

Options for smallholder milk processing in sub-Saharan Africa*

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Summary

MILK IS PRODUCED *in almost every production system of sub-Saharan Africa, but only a minor portion of this milk enters the commercial sector owing to marketing constraints and lack of processing techniques suitable for smallholder dairying. ILCA's Dairy Technology Unit has identified simple standard methods which, when adapted to suit local conditions, can be used to process milk into high-quality dairy products. The manufacture of stable marketable products including butter, ghee, low-moisture cottage cheese, some hard cheeses and fermented milks will provide smallholder producers with an additional source of cash, facilitate reinvestment in the enterprise, yield byproducts for home consumption and enable the conservation of milk solids for future sale or consumption. The technologies described in this paper can be rapidly transferred by appropriate training programmes.*

Introduction

Milk is an important product in most pastoral and agropastoral systems of sub-Saharan Africa and in the smallholder farming systems in areas with high human population density. In these production systems, milk is one of the staple foods, providing such vital nutrients as calcium, protein, phosphorus and lipids, and, in many instances, is a major source of cash for the family. Dairy income is usually used to purchase food grains, clothing and other household items, but it may also provide the means of financing some aspects of rural development. The amount of cash generated by dairying will depend on the form in which milk is marketed, the accessibility of markets, and on whether the prevailing pricing arrangements allow for a realistic margin between the purchase and sale prices of milk.

Most milk produced in the rural areas of sub-Saharan Africa is consumed at home or bartered, either fresh or sour, and only in the vicinity of urban markets are milk surpluses processed into dairy products (especially butter) with longer shelf life. Traditional methods of milk processing generally give low yields of final product per unit of milk and require high labour inputs, while the manufactured products have low stability and are hygienically inferior to similar products produced in large-scale dairy plants.

Although the success of any dairy development scheme depends to a large extent on the available marketing facilities and the pricing policies pursued, an equally important factor at the smallholder level is the availability of small-scale processing techniques for the manufacture of high-quality dairy products with good storage characteristics. The work of the Dairy Technology Unit at ILCA is aimed at developing appropriate physical and technological means for milk processing at the smallholder level. In addition, technologies for small-scale processing of milk by village cooperatives are being investigated. ILCA's efforts in the field of smallholder milk

processing are expected to have an impact on employment and earning opportunities in rural areas, as well as on the viability of smallholder mixed enterprises.

This paper describes the major constituents of cow's milk and their exploitation in milk processing. The technologies needed for small-scale manufacture of such dairy products as fermented milks, milk-fat products and soft or pickled cheeses are discussed, as well as the product options most suitable for on-farm or village-level manufacture. Some suggestions on how best to utilise byproducts of butter and cheese making are made.

Milk composition

In Africa, milk from cows, sheep, goats and camels is used. Of these, cow's milk is the most widely produced and processed and the subsequent discussion in this paper refers to cow's milk only. Since the nutritive quality of milk and its value as a raw material for making food products is determined by its composition, a general overview of its components is presented.

Essentially, milk is an emulsion of fat in a watery solution of sugar and mineral salts, with protein in a colloidal suspension. The major solid constituents of milk are fat, protein and carbohydrate. Milk salts, enzymes, vitamins and trace elements are minor constituents but are very important for balanced human nutrition. The concentration of each constituent varies and is determined by genetic, physiological and environmental factors (Webb et al, 1983). The average composition of milk from *Bos taurus* and *Bos indicus* cows is shown in Table 1.

Table 1. Average composition of milk from *Bos taurus* and *Bos indicus* cows.

Constituent	Average percentage by weight	
	<i>Bos taurus</i> ^a	<i>Bos indicus</i> ^b
Water	87.2	86.1
Fat	3.7	5.3
Protein	3.5	3.4
Lactose (carbohydrate)	4.9	4.6
Ash (minerals)	0.7	0.6
Solids-not-fat	9.1	8.6
Total solids	12.8	13.9

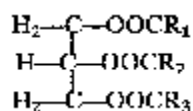
Sources: ^a Webb et al (1983).

^b Ethiopian Nutrition Institute (1980).

Milk processing exploits one or more of the major solid constituents of milk. Commercially, milk fat is the most important solid fraction in milk, while milk proteins are important for human nutrition (O'Sullivan, 1973). Water and minor constituents such as milk salts are incorporated in all milk products to varying degrees.

Milk fat

Milk fat is one of the most complex natural fats known, comprising a mixture of triglycerides—fatty acids esterified with glycerol—and several minor lipid components, such as phospholipids, sterols, carotenoids and the fat-soluble vitamins A, D, E and K. The triglyceride esters are peculiar to milk and markedly influence the texture of dairy products. Their chemical formula is:



where:

R_n = fatty acids with C_4 to C_{20} hydrocarbon chains.

The molecules of fatty acids may be saturated or unsaturated. Saturated fatty acids have no carbon-carbon double bonds, whereas unsaturated fatty acids have one or more of these bonds. The melting point of milk fat increases with the length of the carbon chain and decreases with a higher degree of unsaturation. Because the fatty acids in milk fat vary in chain length and degree of unsaturation, milk fat melts gradually (Webb et al, 1983) and this affects its processing properties (Brunner and Jack, 1950).

Fat is present in milk in the form of tiny droplets (fat globules) suspended in milk plasma and forming an oil-in-water emulsion. Milk fat can be concentrated into cream by gravitational or centrifugal separation and de-emulsified from either milk or cream by agitation. After working, the concentrated mass of fat is recovered as butter containing lipids, some water and non-fat milk solids. Water can be removed from the butter by evaporation and the clear fat separated from non-fat milk solids to produce butter oil (McDowell, 1953).

Milk proteins

The two main groups of milk proteins are caseins, which account for up to 80% of the total protein in milk, and whey proteins, which account for about 20% of the total milk proteins but are of higher nutritional value than caseins (O'Sullivan, 1973).

Caseins can be precipitated from raw skim milk by acidification to pH 4.6 at 20°C. They form relatively large (30 to 300 nm diameter), nearly spherical particles known as micelles. Caseins are heterogeneous proteins which are stabilised by the *k*-casein fraction, and which can be recovered from milk by either acid or enzymatic precipitation (Webb et al, 1983). Enzymatic precipitation of caseins is used to coagulate milk for cheese making. The traditional coagulant is rennin, a proteolytic enzyme extracted from the abomasa of 10- to 30-day old, milk-fed calves. A variety of coagulants of animal, plant and microbial origin are now used in cheese making (Green, 1977).

Whey proteins are also heterogeneous but they are more soluble than caseins and denature at temperatures above 60°C (Harland et al, 1953). Denatured whey proteins are less soluble than undenatured whey proteins, enabling them to coprecipitate with caseins at pH 4.6. Heating milk to 80°C for 30 minutes denatures most whey proteins and they can be recovered with caseins by acid precipitation (Larson and Roller, 1955).

Whey proteins form chemical complexes with caseins at temperatures above 80°C (Hartman and Swanson, 1965), and this inhibits enzymatic coagulation of milk. Heating milk to high temperatures prior to renneting cannot therefore be used to increase the yield of rennet cheeses. Care must also be taken not to overheat milk during pasteurisation, as the denatured whey proteins will again inhibit rennet coagulation.

Lactose

Lactose is a disaccharide found only in the milk of mammals (Webb et al, 1983). Usually it is the predominant solid in milk, but cows of some breeds produce milk containing more fat than lactose. Lactose is present in solution and is therefore more difficult to recover from milk as an isolated fraction. Bacterial fermentations of lactose to lactic, acetic and propionic acids are critical to many milk processing techniques, since the resultant acidity helps to preserve the other milk constituents and to accelerate casein precipitation in cheese making.

Minor milk components

Milk salts, enzymes, vitamins and trace elements are classified as minor milk components. Milk is rich in calcium (Ca), phosphorus (P), potassium (K), sodium (Na) and chlorine (Cl), in addition to containing small amounts of iron (Fe), copper (Cu) and zinc (Zn). As a source of Ca and P, milk is particularly important in diets based on cereals. However, very high concentrations of Ca and P in milk fed to infants can adversely affect its nutritional properties.

On average, milk contains 132.1 mg Ca and 95.8 mg P per 100 ml, with 39.2% of Ca and 37.9% of P being in the soluble phase while 61% of Ca and 61 to 63% of P are associated with casein in the colloidal phase (Webb et al, 1983). These colloidal salts are recovered with caseins in rennet cheeses. The physical stability of caseinates is highly dependent on the type of salts present, which means that the physical state of the salt system affects rennet coagulation time (Fox, 1969b).

