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REVIEW

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Typical dairy products in Africa from local animal resources

Silvana Mattiello[a], Mariangela Caroprese[b], Crovetto Gianni Matteo[c], Riccardo Fortina[d], Andrea Martini[e], Mina Martini[f], Giuliana Parisi[e], Claudia Russo[f] and Massimo Zecchini[a] and ASPA Commission "Animal Productions in Development Cooperation Projects"

[a]Dipartimento di Medicina veterinaria – Laboratorio di Benessere animale, Etologia applicata e Produzioni sostenibili, University of Milan, Milano, Italy; [b]Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente, University of Foggia, Foggia, Italy; [c]Dipartimento di Scienze Agrarie e Ambientali, University of Milan, Milano, Italy; [d]Dipartimento di Scienze Agrarie, Forestali e Alimentari and CISAO – Centro Interdipartimentale di Ricerca e Cooperazione Tecnico-Scientifica con l'Africa, University of Torino, Torino, Italy; [e]Dipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, University of Firenze, Firenze, Italy; [f]Dipartimento di Scienze Veterinarie, University of Pisa, Pisa, Italy

ABSTRACT

Milk is recognised as an important element of the pastoral civilisations in Africa, where it has not only an economic value, but also a social and cultural value. The objective of this review is to identify the main African dairy products, mainly focussing on typical production processes based on the use of local animal resources. To this aim, dairy products were classified into five categories, according to the type and the production method: fresh cheese, ripened cheese, fermented milk, butter and dairy by-products. These categories give rise to an extraordinary range of local products where tradition, culture, and environmental conditions and constraints play a major role in contributing to this diversification. In some countries, some attempts are being made in order to valorise the local dairy products by establishing Slow Food Presidia or including them in the Ark of Taste compiled by Slow Food. One of the main constraints that limits the commercialisation and export of African dairy products is related to the scarce hygiene in milk production and processing, and the frequent absence of starter cultures, which result in products with non-standardised characteristics, short shelf life and high spoilage susceptibility, with consequent risks for human health. Efforts should be made to support the dairy products chain in Africa, by making production processes safer and by valuing local resources, in order to expand the internal market and the export opportunities. Development cooperation projects may play an important role in this respect and should therefore be encouraged.

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Introduction

Milk is recognised as an important element of the pastoral civilisations in Africa. It is a relevant factor in the processes of social organisation, eating habits, trading, development and appropriation of techniques and a cultural heritage, which is also expressed in ritual and symbolic representations. Therefore, milk has not only an economic value, but also a social and cultural value. Indigenous groups like the Maasai, Borani, Fulani and Tuareg have a strong historic dairy tradition. They share many habits and regard milk as a product of harmony that is freely offered to relatives, friends and visitors (Ndambi et al. 2007).

Traditional systems have dominated milk production in Africa for many years and still supply considerable amounts of milk today. These systems account for above 90% of dairy ruminant population in Sub-Saharan Africa (Olaloku and Debre 1992). Pastoral systems can be migratory, transhumant or sedentary. Sedentary farmers live in the same homes all year round while migratory and transhumant farmers move in search for better pastures. In transhumant systems, milk surplus is shared with neighbours or exchanged in barter, but is rarely sold except by households living close (<5 km) to main roads and urban centres, where there is demand for fresh and fermented milk, and butter. Consumption of milk and milk products in Africa is greatly influenced by traditions and cultures (Ndambi et al. 2007).

In 2014, total milk production in Africa was 46,907,955 millions of tonnes (which is only 6% of world average production; FAOSTAT 2016). The

CONTACT Prof Silvana Mattiello silvana.mattiello@unimi.it Dipartimento di Medicina veterinaria – Laboratorio di Benessere animale, Etologia applicata e Produzioni sostenibili, Università degli Studi di Milano, Via Celoria n°10, 20133, Milano, Italy

majority of production is from cow milk (74.05% of the total production), followed by goat (8.74%), buffalo (6.23%), camel (5.76%) and sheep (5.23%) milk. The top six African milk producing countries in terms of milk volume are Sudan (4,391,000 tonnes), Egypt (5,598,477 tonnes), Kenya (4,925,692 tonnes), Ethiopia (3,699,373 tonnes), South Africa (3,337,018 tonnes) and Algeria (4,241,414 tonnes): these six countries produce about 50% of African milk (FAOSTAT 2016). Only about 15% of the total milk produced is processed to standard products (cheese, yoghurt, butter, etc.). More than 70% of total milk production goes through informal markets or is consumed on the farm (Ndambi et al. 2007). In some countries, some attempts are being made in order to valorise the local dairy products. For example, in South Africa a Slow Food Presidium has been established to promote high-quality South African Raw Milk Cheeses, such as *ficksburger*, *ganzvlei vastrap*, *karoo crumble* and *huguenot*, produced by small-scale local farmers using only raw milk, adopting environmentally and welfare friendly techniques and respecting local culture and traditions. In Cape Verde, local goat cheese from raw milk from the Planalto Norte region, produced in difficult harsh environmental conditions from grazing goats, is sold as fresh cheese or, less frequently, as ripened cheese, which are also promoted as Slow Food Presidia (Slow Food Foundation for Biodiversity 2016). In the Fantalle district, in Ethiopia, a Slow Food Presidium has been established in 2010 in order to valorise the local fresh camel milk, produced by the *Karrayyu* nomadic herders. This product has raised a local interest among the Ethiopian herders, but unfortunately it is not well known among the rest of the population (Slow Food Foundation for Biodiversity 2016).

The present review is the result of the work of the Italian Animal Science and Production Association (ASPA) commission 'Animal productions in development cooperation projects'. Together with another review (Mattiello et al. 2017), it represents an effort of Italian Animal Scientists to acknowledge the role of both dairy and non-dairy products in Africa, in order to raise the attention of ASPA members towards these productions, strengthen possible collaboration relationships and foster development cooperation projects.

To this purpose, the present review aims to identify the main African dairy products, focussing on typical production processes, and to describe their strengths and constraints.

Dairy products were classified into five categories according to the type and the production method: fresh cheese, ripened cheese, fermented milk, butter and dairy by-products. The main products in each category are summarised in Table 1.

Fresh cheese

Fresh cheeses are characterised by a usually high moisture content and no or short ripening periods. The fresh cheese production technique is based on coagulation of milk casein by the addition of a product able to produce curds, either of animal or vegetable origin. There are few examples of typical fresh cheese products in Africa, especially due to the difficult conservation of the product because of climatic and environmental conditions. However, some examples can be found in Algeria, Benin, Egypt, Ethiopia, Nigeria, Sudan and Togo.

In Algeria, a traditional cheese called *klila* has been produced and described since 1855 (Duval 1855). It is obtained by coagulation of milk induced by the addition of animal rennet, followed by a light pressure of the curd. *Klila* is usually kept in glass jars or in tulle bags but in some rural areas women retain it in goatskin bags called *mezwed*. It was once the object of trade in Sahara by nomadic tribes, whereas nowadays it is produced and consumed fresh or dried in both rural and urban areas (Sraïri et al. 2013).

