



CHEESE MAKING

Introduction

There are hundreds of different types of cheese, but each is made using similar principles of coagulating the proteins in milk to form curds, and then separating the curds from the liquid whey. The coagulation of milk proteins can be done as follows:

- Using rennet (or 'chymosin') - an enzyme extracted from calves' stomachs that coagulates the proteins in milk. Rennet produced by micro-organisms is available for vegetarian cheeses.
- Fermenting to form lactic acid.
- Adding acid (e.g. lemon juice, lime juice or vinegar).
- Boiling or
- Using plant extracts (e.g. papaya sap (papain enzyme), fig bark (ficin enzyme), stems of *Bryophyllum* species or leaves of *Calotropis procera*).

The different cheese flavours and textures arise from variations in the type of milk, the amount of fat in the milk, bacteria that are used to ferment the milk, and variations in the processing conditions. Cheeses may be broadly grouped into 'soft', 'semi-hard' and 'hard' cheeses (Table 1). Soft cheeses are easier to make than hard cheeses and are traditional foods that are popular in many countries. They are made using lactic acid bacteria (see Technical Brief: *Soured milk and yoghurt*) or an acid, such as lemon or lime juice or vinegar. These cheeses are soft, moist, creamy cheeses and include curd cheese, paneer, and small-curd cottage cheese. Those made from buffalo milk are white and those made from cows' milk are pale creamy yellow. They have a shelf life of around 3 days when refrigerated, or 5 days if covered with brine and refrigerated.

Hard cheeses (e.g. 'Cheddar' cheese) and large-curd cottage cheese are produced using lactic acid bacteria and rennet. Hard cheese requires greater investment in equipment and greater skill to produce than soft cheeses. Cheddar cheese for example, is a firm solid compressed curd that has a pale yellow colour, a texture that varies from rubbery to flaky, a mildly acidic taste and a characteristic flavour/aroma. It is matured for different periods of time, and the flavour gradually changes from a mellow creamy taste after 2-8 months, to a tangy flavour of mature cheese after 8-12 months, and then to a strong, more bitter flavour of vintage cheese after more than 12 months. Hard cheeses may also be made with a variety of flavourings, including caraway seed, chilli pepper, garlic, rosemary or sage, or they may be smoked. It is recommended that market research be undertaken to find which types of cheese are popular before contemplating production, because the demand for hard cheeses may be more limited in some countries and a careful market analysis is needed before starting their production. Training in production should then be obtained from an experienced cheese-maker.

Cheese is preserved by a number of different mechanisms: the raw milk is pasteurised to destroy most enzymes and contaminating bacteria; fermentation by lactic acid bacteria increases the acidity which inhibits growth of food poisoning and spoilage bacteria; the moisture content is reduced and salt is added, both of which inhibit bacterial contamination (see also Technical Brief: *Dairy processing - an overview*, which is intended to be read alongside this Technical Brief).

Type of cheese	Moisture content (%)	Fat content (%)	Texture	Shelf life
Soft cheeses	45-75	<40	Soft, white, spreadable	A few days
Semi-hard cheeses	35-45	<35	Firm, crumbly, can be sliced	A few months
Hard cheeses	30-40	<30	Very firm, dense, sometimes grainy	One year or more

Table 1: Types of cheeses (Adapted from *Dairy Science and Technology Education*)

technical brief

Methods of processing

Soft cheeses (e.g. cottage cheese, paneer, and cream cheese)

Acid is produced by lactic acid bacteria but some soft cheese may also be produced by adding acid. Both methods coagulate milk to create pieces of semi-solid curd. The curd may be heated up to 52 °C to inactivate the bacteria and prevent further acid development. Washing the curd before salting also reduces the acidity. The method below describes production of curd cheese (paneer). In many countries, traditionally produced soft cheeses have a sour taste and pronounced flavour. They are made using fermented buttermilk (see Technical Brief: *Butter and ghee*), which is heated gently for about 30 minutes until completely coagulated. It is then cooled, and the whey is drained to leave the cheese. It is pressed into blocks and stored in brine until it is sold.

