mild taste, whitish in color, highly perishable because of its high moisture content (80%) e.g., cottage cheese, ricotta cheese, feta cheese, etc.

- **Soft cheese**

Soft cheeses are ripened for a short time and have moisture content more than

65% e.g., Brie & Camembert cheese, Mozzarella cheese, Burrata cheese, etc.

- **Semi-hard**

Semi-hard cheeses contain 40-50% moisture content e.g., Muenster, Gouda, Edam

- **Hard cheeses**

Hard cheeses contain 30-40% moisture content, e.g., cheddar cheese, swiss cheese, etc.

- **Very hard cheeses**

Very hard cheeses are aged for the longest time, for one to several years and contains 30% moisture content, with strongest flavour and aroma e.g., Parmesan, Romano, etc.

5.4 Classification on the basis of curing characteristics

Cheeses can be classified on the basis of their curing/ripening characteristics, whether the cheeses are ripened using the microflora of bacterial or fungal origin and the classes are as follows;

- **Bacterial cured or ripened**
  - Surface ripened, e.g., Limburger, Brick cheese.
  - Interior ripened, e.g., Tilster, Munster
- **Mold cured or ripened**

There are three main categories of cheese in which the presence of mold is a significant feature:

- **Soft ripened cheeses.**

Soft-ripened cheeses are those which begin firm and rather chalky in texture but are aged from the exterior inwards by exposing them to mold. The mold may be a velvety bloom of *Penicillium candida* or *P. camemberti* that forms a flexible white crust and contributes to the smooth, runny, or gooey textures and more intense flavors of these aged cheeses, e.g., Brie and Camembert.

- **Washed rind cheeses**

Washed-rind cheeses are soft in character and ripen inwards like those with white molds; however, they are treated differently. Washed rind cheeses are periodically cured in a solution of saltwater brine and other mold- bearing agents which may include beer, wine, brandy and spices, making their surfaces amenable to a class of bacteria *Brevibacterium linens* (the reddish-orange "smear bacteria") which impart pungent odors and distinctive flavors, e.g., Limburger, Munster, Appenzeller, etc.

- **Blue cheese**

Blue cheese is created by inoculating a cheese with *Penicillium roquefortii* or *Penicillium glaucum*. This is done when the cheese is still in the form of loosely pressed curds, and may be further enhanced by piercing a ripening block of cheese with skewers in an atmosphere in which the mold is prevalent. The mould grows within the cheese as it ages. These cheeses have distinct blue veins which give them their name, and, often, assertive flavors, e.g., Roquefort, Gorgonzola, and Stilton.

- **Uncured or un-ripened**

Un-ripened cheeses are not aged using different bacterial cultures. It is used immediately used after processing e.g., mozzarella cheese, cottage cheese.

5.6 Classification on the basis of duration of ripening

Most of the cheeses are ripened under controlled temperature and humidity; however each of the type has its distinguished duration of ripening and on that basis cheese are classified as:

- **Fresh cheeses**

Fresh cheeses are not ripened at all and are consumed as such e.g., Mozzarella, Fiordilatte, etc.

- **Short ripened cheeses**

Short ripened cheeses are ripened for short span upto 30 days e.g., Lombardo, Taleggio, etc.

- **Medium ripened cheeses**

These cheeses are ripened to 6 months, e.g., Pecorina, Bitto, etc.

- **Long ripened cheeses**

These cheeses are ripened for long time, even upto hundred years, thus are expensive and cherished as a delicacy, e.g., Grano Padano, Fiore sado, etc.

5.7 Classification on the basis of denomination

- **Protected Denomination of Origin cheeses (P.D.O.)**

“Cheeses produced in well defined geographical areas, employing local, loyal and constant practices, which derive their distinctive characteristics principally from the particular conditions of the production environment” (Com. I, art. 2. L. 10.4.54 n. 125). At present, this type of denomination is regulated and protected at European

Community level (Council Regulation (EC) N. 510/2006).

Examples of this type of cheeses are: Asiago P.D.O., Bitto P.D.O., Bra P.D.O., Caciocavallo Silano P.D.O., Canestrato Pugliese P.D.O., Casciotta d'Urbino P.D.O., Castelmagno P.D.O.,Fiore Sardo P.D.O.,Fontina P.D.O., Formai de Mut dell'Alta Val Brembana P.D.O., Gorgonzola P.D.O., Grana Padano P.D.O., Montasio P.D.O., Monte Veronese P.D.O., Mozzarella di Bufala Campana P.D.O., Murazzano P.D.O., Parmigiano-Reggiano P.D.O., Pecorino Romano P.D.O., Pecorino Sardo P.D.O., Pecorino Siciliano P.D.O., Pecorino Toscano P.D.O., Provolone Valpadana P.D.O., Quartirolo Lombardo P.D.O., Ragusano P.D.O., Raschera P.D.O., Robiola di Roccaverano P.D.O., Spressa delle Giudicarie P.D.O., Taleggio P.D.O., Toma Piemontese P.D.O., Valle d'Aosta Fromadzo P.D.O., Valtellina Casera P.D.O.

