

Cheese Technology



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CHEESE TECHNOLOGY Course Outline

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*Module 1. History, status and scope of cheese industry***Lesson 1****HISTORICAL DEVELOPMENTS IN CHEESE MANUFACTURE AND WORLD MARKET FOR CHEESE****1.1 History and Developments in Cheese Manufacturing**

Cheese is one of the oldest foods of mankind. It is commonly believed that cheese evolved in the Fertile Crescent between the rivers Tigris and Euphrates in Iraq some 8000 years ago. The so-called Agricultural Revolution occurred here with the domestication of plants and animals.

It seems that cheese originated accidentally as a result of the activities of nomadic tribes. Since animal skin bags were a convenient way of storing liquids for nomadic people, these were used for storing surplus milk. Fermentation of the milk sugars in the warm climate prevailing would cause the milk to curdle in the bags. The swaying animals would have broken up the acid curd during journeys to produce curds and whey. The whey provided a refreshing drink on hot journeys, while the curds, preserved by the acid of fermentation and a handful of salt, became a source of high protein food supplementing the meagre meat supply.

This activity gave rise to the assumption that cheese was evolved from fermented milks. It is perhaps more probable that the crude fermentations progressed in two ways: (1) production of liquid fermented milk such as dahi, yoghurt, laban, kumiss and kefir and (2) drainage of whey through a cloth or perforated bowls, to leave solid curds which when salted, became cheese.

Cheese was a prominent item of the Greek and Roman diet as much as 2500 years ago. It is referred to in the Old Testament several times. Cheese making has been an Art handed down from generation to generation, and evolved as a gourmet food over the years.

Until the 18th century, cheese making was essentially a farmhouse industry, but towards the end of the century scientific findings began to provide guidelines, which were to have an impact on the process of making and ripening cheese. Thus, cheese making became an "Art with Science". The process has undergone many developments during the course of its history.

Now-a-days, instead of using the enzyme rennin, a synthetic chymotrypsin derivative is sometimes used, along with extracts from molds and plants. The plethora of flavors is due to the manipulation of a variety of factors including the kind of milk used (cow, sheep, goat, buffalo, reindeer, camel, yak, etc.), curdling, cutting, cooking, and forming methods, the type of bacteria or mold used in ripening, the amount of salt/other seasonings added, the ripening and curing conditions (temperature, humidity, time, etc.) and many more.

Now the mechanization and automation has been taken to such a high level that several tons of cheese can be produced without the touch of a hand. Many machines have been developed for mass and continuous production of cheese like continuous cheddaring machine, advanced cutting and cooking vats, pressing machines, stretcher or cooker for some varieties of cheese, etc. All these will be discussed in lesson 16.

Another development in cheese making is the accelerated ripening of cheese. Traditionally cheese is kept for ripening for months or even years to develop typical flavour and texture. A great deal of research had been carried out to accelerate the cheese ripening to achieve the desired flavor and texture in very less time.

With over 2000 types, cheese is one of the most versatile foods in the world. Currently, about one third of the milk produced in the U.S. each year is used in the manufacturing of cheese. Cheese contains a concentrated amount of almost all of the valuable nutrients found in milk. In 2010, the top three world cheese producers were: (1) United States of America with 5.10 million tons (2) Germany with 2.08 million tons, and (3) France with 1.90 million tons.

Cheese is a protein rich product but at the same time, it also contains a considerable amount of fat. So, the calorie conscious populace of the world reduced the consumption of cheese. Keeping this in mind, a variety of low fat cheeses have been developed throughout the world to increase its consumption and to make it healthier. Now-a-days, work is being carried out to produce low salt cheese as increased salt consumption is leading to increased heart diseases in many countries particularly United States.

1.2 World Market for Cheese

Cheese continues to be a popular addition to every day diet, thanks to the high amount of protein, calcium, minerals and vitamins it contains. The consumption of cheese, over the years, has improved significantly across the world and subsequently the art of cheese making has now evolved into a lucrative business.

According to a report (**Global Industry Analysts, 2010**), though the economic recession has put a check on the cheese consumption pattern across the world, more importantly in the developing nations, the future outlook for global cheese market still remains bright with consumption of cheese projected to grow by more than 20% during 2008-2015. Purchasing decisions, being increasingly guided by price, cheaper yet healthy and wholesome foods are surfacing back into the spotlight. Consumers are additionally exhibiting shifting preferences from imported cheese brands to locally produced cheese. Post recession, the demand for organic cheese is slated to make a comeback, with manufacturers expected to expand their product offerings. Innovation and product diversification will be the most prominent market strategies for manufacturers and suppliers in the post recession period. The product mix is poised to change from traditional types of cheeses to new cheeses that suit the demand in developing dairy markets like China and India. The growing demand for dairy products that meet consumers changing diet and nutritional needs will result into strong growth for innovative and healthier cheese products, such as, lactose-free goat cheese products, and half-fat and reduced fat cheeses.

Europe and the United States lead the global cheese market, by consumption. However, with consumption levels for cheese in such developed markets nearing saturation, the focus of the global cheese industry now shifts towards emerging markets such as Asia-Pacific and Latin America. Cheese consumption in developed economies will be fraught by challenges, such as a matured market profile, limited growth in population, and most importantly the fast aging population, which account for lesser per capita consumption than younger generation. Therefore, any further development in cheese consumption within these markets is likely to be marginal and only associated with changes in form and type of dairy products consumed. Meanwhile, developing markets such as Asia, Latin America and the combined market of Middle East & Africa, are projected to display superior growth rates over the analysis period (2006-2015). Large

population, and rising incomes in these nations will prove to be the major driving factors for exceptional growth in dairy consumption.

Key players operating in this market include Arla Foods, Amba., Belaya Reka Holding, Bongrain, SA., Belgioioso Cheese, Inc., Crystal Farms Cabot Creamery Cooperative, Inc., Dairy Farmers of America, Inc., Derivados De Leche La Esmeralda, Dairy Crest Group, Plc., Fonterra Group Cooperative Limited, Fromageries Bel, SA., Groupe Danone, S.A., Great Lakes Cheese Company, Inc., Grupo Industrial Lala, S.A. de C.V., Kraft Foods, Inc., Land O' Lakes, Inc., Leprino Foods Company, Inc., Lactalis McLelland, Ltd., Meiji Dairies, Corp., North Downs Dairy Co, Ltd., Parmalat, S.p.A., Snow Brand Milk Products Co, LTD., Sancor Cooperativas Unidas Limitada, Saputo, Inc., Specialty Cheese Co, Inc., Tillamook County Creamery Association, Valio Ltd, Wyke Farms, Ltd., Wisconsin Cheese Group Inc.

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Lesson 2

CHEESE PRODUCTION AND CONSUMPTION IN INDIA AND ABROAD

2.1 Introduction

There has been steady increase in the consumption of cheese in most countries worldwide, the annual growth rate in cheese consumption being over 3% with an acceleration expected due to worldwide trend of adopting Western consumption habits with a high level of cheese in the diet. About 40% of total world milk production is converted into cheese. As can be seen from Table 2.1, conversion of milk to cheese has exhibited an increasing trend unlike in case of other products. The major cheese production has centered in Western countries. In 2008, 17.2 million tonnes of cheese was produced in the world, of which the European Union and United States accounted for more than 50%. Significantly, New Zealand exported 110,000 tonnes (over 75% of the production) and is the world's number two exporter. Both Australia and Switzerland ranking third and fourth, respectively, exported almost 45% of their total production. All these three countries along with EU accounted for 80% of the total world exports of almost one million tonnes in 1993.

Table 2.1 World milk utilization pattern (%)

Products	1955	1974	1984	1990
Butter	34	36	30	29
Cheese	13	28	40	42
Preserved milk	4	5	5	5
Liquid milk and others	49	31	25	24

The scenario of cheese production in India is quite bright because of recent economic reforms based on globalization and liberalization in the marketing arena that have prompted the Indian dairy industry to penetrate the large international cheese market. The growth pattern of cheese production in India has been quite encouraging, being 800 tonnes in 1977 and 1000 tonnes in 1980. It increased to about 3000 tonnes per annum in 1987. In 1994, the production was estimated at 8000 tonnes, against the installed capacity of 9000 tonnes.

The growth pattern of cheese production is shown in Table 2.2.

Table 2.2 Cheese production in top cheese producing countries (MMT)

Countries	2005	2006	2007	2008	2009	2010
United States of America	4.51	4.67	4.75	4.85	4.92	5.09
Germany	1.90	1.97	1.99	1.99	2.03	2.08
France	1.80	1.83	1.87	1.86	1.83	1.90
Italy	1.14	1.12	1.14	1.15	1.18	1.17
Egypt	0.63	0.73	0.94	1.04	0.94	0.94
Netherlands	0.67	0.71	0.73	0.72	0.71	0.74
Poland	0.61	0.58	0.59	0.59	0.63	0.66
Argentina	0.36	0.35	0.46	0.49	0.51	0.58
Australia	0.39	0.37	0.36	0.36	0.34	0.35
Brazil	0.04	0.04	0.04	0.04	0.04	0.04

2.2 Mode of Utilization

Cheeses are highly diversified. Names of cheeses number about 2000, although many have little differences. The manufacturing procedure and curing through centuries have resulted in the production of the cheese which ranges in flavour from extremely mild to very sharp and in texture from semi-solid to almost stone hard. Thus cheeses differ in varying degrees in nutritive value, appearance, flavour, texture and cooking properties. Consequently cheese is capable of satisfying a diverse range of sensory and nutritional demands. The use of cheese is extended by secondary processing methods to create an array of cheese-based products. The major usage levels (per cent of total cheese consumed) is: Natural, 39%; Dry, 28%; Processed, 13%; and Low-fat, 20%. The use of cheese as food ingredient accentuated the need for specific and consistent properties, which must be attained with correct flavour synergistic with the food. The comparative usage level of cheese in different food products is shown in Table 2.4. Cheese maker can provide a range of different flavours, texture and compositional properties to suit a variety of needs. It requires knowledge about its functionalities which can be effectively exploited for the benefits of consumers.

Table 2.3 Utilization of cheese in different food products

Food Product	Usage (as % of total usage)
Pizza	26
Snack Foods	17
Soups/Sauces/Dressings	15
Frozen Entrees	14
Baked Goods	11
Appetizers	7
Pet Foods	6
Rice/Noodle mixes	3
Shelf Stable Entrees	1

(Source: Singh, 2011)

The natural cheese can be eaten as such or on bread, biscuits, etc as slices. At the turn of this century, developments in melting processes, involving natural cheese at various ages, have given birth to a line of process cheese products with controlled flavour, texture and extended shelf life. In addition, various shapes, sizes, configurations and sliced versions are created to provide varieties with novel applications. The consumer can use these products as ingredients in cooking of several dishes or as ready-to-eat snacks. These products are designed to be consumed as a spread or as slices in sandwiches and function as dip or toppings on snacks. Cheese crackers are quite popular in Western countries. Natural cheese can be dried to prolong its shelf life. Dried products can be used in bakery products, soups, sauces, snacks, pasta products, ready meals, biscuits, fillings, cheese substitutes/imitations, etc.

Cheese consumption opportunities exist around all meals – breakfast, lunch, dinner and in between meal snacks. We can, therefore, assume consumption of about 20-25 grams cheese per head twice a week in one form or another. Assuming the Indian population at 100 crores, this leads to an estimated potential annual demand of about 50000 tonnes. This is the domestic

potential in cheese demand. In this projection, the production and consumption of *paneer*, *chhana* and *shrikhand* is not included, though technically they are also classified as cheese.

Process cheese spread and slices have proven to be ideal bread-mates. There is a very high growth rate in consumption of bread. Butter, the traditional spread for bread is now avoided by people due to its high fat content which is implicated with obesity and cardiovascular diseases. The other conventional spreads like jam and jelly are avoided owing to their high calorific value. The introduction of pizza in India has added new fillip for enhanced consumption of Mozzarella cheese.

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Module 2. Definition, standards, classification, nutritive value and basic principles of cheese making

Lesson 3
DEFINITION AND STANDARDS OF CHEESE

3.1 Introduction

The word 'cheese' is derived from the Old English 'cese' which in turn was derived from the Latin 'caseus' which means correct or perfect thing. Cheese may be defined 'as the curd of milk separated from the whey and pressed into a solid mass'. This definition of cheese is satisfactory but too limited and vague from a technical standpoint. Therefore, a relatively complete definition is as follows:

Cheese is the curd or substance formed by the coagulation of milk of certain mammals by rennet or similar enzymes in the presence of lactic acid produced by added or adventitious microorganisms, from which part of the moisture has been removed by cutting, warming and pressing, which has been shaped in mould and then ripened (also unripened) by holding for sometime at suitable temperatures and humidity.

The expansion of the numbers of types of cheese makes a simple definition of cheese difficult. Thus the definition, the curd produced from milk by enzyme activity and subsequent separation of whey from the coagulum does not cover whey cheese, lactic cheese, cream cheese and some of the cheeses produced by newer techniques, viz. ultrafiltration and reverse osmosis. The definition is, therefore, not universally acceptable.

3.2 Definition of Cheese

Cheese is the fresh or matured solid or semi-solid product obtained:

- a) By coagulating milk, skim milk or partly skimmed milk, whey, cream or butter milk or any combination of these materials, through the action of rennet or other suitable coagulating agents and by partially draining the whey resulting from such coagulation, or
- b) By processing techniques involving coagulation of milk and/or materials obtained from milk (provided that the whey protein casein ratio does not exceed that of milk) and which give an end product which has similar physical, chemical or organoleptic characteristics as the product defined under (a).

According to the FSSR (2011), cheese means the ripened or unripened soft or semihard, hard and extra hard product, which may be coated with food grade waxes or polyfilm, and in which the whey protein/casein ratio does not exceed that of milk. Cheese is obtained by coagulating wholly or partly milk and/or products obtained from milk through the action of non-animal rennet or other suitable coagulating agents and by partially draining the whey resulting from such coagulation and/or processing techniques involving coagulation of milk and/or products obtained from milk which give a final product with similar physical, chemical and organoleptic

characteristics. The product may contain starter cultures of harmless lactic acid and/or flavor producing bacteria and cultures of other harmless microorganisms, safe and suitable enzymes and sodium chloride. It may be in the form of blocks, slices, cut, shredded or grated cheese. FSSR (2011) has also defined cheese on the basis of ripening as follows:

- (i) Ripened cheese is cheese which is not ready for consumption shortly after manufacture but which must be held for some time at such temperature and under such other conditions as will result in necessary biochemical and physical changes characterizing the cheese in question.
- (ii) Mould ripened cheese is a ripened cheese in which the ripening has been accomplished primarily by the development of characteristic mould growth through the interior and/ or on the surface of the cheese.
- (iii) Unripened cheese including fresh cheese is cheese which is ready for consumption shortly after manufacture.

Cheese or varieties of cheeses shall have pleasant taste and flavor free from off flavor and rancidity. It may contain permitted food additives and shall conform to the microbiological requirements prescribed in the regulation.

3.3 Classification of Cheese

Several schemes to classify cheese have been proposed to assist international trade and to provide compositional and nutritional information. The basis for such classification include age, type of milk, country of origin, ripening process/agents, important compositional varieties, like moisture and fat, general appearance, texture and rheological qualities. However, none of the above schemes is complete in itself. There are about 2000 names of cheeses. It is very difficult to classify the different cheeses satisfactorily, in groups. There are probably only about 18 types of natural cheeses. These are: Cheddar, Gouda, Edam, Swiss, Brick, Herve, Camembert, Limburger, Parmesan, Provolone, Romano, Roquefort, Sapsago, Cottage, Neufchatel, Trappist, Cream and Whey cheeses.

Such a grouping, though informative, is imperfect and incomplete. These can also be classified on the basis of their rheology, and according to the manner of ripening as shown below:

- 1) Very hard (grating) - Moisture < 35% on matured cheese and ripened by bacteria, e.g. Parmesan, Romano.
- 2) Hard - Moisture < 40%
 - a) Ripened by bacteria, without eyes: Cheddar
 - b) Ripened by bacteria, with eyes: Swiss
- 3) Semi-hard - Moisture 40-47%
 - a) Ripened principally by bacteria: Brick
 - b) Ripened by bacteria and surface microorganisms: Limburger
 - c) Ripened principally by blue mould:

- i) External – Camembert
- ii) Internal – Gorgonzola, Blue, Roquefort.
- 4) Soft - Moisture > 47%
- a) Unripened – Cottage
- b) Ripened – Neufchatel

Table 3.1 Legal standards for cheese

Type of cheese	Moisture, maximum	Milk Fat (on dry basis), minimum
Hard pressed cheese	39.0%	48.0%
Semi hard cheese	45.0%	40.0%
Semi soft cheese	52.0%	45.0%
Soft cheese	80.0%	20.0%
Extra hard cheese	36.0%	32.0%
Mozzarella cheese	60.0%	35.0%
Pizza cheese	54.0%	35.0%

Table 3.2 Ten distinct types of natural cheeses classified according to differences in processing

Distinctive Processing	Distinctive Characteristics	Typical Varieties
Curd coagulated primarily by acid	Delicate, soft curd	Cottage, Neufchatel
Curd particles matted together	Close texture, firm body	Cheddar, Cheshire
Curd particles kept separate	Open texture	Colby, Monterey, Gouda, Edam
Presence of small amount of copper from copper cheese kettle or vat	Granular texture, brittle body	Grand-hard grating types: Parmesan, Romano
Stretched curd	Plastic curd, thread-like or flaky texture	Mozzarella, Provolone
Bacteria-ripened internally accompanied by eye formation	Gas holes or eyes throughout cheese	Emmentaler or Swiss (large curd), Gruyere
Mold ripened throughout interior	Visible mold veins, typical piquant, spicy flavor	Blue, Roquefort, Stilton, Gorgonzola
Surface ripened principally by mold	Edible crust, soft creamy interior, typical pungent flavor	Camembert, Brie
Surface ripened principally by bacteria and yeast	Surface growth; soft, smooth waxy body, typical mild to robust flavor	Brick Limburger, Muenster
Protein of whey and milk coagulated by heat	Sweetish flavor of whey	Whey cheeses: Ricotta, Mysost, Primost

Lesson 4 COMPOSITION AND NUTRITIONAL VALUE OF CHEESE

4.1 Introduction

Cheese is a nutritious and versatile dairy food. It contains a high concentration of essential nutrients relative to its energy level. Its precise nutritional composition is determined by multifactorial parameters, including the type of milk used (species, breed, stage of lactation, and fat content) and the manufacturing and ripening procedures. In general, cheese is rich in the fat and casein constituents of milk, which are retained in the curd during manufacture. It contains relatively small amounts of the water soluble constituents (whey proteins, lactose, and water-soluble vitamins), which partition mainly into the whey. The composition of some varieties of cheese is given in Table 4.1.

Table 4.1 Approximate composition of some varieties of cheese (%)

Variety	Moisture	Fat	Protein	Ash (Salt-free)	Salt	Calcium	Phosphorous	Food energy (calorie/100 g)
Cheddar	37.5	32.0	25.0	2.0	1.5	0.86	0.60	398
Gouda	38.5	28.5	25.5	2.5	1.5	-	-	377
Swiss	39.0	28.0	27.0	2.0	1.5	0.90	0.75	370
Roquefort	39.5	32.0	22.0	2.0	4.0	0.65	0.45	385
Brick	41.0	31.0	22.0	1.2	1.8	-	-	370
Limburger	45.5	28.0	22.0	2.0	2.1	0.50	0.40	345
Mozzarella	54.0	18.0	22.1	2.3	0.7	-	-	290
Cottage (uncreamed)	79.5	0.3	15.0	0.8	1.0	0.10	0.15	200

(Source: Upadhayay, 2003)

4.2 Protein

Cheese contains a high content of biologically valuable protein. The protein content of cheese ranges from approximately 4-40%, depending upon the variety. It varies inversely with the fat content of cheese. During cheese manufacture, most of the whey proteins are lost in whey and thus only casein remains in cheese. Casein is slightly deficient in sulphur-containing amino acids. Thus the biological value of cheese protein is slightly less than that of the total milk protein. Cheese protein is almost 100% digestible, as the ripening phase of cheese manufacture involves a progressive breakdown of casein, to water-soluble peptides and free amino acids. Hence, a significant degree of breakdown of cheese protein has occurred before it is consumed and subjected to the effects of gastrointestinal proteolytic activity. A range of bioactive peptides are released during proteolysis of cheese, which exert specific health benefit to the human body (e.g.

the peptides that inhibit the activity of angiotensin-I converting enzyme which give rise to antihypertensive and immunomodulatory effects).

4.3 Carbohydrate

The principal carbohydrate in milk is lactose, most of which is lost in whey during cheese manufacture. Only trace amount of carbohydrate remains in the cheese, this too is hydrolysed by starter lactic acid bacteria. Cheese is therefore, a safe food for lactose-intolerant people.

4.4 Lipids

Most of the cheese varieties are rich in fat. Fat affects cheese firmness, adhesiveness, mouthfeel and flavour and also provides nutrition. It contributes a significant amount of both saturated and total fat to the diet. Cheese fat generally contains 66% saturated, 30% monounsaturated and 4% polyunsaturated fatty acids. Thus, cheese represents a significant dietary source of both total fat and saturated fatty acids. The cholesterol content of cheese is a function of its fat content and ranges from approximately 10-100 mg/100 g, depending on the variety. Dietary cholesterol has much less influence on blood cholesterol level than dietary saturated fat. Thus, the cholesterol content of cheese is of lesser importance than its saturated fat content.

4.5 Vitamins and Minerals

As most of the milk fat is retained in cheese curd, the fat soluble vitamins remain in the curd while most of the water soluble vitamins are lost in whey. However, some microbial synthesis of B vitamins may occur in cheese during ripening. In general, most cheeses are good sources of vitamin A, riboflavin, vitamin B12, and, to a lesser extent, folate. Cheese contains negligible amounts of vitamin C.

Cheese is also an important source of several nutritionally important elements, including calcium, phosphorus, and magnesium. It is a particularly good source of bioavailable calcium, with most hard cheeses containing approximately 800 mg calcium/100 g cheese. Cheese has a potential role in supplying extra and highly bioavailable calcium. However, acid-coagulated cheeses (e.g., Cottage) contain considerably less calcium than rennet-coagulated varieties. Bioavailability of the calcium from cheese is equivalent to that from milk. It has been reported that 22.9, 26.7 and 25.4% of total calcium was absorbed from cream cheese, whole milk and yoghurt, respectively. Adequate calcium intake during childhood and in teenage years is important in development of high bone mass which may prevent osteoporosis in the later years.

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Lesson 5 PRINCIPLES OF CHEESE MANUFACTURE

5.1 Introduction

Cheese is the most diverse group of dairy products and is, arguably, the most academically interesting and challenging. While many dairy products, if properly manufactured and stored, are biologically, biochemically and chemically very stable, cheeses are, in contrast, biologically and biochemically dynamic, and consequently, inherently unstable. Throughout manufacture and ripening, cheese production represents a finely orchestrated series of consecutive and concomitant biochemical events. These, if synchronized and balanced, lead to products with highly desirable flavors and body and texture, but when imbalanced, result in off-flavors. Considering that the same raw material (milk) is subjected to a manufacturing protocol whose principles are common to most cheese varieties, it is fascinating that such a diverse range of products can be produced. No two batches of the same variety and indeed no two cheeses are identical. A further important facet of cheese is the range of scientific disciplines involved. Cheese manufacture and ripening involves the chemistry and biochemistry of milk constituents, fractionation and characterization of cheese constituents, microbiology, enzymology, molecular genetics, flavor chemistry, rheology and chemical engineering.

Cheese consists of a concentration of the constituents of milk, principally fat, casein and insoluble salts, together with water in which small amounts soluble salts, lactose and albumin are found. To retain these constituents in concentrated form, milk is coagulated either by means of lactic acid produced by bacteria or by the addition of rennet or by both. A portion of water is removed by cutting, cooking, stirring or draining the curd or by mechanical application of pressure. The cheese may or may not be ripened; the nature of the process depends upon the particular variety of cheese.

The hundreds of varieties differ very much in size, shape, color, hardness, texture, odour and taste. However, all cheeses, irrespective of country of origin and method of manufacture possess certain common characteristic steps as follow:

1. They are made from the milk (or derivatives of milk) of certain mammals derivatives
2. Souring
3. Clotting by rennet or a similar enzyme preparations
4. Cutting or breaking up of the coagulum to release the whey
5. Consolidation or matting of the curd
6. Maturing

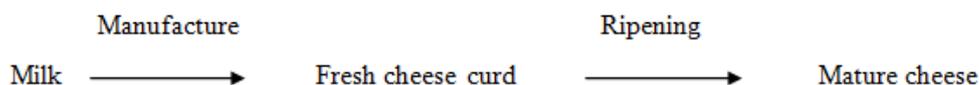
The above traits are common to all cheeses, but the conditions vary considerably. The chief factors responsible for differences in the final cheese are:

1. type of milk used
2. degree of souring and type of souring organisms added
3. temperature of renneting and subsequent cooking or scalding of the curd in the whey
4. milling and salting of the curd before putting in the hoop or mould
5. pressure applied to the green cheese
6. time, temperature and relative humidity of ripening
7. special treatments such as stabbing the cheese, bathing in the brine and surface treatment to produce a certain type of coat.

5.2 Outlines of Cheese Manufacture

Cheese manufacture involves the controlled syneresis of the rennet milk coagulum, the expulsion of moisture being affected by: i) acid development, the pH falling from 6.6 to about 5.0 as a result of lactic acid bacteria of the starter, chiefly *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris*, ii) warmth, the temperature being raised to about 31°C for renneting and to about 38°C for scalding the curd, and especially iii) repeated cutting of the curd and stirring.

Although some soft cheese varieties are consumed fresh, i.e. without a ripening period, the production of the vast majority of cheese varieties can be subdivided into two well-defined phases, manufacture and ripening.



The manufacturing phase might be defined as those operations performed during the first 24 h, although some of these operations, e.g. salting and dehydration, may continue over a longer period. Although the manufacturing protocol for individual varieties differ in detail, the basic steps are common to most varieties. These are acidification, coagulation, dehydration (cutting the coagulum, cooking, stirring, pressing salting and other operations that promote gel syneresis), shaping (moulding and pressing), and salting. During the dehydration process of cheese manufacture, the fat and casein in milk are concentrated between 6-12 fold, depending on the variety. The degree of dehydration is regulated by the extent and combination of the above five operations, in addition to the chemical composition of milk. In turn, the levels of moisture and salt, and pH and cheese microflora regulate and control the biochemical changes that occur during ripening and hence determine the flavor, aroma and texture of the finished product. Thus the nature and quality of the finished cheese are determined to a very large extent by the manufacturing steps. However, it is during the ripening phase that the characteristic flavor and texture of the individual cheese varieties develop.

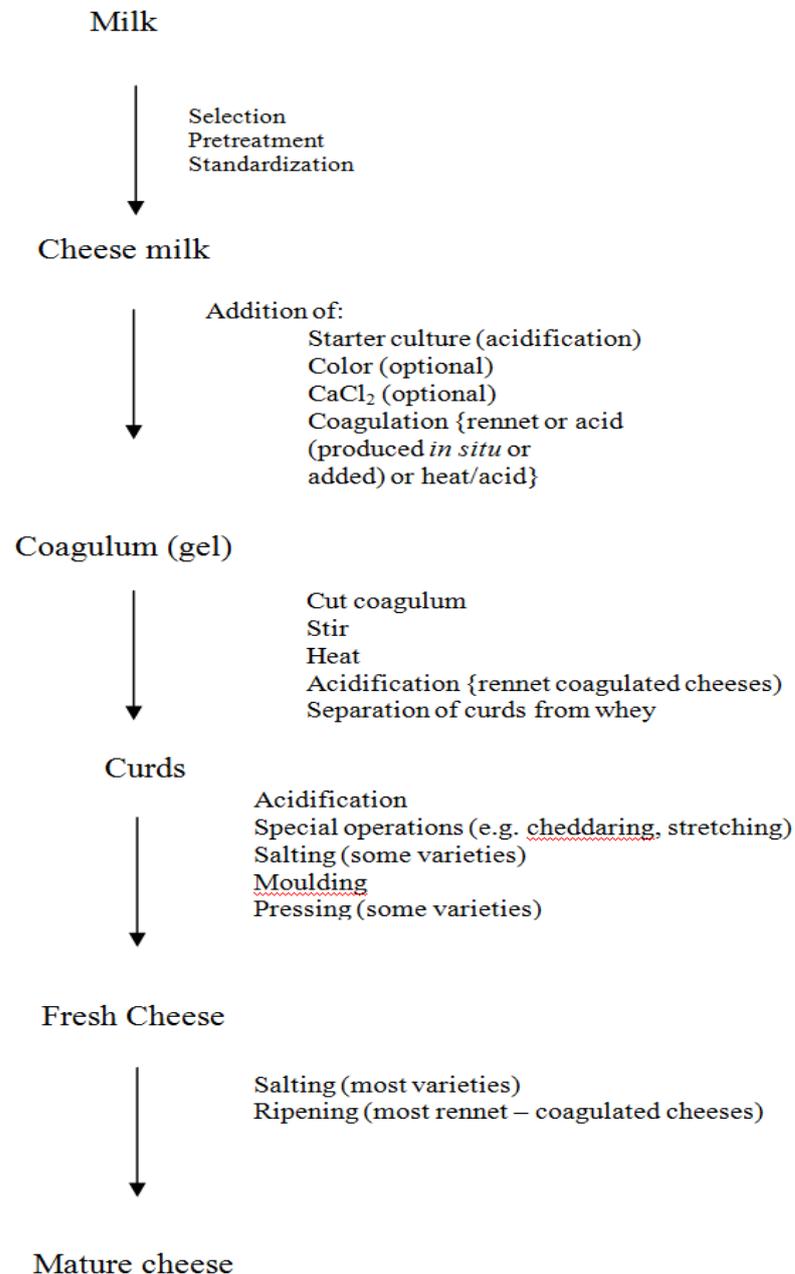


Fig 5.1 General protocol for cheese manufacture

5.3 Selection of Milk

The quality of milk has a profound effect on the quality of cheese made from it. The composition of cheese is strongly influenced by the composition of the milk, especially the content of fat, protein, calcium and pH. The constituents and composition of milk are influenced by several factors, including species, breed, individual variations, nutritional status, health and stage of lactation of milk-producing animals. Owing to major compositional abnormalities, milk from cows in the very early or late stage of lactation and those suffering from mastitis should be excluded. Somatic cell (leucocyte) count is a useful index of quality. It is safe to say that all changes brought about by mastitis are bad from cheese making standpoint. The bad effect of mastitis is due almost entirely to the changes in the chemical composition of the milk. The firmness of the rennet coagulum or cheese curd is enhanced by: a) acidity, b) high calcium and c) high casein content. It is reduced by alkalinity, low casein, high albumin plus globulin and high sodium. Mastitis nearly always changes the composition of milk in this direction and so leads to weak curd formation. Some genetic polymorphs of the milk proteins have significant effect on cheese yield and quality and there is increasing interest in animal breeding for desirable

polymorphs. The milk should be free of taints of chemicals and free fatty acids that cause off-flavors in the cheese, and antibiotics that inhibit bacterial cultures.

A major cause of variation in the characteristics of cheese is the species of dairy animals from which milk is obtained. The principal dairying species are cattle, buffalo, sheep and goats, which produce 85%, 11%, 2% and 2% of commercial milk, respectively. Goats and sheep are significant producers of milk in certain regions, e.g. around the Mediterranean, where their milk is used mainly for the production of fermented milks and cheese. Many world famous cheeses are produced from sheep's milk, e.g. Roquefort and Feta and Romano; traditional Mozzarella is made from buffalo milk. There are very significant differences in the composition and physicochemical properties of milk, which are reflected in the characteristics of cheese, produced therefrom. Some varieties are always made from the milk of a particular mammal. Whereas the caseins of all tyrogenic milk (capable of being converted into cheese) are much the same, the fats of this milk may differ significantly in the proportions of the fatty acids in the triglycerides. The medium chain (C₆-C₁₀) fatty acids liberated during ripening are markedly more 'peppery' or biting in flavor than the very short (C₂-C₄) or longer (C₁₂-C₁₈) fatty acids. As it is known that cheese flavor is due to fat break down, it might be expected that varieties made from the milk of those mammals containing a higher proportion of C₆-C₁₀ fatty acids would develop a characteristic peppery flavor, as seen in Roquefort, which is always made from sheep milk. There are significant differences in milk composition between breeds of cattle, which influence cheese quality.

The milk should be of good microbiological quality, as contaminating bacteria are concentrated in the curd and may cause defects or public health problems. However, cheese milk is usually pasteurized or subjected to alternate treatments to render it free of pathogenic, food poisoning and/or spoilage bacteria.

5.4 Inhibitory Substances in Milk

All cheeses depend on the growth of lactococci and all matured cheese depends on the development of lactobacilli. It has been known for a long time that milks behave differently in the way lactic acid bacteria grow in them. Most important in cheese making is the slow growth of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* in some milk, especially raw milks. One of the factors may be the presence of a group of inhibitory substances naturally occurring in milk. It has been reported that a substance called lactenin found in milk may inhibit the growth of certain streptococci. Lactenin has been shown to have two components, L1 and L2. L1 is present in colostrum and is inactivated by heating to 70°C for 20 min and L2 present in mid-lactation milk and is inactivated by heating to 70°C for 20 min.

The presence of antibiotics in milk has been a major cause of trouble in cheese making. Penicillin and other antibiotics used to control mastitis in cows find their way into milk and inhibit the growth of starter organisms. The best method to control this problem is to exclude such milk for cheese making. Alternatively, starters resistant to antibiotics should be used. Also enzymes such as penicillinase can be used to neutralize the antibiotics.

Preservatives like formalin, hypochlorite, quaternary ammonium compounds and other disinfectants present in milk may inhibit the growth of starter organisms.

5.5 Storage of Chilled Milk

In modern commercial practice, particularly in Western countries milk for cheese is normally chilled to 4-5°C immediately after milking and may be held at about this temperature for several

days on the farm and at the factory. Apart from the development of an undesirable psychrotrophic microflora, cold storage causes physicochemical changes (e.g. shift in calcium phosphate equilibrium and dissociation of some micellar caseins), which have undesirable effects on cheese making properties of milk.

