ELSEVIER

International Journal of Food Microbiology 68 (2001) 173–186

INTERNATIONAL JOURNAL OF
Food Microbiology

www.elsevier.com/locate/ijfoodmicro

Review article

Field survey and literature review on traditional fermented milk products of Ethiopia

Almaz Gonfa [a], Howard A. Foster [b,*], Wilhelm H. Holzapfel [c]

[a] *Ethiopian Health and Nutrition Research Institute, P.O. Box 5654 / 1242, Addis Ababa, Ethiopia*
[b] *Division of Biological Sciences, School of Environmental and Life Sciences, University of Salford, Salford, Lancs M5 4WT, UK*
[c] *Institute of Hygiene and Toxicology, BFE, Haid-und-Neue Str. 9, D-76131-Karlsruhe, Germany*

Received 9 June 2000; received in revised form 8 January 2001; accepted 9 February 2001

Abstract

The wide variety and the socio-economic and dietary importance of traditional fermented milk products of Ethiopia are discussed in this paper. Information on the microbiology of these products is sparse and has relevance to those organisms associated with spoilage and to those considered desirable for fermentation. There is a clear need to improve the production of African foods and beverages [Int. J. Food Microbiol. 18 (1993) 85]. The objective of this review was to document traditional technology used and information on the microbiology of the products, and to identify various constraints to the development and commercialisation of fermented milk products. Thereby the major problems and potential areas for improvement are pointed out. *Ergo*, the most important traditional product resembles yoghurt and, as the other traditional products, is prepared by "spontaneous" fermentation, commonly initiated by either "back slopping" or by repeated use of the same utensil. Other products include traditional fermented curd or *ititu*, traditional butter or *kibe*, *neter kibe* or traditional ghee, *ayib* resembling cottage cheese, *arrera* or defatted buttermilk and *augat* or traditional whey.

Keywords: Ethiopia; Dairy products; Fermentation; Lactic acid bacteria (LAB); Traditional processing

1. Introduction

Ethiopia (Fig. 1) is a typical highland country with half of its total area situated over 1500 m above sea level and 49.2% of all African highland areas within its borders (Dersch, 1986). Ethiopia's population is estimated at 50 million with an annual growth rate of ca. 2.9%; about 38 million of which were living in the highland areas in 1983. The country covers a total land area of 1.2 million km^2. Agriculture, which includes both subsistence crop production and animal husbandry, dominates the economy of these areas. This population contributes 50% to the gross domestic product (GDP) and 35% of the country's export revenue (Mekonen, 1989). Livestock was estimated to contribute about 3% of Ethiopia's agricultural GDP in 1980, apart from the contribution to draft power, transport and manure (Coppock, 1993).

* Corresponding author. Tel.: +44-161-295-3832; fax: +44-161-295-5210.
E-mail address: h.a.foster@salford.ac.uk (H.A. Foster).

0168-1605/01/$ - see front matter
PII: S0168-1605(01)00492-5

Fig. 1. Map of Ethiopia. *Ergo* is produced in all regions but is known by many different names. *Ititu* is only produced in the Borena region.

Ethiopia has a large livestock population which makes it first in sub-Saharan Africa and amongst the top 10 in the world. Recent surveys showed that there were 27 million head of cattle, 24 million sheep, 18 million goats, 7 million equines, 1 million camels and 52 million poultry (Gryseels and De Bookt, 1986; WHO, 1996). Milk in Ethiopia comes from four main sources, local Zebu cattle, crossbreed cattle (mainly with Friesian and Holstein) and pure or nearly pure breed Friesian or Holstein cattle. In some regions, milk of lesser quality is also derived from sheep and goats. The percentages contributed by hybrid cattle, sheep and goats are estimated at 0.26%, 0.21% and 0.01%, respectively. A recent survey (Central Statistical Authority, 1994/95) showed that the average milk yield per cow per day ranged from 0.97 l in Tigray to 1.50 l in Addis Ababa with an average of 1.17. The average lactation period of milking cows for private peasant holdings for the country was about 6.33 months. A survey of the smallholders within a radius of about 55 km of Debre Ziet (but excluding Addis Ababa and its suburbs) by studies organised by the International Livestock Centre for Africa (ILCA) showed

that the number of cows per smallholder ranged from 1 to 5, with an average of 2.3 (O'Connor, 1992). The majority of the cattle population (78%) and over 60% of the sheep are found in the highland settled crop farming area, as compared to 22% of the cattle population and the predominant goat and camel populations in lowland pastoral areas. In both areas, milk and milk products have an important place in the traditional diet of the people and are part of the main staple foods. Frequently, milk serves as a major source of cash income for the family. Most of the milk produced by smallholders is processed on the farm using traditional dairy technology (O'Mahony, 1988) in the same way as other traditional fermented foods (Oyewole, 1997). Milk is either sold fresh or consumed raw or allowed to ferment naturally, but is rarely boiled unless used for tea making. In fact, in some communities such as among the Masai, it is taboo to heat milk (FAO, 1990). Sour milk is the most common fermented milk product and milk is usually soured before further processing.

Fermented milk products fulfil multiple purposes in the rural life (O'Mahony, 1988). They are consumed as food and as beverages and the market value and storage life are improved over that of raw milk (Motarjemi and Nout, 1995). Milk products are also used as cosmetics by rural people. For example, butter is used as hair and body oil in the rural areas. These products may constitute a major means in rural areas, especially for women, to buy other household goods (such as salt, sugar, coffee, soap, clothes, etc.), to pay taxes and school fees. Studies show that in the Ethiopian highlands, animals and their products contribute about 30% of smallholder families' gross cash income (O'Mahony and Bekele, 1985). Therefore, improvement in milk processing could provide a substantial boost to the economy of these areas. Such cash income is also used to purchase cereal grains in the pastoral regions.

Consumers, particularly in the centre of the city, obtain their milk from dispersed rural producers, state owned selling points and private shops. Under these conditions, spoilage may occur due to long transportation times, and lack of appropriate storage facilities (Michelin et al., 1991). Traditional smallholders in Ethiopia use acid fermentation to convert milk into products with good storage stability. As processed fresh milk is essentially unavailable in rural areas, most people in these regions have developed a palate for sour milk and its products over the centuries (O'Connor and Tripathi, 1992). Only small volumes are available daily to Ethiopian smallholders and allowing the milk to sour means that it can be collected over a few days until a sufficient amount is available for processing (FAO, 1990). The souring of milk retards the growth of undesirable microorganisms, such as pathogens and spoilage bacteria, and it is required before churning (Coppock et al., 1992; O'Mahony, 1988; Ashenafi, 1993, 1994; Gonfa et al., 1999).