- **Cheeses with Protected Geographical Indication (P.G.I.)**

"Cheeses produced on the national territory, employing loyal and constant practices, which derive their distinctive characteristics from peculiar characteristics of the raw materials and of the processing technology" (Com. I, art. 2. L. 10.4.54 n. 125). Also this type of denomination is regulated and protected at European Community level (Council Regulation (EC) N. 510/2006).

- **"Guaranteed Traditional Specialty" cheeses (G.T.S.)**

"Cheeses produced according to a detailed traditional processing technology, without any link existing with geographical area: these cheeses may therefore be produced on the whole national territory. Protected by Council Regulation (EC) N. 509/2006.e.g., Mozzarella GTS.

- **Traditional cheeses**

Over 450 ‘regional’ cheeses, e.g.: Piave, Squacquerone, Formaggio di Fossa, Puzzone di Moena, Burrata delle Murge, Cacio Marcetto, Bagòss, Piacentinu di Enna, Casieddu di Moliterno, Casolet Val Camonica, Dobbiaco, Paglierina Rifreddo, Tosèla del Primiero, Formaio Embriago, Morlacco del Grappa, etc.

5.8 Classification on the basis of processing technology

On the basis of processing technology and the temperature at which the curd is cooked, cheeses are classified as follows:

These are obtained without applying any heat-treatment to the curd after coagulation (e.g. *Robiola, Mozzarella, Crescenza, Gorgonzola, etc)*

- **Semi-cooked cheeses**

The curd is cooked at temperatures up to 48°C (e.g. *Asiago, Fontina*, *Italico,* etc)

- **Cooked cheeses**

The curd is cooked at temperatures over 48°C (e.g. *Grana Padano, Parmigiano-Reggiano, Montasio, Bitto,…)*

- **“Pasta filata” cheeses**

These are characterized by a treatment of the curd with water at 70-90°C *(*e.g. *Mozzarella, Fiordilatte, Caciocavallo, Provolone, Ragusano,* etc)

- **Moulded (or “blue”) cheeses**

These are obtained from milk intentionally inoculated with mold spores which, growing inside the cheese body, contribute to ripening through specific enzymatic activities (e.g. *Gorgonzola, Castelmagno,*etc).

6. Cheese production

Though there are numerous cheese varieties, the manufacturing processes of most of them share several common steps. Variations at one or more steps during manufacture produce cheeses of different textures and flavors.

Steps for cheesemaking

The essential steps in cheesemaking are given below and some variations for a few types of cheeses are schematically illustrated in Figure 2.