The most widespread and consumed local cheese in Benin (Kora 2005), Nigeria (Iwuoha and Eke 1996) and northern Togo (Dossou et al. 2006) is *warankasi* (or *wagashi* or *waragashi* or *woagashi*), produced by the local *Fulani* and *Peuhl* ethnic groups. The production method is based on the coagulation of cow or goat milk induced by leaves of the so-called apple of Sodom (*Calotropis procera*) that contains an enzyme called calotropain (Iwuoha and Eke 1996; Zecchini and Cantàfora 2010). In order to extract the rennet, the leaves are initially washed and grinded in a mortar. This material is then mixed with a small amount of cool or warm milk. The resulting mixture is filtered and added to the milk. This method avoids the green colouration that the leaves give to the cheese. After coagulation, the curd is heated, drained and moulded before introducing it on the market in different forms and sizes (Dossou et al. 2006). For a better conservation, the cheese is exposed to sunlight either on the roof of the houses, or smoked over a wood fire or cut into pieces and fried in oil. The *woagashi* can be stored in whey to retain its moisture, or it can be treated with sorghum panicle (*Sorghum vulgaris*) or young leaves of teak (*Tectona grandis*) that give a red or brown surface colour to make it more attractive. After these treatments, the dried cheese can be stored

Table 1. Dairy products in African countries, classified according to product type.

Product type	Local name	Country	Type of milk	References
Fresh cheese	*Ayib*	Ethiopia	Cow	Gonfa et al. 2001; Andualem and Geremew 2014
	Gibna Bayda	Sudan	Cow	Abdelgadir et al. 1998; Mohammed Salih et al. 2011
	Kariesh	Egypt	Buffalo or cow (or mix)	Todaro et al. 2013
	Klila	Algeria	Not specified	Sraïri et al. 2013
	Warankasi	Nigeria	Goat or cow	Iwuoha and Eke 1996
	Woagashi	Benin	Cow	Dossou et al. 2006; Kora 2005
Ripened cheese	*Aoules*	Algeria (Ahaggar region)	Goat	FAO 1990
	Bouhezza	Algeria (Aurès region)	Goat, sheep or cow	Zitoun et al. 2012; Belbeldi 2013
	Domiati (or *domyati)*	Egypt, Sudan	Buffalo or cow (or mix)	El-Baradei et al. 2007
	Mish	Sudan, Egypt	Cow	Abdelgadir et al. 1998; Mohammed Salih et al. 2011
	Tallaga cheese	Egypt	Buffalo or cow (or mix)	El-Kholy et al. 2016
	Tchoukou	Niger	Cow, goat or mix	Kora 2005; Maazou 2013
	Tuareg cheese	Mali	Cow, goat or sheep	Kora 2005
Fermented milk	*Amabere amaruranu*	Kenya	Cow	Nyambane et al. 2014
	Amasi	Lesotho, South Africa and Zimbabwe	Cow	Gadaga et al. 1999, 2000; Beukes et al. 2001; Todorov 2008; Schutte 2013
	Biruni	Sudan (Nuba Mountains)	Cow	Abdelgadir et al. 1998; Mohammed Salih et al. 2011
	Ergo	Ethiopia	Cow	Gonfa et al. 2001
	Fulani traditional fermented milk	Burkina Faso	Not specified	Savadogo et al. 2004
	Gariss	Sudan	Camel	Abdelgadir et al. 1998; Mohammed Salih et al. 2011
	Ititu	Ethiopia	Cow	Gonfa et al. 2001; Andualem and Geremew 2014
	Kindirmu	Cameroon	Not specified	Kameni et al. 1999
	Kivuguto	Rwanda	Cow	Karenzi 2015
	Kule naoto	Kenya	Cow	Mathara et al. 2004
	Kwerionik	Uganda	Cow	Schutte 2013
	Lben	Algeria, Northern Africa	Goat, sheep or cow	Belbeldi 2013; Benkerroum 2013; Zitoun et al. 2012
	Madila	Botswana	Cow or goat	Ohiokpehai 2003; Schutte 2013
	Masse	Mozambique	Cow	Schutte 2013
	Nono	Nigeria	Cow	Ogbonna 2011
	Nunu	Ghana	Not specified	Akabanda et al. 2010
	Nyarmie	Ghana	Cow	Obodai and Dodd 2006
	Omashikwa	Namibia	Not specified	Bille et al. 2007
	Pendidam	Cameroon	Not specified	Kameni et al. 1999
	Pokot ash	Kenya	Cow or goat	Slow Food Foundation for Biodiversity 2016
	Rob	Sudan	Goat, sheep or cow	Abdelgadir et al. 1998; Mohammed Salih et al. 2011
	Sussa	Somalia	Camel	Farah et al. 2007
	Suusac	Ethiopia and Sudan	Camel	Mohammed Salih et al. 2011; Andualem and Geremew 2014
	Urubu	Burundi	Cow	Aloys and Angeline 2009
	Zabady	Egypt	Buffalo or cow (or mix)	Abou-Donia 2004; El-Baradei et al. 2008
Butter	*Amavuta*	Burundi	Cow	Aloys and Angeline 2009
	Kibe	Ethiopia	Cow	Gonfa et al. 2001
	Kimuri	Rwanda	Cow	Karenzi 2015
	Nebam	Niger	Not specified	Maazou 2013
	Neter kibe	Ethiopia	Cow	Gonfa et al. 2001
	Samin	Sudan	Goat, sheep or cow	Abdelgadir et al. 1998; Mohammed Salih et al. 2011
	Samuli	Uganda	Cow	Sserunjogi et al. 1998
	Semna	Egypt	Camel	Sserunjogi et al. 1998
	Shmen	Algeria, Northern Africa	Camel	Kacem and Karam 2006
	Zebda beldi	Northern Africa	Cow	Benkerroum 2013
Dairy by-products	*Amacunda*	Rwanda	Cow	Karenzi 2015
	Amateregwa	Burundi	Cow	Aloys and Angeline 2009
	Arrera	Ethiopia	Cow	Gonfa et al. 2001

for 45 days without significant changes of its organoleptic characteristics (Dossou et al. 2006).

In Egypt, cheese production is witnessed since the Pharaonic period (Todaro et al. 2013). Nowadays a fresh cheese – *kariesh* – is still produced from cow and/or buffalo milk. The method involves leaving the milk in special earthenware containers called *shalia* until fat rises to the surface. After removing the cream, semi-skimmed milk sours and forms clots, which are placed on a canvas, which is hung to drain the whey. This draining period takes two or three days and then the cheese is cut into pieces and salted and is finally ready to be consumed within 1 or 2 weeks as fresh cheese (Todaro et al. 2013).

