Technology options for small-scale processing of milk, yoghurt and cheese

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Introduction

Cultured milks, yoghurt and soft cheeses have been produced for thousands of years in some ACP countries, especially among African nomadic herding communities to preserve milk for home consumption and food security. Only recently has commercial dairy processing begun to produce pasteurised milk and hard cheeses arisen in ACP countries, as local demand increased. A lack of reliable 'cold chains' for transporting, storing and selling dairy products and a relatively high incidence of lactose intolerance in some populations limit expansion. Feasibility studies can be used to guide investment decisions of prospective dairy processors before making any investment decisions.

Processing

Cow's milk is popular, but milk from goats, horses, camels and sheep is important in some areas. A dairy that produces short shelf-life dairy products may be located close to consumers in urban centres, whereas one producing longer shelf-life products may be in a rural area, closer to milk sources: it is cheaper and less risky to transport products than fresh milk.

Facilities & Equipment

A processing room should be hygienically designed, with tiled walls and floors that are easily cleaned and a ripening cellar if hard cheese is produced. Incoming milk and dairy products should be stored in separate refrigerators or cold rooms. There should be an adequate supply of potable water, free from micro-organisms, chemicals and other particles that can contaminate the product. The processing room and equipment should be thoroughly cleaned and sanitized after production. Dairy effluents are highly polluting and processors should ensure that effluent disposal meets local regulations.

General dairy equipment includes milk churns, filters for incoming milk, measuring jugs or scoops for ingredients, weighing scales, a lactometer, an electronic pH meter and an electronic thermometer. Ideally, all dairy equipment should be stainless steel, but cheaper alternatives may include polished aluminium, or for containers and equipment that are not heated, food-grade plastic. Specific equipment required for different dairy products is shown in Table 1.

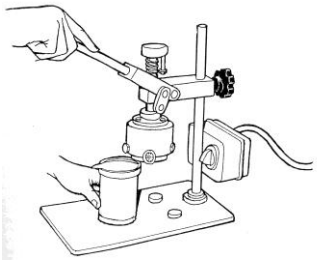
Product	Main items of equipment
Pasteurised milk	Cream separator, pasteuriser, filler, sealer
Yoghurt & cultured milks	Incubator, filler, pot sealer
Cheese	Double-walled vat, pasteuriser, cheese cutters, cheese press, cheese moulds, cheese cloths

Table 1. Equipment required for dairy processing

Case study: Dairy equipment
"My yoghurt processing equipment includes a jacketed processing tank, heated by a liquid propane gas-fired boiler, a cold room and a packaging machine. They were financed from our own funds and a bank loan. The process can handle 500 litres per batch, which yields 4,000 125 mil cups of yoghurt." (Axtell *et al.*, 2008)

Milk and yoghurt are typically packed in plastic bags, wax-coated paperboard cartons, plastic bottles and cups, or glass bottles. Cheese may be wrapped in foil or plastic film. A heat sealer is used for sealing plastic bags at a small scale, whereas larger operations use a form-fill-seal machine (Fig. 1a). Sealers for plastic yoghurt pots (Fig. 1b) have a thermostatically-controlled sealing head that can be adjusted for sealing foil or plastic lids.

a)



b)

Fig.1. a). Form-fill-seal machine, b) pot sealer (Courtesy of Practical Action (http://practicalaction.org))

Product handling

All milks have low acidity and a high nutrient content, which can allow the growth of bacteria that spoil milk and/or cause food poisoning. To prevent this, milk is processed by heat treatment (pasteurisation or boiling) or by increasing the acidity to produce yoghurt, cultured milks or cheese.

Pasteurised milk

The processing stages for pasteurised milk include:
1. Filtration of raw milk.

2. Separation of milk fat using a cream separator (Fig. 2) if ‘skimmed’ or ‘semi-skimmed’ pasteurised milks are required or milk for yoghurt or cheese needs a specific fat content.
3. Pasteurisation, followed by cooling to <10ºC.
4. Packaging.
5. Cold storage and distribution.