5.6 Standardization of Milk

The composition of cheese is prescribed in 'Standards of Identity' with respect to moisture and fat in dry matter, which in effect defines protein:fat ratio. Fat and casein together with moisture left in the curd control cheese yield, but fat also has a marked influence on appearance and feel of the curd and cheese. When ratio of casein to fat is high, the curd is more leathery and the final cheese does not acquire the mellow, velvetiness of a whole milk cheese. Skim milk cheeses are usually consumed 'green'. In general, the casein:fat ratio (C/F ratio) in milk should be about 0.7 for good quality cheese. Depending on the ratio required, it can be modified by:

- Removing some fat by natural creaming or centrifugation,
- Adding skim milk,
- Adding cream,
- Adding milk powder, evaporated milk or ultrafiltration retentate.

Such additions also increase the total solids content of the milk and hence increase the yield of cheese curd per unit volume.

5.7 Heat Treatment of Milk

Traditionally, cheese was made from raw milk, a practice that was almost universal until the 1940s. Although cheese made from raw milk develops more intense flavor than that produced from pasteurized milk, the former is less consistent and poses a public health risk. When cheese was produced from fresh milk on farms or in small, local factories, the growth of contaminating microorganisms was minimal but as these factories became larger, storage of milk for longer periods became necessary and hence the microbiological quality of milk deteriorated and varied. Thermization of cheese milk is fairly widely practised on receipt at the factory to reduce the microbial load and extend the storage period. Pasteurization of cheese milk became widespread about 1940, primarily from public health reasons, but also to provide a milk supply of more uniform bacteriological quality. Although a considerable amount of cheese is still produced from raw milk, especially in Southern Europe (including such famous varieties as Swiss and Emmental) pasteurized milk is generally used, especially in large factories.

Pasteurization alters the indigenous microflora and facilitates the manufacture of cheese of more uniform quality, but unless due care is exercised, it may damage the rennet coagulability and curd-forming properties of milk. Even when properly pasteurized, Cheddar cheese (and probably other varieties) made from pasteurized milk develops a less intense flavor and ripens more slowly than raw milk cheese. Several heat induced changes, e.g. inactivation of indigenous milk enzymes, killing of indigenous microorganisms, de-naturation of whey proteins and their interaction with micellar κ -casein, perhaps even shifts in salt equilibria and destruction of vitamins, could be responsible for these changes. Until now it has not been possible to establish which of these factors was principally responsible for the differences in quality between raw and pasteurized milk cheese. Therefore, normally sub pasteurization temperature is preferred to heat cheese milk,

which is termed as 'thermization'. Thermization (65°C/15 s) of cheese milk on arrival on factory is common or standard practice in some countries. The objective is to control psychrotrophs and milk is normally pasteurized before cheese making.

5.8 Ripening of Milk (Acidification)

The increase in acidity in the milk to be used for cheese making known as 'ripening' is usually brought about by starter culture. Acidity developed inhibits the growth of undesirable organisms and influences the rate of coagulation. When the desired acidity (0.01% increase) is reached, most varieties of cheese require the addition of rennet to the ripened milk in order to obtain a curd of the desired characteristics. Acidification is normally via in situ production of lactic acid, although preformed acid or acidogen (gluconic acid- δ -lactone) are now used to directly acidify curd for some varieties, e.g. Mozzarella cheese, UF Feta and Cottage. Until recently, the indigenous microflora of milk was relied upon for acid production. Since this was probably a mixed microflora, the rate of acid production was unpredictable and the growth of undesirable bacteria led to the production of gas and off-flavors. It is now almost universal practice to add a culture (starter) of selected lactic acid bacteria to pasteurized cheese milk to achieve a uniform and predictable rate of acid production. For cheese varieties that are cooked to not more than 40°C, a starter consisting of *Lactococcus lactis* subsp. *lactis* and/or *Lc. lactis* subsp. *cremoris* is normally used while a mixed culture *Streptococcus salivarius* var. *thermophilus*, *Lactobacillus* spp. (*L. bulgaricus*, *L. helveticus*, *L. casei*) or lactobacillus culture alone is used for varieties that are 'cooked' to higher temperature, e.g. Swiss, hard Italian varieties.

5.9 Coagulation

The essential step in the manufacture of all cheese varieties involves coagulation of casein of milk to form a gel, which entraps the fat, if present. Coagulation may be achieved by:

- Limited proteolysis by selected proteinases (rennets)
- Acidification to pH 4.6
- Acidification to pH 5.2 and heating to 90°C.

Most cheese varieties, and about 75% of total production, are produced by rennet coagulation but some acid coagulated varieties, e.g. Quark and Cottage cheese, are of major importance. The acid/heat coagulated cheeses are relatively minor varieties which are usually produced from rennet cheese whey and a blend of whey and skim milk and evolved as a means for recovering the nutritionally valuable whey proteins; they are usually used as food ingredients. Important varieties are Ricotta (Italy), Anari (Cyprus) and Manouri (Greece). A fourth minor group of cheese is produced not by coagulation, but by thermal evaporation of water from a mixture of whey and skim milk, whole milk or cream and crystallization of lactose (e.g. Mysost).

Rennin is milk-curdling enzyme, which is usually obtained from the fourth stomach (abomasum) of suckling calves. In other animals, the proteolytic enzyme, pepsin, substitutes rennin. Rennin is prepared commercially for use in cheese making as a salt extract of dried calf stomach. Such an extract containing the enzyme is called rennet or rennet extract.

Rennin is an extremely powerful clotting enzyme; one part of pure rennin can clot more than five million parts of milk. The optimum pH for rennin action on milk is 5.4 and for pepsin it is 2.0. However, it can function very powerfully as a clotting agent at almost neutral pH (6.2-6.4). The

ratio of clotting to proteolytic power is very high in case of rennin, but is lower in case of pepsin and other proteolytic enzymes tried in cheese making. The latter type of enzymes result in a bitter product. For hard cheese such as Cheddar, usually about 2.5 g of commercial rennet powder is used for 100 l of milk. In case of Meito rennet it is 1.65 g/100 l milk.

The formation of curd depends upon the coagulation of the casein in milk. With rennet this occurs in two steps. The calcium caseinate in milk is first changed to the paracasein, which then combines with the calcium ions present in the milk to form an insoluble curd. This curd is elastic and when heated or pressed it will shrink, squeezing out most of the retained whey. Slow development of curd may be due to too little rennet or to the use of overheated milk. In the latter case, the addition of small amount (0.02%) of calcium chloride to the milk usually will restore the calcium ion balance and permit the normal functioning of rennin. No satisfactory substitute for rennin has been found but at times other milk clotting enzymes, such as pepsin, papain, and microbial and recombinant rennets have been used.

Rennet extract is diluted up to 20-30 times with clean potable water before added to the cheese milk. After addition of rennet, the milk is stirred for about two minutes to distribute the rennet thoroughly, and then currents are stopped in the milk with a paddle or rake. Vibration of the vat must be prevented during setting. Steam leakage into the jacket of the vat during setting should be avoided. The milk is then left undisturbed for the curd to form, and this becomes apparent in about 15 min. After about 30 min the milk is 'set' with a firm curd.

5.10 Post-Coagulation Processing Operations

One of the main reasons for the great interest in studying rennet coagulation is to optimize the gel cutting time. When the gel (coagulum) is firm enough, it is cut by mechanical knives in both the horizontal and vertical directions to produce curd particles. In cheese making, the cutting range between 20 and 50 min, depending on:

1. Concentration of rennet used, e.g. 20 ml of single strength rennet per 100 l milk, although this depends on the strength of the rennet used and the other coagulation conditions.
2. Whether CaCl_2 is added, as this accelerates clotting (the maximum legal level in many countries is 0.2%)
3. Coagulation temperature (coagulation occurs faster at higher temperature)
4. pH (the activity of chymosin decreases with an increase in pH)
5. Seasonal changes in milk composition; e.g. late-lactation milk can be slow to clot due to its high pH and hydrolysis of caseins within the mammary gland by plasmin. Low levels of plasmin hydrolysis reduce RCT and increase the initial rate of aggregation of rennet-altered micelles although final gel strength is reduced.
6. The quality of the dilution water used to make the rennet solution prior to the addition of cheese vat, as both excessive chlorine and a high level of water hardness can adversely affect activity.

5.11 Cutting the Coagulum

The rennet gel is quite stable if maintained under quiescent conditions but if it is cut or broken, syneresis occurs rapidly, expelling whey. Syneresis concentrates the fat and casein of milk by a factor of about 6.012, depending upon the variety. The rate and extent of syneresis are influenced by milk composition, especially Ca^{++} and casein, pH of the whey, size of cutting of cubes, cooking temperature, rate of stirring of the curd-whey mixture and time. The composition of the finished cheese is to a large degree determined by the extent of syneresis and since this is readily under the control of the cheesemaker, it is here that the differentiation of the individual cheese varieties really begins, although, the composition of cheese milk, the amount and type of starter and the amount and type of rennet are also equally significant.

The coagulum is ready to cut after a period of from 25 min to 2 h, as defined by the recipe. The determination of exact time of cutting is very critical for the quality of cheese. However, the cheese makers' attempts to judge the exact point of cutting are fraught with difficulties. The surface layer of coagulum is often some degree colder than the coagulum underneath and is, therefore, softer. To judge firmness of curd on the surface, therefore, has little meaning.

The main method employed by cheesemakers is to plunge the hand, rod or thermometer stem below the surface layer and to lift the coagulum causing it to break in a cleavage line. A clear cleavage with green whey at the base of the cleft indicates that the curd is ready to cut. A soft irregular cleavage with white whey indicates that the curd is too soft. The sides of the cleft show the quality of the curd. Granular curds indicate that the curd is too firm. A rule used by some cheesemakers is that the curd should be cut earlier rather than later, and once cut; the curd should be left to complete its forming process in the warmer whey which rises over it. If the coagulum becomes too firm, knives or curd breakers crush the curd rather than cut it cleanly. When curd is ready for cutting, it is first cut horizontally and then vertically. This sequence is essential to follow because if the curd is cut vertically first, slabs so made will not have sufficient strength to stand and thus, will shatter.

The curds, which have been cut cleanly, will 'heal' or join up the cut fibrils on the new curd surfaces and thus prevent loss of fat and other milk components. Surface-active materials such as phospholipids and whey proteins accumulate on the cut surface and form a thin osmotic membrane. This membrane controls the whey expulsion during cooking.

The fat globules are held in the matrix of the casein network, partly by physical enclosure and partly by loose bonding of the globule membrane and protein. Fat globules near the cut surfaces leak away. Such fat although only 0.2-0.3% in the whey, is really 10% of the original fat in the milk and leads to loss of cheese yield. The whey from the cut curds carries water-soluble components including lactose, whey proteins, salts, peptides and other non-protein nitrogenous substances.

The size of the curds after cutting depends on type of cheese to be manufactured. Thus curds, which need to be scalded to higher temperatures, are cut into smaller pieces, while those curds, which are scalded to lower temperatures, can be left in large pieces unless the curds are very acid.

Curved-wire-strung, harp-like curd breakers are used manually in the smaller cheese dairies. The larger installations use multibladed, hand held steel knives. The blades vary from 6-18 mm apart and 76 cm long. Some cutters are composed of wires strung on steel frames.

Mechanically operated curd knives are larger than the manual knives and use either blades or wires. It is very important that the edges of the blades are kept sharp enough to cut cleanly. Heavy

gauge wires tend to tear the curd more than steel knives, and some cheesemakers cut slightly earlier with wires than the knives.

Cutting the coagulum lengthwise once manually in the long rectangular vats normally cut by mechanically operated knives prevents crushing of the soft curds during the first mechanical cutting. The rotating knives in round or oval vats do not crush the curd against the vat sides. Even so, the speed of rotation in some equipment can be controlled. The angle of the blade presented to the curd is such that if the rotation of the knife is reversed it stirs rather than cuts the curd.

5.12 Cooking

The curd, when first cut, is soft and the coat surrounding the particles is open. Stirring the curd gently until the first flush of whey has left the curd particles is necessary to prevent undue crushing and loss of fat and curd dust. Once the curd coat becomes more membrane-like the agitation rate can be increased.

Cooking or scalding the curd causes the protein matrix to shrink and expel more whey. The increase in temperature also speeds up the metabolism of bacteria enclosed within the curd. Lactic acid production increases, pH declines, and acidity assists in shrinking the particles to express more whey.

Since the whey has, in solution, lactose and salts, the amount of these substances retained in the cheese is proportional to the amount of moisture in the curd. The calcium phosphate associated with the casein and in colloidal state, will gradually become solubilized as the pH falls. Thus, high acid curds (i.e. blue veined cheese curds) lose more calcium (92%) than low acid curds such as Edam (35%).

Lactose is the main metabolite of the lactic acid bacteria in the curd for the production of lactic acid. Since lactose must cross the cell wall membrane, it is not only the presence of lactose but also the strength of the lactose solution, which is a controlling factor in the metabolism of the bacteria. Thus, once the lactose concentration has decreased to a certain point, then much smaller decreases have greater effect on the growth of bacteria and on the production of lactic acid. The cheese maker has control over lactose in the curd, and, therefore, the amount of lactic acid formed, through the size of the curd particles, scald temperature and the rate of rise of temperature of the curds. There are two methods of reducing the amount of lactose in the cheese curds:

1. Shrinkage of the curds brought about by heat and lowering of the pH owing to development of lactic acid in the curd.
2. The addition of water to the whey, which increases the osmotic effect across the curd membranes and thus extracts the lactose from the curd moisture into the diluted whey.

The addition of hot water to the whey/ curd mixture is used as a method of scalding (heating) the curd in the washed curd cheese processes.

The aim of scalding the curd is to shrink the curd to expel moisture and so firm up the curd to a state ready for texture formation, pressing or salting. This state provides the dividing between four main groups of cheese (excluding soft cheese, some of which may be scalded).

1. The textured cheese like Cheddar, Cheshire.

2. The pasta filata types or kneaded cheese.
3. The cheese untextured in the vat stage, like Edam and Gouda cheese, and also those which acquire texture later, like Tilsiter, Emmental, etc.
4. Blue veined cheese.

The variation of scalding rates is carried out according to the acidity produced and is under the control of cheesemaker. This is a further point in the recipe where previous experience aids in interpretation. A high rate of scald will shrink the coat of the curd particles so much that the membrane is so firm that moisture is locked in the curd. The resultant cheese is acid, harsh texture, crumbly and eventually dry.

Low rates of scald may be necessary for curds in which the bacteria are slow to produce acid. Alternatively, curd shrinkage may be by acid alone without the use of scald. The recipe determines the maximum scald temperature but it is important to note that the normal lactic starter bacteria will be inhibited, if not destroyed, if the scald temperature is too high (i.e. temperature beyond 40°C). Scald temperatures higher than normal need the inclusion of high-temperature-enduring starter bacteria (i.e. *S. thermophilus*, *L. bulgaricus*, etc.). Although lactose, being soluble tends to leave the curds to be concentrated in the whey, there may be reverse movement back into the curd if the curd and whey acidities are too different.

The cheesemaker has a decision to make in respect of when to cease stirring the whey curd mixture; this is not often included in the recipe. The cessation of the stirring is called the 'pitching' point when the curd sinks down to the bottom of the vat.

Normally, fast acid curds are stirred until the whey is removed. With very slowly developing curds, the stirring ceases altogether and the curd is 'pitched', or sometimes, to prevent excessive 'matting' of the curd into lumps, the curds are stirred at intervals.

5.13 Curd Treatment

The manner in which the curd is handled varies in some degree according to the kind of cheese to be made. The acidity of the curd continues to increase and its body becomes firmer owing to a decrease in its content of whey. Heating the curd favors these reactions. If a soft high moisture cheese is made, the curd is removed from the vat quickly and the whey is drained. For some varieties of cheese, the curd is cut and stirred in the whey while it is being heated. For Cheddar type cheese, the curd is heated in the whey and allowed to form continuous mass, which is then cut and milled into small pieces before further processing.

The manner in which the whey is drained from the curd varies with the kind of cheese:

1. Cream cheese, for example, is prepared by placing the curd on cloths which allow the whey to drain away.
2. Sometimes the curd is placed in forms or hoops put on mats or coarsely woven screens which allow the whey to drain as in the manufacture of Brick cheese,
3. In the making of Cheddar cheese, curd is allowed to sink in the vat and the supernatant whey is drawn off,

4. In making Swiss cheese, the curd is separated by placing a cloth under the curd and lifting it out of the vat or kettle.

The rate at which the whey is allowed to drain away is determined by the kind of cheese being made. Acid continues to develop in the curd as long as appreciable amounts of whey are present. With the increase in acidity the curd becomes elastic and can be stretched or, if heated, it can be drawn out into silky strings. This is the basis of practical test used by makers of Cheddar cheese. A hot iron rod is touched to the curd, and as it is drawn away, the length of the curd fibers at their breaking point is noted, the higher the acidity the longer the threads.

5.14 Pressing

The last portion of the whey is removed from the curd by pressing. This operation is also used to mould some varieties of cheese in their conventional shape. The degree of pressure used varies with the kind of cheese.

The curd is composed of a matrix of protein enclosing fat globules, moisture, lactose, salts, non-protein nitrogenous substances, as well as peptides. The curd also contains air and some gas (CO₂) so that while it is warm it is springy, elastic and soft. The fat is also mainly in the liquid state. Salt (NaCl) may or may not have been applied and salt will dissolve some of the casein surfaces, and also releases water. Thus the surface layer of casein may be rendered hard and horny if the salt is not allowed to dissolve freely into the warm curd.

Pressing the curd should, therefore, be gradual at first, because high pressure at first compresses the surface layer of the cheese and can lock moisture into pockets in the body of the cheese. The temperature of the curd before pressing should be below the liquid fat temperature, i.e. 23.9°C in summer and 26°C in winter. Otherwise, fat will leak from the curd and be lost in the whey, or will fill spaces in between the curds and give a greasy cheese. The pressure applied to the cheese should be per unit area of the cheese and not per cheese, which may vary with size. Table 5.1 shows the pressure, traditionally applied and a comparison with pressures applied to 18 kg block cheese.

Since the cheese curd holds a volume of air before pressing, those cheeses requiring very closed curds (e.g. Cheddar) have been pressed under a vacuum of 85-95 kN/m² (25-28 in Hg). The vacuum applied for only a short time (2-3 h), also assists in cooling the curd.

Pressures have been traditionally applied for 2-3 days to Cheddar cheese, but the more recent 'block cheese' pressing has been limited to 24-36 h, and with vacuum pressing, 10-15 h. This has enabled the cheese mould to be washed and reused the following days.

Cheese presses are either spring, dead weight, pneumatically or hydraulically operated. Recently, the larger 'ton' or 'box' presses have been used. The presses have vacuum cylinders so that the curd can be pressed under vacuum.

One of the requirements of the pressed cheese is that the outside (rind) surface is close, smooth and with no crevices for mold penetration. The traditional methods used coarse Hessian cloths to assist in closing up the holes in the curd. Sometimes, the cheese was immersed in hot water at 48.9°C to plasticize the coat and the cheese was then repressed in stiff Calico cloth to obtain a close finish.

These systems were highly labour intensive, and textured synthetic films have replaced the cloths

previously used. Traditional cheesemakers and certain cheese buyers still prefer the older methods of cheese preparation, especially for the texture cheese varieties such as Cheddar, Cheshire etc.

Table 5.1 Pressures applied to cheese of various sizes

Cheese size	Traditional (weight per cheese)			Equivalent pressure as applied to 18 kg block cheese kN/m^2
	Ton	Cwt	Metric kN/m^2	
41 cm diameter, 1297 cm^2 area (i.e. Cheddar)		10	38	65
	1		76	130
	2		153	260
30 cm diameter, 729 cm^2 area (i.e. Cheshire)		10	68.4	36.6
	1		137	73.2
	2		274	146
Block Cheese 36x28x18 cm, 994 cm^2 area		10	50	50
	1		100	100
	2		200	200

5.15 Treatment of Rind

The manner in which the surface of the cheese is treated also influences its characteristics, for example, frequently cleaning the rind, for Cheddar.

1. Cheddar and Swiss cheeses are given a smooth and uniform surface or rind by pressing the curd while it still is warm, and curing the cheese under conditions that allow the moisture to evaporate from the surface
2. The activity of organisms on the surface is prevented in Swiss cheese by frequently cleaning the rind. For Cheddar cheese, this is done by coating the cheese with paraffin wax and holding it in a cool room with low humidity,
3. Holding them in cool, moist environment encourages the growth of mold on Camembert and Roquefort type cheeses, and the growth of yeasts and bacteria on Brick and Limburger cheeses.

The soft types of cheese acquire a rind during ripening, often as a result of the growth of molds and bacteria. Later, the evaporation of moisture hardens the rind so that it is more rigid to handle. In many instances the rind is kept clean by repeated washing with a salt impregnated cloth (e.g. Emmental) or repeated brushing to remove mould growth (e.g. Cantal). When these cheeses are ripe and ready for sale, the rind is simply coated with vegetable (olive) oil, which may be colored brown or black (e.g. Parmesan, Romano).

Smoking of cheese also gives the coat a fatty layer and has a preservative effect, due to phenolic compounds from the smoke. Spices are also used on the coats of some cheese to impart a flavor to the curd, but mainly the spices are included in the curd. Feta and similar cheeses are packed in casks or drums filled with brine or salted whey.

Gorgonzola has also been coated with Plaster of Paris as a protective coat inside a woven basket. The plaster is not completely airtight and allows the cheese to 'breathe' and mold to remain blue.

The larger hard-pressed cheeses, like Cheddar, Emmental, etc. have in recent years been produced in block shapes for two main reasons:

1. The packing of cheese in retail markets for consumer sale in small portions has accelerated the use of block cheese shapes. These cheese blocks range from 10 to 20 kg in weight, are rectangular and can be cut mechanically without waste into consumer portions.
2. The second reason is with respect to mold or cheese mite damage, which has caused serious loss in traditional round-shaped cheese.

Attempts to overcome these defects first employed, and still use, chemical treatments, i.e. sorbic acid and its salts, or pimaricin to stop mold growth, and/or waxing or resinous coating of the cheese rind to prevent both mould growth and mite infestation.

Waxing of cheese, like Cheddar, Cheshire, etc. over the bandage requires that the bandage is completely dry (2-3 days drying). If the bandage is not dry the wax coat eels away and is not effective as mold preventive. The waxes used are available with different melting points, from 49-82°C, for either temperate or tropical usage. The application of wax is usually by dipping the cheese in a bath of melted wax for up to 30 s and then allowing it to cool quickly. It may be necessary to dip twice if the cheese is not totally covered on the first occasion.

5.16 Salting

Salting of perishable foods is among the most ancient and widely practiced techniques of food preservation. Salt has achieved universal acceptance as a mineral of great importance in trade and industry, and, in view of its preservative qualities, it has become a peculiarly appropriate symbol of fidelity in many cultures. It is, therefore, no surprise that salting is a key element in that combination of techniques that has evolved for preserving the solids of milk in the form of cheese.

Common salt (NaCl) is an ingredient of practically every variety of cheese. It may be added to subdivide cheese curds, as is the case with Cheddar and related types, or apply by immersion of the formed cheese in brine, as for Gouda, Swiss, Feta and related types. For some cheeses, the salt is rubbed on the surface after moulding is complete and, for a few types (e.g. Domiati), some or all of the salt is added to the cheese milk before curd production commences. The presence of salt in cheese and the manner of its incorporation has a significant impact on the course of the cheese fermentation, and on the final characteristics of the cheese as consumed.

The salt in cheese:

- Draws the whey out of the curd,
- Suppresses the proliferation of unwanted microorganisms, including pathogens,
- Regulates the growth of desirable organisms, including lactic acid bacteria (acidity, oxygen tension and temperature also regulate the growth of these organisms),
- Promotes physical and chemical changes in the maturing cheese,
- Directly modifies taste, and

- Serves as a factor in control of acidity.

The salt in cheese is held in solution in the aqueous phase and its concentration in solution is a strong determinant of much of the biological and biochemical changes that occur during cheese maturation. The actual level of salt in cheese varies with the type, ranging from 0.5% to about 3% (w/w) but this range is amplified by the wide differences in water content between cheese varieties, such that the concentration of NaCl in the aqueous phase may range from less than 1% to about 8%. The level of salt in cheese, the manner of its addition and the joint impact of these factors on the time needed for equilibration of the salt concentration in the aqueous phase are key determinants of varietal differences in cheese characteristics.

Within any one cheese, the distribution of salt may vary considerably according to the method of application. Dry salted cheese, such as Cheddar, should have uniform salt levels throughout the body within just a few hours after salting, whereas for brine-salted cheese, there is a marked difference between the salt content of the surface and the interior, which persists for many days or weeks, dependent on the dimensions of the cheese. Rapid attainment of salt uniformity within dry salted cheese curds generally slows or stops fermentation of the residual lactose, leaving a pool of fermentable carbohydrate to support the growth of the more salt-tolerant strains of the starter bacteria and/or the growth of the non-starter lactic acid bacteria (NSLAB), with a potentially profound impact on the course of maturation. A low internal salt level in brine-salted cheese allows for continuation of the fermentation by the added starter organisms of practically all of the lactose to lactic acid and associated end products, thus leaving little fermentable carbohydrate to support the growth of NSLAB, resulting in a different course of maturation and different flavor profiles.

5.16.1 Methods of salting

There are three main techniques for salting of cheese:

- Mixing of dry salt crystals with subdivided cheese curds prior to the moulding/pressing stage of manufacture,
- Immersion of the moulded cheese in a brine solution,
- Application of dry salt or salt slurry to the surface of the formed cheese.

For a number of varieties, a combination of these techniques is used, and for a few cheese types, salt is added either to the milk or the whey.

Brined cheeses are formed into their final size and shape prior to being immersed in a solution for a period ranging from a few hours to a few days in vat containing circulating or static brine. Static brine systems usually have un-dissolved salt at the bottom of the vats and stirring must be carried out frequently. Circulating systems have means for automatically maintaining the strength of the brine. Brine concentration typically ranges from 15% to 25% (w/w) NaCl in water and temperature may vary from about 8 to 20°C.

The salting time depends primarily on the desired salt content, and is further influenced by:

- Brine temperature (Diffusion rate increases with temperature)

- Salt concentration (Higher concentration gives faster salt uptake, but more extreme variations within the young cheese)
- Cheese dimensions (Smaller and flatter cheeses take up salt more rapidly; spherical cheeses take up salt more evenly)
- Cheese moisture and pH (Higher moisture and pH both lead to more rapid salt intake).

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Module 3. Milk quality in relation to cheese making
Lesson 6

SELECTION AND COMPOSITION OF MILK

6.1 Introduction

Cheese making commences with the selection of milk. The quality of raw milk used for cheese making has an important bearing on the quality of cheese resulting from it. Milk quality influences starter growth, rennet coagulation, manufacturing methods, development of taints and other defects in body and texture of cheese and other changes taking place during ripening of cheese. Milk quality is assessed in terms of sensory, microbiological and chemical quality attributes. As soon as milk is received at the reception dock of the cheese factory, it is evaluated for its odor and appearance. It must not possess any objectionable odor and must be free from extraneous matter. Once the milk has been accepted for further processing, it is assessed for the following group of factors.

6.2 Quantitative Factors

6.2.1 Composition of milk

The composition of milk affects mainly the yield and texture of cheese. The composition of milk affects coagulum properties thereby influencing yield and texture. The milk constituents of prime importance in cheese making are milk proteins (particularly casein), milk fat and mineral salts (particularly calcium). Influence of each of these factors on cheese making is discussed below:

6.2.1.1 Milk proteins

Casein, the major milk protein, exists largely in micellar form in milk. It constitutes about 70-80% of the total milk protein. The casein micelles are composed of α -casein, β -casein, κ -casein and some minor components. In addition, genetic variants of these components are also found. The composition and concentration of such a mixture is not constant and subjected to variations due to influence of species, breed, animal health, stage of lactation, climate, time of year and environmental factors. These alterations in the concentration of total casein, relative proportion of its constituents and genetic variants, size of the casein micelle and mineral make up of the casein micelles affect cheese making properties of milk such as clotting time, curd strength, syneresis, cheese yield, proteolysis of cheese and composition of the cheese.

During cheese making, serum proteins and lactose are lost in whey. So, milk high in casein is desirable. Milk high in whey protein content may delay clotting time as β -lactoglobulin undergoes aggregation when subjected to heat and may react with κ -casein. Apart from longer clotting time, the interaction between β -lactoglobulin and the casein tends to cause softer curds which lose moisture more slowly. Cheese milk containing B variant of β - and κ -casein give shorter clotting time, higher curd strength as compared to the milk devoid of this variant. Size of the casein micelle also affects clotting time. Smaller micelles having more κ -casein give shorter clotting time than the larger ones.

6.2.1.2 Milk fat

The amount, composition and nature of milk fat are affected by the same factors as discussed in the case of milk proteins. Alterations in milk fat composition and the amount of milk fat have direct influence on cheese making characteristics and quality of cheese like rennet coagulation time (RCT), coagulum strength, syneresis, yield, flavor and texture of cheese and cheese composition.

Increase in the fat content of milk gives reduced syneresis and thus longer times are required to achieve desired moisture content in cheese. Too low fat in milk is also not desirable as it poses problem of moisture retention and results in hard and dry body cheese. Texture of cheese is also affected by the fat content. Low fat milk gives cheese with leathery texture and lacks mellow, velvetiness while high fat milk produces too soft, buttery and greasy texture. Fat is also important for flavor development of cheese. During ripening, lipolysis of fat results in formation of fatty acids, which impart to cheese, its peculiar flavor.

The physical and chemical nature of milk fat also plays a significant role in cheese making. Fat is incorporated in the casein matrix. This incorporation of fat is dependent on size of fat globule and its composition. Smaller sized globules are easy to incorporate in curd than larger ones. Milk fat with higher melting point is better incorporated in the curd.

The milk used for cheese making must be of uniform quality in terms of its fat and casein content. So, it is always desirable to pool all the milk supply prior to standardization to a definite casein/fat ratio. In case of Cheddar cheese making, milk is standardized to a casein/fat ratio between 0.67 and 0.72.

6.2.1.3 Milk salts

The milk salts are normally classed as ash. Ash contains a large proportion of the metallic components, potassium, sodium, calcium, zinc, chromium, and nickel as well as the non-metallic elements such as sulphur, chlorine, phosphorous, iodine, etc. The salts in milk which are of primary importance to the cheese making process are calcium and magnesium salts of phosphoric and citric acid. Calcium makes casein complex with phosphates. Calcium content of milk greatly influences rennet coagulation time, strength of the clot and body and texture of cheese. The quantity of calcium affects the size of the casein aggregates. More calcium content in milk leads to increased micelle size of the casein. Variation in concentration of calcium as well as magnesium, phosphates, citrates and sodium has a direct influence on RCT of milk. High soluble phosphates, citrates and sodium and low soluble calcium and magnesium and also low proportion of casein bound calcium have been found to give slow coagulation of milk by rennet.

6.2.2 Qualitative factors

Chemical qualities of milk which affect the cheese quality fall into three main groups:

- A. Quality that inhibits starter growth
- B. Quality that affects coagulation
- C. Quality that produces taints, gas-holes, etc., in cheese.

Starter is said to be 90% of importance of cheese making. This statement emphasizes the importance of starter organisms in cheese making. Therefore, the milk used for cheese must be free from inhibitory substances of physiological origin, preservatives, and antibiotics. Presence of

even 0.01 IU/ml antibiotics in milk can affect the starter growth.

In cheese making one of the most important factors is the time taken for coagulation of milk with rennet. Mixing of mastitis milk, colostrum or late lactation milk adversely affects the coagulation. Therefore, milk must be free from these contaminants.

Mastitis milk is high in serum albumins and often high in sodium and chloride content as well. It is low in fat, casein, lactose, phosphate, potassium and calcium content than the normal milk. Since it is low in casein it produces low yield and moist cheese. It has high concentration of immunoglobulins, several enzymes (e.g. proteinase, protease-peptone and catalase) and leucocyte count. Content of short chain fatty acids are more. Lipolysis in milk increases with initial count, but later decreases with high cell count. Mastitis milk has a changed casein composition like less β -casein, more γ and κ -casein, presence of para- κ - casein in comparison to good quality milk.

Late lactation milk resembles sub-clinical mastitis milk biochemically. It is slightly alkaline, high in albumin and chloride and low in casein, lactose and calcium and its effect on coagulation of milk with rennet is similar to that of mastitis milk.

Colostrum is grossly different from the normal milk. It is very rich in proteins, vitamin A, and sodium chloride, but contains lower amounts of carbohydrates, lipids and potassium than normal milk. It contains many antimicrobial substances like lactoferrin and lactoperoxidase (LP), which inhibit starter cultures used in cheese making. Therefore, colostrum must not be mixed with the milk at least for three days but preferably up to 15 days to avoid coagulation delays.

6.3 Natural Inhibitory Substances and Antibiotic Residues in Milk

Raw milk contains a number of natural inhibitory systems such as immunoglobulins, lactoferrin, lysozyme and LP system. Presence of such inhibitory systems in milk can influence cheese making properties, particularly starter growth and acid development. Other than these natural inhibitors, some antibiotics may also gain entry to milk as a result of the medical treatment of animals for various diseases. The presence of antibiotics again affects acid development and may also cause starter failure leading to various defects like high moisture in cheese, early and late blowing, weak and pasty body, cracks, open texture and sponginess.



Lesson 7

MICROBIOLOGICAL QUALITY OF MILK

7.1 Introduction

Cow milk is the commonly used source for cheese making all over the world. The microbiological quality of raw milk reaching the cheese factory is controlled by the following 'H' factors.

- (i) Health of the milch animal.
- (ii) Hygiene during milk production (hygiene of farm, personnel and equipments/utensils).
- (iii) Handling and refrigeration.

Clean milk secreted from the udder of the healthy animal contains only few numbers of microorganism (< 10,000/ml). Milk obtained from mastitis cow may contain high numbers of microorganism as well as leucocytes depending on the severity of infection. Maintenance of hygienic practices during milk production at farm is an important aspect of clean milk production. Cleaning and sanitization of milk contact surfaces directly determine the extent of contamination of milk after it has been drawn from the udder.

The post production hygienic handling of milk and proper refrigeration can check the proliferation of microorganisms in milk before cheese making. Milk should be held at around 4°C during transport and in cheese plant.

7.2 Microorganisms in Raw Milk

The presence and multiplication of saprophytic and pathogenic bacteria in raw milk might change the milk composition and produce toxins, and influence the quality and safety of the milk and milk products. Moreover, flavor of the raw milk may be adversely influenced and heat-stable bacterial enzymes may continue to act in products particularly during long storage and adversely affect the stability of milk and milk products. The pathogenic bacteria include 'classical' microorganisms and 'emerging pathogens'. At present *Salmonella*, pathogenic *Escherichia coli* strains, *Yersinia enterocolitica*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Campylobacter jejuni* are the most important.