Dairy products for smallholder manufacture

Although the manufacture of many dairy products necessitates high technical and capital inputs, there is a range of products suitable for small-scale processing at the farm using simple equipment. The processing steps required to make some of these products, as well as their composition and keeping quality, are given in Tables 2, 3, 4, 5 and 6. Figure 1 shows the major solid constituents of milk incorporated in the dairy products described in Tables 2 to 6.

Table 2. Process, composition, yield and keeping quality of fresh milk, separated milk and cream.

Dairy product	Process	Composition						Yield (litres of milk/kg product)	Keeping quality
		Moisture (%)	Protein (%)	Fat %	Lactose (%)	Ash (%)	Whey protein (%)		
Fresh milk ^a	None	87.2	3.5	3.7	4.9	0.71	0.75	1	5 hours
Fresh milk ^b	None	86.1	3.4	5.3	4.6	0.6	n.a.	1	5 hours
Separated ^a milk	Milk separation	90.5	3.6	0.1	5.1	0.7	0.75	1.2	5 hours
Cream ^a		57.3	2.2	36.8	3.2	0.6	n.a.	10 ^c	1 day

Sources and notes: ^aWebb et al (1983) for milk from *Bos taurus* cows.

^bEthiopian Nutrition Institute (1980) for milk from *Bos indicus* cows.

^cThe yield of cream varies with the composition of milk and separation method used.

n.a.= not available.

Table 3. Process, composition, yield and keeping qualities of fermented milks.

Dairy product	Process	Composition						Yield (litres of milk/kg product)	Keeping quality
		Moisture (%)	Protein (%)	Fat %	Lactose (%)	Ash (%)	Lactic acid (%)		
Sour milk (irgo) ^a	Natural fermentation	88.5	4.7	2.2	3.9	0.7	0.91	1	10 days
Kefir ^b	Sterilisation followed by inoculation	89.4	3.5	2.0	4.0	0.7	0.60	1	10 days
Yoghurt ^b	Sterilisation followed by inoculation	87.2	3.4	3.4	4.1	0.6	0.90	1	10 days
Acidophilus skim milk ^b	Acid fermentation	90.1	3.5	0.5	4.4	0.7	0.70	1	1 day

Sources: ^a Ethiopian Nutrition Institute (1980).

^b Webb et al (1983).

Table 4. Process, composition, yield and keeping quality of milk fat products.

Dairy product	Process	Composition						Yield (litres of milk/kg product)	Keeping quality
		Moisture (%)	Protein (%)	Fat %	Lactose (%)	Ash (%)	Lactic acid (%)		
Sour milk (<i>irgo</i>) ^a	Natural fermentation	88.5	4.7	2.2	3.9	0.7	0.91	1	10 days
Kefir ^b	Sterilisation followed by inoculation	89.4	3.5	2.0	4.0	0.7	0.60	1	10 days
Yoghurt ^b	Sterilisation followed by inoculation	87.2	3.4	3.4	4.1	0.6	0.90	1	10 days
Acidophilus skim milk ^b	Acid fermentation	90.1	3.5	0.5	4.4	0.7	0.70	1	1 day

Sources and notes:

^a Webb et al (1983) for milk from *Bos taurus* cows.

^b Ethiopian Nutrition Institute (1980) for milk from *Bos indicus* cows.

^c The yield of cream varies with the composition of milk and separation method used.

n.a.=not available.

Table 5. Process, composition, yield and keeping quality of byproducts of butter making.

Dairy product	Process	Composition								Yield (litres of milk/kg product)	Keeping quality
		Moisture (%)	Protein %	Fat %	Lactose %	Ash %	Salt %	Whey protein %	Lactic acid (%)		
Separated milk ^a	Milk separation	90.5	3.6	0.1	5.1	0.7	0	0.75	0	1.1	5 hours
Buttermilk (A) ^b	Churning of sour milk	91.5	3.1	1.4	3.2	0.6	0	0.75	0.8	1.1	5 days
Buttermilk (B) ^a	Cream Churning	90.5	3.6	0.4	4.3	0.7	0	n.a	0	16	5 days
<i>Ayib</i> ^b	Heating ripened buttermilk (A)	79.5	14.7	1.8	— ^c	0.9	0	— ^c	— ^c	8	5 days
Whey	Heating ripened buttermilk (A)	93.5	0.7	0.4	— ^d	0.8	— ^d	0.7	0	0	—

Sources and notes: ^aWebb et al (1983).

^bData obtained from ILCA studies in Debre Zeit and Debre Berhan, Ethiopia. *Ayib* resembles cottage cheese in texture but differs from it in the way it is made.

^{c, d}Content of constituents varies with the process used.

Table 6. *Process, composition, yield and keeping qualities of Halloumi, Queso Blanco, Feta, 'White cheese' and Domiati cheeses.*

Cheese Variety	Process	Composition				Yield (litres of milk/kg product)	Keeping Quality
		Moisture %	Protein %	Fat %	Ash %		
Halloumi	Rennet coagulation, and boiling the curd	35	26	33	3	9.5	>60 days
Queso Blanco	Heating milk to 83°C and acidification	46	24	23	3	8.00	>60 days
Feta	Rennet coagulation and pickling	49	17	27	3	9	1 year
'White cheese'	Rennet coagulation and salting	52.3	22	23	4.3	9.00	1 year
Domiati/ Gybna Beyda	Salting milk, rennet coagulation	61.5	12.5	120	4.0	6.00	1 year

Source: Unpublished ILCA data.

Sour milk and yoghurt contain all milk constituents, while cream, butter and butter oil are high in fat. Caseins are incorporated with fat and moisture in hard cheeses and can also be precipitated from defatted milk as cottage cheese. Lactose and whey proteins are incorporated in whey.

Fermenting milk reduces its pH, which in turn limits the growth of putrefactive and lipolytic bacteria, thereby preserving milk solids (Kosikowski, 1982). The low moisture content of butter and cheese retards bacterial growth, and as a result these products have greater storage stability than whole milk. Salting butter and cheese also retards bacterial growth (Hunziker, 1927; Kosikowski, 1982). Thus dairy products of good storage stability can be made by applying the three basic methods of pH reduction, moisture reduction and salting.

Fermented milks

Background

Fermented milks originated in the Near East, perhaps before the Phoenician era. They are nutritious, tasty and stable products obtained from good-quality milk subjected to one of a number of controlled fermentations (Fox, 1967). In some countries, fermented milks (e.g. yoghurt, kefir, acidophilus skim milk) are preferred to fresh milk because of their hygienic safety, better flavour and texture and possible therapeutic effects (Kosikowski, 1982). The Russian biologist Metchnikoff, who was a research associate of Louis Pasteur, attributed the longevity of the people in the Balkan states to their very high consumption of fermented milk products (Fox, 1967); more recently, other scientists have also begun speculating that the unique qualities of fermented milks may be of value in geriatrics.

Natural fermentation

Production of fermented milk is wide-spread in sub-Saharan Africa. In Ethiopia, milk is allowed to ferment naturally without addition of a starter. Milk is accumulated over a number of days in a clay pot vessel (of about 24 litres volumetric capacity) or in a bottle gourd (O'Mahony and Ephraim Bekele, 1985a) and allowed to develop up to 1% acidity. In cold weather the vessel is placed near the fire to keep the milk warm. The soured milk (*irgo*) is viscous, has a strong acid flavour, and is consumed as a side dish. If not consumed, sour whole milk is used for butter making.

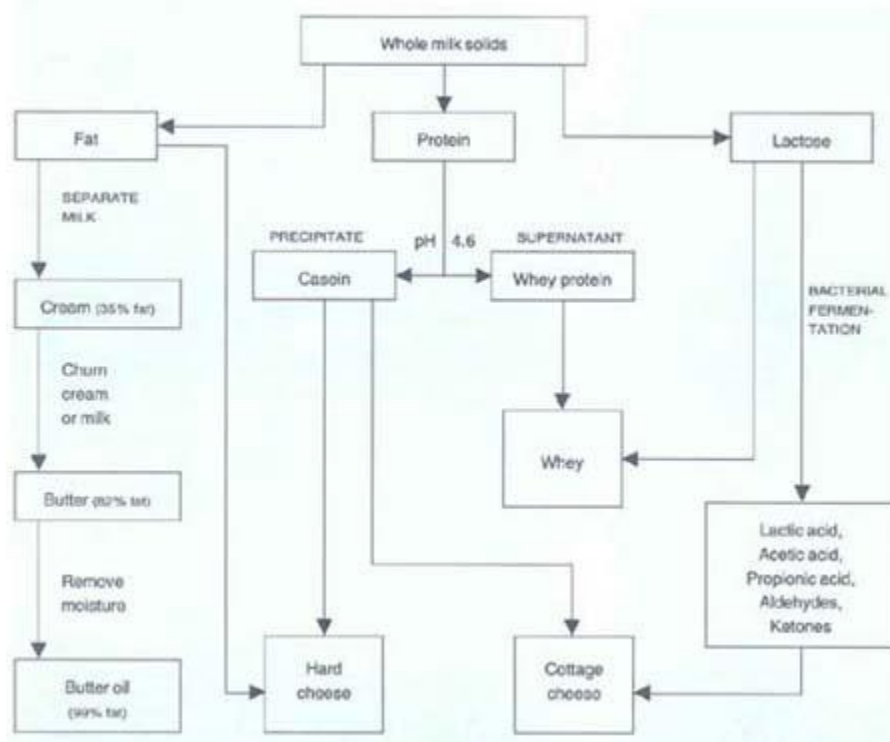
Natural fermentation of milk exploits lactic-acid-producing streptococci and lactobacilli which are present in any milk and which generally suppress spoilage and pathogenic organisms. A similar fermentation process is used by the Fulani (Waters-Bayer, 1986) and Maasai pastoralists (Grandin, personal communication). Borana pastoralists in Sidamo, Ethiopia, make a concentrated fermented milk by removing clear whey (about one sixth of the total milk volume) from coagulated cow's milk. The product can be stored for up to 20 days (O'Mahony, 1986).