Ayib is a soft curd-type cheese (similar to cottage cheese), typical of many regions in Ethiopia, and is made from the buttermilk resulting from the churning of sour whole milk (Gonfa et al. 2001). It is very acid, but it is not stable enough for wide distribution and it is mainly consumed locally because its shelf life lasts only few days (Andualem and Geremew 2014). *Ayib* is made by heating the *arrera* (see paragraph *Fermented milks*) to about 50 °C for 20–25 min until the formation of a curd mass (Vedamuthu 1979). This mass is then allowed to cool gradually and the curd is separated from the whey through a fine mesh cloth or a sieve. It is consumed fresh or spiced with *kochikocha* (*Capsicum annuum)*, salt and other herbs and spices or even, on special occasions (holy days), added with traditional clarified butter *neter kibe* (Gonfa et al. 2001).

The production of the white cheese called *gibna* in Sudan started in the early 18th by some Greek families who migrated into this country (Mohammed Salih et al. 2011). According to Ali (1987) and Abdelgadir et al. (1998), this soft cheese can be assimilated to the Egyptian Domiati and the Greek feta cheese. Two major types of this local product are *gibna bayda* and *gibna mudaffara* (El-Sheikh 1997; Hamid and El Owni 2007) that differ in composition, texture, colour, taste and flavour because of the differences in the methods of production, microbial flora, type of packaging and microbial activity (Abdelgadir et al. 1998). The process for making *gibna bayda* includes heating of the fresh milk to 35 °C followed by salt addition to reach a concentration of 6–10% in the milk. The bacteria naturally present in the raw milk carry out the fermentation process; no additional starter is used (Abdelgadir et al. 1998; El Owni and Hamid 2008). *Gibna* is unique in containing high concentrations of salt (sodium chloride), which is added to the milk before processing (Mohammed Salih et al. 2011) in order to preserve cheese from rapid deterioration before it ripens (Taormina 2010). The production of *jibna mudaffara* includes a high percentage of salt and rennet added to the milk (Mohammed Salih et al. 2011) to obtain a firm coagulum, which develops in 4–6 h. The coagulum is then transferred to wooden moulds lined with cheesecloth muslin and the whey is allowed to drain overnight. The drained whey is collected into a clean pan, boiled for 15 min, followed by removal of fat and of coagulated whey proteins, and then a starter from previous fermented milk is added and left overnight to ferment. On the following day, the cheese is removed from the moulds and the curd is cut into 10 cm cubes. *Gibna mudaffara* is stocked for a long time by immersion in the whey (Mohammed Salih et al. 2011) and it is sold after packaging in tins or other suitable sealed containers (Abdelgadir et al. 1998).

Ripened cheese

Only few examples of production of hard ripened cheese are reported in the available literature. In fact, with the exception of North Africa, in other parts of Africa hard cheese production is not very common. While in the past the production of ripened cheese has been limited to rural areas, where families used to prepare this food for their own consumption, ripened cheese has recently started to be offered for sale in some urban centres, where its production process may differ from the traditional cheese-manufacturing process (Zitoun et al. 2012).

Regarding North Africa, the production and consumption of cheese are significantly more common in Egypt than in the other countries of the area. In Egypt, there are several diversified and elaborated cheese types, among which brined cheeses are the most represented (Abd-El Salam and Benkerroum 2007). *Domiati* (or *domyati*) cheese is a typical Egyptian brined cheese usually made from buffalo milk, cow milk, or a mixture. The raw milk is salted (10–15 g/100 mL) and coagulated (mixed coagulation: acid and rennet); the curd is drained under moderate pressure. Pieces (about 500 g) are put into brine (15–20 g salt/100 mL of whey) and then conditioned into tightly closed containers where they ripen for about three months at room temperature (El-Baradei et al. 2007). *Tallaga cheese* is similar to *domiati* cheese, but it is not brined and is matured under refrigeration temperature (4–7 °C) for a longer period (up to nine months) (El-Kholy et al. 2016).

Mish is a ripened soft cheese produced in Egypt and Sudan, starting from fresh soft cheese (*lben* in Egypt or *rob* in Sudan) blended in a porous

earthenware pot with milk or sour milk. The mixture is salted (about 10 g/100 g) and placed in a warm place to ripen. It can be flavoured with different types of pepper (e.g. green, red, hot and paprika), black cumin (which plays a remarkable inhibitory effect on the growth of *Staphilococcus aureus*) or garlic (Abdalla and El-Zubeir 2006; Mohammed Salih et al. 2011). The intensity of spicing may differ depending on spices availability and local taste (El-Mardi 1988). Brine permeation through the porous walls of the earthenware pot during the ripening period (for at least 1 month) allows *mish* to concentrate and be eventually converted into a paste, which is cut into cubes and dried in the sun. The *mish* prepared by nomadic tribes often contains fly maggots, which are normally consumed alive with the product (Abdelgadir et al. 1998).

In Algeria, an ancient and traditional cheese is *bouhezza*, which is manufactured and ripened in a goatskin bag, known as a *chekoua*, using raw goat, ewe and/or cow milk. The cheese-making process is based on the use of raw milk and *lben*, which are regularly added to the *chekoua* for several weeks. Salting, draining and ripening steps are performed simultaneously in the skin bag and the final product is stored in the *chekoua* or in glass or plastic containers. Before consumption, the cheese is spiced with red hot pepper (Zitoun et al. 2012). Cheese can be consumed in the form of firm paste, spread on bread or dehydrated after drying for seasoning traditional dishes (Belbeldi 2013). *Aoules* is another typical Algerian dry cheese (87–92% dry matter) obtained from spontaneously coagulated goat milk, which is churned to remove butter. The resulting product is poured into a clay pot and heated moderately on an open fire until proteins precipitate, in a similar manner as *klila*. The precipitate is strained in a straw basket and the curd is kneaded in small quantity at a time to be given the shape of a flat small cylinder (2 cm thick, 6–8 cm diameter). The cheese is then sun-dried. *Aoules* is ground and mixed with date paste or beverage for consumption.

In East Africa, *Touaregh* cheese (Mali) and *tchoukou* (Niger) are produced. *Touaregh* cheese is prepared from ruminant fresh milk (sheep, goat and cow) with rennet from a young goat or lamb, put into a clean bowl and stirred 2–3 times with a stick soaked in the rennet. The coagulation of milk takes about 10–15 min and subsequently the coagulum is drained on a mat. The cheese is dried on tree branches in pieces of 0.5–1 cm thickness (Kora 2005). *Tchoukou* is another hard cheese, made from cow or goat milk, or a mixture of both. For coagulation, the abomasum fluid is prepared from a cleaned and dried curd fragment, added to a small amount of whey. The clotting time is 30–60 min and the curd is deposited on a mat; its shape and size vary depending on local traditions (Maazou 2013). The drying time is 24–48 h, depending on the time of year (Kora 2005). Well dried and stored, *tchoukou* can be conserved for 6 months to 1 year.