According to the main points of attack on the major milk constituents, the saprophytic bacteria are subdivided as follows:

- a) Microorganisms degrading lactose are classified as glycolates, e.g. Streptococci, Lactobacilli and Coliforms
- b) Microorganisms degrading proteins are classified as proteolytes, e.g. Pseudomonas, Enterobacteriaceae, and aerobic sporeformers.
- c) Microorganisms degrading lipids are classified as lipolytes, e.g. Pseudomonas, Micrococci, Aeromonas and Corynebacteria.

The effect of growth on saprophytic bacteria in milk may be important in three ways as follows:

- a) The change in milk composition may interfere with manufacture, if fermentation is involved in the manufacture process, and this may affect the yield and quality of the product.
- b) The flavor of the raw milk may be adversely influenced (e.g. rancidity) and this may directly affect the flavor of the product e.g. Cottage cheese.
- c) Heat-stable bacterial enzymes may continue to act in the product, particularly during long storage, and adversely affect the stability and/or flavor of cream and UHT milk.

Milk is generally held at refrigerated condition for 1-3 days before processing. The milk stored under such conditions contains predominantly psychotropic bacteria (over one million/ml). The common genera encountered are *Pseudomonas*, *Aeromonas*, *Alcaligenes*, lactic acid bacteria, gram positive sporeformers, coryneform group, enterococci and coliforms. The psychotropic bacteria may further increase in number due to proliferation, especially when the temperature of the refrigerated milk increases. These conditions facilitate the release of some heat stable (surviving pasteurization) enzymes like proteinases, lipases, and phospholipases in milk which leads to proteolysis and lipolysis. Lipolysis of milk leads to rancidity that inhibits growth and activity of lactic culture because of lower surface tension or specific toxic effects of certain free fatty acids (C₈-C₁₂ fatty acids).

7.3 Somatic Cells

The milk used for preparation of cheese should be from healthy animal with a somatic cell count of < 50,000/ml. If raw milk contains > 50,000 somatic cells/ml results in phagocytosization of lactic acid bacteria (LAB) leads to slow starter activity in cheese vat, increase in rennet clotting time causing decreased curd firmness and a loose final body and texture.

7.4. Antibiotic Residues

In lactating cows, antimicrobial agents are used mostly for the therapy of mastitis but also of other diseases (e.g. laminitis, respiratory diseases, metritis). Antimicrobial agents administered to cows in the course of lactation can pass to milk in various levels and inhibit starter activity.

7.5 Disinfectants and Preservatives

Occasionally, chemical sanitizers may contaminate milk, usually as a result of human error. Quaternary ammonium compounds (QAC's) present more potential problems, because they maintain activity in milk, and LAB are sensitive to low concentrations. The amount of chemical sanitizer that might enter milk through lack of rinsing should not be sufficient to cause culture inhibition. However, problems can be encountered when sanitizer solution is not drained from tanks or trucks.

7.6 Bacteriophages

Bacteriophages (phages) are viruses that infect bacteria. Bacteriophagic infection of starter cultures can result in failure of the fermentation and loss of product. Despite implementation of control measures, bacteriophagic infection still causes production problems in the modern dairy fermentation industry.

7.7 Raw Milk Associated Inhibitors

Lactic starter cultures grow more slowly in raw than in heated milk; a phenomenon caused by the presence of natural inhibitors. The lactoperoxidase system is the most significant microbial inhibitor in raw milk, but the presence of agglutinins is an important problem in acid-coagulated cheeses. Other naturally occurring microbial inhibitors in milk include lysozyme and lactoferrin.

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*Module 4. Pretreatments of milk for cheese making***Lesson 8****CHILLING, STORAGE, CLARIFICATION AND BACTOFUGATION****8.1 Introduction**

For centuries, milk for cheese making had been subjected to no pre-treatment before curdling, and many cheese varieties worldwide are still made from raw milk. However, predominantly for reasons of safety, but also for consistency of quality and manipulation of product characteristics, most cheese making today involves the treatment of milk by one or more processing steps prior to addition of coagulant and starter culture. Perhaps the simplest and earliest technological intervention, driven by safety concerns, was the pasteurization of milk. Pasteurisation inactivates some enzymes, reverses shifts in the mineral balance of milk and influences the microflora of non-starter lactic acid bacteria (NSLAB) in the final cheese. Pasteurization unacceptably impairs the cheese flavor as a result of its influence on NSLAB. On the other hand, more severe heat treatments than pasteurization result in significant denaturation of whey proteins and their resulting incorporation into cheese curd, with significant effects on cheese yield and composition. This chapter deals with the effect of the various treatments given to milk on cheese quality.

8.2 Chilling and Cold Storage

Raw milk is sometimes cooled to about 4°C and stored in refrigerated tanks or storage tanks prior to its conversion into cheese. This practice of storing milk at refrigerated temperature not only increases the possibility of growth of psychrotrophs but also alters the physico-chemical properties of milk components like casein and minerals. Due to these alterations, many properties change significantly like rennet coagulation time, firmness, moisture retention etc. Rennet coagulation time increases, firmness decreases and moisture retention increases due to cold storage of milk. The impaired technological properties as a result of chilling and cold storage of the raw milk can be improved by adopting measures such as:

1. Acidification of cheese milk with lactic acid to pH 6.5
2. Addition of calcium chloride @ 0.02%
3. Addition of more rennet within permissible limits
4. Use of higher renneting temperature
5. Use of higher cooking temperatures

Among all above stated measures, first two have been found to be most effective.

8.3 Clarification

Clarification is one of the centrifugal processes used in dairy industries. It is used to remove leukocytes, cellular debris and particles from earth or fodder gaining entry into milk. Centrifugation of milk by the clarifier removes much of the small sized particles in milk, having a specific gravity higher than 1.032, particularly dirt, cells and larger microorganisms if they are present in clumps. Clarification decreases the tendency of fat to form aggregates on standing, increases the rate of multiplication of starter organisms, may increase the fat losses in whey and may also decrease the moisture and yield of cheese. Due to the removal of anaerobic sporeformers, marked improvement in cheese quality has been recorded.

8.4 Bactofugation

Bactofugation is a physical process through which bacteria are removed from milk, the size and density of bacteria being the criteria for their removal. The other factors deciding the efficiency of bactofuge to remove bacteria are initial bacterial load, pre-treatment of milk, throughput of machine, volume of bactofugate to throughput, frequency of partial desludging and duration of the run. Bactofuge is a clarifier with one inlet for raw milk and one outlet for treated milk. There are 2-4 nozzles fitted into the bowl wall for the discharge of skim milk. Bacteria are subjected to a centrifugal force of the order of 7000- 9000 G. The process is also able to remove the heat resistant spores which otherwise are not removed by any other thermal process.

The bactofuge system has been used in the cheese industry where its high-cleaning capabilities have been used to remove spores from cheese milk that could cause late fermentation in semi-hard cheeses.

Effect of bactofugation on cheese making may be summarized as follows:

- Effective method for preventing late blowing defect in semi-hard or hard varieties of cheeses. It is mainly due to removal of anaerobic microorganisms
- Facilitates reduction or elimination in the use of nitrates (nitrates are added to prevent 'late fermentation' in cheese)
- Weakens the coagulum during cheese making which can be overcome by addition of calcium chloride.

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Lesson 9

MEMBRANE PROCESSING OF MILK FOR CHEESE MAKING

9.1 Introduction

Membrane separation processes are commonly applied to separate a liquid under a pressure gradient through a semi-permeable membrane into two liquid streams of different composition, the permeate (which flows through the membrane) and the retentate (which concentrates those substances which do not pass through the membrane in a reduced volume of fluid). These processes are applied in dairy processing for an ever-increasing range of applications, e.g. concentration, demineralization, protein separation, or removal of bacteria.

9.2 Ultrafiltration

Ultrafiltration (UF) enables concentration of casein content and recovery of whey proteins for cheese manufacture. UF of milk at pH 6.6–6.8 concentrates mineral salts bound to casein micelles in the same proportion as proteins and increases buffering capacity, which affects acidification, pH, rennet coagulation and rheological characteristics of curd. Acidification before or during UF and/or salt addition to retentate leads to solubilisation of colloidal calcium in the permeate.

As a result of UF of milk, globular fat, caseins, whey proteins and micellar salts, are selectively concentrated in the UF retentate, whereas lactose, serum salts and peptides, are found largely in the UF permeate at their original concentration. This has two major implications for cheese making properties of milk:

- (1) The inter-micellar mean free distance is reduced considerably, thereby forcing the micelles to interact more frequently with each other as a result of collisions induced by Brownian motion.
- (2) The buffering capacity of the milk is increased considerably due to the increased concentrations of proteins and micellar minerals in the UF retentate, both of which are key contributors to the buffering capacity of milk, particularly in the pH region 5.5–7.0.

As a result of these changes, the cheese making properties of UF retentates differ from those of unconcentrated milk in several aspects. RCT decreases and firmness increases when cheese milk is partially supplemented with UF retentate. Cheese made from UF retentate is often characterized by a long time required to reach the desired pH and an acidic taste which is related to the higher buffering capacity of a UF retentate. Furthermore, flavour development in hard and semi-hard cheese made from UF retentate is generally slow, which has been related to a reduced rate of proteolysis of caseins during ripening of such cheese, probably resulting from retention of inhibitors of chymosin and plasmin in the UF retentate.

9.3 Microfiltration

Microfiltration (MF) may be used for partial microbial decontamination of cheese-milk and standardization of the casein content of milk, rather than the total protein content that is standardized by UF. Cheese prepared from microfiltered milk may lack flavour development due

to absence of flavour producing organisms during ripening as they are filtered out in permeate during MF. MF uses larger pore sizes and lower pressures than UF. Whey proteins are smaller molecules (3 to 5 μm) compared to casein micelles (15 to 600 nm) and can be separated by use of 0.1 to 0.2 μm pore size membranes. This separation produce casein-enriched retentate and permeate containing significant amounts of native state α -lactalbumin and β -lactoglobulin. Casein-enriched milk prepared by MF has been reported to have improved rennet coagulation properties and reduced loss of fat and fines in the whey. Increasing MF concentration factor result in increased moisture, protein and calcium contents, total solids recovery, actual and composition-adjusted cheese yields, proteolysis and flavour and decreased hardness.

9.4 Standardization of Cheese-Milk by Protein Addition

Standardization of milk protein/casein levels may be used to reduce some negative defects associated with a seasonal milk supply such as variable protein/casein contents which result in poor curd-forming properties and in variations in yield and in composition and consistency of resultant cheeses. Increased yield results from reduced losses of fat and casein particles in whey and better retention of whey proteins in the aqueous phase of cheese. Furthermore, standardisation of milk protein to higher than normal levels enables increased plant throughput without installation of extra cheese vats. Protein standardization may be achieved by: use of low-concentrated retentate (LCR) produced by UF or Reverse Osmosis (RO) of cheesemilk; enrichment of casein by MF; or addition of phosphocasein powder (PC) or milk protein concentrate (MPC), typically followed by cheese manufacture using conventional equipment. Standardization of cheese is normally done to a casein/fat ratio of 0.70:1.0.

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Lesson 10

HEAT TREATMENT AND HOMOGENIZATION OF CHEESE MILK

10.1 Introduction

Most cheese-making today involves the treatment of milk by one or more processing steps prior to addition of coagulant and starter culture. Perhaps the simplest and earliest technological intervention, driven by safety concerns, was the pasteurization of milk. Pasteurisation inactivates some enzymes, reverses shifts in the mineral balance of milk and influences the microflora of non-starter lactic acid bacteria (NSLAB) in the final cheese. Pasteurization unacceptably impairs the cheese flavor as a result of its influence on NSLAB. On the other hand, more severe heat treatments than pasteurization result in significant denaturation of whey proteins and their resulting incorporation into cheese curd, with significant effects on cheese yield and composition.

10.2 Heat Treatments

Milk for cheese manufacture is heated to eliminate pathogenic bacteria, to minimise damage to caseins by proteolytic bacteria on storage or to incorporate heat-denatured whey proteins in curd, thereby improving cheese yield. Furthermore, more severe heat treatment of milk may be applied to inactivate spores from *Clostridium tyrobutyricum*. Heat treatment of milk at conditions severe than those used for conventional pasteurisation results in denaturation of whey proteins, interactions between whey proteins and casein micelles and transfer of soluble calcium, magnesium and phosphate to the insoluble colloidal state. Casein micelles are very stable at high temperatures, although changes in zeta potential, size, hydration of micelles and some association-dissociation reactions do occur under severe heat treatments. Denaturation of whey proteins exposes side chain groups originally buried in the native structure, particularly reactive thiol groups, and the unfolded proteins may self-aggregate or interact with casein micelles, through interactions with κ -casein. The extent of association of denatured whey protein with casein micelles is dependent on the pH of the milk prior to heating, levels of soluble calcium and phosphate, milk solids concentration and mode of heating (direct or indirect). For cheese-makers, the principal interest has been in increasing yield by exploiting this heat-induced association of caseins with whey proteins, while attempting to minimise undesirable changes in cheese quality.

In the cheese vat, high heat treatment of milk prolongs rennet coagulation times and reduces the strength of rennet gels leading to impaired syneresis. The adverse effects on coagulation are attributed to the inhibition of hydrolysis of κ -casein by chymosin due to the β -lactoglobulin/ κ -casein complex at the micelle surface impairing the accessibility of κ -casein to the coagulant, to reduced reactivity of renneted micelles with attached denatured whey proteins to aggregation, or to a reduction in the concentration of micellar calcium.

10.3 Homogenization of Cheese-Milk

The primary aim of homogenization of milk is to reduce the size of the fat globules, thereby delaying their creaming rate. In raw milk, fat globule size commonly ranges from 0.2–15 μm , and

homogenization generally aims to reduce the maximum to $< 2 \mu\text{m}$. For this purpose, two-stage valve homogenizers are used, which operate at pressure of 20 MPa. Recently, novel homogenization devices, e.g. high-pressure homogenizers and microfluidisers, which can operate at pressures of several hundred MPa and achieve greater reductions in fat globule size, have been developed. In cheese making, homogenization of cheese milk can be of interest for preventing creaming of fat globules, reducing fat losses in the whey or controlling development of free fat in the cheese. Due to the reduction in fat globule size on homogenization, the total surface area of the fat globules increases and the amount of original fat globule membrane material is by far insufficient to fully cover the newly-formed surface. As a result, other surface-active components of milk, primarily caseins and, to a lesser extent, whey proteins, become adsorbed onto the surface of the newly formed globules. Thus fat globules in homogenized milk almost resemble casein covered emulsion droplets. The adsorption of caseins onto the fat globules has the following implications for cheese-making characteristics of milk:

- (1) Casein surface area in milk is increased, but the amount of micellar casein is reduced;
- (2) Two types of particles with a casein micelle surface layer exist: native casein micelles and casein-covered fat globules;
- (3) When adsorbed, casein micelles tend to spread over the surface of the fat globule and hence increase in effective surface area but with reduced surface density of κ -casein.

The rennet coagulation time (RCT) of unhomogenised milk is generally lower than that of homogenized milk. This is probably related to the larger casein surface area in homogenized milk, as well as the lower surface density of κ -casein. The former increases the probability of interactions between particles, whereas the latter reduces the amount of κ -casein that needs to be hydrolyzed before micellar flocculation is induced. Negative aspects of homogenization occur in the subsequent stages of cheese making, i.e., the syneresis of the paracasein matrix and the fusion of the paracasein micelles into a strong and cohesive network. Cheese curd from homogenized milk shows poor syneresis and, as a result, has high moisture content. Furthermore, cheese curd prepared from homogenized milk is also often characterized by a coarse and brittle structure.

10.4 High-Pressure Treatment of Cheese milk

Cheese prepared from raw milk is better than the cheese manufactured from pasteurized milk but for safety reasons, pasteurization of milk before cheese making is essential. High pressure treatment (HPT) of milk can be used as an alternative to pasteurization so that raw milk quality cheese can be produced without compromising safety aspects. High pressure treatment is a non-thermal process wherein a high pressure in the range of 200 to 1000 MPa for different time periods is used for destruction of microorganisms.

HPT of milk causes several protein modifications such as whey protein denaturation and micelle fragmentation and alters mineral equilibrium. These changes improve rennet coagulation of cheese milk and yield of cheese. HPT of milk results in smaller casein micelles due to which RCT decreases. Cheese yield increases owing to denaturation of whey proteins by HPT (resulting in their incorporation in cheese curd), which also leads to increased moisture retention.



*Module 5. Cheese additives***Lesson 11****CHEESE ADDITIVES AND PRESERVATIVES****11.1 Introduction**

In addition to certain major processing aids such as starter bacteria, internal and external molds and coagulants, various additives used in the manufacture of cheese serve as manufacturing aids. Some of them also prevent fermentation faults (e.g. late blowing).

11.2 Salts to Restore the Calcium Balance in Milk

Calcium in milk is present as soluble, colloidal and complexed forms in a very delicate balance. Successful coagulation depends on this balance of calcium. Sometimes the balance among the three different forms is disturbed due to heat treatment, cooling or disturbances in milk itself (colostrum, late lactation, mastitis). In such cases it has become a common practice to add calcium salt, usually calcium chloride, to milk. This is especially necessary when some of the vegetable or microbial coagulants are used. Other calcium salts which can be added include calcium lactate and calcium hydroxide. They are in the form of a solution. Bovine milk contains 0.123% calcium while maximum clotting advantage occurs at a concentration of 0.142%. Therefore, addition of 0.02% calcium chloride is suggested. If excess is added, α_s casein- κ casein complex dissociates and the α_s casein no longer has the protection from the κ casein and a precipitate forms. Slightly less calcium chloride will produce a harsh inflexible curd. Rarely is more than 0.02% of calcium chloride needed for satisfactory coagulation even when using highly heated milks. Retention of too much calcium chloride, apart from producing a hard unyielding curd, produces a cheese which is bitter in flavor and with a harsh body.

11.3 Salts Inhibitory to Undesirable Organisms

Salts like potassium nitrate, sodium hydrogen carbonate, calcium carbonate, mono-sodium dihydrogen phosphate and nisin are added to arrest the growth of undesired microorganisms. These are commonly added in some of the less acid curd cheese like Edam, Gouda etc. mainly to prevent the growth of gas producing organisms which cause 'blown' defect in cheese. Nitrate in combination with salt has been used to control the gas forming butyric acid bacteria and at the same time, it does not have any affect on the growth of lactic and propionic acid bacteria. But the use of nitrates in cheese is limited due to two main reasons:

1. Certain amino acids react with nitrite to produce color defects
2. Production of nitrosamines which are carcinogenic

Nisin may be used in processed cheese to inhibit the activity of gas producing organisms but not in natural cheese, because the bacteria present in natural cheese destroy the activity of nisin.

Sorbic acid is used to inhibit the growth of yeasts, molds and some bacteria. However, its activity against bacteria is not as comprehensive as that against yeasts and molds.

11.4 Use of Common Salt (NaCl)

Salt normally used in cheese making is about 2% of the weight of the curd. Salt is added to cheese:

- a. To suppress growth of unwanted micro-organisms,
- b. To assist the physico-chemical changes in the curd,
- c. To slow down the growth of the lactic acid and other types of unwanted microorganisms,
- d. To give the cheese an appetizing taste.

Specification

Common salt contains 99.6% NaCl on moisture-free basis limits are given for alkalinity (0.03% Na_2CO_3), insoluble matter (0.03%), sulfide (0.3% Na_2SO_4), iron (0.001%), copper (0.002%), arsenic (0.0001%), lead (0.0005%), calcium (0.1%), and magnesium (0.01%) dried salts should pass completely through an 18-mesh sieve.

Effect of quality of salt on cheese:

- 1) Use of impure salts results in faulty color in presence of iron, copper and lead. The fault could be avoided by acidifying the brine to pH 5.0 with lactic acid.
- 2) Fine salts may increase the rate of loss of whey and thus protein and fat from the curd.

Effect of quantity of salts on cheese:

- 1) Exert an appreciable effect on growth of molds in blue veined cheese.
- 2) Low concentration stimulates most microorganisms and some enzymes.

11.5 Acidulants

The most common acidulant used in cheese making is lactic acid, which is produced in situ by lactic acid bacteria present naturally in milk. Pure defined cultures of lactic acid bacteria (LAB) can also be used. However, the use of acids for chemically acidifying the milk is also practised. Acids of food grade quality (e.g. lactic, glacial acetic, lemon juice, vinegar, D-glucono-delta-lactone, phosphoric) are used to increase the acidity of milk.

- Glacial acetic acid (12.5% concentrated acid @ 2.7% of milk) is used in Queso Blanco cheese and vinegar (0.03%) for mozzarella cheese manufacture.
- Lime juice is used in India to manufacture Bandal cheese, paneer and channa.
- D-glucono-delta-lactone when heated produces acid and it has been used for the production of acid in milk and curd. The cheese made by using this acidulant is bland and lacks flavor as no enzymes are formed in this process.

- Phosphoric acid (10% strength) is diluted @ 4 l in 40 l of water and then added to 1000 l of milk with vigorous stirring.

11.6 Colors and Bleaching Agents

The color of the product is an important factor in the consumer appeal of the product. It is a common practice to add extra color to pale colored milk to give cheese an attractive and appetizing appearance. The colors of importance in milk are riboflavin and carotenoids. Riboflavin is yellow in solution with a green-yellow fluorescence and tends to give curd a greenish tinge. However, most of this color is lost in whey as riboflavin is water soluble. Therefore, its effect as color in cheese is small. The deep yellow orange color due to carotenoids is more significant. As there is a large seasonal variation in color of milk, colors are added to obtain uniform color in cheese. Annatto is, by far the most widely used color. It is extracted from seeds of a plant *Bixa orellana* in sodium hydroxide. The pigment in annatto is the acid bixin which, in the alkaline extract becomes norbixin. The color is composed of tints of yellow and red units, and in cheese, becomes a protein dye attached to the casein. Annatto is very susceptible to oxidation. Agents such as H_2O_2 , air, -SH groups in ripening cheese and copper and iron act as catalysts in oxidation of annatto pigment. Thus, bleaching of the red color in patches in cheese is frequently found in poor quality, moist or contaminated curd.

Sometime it becomes desirable to bleach the color to meet the market demand particularly in traditional products. For example the customers expect Mozzarella cheese to be white as it is made from buffalo milk. In case cow milk has been used, it will yield a yellow product. In such cases bleaching agents may be added to milk. Benzoyl peroxide, H_2O_2 and other color masking agents are used for this purpose.

11.7 Flavors, Spices and Herbs

There are two groups of flavoring agents which are added to cheese: (a) those which are added for imparting flavor to the cheese (herbs and spices), and (b) those flavors which are nutritive foods in their own right (ham, meats etc.), which are enclosed in the cheese which serves simply as a soft enclosing base.

Chopped herbs, or their juices, or dried crust semi powders have been used to impart flavor and aroma in cheese curds. The herbal mixes are incorporated in the raw cheese at moulding time before pressing, or are mixed with partially or wholly ripe curds pressed into shapes or containers. Spices which have been used include aniseed, caraway seed, cloves, cumin, cinnamon, ginger, nutmeg, pepper etc. Herbs used in cheese include mint, sage, lavender, chives etc.

11.8 Smokes

Certain cheeses are exposed to a smoke-charged atmosphere for smoky flavor development. It causes fat to melt and come out the surface of the cheese block, and no moisture to evaporate. Incorporation of smoke vapors containing phenolic substances has preservative effect and also impart typical flavor to cheese. Sometimes cheese is dipped in liquid condensed smoke.

11.9 Addition of Beverage

Alcoholic beverages, beers, wines and liquors have been added to the raw cheese curd or alternatively, the whole cheese has been immersed in the liquid. The mixing of flavors, vegetables,

spices, meat, etc. seems to break with tradition to satisfy the taste of modern society particularly for snack foods.

11.10 Cheese Bases

The use of a bland cheese base along with a filling of herbs, vegetables and chopped cooked meats is probably a spillover from the use of processed cheese in the similar manner. The typical mixtures use cheese as a base, with the addition of lettuce, chives, onions, spinach, potatoes, carrots, chopped ham etc.

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*Module 6. Role of starter culture in cheese making***Lesson 12****STARTER CULTURES****12.1 Introduction**

The use of starter cultures is an essential requirement in the manufacture of most cheeses. A cheese starter may be defined as a milk culture containing selected lactic acid bacteria, usually *Lactococcus lactis* subsp. *lactis*, *Lc. lactis* subsp. *cremoris*, *Lc. lactis* subsp. *diacetylactis*, which convert about 1% (absolute) of lactose in milk almost entirely to lactic acid, along with very little amounts of byproducts such as acetic acid and carbon dioxide. Acid production at an appropriate rate and time are the key steps in the manufacture of good quality cheese.

Milk sours on storage, but if the milk is heated, the souring is delayed because the acid-producing bacteria present in milk are destroyed by heat treatment. The course of deterioration then becomes not a clean, wholesome souring, but a change which may include souring but also often produces taints, protein and fat break down and sometimes even putrefaction. It is, therefore, essential to re-inoculate heated milk with acid producing organisms if clean, sour milk is desired. Starter cultures are intentionally added to cheese milk to initiate and accomplish the desired fermentation. It ensures consistent souring at a controllable rate, gives desired clean lactic flavor and helps to suppress any tendency for taint-producing microorganisms to grow in milk. Acid production affects several aspects of cheese manufacture, e.g.

1. Denaturation and retention of the coagulant in the curd during manufacture and hence the level of residual coagulant in the curd. This influences the rate of proteolysis during ripening and may affect cheese quality.
2. Curd strength, which influences yield.
3. Extent of dissolution of colloidal calcium-phosphate.
4. Gel syneresis, which controls cheese moisture and hence regulates the growth of bacteria in the cheese. Consequently it strongly influences the rate and pattern of ripening and the cheese quality. Acid production, combined with milk heating and stirring of curd-whey mixture causes the casein curd to shrink and expel moisture from the coagulum.
5. The rate of pH decrease determines the extent of dissolution of colloidal calcium phosphate which modifies the susceptibility of the caseins to proteolysis during manufacture and influences the rheological properties of cheese, e.g. textural differences among Emmental, Gouda, Cheddar and Cheshire cheeses.
6. Acidification controls the growth of many species of non-starter bacteria in cheese, especially pathogenic, food poisoning and gas producing microorganisms. In addition to producing acid, many starter bacteria produce probiotics which also restrict or inhibit the growth of non-starter microorganisms.

7. Starter organisms govern flavors and body and texture of cheese.
8. Acid production influences favorably the changes that take place in the curd during cheddaring.
9. Growth of LAB produces the low oxidation-reduction potential (Eh) necessary for production of reduced sulphur compounds such as methanethiol which may contribute to the aroma of Cheddar cheese.

12.2 Requirements of a Good Starter

- It must be vigorous, and produce acid at a quick, consistent and controlled rate.
- It must produce a clean lactic acid flavor and other aroma.
- Must not produce any off flavor, taint, pigment or gas. There must be no appreciable proteolysis or lipolysis.
- Must contain only lactic acid bacteria of desired type.
- It must produce acidity smoothly under the conditions of manufacture.

12.3 Type of Cultures

Essentially two types of starter cultures are used: Mesophilic milk an optimum temperature of ~30°C and thermophilic milk an optimum temperature of ~45°C. The choice of culture depends on the cheese being made, e.g. mesophilic cultures are used in the production of Cheddar, Gouda, Edam, Blue and Camembert while thermophilic cultures are used for Swiss and Italian varieties (Table 12.1). This choice is related to the method of manufacture since Swiss and Italian cheeses are cooked at much higher temperature (50-55°C) which the starter bacteria must be capable of withstanding. Growth at 10 and 45°C can be used to distinguish mesophilic from thermophilic cultures while microscopic observations, measurement of the amount and isomer of lactic acid produced and the ability to metabolize citrate can readily distinguish most of the species within these broad categories. Both mesophilic and thermophilic cultures can be further subdivided into mixed (undefined) cultures, in which the number of strains is unknown and defined cultures in which the member of strains is known.

Table 12.1 Starter cultures used in major cheese varieties

Cheese	Bacteria
Cottage, Camembert	<i>Lactococcus lactis</i> subsp. <i>Lactis</i> , <i>Lactococcus lactis</i> subsp. <i>cremoris</i> , <i>Leuconostoc mesenteroides</i> subsp. <i>cremoris</i>
Gouda	<i>Lactococcus lactis</i> subsp. <i>lactis</i> , <i>Leuconostoc mesenteroides</i> subsp. <i>cremoris</i>
Cheddar	<i>Lactococcus lactis</i> subsp. <i>Lactis</i> , <i>Lactococcus lactis</i> subsp. <i>cremoris</i>
Emmental	<i>Streptococcus thermophilus</i> , <i>Lactobacillus helveticus</i> , <i>Lactococcus</i> <i>lactis</i> subsp. <i>bulgaricus</i> , <i>Propionibacterium shermanii</i>
Parmesan	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> , <i>Streptococcus</i> <i>thermophilus</i> , <i>Lactococcus lactis</i> subsp. <i>lactis</i> , <i>Lactococcus lactis</i> subsp. <i>cremoris</i>

12.3.1 Mixed strain mesophilic cultures

Undefined or mixed-strain mesophilic cultures are composed mainly of *Lc. lactis* subsp. *cremoris*, although occasionally they also contain the closely related *Lc. lactis* subsp. *lactis*. Some mesophilic mixed cultures also contain a lactococcus (*Lc. lactis* subsp. *diacetylactis*) which metabolizes citrate (Cit⁺) to CO₂ and flavor compounds. Thus, many mesophilic cultures are comprised of Cit⁻ and Cit⁺ lactococci. Depending on the nature of the flavor producers, mesophilic mixed cultures are classified as: L-type, containing leucococcus spp; D- type, containing Cit⁺ lactococci (diacetylactis), DL- type containing both, and O-type containing no flavor producers. The flavor producers use citrate as energy source. The acid and flavor producers in mesophilic cultures comprise about 90% and 10% of the microflora respectively. They are called mixed cultures not only because they contain different bacterial species but also because they contain different strains of the same species.

Mixed starters consist of two or more strains or species and so may be more variable in behavior. These are safer to use because if one strain becomes phaged, others can usually continue to work. However, it is difficult to maintain a constant mixed starter because one strain becomes dominant after a few transfers. Therefore, each strain should be cultured separately, and mixed immediately before addition to the vat.

12.3.2 Defined strain mesophilic cultures

These are mainly pure cultures of *Lc. lactis* subsp. *cremoris*. The important differences between these cultures and traditional mixed cultures are that the number of strains is known and they do not contain flavor producers.

Single strain starter is a pure culture usually consisting of either *Lc. lactis* subsp. *lactis* or *Lc. lactis* subsp. *cremoris*. This type of culture has the advantage that if found satisfactory in vigor and flavor, it can give a steady acid production and thereby a predictable quality fermented dairy product. However, there is serious disadvantage as well with this type of starter. During its application, if it gets attacked by phage or fails by any other reason the quality of the product can be adversely affected.

Other bacterial species are sometimes incorporated into a dairy starter cultures and these are as follows:

1. *S. faecium*: for manufacture of modified Cheddar cheese.
2. *Brevibacterium linens*: Imparts distinctive, reddish orange color to the rind of Brick and Limburger cheese.
3. *Propionibacterium freudenreichii* subsp. *shermanii*, for Swiss cheese; produces large gas holes in cheese.

Molds like *Penicillium camemberti*, *P. caseiocolum* and *P. candidum* and the blue mold *P. roquefortii*, which grows internally in the cheese are used in Blue cheeses like Roquefort, Blue stilton, Danish blue, Gorgonzola and Mycella.

Most cultures are used in dairy industry either singly, in pairs or in a mixture, thus, giving the industry the opportunity to manufacture different types of fermented dairy products. In theory, a

single strain starter consists of one type of organism but in practice, it is rarely used. However, single strains can be paired to safeguard against bacteriophage attack, intolerance of salt, or cooking temperature and variation in the quality of the product. Multiple strain starter cultures consist of known member of single strains, so that the starter can be used for an extended period of time during cheese making season. A mixed strain starter is a combination of *Lc. lactis* subsp. *lactis*, *Lc. lactis* subsp. *cremoris* and the gas and aroma producing mesophilic LAB (*Lc. lactis* subsp. *diacetylactis*, *Lc. lactis* subsp. *cremoris* and/or *Leuc. dextranicum*).

12.4 Factors Affecting Activity of Starter Culture

- Temperature
- pH
- Strain compatibility
- Growth medium inhibitors
- Bacteriophage
- Incubation period
- Heat treatment of milk
- Degree of aeration (aeration, agitation and surface culture not favorable)
- CO₂ (minimum concentration is essential)
- Storage conditions

12.5 Desired Characteristics

Good starter should show a smooth curd. At the completion of the incubation, there should be no separation of the whey from the curd. After the cooled starter has been stirred or shaken, it should have the consistency of rich cream. It should be glossy in appearance and not dull or chalky. The starter should show no curd particles or lumps, and when poured from the container it should not show a ropy consistency. The flavor should be pronounced, yet delicate. Neither a flat flavor nor a sharp acid taste is desired.

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Lesson 13

PROBLEMS ASSOCIATED WITH CHEESE STARTERS

13.1 Introduction

Starter trouble has been known since the beginning of cheese technology, but it has only become acute since pasteurization of milk has been practiced for cheese making. This is not because pasteurization 'weakens' the milk, but because bulk raw milk is a starter itself; some lactococci will always grow and sour the milk. In pasteurized milk, if for any reason the starter fails, there are too few lactococci left in the milk to permit souring. As already emphasized in the previous lesson, a good starter must produce lactic acid at a vigorous and steady rate. When it no longer does so, the starter is said to be slow or defective.

13.2 Defects in Starter

Sharp acid taste: It is due to over-incubation (due to higher temperature and longer time) of milk and increased rate of inoculum.

Bitter taste: This may come from milk.

Cheesy flavor: This may be due to growth of undesirable bacteria.

Flat flavor: This is caused by less citrate in milk, less number of citrate fermenting organisms or unfavorable incubation conditions for the growth of citrate fermenting organisms.

Uncoagulated starter: This is due to too low/high incubation temperature of starter or poor activity of mother culture or due to the presence of bacteriophage and antibiotics.