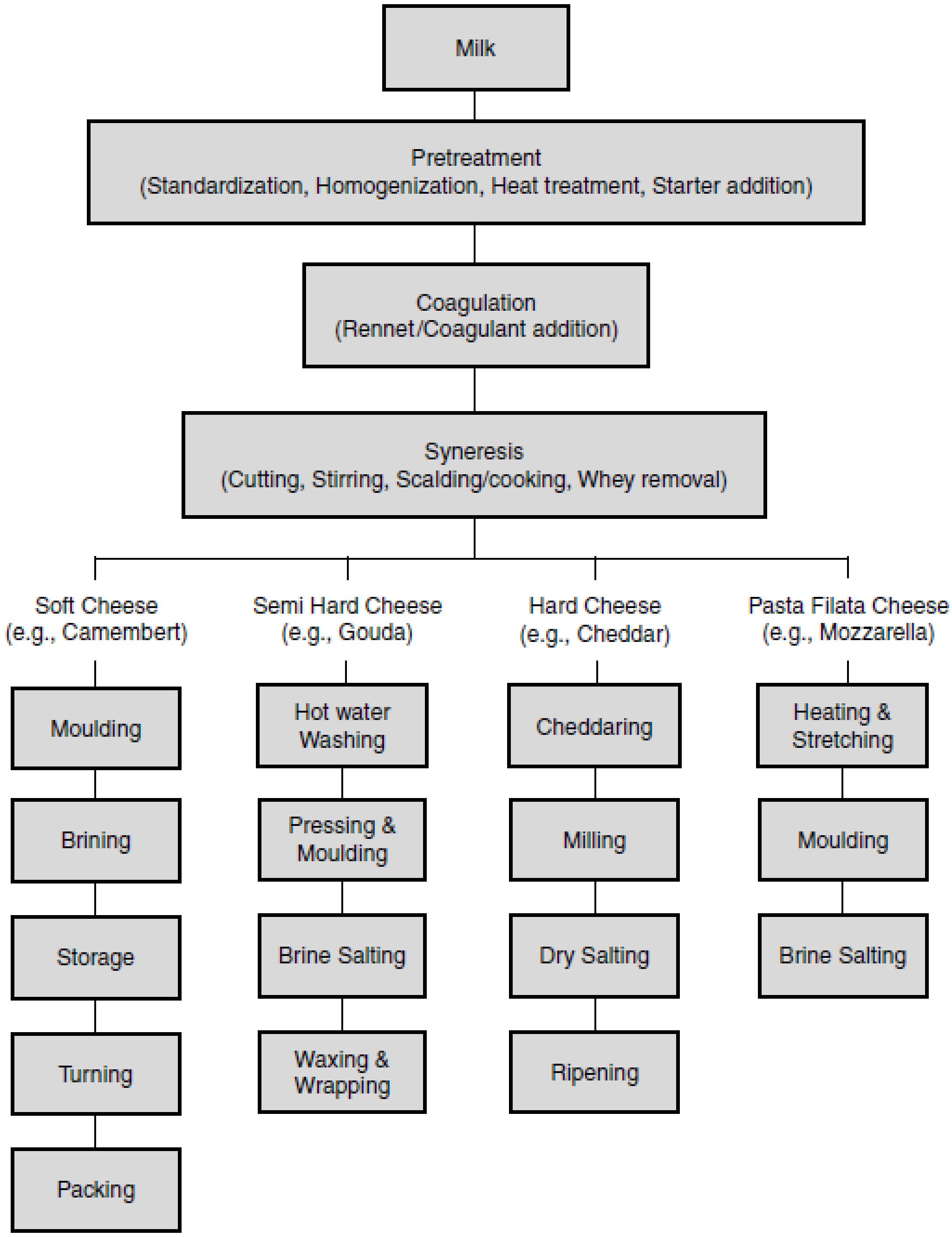

Figure 2. Major steps in cheesemaking (actual steps and/or conditions for a particular cheese may vary).

- **MILK PRETREATMENT**

Milk used for cheesemaking is normally standardized and heat treated. In some cases, milk is homogenized. An acid-producing starter culture is then added. The standardization of milk has become necessary to ensure that milk obtained from several producers or dairies is of a “standard” composition and condition throughout the year. This is critical in cheesemaking because the legal standards of various cheeses specify certain fat-to protein ratios. The fat-to-protein ratio is determined mainly by the fat-to-casein ratio in the milk which can be modified by removing fat or by adding cream or skim milk or skim milk powder, etc. It is also common to add colour (annatto or carotene) and calcium (in the form of $CaCl_2$) to the milk and to adjust milk pH to a desired level, known as pre-acidification. Adding calcium speeds up coagulation or reduces the amount of rennet needed and produces a firmer gel. Heat treatment of milk is primarily intended to destroy the harmful microbial population and enzymes in raw milk to assure product safety and quality. Pasteurization is the most commonly used heat treatment (72°C with 15 s holding time). It not only destroys most of the bacteria present, including lactic-acid bacteria, but also inactivates many enzymes. A gentle heat treatment, known as thermization (60 to 65°C with 15 to 30 s holding time) may also be used advantageously before or after pasteurization. However, many cheeses are still produced from raw milk, especially in Europe. If the cheeses are made from unpasteurized milk, they must be cured for at least 60 days at not less than 1.7°C (35°F), and the label should indicate the manufacturing date or state “held for more than 60 days”.

In traditional cheesemaking, the acid produced by microorganisms present in raw milk lowers the milk pH to a level sufficient for subsequent coagulation. However, if the milk undergoes a heat treatment, selected cultures of lactic-acid bacteria must be added. The type of bacteria added depends on the cheese type and cheesemaking protocol used. These bacteria break down the milk sugar, lactose. Lactic acid produced during this process lowers the pH. An alternative to adding starter culture is to acidify the milk directly by adding lactic acid or hydrochloric acid or gluconic acid-lactone, an acidogen. Though this direct acidification allows better control, starter culture remains active in the cheese during ripening, months after cheese manufacture, and contributes to cheese flavor. Therefore, direct acidification is used primarily when manufacturing cheese varieties for which texture is more important than flavor, e.g., cottage cheese, quark, Mozzarella, etc.

- **Coagulation**

Since pretreating milk is a fairly recent practice relative to the history of cheesemaking, many consider coagulation as the first and most important step in cheesemaking. Coagulation is the step during which milk undergoes a profound physical and rheological change i.e., gelation. Milk gel is formed by aggregation of milk protein, the caseins. This can be accomplished by:

- The action of a proteolytic enzyme
- Lowering the pH below the isoelectric point of protein (~ 4.6)
- Heating to about 90ºC at a pH of about 5.2 (i.e., higher than the isoelectric point)

Among these, enzymatic coagulation is the most popular. Acid coagulation via food-grade acidulants is used to manufacture quark, cottage, and cream cheeses. Heat coagulation is used for Ricotta and Queso Blanco cheeses.

Enzymatic coagulation is accomplished by enzymes from animal (e.g., calf rennet, porcine pepsin), plant (e.g., Cynara Cardunculus from Cardom, Circium and

Carlina Spp. from thistle), or microbial (e.g., *Endothia parasitica* ,*Rhizomucor miehei*) origin. Enzymatic coagulation consists of two phases. During the first or primary phase, the hydrophilic hairy structure, stabilized by steric hindrance, of k-casein is cleaved off at Phe105-Met106 bond. The secondary or clotting phase is initiated as 85 to 90% of the k-casein is cleaved and results in the aggregation of the altered protein micelles.