2. Typical fermented products

Ethiopia has a wide range of climatic conditions ranging from the hot humid low lying areas, through dry and semi-arid grass hinterlands (areas of extensive pastoralism) to high altitude highlands with subtropical to temperate type climates (Coppock, 1993; Kassaye, 1991). Mean diurnal temperatures may range from as low as 15–17°C in the highland areas to as high as 35°C in semi-arid and arid areas. These high ambient temperatures coupled with the general lack of refrigeration facilities, mean that the milk, often containing high contamination bacterial loads, acidifies within 12–24 h. This explains why spontaneously fermented milk forms the basis of traditional dairy processing at household level in the region (FAO, 1990).

Uniform traditional techniques are used in different parts of Ethiopia to prepare fermented milk and its products (O'Connor et al., 1993; O'Mahony, 1988). Milking animals are typically kept for the night with the stock in a shade or enclosure. The milking is done in the shade, kraal, grazing field in front of the homestead, under the trees, none of which are clean environments for milking. As it is not a common practice to clean the udder and hindquarters before milking, the milk is often highly contaminated (Gonfa and Holzapfel, unpublished data; O'Mahony, 1988).

Sour milk used for further processing is prepared in the traditional way by leaving fresh milk after collection to sour for 2 or more days in pre-smoked traditional dairy utensils (FAO, 1990; Gonfa, unpublished data). The smoking of the vessels used for

milking and storage is commonly practised by smallholders in pastoral and agro-pastoral communities (Anon, 1983; O'Connor, 1992). Plant materials, including grass, shrubs and hardwoods, are used for smoking as well as cleaning. The general processing method for fermented milks is by transferring fresh raw milk from the pre-smoked collecting utensil commonly known as *okole* (made from woven grass and, in pastoral regions, from skin of animals especially giraffe), into a smoked clay pot or containers of calabash, woven grass, or plant fibre vessels or hollowed wood vessels prepared for storage purposes. These are commonly known as *kussa* in the Oromyia region (Coppock et al., 1991, 1992; Gonfa, unpublished data). This equipment is washed with hot water and plant leaves and rinsed with cold water before the application of the smoke. The vessels are then smoked by burning wooden chips of trees and shrubs specifically used for this purpose. In some areas, hot smoking chips are introduced into the vessels and whirled inside for a few minutes with the lid of the vessels on. In other cases, the vessel is inverted over the smoking chips until the smoke dies out. The vessels are allowed to cool and cleaned with some kind of stem fibres (from false banana and/or *Urtica simensis*), root fibres of some local plants in the Borena pastoral regions or a clean cloth to remove residual charcoal after which fresh raw milk is introduced (Coppock et al., 1991; Gonfa, unpublished data; O'Connor and Tripathi, 1992). In some cases, the inside of the lid of these vessels is scrubbed with plant leaves. Traditions in using the plant species described have been handed down from generation to generation. According to the local understanding, the practice of smoking the vessels used for collection and storage of the milk has two main advantages: firstly, that the smoke flavour imparts a special taste and odour to the products, and secondly, to decontaminate the vessels due to anti-microbial activity, thus reducing spoilage and extending the shelf life of the product (Coppock et al., 1991; Gonfa, unpublished data; Kurwijila, 1992; O'Connor, 1992; Ashenafi, 1996).

The major fermented milk products produced in Ethiopia by smallholder farmers by traditional methods are *Ergo* (fermented sour milk), *Ititu* (Fermented milk curd), *Kibe* (traditional butter), *Neter kibe* (traditional ghee), *Ayib* (cottage cheese), *Arerra* (sour defatted milk), and *Augat (whey)*. The relationships between these products are shown in Fig. 2.

2.1. Ergo (traditional fermented milk)

Ergo is a traditional, "spontaneously" fermented milk product which has some resemblance to yoghurt. It is thick, smooth and of uniform appearance and usually has a white milk colour when prepared carefully. The product is semi-solid and has a pleasant odour and taste. It constitutes a primary sour milk product from which other products may be processed. Depending on the temperature, it can be stored for 15–20 days (Gonfa, unpublished data; O'Connor, 1994).

Ergo is produced from raw milk of cattle in all parts of Ethiopia by smallholder farmers. It is also made from milk of goats and camels in the lowland regions in relatively small amounts. As the major fermented dairy product, *ergo* is popular and is consumed in all parts of the country and by every member of the family. It is known by many different names by the many ethnic groups in the country. *Ergo* is considered as a special food which serves as a basis for further processing and it is particularly used as a nutritional support to sick people, children and to pregnant and lactating mothers. In addition, it is served to respected guests. In the highlands it is mainly given to male members of the family, whilst in the lowland pastoral regions fresh milk is preferred (O'Connor, 1992). In addition to being served on its own, *ergo* is also consumed, either spiced or "natural", as a side dish with different traditional foods, such as *markaa* (*ganfo*), *injera*, *qinchea*, *dabbo* and *anchotea*.

Ergo is mainly produced by married women who may further process it into more stable products which may be sold in the market, and thus generates income by which other household items may be afforded. *Ergo* is consumed by weaning age children and the elderly. It is an important part of the diet because it is rich in major nutrients (protein, carbohydrate, vitamins, fat) and, when consumed fresh, it constitutes low health risks due to its low pH, at which most pathogenic and spoilage organisms are inhibited (Gonfa et al., 1999; Gonfa and Holzapfel,

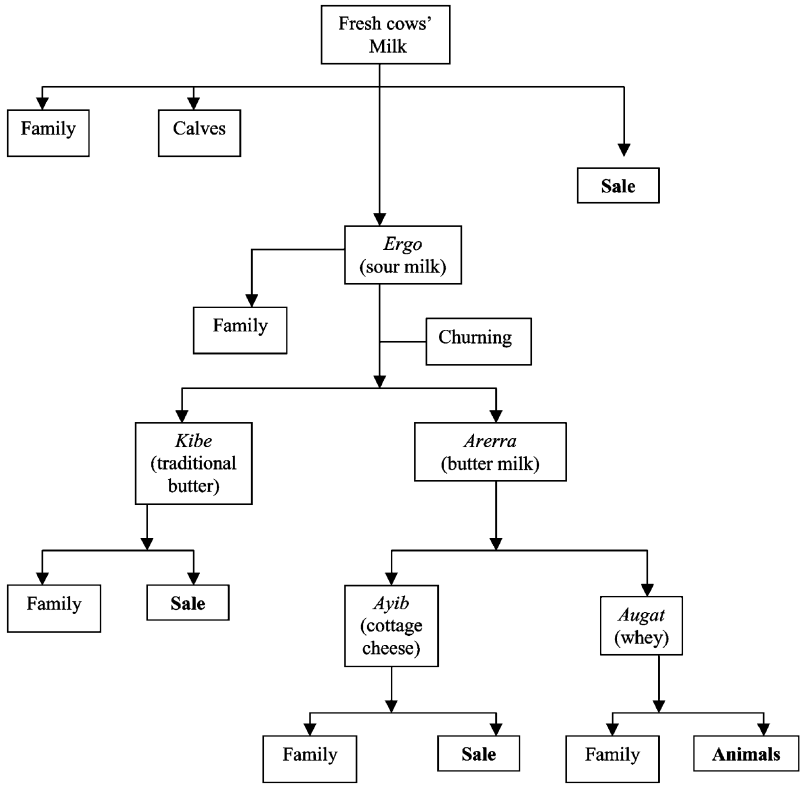

Fig. 2. Flow scheme for milk and milk products available to rural smallholder milk producers in Ethiopia.

unpublished data). It is also less expensive than other commodities.