Gassiness: This is due to improperly pasteurized milk, post-pasteurization contamination of milk, unsterilized transfer equipment and/or contaminated mother culture.

13.3 Bacteriophage

Phages are viruses or ultra-microscopic organisms, specifically parasitic on bacteria. Bacteriophage causes lysis or destruction of bacteria and can be transmitted from one culture to another. Lysis of bacteria by phages involves the attachment of the phage particles to the cell wall, which is then digested to permit entry and multiplication of the phage in the bacteria.

Preventive measures against phage attack:

- There are two sterilization methods of combating phage in cheese premises: the use of heat or chemicals. Neither method is fully effective unless the plant surfaces and equipment are thoroughly clean.

- Contamination by droplets of moisture containing phage should be avoided in the vicinity of cheese or starter rooms (curd and whey separation).
- Cracked floors should be repaired.
- Hypochlorite solution should be sprayed/ applied on the interfaces of the equipment (20-50 ppm for overnight or 200-300 ppm for immediate use of the equipment).
- Starter cultures should be used in rotation.
- Phage-resistant and/ or mixed-strain starters can be used.

13.4 Causes of Slow Starters

1. Spontaneous loss of viability inherent in the starter culture.
2. Incompetence in the handling of starter
 - Allowing contamination
 - Too infrequent sub-culturing
 - Use of unsuitable media
 - Culturing at inappropriate temperature.
3. Inhibitory causes in the milk itself
 - Abnormal milk
 - Silage milk
 - Seasonal factors
 - Conditions in milk adverse to the growth of organism e.g. changes in chemical composition
 - Inhibitory bacteria in milk
 - Inhibitory substances in milk
 - Excessive leucocytes
 - Presence of antibiotics
 - Presence of preservatives
4. Deviation from standard cheese making procedure
5. Bacteriophage action

13.5 Causes of Starter Failures

13.5.1 Intrinsic factors

a) Physiological starter: LAB produces lactic acid at the rate of 10% of their weight. This rapid production of acid, though advantageous in the manufacture, is a marked disadvantage to culture itself.

b) Genetic instability: LAB spontaneously produces mutants which are unable to utilize lactose and become deficient in protease activity. Consequently, they do not grow properly in milk.

13.5.2 Extrinsic factors

a) Variations in processing conditions e.g. temperature, salting rate, etc.

b) Variations in milk composition e.g. due to mastitis, mineral content, period of lactation, etc.

c) Variations in levels of natural and added inhibitors e.g. bacteriophage, antibiotics, detergents and sanitizers etc.

d) Mastitis:

- Changes the chemical composition of milk: decrease in lactose, casein, calcium and acidity
- Changes concentrations of some enzymes, vitamins and bacterial growth factors
- Increases the number of bacteria
- Produces substances toxic to starter organisms

e) Colostrum - Milk drawn up to 24 h after calving does not promote growth.

f) Late lactation - Changes the chemical composition of milk in terms of decreased lactose and increased chlorides.

g) Excessive aeration - LAB grow and multiply on energy derived from the breakdown of milk sugars. This is an anaerobic process. Also, some bacteria are provided with a mechanism which can convert the oxygen of the air to H_2O_2 which in turn is strongly toxic to LAB. Aeration reduces the CO_2 which stimulates growth of many contaminants.

h) Inhibitory bacteria: A large member of microorganisms can produce chemical substances which are inhibitory.

13.6 Natural Inhibitory Substances in Milk

13.6.1 Antibiotics in milk

Widespread use of penicillin and other antibiotics may lead to the animals, under treatment, excreting antibiotics in their milk to be a cause of starter inactivity. Antibiotics may also be

produced by the starter organisms themselves, by one or more strains in a mixed starter culture or by contaminating microorganisms.

13.6.2 Inhibitions by rancid milk

Raw milk rapidly turns rancid, unless cooled quickly because of the presence of an abnormal concentration of lipase. Such rancid milk may be inhibitory to LAB and other microorganisms. Fatty acids (C₈-C₁₂) exert specific effect on the growth of microorganisms.

13.6.3 Lactenins

Lactenins (L1 and L2) are present as natural inhibitory substances in milk. They are inactive under anaerobic conditions and in the presence of -SH compounds. The presence of both fractions is necessary for maximum inhibition, and even then the effect is bacteriostatic rather than bactericidal. Lactenins are destroyed by heating at 74°C/20 min.

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*Module 7. Rennet preparation and properties***Lesson 14****CALF RENNET: PREPARATION AND PROPERTIES****14.1 Introduction**

Rennet is a complex of enzymes produced in any mammalian stomach to digest the mother's milk. Rennet contains many enzymes, including a proteolytic enzyme (protease) that coagulates the milk, causing it to separate into curd and whey. The active enzyme in rennet is called chymosin or rennin but there are also other important enzymes in it, e.g. pepsin and lipase. There are non-animal sources for rennet also that are suitable for vegetarian consumption.

Natural calf rennet is extracted from the inner mucosa of the fourth stomach chamber (the abomasum) of young, unweaned calves. If rennet is extracted from older calves (grass-fed or grain-fed) the rennet contains less or no chymosin but a high level of pepsin and can only be used for special types of milk and cheeses. As each ruminant produces a special kind of rennet to digest the milk of its own species, there are milk-specific rennets available, such as kid goat rennet for goat's milk and lamb rennet for sheep's milk.

14.2 Enzymes in Rennet

Rennin is an enzyme which can function very powerfully as a clotting agent at pH 6.2 to 6.4. The term chymosin is used in place of rennin to avoid confusion with another enzyme renin, which can be extracted from the kidney. The ratio of clotting to proteolytic power of chymosin/rennin is very high. Conversely, the other enzyme pepsin, functions best at high acidities (pH 1.7-2.3) and the ratio of clotting to proteolytic power is lower. All proteolytic enzymes can clot milk but the specific value of rennet in cheese making is that it gives rapid clotting without much proteolysis. Proteolysis by enzymes like pepsin, papain etc. can lead to bitterness in cheese.

The rennet extract from the young milk-fed calf contains 88-94% rennin and from 6-12% pepsin, while in extracts from the older fodder eating bovine, it is almost reverse i.e. 90-94% pepsin and only 6-10% rennin. So, there is variable amount of pepsin in rennets depending on the age and food of the calf from which the rennet is obtained.

14.3 Preparation of Rennet**14.3.1 Traditional method**

Dried and cleaned stomachs of young calves are sliced into small pieces and then put into saltwater or whey, together with some vinegar or wine to lower the pH of the solution. After some time (overnight or several days), the solution is filtered. The crude rennet that remains in the filtered solution can then be used to coagulate milk. The enzyme present at this stage is called prorennin which on acidification, becomes rennin with an increased clotting ability. About one

gram of this solution can normally coagulate 2 to 4 litres of milk. This method is still used by some traditional cheese-makers, e.g. in Switzerland, France, Romania, Italy, Sweden, United Kingdom and Alp-Sennereien in Austria.

14.3.2 Modern method

The commercial enzyme is prepared from the fourth stomach (abomasums) of the calf, known as the vell. The lining of the stomach is washed, dried, cut into small pieces and macerated in water containing about 4% boric acid at 30°C for about 5 days. Alternately, a brine extract at 15-20°C can be prepared. A common method is to dry the vells by inflation and afterwards cut them into strips and extract with sodium chloride solution (up to 10%) for few days. Crude rennet extract contains active rennin as well as inactive precursor (prorennin). Addition of acid to the extract facilitates conversion of the prorennin to rennin and allows the extract to reach maximum activity. Finally, the activated rennet is standardized with respect to activity, salt concentration, pH and colour. Liquid rennet is usually preserved by a high salt content (14-20%) and by the addition of preservatives such as sodium benzoate and propylene glycol. Rennet powders are prepared from precipitates obtained by acidifying activated extracts or by saturating with sodium chloride, or both.

In one kg of rennet extract, there are about 0.7 g of active enzymes. The rest is water and salt and sodium benzoate. Typically, one kg of cheese contains about 0.0003 g of rennet enzymes.

14.4 Properties of Rennin

Rennin is a sulphur-containing protein. One part can clot about 50, 00,000 parts of milk. It is easily destroyed by heat, many chemical substances and many physical conditions. The isoelectric point of rennin is about 4.55 and it is easily destroyed by factors such as heat and high pressures. It is also digested by proteolytic enzymes and is readily adsorbed. It is very sensitive to alkali, and heating at 70°C at pH 6.8-7.0 will destroy it in 14 min.

Optimum pH for clotting of milk is 5.4 and the proteolytic power of this enzyme virtually disappears at pH 4.5.

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Lesson 15 RENNET SUBSTITUTES

15.1 Introduction

Milk coagulation is a basic step in cheese manufacturing. Calf rennet, the conventional milk-clotting enzyme obtained from the fourth stomach of suckling calves was the most widely used coagulant in cheese making all over the world to manufacture most of the cheese varieties. The worldwide reduced supply of calf rennet and the increase in cheese production and consumption have stimulated research for milk-clotting enzymes from alternative sources to be used as calf rennet substitutes. Further, if calf rennet is used as a coagulant for cheese making, the product has to carry a tag of non-vegetarian which may lead to non-consumption of cheese by vegetarian population of the world. Thus, it was found necessary to discover milk clotting enzymes from alternative sources.

15.2 Desirable Characteristics of Rennet Substitutes

Other than fulfilling the legal requirements, rennet substitute from any alternative source should possess the following characteristics:

- The ratio of milk clotting activity to proteolytic activity should be high. This means that the milk should clot without much proteolysis i.e. breakdown of proteins to peptides. This prevents excessive nonspecific proteolysis during manufacture and hence protects against a weak gel structure, high losses of protein and fat in the whey, and reduced yields of cheese solids. Moreover, it avoids excessive proteolysis during maturation and thus ensures the correct balance of peptides of different molecular weights and hence desirable flavor, body, and functional characteristics in the ripened cheese.
- It should be thermally stable (comparable to calf rennet) at pH and temperatures used during cheese making. This influences the level of residual rennet in cheese and hence influences the biochemical changes that take place during ripening.
- It should have low thermal stability at temperatures of whey processing otherwise it may hinder the utilization of cheese whey in various products.
- It should impart desired flavor, body, and texture characteristics to the finished cheese.

15.3 Milk-clotting Enzymes from Plants

Enzymes from many plant sources may be used as clotting enzymes in cheese making but most of the plant proteases are strongly proteolytic and cause extensive digestion of the curd, resulting in reduced yields, bitter flavors and pasty-bodied cheese.

15.3.1 Papain

The latex of the plant *Carica papaya* yields papain and several other proteases. It has powerful milk clotting activity but it is also highly proteolytic. It requires a free sulfhydryl group for its catalytic activity.

15.3.2 Ficin

Ficin is present in the latex of several species of the genus *Ficus* (fig) such as *Ficus glomarata*, *Ficus religiosa* and *Ficus carica* but the best source is *Ficus carica*. Cheese made with ficin develops bitter flavor which decreases in intensity during curing.

15.3.3 Others

Bromelain from pineapple has also been considered as a possible substitute for calf rennet. An enzyme extracted from *Withania coagulans* was also used in the manufacture of Surati and Cheddar cheese. Extracts from the flower petals of *Cynara cardunculus* were used for the manufacture of Serra cheese from sheep's milk by Portuguese farmers.

15.4 Microbial Rennet

A large number of microorganisms are known to produce milk clotting enzymes. The possibility of a few of the microorganisms proving successful as rennet substitutes may appear from the fact that they play an important part during the manufacture of cheese. Microbial enzymes are known to exhibit considerable variations in the range of activity, substrate specificity and mode of action. Even more important is the fact that they can be produced economically on any desired scale.

Many hundreds of bacterial and fungal cultures have been investigated for milk clotting enzymes and their proteolytic abilities. Milk clotting enzymes from bacteria like *Streptococcus liquefaciens*, *Micrococcus caseolyticus*, *Bacillus cereus*, *B. polymyxa*, *B. mesentericus*, *B. coagulans* and *B. subtilis* have been used as coagulating enzymes. Milk clotting enzymes from fungi are also used during cheese making. Some of the fungi producing such enzymes are *Aspergillus nidulans*, *A. galucus*, *Syncephalastrum racemosum*, and *Cladosporium herbarum*. Some of the microorganisms used in commercial production of microbial rennet are listed in Table 15.1.

Table 15.1 Micoorganisms used in commercial production of microbial rennet

Name	Source of Enzyme
Hannilase	<i>Mucor miehei</i>
Rennilase	<i>Mucor miehei</i>
Fromase	<i>Mucor miehei</i>
Miki	<i>Mucor miehei</i>
Marzyme	<i>Mucor miehei</i>
Novadel	<i>Mucor pusillus</i>
Noury	<i>Mucor pusillus</i>
Meito	<i>Mucor pusillus</i>
Emporase	<i>Mucor pusillus</i>
Suparen	<i>Endothia parasitica</i>
Mikrozyme	<i>Bacillus subtilis</i>
Sure curd	<i>Endothia parasitica</i>

Various strains of these organisms behave differently; therefore, the cheesemaker should use only well tried and tested rennet for the types of cheese contemplated. The activity of various microbial rennets varies according to pH and enzyme system.

The protease of the *Mucor miehei* coagulants degrade casein fairly rapidly in the pH range 5.5-7.0; but in spite of this, the incidence of bitter cheese using this enzyme is low. The enzyme is very sensitive to temperatures in the region 37-45°C and is destroyed at 70°C. This enzyme is used successfully for many types of cheese.

Mucor pusillus extract is also used as microbial rennet. It is highly proteolytic than calf rennet or the *Mucor miehei* extract. An increase in calcium ion concentration in milk decreases the clotting time but activity of this enzyme is not so pH-dependent as for other coagulants. It tends to give hard curds because of its high proteolytic activity and the curd tends to lose fat into the whey, thereby giving lower yield as compared to others. Thus, this enzyme is usually used in combination with other enzymes.

The enzyme extracted from *Endothia parasitica* is more caseolytic than those from *Mucor* sp. or calf rennet and tends to produce more bitter flavors in high moisture cheese.

Continuous research is being carried out in exploring the milk coagulating activity of enzymes from different cultures. Recently, commercial starter 'natto' (*Bacillus subtilis*) has been studied for its milk clotting activity and it was found to be a potential rennet substitute.

15.5 Recombinant Chymosin

As discussed earlier, many rennet substitutes are used for cheese making but many of these proteolytic enzymes from microbial or plant origin cause flavor, texture and yield changes in certain types of cheese that are different than those produced by calf rennet. Further, they are not suitable for long ripening cheeses as they have a different range of non-specific activities than chymosin and do not produce the correct flavors on prolonged ripening.

Recombinant rennet/chymosin can be prepared by gene transfer technology in which the bovine chymosin is cloned in a suitable production strain and the enzyme is produced by fermentation. This enzyme can be isolated and used in cheese making as a coagulant having properties similar to that of calf rennet. *Escherichia coli*, *Kluyveromyces lactis* and *A. niger* var. *awamori* have been successfully used for production of calf rennet.

In addition to the benefit that such chymosin can be produced in large-scale fermentors at low cost, recombinant and highly pure chymosin also has some other advantages such as specific, low proteolytic activity, predictable coagulation behavior and vegetarian approval.

With the advent of various sources of rennet substitutes, a number of firms are manufacturing these substitutes at commercial level. Among these microbial rennet is most widely used.



Lesson 16

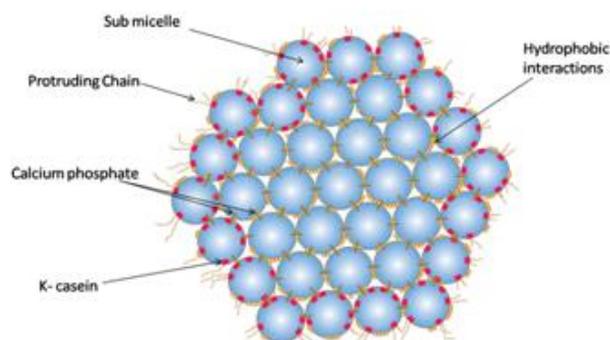
ACTION OF RENNET ON MILK

16.1 Introduction

Casein and whey proteins are the two groups of proteins present in milk. Casein is mainly present in micellar form and whey proteins are present in soluble form. When rennet is added in milk, the enzymes present in rennet act on the casein micelle leading to its destabilization and thus coagulation takes place. So, to understand the basic chemistry behind this enzymatic coagulation of milk, it is important to understand the structure of casein and the forces that stabilize casein in milk.

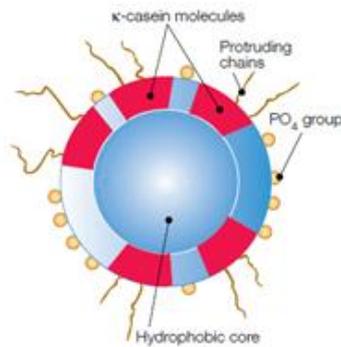
The casein micelles are spherical colloidal particles, with a mean diameter of around 120 nm and a mean particle mass of about 108 Da. The micelles contain protein and non-protein species (calcium and phosphate), with smaller amounts of magnesium and citrate and traces of other metals. All these are collectively called as colloidal calcium phosphate (CCP). The microstructure of casein micelle and its stability has been a subject of research for long. Numerous models have been proposed such as sub-micelle model and dual-binding model. The sub-micelle model proposes that the micelle is built up from sub-micelles which are held together by CCP and surrounded and stabilized by a surface layer rich in κ -casein but with some of the other caseins exposed also. Further, it was proposed that hydrophilic C-terminal region of κ -casein protrudes from the surface, creating a hairy layer around the micelle and stabilizing it through a zeta potential of about -20 mV and steric stabilization. The dual-binding model of Horne proposes that individual casein molecules interact via hydrophobic regions in their primary structures, leaving the hydrophilic regions free and with the hydrophilic C-terminal region of κ -casein protruding into the aqueous phase.

Calcium salts of α s-casein and β -casein are almost insoluble in water, while those of κ -casein are readily soluble. Due to the dominating localization of κ -casein to the surface of the micelles, the solubility of calcium κ -caseinate prevails over the insolubility of the other two caseins in the micelles, and the whole micelle is soluble as a colloid. Here calcium has the role to integrate the sub-micelles. If calcium leaves the micelle, the micelle will disintegrate into sub-micelles. The structure of the casein micelle is shown in figures 16.1 and 16.2.



(Courtesy: Tetra Pak Processing Systems AB, Lund, Sweden)

Fig. 16.1 Casein Micelle Structure



(Courtesy: Tetra Pak Processing Systems AB, Lund, Sweden)

Fig 16.2 Structure of casein sub-micelle

16.2 Enzymatic Coagulation of Milk

The enzymatic coagulation of milk is essentially a two stage process (Fig. 16.3). As discussed earlier, the casein micelle is stabilized by κ -casein layer on the surface of the micelle. The enzymes present in rennet (proteinases) hydrolyse κ -casein layer to form paracasein micelles which aggregate in presence of calcium and thus milk is coagulated. The hydrolysis of the κ -casein layer is called as the primary phase of rennet coagulation while the aggregation of paracasein micelles in presence of calcium is called the secondary phase of rennet coagulation of milk.

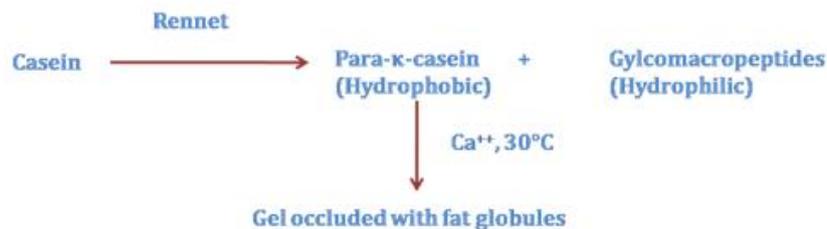


Fig 16.3 Enzymatic hydrolysis of casein

The amino acid chain forming the κ -casein molecule consists of 169 amino acids. Rennet enzymes act specifically at 105 (phenyl alanine)-106 (methionine) bond of this amino acid, thereby splitting it into two parts. One part consists of amino acids from 1-105, called as para- κ -casein. This part is insoluble and remains in the curd together with α s and β -casein. The other part of amino acids from 106-169 is soluble part. These amino acids are dominated by polar amino acids and the carbohydrate, which gives this part its hydrophilic properties. This part of the κ -casein molecule is called the glycomacro-peptide and is released into the whey in cheese making.

The formation of the curd is due to the sudden removal of the hydrophilic macropeptides and the imbalance in intermolecular forces caused thereby. Bonds between hydrophobic sites start to develop and are enforced by calcium bonds which develop as the water molecules in the micelles start to leave the structure. This process is usually referred to as the phase of coagulation and syneresis. Hydrolysis of κ -casein during the primary phase of rennet action releases the highly charged, hydrophilic C-terminal segment of κ -casein (macropeptide), as a result of which the zeta potential of the casein micelles is reduced from -10/-20 to -5/-7 mV and the protruding peptides are removed from their surfaces, thus destroying the principal micelle-stabilizing factors

(electrostatic and steric) and their colloidal stability. When roughly 85% of the total κ -casein has been hydrolyzed, the stability of the micelles is reduced to such an extent that when they collide, they remain in contact and eventually build into a three-dimensional network, referred to as a coagulum or gel.

16.3 Factors Affecting Rennet Coagulation

The primary and secondary phase of rennet coagulation are affected by some of the compositional and environmental factors like milk composition, temperature, pH, calcium content, pre-heating of milk, rennet concentration etc. The effects of all these factors are summarized here.

16.3.1 Composition of milk

Variation in the composition of milk mainly affects the rate of coagulation and the curd firmness. Fast coagulation results in firmer curd. The rate of clotting is largely dependent on the nature of the casein micelles and the equilibrium with the calcium phosphate and calcium ions. The firmness of the curd are affected by pH value, calcium concentration, temperature, fat content and the ratio of rennin to casein. The rennet coagulation time (RCT) is markedly affected by the protein content in milk. RCT decreases with protein content in the range of 2-3%. Further increase in milk protein level i.e. more than 3% result in a slight increase in gelation time. This is due to decrease in rennet:casein ratio, which necessitates an increase in the time required to generate sufficient hydrolysis of κ -casein to induce aggregation of paracasein micelles. A minimum protein content of 2.5-3.0 is necessary to obtain gel in about 30-40 minutes during cheese making. Increase in fat content also results in decreased RCT but the effect is lower than that of the protein content.

16.3.2 Heat treatment of milk

Heating milk to pasteurization temperature has beneficial effect on rennet coagulation due to heat induced precipitation of calcium phosphate and a concomitant decrease in pH. But heating further to higher temperatures causes other effects which in combination dominate the positive effects of heating to pasteurization. Some such effects are:

- whey protein denaturation and the interaction of denatured β -lactoglobulin with micellar κ -casein
- The deposition of heat-induced insoluble calcium phosphate leading to reduction in the concentration of native micellar calcium phosphate. This micellar calcium phosphate is important for cross linking para- κ -casein micelles and their aggregation during gel formation.

16.3.3 Set temperature

The principal effect of set temperature is on the secondary phase of enzymatic coagulation, which does not occur at temperatures below around 18°C. Above this temperature, the coagulation time decreases to a broad minimum at 40-45°C and then increases again, as the enzyme becomes denatured. In cheese making, rennet coagulation normally occurs at around 31°C. This is necessary to optimize the growth of starter bacteria which will not survive the temperature more than 40°C. In addition, the structure of the coagulum is improved at the lower temperature, which is therefore used even for cheeses made using thermophilic cultures.

16.3.4 Rennet concentration

The rate of enzymatic coagulation is directly related to the concentration of enzyme. Increase in concentration of rennet decrease RCT. During cheese making, rennet is added in such a concentration so as to coagulate the milk 30-40 minutes. More rennet concentrations can be used to shorten the coagulation time but it leads to retention of more rennet in the curd which has pronounced effect in ripening of the cheese, particularly proteolysis. Some studies also suggest that using increased concentration of rennet may jeopardize the curd firming rate and curd firmness.

16.3.5 Concentration of calcium ions

The concentration of calcium ions mainly affect the secondary phase of enzymatic coagulation. Increased calcium concentration is beneficial for coagulation of milk. For this reason, sometimes CaCl_2 is added to milk prior to cheese making. This promotes cheese making via three beneficial changes, viz. an increase in calcium ion concentration, an increase in the concentration of colloidal calcium phosphate and a concomitant decrease in pH (the addition of CaCl_2 to 0.02%, i.e. 1.8 mM Ca, reduces the pH by ~ 0.05-0.1 units, depending on protein level).

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*Module 8. Manufacture of different varieties of cheese***Lesson 17****CHEDDAR CHEESE****17.1 History**

Cheddar cheese originated from the village of Cheddar in Somerset, South West England. Cheddar Gorge on the edge of the village contains a number of caves, which provided the ideal humidity and constant temperature for maturing the cheese.

Central to the modernization and standardization of Cheddar cheese was the nineteenth century Somerset dairyman Joseph Harding. Owing to the technical developments, promotion of dairy hygiene and unremunerated propagation of modern cheese-making techniques he suggested, he has been described as the father of Cheddar cheese. Harding introduced new equipment into the process of cheese making, including his 'revolving breaker' for curd cutting, saving much manual effort. The 'Joseph Harding method' was the first modern system for Cheddar production based on scientific principles. He and his wife were behind the introduction of the cheese into Scotland and North America. Joseph Harding's son, Henry Harding, was responsible for introducing Cheddar cheese production to Australia.

Cheddar is the most popular cheese in the United Kingdom, accounting for 51% of the country's £1.9 billion annual cheese market. In 2010, the UK produced 2,58,000 tons of Cheddar cheese. It is the second most popular cheese in the USA (behind Mozzarella), with an average annual consumption of 4.5 kg per capita.

17.2 Chemical Composition**Table 17.1 Composition of Cheddar cheese made from cow and buffalo milk**

<u>Constituent (%)</u>	Cow Milk Cheddar Cheese	Buffalo Milk Cheddar Cheese
Moisture	37.00	34.75
Fat	32.00	33.33
FDM	50.79	51.07
Protein	25.00	25.32
Lactose	2.10	1.94
Salt	1.50	1.37
Salt-in-moisture	4.05	3.93
Ash	3.70	4.66
Calcium	0.725	0.836
Phosphorous	0.495	0.484
pH	5.2-5.4	5.21

17.3 Method of Manufacture

The manufacturing of Cheddar cheese consist of (a) addition of starter culture to milk; (b) coagulating milk; (c) cutting the resultant coagulum into small cubes; (d) heating and stirring the cubes with the concomitant production of a required amount of acid; (e) whey removal; (f) fusing the cubes of curd into slabs by cheddaring; (g) milling the cheddared curd;(h) salting ; (i) pressing ; (j) packaging and ripening. The detailed method is shown in Fig. 17.1.

17.3.1 Cheddaring

Steps upto cutting, cooking and whey removal are similar to the other varieties of cheese but the step which separates Cheddar cheese from other varieties is cheddaring. It is a step which involves a series of operations consisting of packing, turning, piling and re-piling the slabs of matted curd. This process of piling and re-piling is repeated every 15 min. This process squashes the individual curd particles as well as releases more whey. In this process, the curd granules fuse under gravity into solid blocks. Rapid matting of the curd particles occurs under the combined effect of heat and acid. The original rubber-like texture gradually changes into a close-knit texture ('chicken breast' structure, typical of Cheddar cheese) with the matted curd particles becoming fibrous. When the acidity of whey reaches 0.45-0.50% and cheddaring is complete, the curd is milled. The milled curd is salted, pressed, packaged and kept for ripening in the manner followed for all cheese varieties.

Later research has suggested that cheddaring is not an essential step and serves no purpose other than to provide a holding period which is required for acidity development and whey removal. The major factors affecting the process of whey removal are acidity and temperature of the curd. Mechanical forces (pressure and flow) are important in the development of fibrous structure in the curd. Fibrous structure cannot be brought about by pressure and deformation unless the curd has reached a pH of 5.8 or less. This suggests that pressure and flow serve to knit, join, stretch and orient the network of casein fibres already formed in response to rising acidity. This structure formation is also influenced by temperature and moisture.

17.4 Texture of Cheddar Cheese

Cheddar cheese has a texture that is intermediate between those of high pH cheese (Gouda cheese), which flows readily when a force is applied and the low pH cheeses (Cheshire) which tend to deform, by shattering, only at their yield point. Much of the protein in Cheddar cheese is in the form of smaller particles than Gouda. As the pH decreases towards that of the isoelectric point of paracasein, the protein assumes an increasingly more compact conformation and the cheese becomes shorter in texture and fractures at a small deformation.

17.5 Flavor of Cheddar Cheese

Flavor of Cheddar cheese is affected by a number of factors like milk fat, proteolysis, starter and non-starter bacteria etc. It has been studied that when a series of batches of Cheddar cheese were made with fat content increasing from 0 to 4.5%, the flavor improved as the fat content increased but above a certain limit, there was no increase in flavor. This suggested that the water-fat interface is important and the flavor components are dissolved and retained in the fat. Thus, it is clear that fat plays an important role in flavor development of Cheddar cheese. As breakdown of casein is also involved in the production of Cheddar cheese flavor, proteolysis plays a major role in flavor development. Other than milk fat and proteolysis, the factors that affect flavor of Cheddar cheese are starter and non-starter bacteria.

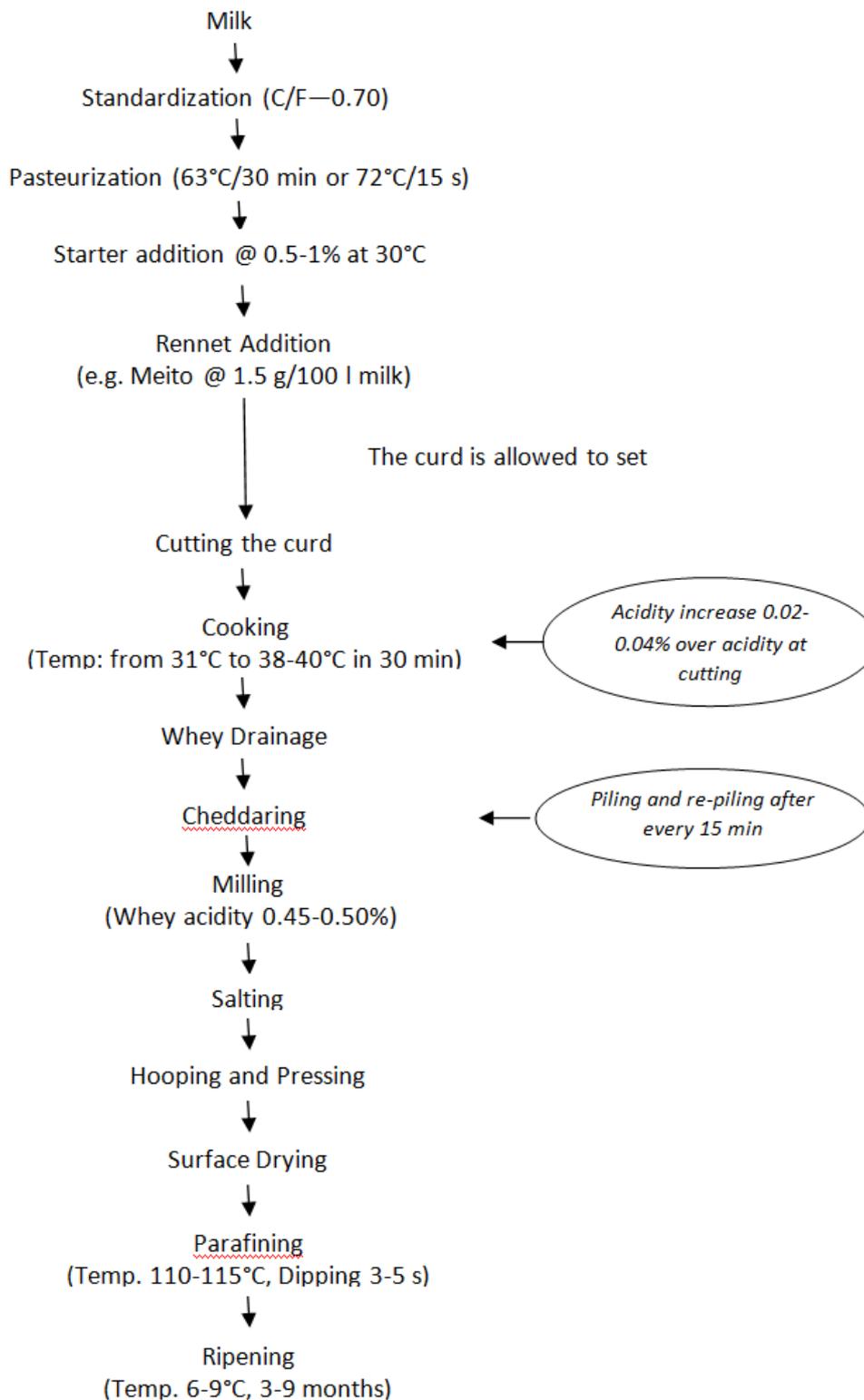


Fig. 17.1 Flow diagram for Cheddar cheese



LESSON 18 GOUDA CHEESE

18.1 Introduction

Gouda cheese, originated in the vicinity of Gouda in the province of South Holland, is one of the most important Dutch type varieties of cheese produced in the world. It belongs to semi-hard to hard varieties of cheese with few or no eye holes. Dutch type varieties of cheese are those that are made from fresh cow's milk having fat such that the product contains at least 40% fat in the dry matter, starters consisting of mesophilic lactococci and leuconostocs that produce CO₂, clotted by rennet, pressed to obtain a close rind, are salted in brine after pressing and have no essential surface flora (Walstra et al., 1998).



Fig 18.1 Gouda cheese with small eyes

Traditionally, two main types of cheese were made in the Netherlands, namely Gouda and Edam. Gouda cheese was made from fresh unskimmed milk and was matured for 6-60 weeks while Edam cheese was made from a mixture of skimmed evening milk and fresh morning milk such that fat in cheese is about 40% on dry matter basis. The cheese has a somewhat shorter texture than Gouda and was usually ripened for 6 months or more.

Table 18.1 Chemical Composition

Constituent (%)	Cow milk Gouda cheese
Moisture	41.00
Fat	28.50
Protein	26.50
Salt	2.00
Ash	3.00
pH	5.8

18.2 Method of Manufacture

18.2.1 Standardization, renneting and cutting

For the manufacture of good quality Gouda cheese, cow milk is considered to be the most suitable raw material. Manufacturing of Gouda cheese starts with acidification of the standardized milk.