Fermented milk

Fermentation has been used to preserve and store milk since the days of the Pharaohs (Wilson 1988). Milk fermentation is generally carried out by the spontaneous enzymatic activities of lactic acid bacteria (LAB) and is known to inhibit the growth of several pathogenic bacteria (e.g. *Staphylococcus aureus*, coliforms, *Escherichia coli*, *Campylobacter jejuni* and *Vibrio cholera*), mainly due to pH reduction induced by the action of microorganisms and enzymes (Asogwa et al. 2017). For these reasons, fermentation is considered a successful preserving method, even though some cases of milk contamination by pathogenic bacteria due to the high temperature and humidity characteristics of the African regions, and by the lack of refrigeration, have been reported (Mensah 1997; Mogessie 2006).

Fermented milk has an important socio-economic role and is widely practised in Africa (Asogwa et al. 2017), due to the low energy required by the process and to the high nutritional value of fermented dairy products, such as yoghurt and sour milk. The majority of fermented milk types in Africa is obtained from cow's milk, but milk from camel, goat, buffalo, sheep and horse is also commonly used. Production protocols differ across African regions, because they depend on local indigenous microbiota, which in turn reflects the climatic conditions of each area. As a consequence, traditional fermented milk from regions with cold climatic conditions usually contains mesophilic bacteria, such as *Lactococcus* and *Leuconostoc* spp., whilst that from regions with hot climatic conditions is characterised by thermophilic bacteria, mainly *Lactobacillus* and *Streptococcus* (Jans et al. 2017).

In Algeria and North Africa milk from cows, sheep and goats is fermented to obtain *lben* (also called *leben, laban, labna* or *labneh*), a widely consumed dairy product (Belbeldi 2013; Benkerroum 2013). *Lben* is produced by a spontaneous acidification and coagulation by milk original microbiota; then, the curd is introduced into the *chekoua*, a bag made from goat skin, together with water (hot or cold, depending on the ambient temperature) and it undergoes vigorous churning. This product is often consumed with pancakes, dates or added to popular dishes as couscous, mainly in Ramadan period (Belbeldi 2013).

In Egypt, the most popular fermented milk is *zabady*, which is considered the oldest fermented milk known in the world. *Zabady* is usually made from buffalo's milk, but it can also be made from cow's milk or from a mixture of both (Abou-Donia 2004), and is characterised by a consistency similar to that of yoghurt and by a cooked flavour. The preparation of the traditional *zabady* starts by boiling raw milk for a few minutes, followed by cooling to about 45 °C. A portion of the *zabady* production from the previous day is added as a starter. The quality of *zabady* is the result of the starter bacterial composition, the sanitising procedure and the incubation temperature used, being the incubation conditions uncontrolled and the manufacturing facilities almost rudimentary (El-Baradei et al. 2008). El-Baradei et al. (2008) identified several LAB species in *zabady* samples, such as *Streptococcus thermophilus, Lactococcus garvieae, L. raffinolactis, L. lactis, Leuconostoc citreum, Lactobacillus delbrueckii* subsp. *bulgaricus* and *L. johnsonii.* In particular, some strains of *L. johnsonii* are considered probiotic and may be used for their health-promoting effects. As a result of the time of the Anglo-Egyptian rule (1898–1956), the use of *zabadi* has been reported also in urban areas of Sudan, where it is prepared from cow's milk. The mean composition of *zabadi* was found to be: 2.8% protein, 3.1% fat and 2.7% lactose, with a total acidity of 1.9% and a pH of 3.6 (Abdelgadir et al. 1998).

In Sudan, the most important fermented milk is *rob* (also called *roub* or *robe*), which is produced in rural areas mainly by households, in order to use the surplus milk produced during the rainy season; about 80% of the rainy season milk is fermented into *rob*, and *rob* represents about 90% of all fermented milk (Abdelgadir et al. 1998). This product is made mainly from cow's milk, but occasionally also from sheep and goat's milk (Mohammed Salih et al. 2011). *Rob* production starts from both boiled and raw milk collected into a container; then milk is inoculated with a natural starter from the batch of the previous day and fermented overnight. The fermentation process usually starts in the evening, when the animals return from grazing, and the sour product is churned in the morning, when the herd leaves for grazing. Fermentation and churning can occur in one container or in two different containers called *dayyara* and *daggaga* or *khashash*. Alternatively, churning can be done in a leather container called *si'in* or *girba,* made of goat skin, or in a gourd called *bukhsa*, made from the dried fruit of the plant *Lagenaria leucantha*. Freshly produced *rob* has a pleasant taste and a pH of about 4.5. Subsequently, *rob* begins to sour and the whey, called *safwa*, separates from the curd, called *kush-kush*. At this stage, it can be used in hot climatic conditions against thirst, after dilution with 2 or 3 volumes of water to give *gubasha* (Abdelgadir et al. 2001); alternatively, in urban areas, it can be refrigerated and consumed with sugar as a dessert or eaten with wheat bread.

Another fermented milk typical of Sudan is *biruni*. This product originally came probably from the Nuba, one of the indigenous peoples of the Sudan, and then spread to the nomadic Arab tribes, that named it *laban-gedim,* meaning 'aged milk' (Abdelgadir et al. 1998). The Nuba families used to give their surplus cow's milk to the medicine man of the village, called *kujur,* who had large gourds to store the milk and would bless the family's cattle in return. During the dry season, when there is a shortage of fresh milk, the families were welcome to use *kujur*'s *biruni* for food. During the production process, fresh milk is continuously added. Milk fermentation lasts from a minimum of 1 to up to 10 years; during this period, *biruni* becomes thick and brown, with a rancid flavour. Mixed with another product called *oka,* made from cow's urine and tamarind, *biruni* is used to cure malaria (Abdelgadir et al. 1998; Mohammed Salih et al. 2011).

A particular fermented milk is produced in Sudan from camel's milk: *gariss,* made by a semi-continuous or fed-batch fermentation process involving *Lactobacillus helveticus*, and *L. debrueckii* subsp. *lactis*, together with yeasts such as *Candida* and *Kluveromyces* (Mirghani 1994). The milk is fermented in two leather bags which are saddled on a burden camel, called the *gariss* camel that shakes the bags by walking. The bags are often covered with green or dry grass. The consumed *gariss* is replaced by an equal volume of fresh camel's milk, and this process of retrieval and replacement of milk continues for months (Abdelgadir et al. 1998). The production process of *gariss* is an anaerobic fermentation, even if the camel shaking may contribute to the aeration of the process.