The processing steps of heating milk to sterilisation temperature, followed by cooling and inoculation with bacteria (starter cultures) to achieve a controlled fermentation, are not used by either pastoralists or smallholders in sub-Saharan Africa. Heating kills undesirable organisms and also concentrates the milk, giving the fermented product a heavier body (Fox, 1967). The use of pure bacterial cultures as starters enables different acid flavours to be developed, leading to a range of fermented ('cultured') products. Since 'cultured' milks have better storage stability than fresh milk, and a better product consistency than naturally soured milks, their introduction into the small-holder processing system should be considered.

Technology of fermented milks

Milk for fermentation is first boiled for a considerable time to reduce the microbial population. It is then cooled, inoculated with starter culture or fermented milk from a previous batch and incubated at 30 to 38°C for 3 to 4 hours. Higher temperatures cause wheying off, while lower temperatures result in slow fermentations and may lead to the establishment of undesirable micro-organisms. Fermented milks can be made in simple containers of any size.

Figure 1. *Incorporation of major milk solids in the dairy products described in Tables 2 to 6.*



Defects

Off-flavours described as 'unclean', 'putrid' and 'bitter' are caused by coliform and putrefactive organisms. Good sanitary procedures and adequate heat treatment prior to fermentation help to prevent spoilage. Other problems are sharp acid flavour, which occurs if the fermentation is too vigorous, and wheying off, which is the result of the temperature being too high during fermentation.

Milk fat products

Butter

Commercially, milk fat is the most significant solid fraction in milk. The two main products made from milk fat are butter and butter oil. Butter can be produced under smallholder conditions by churning either sour whole milk or ripened cream (Figure 2). Sour milk is usually churned in a bottle gourd or an earthenware jar (O'Mahony and Ephraim Bekele, 1985a), but any watertight vessel of the required volume is suitable. Churning efficiency can be improved by the use of an agitator (Figure 3). Provided that the churning temperature is held below 16°C the process enables efficient recovery of milk fat as butter from up to 12 litres of milk in each batch (O'Mahony and Ephraim Bekele, 1985a). Churning temperature can be reduced by evaporative cooling.