Curd cheese or paneer

1. Heat cow or buffalo milk to boiling and then reduce the heat to simmering for 5 minutes.
2. Slowly pour lime juice or lemon juice (at 1 - 1.5% by weight) into the simmering milk, stirring it slowly using a slotted spoon.
3. Continue to stir as the milk starts to separate into curds while adding more lime/lemon juice.
4. When the curds have formed a large mass, stop stirring and remove the pan from the heat.
5. Allow the curds to sink to the bottom of the pan and pour off the whey (whey may be used as a drink, made into whey cheese, or fed to animals).
6. Place the curds into a mesh sieve or colander and, without pressing, allow the liquid to drain from the curds.
7. Cut the curds to release any extra liquid and leave it until a solid curd is formed.

Depending on the fat content of the milk (see Technical Brief: *Butter and ghee*) 1 litre of milk produces about 250 g of curd cheese/paneer.

Small-curd cottage cheese

This cheese can be made with either whole milk, skimmed milk or with added cream. Adding cream increases its smoothness and improves its flavour and texture. The method of production for skimmed milk cottage cheese is:

1. Prepare skimmed milk using a cream separator (see Technical Brief: *Butter and ghee*).
2. Pasteurise the skimmed milk (see Technical Brief: *Pasteurised milk*).
3. Prepare the starter by adding a culture of lactic acid bacteria (either liquid or powder) to a one litre sample of milk and incubate it at 20-25°C for 16-24 hours, or until curds form. Keep refrigerated.
4. Pour pasteurised milk at about 20°C into a stainless steel jacketed cheese vat (Fig. 1)) with the jacket filled with hot water.
5. Add starter culture (2-3% of the weight of the batch of milk) and cover the container with a clean cloth.
6. Do not stir the milk and allow it to stand at 20 - 25 °C for 16-24 hours. If necessary, control the temperature of water in the outer container to maintain the temperature at 20 - 25°C.
7. When curds form, insert a knife or spatula into the curd. Gently pull the curd away from the container side. If it breaks quickly and smoothly, it is ready to be cut.
8. Cut the curd in each direction to form approximately 0.5 cm pieces, using a knife or a curd cutter (Fig. 2).
9. Allow it to stand for 10 minutes to drain the whey and allow the curd to become more firm.
10. Heat the water in the jacketed container to heat the curd slowly to 40 °C within 30-40 minutes (a temperature increase of about 0.5° per minute).
11. During heating, stir the curd gently with a large spoon for about a minute at a time, every 4 or 5 minutes. This allows the curd to heat uniformly and prevents curd particles from sticking together.
12. When the curd and whey reach 40°C, increase the heat and stir it more frequently until the temperature reaches 45-46°C (within 10-15 minutes).
13. Hold at this temperature for 20-30 minutes, or until the pieces are firm and do not break easily when squeezed. If the curd doesn't become firm enough at this temperature, heat it to 50°C.

14. When the curd has firmed sufficiently, drain most of the whey and pour the remaining curd onto fine cheesecloth on a mesh screen or a colander and drain the whey for 2-3 minutes (not longer or curd particles will stick together in large clumps).
15. Wash and cool the curd by immersing the cheesecloth and curd in a pan of clean, cool water and then for 3-5 minutes in ice water.
16. Drain the curd using a mesh sieve or colander.
17. Pack the curd in pots and store in a refrigerator.
18. For salted curd, mix salt into the curd according to taste. For creamed curd, mix in either sweet or sour cream according to taste.

Figure 1: Cheese vat.
Photo: Courtesy of Kleen-Flo Small Scale Dairy Equipment.



Figure 2: Curd cutters.
Photo: Courtesy of Glengarry Cheesemaking and Dairy Supply Ltd.

Vertical or horizontal curd cutters may be either motorised and fitted to a cheese vat or manual cutters as shown in Figure 2. These are stainless steel frames strung with thin wires or blades. The vertical cutter is first pulled through the cheese vat to cut the curd in one direction. It is then used to make vertical cuts across the vat. Finally, the horizontal cutter is used to cut the curd in one direction to cut the curd into cubes.