The k-casein loses its ability to stabilize the remainder of the caseinate complex. The result is soluble glycomacropeptides (residues 106–169), and hydrophobic, para-casein (residues 1–105). As the protein micelles continue to aggregate, a loose network forms, entrapping fat globules, water, and water-soluble materials. The para-casein left on the micelle is still connected to α and β-casein, but it is highly hydrophobic and basic, leading to destabilization of the micelle. Gel formation by association of the modified micelles in the secondary phase is highly dependent on the milk's temperature and calcium content. The coagulation rate is also highly dependent on the concentration and activity of the enzyme solution. Increases in both of these factors shorten coagulation time and increase firmness. Although it is not clear how the micelles aggregate, there are two hypotheses. One is that hydrophobic bonding occurs between the para- k-casein. The other is that calcium and calcium phosphate bonding occurs in α and β-caseins.

Other factors that affect aggregation are casein concentration and milk pH. The aggregation rate is proportional to the square of casein concentration. As discussed previously, the effect of renneting action strongly depends on milk pH. Each milk-clotting enzyme has an optimum pH at which it is most active. Extremes in acid or base also denature the enzymes but not as irreversibly as high temperatures. Lowering the pH leads to a decrease in coagulation time mainly due to increased enzyme activity, but rate of aggregation is also affected. The aggregation of casein micelles forms strands of casein particles of about three particles wide and 10 particles long, alternated by some thicker nodes of particles. After this, the aggregates grow more compact. The time when aggregates become visible is known as the flocculation time or rennet coagulation time (RCT). When the flocs grow to occupy the entire volume, the gel is said to have been formed. The gel network is very irregular, with many pores several micrometers in width. Aggregation of casein micelles into chains, then into strands and clusters, and eventually into an amorphous mass has been observed by microscopic evaluation in both acid- and enzyme-coagulated systems.

6.3 SYNERESIS

Due to its porous nature, the coagulum has the propensity to contract and expel entrapped liquid. This is known as syneresis, an important step in concentrating the milk. To a great extent, the success of the remaining cheesemaking steps depends on satisfactorily draining the whey. Also, most of the lactose, a substrate for postproduction microbial activity, is lost in the whey, which helps to prevent some adverse effects. In an undisturbed gel, however, syneresis occurs very slowly. Therefore, during cheesemaking, syneresis is accelerated by cutting the coagulum into small cubes, which increases the surface area and reduces the distance for the diffusion process to facilitate whey removal. Syneresis can also be enhanced by decreasing the pH or increasing the temperature of the coagulum.

Cutting the coagulum to facilitate faster whey removal must be timed precisely. If the coagulum is cut too soon, some milk solids leave the curd along with whey. Whey normally carries water-soluble components including lactose, whey proteins, salts, peptides, and other non-protein nitrogenous substances. If it is cut too late, more water gets trapped in the matrix, resulting in high-moisture cheese. Therefore, cheesemakers have been striving for many years to identify the correct curd-cutting time. Since the coagulum firmness continues to increase uneventfully over several hours, it is hard to determine an optimal curd-cutting time. Many instrumented and so-called objective curd-cutting-time predictions have been made. Some commercial units are available based on some of these techniques. However, there is still no universal procedure to identify optimal curd-cutting time. Most large factories apply a set time schedule, depending on the cheese type, to cut the curd after adding the rennet. In many smaller cheesemaking facilities, cutting time is still determined by the subjective judgment of the cheesemaker. Recently, a novel rheological technique has been observed for identifying the curd-cutting time.

Syneresis is the process that a cheesemaker can use to closely control the moisture content of the cheese and hence the microbial and enzymatic activity in the cheese, which affects ripening, stability, and quality of the cheese. Therefore, it is specific to a particular cheese type or cheese family. Factors as affecting syneresis: firmness of gel at cutting; surface area of the curd; any applied pressure; acidity; temperature; composition of the milk; and other variables.

Stirring exerts pressure, causing curd particles to collide, and facilitates their compression for a short time. Stirring also keeps the curd from settling in the vat. For Cheddar- and Swiss-type cheeses, the cut coagulum is not stirred immediately after cutting. The curd–whey mixture is cooked (at about 40ºC for Cheddar-type and 50ºC for Swiss-type) and vigorously agitated during cooking. For soft cheeses, the curd is ladled and hooped which allows whey to drain without stirring. Cooking the curd, also known as scalding, enhances syneresis by facilitating contraction of the protein matrix. Heating further enhances acid production by the starter organisms. Lowering pH, combined with increased temperature, not only helps to expel more whey but also affects the dissolution of calcium phosphate, and thus has major implications for characteristics of the cheese. The scalding step can be used to distinguish four major groups of cheese — excluding soft cheeses, some of which may be scalded.