In Ethiopia, Somalia and Kenya, the arid and semi-arid part of Eastern Africa, as well as in Sudan, milk from camels plays an important role for pastoral communities (Andualem and Geremew 2014). Camel's milk is traditionally used to make a spontaneously fermented product called *sussa* or *suusac*. *Sussa* production starts from fermentation for 1–2 days of raw fresh camel milk in smoked gourds, at room temperature (26–29 °C) (Farah et al. 2007; Mohammed Salih et al. 2011; Andualem and Geremew 2014). The predominant LAB in *sussa* from Kenya and Somalia were *Streptococcus infantarius* subsp. *infantarius, L. lactis* subsp. *lactis*, *S. thermophilus* and lactobacilli

(Andualem and Geremew 2014). Considering that *S. infantarius* can be considered a risk for consumers' health, the authors recommend to use starter cultures, such as *S. thermophilus*. *L. lactis* and *Lactobacillus* spp. both to standardise *sussa* quality and to reduce the risks for human health.

In Ethiopia, cow's raw milk is mainly processed into *ergo*, that is a traditional, spontaneously fermented milk product, similar to yoghurt. In the lowland regions, relatively small amounts of *ergo* can be made also from goat's and camel's milk. *Ergo* is thick, smooth, of uniform and semi-solid appearance, and, when carefully prepared, usually has a white milk colour with pleasant odour and taste. The relatively low pH of *ergo*, ranging from 4.3 to 4.5, enables its further storage (Gonfa et al. 2001); however, a risk for human health exists, caused by the growth of *Salmonella* spp. and *Listeria monocytogenes* (Mogessie 2006). In order to reduce this risk and to induce a good flavour and a slow development of flavour components, in rural areas *ergo* can be produced in smoked vessels, which slow the growth of both coliforms and lactic and non-lactic bacteria compared with *ergo* produced in non-smoked vessels (Mogessie 1996; Gonfa et al. 2001; Mekonnen and Mogessie 2005). At an ambient temperature of 16–18 °C, milk stored in smoked vessels takes 2–4 days to ferment and can be stored for 15–20 days, depending on the ambient temperature (Gonfa et al. 2001). *Ergo* is rich in protein, carbohydrate, vitamins and fat, and it is therefore used mainly by sick or elder people, children, pregnant and lactating mothers, and it can be either directly consumed or further processed. When being served for direct consumption, *ergo* can be consumed either spiced (flavoured with fresh leaves of *Ruta chalepensis* var. *tenuifolia*, *Ocimum hadiense*, *Coriandrum sativum* mixed with mashed *Allium sativum* and green *Capsicum annuum*), or natural as a side dish along with different traditional foods. *Ergo* can also be further processed, being used as basis for various fermented milk products such as *kibe*, *ayib*, *neter kibe*, *arerra* and *augat* (Gonfa et al. 2001).

Another fermented milk from Ethiopia, which is similar to *ergo*, but more solid, is *ititu*, a concentrated fermented milk, which is traditional of Borana tribes in the southern part of Ethiopia (Andualem and Geremew 2014). In this area, the traditional zebu cattle (*Bos indicus*) breed takes the name of the local tribe, Borana. The importance of this local breed for manufacturing of traditional dairy products is witnessed by its inclusion in the Ark of Taste compiled by Slow Food (Slow Food Foundation for Biodiversity 2016). *Ititu* is prepared from cow's milk (but milk from small ruminants or from camels can also occasionally be used; Gonfa et al. 2001) of the rainy season to be consumed during the dry season (FAO 1990; Coppock et al. 1991; O'Connor 1992; O'Connor and Tripathi 1992). Milk is fermented for up to 14 days in a large *gorfa,* a vessel woven from fibres of selected plants with a lid treated with leaves of *Ocimum basilicum* for both cleaning and giving a desirable flavour to *ititu*, or in a wooden *amuyou* (Coppock et al. 1991; Andualem and Geremew 2014). *Ititu* is considered as a special food and reserved for guests, children in weaning age and the elderly (Andualem and Geremew 2014).

In Kenya, the Maasai community consumes large amounts of a traditional fermented milk called *kule naoto*. This product is obtained from unpasteurised zebu's milk, spontaneously fermented for at least 5 days into a gourd from *Lagenaria siceraria*, gently rubbed with a burning end of a chopped stick from *Olea africana*, a tree locally known as *enkidogoe*. After fermentation, the product is gently shaken before consumption (Mathara et al. 1995; Mathara 1999). *Kule naoto* is a very popular product among the Maasai and Kenyans, who generally prefer it to the other traditional fermented milk products, due to its excellent natural taste and aroma, and to its therapeutic effects against diarrhoea and constipation (Mathara et al. 2004).

In the south-western Kenya, in the Kisii highlands, members of Abagusii community produce a very popular fermented milk called *amabere amaruranu,* made from cow's milk. *Amabere amaruranu* is made by spontaneous fermentation of milk using a gourd made from *Lagenaria* spp., heated and held at boiling point for 10 min. After cooling for 10–20 min, a small portion of fermented milk from a previous batch is then added to the milk. The fermentation occurs at ambient temperature ranging from 10 to 32 °C in gourd or plastic containers. *Amabere amaruranu* has a grain-like appearance, and acidic taste (Nyambane et al. 2014). Microorganisms found in *amabere amaruranu* are LAB from the three genera *Lactobacillus*, *Leuconostoc* and *Streptococcus*; the most dominant species are *S. thermophilus* and *L. mesenteroides* subsp. *mesenteroides*. Yeasts include *Candida*, *Saccharomyces* and *Trichosporon*, and the most predominant yeast species is *S. cerevisiae* (Nyambane et al. 2014).

In Eastern Africa, in particular in Eastern Uganda, people use to ferment raw cow's milk to obtain a traditional curdled milk called *kwerionik,* usually consumed during the dry season. The raw milk is fermented in smoked gourds at ambient temperatures for 3–7 days; the product is consumed within 7 days. *Kwerionik* is called *katanik* if it is kept for 8–28 days, and

chekapmkaika if it is kept for a longer time (up to a year). Whey is constantly removed from the *chekapmkaika* and fresh or boiled milk is added every second day or once a week, depending on the ambient temperature. The removal of the top layer, containing fungi, extends storage (Schutte 2013).

In Rwanda, the most popular fermented milk is *kivuguto*, traditionally produced by spontaneous acidification of raw milk, induced by a microbiota which is on utensils and containers used for milk preservation. However, this method does not allow the standardisation of the process and of shelf stability of the product, which depend on different factors, such as the level of personal hygiene of people preparing the *kivuguto*. For these reasons, modern dairies now produce fermented milk and other dairy products using non-autochthonous strains. Nevertheless, despite the disadvantages of the process, traditional fermentation remains the most convenient method in Rwanda. The microorganisms used are indigenous strains, which are left to develop naturally during the production process. In the traditional method of producing *kivuguto*, once the cow has been milked, the milk is placed in a jar called *inkongoro*. In order to keep the product safe, the jar is usually covered either with a straw-woven lid known as an *umutemeri* or with a lid made from a calabash. A fermentation period of at least 2–3 days is required. In areas of eastern Rwanda, to ensure a reduction in the number of pathogens in the subsequent curd making, the containers to store milk undergo a special preparation by using the smoke derived from burning two different plants, one of which is from the Gramineae family, and the other from the Combretaceae family. The fermented milk stored in these containers has a solid texture and a smoked smell and taste, which are highly appreciated. If fermentation takes place in a small gourd, a liquid *kivuguto* milk is produced and is ready to be consumed; if a large gourd (*igisabo*), or a calabash are used, additional processing is applied to the resulting *kivuguto* milk, which is churned to produce *kimuri* (butter) or *amacunda* (buttermilk) (Karenzi 2015).