The milk is standardized so as to give 40-50% fat in cheese on dry matter. Starter is added @ 0.7% of the milk. No ripening is done for this type of cheese. Renneting is usually done at about 30°C @ 0.022% of milk and allowed to set for about 20-30 minutes. After the curd is properly set, it is cut in cubes of some 8-15 mm size. Stirring, at first gently till acidity rises by 0.02% (to minimize loss of fines) and later more vigorously, is done with the knives used for cutting or with special stirrers.

18.2.2 Scalding

After cutting, part of the whey (about one third) is removed for more effective stirring and to promote syneresis. It also facilitates partial removal of lactose, which aids in achieving a lower acidity. The temperature is also increased at the same time to aid syneresis process but not too high to injure starter organisms. Usually, it is kept below 38°C. This process of heating curd in whey is called 'scalding'. The temperature is increased usually by addition of hot water at about 60°C (about equal quantity of whey drained) which also helps in controlling water content and the pH of the cheese.

18.2.3 Draining and pressing

After the curd has lost enough moisture i.e. around 65% moisture is left in the curd and pH is around 6.5, stirring is stopped and the curd grains are allowed to sediment. Continuous mass of curd is then formed due to fusion of the curd grains. This curd can now be cut into blocks and taken out of the whey. Blocks may be pressed further to remove whey. This may also cause considerable loss of fines. Fat loss in whey can be recovered by passing it through cream separator and loss of fines can be recovered by the use of hydrocyclones. The blocks are then put into moulds and pressed.

18.2.4 Brining

Brine salting is generally done using about 18-20% brine in tank. The pH of brine is adjusted to 4.8-4.9 to prevent dissolution of cheese protein in the brine. Cheese blocks should be inverted few times daily. Time taken for brining will depend on size, viz., 0.45 kg - 20 h, 0.90 kg - 36 h, and 3.83 kg - 3 days.

After brining, paraffining is done and the cheese blocks are kept for ripening. A maximum of 3-4 months are required for development of flavour and texture of Gouda cheese.

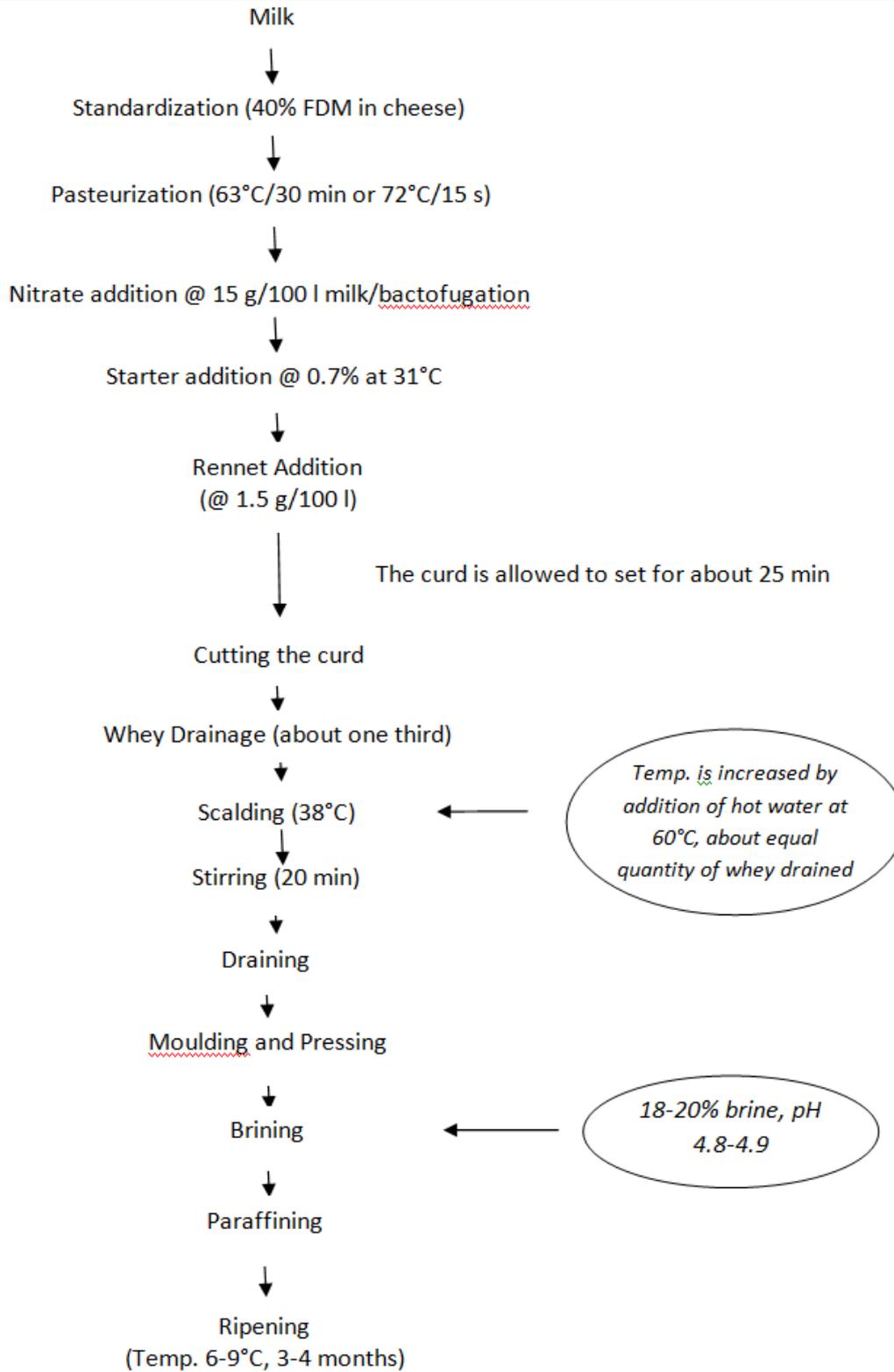


Fig. 18.2 Flow diagram for manufacturing Gouda cheese

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Lesson 19 SWISS CHEESE

19.1 Introduction

Swiss cheese originated in the Emme valley in Switzerland around the 15th century. It is known as Emmental cheese in the country of its origin. Besides the USA and Switzerland, many other countries such as Italy, Austria, Finland, Denmark, Germany and Argentina are known to make excellent Swiss cheese.

This cheese is a hard variety, known by the presence of shining eyes with smooth, waxy texture and sweet nutty taste with a mild flavor. It is reported that a specific grass available in the Emme valley produce typical cheese, this being the probable reason that no other country has duplicated exactly, the flavor and body characteristics of Emmental cheese from Switzerland. Swiss cheese should have a sliceable texture, regular round eye holes, dull to brilliant appearance, 45% min fat on dry matter basis, mild nut-like taste and should be minimum of 60 days old before consumption. Swiss cheese production ranks third in the world, next only to Cheddar and Mozzarella.

Table 19.1 Composition

Moisture	34.5-36.5%
Ash	3.0-5.0%
Fat	29.5-30.5%
Salt	1.0-1.4%
Protein	27.0-28.0%
FDM	45.0-48.0%

19.2 Mechanism of Eye Formation

Most Swiss-type cheeses undergo a more or less pronounced propionic acid fermentation, which is brought about by propionic acid bacteria. They grow under anaerobic conditions, using calcium lactate as the substrate. The end products are the corresponding propionate, acetate, water and carbon dioxide.

Part of the CO₂ may be produced by dicarboxylation of amino acids (e.g. tyrosine and arginine) by enterococci due to high salt concentration and low pH (5.1 to 5.2) in the periphery of the cheese. It has been reported that 50% of the lactate is metabolized by propionibacteria and lactate fermentation is more intense in the centre than in the periphery.

To initiate propionic acid fermentation, the ripening temperature of the cheese must be raised approximately to 18-25°C for a certain period of time. The relative humidity (RH) of the curing room during hot curing (22°C/85% RH/6-8 weeks) influences the eye formation. Uneven RH results in uneven eye formation. The eyes are formed by the continuous production of CO₂ which diffuses out at weak points. They have 1.25–2.54 cm diameter and are spaced at 2.54 – 7.62 cm. As

soon as the development of sufficient eyes is accomplished, the propionic acid fermentation is usually retarded by storing the cheese at lower temperatures. About 130 l of CO₂ is produced in 120-150 days in 80 kg Swiss cheese where 80 l of CO₂ diffuses out and 50 l of it remains in the eyes at 85 – 92% RH.

19.3 Method of manufacturing

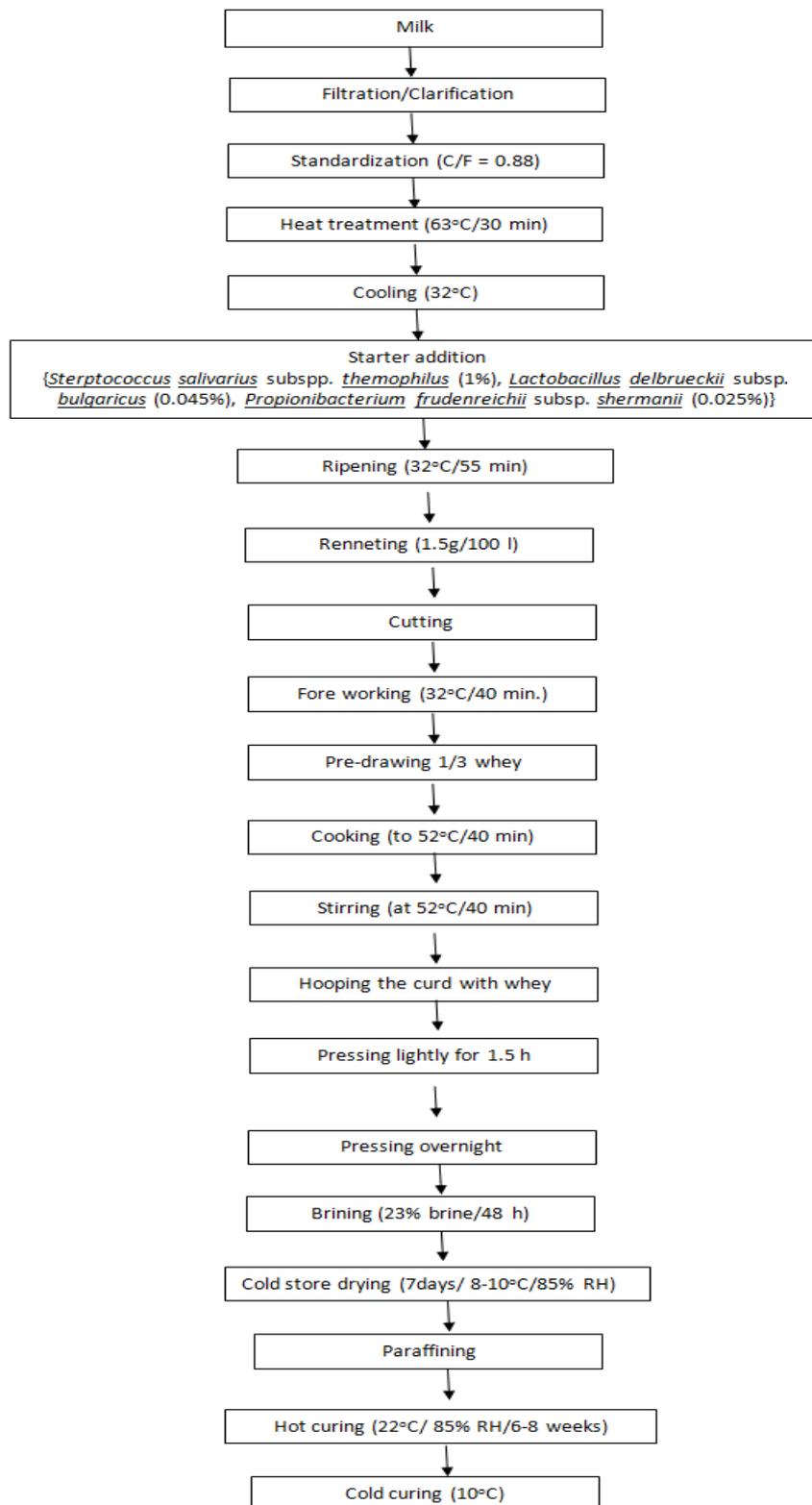


Fig 19.1 Steps of Manufacture

19.4 Defects

19.4.1 Late fermentation

This occurs during ripening of cheese. The gas may form pin holes or the resulting eyes may appear in clusters. This defect is usually caused by lactate fermenting bacteria belonging to the genus *Clostridium*, strains of butyric acid bacteria, the name usually used by Swiss cheese makers for those organisms isolated from brown cheese. Among the various species like *Clostridium tyrobutyricum*, *C. butyricum* and *C. sporogenes*, it has been found that only *C. tyrobutyricum* produces brown cheese.

19.4.2 Bitter Cheese

Streptococcus faecalis var. *liquefaciens* forms the major part of the ripening flora and is directly responsible for bitterness. Generally, this is not caused by a detrimental flora, but by some starter strains that may not contain enough peptidases to degrade the peptides produced by proteolysis. This may result from the higher proteolytic activity of the rennet at lower pH, which leads to accumulation of polypeptides including bitter ones. Cheese manufactured using temperatures higher than normal has a greater incidence of bitterness than those made by traditional methods.

19.4.3 Flavor Defects

The most common among these are putrid, unclean, fermented, yeasty, rancid and fruity. Putrid flavor is probably caused by objectionable protein decomposition and the odor frequently resembles H₂S with equally offensive aromas. Large numbers of *Clostridia* and *Micrococci* have been found in such spoiled cheeses. *Clostridium lentoputrescens* is associated with a putrid flavor and with development of a white, crumbly conditions and large irregular eyes.

Rancid flavor is usually because of higher concentrations of butyric acid produced by *C. butyricum* or *C. tyrobutyricum*. Oxidative rancidity resulting from lipid oxidation also may occur. Use of lipolysed milk may also yield rancid cheese.

19.4.4 Colour Defects

Colored spots may be formed by the growth of pigmented propionibacteria in Swiss cheese. The round brown spots on the cut surface or eyes of cheese could be overcome by adding starter propionibacteria. This defect is most pronounced when cows are not on pasture and when milk contains fewer propionibacteria. *Propionibacterium rubrum* and *P. theonii* are brightly colored and may cause spots. Dark spots may be caused by other pigmented microorganisms.

Table 19.2 Defects in Swiss cheese

Defect	Description	Probable cause
Blind	No eyes	Overripe or too acid milk
Small eye – overset	< 0.4" dia. Excess in number	Excess gas generation or inclusion, disturbed curd
Shell	Crinkled, nutshell appearance on eye surface	Excess fat in milk and curd, eyes that develop too slowly
Glass	Noticeable, clear-cut parallel cracks. If excess, cheese does not slice properly	Too acid & too fat rich milk. Poor whey drainage & curd becomes brittle
Frog mouth	Rind splits on surface to give appearance of an open frog's mouth	Poorly developed, weak, inelastic rind, careless handling of cheese in the press, becomes too cold
Blow hole	Very large eyes (5" or more in dia) if extreme, only one large hole in the centre of cheese. Structure of cheese torn & deformed	Poor sanitary conditions of milk production, cows fed on grass silage.
Uneven normal eye distribution		Cooled too quickly on one side
Whey spotted		Poor whey drainage – becomes water logged under rind surface

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Lesson 20 MOZZARELLA CHEESE

20.1 Introduction

Mozzarella cheese was originally manufactured from high fat buffalo milk in the Battipaglia region of Italy, but it is now made all over Italy, in other European countries and USA from cow milk. It belongs to the cheese classified as 'pasta filata' which involves the principle of skillfully stretching the curd in hot water to get a smooth texture and grain in cheese. It is a soft, white un-ripened cheese which may be consumed shortly after manufacture. Its melting and stretching characteristics are highly appreciated in the manufacture of Pizza where it is a key ingredient.

The method of manufacture of Mozzarella cheese, irrespective of the milk system from which it is made involves (1) optimum addition of starter culture or proper acidification of milk, (2) renneting of milk, (3) cutting the curd at the right firmness, (4) stirring and cooking the curd particles to the correct consistency and (5) proper cheddaring, stretching and salting of curd for optimum plasticity and elasticity.

Table 20.1 Chemical composition

(%)	Mozzarella	Low moisture Mozzarella
Fat	18.0	23.7
Moisture	54.0	47.0
Total solids	46.0	53.0
Protein	22.1	21.0
Salt	0.70	1.00
Ash	2.30	3.00
pH	5.20	5.30

20.2 Chemistry of 'stretch' of Mozzarella Cheese

In the calcium rich environment of milk, the casein precipitates out of milk as di-calcium paracaseinate, entrapping fat, insoluble minerals and some sugar. At a pH between 5.2-5.4, resulting from the development (or direct introduction) of acid, some of the calcium of the dicalcium paracaseinate gets dissolved, leading to the formation of monocalcium paracaseinate. This when heated to 54°C or higher becomes smooth, pliable and stringy and retains fat. If acidification is excessive, generally below pH 5.2, monocalcium paracaseinate will continue to lose calcium and form paracasein, which may stretch, but has difficulty in retaining fat. The curd generally does not stretch above pH 5.6.

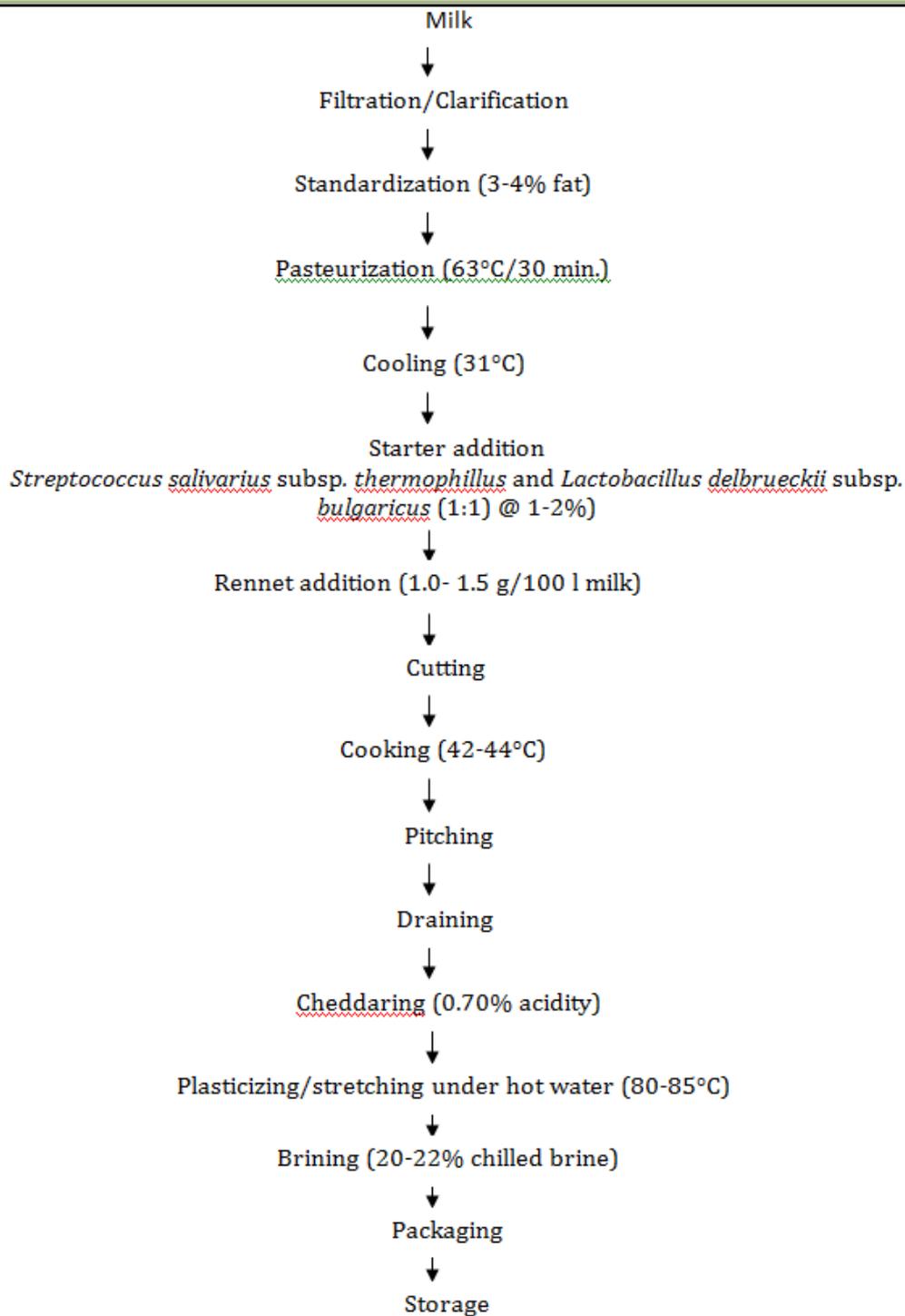


Fig 20.1 Manufacturing steps (Traditional method)

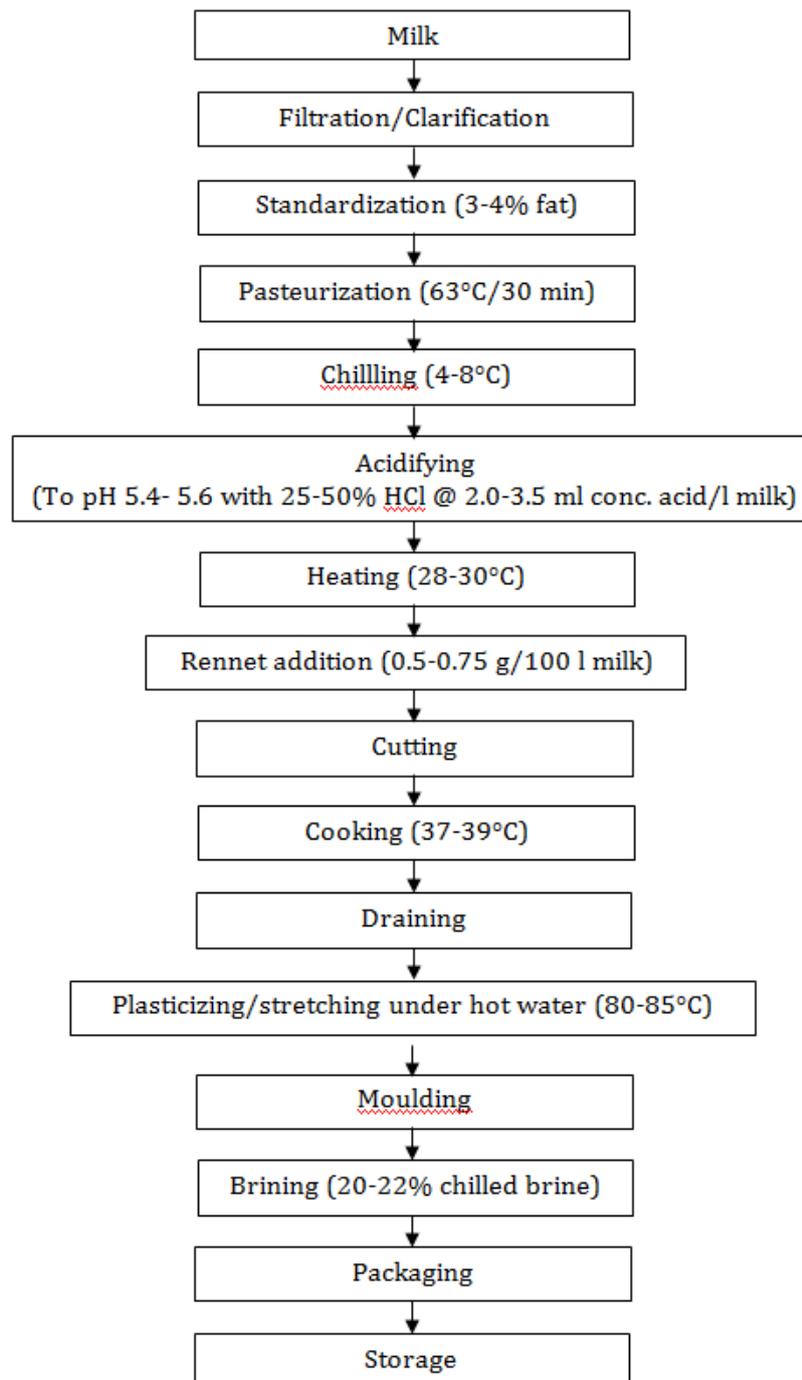


Fig 20.2 Manufacturing Steps (Direct Acid Method)

20.3 Advantages of the Direct Acidification Technique

- 1) Curtailed manufacturing time and expenses
- 2) Simplified technology due to elimination of propagation and maintenance of starter cultures
- 3) Starter failures due to bacteriophages and antimicrobial agents avoided
- 4) Less rennet required
- 5) Amenable to mechanization

20.4 Disadvantages

- 1) Slight reduction in yield of cheese
- 2) Bland flavour

An ideal Mozzarella cheese has a smooth surface with a perfect sheen, elastic, stringy body free from mechanical openings.



Lesson 21 COTTAGE CHEESE

21.1 Definition

- a) Cottage cheese is a soft, unripened cheese that is usually made from skim milk. It has a mild acid flavor. It consists of small particles or flakes of curd, which have a meaty consistency.
- b) Creamed Cottage cheese is cheese which is mixed with cream so that the mixture contains not less than 4% fat. Both Cottage cheese and creamed Cottage cheese are usually salted.

21.2 Method of Manufacture

- a) There are two methods of manufacture i) Milk coagulated by acidity developed by the action of lactic starter, ii) Coagulation accomplished by the combined actions of lactic starter and a small quantity of rennet.
- b) The two types of curd may be characterized as below:

Table 21.1 Types of curd

Type of curd	Character
Acid	Smaller granules/particles Extremely acid flavor (mildly acid if thoroughly washed) Lower yield
Rennet	Large flakes/particles Mild flavor, Meaty body

Table 21.2 Characteristics of long set and short set rennet curd

Particulars	Short Setting	Long Setting
Coagulation time	4-6 h	16 h (overnight)
Setting temp.	29-32°C	22°C
Amount of starter added	4-6%	0.5 to 1%

21.2.1 Milk for Cottage cheese

Fresh, sweet, clean-flavored skim milk of low bacterial count is preferable for manufacturing Cottage cheese. Skim milk is pasteurized immediately after separation. Low Temperature Long Time (LTLT) method of pasteurization is preferable as excessive heating of milk causes soft curd formation (which is easily broken during cutting and handling).

21.2.2 Starter

High quality lactic starter is used. Bulk starter culture is prepared using skim milk.

21.2.3 Rennet

Rennet, if added, is at the rate of 15 mg per 100 l milk. Rennet diluted about 40 times with potable water for uniform distribution. Calcium chloride may be added (before adding rennet), if desired, for firm curd formation. Color may be added @ 0.5-1.0 ml/100 l (before adding rennet), if desired.

The most desirable titratable acidity of whey at cutting is approximately 0.5% (optimum pH 4.6-4.7). The whey must come from interior of curd and must be clear and free from curd particles. If the acidity is too low at cutting, curd develops a rubbery consistency. Too high acidity results in shattering of curd, giving low yield. Method of cutting and size of curd cubes is same as for Cheddar cheese.

21.2.4 Cooking

Cooking begins soon after cutting and continues for 1-2 h until temperature is about 46°C or until curd becomes firm enough to remove whey. Stirring during heating kept at a minimum and is very gently done in the early stages. The temperature is increased slowly at first. The final temperature is attained in 1 1/2 to 2 h.

21.2.5 Removal of whey

Whey is removed when curd cubes have no soft centres and when a handful of them squeezed gently show slight elasticity. The whey is removed from curd approximately 2 h after cutting. At this time the size of curd cubes approximate two third of their original volume. The drainage of whey is done the same way as for Cheddar cheese.

21.2.6 Washing the curd

The curd is washed after all the whey has been removed. This treatment makes the curd firmer and hard to touch; it also removes acid whey from around it and aids in producing desired mildness in flavor. The wash-water is applied in at least two treatments. The first is at a temperature of about 21°C and in amounts not less than twice the volume of curd in the vat. After 15 minutes soaking of cubes, the wash-water is removed. The second (or third, if necessary) wash-water is at 15°C or lower, in amounts as above.

21.2.7 Draining

Draining should be thorough. It is best done by placing curd cubes in a draining rack with perforated bottoms, which can be wheeled into rooms under refrigeration.

21.2.8 Salting

Salting is done when free moisture is drained from the curd. Salt can be applied to the curd in the vat or it can be dissolved in the cream for creamed Cottage cheese. It is usually done in 2 applications. Coarse salt preferred. Salt is added @ 1% or curd weight of 1.5 kg/1000 kg milk. Salted or unsalted curd is held at about 2°C till shipping.

21.2.9 Creaming

Cottage cheese is creamed immediately after draining, if the product is to be packaged at once. Holding the curd overnight in a cold room before creaming makes it more firm at creaming.

Calculated amount of 20% cream is homogenized before mixing so as to form a thick glossy coating over the curd particles.

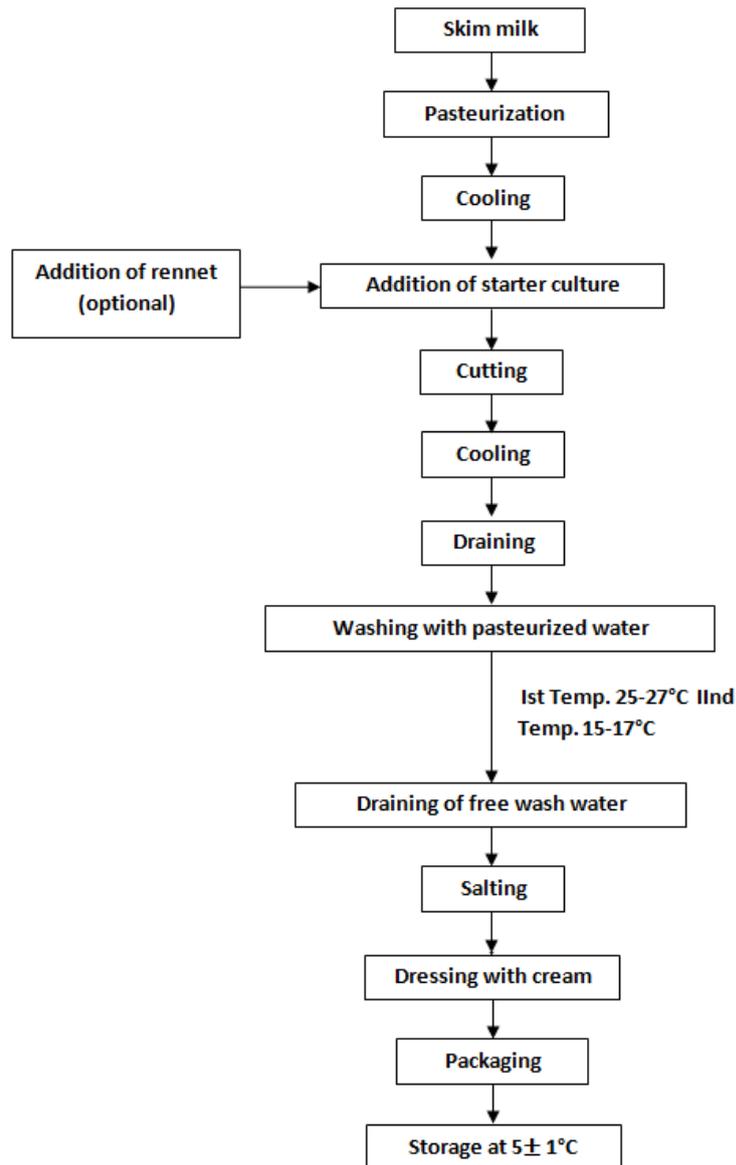


Figure 21.1 Manufacture of cottage cheese

21.2.10 Yield

The yield of curd before creaming depends essentially upon:

- i) The composition of milk
- ii) The manufacturing losses
- iii) The moisture content of the cheese

While the approximate yield of uncreamed Cottage cheese is 15% of milk, that of creamed Cottage cheese (with 20% fat in cream and 4% fat in finished product) is 18.3%. The yield of Cottage cheese is given by the formula:

$$\% \text{ yield} = \frac{\text{Amount of skim milk}}{100} \times [(4.9 \times \% \text{ T.S. in skim milk}) - 29.7]$$

21.2.11 Keeping quality

Both Cottage cheese and creamed Cottage cheese have short keeping quality even under refrigerated storage (5-10°C). Uncreamed Cottage cheese may be preserved for 90 days or longer by freezing or by brine storage. However, quality will deteriorate because freezing often leads to graininess and curd shattering, particularly with rennet cheese.

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*Module 9. Changes during ripening of cheese***Lesson 22****CHEMICAL, PHYSICAL, MICROBIOLOGICAL AND SENSORY CHANGES****22.1 Cheese Ripening**

Unique characteristics of each cheese variety are determined by the curd manufacturing operations but these characteristics are largely developed during ripening process. For example, the type of microflora established in the curd is determined by the manufacturing process but its effect on cheese characteristics develop largely during the ripening process.

Ripening involves microbial and chemical changes which are responsible for development of typical characteristics of varieties of cheeses. Microbial changes involve death and lysis of the starter cells, development of non-starter microflora and growth of secondary microflora. Ripening usually causes softening of the cheese texture due to hydrolysis of the casein matrix, change in pH and change in water binding ability of the curd. Flavor production is largely described by a series of biochemical events taking place during ripening.

The primary events occurring during cheese ripening are metabolism of residual lactose, lactate metabolism, proteolysis and lipolysis. These reactions are mainly responsible for textural changes and development of flavor in cheese. However, many secondary changes occur simultaneously and modify cheese texture and flavor. Since the biochemistry of cheese ripening is complex, the objective of this chapter is to present an overview of the principal biochemical pathways contributing towards cheese ripening.

22.2 Metabolism of Residual Lactose

Lactic acid bacteria (LAB) is added in the form of starter culture to cheese metabolize lactose to lactate. The rate and extent of acidification influence texture of the curd by controlling the rate of demineralization. The pH of the cheese curd is largely determined by the extent of acidification during manufacturing process. This influences the solubility of the casein, which in turn affects the texture of curd. pH also affects the activity of enzymes involved in ripening, thereby having an indirect effect on cheese texture and flavor development.