- Textured cheeses such as Cheddar or Cheshire
- Pasta filata types or kneaded cheeses
- Cheeses untextured in the vat (e.g., Edam and Gouda) and those

which acquire texture later (e.g., Tilsiter and Emmental)

- Blue-veined cheeses

To manufacture some cheeses (e.g., Edam, Gouda, or Havarti), the curd is washed by adding water to the curd–whey mixture. This accomplishes two things:

- It adjusts the pH of the cheese independently of its moisture content by removing lactose and other solubles from the curd.
- It enhances whey removal by adding hot water to raise the curd temperature, as is the case during direct heating.

It should be noted that using hot water to stretch pasta filata cheeses (e.g., Mozzarella, Provolone, etc.) is not considered as washing.

6.4 SHAPING AND SALTING

When the curd is at the desired moisture content and pH, it is separated from the whey. The curd particles are subsequently shaped into some form and salted (primarily by NaCl), not necessarily in that order. These steps, though common for most cheeses, are performed very differently, depending on the cheese type. The manner in which cheese curd and whey are separated can affect texture as well as color and flavor. When manufacturing hard cheeses such as Cheddar, the curd–whey slurry is pumped into a vat with a perforated bottom for whey removal. The curd is "cheddared" for about 90 min. Cheddaring is the process in which curd particles are allowed to fuse or "mat" together. The mats are then cut into slabs and stacked on top of each other. Physical properties and pH of the curd at this stage affect curd fusion and appearance of the finished cheese. When the desired pH has been reached, the slabs are milled into small pieces. At this stage, the curd may be sprayed with warm water and stirred for further whey removal. Salt is sprinkled on at a level of about 2 to 3% which expels additional whey. The salted curd is then hooped in molds and pressed overnight. Manufacturing steps for Mozzarella and other pasta filata cheeses differ markedly after the milling stage described above. The milled curd is "kneaded," i.e., heated and stretched in warm water (about 60 to 70°C) using an open-channel, single-screw or twin-screw extruder/auger. This transforms the curd into a cohesive, viscoelastic mass. Due to the conveying action of the auger, the curd mass gets stretched into a continuous stream of molten material. This stretching step is unique to Mozzarella manufacturing. It imparts the characteristic oriented microstructure and related textural attributes of these cheeses. The molten cheese is then placed into molds and cooled. When the cheese is cool enough to keep its shape, the mold is removed and the cheese is salted by dropping it in a nearly saturated brine solution (about 25% salt) at 1 to 4°C. The cold brine temperature cools the cheese further. In fact, much of the total cooling of Mozzarella occurs during brining. Brine salting is a slow process, taking several days for uniform salt distribution within a cheese block. The salt and moisture gradients in a cheese during salting are opposite to each other. Though brine salting is the traditional method, salting of Mozzarella can also be done by adding salt directly to the curd just before stretching, during stretching, or between stretching and moulding. This direct salting reduces the subsequent brining time. Another major variation is surface salting. Salt is rubbed directly on the cheese surface (e.g., Romano and Gorgonzola). This is repeated for several days so the salt diffuses throughout. In many other cheeses, surface salting and brining are used in combination (e.g., Gruyere and Emmental). Regardless of the method used, salting is a vital step in cheesemaking because unsalted cheese is virtually tasteless. Salt also plays a major role in the texture, flavor, and microbial quality of cheese. Salt inhibits the growth of certain bacteria, which are harmful to the cheese and cause spoilage, especially on the surface. It further assists in dissolving the casein and in rind formation, as well as in slowing down enzyme activity. Salt concentration in cheese varies greatly from less than 1% in Emmental to 7 to 8% in Domiati cheese. The salt content may also vary considerably within a cheese block due to the slow diffusion of salt. Thus, there is more water and less salt at the center of a cheese block compared to at the surface. This unevenness in the salt (and water) distribution also leads to variation in the rheological properties of the cheese within the block. As already noted, the hard and semi-hard cheeses are shaped by applying external pressure. Pressing expels whey and facilitates faster curd fusion into an integral mass of a desired shape with a rind. Though simple enough, pressing is perhaps the least understood step in cheesemaking. The time, pressure, and efficiency of pressing are related to the condition of the curd at pressing time and the decrease in pH during pressing. Sometimes pressing is done in conjunction with vacuum to force out any entrapped air. The complex nature of the interrelationships among many of the cheesemaking parameters makes controlling cheese properties very hard.

6.5 RIPENING

Ripening is the natural process of microbial and biochemical reactions that occurs in a cheese after its manufacture and during storage. Ripening gives different cheeses their unique flavors, textures, and appearances. Except for some soft cheeses (e.g., cottage cheese, cream cheese, quarg, etc.), almost all cheeses are held under controlled conditions to develop distinct attributes. Ripening, essentially results from the action of microorganisms present within the curd mass and on its surface. Ripening is also influenced by residual enzymes present in the cheese curd. Cheeses are ripened over a range of time from several days (e.g., Mozzarella) to more than a year (e.g., Cheddar).