Figure 2. *Products and byproducts of butter making.*

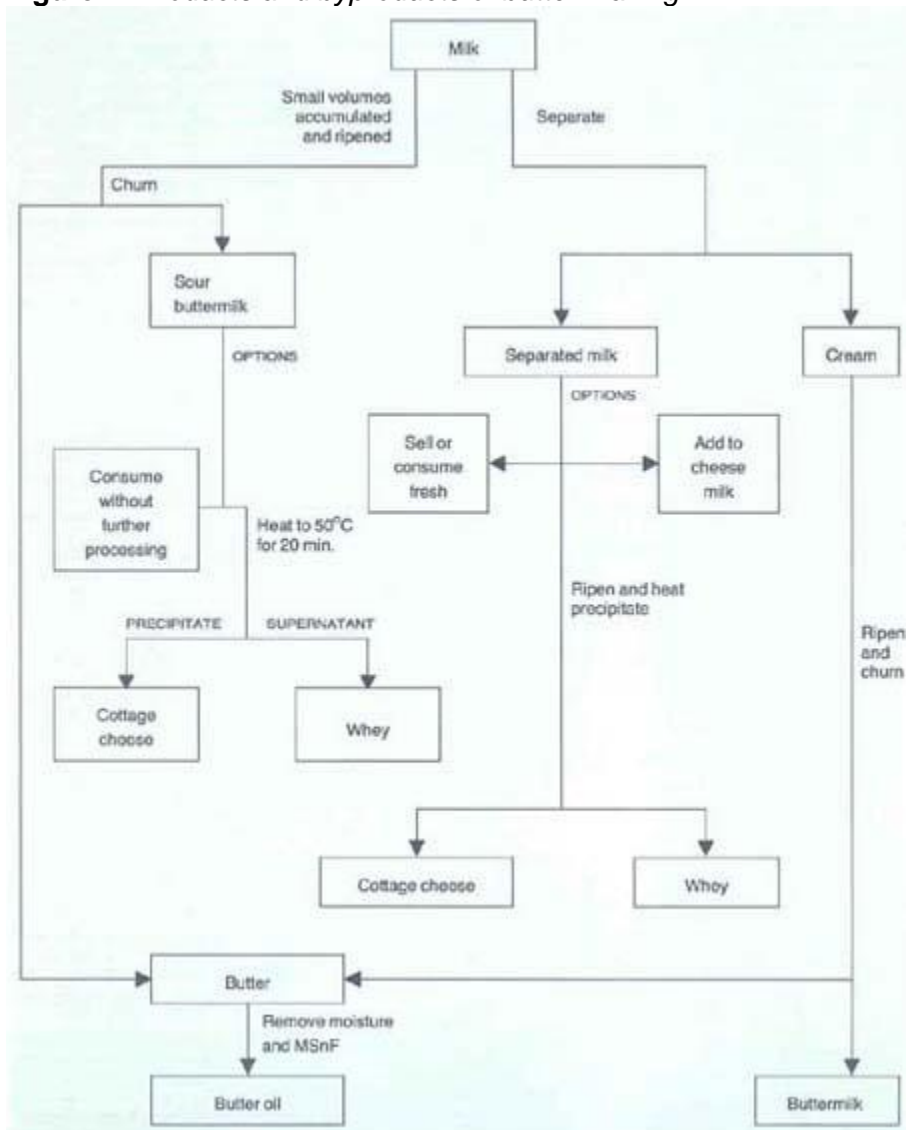
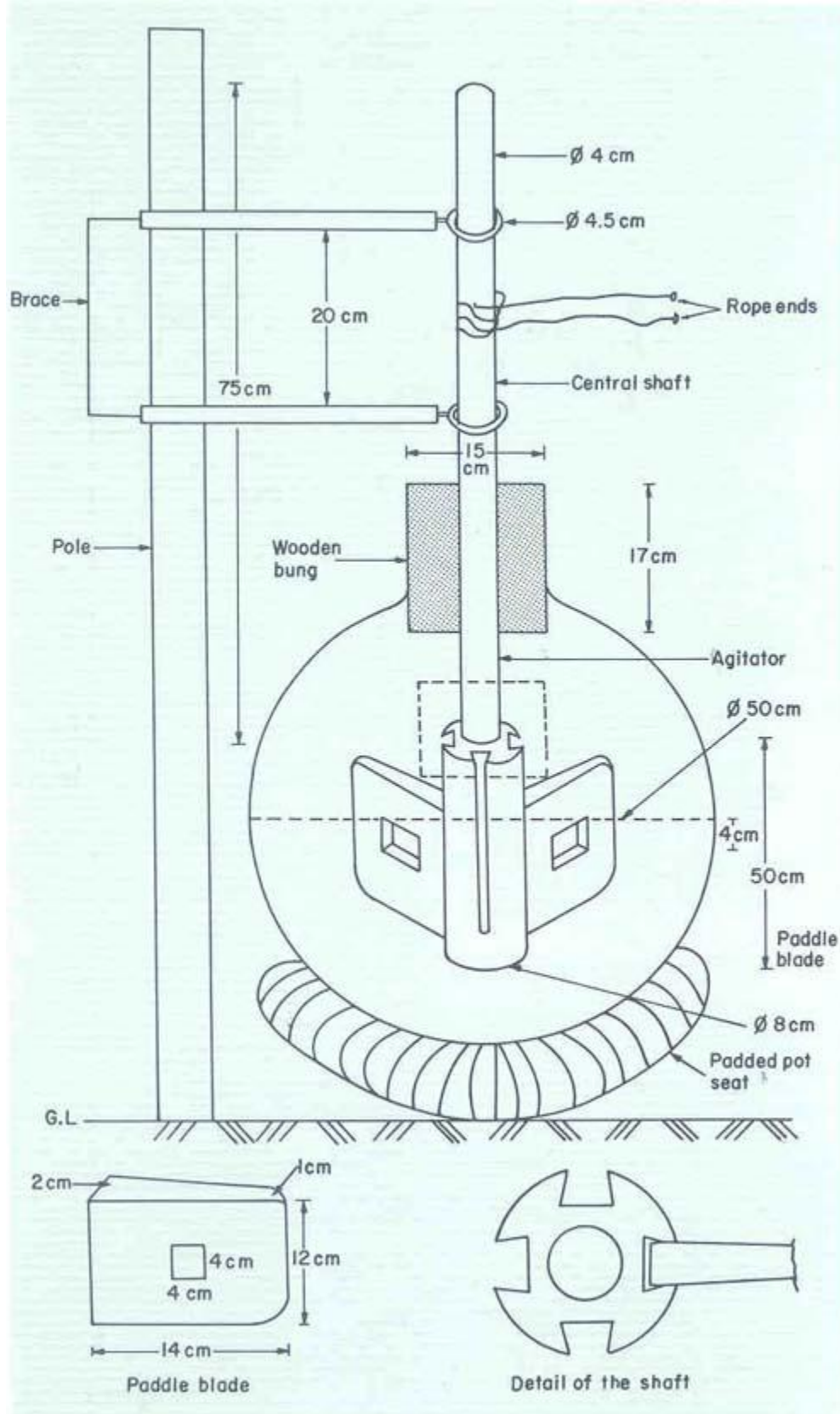
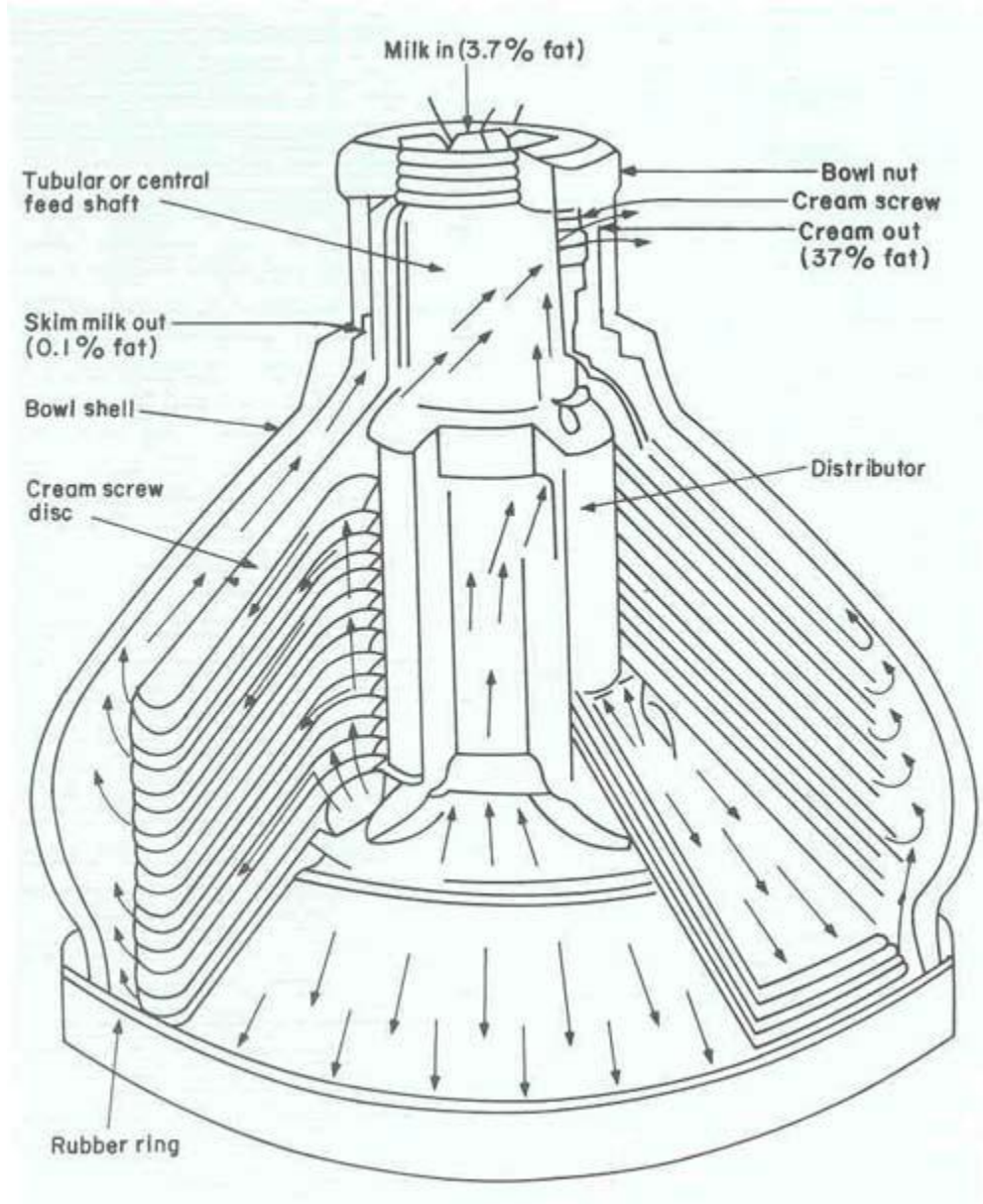


Figure 3. *Traditional churn fitted with a wooden, detachable agitator.*



For larger milk volumes (up to 300 litres), centrifugal separation of cream (Figure 4) followed by churning cream in a wooden churn (Figure 5) is more appropriate. Centrifugal separation concentrates milk fat in the cream phase; with proper temperature control (35–40°C) and correct operation of the separator, as little as 0.1% of the milk fat remains in the separated milk (Hunziker, 1927). Cream separation offers more processing options than are available with soured milk.

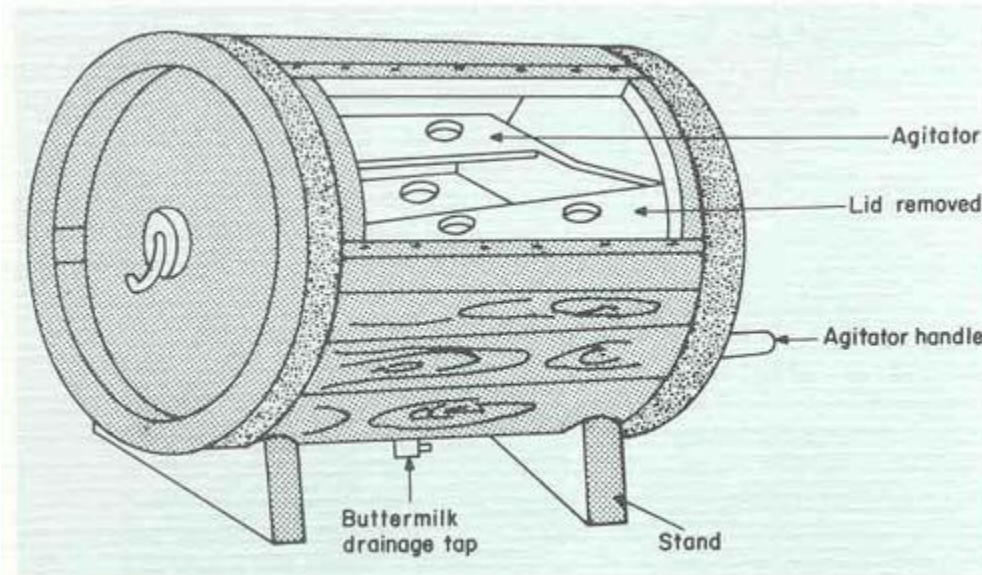
Figure 4. *Centrifugal cream separator.*



After separation, cream is allowed to ferment for 2 to 3 days until serum acidity exceeds 0.5 % and milk fat becomes viscous and solidifies. Both factors influence the speed and effectiveness of churning, while the diacetyl, propionic and acetic acids developed during fermentation

contribute to the more aromatic flavors of ripened butter. The churn should be filled to not more than half its volumetric capacity. The type shown in Figure 5 is normally used to churn up to 20 litres of cream per batch.