Fig. 2. Hand-operated cream separator with a throughput of 60–100 litres of milk per hour.

Flavoured milks (e.g. chocolate, vanilla and fruit flavours) have appropriate flavourings and colourings added before pasteurisation. The law in many ACP countries specifies minimum pasteurisation conditions of 63ºC for 30 min or 72ºC for 15 sec. At the smallest scales of operation, milk is pasteurised using a stainless steel pan over a heater, but care is needed to control the heat and continuously stir the milk to avoid it scorching. A jacketed stainless steel boiling pan, heated by steam or hot water, avoids this problem. Pasteurisation at 72ºC for 15 seconds cannot be achieved using boiling pans and a heat exchanger (Fig. 3) is required. Pasteurised milk has a shelf-life of about a week under refrigeration.

Fig. 3. Plate heat exchanger for pasteurising milk.

Cultured milks and yoghurt

These products are produced using lactic acid bacteria to ferment lactose in milk to lactic acid. The acid helps to prevent the growth of bacteria and coagulates milk proteins to form curds. Traditional cultured milks, including kefir, koumiss and labneh, are thick, clotted with a strong flavour and acidic taste. They have a shelf life of 3-8 days at ambient temperatures or a few days longer under refrigeration. Raw milk is allowed to sour by naturally occurring bacteria in covered containers in a warm room for 1-2 days. In an upgraded method, the milk is inoculated with a *Lactobacillus* sp. or *Leuconostoc* sp. starter culture and held at 25-30°C for a few hours. 'Acidophilus' milk is a traditional milk that is fermented with *Lactobacillus acidophilus*. Cultured buttermilk, remaining after butter production, is produced using *Streptococcus lactis* or *S. cremoris*. Milk is heated to 95°C and cooled to 20-25°C before fermenting for 16-20 hours. Yoghurt is produced by fermenting whole or skimmed milk using *Streptococcus salivarius* subspecies *thermophilus,* which causes the pH to fall to ≈5.0, and then *Lactobacillus delbrueckii* subspecies *bulgaricus,* which causes a further decrease to pH 4.0 and coagulates the milk. Milk and any added ingredients are blended in a mixing tank, pasteurised and cooled to 40-45°C, and fermented for 4–6 hours until the acidity is 0.85-0.90%. For 'set' yoghurt, the mixture is fermented in the pots that are used as the retail packaging. Incubators for pots of yoghurt may be made using: 1) an insulated cabinet fitted with a 40W light bulb to maintain the correct temperature; 2) a shallow water bath fitted with a small electric heater and thermostat; 3) a block of thick polystyrene with indentations to hold plastic pots, covered with a polystyrene lid. At a larger scale for bulk yoghurt, insulated, thermostatically-controlled stainless steel tanks are used. After fermentation, yoghurt is cooled to ≈10°C and stirred to break the gel if stirred yoghurt is

required. Thicker yoghurt is made by adding dried skimmed milk to the milk and other ingredients may include sweeteners, flavours, colourings, fruit pulps or chopped nuts. Yoghurt has a shelf life of ≈10 days at refrigeration temperatures.

Making starter cultures
Dried starter cultures of lactic acid bacteria for yoghurt or cheese are grown in pasteurised milk to make a 'mother culture' that is used each day for a week. The last part is re-inoculated into milk to form a new mother culture. With good hygiene, this method can be continued for several months, but eventually undesirable bacteria contaminate the culture and it must be replaced. It is also possible to use commercial yoghurt that has not been pasteurised as the starter culture or add part of the previous day's production to a new batch of milk.

Cheese

There are hundreds of varieties of cheese, but each relies on similar principles of coagulating the proteins in milk to form curds and then separating them from the liquid whey. Cheeses may be broadly classified into 'soft', 'semi-hard' and 'hard' cheeses (Table 2).