Following are the ripening agents in cheese:

- Coagulant — chymosin or other suitable proteinase
- Milk — some indigenous enzymes contained in milk, e.g., plasmin
- Starter culture — host of enzymes released upon cell death and lysis
- Secondary microflora — microflora that perform some specific secondary function (e.g., propionic acid, bacteria, and yeasts and molds)
- Exogenous enzymes — proteinases, peptidases, and lipases added by cheese-makers to accelerate ripening

Factors influencing cheese ripening

The primary factors in this process are storage temperature and humidity, however, humidity plays less important role in hermetically packed cheeses (e.g., with a wax coating). Fat content, level of amino acids, fatty acids, and other by-products of enzymatic action and also the residual microflora of the curd also play an important role in cheese ripening. Based on these factors, the different methods that are observed to influence the process of cheese ripening are summerised in Table 2.

Table 2. Methods of Influencing Cheese Ripening and Their Advantages and Disadvantages

Method of Influence	Advantages	Disadvantages
Increased storage temperature	Easy to perform No aspects determined by law	No specific effect Risk of destroying bacteria
Increased inoculation level in starter culture	Natural enzyme balance No aspects determined by law	Influences pH and consistency
	Addition of Enzymes	
Proteases/peptidases Lipases, animal, and microbial	Relative low cost Specific effect	Few usable enzymes Risk of over-ripening Aspects determined by law Use of whey
	Special Cultures	
Lactobacillus/pediococci Brevibacterium lines Mold Propionic-acid bacteria	Naturally balanced No aspects determined by law	Opposite effect on pH and consistency Different taste profile
	Modified Starter Cultures	
Cold/warm treated Lysozyme treated Nonacidic producing	Natural enzyme balance Easy to conform to	Technologically complex

Temperature and humidity are factors that cheesemakers can control during ripening. In general, higher temperatures increase the microbial growth rate and other biochemical reactions occurring in the curd. Thus, cheeses matured at different temperatures can have different flavor profiles. Accordingly, proper control of storage temperature is essential. Variety-specific storage temperature control protocols have been developed to optimize cheese quality. For example, Swiss-type Emmental is held at a low temperature initially (10 to 15°C) to facilitate the growth of lactic-acid bacteria. Later, the temperature is increased (20 to 24°C) so that propionic bacteria can grow. These are essential for the characteristic Emmental flavor and "eyes." For blue-veined cheeses (e.g., Gorgonzola, Roquefort, Stilton), warm-temperature storage is followed by low-temperature storage. Prevailing relative humidity during storage (80 to 85%) helps to control the moisture content of cheeses not covered with moisture barriers such as a wax coating. The moisture equilibrium in the cheese changes due to reactions occurring that require or release water. Increase in moisture content during storage affects the solute concentration and microbial growth rate. In general, higher moisture content promotes more vigorous growth of microorganisms than lower moisture content does. In addition to temperature and moisture, other factors, such as curd pH, inhibitory substances (e.g., antibodies and salts), and oxidation–reduction potential affect the microbial population in the cheese. The enzymes relevant for maturation in most hard cheeses are active in the pH range of 4.9 to 5.5, and in soft cheeses from pH 5.3 to 6.0. Protein, fat, and lactose are hydrolyzed (i.e., proteolysis, lypolysis, and glycolysis, respectively) to varying extents during cheese ripening. Among these, proteolysis of casein is the most important. Proteolysis of α- and β-casein occurs due to any residual rennet from what was added for coagulation, natural proteases, and proteases and polypeptidases from starter or adventitious bacteria. This is essential for cheese flavor development. Fat contains lipophilic flavor compounds, which develop or are released by microbial or enzymatic action through oxidation, decarboxylation, and eventually reduction of decarboxyl compounds. Glycolysis is also initiated by adding a starter culture and reaches its peak in the milk during the preripening stage. Here lactic acid, acetic acid, and CO_2 are produced. In some cheeses, citrate is also metabolized into citric acid. Proteolysis is also mainly responsible for changes in the body and texture of cheeses. The breakdown of proteins first involves the conversion of casein fractions into large peptides. These peptides are later broken down to lower molecular weight products. The primary proteolysis in ripening has been defined as the changes in caseins, which can be detected by polyacrylamide gel electrophoresis. The products of secondary proteolysis include the peptides and amino acids that are soluble in the aqueous phase of the cheese. In mature Cheddar, approximately one-third of the protein has been broken down to forms that are soluble at pH 4.6.

7. Processed cheese

Processed cheese is manufactured from one or more of the natural cheeses described thus far. The basic premise is to stabilize the proteins that are normally affected already during one or more of the cheesemaking steps. This is accomplished by heating and mixing cheeses with some emulsifying salts. The careful selection of cheeses, emulsifying salts, and processing factors allows making process cheeses of varied textures suitable for many end uses.