The typical raw material, fresh cows' milk, is collected in traditional milking equipment, *okole*, and traditionally stored and fermented in *kussa*. Pre-smoking is applied to these utensils before use (Coppock et al., 1991; Gonfa, unpublished data). *Ergo* is flavoured with fresh leaves of *Ruta chalepensis* var. *tenuifolia*, *O. hadiense*, *Coriandrum sativum* mixed with mashed *Allium sativum* and green *Capsicum annuum* (locally called *kochikocha*) before serving. Its preparation is indicated stepwise in the flow scheme of *ergo* processing (Fig. 3). Although "spontaneous" fermentation is still the usual method, "back-slopping" may also be applied in rare cases. Only traditional household utensils, called *okole*, *kussa* and *wesso* (used for collecting or milking, storing or fermenting *ergo* and churning respectively) are required for further processing (Gonfa, unpublished data). *Ergo* is processed at the household level with these traditional utensils. *Ergo* is also produced in urban areas but in this case traditional utensils are substituted by glasses or cans and smoking of utensils is not practised. In contrast to traditionally prepared *ergo* with 15–20 days shelf life, the urban product may be stored without spoilage only for relatively short periods unless refrigerated (Gonfa, unpublished data).

At an ambient temperature of 16–18°C, milk stored in smoked vessels takes 2–4 days to ferment depending on the ambient temperature. The relatively low pH of *ergo*, ranging from 4.3 to 4.5, enables its further storage (Gonfa et al., 1994; 1999).

Unhygienic milk production and processing and absence of starter cultures result in *ergo* with variable characteristics and short shelf life and higher spoilage risks due to the wide variety of microorganisms in the product (Mahari and Gashe, 1990; Gonfa

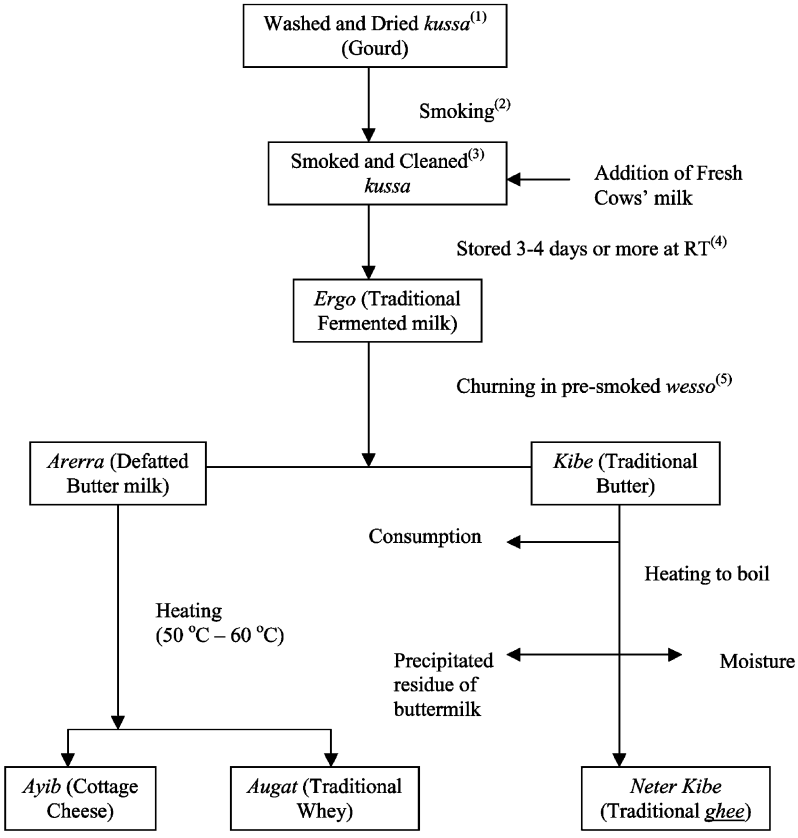

Fig. 3. Flow scheme for processing of various traditional fermented milk products. (1) *Kussa* is a traditional storage utensil made up of calabash, clay pot or hollowed wood. (2) Smoking is done using burned stems of selected plants. (3) Cleaning is done using plant fibre materials commonly known as *foxso*. (4) RT—room temperature. (5) *Wesso* is a traditional utensil, which may be either a calabash, larger clay pot, hollowed wood or animal skin for the purpose of churning.

et al., 1991). If the temperature during incubation is too high, fermentation is rapid and over-souring occurs, causing a separation of the liquid and solid phase and gas production, thus leading to deterioration of appearance and texture, especially when unsmoked vessels are used. Undersouring is a problem in the highlands in rare cases and requires an extended fermentation time of 3–5 days.

Different species of microorganisms have been isolated during a microbiological study of *ergo* (Gonfa et al., 1991, 1994, 1999). Among the isolates, Gram-positive bacteria, especially cocci, were dominant and appeared to play a major role in the fermentation process in *ergo* samples fermented in the laboratory using unsmoked glass bottles. Yeasts and moulds were also isolated, but not further identified. The general sanitary status of raw milk was poor due to uncontrolled and variable presence of several different microorganisms, and spoilage organisms were found to dominate after 120 to 165 h in laboratory fermented *ergo* (Gonfa et al., 1991). Gonfa and Gashe identified several microorganisms, dominated by LAB, from *ergo* (Gonfa et al., 1999). The LAB included *Streptococcus thermophilus*, *Strep. acidominus*, *Enterococcus faecalis* var. *liquefaciens*, *Strep. bovis*, *Strep. mitis*, *Strep. agalactiae*, *Lactococcus cremoris*, *Leuconostoc dextranicum*, *Leuc. lactis*, *Lactobacillus xylosus* and *Lact. lactis*. Other bacteria belonged to *Micrococcus* spp., and coliforms. Yeasts and moulds were isolated in fairly

high numbers after 96-h fermentation in glass bottles. A further study of ergo fermented in pre-smoked traditional container showed that LAB (7×10^8 cfu ml^{-1}) predominated followed by yeasts (2×10^5 cfu ml^{-1}) and moulds (3×10^4 cfu ml^{-1}; Gonfa and Holzapfel, unpublished data). The LAB were represented by the genera *Lactococcus*, *Pediococcus*, *Enterococcus*, *Streptococcus*, *Leuconostoc* and *Lactobacillus* as dominant, with micrococci and coliforms present in low numbers in the early stages of the fermentation, and which were undetectable after 48 h. Yeasts and moulds were also present in relatively low numbers.