Cottage cheese

Milk is coagulated by adding either a lactic acid starter culture or live yoghurt (see Technical Brief: *Soured milk and yoghurt*), and rennet using the following method:

1. Warm chilled pasteurised milk to 20°C and stir in the starter culture or live yoghurt.
2. Mix rennet in water (1 tablet, 2.5 teaspoons of powder or 20 - 30 ml liquid per 100 litres of milk) and add to the milk. Mix for 5 minutes.
3. Allow the milk to stand for about 10 hours at 20°C or until the curd has formed.
4. Insert a knife into the curd. If the curd cuts cleanly, it is ready to be cut, otherwise wait longer. Cut the curd into 1 cm cubes using curd cutters.
5. Let it stand for 15 minutes and then heat it slowly to 35-38°C for 30 minutes. The higher the temperature, the firmer will be the curd. Stir occasionally to separate the curds. Cooking shrinks the curds and they settle to the bottom of the pan.
6. Drain the curds through cheesecloth on a mesh sieve for 20 minutes.
7. Chill and harden the curds in the cheesecloth in ice cold water for 5 minutes.
8. Mix in salt to taste and refrigerate at 4-6°C.

Semi-hard cheeses

This is a large group of cheeses and includes Edam, Gouda, Colby, Montasio, and Muenster. Production is by rennet coagulation, and lactic acid production is restricted. The amount of moisture removed from the curd depends on the temperature and time of cooking and by the wash water temperature. Higher temperatures during cooking or washing cause the curd to contract and expel more moisture. Typically, these cheeses are matured for between 2 weeks and 9 months.

Hard cheeses

Hard cheeses (e.g. Cheddar, Parmesan, Swiss, Romano) have lower moisture contents than other types, produced by higher temperature cooking or by controlled fermentation and curd handling. Pasta Filata types are worked and stretched in hot water and salted using brine. Cheddar types are salted before pressing. The cheeses are ripened for 1-36 months. The following process is used to make Cheddar cheese:

Process	Notes
Raw Milk	
Pasteurise	Heat to 63 °C for 30 minutes (see Technical Brief: <i>Pasteurised milk</i>).
Cool	Cool with stirring to 25-30 °C.
Inoculate	Place in a stainless steel cheese vat and add 2% starter culture for faster acid production (less for a slower fermentation).
Mix	Mix rennet (1 tablet, 2.5 teaspoons of powder or 20 - 30 ml liquid per 100 litres of milk) and add to the milk.
Incubate	Allow milk to stand for 30 minutes until it sets to a firm curd.
Cut	Check the curd with a spatula to determine if it is firm enough to cut. Cut curd into 8 mm cubes, using curd cutters (Fig. 2).
Stand	Stand for 5-10 minutes for curd to become firm.
Heat	Slowly increase the temperature by 1°C each 7.5 minutes up to 38°C.
Stir/Drain	Stir and drain until the whey is removed.
Cut	Cut curd into blocks 150 cm thick and turn them every 15-20 minutes.
Cut	Cut blocks into large pieces (e.g. 2-3 cm) using knives.
Mix	Add salt (approx 2% of weight of curd) and mix into the curd pieces.
Fill	Fill the required amount of curd into a cheesecloth (which has been boiled for 15 minutes or sterilised in dilute bleach), and place in the cylinder of a cheese press (Fig. 4).
Press	Apply pressure gently, allow to stand for 30 minutes and apply more pressure. Press for 8 hours (usually overnight)
Pack	Remove cheese from press, inspect, trim and pack in cheese cloth.
Store/ripen	Store at temperature below 15 °C, with a high air humidity (above 85%) and mature for 3-12 months, turning the cheese periodically.

Figure 3: Production of Cheddar cheese.

Figure 4: Cheese press
Photo: Courtesy of Lehman's.



technical brief

Quality assurance

The quality of milk and the processing conditions that are used for making cheese should be standardised so that consistent quality products are made each time. This involves control of factors in the process that affect the quality or safety of the product. These are known as 'control points' and are the points at which checks and measurements should be made.

HACCP¹

The specific potential hazards in making cheeses are food poisoning bacteria from the raw milk, poor hygiene and sanitation during processing, and incorrect processing conditions. Other hazards that are common to all types of food processing (including contamination of foods by insects, glass etc.) are prevented by correct quality assurance, including the design and operation of the processing facilities, staff training in hygiene and production methods, and correct cleaning and maintenance procedures.