Figure 5. *Wooden churn for cream churning*



The efficiency of churning is influenced by the churning temperature; as this decreases from 24 to 14°C churning time increases, resulting in increased fat recovery as butter (Hunziker, 1927). The break point in churning sour whole milk or cream is reached when visible butter grains begin to form, which is also indicated by the changing sound of the churn. Churning should be stopped when the butter granules are the size of sorghum grains or small peas; if they are smaller, fat losses will be high, while overchurning makes it difficult to control the moisture content of the finished product. After churning the contents of the churn are strained through a muslin cloth to recover the butter. Washing butter in cold water removes residual non-fat milk solids and reduces the off-flavours associated with them, but it also depresses butter yield.

Butter yield. The two main factors determining butter yield are the quantity of butter fat extracted from milk and the amount of moisture incorporated in the butter. The standard level of fat in butter is set at not less than 80% milk fat, and most developed countries also specify that moisture level should not exceed 16% (Webb et al, 1983). While processing losses are unavoidable, these should not exceed 5% of the total fat available in sour whole milk and 3% of the total fat in cream. Care should also be taken to ensure complete moisture incorporation to 16%, of the weight of butter.

Assuming that butter is composed of 82% fat, 2% non-fat milk solids and 16% moisture, the expected yield of butter from 100 kg of milk containing 3.7% fat can be calculated as follows:

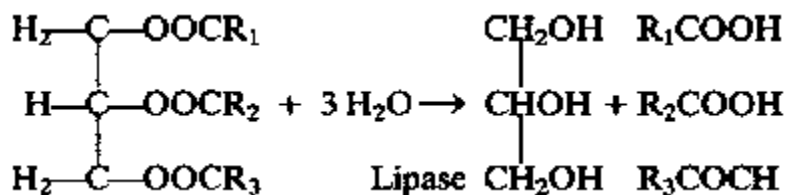
1. Weight of fat = 3.70 kg
2. A 5% fat loss during production = 0.19 kg

3. Fat available for butter making = 3.51 kg

4. Expected yield of butter containing 82% fat = $3.51 \times 100/82 = 4.30$ kg

Salting butter to 2% increases its keeping quality and yield. The expected yield of salted butter containing 80% milk fat, 2% milk solids non-fat, 2% salt and 16% moisture is $3.51 \times 100/80 = 4.4$ kg.

Butter quality. Butter deteriorates rapidly at high temperatures. Besides the off-flavours attributed to the non-fat milk solids there are two other off-flavours—caused by hydrolytic and oxidative rancidity—which develop in the fat itself (Downey, 1970). Hydrolytic rancidity is caused by lipolysis, i.e. hydrolysis of the triglyceride to glycerol and component free fatty acids:



which is:

triglyceride + water + enzyme = glycerol + free fatty acids

where:

R_n = fatty acids of C_4 to C_{20} chain length.

Off-flavours caused by hydrolytic rancidity dominate the flavour of traditionally produced butter. Rancid butter is favoured in certain markets, but as the level of free fatty acids increases above 10%, the market value of butter decreases. Hydrolytic rancidity can be retarded by salting butter to 2% salt by weight, which delays its development, presumably by inhibiting bacterial activity. This type of rancidity in butter can also be minimised by using polythene-lined, opaque packaging and storing in a cool place.

Oxidative rancidity is caused by lipid oxidation and occurs in unsaturated fatty acids. In butter, it is manifested by off-flavours which are due to a number of breakdown products formed in a series of chemical reactions. Lipid oxidation is accelerated by the presence of metals (Cu, Fe and Ni), low pH, oxygen, high temperature and light (Downey, 1970). It can be retarded by packing butter in opaque packages and storing in a cool place.

Butter oil

Butter oil, also known as dry butterfat or ghee, consists of fat which is almost completely free of water, protein, milk sugar and mineral substances (McDowell, 1953). In some areas of India the product is made by direct evaporation of milk or cream (Madan Pal and Rajorhia, 1975). This process requires a lot of heat and results in much of the fat becoming entrapped in curd particles. A more efficient method is to evaporate moisture from butter made by churning sour whole milk or cream (Madan Pal and Rajorhia, 1975). Melting butter in an equal volume of water

at 60°C, followed by centrifugal separation, gives a good yield of butter oil. The product is free from non-fat milk solids and contains not more than 1.5% moisture (O'Mahony, un-published data). The residual moisture can be removed by further heating. According to Madan Pal and Rajorhia (1975), the product yield in butter oil manufacture should be about 97% of the total fat processed.

Preservation of butter oil. Heat treatment and the low moisture content in butter oil prevent the development of hydrolytic rancidity in the product. Oxidative rancidity will occur but can be minimised by packing butter oil in opaque, air-tight containers and storage in a cool place (McDowell, 1953).

Byproducts of butter making

Butter making recovers almost all the milk fat but not the proteins and lactose. Further processing of milk after removal of fat yields protein in a stable form. Churning sour whole milk gives buttermilk, cottage cheese (known as *ayib* in Ethiopia) and whey as byproducts. The main byproducts of butter making based on milk separation and cream churning are skim milk, cottage cheese, whey and buttermilk. Fresh, separated milk can be consumed by humans, fed to animals or added to cheese milk. The latter is an attractive option since it increases the yield of cheese. Separated milk can be ripened and heated to precipitate soft cheese. The supernatant whey can either be consumed by people or fed to animals.

Buttermilk, which is a byproduct of traditional butter making, is usually consumed without further processing (Beyene Kebede, 1983). In some areas of Ethiopia, it is heated to produce *ayib*. The process enables good recovery of caseins and residual fat and yields a marketable product (Whalen, 1985). Initial studies by ILCA showed that the remaining whey contains as little as 0.75% protein, indicating a near-complete recovery of casein.

About 8 litres of buttermilk are needed to produce 1 kg of *ayib*. The product contains 79.5% water, 14.7% protein, 1.8% fat and 0.9% ash. The high moisture content in the product contributes to its poor keeping quality. It has been reported that *ayib* with longer shelf life is produced in some parts of Ethiopia, by heating buttermilk to very high temperatures and then pressing out as much water as possible.

In summary, the on-farm method of processing small quantities of accumulated sour milk is flexible, requires little capital input and enables good product recovery. Processing larger volumes of milk into butter and skim milk gives the processor more efficient recovery of butterfat and provides more options for the disposal of separated milk, but also requires more equipment.

Cheese varieties

Background

Cheese is known to have been the standard fare of the ancient Greeks and Egyptians. The art of cheese making was popularised by the Romans, and at present there are over 2000 known varieties of cheese (Kosikowski, 1982). Cheese is a good source of fat and protein (Scott, 1981), and as such it has a high nutritional value. Many cheese varieties require considerable technical skill and equipment in their manufacture. An important aspect of cheese making is the

treatment of milk with starter cultures to produce controlled amounts of lactic acid in the curd, while many cheese varieties require special storage facilities for ripening.

Small-scale cheese making

The five cheese varieties (Halloumi, Queso Blanco, Feta, Domiati and 'White cheese') discussed in this section are relatively simple to manufacture under smallholder conditions in Africa. The processing steps required are shown in Figures 6 to 10. Some of the varieties are already made in parts of Africa and resemble either boiled-curd or pickled cheeses which can be ripened and preserved under tropical conditions. The compositions and expected yields of the five varieties tested at ILCA are given in Table 7. Cheese yield is affected by the concentration of fat, caseins and insoluble salts in milk, as well as by processing efficiency and moisture incorporation in the final product.

Figure 6. Processing steps for Halloumi cheese.