Ashenafi (1996) showed the importance of smoking of the containers and incubation temperatures. Smoking slowed souring, improved flavour and slowed the growth of coliforms. At lower temperatures (20°C) and in smoked containers, lactococci dominated whereas lactobacilli were predominant in unsmoked containers and at higher temperatures.

Ergo is the main product that is used as basis for further processing of various fermented milk products such as *kibe*, *ayib*, *neter kibe*, *arerra*, and *augat* (Fig. 3).

2.2. Ititu (hard fermented curd)

The preparation is similar to that of naturally fermented milk, except that the milk is allowed to ferment for a long time of up to 14 days in a large *gorfa* or wooden *amuyou* and separation of the curd from the whey (Fig. 4). *Ititu* is white in colour and similar to *ergo* in appearance, but more solid, resembling a traditional white cheese. The product has a good taste and pleasant odour that are preferred by local people. It has better keeping quality than all other fermented milk products in the region except *kibe* (traditional butter) and can be stored for up to 90 days (Coppock et al., 1991).

Ititu is prepared by the Borena tribes, pastoral farmers in southern Ethiopia, for use during the dry season when there is a shortage of fresh milk and *Ititu* is considered as one of the special staple foods of the people in Borana region (FAO, 1990; Coppock et al., 1991; O'Connor, 1992; O'Connor and Tripathi, 1992; Gonfa and Holzapfel, unpublished data). It is consumed as side dish with *marqaa* (traditional porridge) and *chachabissa* (a kind of traditional chips made from any cereal flour), unfermented bread (*kitta*) and *neter kibe*. It can also be consumed as food or drink alone. It is considered as one of the special foods and served to very respected guests as well as to weaning age children and the elderly. *Ititu* plays an important role in the pastoral life of the Borenas, especially during the dry season. The product is not sold in the market. People in this region sell only fresh milk and *kibe* (traditional butter) to buy other household goods. However, the product has an indirect effect on the cash income of the people, as, during the dry season, people use it for home consumption while they sell all fresh milk (which is produced in lower quantities during this time) to buy grains and other necessary materials. This has also significance for dwellers of nearby towns, as otherwise there would be a shortage of fresh milk and *kibe* supply to the towns. It is affordable by the local people who otherwise are not in a position to purchase industrial products. They are then able to overcome the problem of shortage of dairy products during the relatively long dry season.

Fresh cow's milk is the main raw material, although milk from small ruminants or dromedary camels may be occasionally used in addition except by the Borenas (Coppock et al., 1991, 1992). Local traditional utensils known as *okole* (for milking or collection of milk) and *gorfa* (for storing, fermenting and churning) are used for processing (Coppock et al., 1991; Gonfa, unpublished data). The Borenas make *okole* from leather but different materials may be used in other parts of the country. Women, using root fibres of *Asparagus* sp. or some other selected plants weave a gorfa in an intricate fashion into a pear-shaped, lidded container of 1- to 3-l capacity. It takes at least 60 h to weave a 2-l *gorfa*.

A new *gorfa* is washed with hot water (which helps seal the inner surface), air dried, and, just prior to use, is rinsed with fresh milk and then smoked for a few minutes with pieces of burning charcoal placed inside. Plants such as *Acacia nilotica*, *Cordia gharaf*, *Cord. ovalis*, *Combretum molle* and many other plants are used for smoking. Leaves of *O. basilicum*, *O. hadiense*, or *Endostemon tereticaulis*, are used for scrubbing and cleaning the inside of the lids and also to add flavour. The *gorfa* is then shaken with the lid on. The charcoal is removed prior to the addition of fresh milk. The inside is then scrubbed with fresh

leaves of plants listed above. People state that they prefer the taste imparted to the product from the smoke of the charcoal, whilst, at the same time, it helps to prevent spoilage. Further preparation is similar to that for *ergo* except that the whey is removed daily by the women using a wooden pipette, after which fresh milk is added until the vessel is filled with hard curd. The curd and the lids are occasionally checked visually for mould, which, if present, is removed by taking off the surface growth. The lid is washed with hot water and scrubbed with plant leaves as before. Smoke is then applied to the lid before replacing it.

Over-souring and risk of spoilage due to the high frequency of surface mould growth are some of the major problems encountered. If the product is stored for a long time without refrigeration this can lead to over-souring. Local people control this problem by adding an amount of roasted *Trigonella foenum-graceum* (fenugreek) powder, pre-mixed with fresh raw milk and/or melted *ghee*, prior to serving (Gonfa, unpublished data).

The curds and lid of stored *gorfa* are occasionally checked for mould growth, which is removed and the lid is washed with hot water and scrubbed with leaves as before. After removal of the whey and addition of fresh milk, the lid is replaced capturing some smoke from a piece of charcoal, thereby decontaminating the inner surface of the lid. If this is not done occasionally, the risk of spoilage by moulds is increased (Gonfa, unpublished data). The product is not further processed like *ergo*, but is either used for direct consumption or spiced and stored for later use.

A microbiological and chemical study of *ititu* reported improbably high microbial numbers (7×10^{12} cfu g^{-1}) with lactobacilli as the prevalent group at 2.7×10^{12} cfu $g^{-1.}$ The predominant LAB were *Lb. casei* and *Lb. plantarum*. (Kasseye, 1991; Kasseye et al., 1991). According to this study, coliforms were below 10 cfu g^{-1} and yeasts and molds were 9×10^{8} cfu g^{-1}. The authors suggested that the high microbial counts of *ititu* could have been due to the effect of handling and sanitary conditions during its preparation. These are very high figures and the author's data suggest more realistic values for LAB of 2×10^{8}, 3×10^{5} cfu g^{-1} yeasts and moulds and total absence of coliforms from *ititu* samples (Gonfa and Holzapfel, unpublished data). *Ititu* had a pH of 3.53–3.90 with a mean of 3.65 ± 0.08 and on average contained about 1.92% lactic acid, 9.05% fat, 7.17% protein, 20.87% total solids, 0.74% ash, 0.16% P and 0.09% Ca (Kasseye, 1991; Kasseye et al., 1991). Scientific data on effects of temperature and time relationships are not available.