The primary reasons for manufacturing processed cheese are:

- Long shelf life due to heat treatment and hot filling
- Wide variety due to a multitude of ingredients and composition
- Efficient utilization due to spreadable consistency and small portions
- Upgrading of defective rennet cheese products if the defects limit the shelf life

but the products are still edible

The basic steps in the manufacture of processed cheese are selecting and blending raw materials, heat processing, forming and packaging. The raw materials include the natural cheeses, emulsifying salts, and other ingredients. Using the appropriate cheeses in the blend is very critical to obtain the desired texture and flavor. The emulsifying salts, primarily phosphates and citrates, are selected for their ability to disperse and increase hydration of the cheese proteins, which creates smoothness and fat emulsification. Other ingredients vary, from dairy and non-dairy products such as skim milk powder, whey protein concentrate, spices and vegetables, and muscle food ingredients, etc. In general, good quality raw materials ensure good quality process cheese.

Processed cheeses can be grouped into three major categories based on composition and consistency: processed cheese block, processed cheese food, and processed cheese spread. The selection of type of heat processing and raw materials for each is done accordingly. A fourth group, process cheese analogue based on vegetable fat-casein blend, is also manufactured. The manufacturing conditions for sliceable and spreadable processed cheese are summarized in Table 3.

The heat-processing step converts the raw material into a homogeneous product. Heating is performed under atmospheric pressure or vacuum at 85 to 95°C or under pressure at 105 to 120°C. Temperatures under 90°C are desirable to avoid a browning reaction when the raw materials are high in lactose. During heating, the mix is continuously stirred at 60 to 140 rpm. The process duration varies from 4 to 8 min for processed cheese blocks to 8 to 15 min for processed cheese spread. After heat processing, the melt is conveyed to filling machines where it is moulded into different shapes or put into containers. It can also be spread on conveyor belts and sliced. The cheese is then cooled. Cooling is performed fairly slowly (10–12 h) for process cheese blocks and very quickly (15–30 min) for process cheese spread to facilitate softening of the product.

Table 3. Manufacturing Conditions for Sliceable and Spreadable Processed Cheese.

Condition	Process Cheese Type	
	Sliceable	Spreadable
Average age of the raw material	Fresh to half-mature; mostly fresh	Combination of fresh, half-mature, and over-ripe
Relative casein content structure	75–90%, mostly long	60–75%, short to long
Melting salt	Structure: not creamy Emulsifier: high molecular Polyphosphate, etc.	Structure: creamy Emulsifier: lower or medium molecular Polyphosphate, etc.
Water, how added	10–25%, all at once	20–45%, in portions
Temperature	80–85ºC (176–185ºF)	85–98ºC/150ºC (185–208ºF/302ºF)
Time for melting, stirring	4–8 min, slow	8–15 min, fast
pH	5.4–5.6	5.7–5.9
Process cheese	0–2%	5–20%
Whole milk powder or whey powder	0	5–10%
Homogenization	None	Desirable
Packaging (filling)	5–15 min	
Cooling	Slow (10–20 h) at room temperature	Fast (15–30 min) in freezing conditions (cool air)
Treatment	Very careful	Intensive (powerful)

8. MICROBIAL SPOILAGE OF CHEESE AND ITS PREVENTION

Microbiological spoilage of cheese is one of the important reasons that render the nutritious and tasty cheese not only inedible but also a potential source of infection. The spoilage may be due to bacteria or fungi. The defect due to contamination may arise from the surface of the cheese showing visual and organoleptic changes or it may be hidden internally.

Fungal Spoilage

Although, mould varieties are essential for ripening of certain cheese varieties like *Roqueforte* cheese, growth of other moulds is strictly undesirable. Mould spoilage makes the cheese unpleasant in appearance, conferring it with a musty taint/odour and liquefaction of the cheese. In some cases, moulds produce mycotoxins. Moulds responsible for spoilage of cheese include *Penicillium, Aspergillus, Cladosporium, Mucor, Fusarium, Monilia* and *Alternaria*. Most of these moulds contaminate cheese during ripening and hence suitable measures have to be taken to control them by following rigorous cleaning procedures, supplying sterilized air through filtration or ultra violet treatment.

Modified atmosphere packaging may be adopted in pre-packed cheese varieties but there are incidences of growth of moulds in the residual air pockets due to improper packaging or puncture. In countries where there is legal sanction, natamycin or sorbic acid may be incorporated into the packaging to prevent cheese spoilage.

Spoilage due to yeasts

Yeasts too cause spoilage of cheeses, especially, that of fresh or soft varieties like cottage cheese, during storage. The defects produced are gassiness, off-flavours and odours. Yeasts are also capable of proliferating on the surface of ripened cheeses, more so, if the surface becomes wet, causing slime formation. Yeasts most frequently encountered in spoiled cheese include *Candida, Pichia, Yarrowia lipolytica, Geotrichum candidum, Kluyveromyces marxianus and Debaryomyces hansenii.*

Bacterial spoilage

Bacterial spoilage may occur in fresh cheeses having a sufficiently high pH such as cottage cheese. The causative organisms are Gram negative, psychrotrophic species viz. pseudomonads and certain coliforms. These organisms gain entry and infect the product through contaminated water used to wash the curd. Psychrotrophic bacteria like *Pseudomonas*, *Alcaligenes*, *Achromobacter* and *Flavobacterium* species are of primary concern in cheese spoilage due to bacteria. Pseudomonas fluorescens, Pseudomonas fragi and Pseudomonas putida cause bitterness, putrefaction and rancid odour, liquefaction, gelatinization of curd, and slime and mucous formation on cheese surfaces. Alcaligenes viscolactis produces ropiness and sliminess in cottage cheese, and Alcaligenes metacaligenes flat, or poor flavour in cottage cheese. Psychrotropic Bacillus species cause bitterness and proteolytic defects.