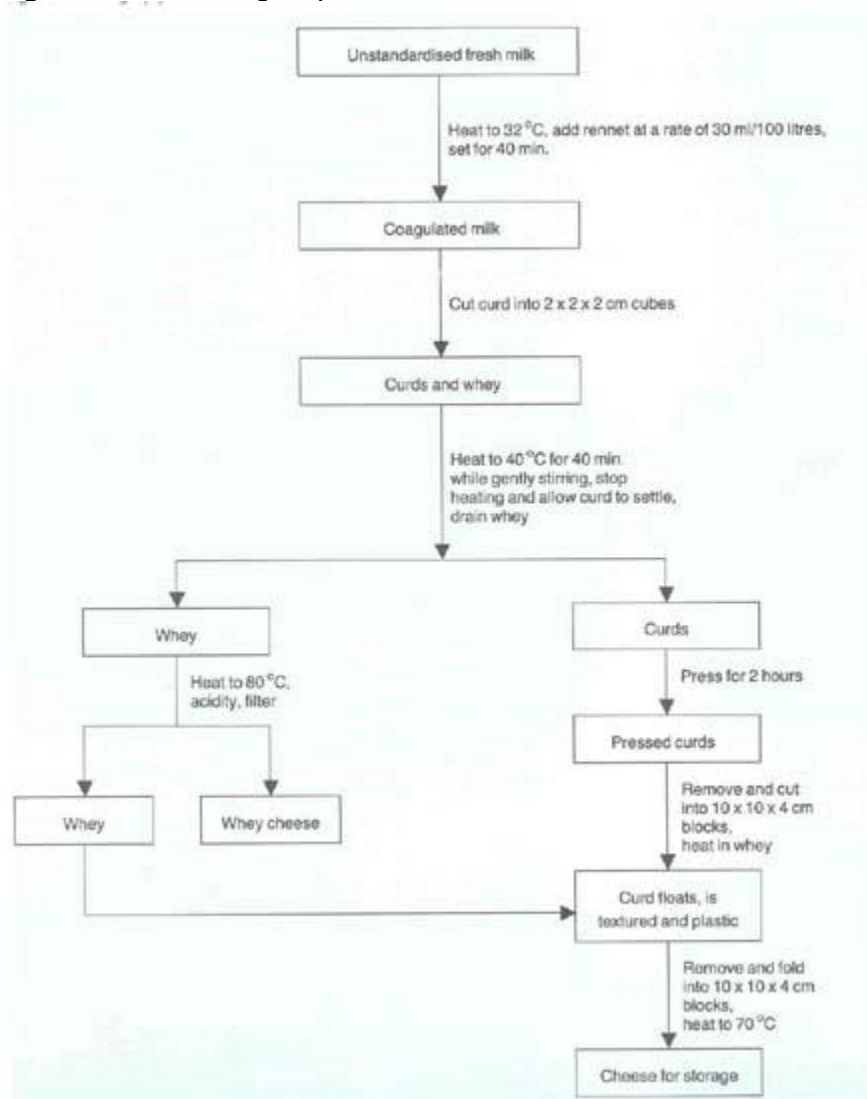


Figure 7. Processing steps for Queso Blanco cheese.

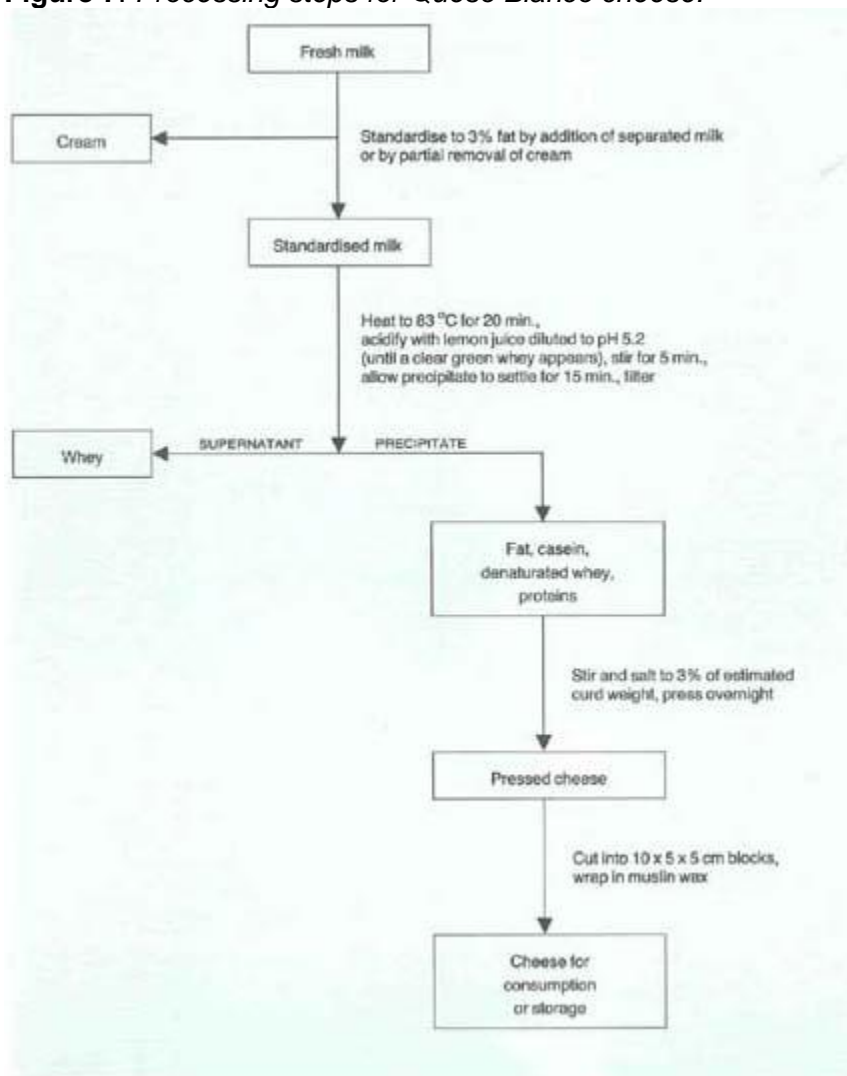


Figure 8. Processing steps for Feta cheese.

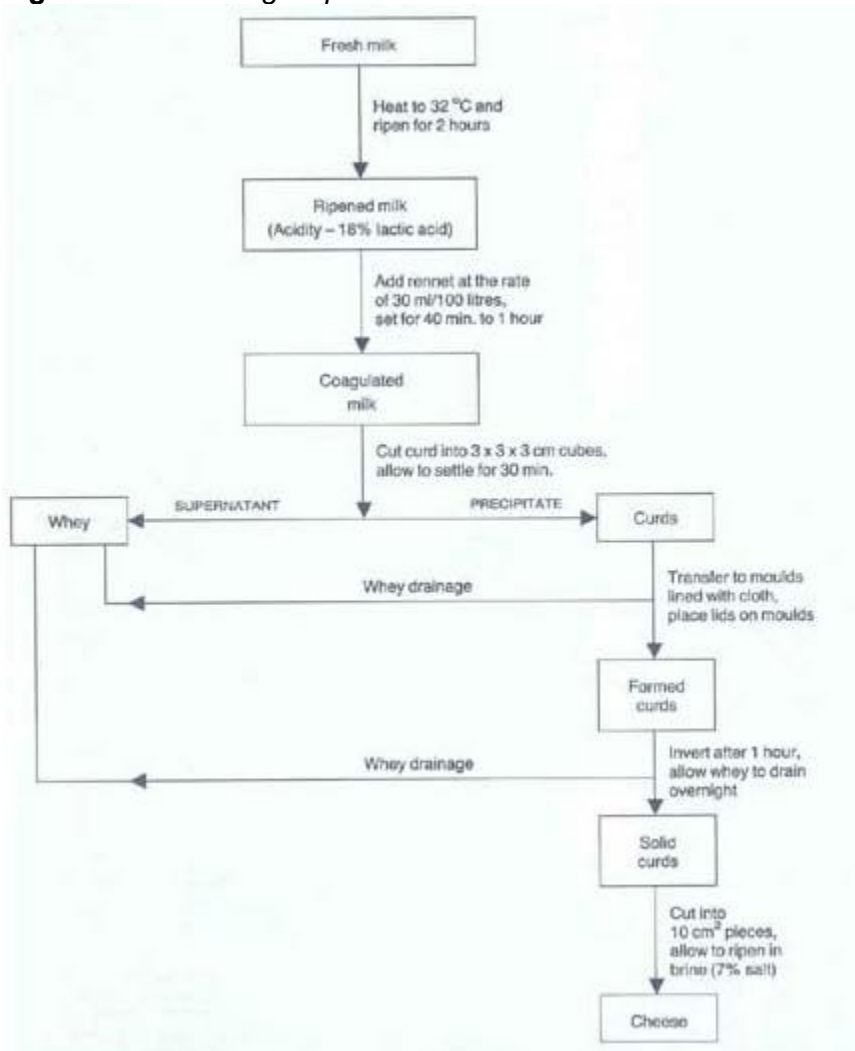


Figure 9. Processing steps for Domiati cheese.