2.3. Kibe (traditional butter)

Traditional Ethiopian butter (*kibe*) is always made from *ergo* and not from cream (FAO, 1990; O'Connor and Tripathi, 1992; O'Connor et al., 1993) and is processed and sold by women in every community. *Kibe* has an attractive appearance with a white to light yellowish colour. Like factory processed butter, it is semi-solid at room temperature. It has a pleasant taste and odour when fresh, but with increased storage, changes occur in odour and taste, unless refrigerated or further processed into *neter kibe* (traditional *ghee*) by boiling with spices. *Kibe* has a relatively good keeping quality and is the most stable of all traditionally processed fermented milk products except for *neter kibe*. All over the country, it is the major product from further processing of fermented sour milk by using traditional utensils.

Kibe is important in the diet, both in rural and urban areas, and is utilised also by children of weaning age and the elderly. Apart from direct consumption as a side dish, it is used as oil for food preparation and, after processing into *neter kibe*, it is also used for hairdressing and as a skin cosmetic by both sexes (Coppock et al., 1991; Gonfa, unpublished data) and it is used for roasting coffee beans in special traditional ceremonies. *Kibe* is a preferred ingredient in the preparation of *wott*, the meat and vegetable stew eaten with *injera*, a pancake-like bread, which is the most commonly consumed Ethiopian fermented cereal. According to a survey in 1994/1995, the amount of milk converted into butter varied from 2% in Hararei to 54% in Addis Ababa, with the national average for private peasant holdings around 28% (Central Statistical Authority, 1994/95).

Being relatively stable, it is the major traditional fermented milk product offered in the rural market, and is offered either once a week or once a month, following accumulation of small portions by smallholders. When sold for cash, the income is used to

buy other household goods and cereals. This traditional butter sells at a lower price than factory processed butter and may be attractive for urban communities. Distribution to provincial towns may be through various channels, starting from the local market where women sell it to small traders, by whom the product, in ca. 30 kg quantities, is transported by donkeys to collection points up to 40 km from the market. From there it is taken to the wholesale markets in larger cites such as Addis Ababa (Anon, 1983; Coppock et al., 1992).

With *ergo* as raw material for *kibe* production, collection, handling and fermentation procedures are similar to those for *ergo* (Fig. 3). *Kibe* is produced by churning *ergo* in a traditional utensil commonly known as *wesso* in the Oromya region. Milk for churning is accumulated over several days in the traditional spherical earthenware churns or *wesso*, which after hold up to 20–25 l (O'Mahony and Bekele, 1985; Gonfa and Holzapfel, unpublished data). Traditionally, *kibe* is produced by women and for 20–25 l of sour milk, 1–4 h of churning time are required, yielding ca. 1 kg of *kibe* (O'Mahony and Bekele, 1985).

The churn is usually smoked beforehand, by which distinct flavour is imparted to the *kibe*, in addition to the preservative effect and the reduction of the processing time by the heat (Coppock et al., 1991; Kumisa, 1993; Tittarelli, 1990). The curd is broken either by hand or by agitation with a wooden stick before churning. After filling, the churn is stoppered with a plug, a false banana leaf, or piece of skin or leather stretched over the mouth and securely tied (Coppock et al., 1991; Coppock, 1993; Gonfa, unpublished data).

The churn is agitated using different methods. In the most common procedure, the churn is placed on a mat consisting of a layer of grass, sheepskin, or straw, and rocked forwards and backwards (Coppock et al., 1991; O'Connor and Tripathi, 1992; Gonfa, unpublished data). In another method, the churn is suspended from a tripod or doorpost, whilst in a third method the churn is shaken on a person's lap. Furthermore, among some pastoral families, the women carry the sour milk in goat skin bags on their backs and agitate it with their elbows while walking or working (FAO, 1990). The breakpoint, i.e. the point when butter starts to form, can be detected by a change in the sound of the milk. Frequently, a straw is inserted through the vent into the churn; if small *kibe* grains adhere to the straw surface, the breakpoint has been reached (Gonfa, unpublished data). After a few minutes, the straw is again inserted through the vent. If it is clean, it indicates that the *kibe* granules have coalesced into larger grains. The churn is then rotated on its base by which the grains in the centre form lumps of butter that are then skimmed off. The *kibe* is then kneaded in cold water and washed to remove visible residual buttermilk (*arerra*).

The moisture content of the traditional *kibe* ranges from 20% to 43% as compared to the international commercial standard for butter of 16%. No data on pH of the final product are available. Spoilage when stored at room temperature for a long time is probably mainly by putrefactive microorganisms. Microbiological information on this product is not available.

2.4. Arrera (defatted buttermilk)

Arrera is a byproduct of the formation of *kibe* from *ergo*. It has a similar colour to *ergo*, but its appearance is slightly smoother and its consistency thinner, although thicker than fresh milk. It has a pleasant odour and taste. It has a shorter shelf life compared to all other fermented milk products (only 24–48 h), even when smoke is applied to the equipment used for its storage (Gonfa, unpublished data).

The product is consumed in all parts of the country where fermented milk is produced and it serves as a beverage either plain or spiced. It is preferred by women for consumption as a side dish or as drink (FAO, 1990; O'Mahony, 1988). *Arerra* contains protein, residual fat, milk salts, lactic acid, lactose and vitamins (O'Connor and Tripathi, 1992). Being rich in several nutrients, it serves to enrich the diet. It is given to weaning age children and elderly and is specially considered as food of children and women in rural areas. Surpluses are given to calves, lactating cows and dogs. However, it may indirectly serve as additional income for the women by its use as raw material for cottage cheese (*ayib*) manufacture, which may be sold in the market. Due to its relatively short shelf life and some traditional taboos or beliefs, *arrera* is not sold in the market for direct consumption. It is a custom to give *arrera* freely to