In Burundi, the traditional spontaneously fermented milk is called *urubu;* it is made from raw cow's milk, has a thick, smooth and uniform appearance, a semi-solid consistency, a white milk colour and a pleasant odour and taste. *Urubu* has some similarities with the Ethiopian *ergo*, and it is made by natural fermentation of fresh milk at ambient temperature in earthenware pot or in any other suitable container (Nibikora 2000). Depending on the ambient temperature and on the microorganisms in milk, containers and environment, milk is assumed to ferment within 1–3 days (Nsabimana 2005). *Urubu* consumption represents a low risk for human's health, because of its low pH; nevertheless, the scarce hygiene in milk production and processing, together with the absence of starter cultures, result in a wide variety of microorganisms in *urubu*, which can show non-standardised characteristics, short shelf life, and high spoilage risks (Nibikora 2000). *Urubu* is consumed by all categories of people, being rich in proteins, carbohydrate, vitamins and fats (Nibikora 2000; Nsabimana 2005).

In Mozambique, raw cow's milk is used to produce *masse,* an unsweetened curdled milk, with a strong acidic taste and a firm semi-fluid consistency, to be consumed within seven days. Homemade yoghurt, with a less acidic taste and a more creamy texture than *masse*, is prepared by adding one cup of yoghurt from the previous day to approximately 20 L of boiled milk in a pot. The milk is then left to ferment for a day at ambient temperature. Homemade yoghurt is consumed as a beverage, sometimes added with sugar (Schutte 2013).

In West Africa, in Burkina Faso, the Fulani community uses to ferment milk in calabashes, gourds or clay pots, which have a natural microbial inoculum before being used for fermented milk production. The containers are filled with fresh milk, covered and placed indoor. In Burkina Faso the rural population still produces unpasteurised fermented milk by traditional methods, handed down from one generation to the next (Savadogo et al. 2004). In Fulani fermented milk, the predominant lactic microbiota is represented by the genus *Lactobacillus*, *Leuconostoc*, *Lactococcus*, *Streptococcus* and *Enterococcus* (Savadogo et al. 2004). People from the Fulani community of Ghana produce the so-called *nyarmie,* by a natural fermentation of cow's milk without the use of starter cultures, and therefore this product is characterised by high variability from producer to producer. Bulk milk is pasteurised (at 65–75 °C) for 30–45 min, cooled, and the fat accumulated on the surface is collected; then it is partially covered and kept overnight at room temperature (28–30 °C), resulting in curdled milk. This is vigorously stirred or whipped with a wooden stirrer to give a yellowish and slightly viscous product, which on the next day becomes whitish and more viscous. *Nyarmie* has a pleasant taste and is preferred to both fresh and pasteurised milk because of its diversified properties. It can be stored for 5 days if unrefrigerated, or for several weeks if refrigerated at 4 °C (Obodai and Dodd 2006).

Another fermented milk produced by the Saharan tribes of West African sub-region and the inhabitants of the Mediterranean region and also of the Middle

East is *nono*. It is an opaque white to milky coloured fermented raw cow's milk. Its nutritional composition makes it not only suitable for human nutrition, but also ideal for the development of LAB and of other microorganisms. Also for this product, milk fermentation arises spontaneously from environmental microbes (Akabanda et al. 2010*)*, and therefore non-indigenous people consider its preparation unhygienic (Yahuza 2001): as a result, its consumption is limited to Fulani/Hausa indigenous (Obi and Ikenebomeh 2007; Adesokan et al. 2011). A similar product, *nunu* is produced in Ghana by the Fulani people; when mixed with a millet-based spontaneously fermented product and spices, the product is called *fura de nunu*.

In the north of Cameroon, in Garoua and Maroua, the most popular fermented milk is *pendidam*, a viscous, semi-liquid product from cow's milk, with a very sharp and sour taste. The high acidity and the heating process make *pendidam* stable at room temperature (Kameni et al. 1999). A similar product, *kindirmu*, is produced in Cameroon from cow's milk, but in this case the process includes the addition of *kindirmu* from a previous batch as a starter culture, and the final consistency is thicker, due to the high solids content of the boiled milk (Kameni et al. 1999).

In the Southern part of Africa, in particular in Botswana, cow's and goat's milk is naturally fermented to produce *madila*. The milk is fermented for 24 h and then added to previously fermented milk to produce a liquid or semi-solid curdled product, which is then often flavoured with fruit juice or artificial colourants (Ohiokpehai and Jagow 1998; Ohiokpehai 2003; Parry-Hanson et al. 2009).

In South Africa, Zimbabwe and Lesotho a well-known fermented milk is *amasi* (also known as *mukaka wakakora* or *zifa* among the Shona people; Mutukumira 1995; Mutukumira et al. 1995), which is consumed alone, with maize porridge or with ground sorghum between meals (Gadaga et al. 1999; 2000; McMaster et al. 2005; Todorov et al. 2007). In South Africa, it is also produced on a commercial scale (Schutte 2013). According to the description by Bryant (1967), to produce *amasi* a calabash is filled with fresh milk, covered and placed outside the hut. The whey is drained through a hole at the bottom of the calabash, whereas the calabash is filled with fresh milk again. After 2–3 h of fermentation, the curd is poured out as snow-white lumps. The specific container used, as well as the environmental conditions, contribute to the gradual selection of specific microorganisms that are responsible for the rich, full flavours that cannot easily be imitated by dairy starter cultures.

In Namibia, both Owambo and Herero communities produce a traditional fermented buttermilk known as *omashikwa,* which is prepared by fermentation of milk from indigenous zebus and consumed both as a refreshing drink and as a condiment for other foods. The traditional production of *omashikwa* starts from calabashes, gourds or plastic barrels which are filled with approximately 20 L of milk, with the addition of roots of the *omunkunzi* tree (*Boscia albitrunca*). As a starter culture, a portion from a previous *omashikwa* production is introduced. The fermentation lasts 2–3 days at 27–36 °C; after fermentation, the roots are removed and the product is manually shaken until the butter is formed and discarded, to obtain the remaining buttermilk (Bille et al. 2007). *Omashikwa* is usually thick and slimy in texture, with bitter and rancid taste and a peculiar rooty flavour.

