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A review of artisanal cheese making: An African perspective

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Abstract

Artisanal cheeses and other fermented milk products have long been part of the diet of African rural communities. Cheese is a source of nutrients that are essential to the development and growth of children in rural areas, where intake of amino acids, vitamin A, vitamin B₁₂, calcium, phosphate, and polyunsaturated fatty acids may be limited. Wara, Karish, Ayib, Takammart, Wagashi, Domiati, and Ras are prominent cheeses of African origin. Artisanal cheese making should be expanded to improve people's nutritional status at low cost, stimulate the local economy, and empower small-scale farmers. This review firstly gives an overview of artisanal cheese production and consumption, and evaluates opportunities and challenges, while focusing on an African perspective. Secondly, it provides an insight into strategies that could improve cheese making at small-scale level. Possible areas of research and knowledge gaps are highlighted, particularly ways of improving cheese quality and safety.

Keywords: cheese quality, fermented products, nutritional qualities, raw milk

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In 2018, total cow milk cheese production in Africa was 405 098 tonnes, which is only 2.1% of world average production. Most of this production was from Egypt (274 800 tonnes), South Africa (53 949 tonnes), South Sudan (30 965 tonnes), Tanzania (16 678 tonnes), Zambia (6 022 tonnes), and Ethiopia (5 033 tonnes). Milk production has increased worldwide, and it is projected to continue to increase 1.6% per annum to 997 Mt by 2029 (OECD-FAO, 2020). As a consequence, the production of dairy products such as cheese, butter, and whole and skim milk powders is expected to increase, creating new markets for these products (OECD-FAO, 2015). However, production and per capita consumption of milk and cheese are higher in developed countries than in developing ones (Mikkelsen, 2014). But this gap is reported to be narrowing because of population growth, dynamic economic developments, urbanization, income increase, and changing eating habits and lifestyle (Ndambi & Hemme, 2009; OECD-FAO, 2015). There is a shift in the structure of people's diets towards value-added dairy products such as cheese (Ronquest *et al.*, 2015). This is having a positive influence on the growth of artisanal cheese markets (Mulder & Wasserfall, 2013; Mikkelsen, 2014). Generally, in Africa, milk constitutes an important part of rural peoples' diet and is consumed fresh and processed at the household level (Gadaga *et al.*, 1999; Nzigamasabo & Nimpagaritse, 2009; Abdelgadir *et al.*, 2001). Fermentation is one of the oldest effective and inexpensive food preservation technologies that help in milk preservation and improve nutritional and sensory properties (O'Connor, 1993). There are many fermented artisanal milk products and consumption varies significantly among countries and regions because of social and cultural circumstances.

In African rural households, naturally soured milk is one of the most common fermented dairy products (Gadaga *et al.*, 1999). The sour milk is processed with traditional equipment and techniques according to the culture and region of origin (Gadaga *et al.*, 1999; Nzigamasabo & Nimpagaritse 2009; Abdelgadir *et al.*, 2001; Beukes *et al.*, 2001). In Zimbabwe, sour milk (*mukaka wakakora*) is processed at household level by leaving the fresh raw milk to ferment naturally at ambient temperature, mostly in earthenware pots, for 1 - 3 days and at times whey from previous batches can be added to speed up the fermentation process (Gadaga *et al.*, 1999). Similarly, *Urubu* a sour milk product from Sudan is processed using the same technique in earthenware containers (Aloys & Angeline, 2009). A slightly different technique is used for *Rob*, a fermented milk product from Sudan which is initiated by adding a starter from the fermentation of the previous day and

left overnight (Abdelgadir *et al.*, 2001). The milk is then churned after 24 hours in a leather container or a gourd from the *Lagenaria leucantha* plant. It is consumed as a drink or used for sauce making (Abdelgadir *et al.*, 2001). In some regions, sour milk is processed to products that resemble yoghurt and fresh cottage cheese (Gadaga *et al.*, 1999; Nzigamasabo & Nimpagaritse, 2009), with butter as a by-product (Abdelgadir *et al.*, 2001). However, the main challenge with these products in rural communities is their short shelf-life of two to three days. Thus, they cannot be stored for supplementation during lower milk production seasons. Processing of dairy products with a longer shelf-life, such as long-aged artisanal cheese types, therefore, assumes greater importance. Because cheese is a good source of essential amino acids, vitamin A, vitamin B₁₂, calcium, phosphate, and beneficial polyunsaturated fatty acids (López-Expósito *et al.*, 2012; Jerónimo & Malcata, 2016), this is an ideal way of preserving milk nutrients and helps fight malnutrition in vulnerable communities.