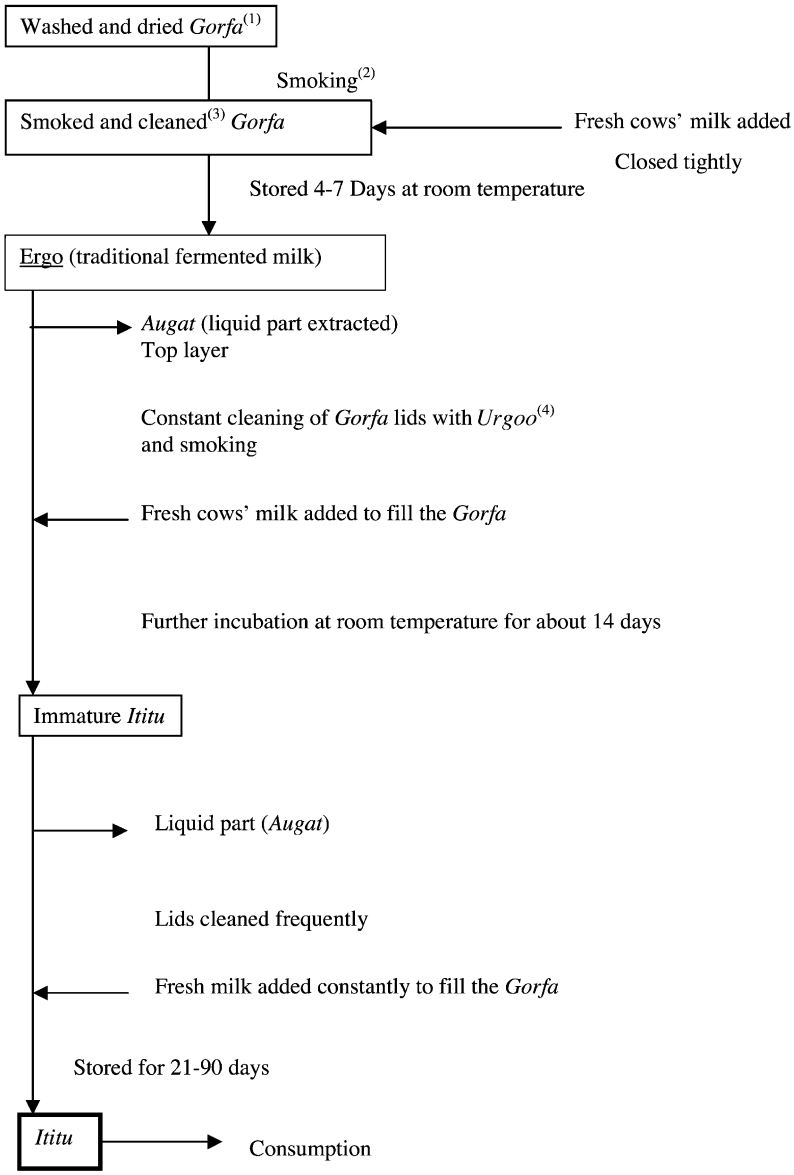

Fig. 4. Flow scheme for processing of *ititu* (hard fermented curd). (1) *Gorfa* is a special traditional dairy utensil only used by Borena Nomads for preparation and storage of *ititu*. (2) Smoking of *gorfa* is always performed in a special way and using special local plants which are used only for *gorfa* smoking. Smoking is slightly longer than that of other dairy utensils. Smoke is applied for about 45 min–1 h (smoke application is 3–4 times within these time intervals) and the temperature of the smoked equipment is slightly higher, as it varies from 75°C to 80°C. (3) Cleaning is done with a special kind of locally made material from plant fibre known as *sosso*. (4) The lid of the *gorfa* is always cleaned with a leaf from some kind of plant locally known as *urgoo* and smoked each time during introduction of fresh milk.

others when it is available because it is cheaper than any other fermented milk product.

With traditional fermented milk as typical raw material, all the steps for *arrera* production are similar to those of *ergo* (Figs. 3 and 4). Fresh leaves of *Ruta chalepensis* var. *tenuifolia*, and *O. hadiense* are most commonly added for flavouring, followed by mashed green *Caps. annuum* and *A. sativum*. Infrastructure and the handling and use of containers are also similar to those for *ergo* and *kibe*.

No scientific data are available on shelf life in relation to storage time and temperature. Data on pH and microbiology of the final product are not available.

2.5. Ayib (cottage cheese)

Ayib is prepared after the manufacture of butter by heating the *arrera* to coagulate the curd. *Ayib* is a soft curd-type cheese typical of many regions in Ethiopia, and is made from the buttermilk resulting from the churning of sour whole milk (O'Mahony and Bekele, 1985; Gonfa et al., 1991; O'Connor, 1994). The product is white and is similar to but grainier than cottage cheese. It is very acidic but it is not stable enough for wide distribution and it is mainly consumed locally.

Ayib is produced both at home level, in small enterprises and in large scale plants owned by the state dairy enterprise (DDE) and is processed from fermented milk in all cases. No detailed information on yield or consumption data is available, but DDE estimated a 15% yield for whole milk to *ayib*. Generally, the expected yield depends on milk composition and on the moisture content of the product, but it amounts approximately to 1 kg of *ayib* from 8 l of milk (O'Mahony, 1988).

Ayib is as important as *kibe* and contributes to the overall nutrition of the people and forms part of the staple diet. It can be consumed as side dish as such, or it may be spiced with *kochikocha*, *Caps. annuum*, salt and other herbs and spices. In some cases, especially during the holy days, traditional ghee (*neter kibe*) may also be added. This recipe is known as *sukumma* or *irra-bussa* in the Oromyia region (Gonfa, unpublished data). *Ayib* has important benefits for both urban and rural populations, as it is used for own consumption and, together with *kibe*, it is one of the major products for sale. It is always sold by volume and there is no published price structure. At present the price of 1 kg of *ayib* is estimated to be 5–6 Birr (ca. US$0.75) in Addis Ababa. There is no rural *ayib* distribution as such, but the product from individual farmers, producers and service cooperatives is sold loose. It can be given to children of weaning age as well as to the elderly. *Ayib* is more affordable than high quality processed cheese, because of its low production costs and local availability.

As for *ergo* and *kibe*, milk souring initiates the process of *ayib* production, although it is mainly made from the further processing of defatted butter milk (*arerra*) (Fig. 3). The initial process of fermentation and the typical utensils required for initial processes are similar to those for *ergo*. *Ayib* is made by heating the *arrera* to about 50°C in a suitable container, e.g. an iron or clay pot. This temperature is maintained for 20–25 min until a curd-mass forms (Vedamuthu, 1979), after which it is allowed to cool gradually and the curd is separated from the whey through a fine mesh cloth or a sieve. The resulting *ayib* contains ca. 76% water, 14% protein, 7% fat and 2% ash (O'Connor and Tripathi, 1992).

Lactose-assimilating yeasts were isolated in high numbers from *ayib* samples purchased from a market (Ashenafi, 1989). The isolates belonged to *Kluyveromyces* spp. (12.5%), *Torulopsis* spp. (6%), and *Leucosporidium* spp. (3.2%). Proteolytic yeasts made up 46.9% of the total isolates. All isolates showed lipolytic activities. The presence of these proteolytic and lipolytic yeasts may affect the flavour and keeping quality of *ayib*. Bacteria were also isolated from *ayib* (Ashenafi, 1990a,b). Mesophilic aerobic bacteria and enterococci were isolated from the majority of samples. About 55% of the samples were positive for coliforms and faecal coliforms. *Listeria* spp. were not detected in any sample, whilst *Bacillus cereus* and *Staphylococcus aureus* were isolated from all samples at different but low frequencies.