Among milk fermented products, it is worth mentioning also the *Pokot ash* yoghurt (also known as *mala ya kienyeji* or *kamabele kambou*), which has been a Slow Food Presidium since 2009. This yoghurt is traditionally produced in Kenya from raw cow milk of local crosses between local cattle breeds and zebu or from goat milk. This product has a special aromatic taste and a characteristic bright grey colour, because it is mixed with the ash of a local tree, called *cromwo*, which is useful for its disinfectant properties (Slow Food Foundation for Biodiversity 2016).

Butter

Butter is produced in North (Algeria, Egypt and Sudan), East (Ethiopia, Burundi, Ruanda and Uganda) and West Africa (Nigeria) to preserve milk and prevent it from becoming rancid. Butter is important in the diet of children at weaning and for the elderly, both in rural and urban areas. In addition to providing calories in the diet, some products, like *samin*, produced in Sudan, supply also fat-soluble vitamins and are therefore given to persons frequently complaining faintness and to healthy pet camels and horses. *Samin* is also used as a remedy for some debilitating ailments, probably caused by energy deficiency (Abdelgadir et al. 1998).

Butter is also used as oil in traditional food preparation: for example, *samin* is poured on porridge, and the Ethiopian *kibe* is used in *wott*, the meat and vegetable stew eaten with *injera* (a pancake-like bread). *Shmen* (butter from Algeria) is used for roasting coffee beans in special traditional Tuareg ceremonies. Butters such as *amavuta* (Burundi), *kimuri* and *amacunda* (Rwanda) and also *shmen*, are also used as hairdressing

and skin cosmetics by both genders (Nsabimana et al. 2005).

Butter is usually produced by women from milk of different ruminant species (Table 1). In rural communities of the Saharan region, it is often made from camel milk (*semna* or *shmen* or *sman*). Some types of butter are produced for direct consumption, while relatively stable products, such as *kibe*, are offered in the rural markets, but also to urban communities. Distribution to provincial towns may be achieved through various channels, starting from the local market, where women sell *kibe* to small traders who transport it by donkeys to collection points up to 40 km from the market. From there, the product is taken to the wholesale markets in larger urban centres (Coppock et al. 1992). Some products are even exported to other African countries, as in the case of solid and liquid butter exported from Niger to Nigeria (Maazou 2013).

Butter is obtained by different techniques. Some techniques are based on the fermentation of milk at room temperature or at high temperature. Churning is often made by using traditional tools.

Regarding butter obtained at room temperature, the traditional Ethiopian butter (*kibe*) is always made by churning sour milk (*ergo*) instead of cream (Mekdes 2008; Gemechu and Tola 2017). Milk for churning is accumulated over several days in the traditional spherical earthenware churns (*wesso*). For 20–25 L of sour milk, 1–4 h of churning time are required, yielding about 1 kg of *kibe* (Gonfa et al. 2001; Gemechu and Tola 2017). The churn is usually smoked for reducing the heat processing time and increasing its storage time. 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 a piece of skin or leather stretched over the mouth of the *wesso* and securely tied. The churn is agitated using different methods. In the most common procedure, the churn is placed on a mat (a layer of grass, sheepskin or straw), and rocked forwards and backwards or, alternatively, suspended from a tripod or doorpost, or it is shaken. 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 (Gemechu and Tola 2017). The breakpoint (the point when butter starts to form) can be detected by a change in the sound of the shaken milk (Gonfa et al. 2001). *Kibe* has a white to light yellowish colour and is semi-solid at room temperature. It has a distinct flavour, because churning is usually smoked, and a pleasant taste and odour when fresh, but, with increased storage, changes occur in odour and taste, unless refrigerated (Mekdes 2008).

Also *amavuta* (Burundi) preparation involves the churning of *ergo* in a variety of vessels (Aloys and Angeline 2009). Preparation also involves the use of hot water. During *urubu* (fermented milk) production, butter is removed from soured milk which has been churned, and the buttermilk is consumed by the family or sold. Churning consists of rocking the container (gourds or clay pots) agitated back and forth until butter granules form. Frequently a straw is inserted through the vent into the churn. If small grains of *amavuta* adhere to the straw surface, the break point has been reached. When large granules are formed, the content of the churn is poured out into a calabash bowl. Cold water is added to the bowl to harden the butter granules, which are then scooped out of the buttermilk and subjected to the final working or kneading stage. Butter is placed in tin or copper containers and heated to around 100 °C to drive off the water. The content is constantly agitated throughout the process to prevent scorching. The heating has to be carefully controlled, especially when most of the moisture has been removed. *Zebda beldi* is a common raw butter from all North African countries (Benkerroum 2013). It is produced by churning spontaneously coagulated milk and separating it from the liquid fraction. It has a strong diacetyl flavour. A different kind of butter, *kimuri*, is produced in Rwanda from fermented milk (*kivuguto*) stirred for at least 2 h in a butter churn usually in the form of a calabash, where the milk is fermented. Bubbles are formed during stirring, in response to the activity of catalase. During churning, the fat from the *kivuguto* coalesces and the separation between liquid and solids becomes more marked. The fat is removed and the liquid left behind in the churn is buttermilk, a product that has a characteristically sour taste, caused by lactic acid bacteria involved in milk lactose hydrolysis during fermentation, and that can be consumed as such (Karenzi 2015).

Samin is made from fermentation of fresh milk in rural Sudan. It can be stored in certain earthenware jars (*kelol*) or simple leather bags (*tuggu*, *helbatib*), but also in a unique dark, heavy pot-like container called *butta*. This container is built from one of the compartments of a camel's stomach or from cow's rawhide and a mixture of ground, roasted sorghum grain, black gum (*kadaba*) and old rags as a source of cotton fibre. *Samin* is usually sold in glass bottles, as *buttas* are becoming rare.

Among butters produced by fermentation coupled with clarification (clarified butter, or *ghee*), using high

temperatures, we find the *semna* produced in Egypt, which is obtained by heating to 50–60 °C under continuous stirring, with 2–4% added salt. The addition of salt is claimed to decrease the water content of the resultant *semna* by increasing the boiling point of the water in the *ghee*. Abou-Donia and El-Agamy (1993) further reported that the addition of salt is believed to help in fat separation arising from the increased difference in density between fat and non-fat phases. Addition of salt also facilitates the precipitation of the proteins in the *ghee* residue during boiling (Sserunjogi et al. 1998). Another *ghee* is *samuli*, made by heat clarification of *mashita*, a milk-fat product produced by the Bahima tribe in Uganda. *Mashita* is made usually by the churning of raw fermented milk (*makamo*). *Makamo* is made in smoked gourds to which a starter from the previous batch has been added. The *makamo* is then churned to *mashita* (butter) in a large gourd by rocking it back and forth while held on the lap. The *mashita* is washed with water 3–4 times and then ripened in small gourds for 2–4 weeks. The *mashita* may be washed again during the ripening period to keep it free from off-flavours resulting mainly from the putrefaction of milk proteins. The *mashita* can be used as such or may be heat clarified to make *samuli*. To make *samuli*, *mashita* that has been collected over several days, is heated in an open aluminium saucepan with constant stirring. *Samuli* has a pleasant nutty aroma (Sserunjogi et al. 1998).