Most of the lactose is lost in whey during cheese manufacturing. However, low levels of lactose remains in the curd. This residual lactose is converted to L-lactate during early stages of ripening by the action of starter bacteria. The rate of conversion is dependent on temperature and salt-in-moisture levels of the curd. Starter activity is stopped very quickly at the end of manufacturing operations due to low pH, salt addition and lesser amount of fermentable lactose. Lactose that remains unfermented by the starter is probably metabolized by non-starter lactic acid bacteria (NSLAB) flora present in curd and they convert the residual lactose to D-lactate. D-lactate can also be formed by the racemisation of L-lactate.

22.3 Lactate Metabolism

Lactate produced by fermentation of residual lactose serves as an important substrate for a range of reactions occurring during cheese ripening. L-lactate can be racemised to D-lactate by NSLAB

flora. D-lactate is less soluble than L-lactate which results in the formation of Ca-D-lactate crystals. These crystals are not harmful but they appear as white specks on the surface of the mature cheese.

Lactose can be metabolized to acetate, ethanol, formate and CO₂ depending on the population of NSLAB and availability of O₂. In cheese wrapped with film, oxidation of lactate occurs to a lesser extent due to low level of O₂ available.

Late gas blowing is a defect which is caused by anaerobic metabolism of lactate by *Clostridium tyrobutyricum* to butyrate and H₂. The release of H₂ causes cracks in cheese during ripening.

The above mentioned metabolisms contribute negatively towards cheese ripening. There are some positive contributions also of lactate metabolism. This is essential for cheese varieties characterized by the development of large eyes during ripening such as Emmental cheese. *Propionibacterium freudenrichii* metabolise lactate to propionate, acetate, CO₂ and H₂O. Propionate and acetate contribute to the flavor of cheese while CO₂ is mainly responsible for eye formation.

22.4 Lipolysis

Milk fat is essential for the development of the correct flavor in cheese during ripening. Cheddar and other cheeses normally made from whole milk do not develop correct flavor when made from skim milk or milks in which milk fat has been replaced with other lipids. Lipids may undergo oxidative or hydrolytic degradation in foods but the redox potential of cheese is very low, so mainly hydrolytic degradation of lipids takes place in cheese. The triglycerides present in cheese are hydrolyzed by lipases which result in the formation of fatty acids.

Sources of lipases in cheese are:-

- Milk (particularly unpasteurized)
- Rennet
- Starter culture
- Starter adjuncts
- Non starter bacteria (may come through ingredients or contamination)
- Exogenous lipase (if added deliberately)

Low level of lipolysis is required for the development of flavor of cheese but excessive lipolysis causes rancidity. Lipolysis of milk fat results in production of free fatty acids which contribute to the flavor of cheese and also act as precursors for development of other flavor compounds in cheese like esters, lactones, ketones and aldehydes. These secondary fat-derived compounds can be very potent flavor compounds.

Fatty acid esters are produced by reaction of fatty acids with an alcohol; ethyl esters are most common in cheese. Thioesters are formed by reaction of a fatty acid with a thiol compound formed via the catabolism of sulphur-containing amino acids. Fatty acid lactones are formed by the intramolecular esterification of hydroxyacids; γ - and δ -lactones contribute to the flavor of a

number of cheese varieties. n-methyl ketones are formed by the partial β -oxidation of fatty acids.

Liberation of short and medium chain fatty acids from milk fat by lipolysis contribute directly to cheese flavor. This degree of flavor development depends on the variety of cheese. For example, it is very extensive in some hard Italian varieties, smear cheeses and blue mold cheeses. Excessive lipolysis causes rancidity in cheese varieties like Cheddar and Gouda.

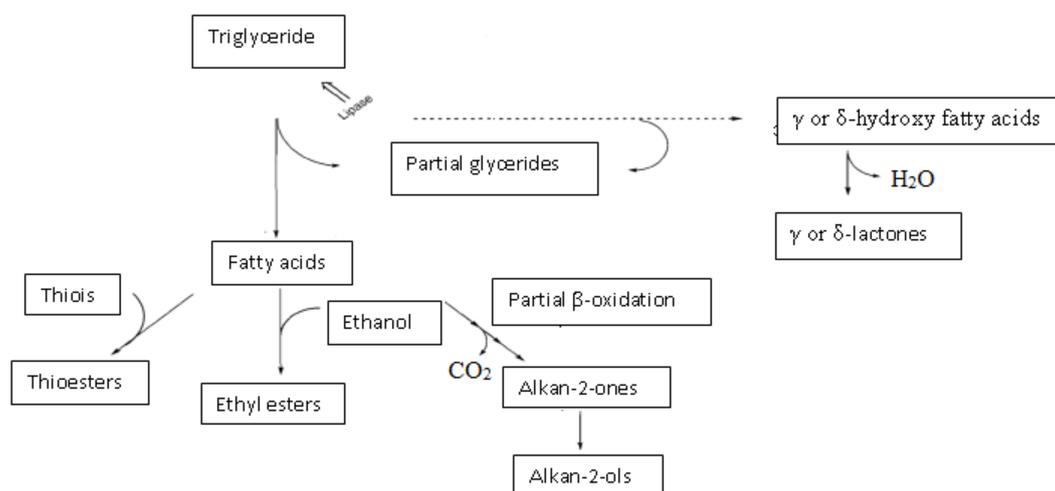


Fig. 22.1 Production of flavor compounds from fatty acids during cheese ripening

22.5 Proteolysis

Proteolysis is the most important and complex of all the events during ripening of cheese. The extent and pattern of proteolysis is also used as an index of cheese ripening and quality of cheese. Proteolysis contributes significantly towards development of texture and flavor in cheese. Textural changes (softening of cheese curd) occur due to breakdown of protein network and release of carboxyl and amino groups resulting in the binding of more water and thus decrease water activity (a_w). Proteolysis leads to the formation of peptides and free amino acids which contribute to cheese flavor. These amino acids also act as precursors for many reactions like transamination, deamination, decarboxylation, desulphuration, catabolism of aromatic compounds such as tyrosine, phenylalanine, tryptophan, etc. and generate many important flavor compounds. Proteolysis in cheese is catalysed by proteinases and peptidases and they originate from the following sources:

- Coagulant
- Milk
- Starter LAB
- Non starter LAB
- Secondary starters (e.g. *P. camemberti* in Camembert cheese and *P. roqueforti* in Blue cheese)
- Exogenous proteinases or peptidases, if added for accelerated ripening of cheese

In majority of cheese varieties, casein is initially hydrolyzed by the residual coagulant, often chymosin, which results in formation of large and intermediate-sized peptides. These peptides are then hydrolyzed by enzymes derived from starter and non-starter microflora of the cheese. The production of small peptides and amino acids is caused by the action of microbial proteinases and peptidases, respectively.

The final products of proteolysis are amino acids, the concentration of which depends on the cheese variety. The concentration of amino acids in cheese at a given stage of ripening is the net result of the liberation of amino acids from the caseins by proteolysis and their catabolism or transformation into other amino acids by the cheese microflora. Medium and small peptides contribute to a brothy background flavor in many cheese varieties; short, hydrophobic peptides are bitter. Amino acids contribute directly to cheese flavor as some amino acids taste sweet (e.g. Gly, Ser, Thr, Ala, Pro), sour (e.g. His, Glu, Asp) or bitter (e.g. Arg, Met, Val, Leu, Phe, Tyr, Ile, Trp).

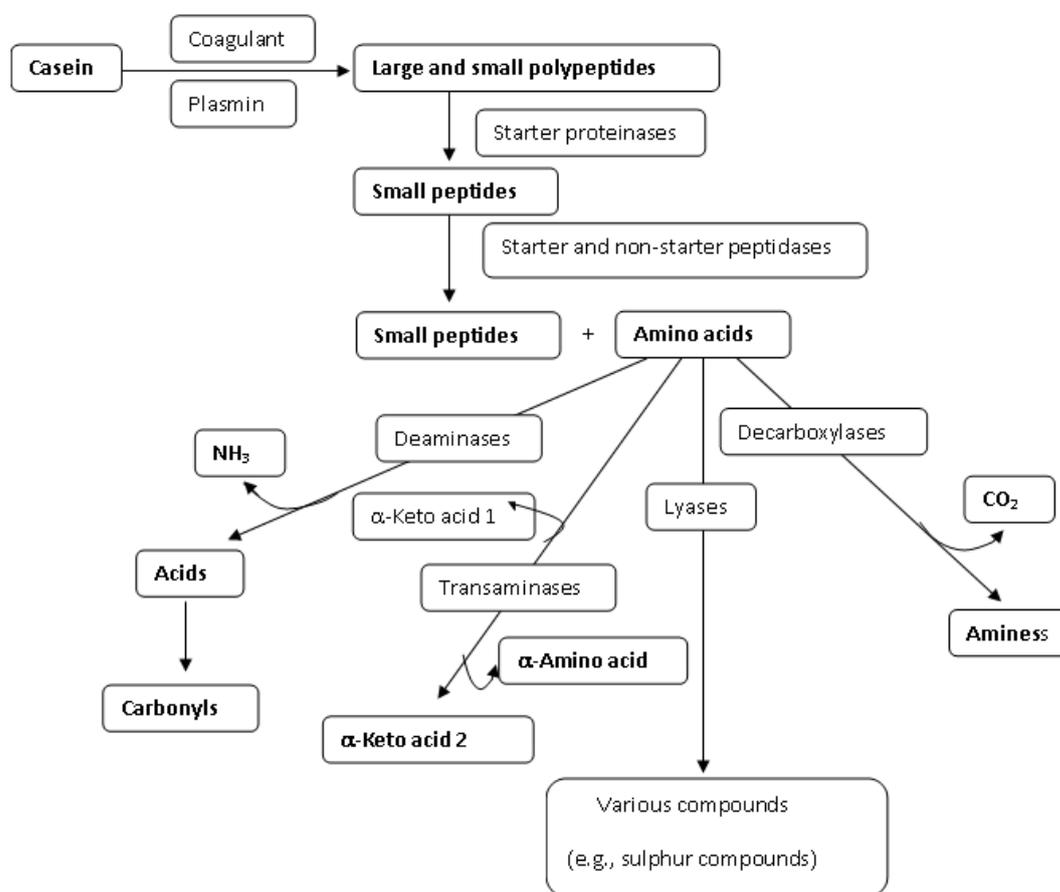


Fig 22.2 Proteolysis in cheese during ripening

22.6 Microbiology of Cheese Ripening

Microorganisms including bacteria, yeasts and molds are present in cheese and contribute to the ripening process through their metabolic activity. The enzymes released by these microorganisms also add to the various metabolic activities like proteolysis, glycolysis and lipolysis.

Microorganisms in cheese may gain entry through their intended addition in the form of starter culture and they may be associated with the ingredients used in cheese making. The microflora associated with cheese ripening may be divided into two groups - the starter bacteria and non-

starter bacteria. Starter bacteria are primarily responsible for acid production during manufacture to reduce the pH of milk to the desired level. The secondary microflora do not play any active role during cheese manufacture but contribute to the ripening process.

The factors controlling the growth of microorganisms in cheese include water activity, concentration of salt, oxidation-reduction potential, pH, ripening temperature, and the presence or absence of bacteriocins (produced by some starters).

22.6.1 Water activity

Water activity (a_w) is defined as the ratio of the vapor pressure of water in a material (p) to the vapor pressure of pure water (p_0) at the same temperature. Its value ranges from 0 to 1.0. It expresses the water availability rather than total water present in the system. Water activity of cheese reduces during ripening process. This may be due to several reasons like:

- Evaporation of moisture if the cheese is not vacuum packed or paraffin coated
- Hydration of proteins bound water rendering it unavailable for bacterial growth
- Hydrolysis of proteins to peptides and amino acids and of lipids to glycerol and fatty acids
- The salt and organic acids (lactate, acetate, and propionate) dissolved in the moisture of the cheese reduce the vapor pressure

Growth of microorganisms at low a_w is characterized by a long lag phase, a slow rate of growth, and a reduction in the maximum number of cells produced. Each of these factors helps to limit the number of cells produced. LAB generally have higher minimum a_w values than other bacteria. The amount of salt in moisture in cheese also affects the growth of microorganisms in cheese.

The salt normally used in cheese making is about 2% of the weight of the curd. Salt is added to cheese mainly to suppress growth of unwanted microorganism and to assist the physico-chemical changes in the curd. The growth of unwanted microorganisms is essentially curbed by reduction in a_w as salt act as a humectant.

22.6.2 Oxidation-Reduction potential

The oxidation-reduction potential (Eh) is a measure of the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species. The Eh of milk is about +150 mV whereas that of cheese is about -250 mV. As cheese ages, the products of proteolysis and lipolysis may reduce the Eh of cheese. This reduction of Eh makes cheese an anaerobic system, in which only facultatively or obligately anaerobic microorganisms can grow. Anaerobic sporeforming organisms present in the cheese may germinate and grow, causing defects like bitter and putrid flavor. Obligate aerobes, like *Pseudomonas* spp., *Brevibacterium* spp., and *Micrococcus* spp., will not grow within the cheese, even when other conditions for growth are favorable. Eh is therefore important in determining the types of microorganisms that grow in cheese.

22.6.3 pH

Most bacteria require a neutral pH value for optimum growth and grow poorly at pH values below 5.0. The pH of cheese curd after manufacture generally lies within the range 4.5-5.3, so pH is also a significant factor in controlling bacterial growth in cheese. LAB, especially lactobacilli,

generally has pH optima below 7, and *Lactobacillus* spp. can grow at pH 4.0. Most yeasts and molds can grow at pH values below 3.0, although their optimal range is from 5 to 7. *B. linens*, an important organism in smear-ripened cheese, cannot grow below pH 6.0. *Micrococcus* spp., which are commonly found on the surface of soft cheeses, cannot grow at pH 5 and only slowly at pH 5.5.

22.6.4 Temperature

The ripening temperature of cheese mainly depends on two considerations: the temperature should be such that the growth of undesirable spoilage causing and pathogenic bacteria can be checked and at the same time, this temperature should be conducive for various ripening reactions essential for development of typical flavor, body and texture of cheese. Ripening temperature for Cheddar cheese is 6-8°C while Camembert and other mold-ripened cheeses are ripened at 10-15°C. Emmental cheese is ripened initially for 2-3 weeks at a low temperature (~12°C), after which the temperature is increased to 20-24°C for 2-4 weeks to promote the growth of propionic acid bacteria and the fermentation of lactate to propionate, acetate, and CO₂. The temperature is then reduced again to around 4°C. Use of higher ripening temperature is one of the techniques used for accelerated ripening of cheese but it also stimulates the growth of other microorganisms present in cheese.

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Lesson 23

CHEESE YIELD, MEASUREMENT OF CHEESE YIELD

23.1 Introduction

The yield of cheese and its control are of great economic importance, determining the profit of cheese plants and the price of milk given to farmers. Therefore, cheese yield and the factors that affect it need to be studied thoroughly. Cheese yield calculation is important for measuring the efficiency of and determining the economic viability of a cheese making operation. It also aids in evaluating the potential usefulness of a particular process or change in technology.

23.2 Definition

Cheese yield may be expressed as the quantity of cheese of a given dry matter produced from a given quantity of milk with a defined protein and fat content (kg/100 kg milk). Actual cheese yield (Y_a) is often slackly expressed as the 'kilogram of cheese per 100 kilograms of milk' or 'per cent yield'.

23.3 Measurement of Cheese Yield

Measurement of cheese yield requires determination of weight of all the inputs and outputs. This can be easily achieved in a pilot scale plant where cheese is made in batches but in commercial/large scale cheese manufacturing, this cannot be done batchwise. In such plants, yield is calculated on daily basis rather than calculating it batchwise. Once all the inputs and outputs are determined, the actual yield can be calculated as:

$$\text{Actual Yield (} Y_a \text{)} = \frac{\text{weight of cheese}}{(\text{weight of milk} + \text{starter culture} + \text{salt})} \times 100$$

Although all different varieties of cheeses have standard limit for maximum moisture content, some batch to batch variations are unavoidable. Thus comparing yields of cheese having different moisture content is erroneous. To avoid the effect of moisture content, yield can be calculated by using the following equation:

$$\text{Moisture Corrected Cheese Yield (MCY)} = \text{Actual yield} \frac{(100 - \text{actual cheese moisture content})}{(100 - \text{reference cheese moisture content})}$$

Other than moisture, many factors affect the yield of a particular variety of cheese, including the milk composition, the cheese making process, and the type of plant equipment. The latter two factors influence cheese yield, since they affect the recovery of milk fat and protein in the cheese. If a manufacturer wants to compare cheese yields of different days in a year, then comparing the

actual yield (Ya) or MCY would be erroneous as the yield is also affected by the actual recovery of fat and protein in cheese and also by the composition of the raw milk. In this situation, if the composition of the cheese milk (protein and fat) and the cheese (protein, fat, and salt) at the different manufacturing times are known, the yield of cheese at the different times may be meaningfully compared by adjusting the protein and fat content of the milk to reference values. The resulting yield expression is termed the moisture-adjusted cheese yield/100 kg milk adjusted for protein and fat (MACYPF):

$$\text{MACYPF} = \text{MACY} \left[\frac{(100)}{\left\{ \frac{100 \times (\text{actual content of protein and fat in milk} + \text{starter})}{\text{content of protein and fat in reference milk} + \text{starter}} \right\}} \right]$$

The above equation assumes that casein content of protein is not changing over time. If it is prone to change over time, then protein content may be replaced by casein content in the same equation.

23.4 Prediction of Cheese Yield

Cheese yield is mainly affected by fat and casein content of milk and recovery of these components in the final product. A general formula for calculating yield may be expressed as $Y = aF + bC$, where Y is the yield, F and C are fat and casein contents in milk respectively, and a and b are the coefficients which are related to fat loss and casein recovery during manufacturing process. Several formulae are developed for prediction of cheese yield, depending on the cheese variety and composition of the cheese milk. Predictive yield formulae are useful in a cheese plant to measure its efficiency by comparing actual and predicted yields, for better production planning and also to plan product mix. Formulae for some varieties of cheese are given below:

23.4.1 Cheddar cheese

Van Slyke and Price Formula:

$$\text{Yield per 100 kg milk} = \frac{(0.93F + C - 0.10)1.09}{(1 - W)}$$

Where F = kg fat/100 kg milk; C = kg casein/100 Kg milk; W = kg water/kg cheese

23.4.2 Mozzarella cheese

$$\text{Yield per 100 kg milk} = \frac{(0.85F + C - 0.10)1.09}{(1 - M)}$$

M = kg water/kg cheese

23.4.3 Cottage cheese

$$4.9\text{TS} - 29.72 = \text{Yield} \pm 0.99$$

Where TS= total solids of skim milk

These formulae are established on the basis of average fat loss in whey and during other processes like plasticizing in Mozzarella cheese, average loss of casein in whey and increase in the weight of cheese due to other constituents and the added salt. For instance, in the formula for Cheddar cheese, 0.93 is the percent recovery of fat, C-0.10 indicates 10% loss of casein and factor 1.09 is for increase in the weight of cheese by other constituents of milk and added salt.

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Lesson 24
FACTORS AFFECTING CHEESE YIELD

24.1 Factors Affecting Cheese Yield

Factors affecting cheese yield can broadly be listed into two groups:

24.1.1 Cheese yield potential of milk

- i) Breed of cow
- ii) Variation between individual cows
- iii) Stage of lactation
- iv) Seasonal changes in climate and natural feed
- v) The type of feed and level of feeding
- vi) Problems due to diseases, especially mastitis
- vii) Milking procedures, such as the time that elapses between milkings and whether milked by hand or by machines
- viii) Effect of genetic variants on milk composition

24.1.2 Processing conditions that affect cheese yield

- i) Storage of milk
- ii) Milk standardization
- iii) Concentration of milk
- iv) Growth media used for bulk starter preparation
- v) Type of starter culture used
- vi) Heat treatment of milk
- vii) Homogenization of milk
- viii) Addition of CaCl_2 to milk
- ix) Type of coagulant used

- x) Curd firmness
- xi) Type of vat
- xii) Curd handling system
- xiii) Cooking of curd
- xiv) Cheddaring of curd
- xv) Washing of curd
- xvi) Proportion of salt added
- xvii) Pressure applied
- xviii) Loss of moisture during storage

The major factors that affect yield of cheese are discussed here. They can be broadly classified in two categories: 1) Uncontrollable factors and 2) Controllable factors. The major factor which is beyond the control of a cheese maker is the composition of milk. The other uncontrollable factor is the equipment used by the cheese maker. Various controllable factors are those related to the method of manufacturing and the processing conditions used while cheese making. The principal factors that influence cheese yield are discussed below:

24.1.3 Milk composition

One of the most important factors that affect cheese yield is the milk composition particularly casein and fat content. As already mentioned, cheese yield can be predicted by using the general equation $Y = aF + bC$. This shows that cheese yield is linearly related with fat and casein content of milk. The greater contribution of casein is expected, as it forms the continuous paracasein sponge-like network that occludes the fat and serum phases. In contrast, fat on its own has little water-holding capacity. Occluded moisture contributes directly to cheese yield and indirectly owing to the presence of dissolved solids, including whey proteins, κ -casein glycomacropeptide, lactate, and soluble milk salts. Fat generally contributes more than its own weight to Cheddar-type cheese (yield increases by about 1.16 kg/kg milk fat). This greater than pro-rata increase, is due to the increase in the level of moisture in nonfat substance as the fat content of the cheese increases. Fat is occluded in the pores of the paracasein network of the cheese and impedes syneresis. The occluded fat globules physically limit aggregation of the surrounding paracasein network and therefore reduce the degree of matrix contraction and moisture expulsion. Hence, as the fat content of the curd is increased, it becomes more difficult to expel moisture, and the moisture-protein ratio increases. However, if the moisture in nonfat substance is maintained constant (e.g. by process modifications such as reduction of curd particle size and slight elevation of the scald temperature), fat contributes less than its own weight to cheese yield (~ 0.9 kg/kg), owing to the fact that about 8-10% of the milk fat is normally lost in the whey.

The coefficients a and b depend on the composition of milk, the manufacturing procedure, equipment design and retention of fat and casein in the cheese. All those factors that affect milk composition, indirectly affect the yield also. Some such factors are species and breed of the animal, stage of lactation, seasonal variations, etc.

24.1.4 Holding milk at low temperature

When it is not possible for the cheesemakers to start cheese making soon after milk reception, the milk is stored in cold storages for some hours, depending on the manufacturing schedule. This action of storing milk at refrigerated temperature results in some physico-chemical changes in milk, which include:

- Solubilization of casein and colloidal calcium phosphate which leads to increase in serum caseins, thereby increasing loss in whey.
- Growth of psychrotrophic bacteria which leads to release of enzymes like proteases and lipases.
- Increase in free fat levels owing to lipase action.

The increased serum casein level can be reversed by pasteurization and thus, the effect of cold storage is nullified but the production of proteases cause protein breakdown into peptides. Some of these peptides are soluble in the serum phase and do not coagulate during curd formation. They are lost in whey leading to a decrease in cheese yield. The reduced casein level has an effect of curd shattering and weak coagulum, thereby increasing fat loss in whey. The dual effect of losing casein and fat in whey reduces the cheese yield considerably.

24.1.5 Heat treatment of milk

Cheese milk can be given heat treatments like thermization, pasteurization, etc. Heat treatment denatures whey proteins and results in their inclusion in the gel and thereby increase yield of cheese. The degree of whey protein denaturation determines the extent of their recovery in cheese. Thermization is done when milk is to be stored for long before making cheese. As discussed in the previous section, cold storage of milk leads to production of enzymes like proteases and lipases. Thermization prevents growth of psychrotrophs in milk, prevents casein solubilization and thus increases cheese yield. Pasteurization of milk (72°C, 15 s) denatures whey proteins to a lower level and thus the cheese yield is only slightly increased. The severe the heat treatment, more is the resultant increase in cheese yield.

24.1.6 Addition of CaCl₂

Addition of CaCl₂ at the rate of 0.02% in cheese milk is a common practice. This results in strengthening the curd, making it less susceptible to shattering at the time of cutting and stirring. This reduces the chances of fat and protein loss in whey and thus increases cheese yield.

24.1.7 Type of rennet

Type of rennet used for coagulation affects cheese yield as it affects the extent of proteolysis. The rennet having more proteolytic activity solubilizes casein and increases its loss in whey. Proteolytic rennet reduces cheese yield significantly only when the pH of the whey at the time of drainage is below 6.0 as in the case of Blue cheese and Camembert cheese.

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*Module 11. Cheese from buffalo milk***Lesson 25****PROBLEMS IN BUFFALO MILK CHEESE MAKING****25.1 Introduction**

Most of the well known cheese varieties of the world are conventionally produced from cow milk. However, buffalo milk too has been utilized with considerable success for manufacture of certain varieties of cheeses. Cheese made from buffalo milk displays typical body and textural characteristics. More specifically, where chewing and stringing properties are especially desired as in case of Mozzarella cheese, buffalo milk is technologically preferable over cow milk. In Italy, fresh and Pasta Filata cheese, especially Mozzarella, has been traditionally prepared from buffalo milk. In Balkan countries, several types of white brined and pickled cheeses are prepared from buffalo milk. Feta (Greece), Domiati (Egypt), Queso Blanco (South and Central America) and Paneer (India) are among the prominent cheeses mainly prepared from buffalo milk. In countries where buffalo milk predominates, several cheese varieties are now manufactured from buffalo milk, which were earlier prepared from cow milk.

25.2 Problems Associated with Cheese making from Buffalo Milk

The manufacture of cheese originated and flourished in countries with relatively cold climate where cows are the main milch animals. Consequently, methods of cheese manufacture were developed for cow milk and emphasis was given to those varieties for which cow milk happens to be most suitable. In contrast, in our country the major share of milk is from buffaloes. Buffalo milk is not considered suitable raw material for making certain ripened cheese varieties such as Cheddar, Gouda, Emmental, etc.

Ripened varieties are characterized by their soft, mellow and velvety body and texture and rich pleasing flavor. The cheese made from buffalo milk results in flat flavor and hard, rubbery and dry body and texture. This is mainly because of the qualitative and quantitative differences between cow milk and buffalo milk. Following phenomena are observed while manufacturing cheese from buffalo milk:

- Slower development of acidity
- Faster renneting time
- Lower retention of moisture in the curd
- Hard, rubbery and dry body

The high buffering capacity of buffalo milk, due to its higher calcium and casein content is the cause for slower development of acidity. Faster renneting time may be attributed to its higher colloidal calcium content (~160 mg/100 ml as compared to only 8 mg/100 ml cow milk). Lower retention of moisture in the curd is the result of low hydration of its casein compared to cow milk casein. Hard, rubbery and dry body may be due to high curd tension which, in turn, is the result

of the following:

- higher content of casein with bigger size of the micelles,
- high content of calcium and magnesium, more so in the colloidal state,
- larger proportion of solid fat with bigger size of globules and
- low voluminosity and solution of its casein micelles compared to the same in cow milk.

Cheddar, the most common variety of cheese made in India does not develop proper flavor and body and texture when it is made from buffalo milk. The major problem is considerably faster rate of renneting and syneresis, which result in lower retention of moisture in the finished product. This in turn, affects adversely, the three most important biochemical reactions, i.e. glycolysis, proteolysis and lipolysis which constitute the cornerstone of cheese flavor development.

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Lesson 26

PROCESS MODIFICATIONS FOR BUFFALO MILK CHEESE

26.1 Process Alterations to Prepare Quality Buffalo Milk Cheese**26.1.1 Heat treatment**

Heating buffalo milk at higher temperature is more suitable while preparing cheese from buffalo milk. The higher heat treatment results in partial precipitation of colloidal calcium and interaction of casein micelles with whey proteins prevents faster coagulation. The curd so formed retains more moisture, thereby improving body and texture of the resultant cheese.

26.1.2 Ripening of milk (acidification)

In case of cow milk about 1% active lactic culture is used for ripening of milk. A rise of 0.02% acidity in about 45-60 min is considered satisfactory for adding rennet. Since in case of buffalo milk acidity development is relatively slower due to its higher buffering capacity, the lactic culture is added at the elevated level of about 2%.

26.1.3 Supplementation of starter culture with starter adjuncts

Supplementation of regular starter culture with *Lactobacillus casei* 300 or *Lactobacillus helveticus* at the rate of 0.5% improves flavor development in buffalo milk cheese.

26.1.4 Ripening temperature of milk

Relatively lower temperature of ripening of milk (28°C) in case of buffalo milk is more conducive for acidity development as compared to the higher temperature (30°C) in case of cow milk.

26.1.5 Cooking temperature

Relatively lower cooking temperature in case of buffalo milk cheese (37°C/40-45 min) is helpful in retention of greater amount of moisture as compared to cow milk cheese (39-40°C/60 min).

26.1.6 Cheddaring

During cheddaring, piling and re-piling of cheese blocks should be more frequent to ensure greater retention of moisture in case of buffalo cheese.

26.1.7 Pressure

Lower pressure should be applied on cheese block in case of buffalo milk cheese as compared to cow milk cheese.

26.1.8 Application of starter culture adjuncts and enzyme preparation

In order to accelerate the ripening of cheese further from buffalo milk application of starter adjuncts and exogenous enzyme preparations should be made.



*Module 12. Manufacture of processed cheese and related products***Lesson 27****PROCESSED CHEESE AND RELATED PRODUCTS****27.1 Introduction**

Processed cheese is a product made by blending natural cheese of different ages in required proportion with emulsifying salts followed by heating and continuous mixing to form a homogeneous mass. Processed cheese was initially manufactured with the aim of increasing the shelf life of natural cheese. Manufacturing of process cheese involves blending of cheeses of different age. These allows sub-graded cheeses like gassy, highly acidic etc. to be utilized, instead of those getting wasted.

According to FSSR (2011), 'Processed Cheese' means the product obtained by grinding, mixing, melting and emulsifying one or more varieties of cheeses with the aid of heat and emulsifying agents. It may contain cream, butter, butter oil and other milk products subject to maximum 5.0 per cent lactose content in the final product and edible common salt, vinegar/ acetic acid, spices and other vegetable seasoning and foods other than sugars properly cooked or prepared for flavoring and characterization of the product provided these additions do not exceed one sixth of the weight of the total solids of the final product on dry matter basis and cultures of harmless bacteria and enzymes. It shall have pleasant taste and smell free from off flavor and rancidity. It may contain food additives permitted in the regulation and it shall conform to the microbiological requirements as prescribed in the regulation. It shall have moisture not more than 47% and milk fat not less than 40% on dry matter basis.

FSSR (2011) has defined Process Cheese Spread as the product obtained by grinding, mixing, melting and emulsifying one or more varieties of cheese with emulsifying agents with the aid of heat. It may contain Cream, Butter oil and other dairy products, subject to a maximum limit of 5.0 percent lactose in the final product, salt, vinegar, spices, condiments and seasonings, natural carbohydrate sweetening agents namely sucrose, dextrose, corn syrup, corn syrup solids, honey, maltose, malt syrup and hydrolysed lactose and food properly cooked or otherwise prepared for flavoring and characterization of the product provided these additions do not exceed one sixth of the weight of total solids of the final product on dry weight basis and cultures of harmless bacteria and enzymes. It shall have pleasant taste and flavor free from off flavor and rancidity. It may contain permitted food additives and shall conform to the microbiological requirements as prescribed in the regulation. It shall have moisture not more than 60% and milk fat not less than 40% on dry matter basis.

27.2 Classification of Processed Cheese Products

As per Code of Federal Regulations (CFR), USA, there are three main categories of process cheese viz., pasteurized process cheese (PC), pasteurized process cheese food (PCF), and pasteurized process cheese spread (PCS). Table 27.1 summarizes the compositional specifications (CFR, US and FSSR, India) and the major ingredients which are used in their preparation.

Table 27.1 Categories of cheese and their specifications

Type of Cheese	Ingredients	Moisture (%)		Fat (%)	
		CFR	FSSR	CFR (%) w/w)	FSSR (%) FDM)
Process Cheese	Cheese, Emulsifying agents, Acidifying agents, Cream, Anhydrous milk fat, dehydrated cream Water, salt, color, spices or flavorings, <u>Enzymatically modified</u> cheese	≤ 40	≤ 47	≥ 30	≥ 40
Process Cheese Food	Cheese and other ingredients allowed in process cheese in addition to milk, skim milk, buttermilk and cheese whey	≤ 44	---	≥ 23	--
Process cheese spread	All the ingredients allowed in process cheese food in addition to food grade hydrocolloids, sweetening agents and nisin	44-60	≤ 60	≥ 20	≥ 40

(Source: Kapoor and Metzger, 2008)

27.3 Preparation of Process Cheese

The manufacturing of process cheese involves selection and computation of ingredients, their blending and shredding, addition of emulsifying salts, heating, packaging, cooling and storage.

27.3.1 Selection and computation of ingredients

It involves selection of type of cheese and various ages of cheese, emulsifying salts, water and other optional ingredients to give process cheese the desired composition, textural and functional properties. The major constituent of process cheese is cheese. Types of cheese, degree of maturity and the blend selected for processed cheese have a major influence on textural attributes of the final product. Processed cheese can be made from only one or several types of cheeses. A blend of cheese having varying degree of maturity is selected on the basis of required flavor and texture in the finished product. General formulation of processed cheese is 70-75% mild cheese and 25-30% medium aged or mature cheese. For producing processed cheese in slices, Kosikowski had suggested a blend composition of 55% young, 35% medium aged and 10% aged cheese in order to obtain optimum firmness and slicing qualities.

Use of higher proportion of young cheese results in lesser raw material cost, formation of a stable emulsion with high water binding properties, firm body and good slicing properties. Sometimes it may also result in a product having mild taste, excessive swelling, and a tendency to harden during storage. Similarly, a high content of mature cheese have the advantages of full flavor development and flow properties while the disadvantages may be the harsh (sharp) flavor, low emulsion stability and a soft consistency.

After selecting all the ingredients, the quantity of the ingredients is calculated on the basis of fat and dry matter content of the natural cheese components. Formulation of material balance of fat and dry matter including all the ingredients, water, and moisture loss during heating is made in a

way to yield the finished product with desired composition.

27.3.2 Shredding and mixing

After calculating the quantities of all the ingredients, all types of cheese are shredded and either pre-mixed with other ingredients or mixed in the process cheese cooker before processing. Pre-mixing of cheese with other ingredients offers some advantages like physico-chemical changes at lower temperature prior to cooking which results in more uniform quality in the end product. Since cheese of different ages is used in manufacturing process cheese, there may be batch-to-batch variation in the hydration time of cheese and the free fat emulsification. Pre-mixing evens out the effects of differences in processability of cheese of varying age on the consistency of the final product.