Ayib is quite acidic with an average pH of 3.7 (Ashenafi, 1990a; Gonfa, unpublished data). It still has a short shelf life of 2–3 days due to its high moisture content. Its keeping quality may be improved by adding salt or by reducing its high moisture content.

2.6. Neter kibe (traditional ghee)

The surplus *kibe* may be converted into *neter kibe* (traditional *ghee*) for later consumption and for distribution. Neter kibe is mainly processed at home, and only in rare cases can it be purchased from the market. It is a more convenient product than *kibe* in the tropics, because of its better shelf life under warm conditions (O'Connor and Tripathi, 1992). It has an attractive appearance, a grainy texture and a light yellow colour. At room temperature it is semi-solid. It has a pleasant odour and good taste. Its good keeping quality allows storage for more than a year without any change (Gonfa, unpublished data).

Neter kibe is a popular food and is considered as a major staple item in the diet and is consumed in all parts of the country and by all people. It may be consumed in various ways, e.g. as oil, mainly for cooking purposes for preparation of different kinds of stew (e.g., *dorro wot*, *siga wot*, *atakilt wot*) or as a side dish with various foods, for example, traditional foods such as *dabbo*, *chumboo*, *anababero*, are dressed with spiced *neter kibe* and used for direct consumption.

Neter kibe (traditional *ghee*) is made by evaporation of the water from *kibe* by heating in an iron pan or clay saucepan (Fig. 3). Heating of the melted butter is continued until bubbling ceases. Fresh leaves of *O. hadiense, O. basilicum*, mashed *Allium sativum* (garlic), mashed *Zigeber officinale* (ginger) and other herbs may be added during processing. For example, *O. basilicum* or *O. hadiense* are added for flavour during heating in the Oromyia region (Gonfa, unpublished data). The *neter kibe* is decanted into another container leaving the curd material in the pan. *Neter kibe* is processed only in the home and therefore only household utensils such as clay pots and iron pans are needed.

No information is available on time–temperature relationships related to spoilage, pH of the final product or its microbial spectrum. The product is prone to spoilage if the oily portion and the precipitated part (the residue curd material) have not been carefully separated.

2.7. Augat (traditional whey)

This is the liquid part of *arerra* after the *ayib* is removed. It is rich in protein and free amino acids. *Augat* contains about 0.75% protein and can be consumed by humans or fed to animals (O'Connor and Tripathi, 1992). The processing of *augat* is explained schematically in Figs. 3 and 4.

3. Future development

Trials to improve small-scale dairy production in Ethiopia have met with mixed success (Kebede, 1987; Kumisa, 1993). One example of how simple technology can bring about improvements arose from ILCA's Dairy technology teams study of the traditional method of butter making to determine the efficiency of the process and the quality of *kibe* produced (O'Connor and Tripathi, 1992; O'Connor et al., 1993). Fat recovery is an important factor determining the efficiency and profitability of smallholder dairy enterprises in the Ethiopian highlands. At present, nearly 50% of the traditional processors recover between 50% and 67% of the butterfat from whole milk, while a further 12.5% of producers recover less than 50%. This leads to fluctuating income, depending on quality and market demand, the latter of which is high during Easter and other festivals but low during the fasting periods prescribed by the Coptic Church. The technology was improved by introducing a simple, low-cost agitator, which could be assembled inside the traditional churn. The modified earthenware churn has considerable advantages over the traditional churn. The innovation was simple, cheap and effective and uses fermented milk for processing. These trials indicate that as much as 90% of the fat can be recovered from whole sour milk with considerable shorter churning time and less labour input than with traditional methods. The improved technology could thus lead to useful increases in the incomes of smallholders. From this trial it could be concluded that simple technologies, involving fermented milk for further processing, are highly desirable for the future development of dairy products for smallholders.

The way forward in the development of the dairy industry of Ethiopia would appear to be to encourage, train and advise smallholders to pool and manage their resources in order to achieve greater efficiency, to use improved technologies and product distribution. Emphasis should be placed on raw milk

quality and upgrading of traditional fermentation methods by use of selected starter cultures. In order to improve the safety of the products good manufacturing practices (GMP) including the application of HACCP will have to be introduced. This could be the first stage towards development of industrial scale processes (Wood, 1991). The feasibility of the use of specific starter cultures with functional (probiotic) properties and the role of individual processing steps and their contribution in ensuring food safety principles need to be examined. The effects of organisms used in starter cultures on parasites, viruses, spoilage and pathogenic bacteria such as *Escherichia coli*, *Salmonella*, *Listeria* and *Campylobacter* in fermented dairy products also need to be determined. Within the EU-funded INCO-STD project "Capability Building for Research and Development in Traditional Fermented African Dairy Products", microbiological studies were conducted on traditional fermented milk products of Ethiopia to provide information on beneficial microorganisms associated with the souring process and their development into starter cultures giving consistent, safe and acceptable products. A special future challenge lies in the handling, maintenance and distribution of starter cultures under rural conditions and for small-scale processing (Holzapfel, 1997).

Acknowledgements

This work forms part of the research funded by the EU–INCO Project No. ERBIC18CT960119 'Capability Building for Research and Development in Traditional Fermented African Dairy Products'. This is gratefully acknowledged.

References

Anon., 1983. Livestock sub-sector review. Annex 14: First draft. Milk marketing, Ethiopia. Ministry of Agriculture, 54 pp.

Ashenafi, M., 1989. Proteolytic, lipolytic and fermentative properties of yeasts isolated from *ayib*, a traditional Ethiopian cottage cheese. SINET: Ethiop. J. Sci. 12, 131–138.

Ashenafi, M., 1990a. Effect of curd-cooking temperatures on the microbiological quality of *ayib*, a traditional Ethiopian cottage cheese. World J. Microbiol. Biotechnol. 6, 159–162.

Ashenafi, M., 1990b. Microbiological quality of ayib, a traditional Ethiopian cottage cheese. Int. J. Food Microbiol. 10, 263–268.

Ashenafi, M., 1993. Fate of *Salmonella enteritidis* and *Salmonella typhimurium* during the fermentation of *ergo*, a traditional Ethiopian soured milk. Ethiop. Med. J. 31, 91–98.

Ashenafi, M., 1994. Fate of *Listeria monocytogenes* during the souring of *ergo*, a traditional Ethiopian fermented milk. J. Dairy Sci. 77, 696–702.