The overemphasis on economic challenges to small-scale farmers often overshadows the debate about potentiality of artisanal cheeses, which can be processed using local resources, with low input of ingredients and machinery (McSweeney *et al.*, 2004; Omemu *et al.*, 2014; Ombarak *et al.*, 2016). There is a need to evaluate the processing of artisanal cheeses in rural areas with appropriate economic approaches that consider the local people's social-economic status, culture, and region. Strategies that could improve farmers' productivity include technical training, indigenous knowledge development, mentorship, financial support and working as cooperatives. Cornelisse and Hyde (2017) highlighted that processing of value-added products, such as cheese, by small-scale farmers guaranteed a better income than the sale of raw milk. Fermented dairy products have been processed for years at household level and most of these skills have been modified and commercialized to meet the demands of people who moved to urban communities (Gadaga *et al.*, 1999; Beukes *et al.*, 2001). Projects aimed at rebuilding these practices in rural communities could improve people's nutritional status and income. The objectives of this review are i) to give an African perspective of artisanal cheese production and consumption, ii) to evaluate opportunities and challenges of artisanal cheese processing in rural areas, and iii) to provide insight into strategies to improve cheese making at small-scale level.

In this review the term 'traditional' is used to refer to cheese produced in a defined geographical area using specific know-how and skills, with little or no prior processing of the milk (Montel *et al.*, 2014). 'Artisanal' refers to products that are handmade in a customary way with little mechanization (Blundel, 2017). Processing techniques and recipes are passed from generation to generation through practical experience and observation (O'Connor, 1993). Over the years, cheeses have been processed with milk from species such as sheep, goats, buffalo, camel and cattle, but cattle have become the dominant dairy species around the world (Fox & McSweeney, 2004). In developing nations, cheese production and consumption are projected to continue to increase (Figure 1). Interestingly, the numbers show that production volumes are far lower than consumption, thus more needs to be done to meet the projected demand.

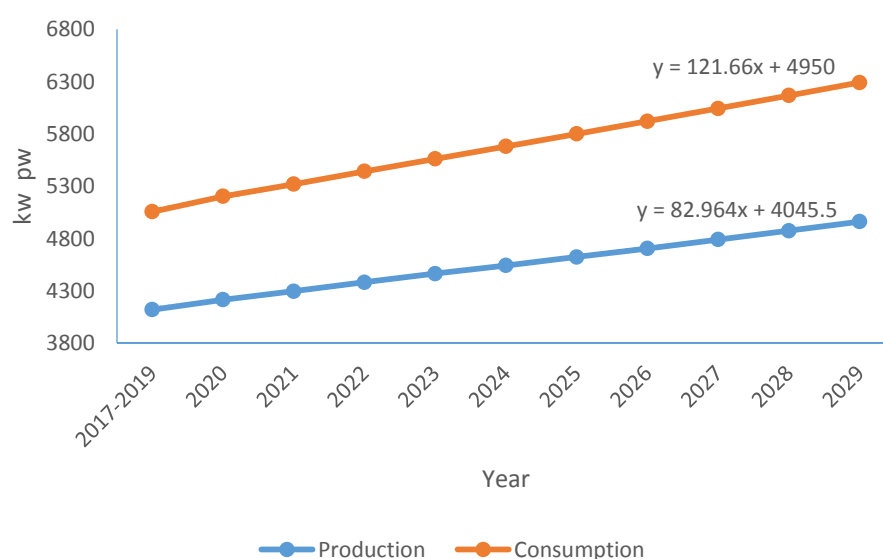


Figure 1 Projected trends of cheese production and consumption in developing nations (OECD-FAO, 2020)

The main steps in making cheese are acidifying, coagulating, separating curds and whey, salting, moulding, and ageing (Fox & McSweeney, 2004). Briefly, raw milk is heated to 37 °C and starter cultures such as *Lactobacillus delbrueckii* ssp. *lactis* and *Streptococcus thermophilus* are added to aid acidification (McSweeney *et al.*, 2004). The lactic acid dissolves the calcium phosphate from the micelles and aggregation influences the formation of a protein network (Lundin *et al.*, 2015). The milk is then coagulated with an animal or plant rennet. The enzymes eliminate the casein macropeptide from k-casein, and paracasein micelles start to aggregate, forming firm curds (Lundin *et al.*, 2015). The curds are then cut and packed in moulds to facilitate whey drainage and give a specific shape. After draining, the cheese blocks are salted using the dry salting technique or a solution (NaCl). Salt helps to develop flavour (Smit *et al.*, 2001), makes the curd firmer, and inhibits bacterial contamination (Atasoy, 2008). Fresh cheeses such as ricotta can be consumed after a few hours of cooling and whey drainage, whereas semi-hard and hard cheeses require weeks and months of ageing (Fox & McSweeney, 2004).

Demand and preference for cheese products differ from region to region and shifts have tended towards more natural and less processed artisanal products, with markets being affected by health-conscious consumers (Claeys *et al.*, 2013). The range of cheese types manufactured in different regions varies significantly because of processing technologies and social and cultural traits. Richer households in urban areas of Kenya consume significantly more milk and cheese than poor households, suggesting that consumption is related to income and availability (Njarui *et al.*, 2011). For the past few decades, cheese has penetrated bigger markets in most developing countries as an ingredient of fast foods such as pizza and burgers (Mikkelsen, 2014), and because of economic developments, changing eating habits, and increased availability (Ndambi & Hemme, 2009; OECD-FAO, 2015).