27.3.3 Processing the blend

Following pre-mixing, the blend is discharged into the cooker, where it is processed. When pre-mixing is not practiced, the ingredients are added directly to the cooker. The ingredients are added in the order of ground cheese, a dry blend of emulsifier and other dry optional ingredients, water and flavors. Emulsifying salt may also be added with a portion of water at the start of cooking process. The remaining water may be added later in the processing stage. This is practiced especially where cooking time is relatively short. Flavors may be added later in the process to minimize the loss of volatile flavor compounds.

Processing refers to the heat treatment of blend by direct or indirect steam with constant agitation. The main functions of processing are killing of pathogenic and spoilage microorganisms to extend the shelf life of the product and to induce physico-chemical and microstructural changes which transform the blend to an end product with the desired characteristics and physico-chemical stability. Processing may be carried out in batch or continuous cookers. The time-temperature combination of processing varies depending on the formulation, the extent of agitation, and the desired characteristics in the finished product.

Batch Processing--- 70-95°C for 4-15 min

Continuous Method – 140°C for 5-20 s

In continuous method, after giving the required heat treatment, it is essential to hold the product at around 70-90°C for 4-15 minutes for interaction of different ingredients and for desired physico-chemical changes to occur. Processing may also be performed continuously using extrusion cookers at a temperature of about 70-90°C. Extrusion cooking gives a high degree of protein hydration and rapid emulsification.

27.3.4 Homogenisation

The processed hot mass may be homogenized in a two stage homogenizer at pressures of 15 and 5 MPa, respectively. It improves the stability of the fat emulsion, consistency, structure, appearance and flavor of the processed cheese.

27.3.5 Hot packing and cooling

Hot processed cheese blend can be transported to packaging machines directly from cooker or a buffer tank can also be installed in between. Processed cheese is usually packed and wrapped in

lacquered foil, tubes, cups, cans and cardboard cartons. It may also be packed in the form of slices wherein, the hot molten cheese is pumped continuously into an endless 'tube' of plastic film, e.g. saran-coated polyester, which is automatically flattened and crimped into a chain of individual wrapped slices using crimping conveyors and rotating crimping heads. The chain of slices is then passed through a water-cooling tank and cooled to $<10^{\circ}\text{C}$, dried by removing water using fans and/or scrapers, and finally cut into individual slices which are stacked and packed.

The body of the finished product may vary from firm and sliceable to semi-soft and spreadable, depending on the blend formulation, processing conditions and the cooling rate. The product that is cooled slowly develops a firmer body as compared to the product that is cooled faster. Thus, the process cheese should be cooled as slow as possible while in the case of process cheese spread fast cooling is required.

27.3.6 Storage

The finished product is stored at less than 10°C . It should not be stored under frozen conditions as low temperature may induce crystal formation.

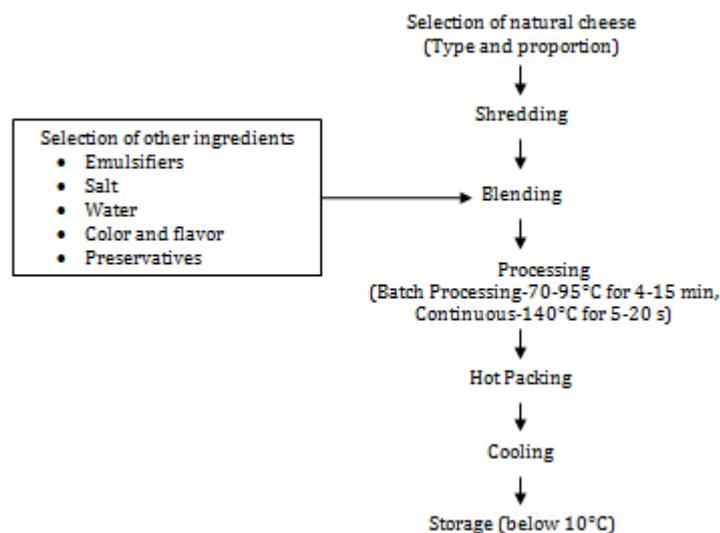


Fig 27.1 Flow diagram for manufacture of Processed cheese products

27.4 Cheese Powder

Cheese is dried to prolong the keeping quality and to reduce weight and bulk. Cheese powders are used as functional and natural flavor ingredients in a wide range of food/culinary applications including biscuits, savory, snacks, soups, bakery, sauces, dressings, ready meals and processed cheese. Majority of hard cheeses can be transformed into powder. Among cheeses which are produced in powder form, Parmesan and Cheddar are the most common. There are several methods of dehydrating cheese. These include direct tray drying, roller or spray drying, extrusion drying and freeze drying. Among these methods, spray drying is most commonly used. The technological process of dried cheese production is different from that of majority of other dry products. Cheese is first ground, and stirred with intensive agitation while adding water at $27-32^{\circ}\text{C}$ to achieve the dry matter concentration optimal for spray drying (35-45%). At this stage,

melting salts, comprising sodium citrate, disodium phosphates or polyphosphates are added to prevent milk fat separation. The well-mixed mass is pasteurized, heated to 60°C and homogenized. It is spray dried at about 175°C inlet air temperature and immediately cooled to 29-32°C, then shifted and packed in bags. Packaging in the atmosphere of inert gas and addition of antioxidants can extend the shelf life of dry cheese.

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Module 13. Defects in Cheese

LESSON 28

DEFECTS IN CHEESE, CAUSES AND PREVENTIVE MEASURES

28.1 Defects in Cheddar cheese

Cheese is a product of fermentation and consequently undergoes constant changes. Its characteristics of flavor, body and texture, color and curing qualities are influenced by the quality of milk, techniques of manufacture, temperature of curing and length of curing time. Cheese develops defects when there is deviation in the selection of appropriate quality of milk, method of manufacture and curing.

Table 28.1 Defects in cheese can be related to the following aspects

Flavor	Body & Texture	Color and Finish
	a)Body	i. Acid cut
i. Acid	i. Corky body	ii. Black discoloration
ii. Bitter	ii. Crumbly body	iii. Bleached
iii. Cowy	iii. Curdy body	discoloration
iv. Feed	iv. Dry body	iv. Mottled cheese
v. Fermented	v. Mealy body	v. Rusty spots
vi. Fruity	vi. Pasty	vi. Seamy color
vii. Mouldy	vii. Sandy	vii. Waxy color
viii. Rancid	viii. Short	viii. White specks
ix. Unclean	ix. Sticky	
x. Weedy	x. Weak	
xi. Yeasty	b)Texture	
	i. Casein texture	
	ii. Yeasty texture	
	iii. Mechanical openness in texture	

28.2 Defects Related to Moisture Content

The presence of either too little or too much moisture in cheese is associated with certain characteristics. The qualities of cheese affected are flavor, body or consistency, texture or openness and color. When the moisture is extremely high or low, the finish of the cheese is also affected.

Moisture has an influence on all of these characteristics because it is directly related to the composition and physical qualities of the cheese. Moisture is indirectly related to these characteristics because it carries lactose and some of the milk salts in solution. Microorganisms change lactose to acid, chiefly lactic. A certain amount of such lactic acid formation is necessary for proper cheese making and ripening; excessive amounts make the cheese taste sour while inadequate amounts may delay ripening or may actually encourage abnormal fermentations of undesirable type. The amount of moisture in cheese must be properly controlled.

28.2.1 Excessive moisture

The characteristics of cheese with excessive moisture are as follow:

- a) Flavor may be sour or acid or merely slightly acid when fresh, and lacking in cheese flavor and sour when aged.
- b) Body may be weak or soft when fresh, and sticky and pasty when aged.
- c) Texture may be open if the acid development during the making operation is inadequate.
- d) Color may be higher.

28.2.1.1 Causes

One or more of the following may be responsible:

- An unusually high fat content in milk fat delays firming.
- Lack of acid development during making.
- Insufficient heating or heating too rapidly.
- Incomplete removal or elimination of whey.

28.2.1.2 Prevention

It is usually not necessary to apply all the measures of control indicated. The results might produce cheese with too little moisture. The corrections may be selected by scrutinizing the manufacturing records.

28.2.2 Effects of insufficient moisture

- a) Flavor - mild or lacking. It may be slightly acid if lack of moisture was caused by excessive acid during making. Cheese flavor develops slowly.
- b) Body - firm, hard or corky, and sometimes crumbly and mealy. Loss of curdy characteristics during ripening is extremely slow.
- c) Texture - usually close and solid but may show mechanical openness where curd particles failed to knit together properly during pressing.
- d) Color - sometimes deeper in shade and rind formation is frequently darker in color than the rest of the cheese.
- e) Finish - may show defective knitting together of curd particles.

28.2.2.1 Causes

May be due to one or more of the following:

- Maximum acid development throughout making process.

- The use of excessive amounts of rennet or CaCl_2
- Fine cutting or breaking of the curd.
- Heating and holding temperature high.
- Excessive stirring of the curd while the whey is being removed and immediately after dipping.
- Lack of piling during cheddaring operation.
- Addition of too much salt.
- Holding the cheese in a warm drying room long before paraffining.

28.2.2.2 Prevention

a) At salting

Steps may be taken to reduce the acid development, ripening period and amount of starter, besides adding the rennet sooner. The amount of rennet should be reduced, use of calcium chloride should be avoided, a firm cut should be developed at cutting and coarser knives may be used for cutting curd.

b) At heating

The temperature may be decreased. If the temperature used approximates 36°C , then acid development may be stimulated.

c) At dipping

Minimum amount of acid recommended for normal making operation should be developed. The curd should be settled 30 min before dipping and it should not be stirred at any time thereafter. As the curd settles under the whey, it should be pushed towards the side of the vat to form layers approximately 25 cm deep. The whey should be removed early and before the curd develops extreme firmness, this measure of control is most commonly used and is entirely adequate even when applied alone in ordinary making practice. The layers of curd should be cut into blocks 25 cm wide and piling should be sooner than usual. It should be piled 4 or 5 high before milling. Allow the curd to cool during cheddaring.

d) At Milling

Use the minimum acid development consistent with recommended making procedure. Cool the curd promptly after milling by stirring and rinsing highly with water at $15\text{-}21^\circ\text{C}$. Salt the curd promptly and use the minimum amount indicated for normal cheese. After pressing remove the cheese to a cool room and paraffin it as soon as the rind is properly dried.

28.3 Defects Related to Acid Content

The presence of too much or too little acidity in Cheddar cheese is associated with certain defects. Excessive acidity is found in cheese that contains more than normal amounts of moisture because such cheese contains more than normal amounts of lactose. Excessive acid development during

the making process can also produce acid defects in the finished cheese even when the moisture content of the product is normal or perhaps less than normal.

28.3.1 Effects of excessive acidity

All the physical characteristics of Cheddar cheese may be affected by excessive acidity.

- a) Flavor – acid or sour. Bitterness is sometimes associated with too much acid development during making. True cheese flavor is lacking or slows in development.
- b) Body – firm, dry, crumbly, short and mealy when the moisture content is low, it may be soft, pasty, sticky, and short when the moisture content is high.
- c) Texture – usually close although in extreme instances the curd particles may be so poorly knitted together that numerous mechanical openings will be formed.
- d) Color – bleached or acid cut and sometimes mottled.
- e) pH – usually less than 5.05 when the cheese is 3 to 4 days old.

28.3.1.1 Causes

- Too much moisture in cheese
- High acid initial milk
- Use of too much starter
- Prolonged ripening period
- Too much acid development before adding rennet
- Too much acid development at other steps

28.3.2 Effects of lack of Acidity

The common characteristics:

- a) Flavor - mild when fresh and fermented, fruity or lacking when aged. True cheese flavor develops slowly, if at all.
- b) Body - corky, pasty, sticky or weak. The cheese remains curdy for long time in curing.
- c) Texture - open, with large mechanical holes. The cheese with insufficient acidity may also show the effects of uncontrolled fermentations of gas producing yeasts or bacteria.
- d) pH - usually more than 5.3 when the cheese is approximately 4 days old.

28.3.2.1 Causes

- Failure of starter - due to inactive starter, improper handling of starter, unfavorable conditions for starter activity, or bacteriophage.
- Abnormal milk - unfavorable manufacturing methods, unnecessary amount of CaCl₂.
- At Milling - Delay milling until the whey draining from the curd shows at least 0.30% acid. The hot iron test should be nearly 3/8" long and the pH of the curd should be not more than 5.6.

If the acidity of the whey after two hours of dipping does not exceed 0.25%, then it is highly probable that the starter is faulty or that it is contaminated with bacteriophage. If contaminated with phage, prolonging Cheddaring operations for 4-5 h do not help acid development. Holding the curd in pack for 12 h or longer sometimes permits acid development in curd affected with phage. The curd must be kept at 29°C during this period.

28.4 Defective flavors

28.4.1 Acid flavor

This results from the development of too much acid at any stage of cheese making or curing. It may occur from high acid milk as received, ripening too long before setting, too much starter, improper cutting, cooking too fast or other factors which may interfere with proper expulsion of whey from the curd, or otherwise developing acid faster and higher than normal. Low salt content of cheese may also be a contributing factor.

28.4.2 Bitter flavor

This is a common defect. It is associated with inferior milk and poor starter, with excessive moisture and high acidity in cheese and using too much rennet and unclean utensils. Relatively higher temperature and use of *Leuconostoc* sp. as starter has been noted to cause the defect. Unclean conditions e.g. rust spots, open seams, milk stones in cans and utensils may cause this defect. Conditions associated directly with the manufacturing operations may also be responsible e.g. excess acid, excess moisture, lack of salt, and high curing temperature.

28.4.3 Fermented flavor

These flavors are characteristics of the odor of fermented whey and possess some of the qualities of the combined odors of alcohol, acetic acid and propionic acid. They may appear in cheese soon after it is made, but they usually develop after the cheese is two weeks old. They are believed to be caused by yeasts or bacteria. These organisms may get into the milk on the farms by contact with unclean and non-sterile surfaces of utensils, milking machines, and milk cans. This can be prevented by:

- (i) Utmost precaution in plant sanitation,
- (ii) Clean and active starter and
- (iii) Ripening at 7°C or below.

28.4.5 Fruity flavor

The fruity flavor defect has been described as pineapple, raspberry or pear-like flavor in cheese. The compounds responsible for the defect are esters, certain acetaldehydes and ketones and some alcohols. This flavor defect is closely related to the fermented flavor defect. Hence the origin, prevention and remedies are identical to that of fermented flavor defect.

28.4.6 Moldy flavor

It is associated with curing conditions. It is caused by the growth of mold in or on the cheese. Mold will grow in Cheddar cheese only when O₂ gains entry through openings in the rind or through openings or cracks inside the cheese which connect with trier holes or other defects in the rind.

Mold grows slowly on cheese held at low temperature and under dry conditions; it grows rapidly at high temperature and high humidity. It grows most luxuriantly on non-paraffined cheese.

Prevention - Proper paraffining, close texture, sound rind, curing at 7°C and relative humidity below 75% minimize the defect.

28.4.7 Rancid flavor

Rancidity is the flavor characteristic of the odor of butyric acid. It is believed to be present in all normal Cheddar. This flavor may come from the milk itself.

28.4.8 Unclean flavor

Flavors that are foreign to milk and cheese but which can not be identified or otherwise described are usually called unclean. Unclean flavors are often attributed to the development of undesirable microorganisms in the milk, curd or cheese.

28.5 Defects Related to Body

The term body is used by technologists in the cheese industry to designate the physical properties of consistency. These properties include firmness, cohesiveness, elasticity and plasticity. These physical characteristics of cheese are sometimes called rheological properties. Firmness is the property of the cheese which causes it to resist deformation or distortion under pressure. Cohesiveness is the characteristics of the cheese that causes it to stick together. Elasticity is the capability of the cheese to recover its size and shape after deformation. Plasticity is the quality of the cheese which enables it to be deformed under pressure without rupture.

The rheological properties of cheese are affected by methods of manufacture and composition of cheese.

Various terms are used to indicate firmness, elasticity, cohesiveness, and plasticity of curd and cheese. These terms describe the appearance and feelings of the cheese when a plug is removed from the cheese block. A normal plug of ripened Cheddar cheese shows a smooth, uniform surface. It feels solid and firm, it does not crumble, when cut or pressed. It bends before breaking and when rubbed between the thumb and fingers, it feels smooth and waxy like cold butter. Some of the common defects are as follow:

28.5.1 Corky

Cheese with a firm, hard, tough and somewhat elastic consistency is called corky. Such cheese is difficult to crush with the fingers, but when enough pressure is applied it breaks apart in a woody manner.

Corky body may be apparent as very firm curd at the time of draining; the characteristics usually appear before salting. Corky characteristics may persist throughout the life of the cheese.

Causes – Low fat content, lack of acid development, over-heating during cooking, lack of moisture and excessive salt content.

28.5.2 Crumbly

This defect is characterized by the falling apart of cheese when sliced, by difficulty in removing a full plug and by the breaking of the cheese into pieces that crumble when crushed between the thumb and fingers. This lack of cohesion is apparent through the whole cheese and is not limited to the surfaces of the curd particles which make up the cheese. Crumbly cheese usually feels firm before breaking. It shatters with a snap, like breaking of chalk.

The defect rarely appears during the making operations, although the first stage of crumbly body may be evident when excessively acid curd fails to mat properly during cheddaring. The defect is usually apparent in fresh cheese within a week after making; it persists throughout the life of the cheese.

Crumbly body in cheese can be prevented by observing the preventions and remedies for excessive acidity.

Crumbly body gradually develops in aged cheese and is not regarded as a defect, if the cheese is sweet in flavor. This crumbly body is caused by ripening changes in the foods and by loss of moisture. This condition is associated only with a fully matured flavor in the cheese.

28.5.3 Curdy

This characteristic is natural in fresh cheese and is rightly regarded as a defect only when it persists beyond about 30 days. Curdy cheese, when broken apart, reveals the size and shape of the original curd particles after salting.

When pressed between the fingers it feels elastic, firm and somewhat like the particles of curd at the time of salting. It cannot be worked together in the fingers after it has once been broken apart.

28.5.3.1 Causes

- Low moisture content which delays curing
- Lack of proper acid development
- Lack of proper cheddaring in the vat before milling
- Addition of excessive amounts of salt, or

- Low temperature storage.

28.5.4 Mealy

This characteristic appears when cheese is crushed and rubbed between the thumb and fingers, the structure of the curd looks and feels rough, the characteristic is the opposite of the waxy, smoothness desired in normal cheese.

Mealy body can be most readily detected after the curdy characteristics of the cheese have fully disappeared; it is actually apparent during the first week of curing but is not so easily discovered. It persists throughout the life of cheese.

Cause - Excessive acidity, it may be regarded as a stage of disintegration of crumbly cheese.

Mealy body in cheese can be eliminated in future lots by observing the preventions and remedies for excessive acidity.

28.5.5 Pasty

Cheese with this defect is soft in consistency, when pressed and rubbed between the fingers, it quickly becomes sticky and clings to the fingers.

Pasty body in cheese becomes apparent as soon as the curdy characteristics disappear. The defect is caused by excessive moisture.

28.6 Defects Related to Texture

Open texture is the most common defect in cheese. It may be due to the formation of gas or mechanical faults. The causes of this defect are as follows:

- a) Contamination of cheese with gas producing bacteria and yeasts.
- b) Lack of acidity
- c) Moisture content
- d) Free whey trapped in curd, and
- e) Lack of sufficient pressure during pressing of cheese.

The defect can be controlled by eliminating source of contamination, using pure culture, and pasteurizing the milk efficiently. Acidity of 0.16% LA at draining, piling high, milling at acidity 0.60% LA, delayed salting; washing the curd with water at 30°C and curing below 10°C also help in controlling the defect.

Table 28.2 Color defects in cheese

Color defects	Causes
Acid cut	Excessive amount of acidity
Black discoloration	Presence of minute traces of lead coming from paint
Bleached color	Reducing action of organisms like <i>Bacillus subtilis</i> , <i>B. fluorescens</i> , etc.
Mottled color	Mixing of curd from two vats, lumpy starter, uneven development of acidity and moisture, adding starter after color, improper salting.
Rusty spots	Presence of anaerobic lactic organisms, moisture, lactose.

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*Module 14. Packaging, storage and distribution of cheese***Lesson 29**
PACKAGING OF CHEESE**29.1 Introduction**

Packaging refers to putting a commodity into a protective wrapper or container for shipment or storage. Any material to be used for packaging natural cheeses must:

- a) afford general protection
- b) prevent moisture loss
- c) improve appearance
- d) protect against micro-organisms and
- e) prevent oxygen transmission

Packaging of cheese is mainly done to protect the cheese at the time of storage and transportation. Traditionally, cloth was used with wood to give support and protection, but the invention of polymers or plastics has revolutionized cheese packaging. Cheese manufacturing is now-a-days highly mechanized and at the same time, many developments are taking place in the area of cheese packaging also.

Cheese is packaged mainly in two forms:

- a) Packaging cheese for storage and ripening (bulk packaging)
- b) Packaging for consumers (retail packaging)

29.2 Bulk Packaging of Cheese

For bulk packaging of cheese, it is either paraffined or vacuum packed in flexible film. For waxing, the cheese can be lifted by means of suction and half immersed in wax and then other half can be immersed. For vacuum packaging, there are now available vacuum packaging machines, gas flushing machines, over wrapping machines and vacuum skin packaging machines. Paraffining is now completely replaced by film packaging as it causes considerable loss of cheese while removing paraffin. Many cheap and easy-to-apply films are now available.

29.3 Modern Packaging Materials and Forms

- a) Materials – the basic ones are paper (usually coated or lined), parchment, foil (usually aluminum), polythene, propylene, treated cellulose and cellulose acetate (e.g. cellophane),

polystyrene, polyester, polyamide (nylon), rubber hydrochloride (e.g. cryovac) and Saran (a mixed polymer). Laminates are now more common.

b) Forms - wrappers, cartons, bags, tubes, tubs, jars, cans, etc.

29.3.1 Film packaging

This has become synonymous with 'rindless cheese'. In the latter, green cheeses of uniform size and shape are ripened in bags made of plastic films. The wrapped cheese may be placed in a wooden box or jig to preserve its shape. If the cheese is made and ripened in the conventional way, it may be cut into retail portions and wrapped by such method as the cryovac.

Desirable properties of films for packaging

- a) The film must be strong so that it does not tear or change its property when rubbed against a sharp point.
- b) It should be easily applied and sealed.
- c) It must be impervious to water vapor and oxygen.
- d) When the film is in contact with cheese, it should not change its inherent properties.
- e) The material must be chemically inert and non-toxic for humans.

Plastic film packaging of cheese is applicable to varieties except such extreme types as cottage (which has very high moisture content) and as Parmesan (which is very low in moisture). There are many advantages and few disadvantages of film packaging which are summarized as follows:

29.3.1.1 Merits

- i) It affords a considerable saving in labor.
- ii) It protects the cheese from attacks by molds, insects, rodents and fault-inducing microorganisms.
- iii) It is easily applied and the method can be readily mechanized.
- iv) There is practically no loss of moisture and of weight in the cured cheese (In traditional ripening the loss may be 3 to 7%, even up to 12 %)
- v) The method permits and is suitable for packaging small quantities, which make handling and retail trade easier.
- vi) The method is most easily used for rectangular blocks.
- vii) It is cheap and convenient.
- viii) Humidity control is unnecessary during ripening and storage.
- ix) More cheese can be stored in a given volume.

x) Turning is unnecessary during ripening.

xi) It permits 'rindless curing' so that whole of the cheese can be eaten. (When rind is formed as in traditional method, the loss can be as high as 10%).

29.3.1.2 Demerits

i) Not all technical problems in film packaging have been solved. (For example, failure to obtain a perfect seal and to remove all air may result in mould growth).

ii) The moisture content of the cheese at packaging must be less than for traditional packaging and must be carefully standardized. Failure to do so may lead to the growth of taint-producing organisms.

iii) The ripening process in some cheeses (such as Camembert) may be affected.

iv) The film does not always give the same mechanical protection to cheese as traditional methods.

v) The most careful attention to detail is necessary in film packaging.

29.4 Retail Packaging of Cheese

Retail packaging is an important aspect which affects not only the shelf life of cheese but also its marketability. Cheese is available in the form of slices, cubes, tubs, paper board cartons with foil overwraps, etc. These are available in different retail sizes like 100 g, 200 g etc. With the developments taking place in packaging technology, cheese packaging is also revolutionized. Active packaging and modified atmosphere packaging is being used for retail cheese packaging.

29.5 Developments in Packaging of Different Types of Cheese

29.5.1 Soft cheese

Special packaging requirements

The packaging material requirements for soft cheeses differ considerably depending on whether the cheese concerned is a soft cheese with a mold formation (surface mold, Camembert), blue-veined cheese (Roquefort), or a so-called smeared cheese (Munster). Different bacteria and mold flora require packaging material to have specific properties.

29.5.2 Fresh Cheese

Special packaging requirements

29.5.2.1 Protection against light

Metals are impervious to light. With regard to fresh cheese packaging this concerns first and foremost aluminium, whether in the form of lids to seal plastic containers or as deep-drawn containers. A high degree of imperviousness to light can be achieved through the addition of carbon black or brown pigments (total transmission approaching 0%). As black cheese packaging would not be acceptable to the consumer, such light-preventing layers are usually produced as the inner sheet of multilayer films by co-extrusion. This has not been done in dairy industry because

of cost. The outstanding barrier property of aluminium is also found with vacuum metalized plastic films (e.g. polyethylene terephthalate polyester (PETP), oriented polypropylene (OPP), cellophane or paper).

29.5.2.2 Protection against the effects of oxygen

In order to avoid the diffusion of oxygen, especially in packed fresh cheese with a long shelf-life, the most impervious packaging material possible must be selected. This is achieved using Al (foil or strips), metalized plastics or by means of O₂-resistant layers in plastic combinations such as polyvinylidene chloride (PVDC), ethylene vinyl alcohol (EVAL) or polyvinyl alcohol (PVAL).

When selecting mono or multilayer combinations (bags or thermoformed containers) it should be borne in mind that the data concerning gas permeability always refers to flat (unfolded) material, measured at +23°C. When a pack is formed, the permeability may change significantly due to capillarity in the sealed seam, thinning of the material at the base of deep-drawn containers or fractures caused by bending in bags.

29.5.2.3 Protection against loss of moisture

The absorption of moisture is not of any significance for packaged fresh cheese. On the other hand, however, fresh cheese with a long shelf-life must be protected against loss of moisture. In addition to the specific properties of water vapor permeability of the various packaging materials, the way they are processed into finished packs is also important.

29.5.2.4 Protection against contamination

Quite apart from contamination through leaks in the packs or lids, the packaging material itself may be contaminated to a greater or lesser extent. Paper which is used as wrappers may be affected as a raw material or during production by bacteria and/or mould conidia.

Due to high temperatures involved in processing, plastics are considered virtually bacteria-free. However, the possibility of contamination from the environment cannot be ruled out during further converting into film and containers.

29.5.3 Hard cheese

29.5.3.1 Emmental cheese

A pressed, 'block'-shaped Emmental Cheese (84 kg) is wrapped in cling film and stacked on a specially designed pallet, which can be mechanically turned during the ripening/storage period. The smaller 'block'-shaped Emmental could be packaged mechanically in a Cryovac-BKIL bag. This type of packaging material is a laminate of different layers of plastics.

29.5.3.2 Cheddar and related cheese varieties

Different systems have been employed for the packaging of Cheddar Cheese and other British varieties. These may include the following:

a) Pukkafilm

This type of packaging material consists of a waxed cellulose laminate. First, the cheese block is

wrapped with the laminate; secondly, it is over-wrapped with waxed cellulose; and thirdly the cheese is placed in a chamber for sealing by the application of heat and pressure.

b) Unibloc system

The pressed cheese is wrapped with a plastic film, e.g. Saran and over-wrapped with a layer of paper prior to packaging within six wooden slats. The cheese is compressed within the slats by a specially designed machine, and the pressure is maintained by placing four metal straps around cheese. In some instances, the wrapped cheese is placed within a thin cardboard box before final packaging. This box serves as a dispatch unit when the cheese leaves the factory, and the wooded slats are retained on the premises.

c) Storpac

The packaged cheese, e.g. in a vacuum pouch or heat-shrink bag is wrapped in a thin cardboard box (optimal) and is placed in a wooded box with a loose cover. The latter piece is held onto the box using a plastic band for strapping. On dispatch the strap is removed from these boxes which are retained in the factory.

d) Heat-shrink bags

An example of such a bag is the Cryovac-BB4L bag, which consists of three main layers: polyolefine, a PVDC barrier layer against oxygen and moisture and a cross-linked polyolefine. Gas production in Cheddar cheese during the maturation period is considered a serious problem, and a quick remedy is to package the cheese in carbon dioxide permeable material, e.g. Cryovac-BKIL bag.

e) Vacuum pouch

Different types of plastic film laminates can be used to package Cheddar cheese, and such pouches should provide a barrier against oxygen ingress and moisture loss. One such example is the Diolon pouch which consists of 20 μm nylon (polyamide) and 60 μm polyethylene.

29.5.3.3 Gouda, Edam and related cheeses

After brining stage, the cheese is plasticized twice to prevent mould growth during the ripening period, and this process is repeated several times if the cheese is to be stored for long periods. Prior to dispatch, the cheese is washed, dried and coated with paraffin wax and over-wrapped with a red cellophane film (the latter packaging material is optional). The mechanical handling of cheese in the store and the waxing equipment are of great concern.

An alternative approach for the packaging of the 'loaf', block or 'round' Dutch cheeses is to wrap the product in a heat-shrink bag, which is then either sealed by heat with a metal clip.

However, recent reports indicate that the protective packaging of foods is not available in a single packaging material if the desired shelf-life has to be achieved. Various packaging materials are used in combination to give the desired shelf-life of cheese. Plastic combinations, Al-foil/paper laminates, cellophane/paper combinations, etc. are in use these days. Modified Atmosphere Packaging has contributed greatly to increase the packaging speed and thus reduce the cost. Still cheaper combination packages and modern methods are in demand mainly as consumer packages with all the desirable properties.

Lesson 30

STORAGE AND DISTRIBUTION OF CHEESE

30.1 Introduction

After completion of the post-processing treatments like bandaging and dressing, the cheeses are kept in the ripening room. This starts the process of ripening. For some varieties of cheese like Cheddar and Parmesan, ripening and storage are the same while for others like Camembert and Roquefort, ripening and storage are two different processes as they need altered temperature and humidity in both the processes. Storage is inevitably, a continuation of the ripening process (except changing temperature and humidity for some varieties) so that all the considerations which apply to the ripening period apply equally to the storage period.

30.2 Shelves for Ripening/Storage of Cheese

In traditional practice, wood was used as the material for construction of shelves. But it has many disadvantages like it gives shelter to pests and is an excellent medium for the growth of molds and other microorganisms, once it is wet. So, wooden shelves need lot of care and maintenance. The easiest materials to clean are glass and stainless steel.

30.3 Factors Affecting Ripening and Storage

The two most important factors controlling ripening and storage are temperature and humidity. Thus the ripening or storage rooms should have means for controlling these two factors.

30.3.1 Temperature

It is necessary to control the temperature during storage and maintain uniform temperature as almost all biochemical reactions are temperature-dependent. Higher temperature accelerates ripening but jeopardizes the quality of cheese as it results in the growth of undesirable microorganisms. For cheeses of Cheddar and related varieties, temperature of 5-7°C is ideal but 8-12°C is considered economically best. Temperature higher than 18°C should be strictly avoided.

30.3.2 Humidity

The relative humidity of a gas is the amount of water vapour present expressed as percentage of that required to saturate the gas. Higher humidity leads to mold growth, accelerated ripening and surface bacterial taints. Lower humidity results in cracking, shrinking, distortion and retardation of ripening in addition to excessive loss of weight. The correct humidity for ripening depends on the type of cheese. Soft cheese requires a higher humidity (95%) than open-textured hard cheese (85%) and these again require greater humidity than close-textured hard cheese (80%). Further, mold ripened cheese require higher humidity than other varieties of cheese.

30.4 Storage Conditions for some of the Cheese Varieties

Cheeses of the Cheddar family (Cheddar, Cheshire, etc.) are ripened at lower temperatures of about 4-8°C, and a relative humidity (RH) lower than 80%. The ripening time may vary from a

few months up to 8–10 months or even 12 months.

Other types of cheese like Emmental are first stored in a 'green' cheese room at 8–12°C for some 3–4 weeks followed by storage in a 'fermenting' room at 22–25°C for some 6–7 weeks. After that the cheese is stored for several months in a ripening store at 8–12°C. The relative humidity in all rooms is normally 85–90%.

Smear-treated types of cheese – Tilsiter, Havarti and others – are typically stored in a fermenting room for some 2 weeks at 14–16°C and a RH of about 90%, during which time the surface is smeared with a special cultured smear mixed with a salt solution. Once the desired layer of smear has developed, the cheese is normally transferred to the ripening room at a temperature of 10–12°C and a RH of 90% for a further 2–3 weeks. Eventually, after the smear is washed off and cheese is wrapped in aluminium foil, it is transferred to a cold store, 6–10°C and about 70–75% RH, where it remains until distributed.

Other hard and semi-hard types of cheese, Gouda, Edam, may first be stored for a couple of weeks in a 'green' cheese room at 10–12°C and a RH of some 75%. After that a ripening period of about 3–4 weeks may follow at 12–18°C and 75–80% RH. Finally the cheese is transferred to a storage room at about 10–12°C and a relative humidity of about 75%, where the final characteristics are developed.

30.5 Factors Controlling the Loss of Moisture in Cheese

The primary factors which control the loss of moisture in cheese are temperature, moisture content, size and shape of the cheese and RH of air. The rate of loss of moisture rises sharply with temperature. With storage at 5, 10 and 15°C, the losses in 6 months were found to be 4.4, 6.4 and 8.7%, respectively. Higher the moisture content, higher will be the rate of loss and more is the free moisture. The smaller the cheese, the more rapid the losses of moisture as a proportion of that initially present. The higher the RH of the air in the cheese storage room, slower will be the rate of moisture loss.

Other factors that influence the loss of moisture during storage are type and quality of the wax or film applied to the outside of the cheese and type of cheese.

30.6 Distribution of Cheese

Distribution of cheese from manufacturer to distributor/retailer should be done under strict conditions of appropriate temperature. For cheese varieties, which continue to ripen in the storage period, it is important to maintain the temperature for ripening during distribution also. For example, Cheddar cheese should be distributed at the temperature of 5–8°C. Refrigerated and insulated vehicles are used for this purpose.