Bacteria may also cause spoilage by producing gas internally in the cheese, resulting in formation of slits, small holes or blown packs. Gas production in fresh cheese in early ripening stage is called as "early blowing" and well into the ripening stage is known as "late blowing". Early blowing is usually caused by members of the Enterobacteriaceae like E.coli and Enterobacter aerogenes, but other organisms, such as Bacillus species are sometimes involved. The problem of early blowing can be effectively controlled by adequate hygiene and process control measures during cheese manufacturing. Late blowing, which usually happens after 10 days in cheese varieties such as Gouda, or after several months in some Swiss cheeses, is caused by clostridia that are capable of producing butyric acid from lactate. Late blowing sometimes also occurs in cheddar cheese. Species frequently implicated in the spoilage are Clostridium butyricum, Clostridium tyrobutyricum and Clostridium sporogenes. Spores of these bacteria are capable of surviving pasteurization temperatures and can be present in cheese milk.

Contamination of milk with these organisms is often seasonal; Clostridium tyrobutyricum is more prevalent in winter and is related to the supplementation of silage as a feed for dairy cows. A very low level of contamination may be sufficient to cause late blowing defect in cheese. In countries where laws permit, nisin, a natural antimicrobial compound produced by strains of Lactococcus lactis subspecies lactis, has been successfully used to control late blowing, by inhibiting the growth of clostridia. Small, irregular slits may also sometimes appear in three to six weeks old Cheddar, and is referred to as “intermediate blowing” which is usually associated with the presence of non-starter gas-producing organisms such as Lactobacilli.

Yeast and enterococci have been frequently isolated from brine-salted cheeses exhibiting white spots on the surface. Surface mould growth by species such as Aspergillus niger may cause discoloration of hard cheeses. Pigmented strains of certain lactobacilli have been linked with ‘rusty spots’ in some cheeses, and the non-starter Propioni bacterium species may sometimes cause brown or red spots in Swiss cheese. Pseudomonas fluorescens forms water-soluble pigments while other pseudomonads cause darkening and yellowing of curd. Yellow discolouration of cheese surface may be attributed to production of flavin pigment by Flavobacterium species and Bacillus species have been associated with dark pigment formation on the cheese surafce

Paneer

Paneer is popular traditional heat and acid coagulated fresh cheese. It is mainly used as a base material for the preparation of large number of culinary South-Asian cuisines. Paneer is highly nutritious and whole some food as it contains milk fat, protein, minerals, vitamins and other minor nutrients of milk.

According to PFA (1983), paneer has been defined as a product obtained from cow or buffalo milk or combinations thereof by precipitation with sour milk, lactic acid or citric acid. It shall not contain more than 70 per cent moisture and milk fat content shall not be less than 50 per cent of the dry matter. The milk fat content of skim milk paneer shall not exceed 13 per cent of dry matter. Typically paneer is a marble to light creamy white in appearance. It must have firm and cohesive body with slight sponginess. The texture should be more compact (close knit), smooth and velvety. The flavour should be pleasingly mild acidic, slightly sweet and nutty. As per the Bureau of Indian standards (IS:1983), the total plate count should not exceed 5x105, coliform count not more than 90 and yeast and mould count not more than 250 cfu/g.

The chemical and physical changes in casein and whey proteins brought about by the combined action of heat and acid treatments, form the basis of paneer making. When milk is acidified, the colloidal calcium phosphate in the casein micelles progressively solubilises and aggregation of the casein occurs as the isoelectric point is approached. In milk of normal pH, the casein micelles are stabilized by hydration and steric repulsion due to their negative charge. On acidification the micelles become unstable and aggregate as a result of charge neutralization, leading to the formation of chains and clusters that are linked together to give a three-dimensional network. In milks preheated at high temperatures (90oC), gelation occurs more rapidly at a higher pH than in unheated milk. Interaction of whey proteins with casein micelles on heating milk at its natural pH may increase the hydrophobicity of the micellar surface and reduce the hydration barrier against aggregation, thus allowing aggregation and gelation to occur at a higher pH than in unheated milk. Heating milk also results in dissociation of k-casein from micelles, and this could further sensitize the α-s-casein frame work to calcium-induced aggregation. The development of typical rheological characteristics of paneer could be due to the intensive heat induced protein-protein interactions. Paneer manufacture essentially involves the formation co-precipitates due to complexion of whey proteins denatured by the heat and the casein. Serum proteins, particularly α -Lactoglobulin, are bonded to α-casein via disulphide bridges and calcium linkages. The higher the degree of co-precipitation, the greater will be the total solids recovery and yield of paneer.