Hygiene

Technical Brief: *Dairy processing - an overview* gives details of hygiene and sanitation, the design of a dairy and the use of correct cleaning procedures. Hygiene requirements are also described in Technical Brief: *Hygiene and safety rules in food processing*.

Avoiding spoilage

Unclean equipment, contaminated milk, poor hygiene of production staff, and incorrect processing and storage conditions will each cause spoilage of cheeses. All equipment should be thoroughly cleaned after use and checked before production starts again. The temperature and time of heating milk should be monitored and controlled to ensure that it is not over- or under-heated. In fermented cheese production, the temperature and time of incubation should be monitored and controlled to ensure that the fermentation takes place correctly.

Raw material control

The milk used for cheese production should be fresh, good quality and free from dirt and excessive contamination by bacteria. Older milk may impart an unpleasant flavour to the final product. Technical Brief: *Dairy processing - an overview* gives details of the methods needed to ensure that good quality milk is used.

Starter cultures

In some types of cheese making, the correct amount of starter culture and the correct proportions of the two lactic acid bacteria are both important to produce good quality product. Commercially produced dried mixed cultures of (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subspecies *bulgaricus*) can be obtained from many large towns/cities or from suppliers elsewhere. The dried culture is grown in pasteurised milk (see Technical Brief: *Pasteurised milk*) and then kept in a refrigerator. A part of this 'master culture' (between 1 - 3% of the weight of the batch of milk) is then used each day for a week. The last part is inoculated into pasteurised milk to form a new master culture. This method can be continued for several months, provided that good hygiene is practised, but eventually undesirable bacteria will contaminate the culture and it must be replaced.

Process control

A process control schedule should be prepared for each product. Table 1 is an example of a process control schedule for Cheddar cheese production.

Stage in process	Activity	Process control points
Pasteurise milk	Heat to destroy micro-organisms and enzymes.	Check temperature and time (e.g. 75°C +/- 2°C for 1 minute).
Inoculate starter	Produce lactic acid	Check amount of starter, activity of lactic acid bacteria, incubation time and temperature
Add rennet	Coagulation of milk proteins	Check amount and activity of rennet, incubation time and temperature

¹ Hazard Analysis Critical Control Point

Heat	Firm the curd	Check time and temperature, rate of temperature increase (see text for details)
Cut/drain	Remove whey	Check size of curd pieces, time for draining
Salting	Add salt	Check amount of salt, degree of mixing
Press	Remove whey, compress curds	Check time of pressing, amount of pressure
Pack	In cheesecloth	Check the weight of the cheese
Ripen	Mature the cheese	Check temperature is <15°C, air humidity is above 80% and time of storage
Pack/Label	In greaseproof paper or plastic film. Attach label or print on the wrapper	Check that correct label is used, that they are correctly positioned, and show the correct batch number and use-by or best-before date (depending on the type of product - check legislation at the Bureau of Standards).
Store	Hold at 4-8°C in a refrigerator	Check refrigerator temperature is 6°C +/- 2°C

Table 2: Process control points in Cheddar cheese production

The following control points affect the safety and quality (flavour and texture) of hard cheese:

- The temperature and time of heating and cooling the milk. Over-heating and slow cooling causes changes to flavour, colour and nutritional value; under-heating may result in inadequate destruction of enzymes and micro-organisms leading to spoilage or food poisoning.
- Correct amount of rennet and starter culture added, which affects the firmness of the curd.
- Incubation temperature to allow rapid production of lactic acid by the inoculated bacteria. If the temperature is too high the bacteria and rennet will be inactivated, if it is too low there may be insufficient acid production.
- Adequate cutting and draining of the curd to remove most of the whey.
- Correct time and temperature of cooking the curd to firm it sufficiently.
- Correct amount of salt added.
- Correct time and pressure during pressing the curd to give the required texture in the final product.
- Correct time of ripening and ripening conditions, which affect the flavour and texture.