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*Module 15. Accelerated ripening of cheese***Lesson 31****ACCELERATED RIPENING****31.1 Introduction**

The ripening of cheese is a complex process of concerted biochemical changes, during which a bland curd is converted into a mature cheese having the flavor, texture and aroma characteristics of the intended variety. Ripening is an expensive and time-consuming process, depending on the variety, e.g. Cheddar cheese is typically ripened for 6-9 months while Parmesan is usually ripened for two years. Extended ripening period involves increased cost due to refrigerated storage, space, labour apart from considerable loss in weight and higher capital cost. Acceleration of cheese ripening can also be a means of increasing the production of cheese in developing countries where investment in storage facility can be a limiting factor.

31.2 Accelerated Ripening of Cheese

Cheese ripening is essentially a process which involves metabolism of key constituents of milk, i.e. lactose, proteins and fat. Most of the lactose is lost in whey but the residual lactose is quickly metabolized to lactate by combined action of starter bacteria and native bacteria of milk. This lactate serves as an important precursor compound for certain reactions which occur during ripening. Citric acid fermentation also plays a role in cheese ripening. Milk contains very low level of citrate, most of which is lost in whey. However, the residual citrate in the curd is acted upon by citrate fermenting microorganisms like *Leuconostoc* sp. to produce important flavor compounds like diacetyl, acetoin, etc. Lipolysis of milk fat is vital for production of important flavor compounds. Milk fat is hydrolysed during ripening by the action of enzymes. These enzymes may originate from milk like lipase or they may come through coagulant like rennin or they may be produced by cheese microflora. Lipolysis converts milk fat into free fatty acids and glycerol. Free fatty acids, particularly short chain fatty acids, contribute directly to cheese flavor and they also act as precursors for various catabolic reactions including esterification of hydroxyacids to form lactones, formation of thioesters by reaction with sulphhydryl compounds and β -oxidation of fatty acids to alkan-2-ones. Other principal metabolism during cheese ripening is proteolysis, wherein protein is broken down to peptides by the action of residual coagulant and the principal indigenous proteinase in milk, plasmin. These peptides are then hydrolyzed by enzymes derived by starter and non-starter microflora of the cheese. The production of small peptides and amino acids is caused by the action of microbial proteinases and peptidases respectively. The final products of proteolysis are amino acids, the concentration of which depends on the cheese variety.

All these biochemical changes which occur during ripening are slow and take about 6 months to years, depending on the variety of cheese. For example, Cheddar cheese is typically ripened for 6-9 months while Parmesan is usually ripened for two years. Such extended period of ripening involves capital investment in form of product and utilities like storage rooms, refrigeration etc. Therefore, various technological interventions are applied to shorten ripening period. This process of reducing normal ripening period is called as accelerated ripening.

31.3 Methods of Accelerated Ripening

Ripening is a slow and consequently, expensive process that is not fully predictable or controllable. Therefore, there are economic and possibly technological incentives to accelerate ripening. The principal methods by which this may be achieved are: an elevated ripening temperature, exogenous enzymes, modified starters and adjunct cultures. At least some of the methods used to accelerate ripening may also be used to modify flavor and in effect to create new varieties/ variants. Slow flavor development and low flavor intensity are major problems with reduced-fat cheese and the methods used to accelerate ripening in general are applicable to low-fat cheese also. Several promising developments have emerged for rapid flavor development in Cheddar cheese and other varieties.

In this regard, various approaches have been used to accelerate cheese ripening process which include:

- Use of elevated temperatures of ripening
- Addition of exogenous enzymes
- Use of adjunct cultures
- Genetic modification of starter bacteria
- Use of high pressure treatment

31.3.1 Use of elevated temperatures of ripening

Cheese is ripened at uniform temperature and humidity, depending on the variety of cheese. Ripening temperatures of some of the varieties of cheeses are as follows: Emmental, 22-24°C (for part of ripening, i.e., the critical 'hot room' period); mold and smear-ripened cheeses, 12-15°C; Dutch varieties, 12-14°C; and Cheddar, 6-8°C (the ripening temperature for Cheddar is exceptionally low). The above temperatures are the maximum in the profiles and are usually maintained for 4-6 weeks to induce the growth of a desired secondary microflora. Thereafter, the cheese is transferred to a much lower temperature (e.g. 4°C). Cheddar is an exception, since it is normally kept at 6-8°C throughout the ripening process. It can be observed from the ripening temperatures of most of the varieties that in no case it is more than 20-25°C as keeping cheese above this temperature causes texture to be too soft and the cheese deforms readily. It may also cause exudation of fat and excessive loss of moisture. Thus, the scope for accelerating the ripening of most cheese varieties by increasing the ripening temperature is quite limited except for Cheddar cheese which is ripened at low temperature of 6-8°C. This is again limited to cheese which is made from good quality pasteurized milk and is microbiologically safe. This approach is the simplest and cheapest method for accelerating ripening as no additional costs are involved rather there may be savings due to reduced refrigeration costs.

Several studies have been carried out to ripen Cheddar cheese at elevated temperatures. For example, the duration of ripening can be reduced by 50% by increasing the ripening temperature from 6°C to 13°C, without adverse effects. The highest temperature that can be used continuously is about 16°C, although 20°C could be used for a short period; 12-14°C is probably optimal. Ripening can be accelerated or delayed by raising or reducing the temperature at any stage during the process.

31.3.2 Addition of exogenous enzymes

Cheese ripening is essentially an enzymatic process and hence it should be possible to accelerate ripening by augmenting the activity of key enzymes. However, addition of single enzyme, which accelerates one particular reaction, is unlikely to produce a balanced flavor. Hence, the need for addition of mixture of enzymes in proper ratio has been advocated by several research workers. The addition of combinations of various fungal proteases and lipases to Cheddar cheese has been reported to reduce ripening time by 50%. Lipase in combination with proteinase gave good cheese flavor with low levels of bitterness. A lipase/proteinase preparation derived from *Aspergillus oryzae* released C₆-C₁₀ fatty acids to produce typical Cheddar cheese flavor. To achieve more intense and balanced flavor in buffalo milk Cheddar cheese, use of mixture 0.001% lipase and 0.01% protease has been advocated. A number of options are available, ranging from the quite conservative to the more exotic.

31.3.2.1 Coagulant

The proteinases in the coagulant is principally responsible for primary proteolysis in most cheese varieties and it might, therefore, be expected that ripening could be accelerated by increasing the level or activity of rennet in the cheese curd. Although, it is suggested that chymosin is the limiting proteolytic agent in the initial production of amino nitrogen in cheese, several studies have shown that increasing the level of rennet in cheese curd (achieved by various means) does not accelerate ripening and in fact probably causes bitterness. Chymosin produces only relatively large oligopeptides which lack a typical cheese-like flavor and may be bitter. Chymosin-produced peptides are hydrolysed by bacterial (starter and non-starter) proteinases and peptidases and hence it would seem that increased chymosin activity should be coupled with increased starter proteinase and peptidase activities in order to accelerate ripening.

Chymosin has very little activity on β -casein in cheese, probably because the principal chymosin-susceptible bond in β -casein, Leu192-Tyr193, is in the hydrophobic C-terminal region of the molecule which appears to interact hydrophobically in cheese, rendering this bond inaccessible. However, *Cryphonectria parasitica* proteinase preferentially hydrolyses β -casein in cheese (possibly because its preferred cleavage sites are in the hydrophilic N-terminal region) without causing flavor defects. Rennet containing chymosin and *Cryphonectria parasitica* proteinase might be useful for accelerating ripening.

31.3.2.2 Plasmin

Plasmin contributes to proteolysis in cheese, especially in high-cooked varieties in which chymosin is extensively or totally inactivated. Plasmin is associated with the casein micelles in milk, which can bind at least 10 times the amount of plasmin normally present, and is totally and uniformly incorporated into cheese curd, thus overcoming one of the major problems encountered with the use of exogenous proteinases to accelerate cheese ripening. Addition of exogenous plasmin to cheese milk accelerates the ripening of cheese made therefrom, without off-flavor development.

31.3.2.3 Other proteinases

The possibility of accelerating ripening through the use of exogenous (non-rennet) proteinases has attracted considerable attention over the past 20 years. The principal problems associated with this approach are ensuring uniform distribution of the enzyme in the curd and the prohibition of

exogenous enzymes in many countries. The earliest reports on the use of exogenous enzymes to accelerate the ripening of Cheddar cheese appear to be those of Kosikowski and collaborators who investigated various combinations of commercially available acid and neutral proteinases, lipases, decarboxylases and β -galactosidase. Acid proteinases caused pronounced bitterness but the addition of certain neutral proteinases and peptidases with the salt gave a marked increase in flavor after one month at 20°C but an overripe, burnt flavor and free fluid were evident after one month at 32°C. Incorporation of the enzyme-treated cheese in processed cheese gave a marked increase in Cheddar flavor at 10% addition and a very sharp flavor at 20%. Good quality medium sharp Cheddar could be produced in 3 months at 10°C through the addition of combinations of selected proteinases and lipases.

With the exception of rennet and plasmin (which adsorbs on casein micelles), the incorporation and uniform distribution of exogenous proteinases throughout the cheese matrix poses several problems:

- Proteinases are usually water-soluble, and when added to cheese milk, most of the enzyme is lost in the whey, which increases cost
- Enzyme-contaminated whey must be heat-treated if the whey proteins are recovered for use as functional proteins. The choice of enzyme is limited to those that are inactivated at temperatures below those that cause thermal denaturation of whey proteins
- The amount of Neutralse that should be added to milk to ensure a sufficient level of enzyme in the curd reduces the rennet coagulation time, yields a soft curd in which at least 20% of the β -casein is hydrolyzed at pressing and reduces cheese yield.

31.3.2.4 Exogenous Lipases

Lipolysis is a major contributor, directly or indirectly, to flavor development in strong-flavored cheeses, e.g. hard Italian, Blue varieties, Feta. Rennet paste or crude preparations of pre-gastric esterase (PGE) are normally used in the production of Italian cheeses. *Rhizomucor miehei* lipase may be used for Italian cheeses, although it is less effective than PGE; lipases from *Penicillium roqueforti* and *Penicillium candidum* may also be satisfactory. The ripening of blue cheese may be accelerated and quality improved by added lipases. A blue cheese substitute for use as an ingredient for salad dressings and cheese dips can be produced from fat-curd blends by treatment with fungal lipases and *P. roqueforti* spores. Although Cheddar- and Dutch-type cheeses undergo little lipolysis during ripening, it has been claimed that addition of PGE or gastric lipase improves the flavor of Cheddar cheese, especially that made from pasteurized milk.

31.3.2.5 β -Galactosidase (Lactase)

β -galactosidase (lactase) hydrolyses lactose to glucose and galactose, results in stimulation of lactococci and shortens the lag period of growth of lactococci. Lactose hydrolysed cow and buffalo cheese milks have been reported to reduce manufacturing time, improve flavor and accelerate ripening. It has been found that the lactase from *Kluyveromyces lactis* available as Maxilact contains a proteinase, which is responsible for increased levels of peptides, and free amino acids.

31.3.3 Use of adjunct cultures

Adjunct cultures are specifically selected strains, which are intentionally added to accelerate ripening of full fat cheese and for flavor enhancement of low fat cheese. Adjunct cultures

reportedly decrease bitterness and contribute desirable flavor compounds. Addition of different *Lactobacillus* spp. (*L. casei* and *L. plantarum*) to Cheddar cheese milk to a level of 10^5 - 10^6 cfu/ml increased the levels of free amino acids to attain highest flavor scores. Augmentation of starter culture with *L. casei* had definite and positive influence on the flavor; body and texture of buffalo milk Cheddar cheese. The flavor development and biochemical changes in buffalo milk Cheddar cheese is faster when *L. casei* is supplemented with cheese.

The principal adjuncts used in accelerated ripening of cheese are mesophilic lactobacilli and thermophilic lactobacilli. Inoculation with mesophilic *Lactobacillus* adjuncts enhanced flavor and accelerated proteolysis at the level of small peptides and amino acids. Essentially the same volatiles were produced in all cheeses but at very different concentrations. Mesophilic lactobacilli modify proteolysis; in particular, they result in a higher concentration of free amino acids and improve the sensoric quality. In contrast to mesophilic lactobacilli, thermophilic lactobacilli die rapidly in cheese, lyse, and release their intracellular enzymes. Consequently, cheeses made with thermophilic *Lactobacillus* spp. as starters contain high concentrations of amino acids (the concentrations are particularly high in Parmesan cheese). Although thermophilic lactobacilli will not grow in Cheddar cheese, their inclusion as a starter adjunct markedly intensifies the flavor of Cheddar. Adjuncts of thermophilic lactobacilli and *Streptococcus thermophilus* are available commercially.

31.3.4 Modification of starter bacteria/Starter cultures

31.3.4.1 Genetically engineered starters

Food-grade controlled lysis of *Lactococcus lactis* for accelerated cheese ripening is an important approach. An attractive approach to accelerate cheese ripening is to induce lysis of *Lc. lactis* starter strains for facilitated release of intracellular enzymes involved in flavor formation. Controlled expression of the lytic genes *lytA* and *lytH*, which encode the lysin and the holin proteins of the lactococcal bacteriophage phi-US₃, respectively, was accomplished by application of a food-grade nisin-inducible expression system. Simultaneous production of lysin and holin is essential to obtain efficient lysis and concomitant release of intracellular enzymes as exemplified by complete release of the debittering intracellular aminopeptidase N. Production of holin alone leads to partial lysis of the host cells, whereas production of lysin alone does not cause significant lysis. Model cheese experiments in which the inducible holin-lysin overproducing strain was used showed a fourfold increase in release of l-Lactate dehydrogenase activity into the curd relative to the control strain and the holin-overproducing strain, demonstrating the suitability of the system for cheese applications.

31.3.4.2 Stimulation of starter cells

The growth of starter cells may be stimulated by the addition of enzymes or hydrolysed starter cells to cheese milk. Ripening of Emmental type cheese has been accelerated by using starters grown to high cell numbers in media supplemented with protein hydrolysates and metalloproteinase from *Micrococcus caseolyticus*.

31.3.4.3 Modified starter cultures

Addition of modified/attenuated starter culture is to increase the number of starter cells without causing detrimental effect on the acidification schedule during manufacture, so that the cells contribute only to proteolysis and other changes during ripening. Modified starter cultures with attenuated acid producing abilities are added with normal starter cultures during cheese

manufacture. Selection of starter strains with enhanced autolytic properties and increased peptidase activity would provide a more balanced flavor.

31.3.4.4 Heat and freeze shock treated cells

Mixed strain starters or *L. helveticus* culture subjected to various heat-shock treatments in an attempt to reduce their acid producing ability but to enhance their rate of autolysis. Some workers used heat-shock cultures to attain large number of a mixed-strain starter, containing *Lactococcus*, *Leuconostoc* or *L. helveticus* strains which were cultivated at a constant pH, followed by heating to 69°C/15 s. Flavor scores increased with increasing numbers of heat-shocked cells reducing the ripening time to 50%. A combination of neutral proteinase with heat shocked *L. helveticus* to a final level of 4×10^6 cfu/g curd also accelerated the ripening of the cheese. Addition of heat-shocked lactobacilli increased peptidolysis and produced good flavor in low-fat semi-hard cheese. Flavor acceleration could be significantly improved by augmentation of starter culture with freeze-shocked *L. helveticus* in buffalo Gouda cheese. The combination of liposome entrapped proteinase and freeze-shocked lactobacilli resulted in development of more intense flavor without bitterness in UF cheese.

The acid-producing ability of lactic acid bacteria can be markedly reduced by a sub-lethal heat treatment while only slightly reducing enzyme activities. Heating at 59 or 69°C for 15 s was optimal for mixed mesophilic and thermophilic lactobacilli cultures, respectively. Most (90%) of the heat-shocked cells added to cheese milk at a level of 2% (v/v) were entrapped in the curd but entrapment efficiency decreased at higher levels. Proteolysis in Swedish cheese was increased and quality improved by addition of the heat-shocked cells to the cheese milk, *L. helveticus* being the most effective. The extent of proteolysis increased *pro rata* the level of heat-shocked *L. helveticus* cells added but not for the mesophilic culture. Bitterness was not observed in any of the cheeses. Heat-shocked (67°C/10 s) *L. helveticus* cells accelerated amino nitrogen formation and enhanced flavor development in Swedish hard cheese; when added alone, Neutrased accelerated proteolysis but it caused bitterness which was eliminated when both heat-shocked *L. helveticus* cells and Neutrased were added to the curd.

31.3.4.5 Lysozyme treated cells

Addition of lysozyme-sensitized cells to cheese milk at a level of equivalent to 10^{10} cells/g of cheese indicated that intracellular dipeptidases were released and as a result, concentration of free amino acids significantly increased. However, there was no effect on the rate of flavor development. Economically, the use of lysozyme treated cells may not be viable for large-scale cheese manufacture owing to the cost of the enzyme. Addition of lysozyme encapsulated in a dextran matrix to cheese milk at renneting, which would be released at Cheddar cheese pH (5.2-5.4) leading to the lysis of the cells with release of intracellular peptidases has also been suggested.

31.3.4.6 Mutant starter cultures

Because the rate of acid development is a critical factor in cheese manufacture, the amount of normal starter cannot be increased without producing an atypical cheese. This has led to the use of lactose negative mutants, which do not affect the rate of acid development but provide additional enzymes. Like attenuated cells, these mutant cells serve as packets of enzymes but are much easier to prepare and would appear to be the logical choice when it is desired to increase the number of cells without a concomitant increase in the rate of acid production. Lac- mutants of starter strains have been reported to provide packets of uniformly distributed proteinases/peptidases, enhancing the production of peptides and free amino acids without interfering with acid

production during manufacture. Cheddar cheese containing 10^{11} cfu/ml of *Lc. lactis* subsp. *cremoris* (Lac Prt-) cells received highest flavor scores. Some workers have showed advancement in ripening of 4-12 weeks after 6 months storage in Cheddar cheese with mutant starter.

It was also recommended to use the Prt starters to reduce bitterness in cheese. It was claimed that the rate of proteolysis in Cheddar cheese made using Prt- starters was similar to that in control cheese. Lac- Lactococcus strains with high exopeptidase activity are commercially available as cheese additives. When inoculated into the cheese milk at 0.002%, individually or as a cocktail, the Lac- cultures enhanced cheese flavor over that of the control. Assessment of proteolysis showed only minor differences between the cheeses with respect to primary and secondary proteolysis but all adjunct-treated cheeses contained higher levels of amino acids than the controls throughout ripening.

31.3.5 Use of high pressure treatment

Using high pressure treatment (HPT) is one of the technological approaches for accelerated cheese ripening. HPT has emerged as a food processing technology primarily due to increasing interest in novel methods for preservation of foods. Applying high pressure to food products modifies interactions between individual components, influences rates of enzymatic reactions and can inactivate microorganism.

In HPT, an increase in pressure tends to result in a decrease in volume, which enhances chemical reactions, phase transitions and changes in molecular configurations. Irrespective of the size and geometry, the pressure is instantaneously and uniformly distributed throughout the food. The increased pressure affects the environment of bacterial cell and many biochemical reactions in cells. HPT can cause conformational change in protein but small macromolecules like amino acids, vitamins etc. are not affected.

The application of HPT to cheese results in an increase in moisture content and pH and cause changes to the cheese matrix and lysis of cells, which contribute to ripening. HPT of cheese affects the pattern of proteolysis during ripening, the effect of which is dependent on the type of cheese, magnitude, duration and temperature of pressure treatment. The use of HPT appears to have advantages in both cheese manufacture and ripening. However, additional research is required to define the operating conditions of HP treatment to provide positive effects in cheese making and ripening.



*Module 16. Mechanized cheese making***Lesson 32****MECHANIZATION AND AUTOMATION IN CHEESE MAKING****32.1 Introduction**

Before starting discussion on mechanization and automation, it is a pre-requisite to understand the basic difference between mechanization, automation and continuous production.

Mechanization is a system in which almost all the stages are carried out by machinery instead of manually, as in the case of traditional practices. Automation is a mechanized system, which is controlled by an instrument fed by a programmer. Mechanization is a necessary precondition for automation, but has different meaning. In a continuous system, raw materials are fed to the machine at one end and product comes out of the machine from the other end continuously. In cheese production, milk is fed to the machine at one end and it is continuously converted into curd and cheese during passage through the machine.

The pretreatments of milk for cheese making like standardization, bactofugation, pasteurization, etc. were already mechanized but with the developments taking place in the area of mechanization and automation, now almost each and every stage of cheese manufacturing is mechanized. Steps like starter production, curd making, cutting, cheddaring, hooping, conveying, packaging, block forming, etc. have been mechanized for continuous and automated cheese production. APV and Tetrapak are two of the leading industries which manufacture and supply mechanized systems of cheese production. Some of their machines are discussed in this chapter.

32.2 Cheese Vats: Double -O-vat

Tetra Damrow™ Double-O-Vat and Curd Master by APV.

The Tetra Damrow Double-O-Vat 8 is specifically designed for the production of high quality cheese curd and whey. The vat is suitable for the production of most cheese types like Cheddar, Emmental, Gouda, Blue, Feta as well as Pasta Filata. The design of the Tetra Damrow Double-O-Vat is based on the double circle principle, which ensures an optimum, efficient, yet careful treatment of the cheese curd.

Curd Master is another double O type vat fabricated by APV. It facilitates fast foamless filling, rapid mixing of all added components including rennet, gentle and precise cutting, fast whey draw, controlled and fast heating and cooling, vertical vat with two outlets for fast emptying, efficient and gentle stirring. It is fully automated with touch screen and the vat can be cleaned by cleaning-in-place (CIP).

32.3 Mould Fillers

Tetra Tebel Casomatic is manufactured by TetraPak. It works in combination with two buffer tanks. Each column is continuously fed by a pump with curd and whey mixture from a buffer tank. The mixture is pumped to the top of the column. The curd settles under the level of whey. Via three perforated sections, whey is drained from the column. The speed of the whey drainage is

controlled by adjusting the drainage valves, depending on the pressure measured in these sections. As the curd moves down inside the column, it is compressed progressively until a curd block can be separated.

32.4 Mechanised Cheddaring Machine

The Tetra Tebel Alfomatic is designed for continuous production of fused and stirred Cheddar and Pasta Filata cheese types. It is a totally enclosed machine, designed to automatically drain, acidify, texture, mill, salt and mellow cheese curd.

The most common version of the machine is equipped with four conveyors mounted above each other in a stainless steel frame. The cooked mass (curd/whey mixture) is uniformly distributed on a special drainage screen where most of the whey is removed. The curd is then passed through the four conveyors one by one. The role of each of the conveyors is

First conveyor--- it is equipped with stirrers to facilitate further whey removal.

Second conveyor--- matting and fusing starts on this conveyor.

Third conveyor--- the mat is inverted and cheddared. At the end of the conveyor, curd is milled.

Fourth conveyor---salting takes place on this conveyor.

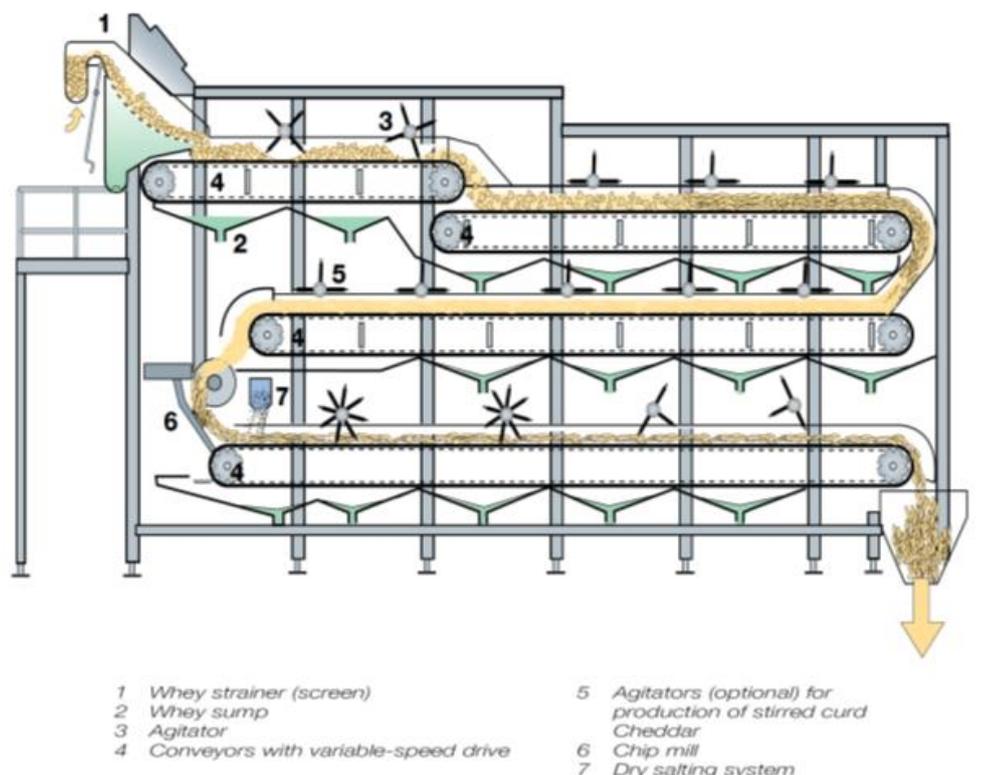


Fig. 32.1 Mechanised system for Dewheying, Cheddaring, Milling and salting (Alfomatic by TetraPak)

(Courtesy: Tetra Pak Processing Systems AB, Lund, Sweden)

In the production of Mozzarella cheese, where salting is not required before stretching, a machine with two or three conveyors is sufficient.

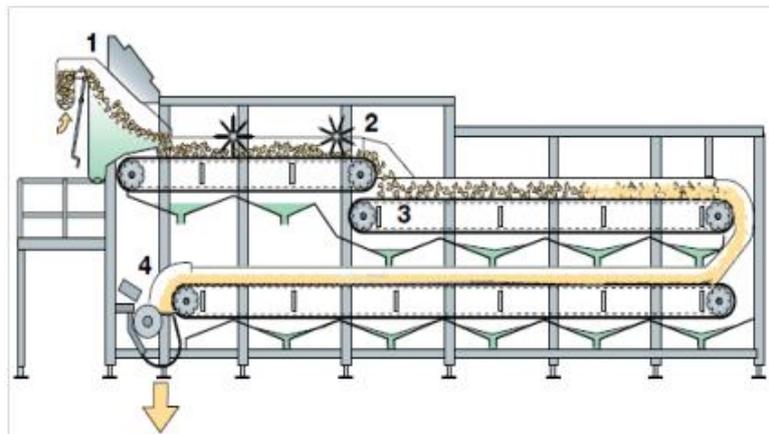


Fig. 32.2 Continuous Cheddaring machine with three conveyors suitable for Mozzarella cheese

(Courtesy: Tetra Pak Processing Systems AB, Lund, Sweden)

The other mechanized system for Cheddar cheese making is manufactured by APV. It has been given the trade name of Cheddar master. It is used for curd draining, cheddaring, milling, salting and mellowing. It is available in the capacity ranging from 1000-9000 kg/h of cheese curd. APV also manufactures Mozzarella master for continuous production of Mozzarella cheese.

32.5 Cooking And Stretching of Pasta Filata Types Of Cheese

Pasta Filata (plastic curd) cheese is characterised by an 'elastic' string curd obtained by cooking and stretching cheddared curd. The cheddared curd is worked in hot water at 82-85°C until they are smooth, elastic, and free from lumps. This step is necessary in order to develop elasticity in cheese which is peculiar to such varieties. Continuous cooking and stretching machines are used in large-scale production. The speed of the counter rotating augers is variable so that an optimal working mode can be achieved. The temperature and level of cooking water are continuously controlled. The cheddared curd is continuously transferred into the hopper or cyclone of the machine, depending on the method of feeding – screw conveyor or blowing.

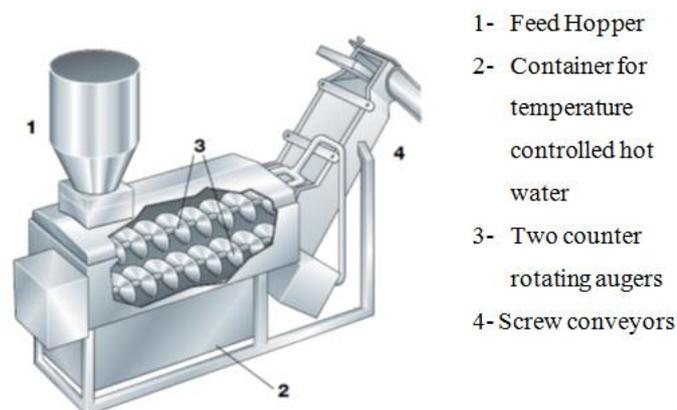


Fig. 32.3 Continuous Stretcher for Mozzarella cheese

The systems discussed so far are mechanized systems for major steps in cheese making. Other than these systems, many other systems are also available like pre-press machines for pressing the curd before cheddaring, final pressing to remove residual whey/moisture, mould emptier, rack filler, rack brining system, rack unloader and rack washer. All these systems when installed in line, continuous and mechanized cheese making can be carried out. Processing lines for some varieties of cheese will be discussed in the following sections.

32.6 Continuous Cheddar Cheese making

Standardized and pasteurized milk is received in the vat where it is ripened, rennet is added to form curd, and curd is then cut and cooked. All these stages are completed in this vat. The double-O-vats described earlier are mostly used to perform all these operations. The cooked curd and whey mixture is then pumped to cheddaring machine where dewheying, cheddaring, milling and salting take place. The curd is then fed to the block forming machine where the milled curd fuse together and blocks of uniform shape and size are formed. After this, the blocks are sealed by vacuum sealer, weighed, packed in cartons and kept for ripening. The process is shown in Fig. 32.4.

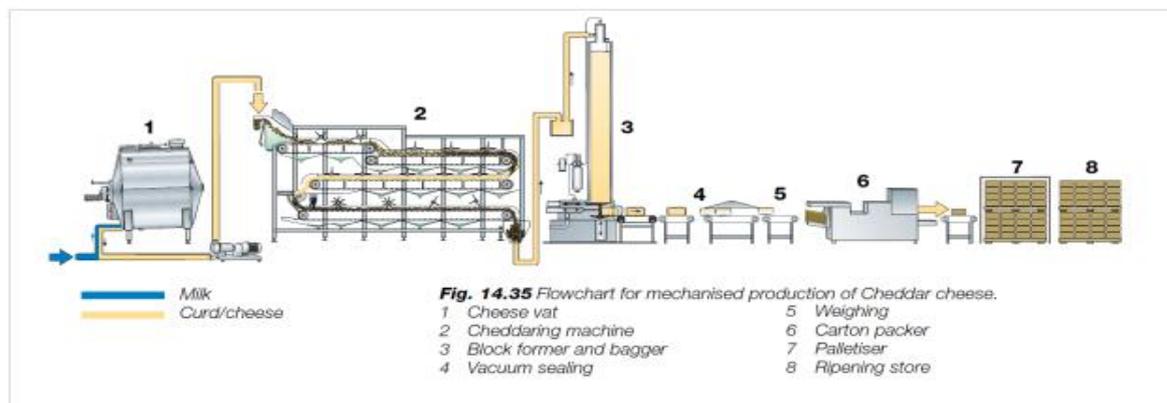


Fig 32.4 Processing line for Cheddar cheese manufacturing

32.7 Continuous Gouda Cheese Manufacturing

In Gouda cheese making, the peculiar step is cooking the curd in whey through addition of about 20% hot water. Before addition of water, about one third whey is drained. This process of heating curd with whey and hot water is called scalding. In mechanized system of Gouda cheese manufacturing, the standardized milk is taken in the vat (1) and all other steps upto scalding are carried out in this vat. After scalding, the content of the vat is transferred to a buffer tank (2) so that the contents of more than one vat can be stored in the tank till further processing. This tank is equipped with agitators and is jacketed to supply chilled water in case activity of starter organisms need to be curbed down. The curd is then pumped to the pre-pressing machine (3) like Casomatic (TetraPak), where whey is removed and blocks of cheese are also formed. A fully mechanized system also comprises of:

- Mechanical lidding (4) of the moulds
- Transfer of moulds to conveyor or tunnel presses
- Filling and emptying of the presses
- Transport of moulds via a de-lidding station (6), a mould turning device (7), a mould emptying

system (8) and a weighing scale (9) to an advanced brining system (10).

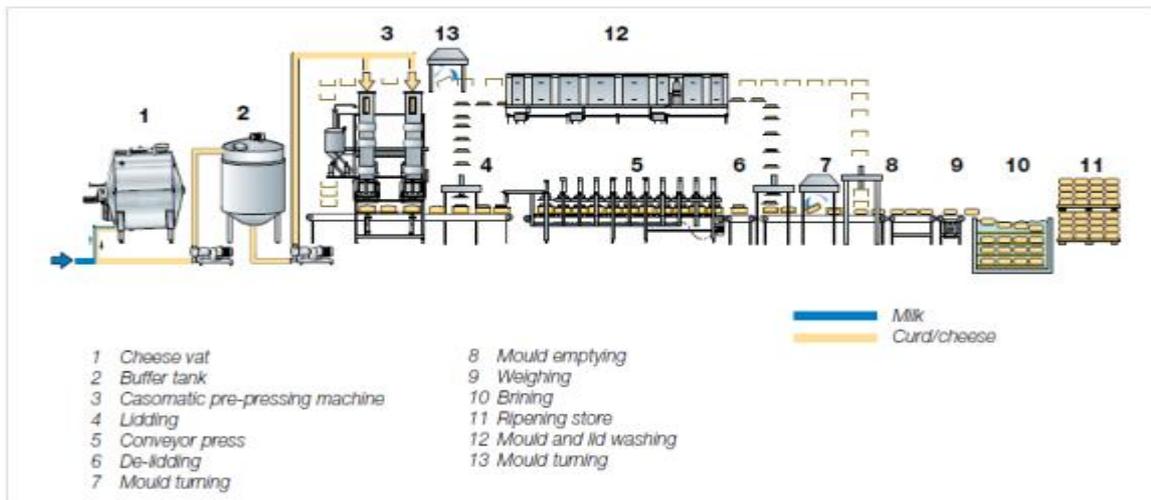


Fig 32.5 Processing line for Gouda cheese manufacturing

Any variety of cheese production can be mechanized keeping in view the particular step that distinguishes one variety from other. For example, in the production of Mozzarella cheese, cheese cooker and stretcher are required which can be installed after Mozzarella cheddaring machine.

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