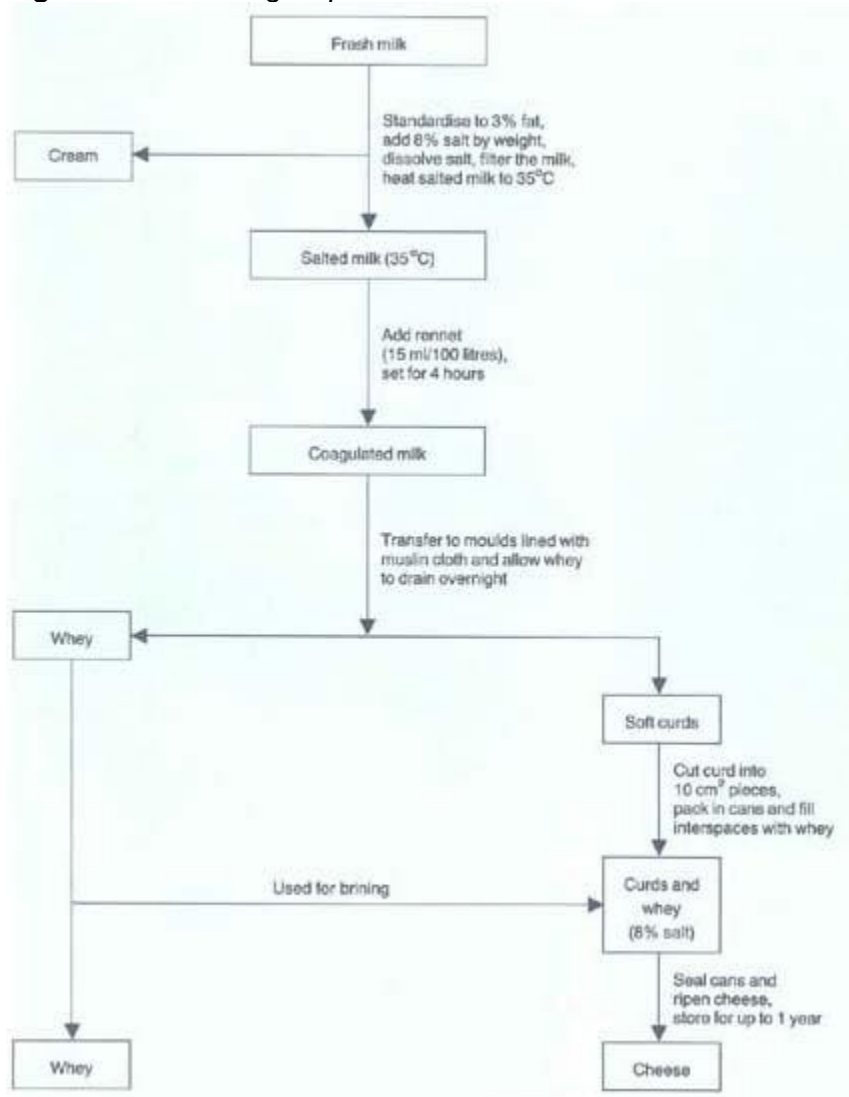
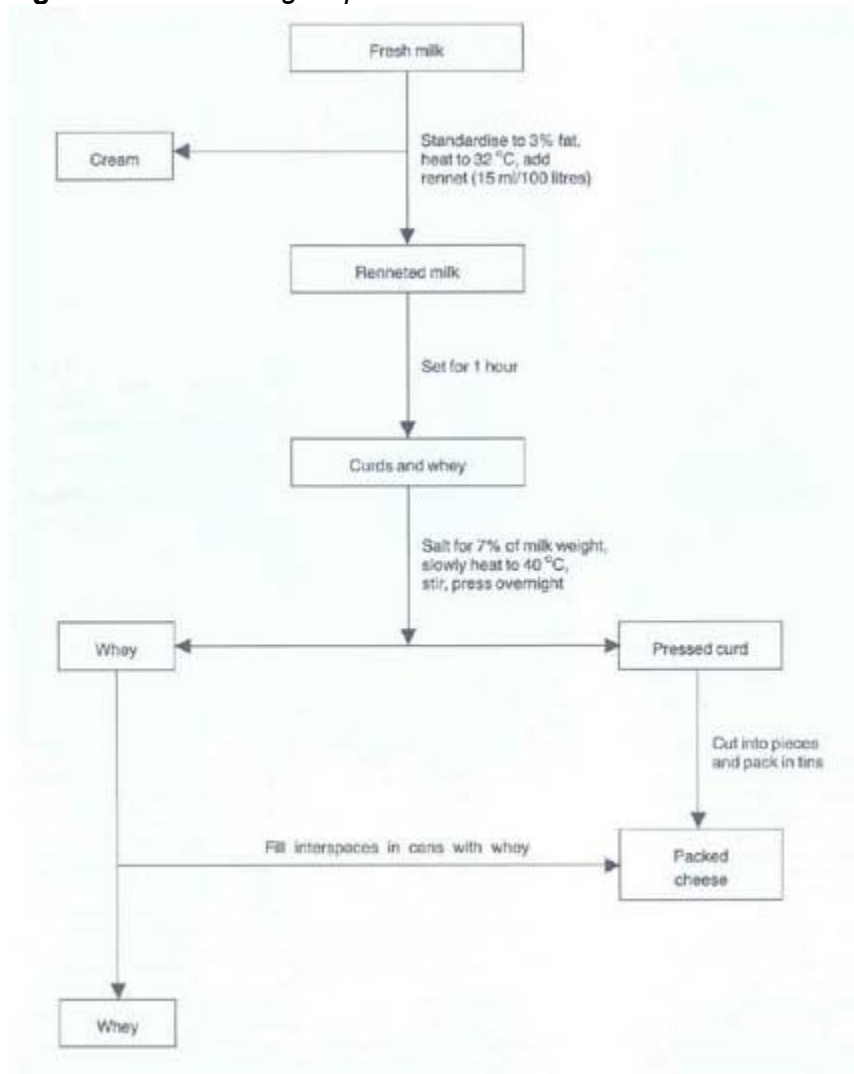


Figure 10. Processing steps for 'White cheese'.



Halloumi cheese originated in Cyprus and was first made from sheep and goat milk (Brumby, personal communication). Its manufacture does not need starter cultures and the milk, now usually from cows, is not standardised. At ILCA, the cheese has been made using rennet and bovine pepsin as coagulants, and the trials have indicated that the latter does not adversely affect the quality and yield of the cheese.

An important processing step in the manufacture of *Halloumi cheese* is heating the curd to between 70 and 80°C. This pasteurises the curd, gives it the correct texture and denatures proteolytic enzymes. After heating the curd is removed, sprinkled with dried leaves of *Mentha viridis* and folded. *Halloumi* can be consumed fresh or ripened in whey brine. A whey cheese (*anari*) can be recovered from the residual whey as a byproduct (O'Mahony and Ephraim Bekele, 1985b).

Queso Blanco originated in Latin America (Kosikowski, 1982) and its name derives from the fact that it is white. This fresh, unripened cheese is made from cow's milk by direct acid precipitation of milk solids at 83°C. Milk is normally standardised to 3% fat, giving a fat-to-casein ratio of

1.3:1. Various acidulants (e.g. acetic, lactic and citric acids) can be used to form the curd, which is then quickly removed, salted and pressed. The end product is white, creamy, with a salty and acid taste, has good slicing properties and a body texture similar to young, high-moisture cheddar, but does not melt well. Queso Blanco is usually consumed fresh, but it can also be cured and stored for extended periods.

Queso Blanco has been made at ILCA using lemon juice diluted with an equal amount of water (O'Mahony and Ephraim Bekele, 1985b). The acidulant imparts a pleasant flavour to the cheese and product yield is good. The low protein content of the residual whey (Table 3) indicates good recovery of whey proteins by coprecipitation with caseins. Cream removed during milk standardisation can be used for butter or ghee making, which is another option worth considering in the context of smallholder dairying. Whey can be fed to animals or consumed by humans.

Feta cheese is a white, pickled cheese ripened in salt brine. It originated in Greece, where it is normally made from sheep milk (O'Keeffe and Phelan, 1979). It can also be made from cow's milk, but the fat content must be adjusted to give a fat-to-casein ratio of 1.3:1. Feta cheese was made at ILCA from unpasteurised milk using the procedures outlined in Figure 8. The cheese ripened well in brine and developed good flavour. The high salt content of the brine ensures good storage stability over a 1-year period.

Domati cheese is a pickled cheese containing up to 10% salt. It is one of the most popular cheeses in Egypt (Fox, 1969a) and it is also made in Sudan, where it is known as Gybna Beyda. 'White cheese' contains more fat and protein and less moisture than Domiati cheese, and it is made by rennet coagulation and salting whereas the salt in the Domiati cheese is added to the milk before coagulation. The high concentration of salt in these cheeses enhances their keeping qualities.

Table 7. Composition and yield of Halloumi, Queso Blanco, Feta, Domiati and 'White cheese', and residual whey protein.

Variety	Fat (%)	Protein (%)	Moisture (%)	Salt (%)	Ash (%)	Yield (litres of milk/kg product)	Whey protein
Halloumi	33	26	35.0	3	3	9.5	0.77
Feta	27	17	49.0	3.5	1	9.0	0.80
Queso Blanco	23	24	46.0	3	3	8.0	0.29
Domati/Gybna Beyda	12	12.5	61.5	7.5	4	5.5	0.76
'White cheese'	23	22	52.32	6.7	4.23	9.5	0.80

The cheese varieties described above can be made using small-scale processing techniques. Other factors favouring their manufacture by smallholders are good yield and stability under tropical conditions. Furthermore, the products proved acceptable to consumers.