Reasons for imperfect cheeses:

- Sour acid flavour is due to too much lactic acid produced by the fermentation, or too much whey retained in the curd.
- Yeasty or sweet flavours indicate that yeasts, moulds or bacteria were introduced into the cheese by unclean utensils or a contaminated starter culture, or that the milk was not properly pasteurised.
- Soft, wet curd is due to too much moisture in the cheese, the development of too much acid during the fermentation, heating the curd at too high or too low a temperature.
- Tough, dry curd results from insufficient acid development in the curd before it is cut, cutting the curd too finely, heating to a temperature that is too high, or holding the curd for too long after cooking.

Product control

The main quality factors for cheese are the colour, taste and texture. The colour is determined mostly by the amount of heating during processing and the fat content of the milk. The taste and texture are both determined by the amount of lactic acid produced during the fermentation and this in turn depends on the amount of inoculum added to the milk and the temperature/time of incubation.

Packaging and storage control

For a shelf life of a few weeks, cheese does not require sophisticated packaging provided that the temperature is kept relatively low and the cheese is not allowed to dry out. In a refrigerator the product may be wrapped in 'clingfilm' or sealed in a polythene bag using a heat sealer.

Summary

Cheeses are medium-risk dairy products that can be made successfully at a small scale. Curd cheeses may be more popular in many countries than hard cheeses and they are easier to make at a small scale and require a lower capital investment. Skill and expertise is required to make hard cheeses, there may also be a delay in receiving income while the cheese matures. A study of the market demand is recommended before starting hard cheese production.

Equipment

- Cheese moulds. Simple cheese moulds can be made from a 10 cm diameter plastic drainpipe cut into 10 cm-25 cm lengths and having holes drilled to allow drainage of whey. They are fitted with a plastic or wooden disc for the base section.
- Cheese press (Fig. 3). Manual cheese presses have a press plate, which is raised and lowered by a screw. A muslin or cheese cloth bag is placed in the mould and curd is poured in. The bag is closed and the press plate is lowered into the mould.
- Cheese vat (Fig. 1)
- Cooler/refrigerator
- Curd cutters (Fig. 2)
- Heat sealer
- Thermometer (0-100°C)
- Scales. 0-1 kg +/- 1 g for weighing ingredients, 0-25 kg +/- 100 g for milk

Materials

- Lactic acid bacteria starter culture and rennet tablets/liquid are likely to be available locally from pharmacies in large towns or from dairy suppliers.

Equipment suppliers**Cheese moulds**

- Servi Doryl, ZI Sud - BP 57 - 37130 Langeais, France, Tel: +33 (0)2 4796 1150, Fax: +33 (0)2 47 96 11 51, E-mail on website at www.servidoryl.com/english/frameset_accueil.htm
- Lehman's, P.O. Box 41, Kidron, Ohio 44636, USA. Tel: +1 877 438 5346, +1 888 438 5346, E-mail: info@lehmans.com, Website: <http://www.lehmans.com>

Cheese presses

- Lehman's, P.O. Box 41, Kidron, Ohio 44636, USA. Tel: +1 877 438 5346, +1 888 438 5346, E-mail: info@lehmans.com, Website: <http://www.lehmans.com>

Cheese vats

- Kleen-Flo Small Scale Dairy Equipment, 10180 S 100 E Lynn, IN 47355, USA, Tel: +1 765-874-1292, E-mail: info@kleenflo.us, Website: www.kleenflo.us/index.html

Curd cutters

- Glengarry Cheesemaking and Dairy Supply Ltd., 5926 Hwy#34, RR#1, Lancaster, Ontario, Canada, Tel: 1-888-816-0903 or 613 347 1141, Fax: 1 613 347 1167, E-Mail: info@glengarrycheesemaking.on.ca, Website: www.glengarrycheesemaking.on.ca

Other cheese, butter & yoghurt making ingredients & equipment

- Finest Kind, P.O. Box 1, Plettenberg Bay 6600, South Africa, Tel: +27 (0) 44 533 1623, E mail: info@finestkind.co.za, Website: www.finestkind.co.za/equipment.html