Ashenafi, M., 1996. Effect of container smoking and incubation temperature on the microbiological and some biochemical qualities of fermenting Ergo, a traditional Ethiopian sour milk. Int. Dairy J. 6, 95–104.

Central Statistical Authority (CSA), 1994/1995. Report on Livestock, Poultry and Beehives population (Private Peasant Holdings). Statistical Bulletin, Addis Ababa, Ethiopia, August, 1995, 243 pp.

Coppock, D.L., 1993. The Borana plateau of southern Ethiopia: Synthesis of pastoral research, development and change 1980–91. ILCA, Addis Ababa, Ethiopia.

Coppock, D.L., Holden, S.J., O'Connor, C.B., 1991. Milk Processing and Peri-urban Dairy Marketing in Semi-arid Ethiopia and Prospects for Development. ILCA, Addis Ababa Ethiopia, 40 pp.

Coppock, D.L., Holden, S.J., Assefa, M., 1992. Review of dairy marketing and processing in a semi-arid pastoral system in Ethiopia. Proceedings of a Symposium on Dairy Marketing in sub-Saharan Africa. ILCA, Addis Ababa, Ethiopia, pp. 315–334, 26–30 Nov. 1990.

Dersch, D, 1986. The production of indigenous Zebu cows under traditional smallholder management conditions in the Debre Berhan area of the Ethiopian highlands. Göttingen University, Germany Inst. fur Tierzucht und Haustierngenetick. International Livestock Centre for Africa paper UDC No. 636.28-DER. Addis Ababa, Ethiopia, 119 pp.

FAO, Rome (Italy), 1990. The technology of traditional milk products in developing countries. FAO Animal production Health Paper, No. 85, 333 pp.

Gonfa, A., Fite, A., Gashe, B.A., Urga, K., 1991. Survey of the microbial population of indigenous fermented milk. Proceedings: Public Health, 2nd Annual Scientific Conference, Publ. Health Association, Addis Ababa, Ethiopi, p. 25.

Gonfa, A., Fite, A., Gashe, B.A., Urga, K., 1994. The Microbiological aspects of ergo (ititu) fermentation. Proceedings: Biological Society of Ethiopia, 4th Annual Scientific Conference, Addis Ababa, Ethiopia, p. 34.

Gonfa, A., Fite, A., Urga, K., Gashe, B.A., 1999. The microbiological aspects of ergo (ititu) fermentation. SINET: Ethiop. J. Sci. 22, 2.

Gryseels, G., de Bookt, K., 1986. Integration of crossbred cows (Boran and Friesian) on smallholder farms in the Debre Zeit area of the Ethiopian highlands. ILCA highlands Programme Report. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.

Holzapfel, W., 1997. Use of starter cultures in fermentation on a household scale. Food Control 8, 241–258.

Kassaye, T., 1991. The microbiological and chemical composition "*ititu*" and factors affecting its production. M. Sc. thesis,

Dept. Food Science and Agricultural Chemistry, MacDonald College, McGill University, Montreal, Canada, 120 pp.

Kasseye, T., Simpson, B.K., Smith, J.P., O'Connor, C.B., 1991. Chemical and microbiological characteristics of ititu. Milchwiss. Milk. Sci. Int. 46, 649–653.

Kebede, B., 1987. The status of dairy research and development in Ethiopia. The Status of Livestock Pasture and Forage Research and Development in Ethiopia. IAR (Institute of Agricultural Research), Addis Ababa, Ethiopia, pp. 24–33.

Kumisa, T., 1993. Smallholder dairy in Ethiopia. In: Kategile, J.A., Mubi, S. (Eds.), Future of Livestock Industries in East and Southern Africa. Proceedings of a workshop, ILCA, 20–23 July 1982, pp. 51–57.

Kurwijila, L.R., 1992. Dairy technology appropriate to rural smallholder production. Proceedings of a Symposium on Dairy Marketing in sub-Saharan Africa. Addis Ababa, Ethiopia, 26–30 Nov. 1990, pp. 131–142.

Mahari, T., Gashe, B.A., 1990. A survey on the microflora of raw and pasteurised milk and the source of contamination in a milk processing plant in Addis Ababa, Ethiopia. J. Dairy Res. 57, 233–238.

Mekonen, G., 1989. Agricultural sample survey report on livestock, poultry and population (private co-operative and state farm) Statistical Bulletin 86. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Michelin, M.J., Walshe, Grindle, J., Nell, A., Bachman, M., 1991. Dairy development in sub-Saharan Africa. World Bank Technical Paper 135. Africa Technical Department.

Motarjemi, Y., Nout, M.R.J., 1995. Food fermentation safety and nutritional assessment. Bull. World Health Org. 74, 553–558.

O'Connor, C.B., 1992. Rural smallholder milk production and utilisation and the future for dairy development in Ethiopia. Symposium on Dairy Marketing in sub-Saharan Africa Addis Ababa Ethiopia, 26–30 Nov. 1990.

O'Connor, C.B., 1994. Smallholder and village milk processing in the highlands of Ethiopia. Proceeding of a seminar on Dairy Development Policy and Implementation, pp. 241–246, FAO Rome (Italy), Harare, Zimbabwe, 12–16 Jan. 1993.

O'Connor, C.B., Tripathi, B.R., 1992. Milk Processing Techniques—Sour Milk. ILCA, Addis Ababa, Ethiopia, No. 2, 20 pp.

O'Connor, C.B., Mezgebu, S., Zewde, Z., 1993. Improving the efficiency of butter making in Ethiopia. FAO World Anim. Rev., 50–53.

O'Mahony, F. 1988. Rural dairy technology. Experience in Ethiopia. ILCA Manual, No. 4, 64 pp. Addis Ababa (Ethiopia). Dairy Technology Unit.

O'Mahony, F., Bekele, E., 1985. Traditional butter making in Ethiopia and possible improvements. ILCA Bull. 22, 9–14.

Oyewole, O.B., 1997. Lactic fermented foods in Africa and their benefits. Food Control 8, 289–297.

Tittarelli, F. (1990). Smallholder dairy marketing pattern in central Ethiopian highland. Selale Awaraja: A case study. Centro per Sviluppo Agricoloe Rurale, Assisi, Italy International Livestock Centre for Africa paper No. 637.1:658.8-III, 60 pp.

Vedamuthu, E.R., 1979. Microbiologically induced desired flavours in the fermented foods of the West. Development in Industrial Microbiology, 20, Elsevier, Amsterdam, pp. 187–202.

WHO, 1996. Report of joint FAO/WHO workshop on fermentation as a household technology and improved food safety. Milchwissenschaft 46, 649–653.

Wood, B.J.B., 1991. Industrial evolution of fermented foods. Food Biotechnol. 5, 279–291.