Processing options for development

Milk, as it comes from the cow, has a temperature of about 38°C. Bacteria multiply rapidly in warm milk (Robinson, 1983). In sub-Saharan Africa, where the temperature, and often humidity, are high for most of the year, raw milk spoils quickly unless it is cooled or treated with a preservative (Korhonen, 1980). Preservatives are not readily available in rural areas and cooling systems are not feasible due to water shortages in many parts of the subcontinent. This makes collection of milk from rural areas counter-productive, as the milk quality will have deteriorated below acceptable standards by the time it reaches the centralised processing plant. In addition, milk collection systems in sub-Saharan Africa are difficult to operate, mainly because of the seasonality of milk supply, small quantities of milk produced and infrastructural problems.

Stimulating efficient on-farm or village-level processing therefore appears to be a better strategy for dairy development in rural areas. The selection of products for small-scale manufacture will depend on the quantity of milk available for processing, the technical skills and equipment needed, marketing infrastructure and consumer preferences.

Given the small amounts of surplus milk produced by smallholders, and the scarcity of small-scale processing techniques, ILCA has tested a number of technologies which could be adopted by small-scale milk producers. Natural fermentation of milk is suitable for on-farm processing, since it is best achieved with small quantities of milk (1 to 2 litres/day) while the acidity developed preserves milk solids (Kosikowski, 1982) and improves churnability (Ephraim Bekele and O'Mahony, unpublished data). ILCA studies have shown that as little as 0.1–0.2% fat (determined by Gerber analysis) remains in the buttermilk when sour whole milk is churned at about 14 to 16°C (O'Mahony and Ephraim Bekele, 1985a). The equipment used to make butter from sour whole milk is available locally, and ILCA has designed a simple detachable agitator to improve churning efficiency. The butter produced can be sold fresh or salted and preserved for subsequent sale, or it can be converted into ghee.

Residual liquid after butter making is highly nutritious (since it contains all the non-fat milk solids) and can be consumed without further treatment. Caseins are often recovered from the liquid in the form of *ayib* which is consumed fresh or preserved by salting or reducing its moisture content. Whey proteins are utilised as animal feed or in human diets.

Village-level processing can be undertaken with milk volumes of up to 500 litres/ day. The recommended equipment includes hand-driven milk separators and wooden churns. ILCA's experience to date has shown that this equipment is quickly adopted in areas where sufficient milk is available for processing. Large yields of high-quality butter are being produced at 15 producer cooperatives throughout Ethiopia, using milk separation and cream churning. Up to 200 litres of milk are being processed daily at each unit.

Centralised village processing of milk supplied by individual smallholders is presently being investigated. It is too early to comment on the effectiveness of this system in sub-Saharan Africa, but experience in India (Mogens Jul, 1977) shows that the system could be successful. Small-scale centralised milk processing reduces labour requirements on the farm, provides a nucleus for sale of farm inputs and strengthens the marketing capability of individual milk producers.

The manufacture of cheese is difficult with small quantities of milk. However, a village cooperative could make cheese and thus widen its product range. The feasibility of making

cheese by village cooperatives is now being investigated in Ethiopia. Preliminary observations indicate that cheese making may be a suitable option for rural cooperatives that are far from all-weather roads, and therefore have to accept a lower price for their butter, and which have difficulties marketing *ayib* locally.

The cheese varieties discussed in this paper are more stable than butter. Their manufacture would give farmers greater independence from local traders who exploit the fact that butter has to be sold before it develops rancidity above the acceptable level. Research on the economics of milk processing by village cooperatives and the potential market for cheese in rural areas of Ethiopia is under way in order to assess the viability of small-scale cheese production.

A rapid introduction of appropriate dairy processing technologies in the field requires adequate training of extension agents. ILCA has held four courses in rural dairy technology during the past 2 years. The trainees were given basic training in milk chemistry and microbiology and were acquainted with the technologies described in this paper. Follow-up visits revealed that the trainees were passing on their newly acquired skills to farmers and that the equipment was being used properly. In October 1986, ILCA's Dairy technologist explained the Centre's dairy technology concept to the participants of a dairy training course organised by FAO in Kenya. In February 1987, ILCA's Dairy Technology Unit gave a dairy technology course to personnel from national training institutes, who are expected to conduct similar training courses in their countries.

Conclusions

At present, only a small fraction of the milk produced by smallholders in sub-Saharan Africa enters the commercial market, owing to lack of milk collection systems in rural areas, low producer prices for milk and scarcity of small-scale processing techniques. Yet making this milk available to consumers would improve both the economic status of smallholders and the nutritional status of the population.

Dairy products suitable for small-scale manufacture include fermented milks, butter, butter oil, and some cheeses. The technology for their manufacture has been adapted to suit local conditions, and some of the modified processing techniques have been tried successfully in Ethiopia.

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References

- Beyene Kebede. 1983. Milk production in Ethiopia. Paper presented at the IDRC Workshop on Potentials for Small-scale Milk Production in Eastern and Southern Africa, Nairobi, Kenya.
- Brunner J R and Jack E L. 1950. The relationship between the degree of solidification of fat in cream and its churning time. II. The physical distribution of the liquid–solid phases within the globule. *J. Dairy Sci.* 33: 267.

Downey W K. 1970. *Butter quality*. Dairy Research Review Series, No. 7. An Foras Taluntais (The Agricultural Institute), Dublin, Ireland.

Ethiopian Nutrition Institute. 1980. *Ethiopian traditional recipes*. ENI, Addis Ababa, Ethiopia.

Fox P F. 1967. *Fermented milks*. Technical Bulletin Dairy Series 6. An Foras Taluntais (The Agricultural Institute), Dublin, Ireland.

Fox P F. 1969a. *Manufacture of Feta cheese*. Technical Bulletin Dairy Series 1. An Foras Taluntais (The Agricultural Institute), Dublin, Ireland.

Fox P F. 1969b. Effect of cold ageing on the rennet coagulation time of milk. *Irish J. Agric. Res.* 8(2).

Green M L. 1977. Review of the progress of dairy science. Milk coagulants. *J. Dairy Res.* 44: 159–188.

Harland H A, Coulter S T, Townley V H and Jennes R. 1953. The denaturation of milk serum proteins at temperatures ranging from 180°–290° F. *J Dairy Sci.* 36: 568.

Hartman G H and Swanson A M. 1965. Changes in mixtures of whey protein and *k*-casein due to heat treatment. *Dairy Sci.* 48: 1161.

Hunziker O F. 1927. *The butter industry*. La Grange, Illinois, USA.

Korhonen H. 1980. A new method of preserving raw milk. *World Anim. Rev.* 35:23.

Kosikowski F V. 1982. *Cheese and fermented milk foods*. Kosikowski F V and Associates, New York, USA.

Larson B L and Roller G D. 1955. Heat denaturation of the specific serum proteins in milk. *J. Dairy Sci.* 38: 351.

Madan Pal and Rajorhia G S. 1975. Effect of multiple separation of cream on the recovery of ghee. *Indian J.Dairy Sci.* 28: 1.

McDowell F H. 1953. *The buttermakers' manual*. New Zealand University Press, Wellington.

Mogens Jul. 1977. Dairy development in India. *World Anim. Rev.* 24(1).

O'Keeffe A and Phelan J A. 1979. *Cheese varieties*. Handbook Series, No. 14. An Foras Taluntais (The Agricultural Institute), Dublin, Ireland.

O'Mahony F. 1986. Milk processing by Borana pastoralists. Mission report. ILCA, Addis Ababa, Ethiopia.

O'Mahony F and Ephraim Bekele. 1985a. Traditional butter making in Ethiopia and possible improvements. *ILCA Bulletin* 22: 9–14.

O'Mahony F and Ephraim Bekele. 1985b. Small-scale manufacture of Halloumi and Queso Blanco cheese. *Appropriate Technology* 12(3): 7–9.

O'Sullivan A C. 1973. Milk processing with emphasis on product processing interactions. Technical Bulletin Series. An Foras Taluntais (The Agricultural Institute), Dublin, Ireland.

Robinson R K. 1983. *Dairy microbiology, Volume 1*. Applied Science Publishers, London and New York.

Scott R. 1981. *Cheese making practice*. Applied Science Publishers, London and New York.

Waters-Bayer A. 1986. Dairy subsector of the agropastoral household economy. In: R von Kaufmann, S Chater and R Blench (eds), *Livestock systems research in Nigeria's subhumid zone*. Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October–2 November 1984. ILCA, Addis Ababa, Ethiopia.

Webb B H, Johnson A H and Alford J A. 1983. *Fundamentals of dairy chemistry*. The AVI Publishing Company, Westport, Connecticut, USA.

Whalen I. 1985. Butter and cheese household utilisation and marketing in Debre Zeit. Unpublished summary draft. ILCA Highlands Programme, Addis Ababa, Ethiopia.