References and further reading

References

- *Dairy Science and Technology Education*, Goff, D., University of Guelph, Canada, www.foodsci.uoguelph.ca/dairyedu/home.html
- Technical Brief: *Butter and ghee*
- Technical Brief: *Dairy Processing - an overview*
- Technical Brief: *Hygiene and safety rules in food processing*
- Technical Brief: *Pasteurised milk*
- Technical Brief: *Soured milk and yoghurt*

Further reading

- *Applications of Biotechnology to Traditional Fermented Foods*, National Academic Press. Washington DC, USA., 1992.
- *Appropriate Food Packaging*, Fellows, P., and Axtell, B., IT Publications, 1993.
- *Cheese and Fermented Milk Foods*, Kosikowski, F.V. and Mistry, V.V. 3rd Edition, F.V. Kosikowski and Associates, Brooktondale, NY. 1997.
- *Cheese Making Made Easy*, Carroll, R. and Carroll, R., Storey Communications Inc., Ponnal, Vermont, USA. 1982.
- *Cheese Making Practice*, Scott, R., Robinson, R.K. and Wilbey, R.A. 3rd Edition. Applied Science. Publ. Ltd., London., 1998.
- *Cheese Monographs*. C. Pfizer and Co., New York. 1. Italian Cheese Varieties, 2. American Cheese Varieties, 3. Cottage Cheese and Other Cultured Milk Products, 4. Ripened Semi-soft Cheeses, 5. Swiss Cheese Varieties, 6. Lactic Starter Culture Technology, from Pfizer and Company, Inc., 235 East 42nd. Street, New York. New York 10017.
- *Cheese*, Davis, J.G., American Elsevier Publ. Co., New York., 1965.
- *Cheese: A guide to the world of cheese and cheese making*. Battistotti, B., Bottazzi, V., Piccinardi, A. and Volpato, G. Facts on File Publications, New York, NY., 1983.
- *Cheese Making Illustrated*, Fankhauser, D.B., University of Cincinnati Clermont College, Batavia OH 45103, available at http://biology.clc.uc.edu/fankhauser/Cheese/Cheese_5_gallons/CHEESE_5gal_00.htm
- *Cheesemaking in the Andes*, *Appropriate Technology*, Vol. 20, No 4, March, 1994.
- *Dairy Processing - Food Cycle Technology Sourcebook*, Aguhob, S and Axtell, B.L.A., IT Publications, 103-105 Southampton Row, London, UK., 1996.
- *Developing Cheese Co-operatives*, *Appropriate Technology*, Vol. 29, No 1, March 2002 (1/2 page article about dairy farmers in Ecuador)
- *French Cheeses: The visual guide to more than 350 cheeses from every region of France*. Masui, K.. and Yamada, T. DK Publishing, New York., 1966.
- *Introduction to cheese-making*, University of Guelph, Canada, available at www.foodsci.uoguelph.ca/cheese/sectiona.htm
- *Making cottage cheese at home*, U S Department of Agriculture, Home and Garden Bulletin, Number 129, Prepared by Agricultural Research Service, available at http://agnic.msu.edu/hgpubs/modus/morefile/hg129_77.pdf
- *Small Scale Food Processing – a directory of equipment and methods*, 2nd Edition (Fellows, P., Azam-Ali, S., Judge, E., and Battcock, M.), IT Publications, London, UK. 2003.
- *Technology of Cheese Making*, Law, B., Sheffield Academic Press, Sheffield, UK., 1999.
- *Traditional Cheese making*, Dubach, J., SKAT/IT Publishers, 1989.

Support organisations

- Agromisa Foundation, P.O. Box 41, 6700 AA Wageningen, The Netherlands, www.agromisa.org
- Centre For Dairy Research, Madison, WI. www.cdr.wisc.edu
- Dairy & Meat Officer (Institutional Support & Training), Animal Production & Health Division, Food and Agricultural Organization (FAO), Rome, Italy, Website: <http://www.fao.org/>
- International Livestock Research Institute ILRI-Kenya, P.O. Box 30709, Nairobi, Kenya, Tel: 254-2 630743. Fax:254-2 631499.E-mail: ILRI-Kenya@cgiar.org. Website: www.cgiar.org/ilri/
- International Livestock Research Institute (ILRI) Ethiopia, P.O. Box 5689, Addis Ababa,

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