A liquid butter, called *nebam* in Fulani (or *man chanu* or *doungoulé* in Hausa and *ghee* in Zarma) is produced in Niger by heating the solid butter until evaporation of a certain quantity of water. *Nebam* shelf life ranges from 15 days in the cold season to 1 week in the hot season. It should be stored in gourds containing water or whey.

The clarified butter *shmen* or *semma* (FAO 1990; Asresie et al. 2013) is obtained by Tuareg in Algeria and Egypt from camel milk fermented for 24–48 h at room temperature in containers made of goat skin. Some cold water is added into the goat skin, in order to improve the firmness of the butter. After churning, the product is placed in a kettle and melted at 100 °C for 30 min. A clarifying agent (e.g. crushed dates or a grated, roasted piece of ram horn or also leaves of certain plants or seeds) is added to hot butter, which is then stirred with a wooden spoon. Heating destroys most of the bacteria and the clarifying agent collects the dirt and floats to the top, where it can be skimmed off. Another clarified butter is the Ethiopian *neter kibe*. The production process consists of the evaporation of the water from *kibe* by heating in an iron pan or clay saucepan. This product is actually more convenient than *kibe* in the tropics, because of its better shelf life under warm conditions. In fact, clarified butter can be preserved without any change for up to one year, depending on the moisture, humidity and temperature of the storage place (Gemechu and Tola 2017).

Some butters are dressed with spices, herbs or additional ingredients. For example, *neter kibe* can be dressed with spices, such as fresh leaves of *O. hadiense*, *O. basilicum*, mashed garlic (*Allium sativum*), mashed ginger (*Zingiber officinale*) and other herbs (Gonfa et al. 2001; Gemechu and Tola 2017), whereas *nebam* can be added with salt, onions and ginger. Also *kimuri* and its by-product *amacunda* (Rwanda) are sometimes seasoned with additional ingredients such as onions, garlic, etc. (Karenzi 2015). These products may be well preserved for a half-year or a full-year period, allowing the manufacture of a solid tasting yellow fat called butter or *amavuta akuze*, which is good for food preparation.

Dairy by-products

Different by-products derive from the manufacture of butter. Being rich in several nutrients, they serve to enrich the diet and are often consumed by all categories of people, and surpluses are often given to domestic animals. In general, by-products are not sold in the market for direct consumption and are consumed at household level.

Amateregwa is a by-product derived from the production of *amavuta* from *urubu* in Burundi (Nsabimana et al. 2005). Its appearance is slightly smoother and its consistency is finer than that of *amavuta*, although thicker than that of fresh milk. Freshly prepared *amateregwa* is a pleasantly sour product, with a characteristic buttery flavour. Little specks of tiny butter pieces are always afloat. With the conservation, the product loses its pleasant flavour and turns sourer, until the whey separates from the curd (Aloys and Angeline 2009). Another common by-product is *arrera* (defatted sour milk), deriving from the production of *kibe* from *ergo* (Bereda et al. 2014). *Arrera* is consumed in all parts of the Ethiopia where fermented milk is produced and serves as a beverage, either plain or spiced. It is consumed mostly by women as a side dish or as drink (FAO 1990). *Arrera* contains protein, residual fat, milk salts, lactic acid, lactose and vitamins (O'Connor and Tripathi 1992). Its colour is similar to that of *ergo*, from which it derives, but its appearance is slightly smoother and its consistency is finer, but it is thicker than fresh milk. It has a pleasant odour and taste. It is given to children during the weaning period and to

elderly people, and it is considered particularly important for children and women in rural areas. Furthermore, it may indirectly serve as additional income for women, who use it as raw material for producing cottage cheese (*ayib*), which may be sold in the market. With traditional fermented milk as typical raw material, all the steps for *arrera* production are similar to those of *ergo*. Fresh leaves of *Ruta chalepensis* var. *tenuifolia*, and *O. hadiense* are commonly added for flavouring, followed by mashed green *Capsicum annuum* and *A. sativum*. The liquid part of *arrera* after *ayib* removal is called *augat*, and is rich in protein and free amino acids. *Augat* contains about 0.75% protein (O'Connor and Tripathi 1992; Gonfa et al. 2001). Procedures and tools adopted for making *arrera* are also similar to those used for *ergo* and *kibe* production (Gonfa et al. 2001). *Amateregwa* and *arrera* can sometimes be smoked, but even after smoking they always have a shorter shelf life compared to fermented milk products. *Arrera* shelf life lasts only 24–48 h (Bereda et al. 2014).

Amacunda is a buttermilk produced in Rwanda that derives from *kimuri* butter production. It has a characteristically sour taste, caused by lactic acid bacteria involved in milk lactose hydrolysis during *kimuri* production (Karenzi 2015).

Conclusions

This review highlights the presence of an extraordinary range of African local products, ranging from fermented, fresh and ripened cheese, to butter and dairy by-products.

Tradition, culture and the environmental conditions and constraints play a major role in contributing to this diversification. Furthermore, the frequent absence of starter cultures results in an even wider diversification and lack of standardisation that may represent an obstacle to the commercialisation of these products.

Current production processes are not always able to guarantee safe hygienic procedures and may not warrant the correct storage of the products; as a consequence, some risks for human health may arise and this certainly represents a further limit for their commercialisation and also contributes to reduce the possibilities to export these products.

Only few products are being promoted and valorised, for example by their inclusion in Ark of Taste compiled by Slow Food, or by establishing Slow Food Presidia. Furthermore, very few attempts are made to value local breeds. The attention of Slow Food towards local breeds and dairy products should be encouraged, as it would be useful both for safeguarding biodiversity and increasing the economic value of local products.

Efforts should be made to support the dairy products chain in Africa, by making production processes safer and by valorising local resources, in order to expand the internal market and the export opportunities. Development cooperation projects have already played a role in this direction (Belli et al. 2013; Pistocchini et al. 2009), and should therefore be further encouraged.

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ORCID

Silvana Mattiello http://orcid.org/0000-0003-1885-949X
Mariangela Caroprese http://orcid.org/0000-0002-5292-3291
Crovetto Gianni Matteo http://orcid.org/0000-0003-1156-2087
Riccardo Fortina http://orcid.org/0000-0002-3949-4402
Andrea Martini http://orcid.org/0000-0003-1011-7352
Mina Martini http://orcid.org/0000-0002-0847-2841
Giuliana Parisi http://orcid.org/0000-0003-4646-6036
Claudia Russo http://orcid.org/0000-0001-6263-009X
Massimo Zecchini http://orcid.org/0000-0003-3161-4411

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