Type of cheese	Examples	Moisture content (%)	Fat content (%)	Texture	Shelf-life
Soft cheeses	Cottage cheese, Halloumi	45–75	<40	Soft, white, spreadable	A few days or weeks
Semi-hard cheeses	Ricotta, Paneer, Feta, Camembert, Brie	35–45	<35	Firm, crumbly, can be sliced	Several weeks
Hard cheeses	Cheddar, Pasta Filata	30–40	<30	Very firm, dense	Several months

Table 2. Types of cheeses

Curd can be formed in a number of different ways: using rennet (as tablets, powder or liquid); fermenting with lactic acid bacteria; adding acid (e.g. lime juice or vinegar); boiling; or using specific plant extracts (e.g. leaves or bark of the Sodom Apple tree).

Making rennet
Rennet can be produced in a dairy if commercial rennet is not available: the 'abomasum' (the fourth stomach of an un-weaned calf) is dried, sliced into strips and soaked for 24 hours in 10% brine with sodium benzoate preservative. The liquid is removed and used as rennet.

The general method for making cheese involves adding rennet and/or a lactic acid bacteria. After fermentation, the curd is cut into small cubes using curd cutters (Fig. 4a). The whey is drained

and for some types of cheeses the curd is washed and/or heated before pressing it in a cheese press. Cheese moulds are normally stainless steel but can be made from 10-25 cm lengths of plastic drainage pipes, with holes drilled to allow drainage, and each fitted with a plastic or wooden lid and base. These are pressed by placing weights on the lids. Manual cheese presses have a press plate operated by a screw (Fig. 4b). Curd is poured into a muslin or cotton bag in the mould and the press plate is lowered to press the curd.

a)

b)

Fig. 4. a) Vertical and horizontal curd cutters (Courtesy of Glengarry Cheesemaking and Dairy Supply Ltd. (www.glengarrycheesemaking.on.ca)), b) cheese press (Courtesy of Lehman's (www.lehmans.com))

Traditional cheeses are hand-pressed into blocks and stored in brine until sold directly from the brine tub. They have a shelf life of 2-3 weeks. Semi-hard cheeses may be ripened for up to 12 months. Hard cheeses have lower moisture contents, controlled by the curd cooking temperature/ time and the amount of added salt, and may be ripened for 1-36 months.

Quality Assurance

Milk carries a high risk of causing food poisoning and processors should only buy high quality fresh milk. Contamination may occur at all processing stages and processors should implement quality assurance programmes to:

1) Prevent contamination in the milking parlour from animals, workers' hands, or milking equipment and ensure milk is cooled before transporting it.
2) Use only milk churns to transport milk and avoid delays that allow the milk to warm.
3) Ensure that staff follow the correct process conditions; enforce personal hygiene and ensure that cleaning schedules are properly completed.
4) Advise retailers on display temperatures and sell-by dates; put storage and use-by information for consumers on labels.

Milk is tested for pH using a pH meter; acidity by titration with sodium hydroxide solution; density using a hydrometer known as a 'lactometer' to detect any dilution with water; and fat content using the 'Gerber' method at a reputable laboratory. A simple microbiological test involves mixing methylene blue dye with milk – if the milk does not decolourise within 30 minutes it has a satisfactory bacterial quality. Phosphatase activity is measured by mixing a dye

with milk and assessing the colour change – absence of phosphatase activity shows that milk has been properly pasteurised.

Conclusion

The food technology units of universities and research institutes as well as the bureau of standards in many ACP countries can provide guidance on the processing of milk and milk products. The scientific and engineering communities should consider conducting more research and development on processed dairy products and on the design of processing equipment and facilities within the context of small and medium-scale dairy enterprise development to improve the value proposition for consumers and entrepreneurs in ACP countries.

Further Information

The FAO Dairy Gateway is a single access point for a wide range of information related to dairy production and products, including publications, training materials and statistics, available at www.fao.org/agriculture/dairy-gateway/milk-processing and following the link to 'Information Resources' [accessed 12 February 2014]

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