Keeping livestock and producing on-farm fermented milk products have long traditions in eastern and southern Africa (Franz *et al.*, 2014). In most sub-Saharan countries, on-farm cheese production and consumption are low, except for Sudan and Ethiopia, where there is a long tradition for fresh cheeses made at farm level (Mikkelsen, 2014). In South Africa, most cheeses have English, Italian, Dutch, French and Swedish origins (Mulder & Wasserfall, 2013), with Cheddar holding a greater share (31%) of the market, followed by Gouda (20%), and Mozzarella (Ronquest *et al.*, 2015). However, a few on-farm artisanal producers make cheeses such as Karoo Crumble, Ganzvlei Vastrap, Ficksburger, and Huguenot. There are limited scientific studies of the production, physicochemical and sensory properties of these cheeses.

Products that resemble cottage cheese are produced traditionally at household level in Ethiopia and Zimbabwe and are known as Ayib and Mukaka wakakodzekwa or Hodzeko, respectively (Gadaga *et al.*, 1999). Hodzeko involves pooling fermented milk from three successive days, from which whey and cream have been removed (Gadaga *et al.*, 1999).

Most of the predominant artisanal cheeses in East Africa and northern Africa are soft and are consumed fresh without ripening or are ripened for a few days (Table 1) and thus have a limited shelf-life. For example, Wara, which is produced and consumed as an important protein source in West African regions, has a shelf-life of two to three days (Adetunji *et al.*, 2008). For a longer shelf-life, cheeses can be preserved with techniques such as salting, smoking, drying, and adding natural preservatives. Lemon juice is used as a coagulant and a preservative in Wara cheese manufacture and reduces its *Enterobacteriaceae* counts significantly (Adetunji *et al.*, 2008).

In southern Algeria and Niger, hard cheeses that are sun dried are common and have a longer shelf-life of about three to six months (O'Connor, 1993). In addition to preservation, appearance is an important sensory attribute for consumers. The appearance of artisanal cheeses can be enhanced by coating them with vegetables and oils. For example, in Benin, Wagashi cheese is coloured with a hot solution of red sorghum (*Sorghum bicolor*) leaves and stems. These techniques give artisanal cheeses their authentic flavours, texture and unique sensory properties (Montel *et al.*, 2014). In addition, the distinct characteristics may be the result of factors such as milk chemical composition, local conditions, and processing skills and experience (Serhan *et al.*, 2010; Niro *et al.*, 2014).

Although in Africa the consumption of cheese and demand for cheese with specific characteristics is limited compared with Europe, several cheeses are believed to be indigenous to Africa (O'Connor, 1993; McSweeney *et al.*, 2004) (Table 1). These cheeses vary in the technologies that are used in producing them, such as cooking, stretching, pressing, using a starter culture, and preserving, and are consumed after various ripening periods. As a result, they express characteristics that give them their distinctiveness, which affects consumer preferences. Most cheese varieties in Table 1 are produced with raw cow milk, natural rennet, and starter cultures.

Table 1 Prominent cheese varieties that are indigenous to Africa

Name	Area of origin	Raw materials	Pasteurization	Starter culture	Characteristics	Ripening	Shelf life
Aoules	Southern Algeria	Goat milk	No	Soured naturally	Dry hard flat cylinder	Sun dried and rarely ripened	< 7 days
Ayib	Eastern Africa, Ethiopia	Sour or skimmed milk	No	Soured naturally	Crumbly soft cheese	Unripened, excess whey removed by heating to 75 °C	7 days at 4 °C
Braided cheese	Mediterranean Region, Sudan	Cow, goat or sheep milk	No	Rennet	Semi-hard, braided with close texture, slightly acid and salty taste	Unripened	3 - 6 months
Country cheese	Nigeria	Cow milk	No	Rennet	Hard, yellowish, smoked rind with small eyeholes, slightly acid and salty taste	Several weeks at 4 °C	6 - 12 months
Fromage blanc	Madagascar	Skimmed milk	Boiled for 5 min	Rennet	Soft fresh cheese with no rind, slightly salty	Unripened	< 7 days
Gibna	Sudan	Cow, sheep or goat milk or mixture	No	Natural bacteria and commercial rennet	Soft white cheese, slightly salty and sour and close texture	Unripened	< 7 days
Mashanza	Democratic Republic of the Congo	Cow milk	No	Natural bacteria	Soft white and ball shaped, no rind with big eyes, slightly sour taste	Unripened,	< 7 days
Mboreki Ya Iria	Kenya	Cow and goat milk	Boiled, cooled to ambient	No rennet or enzyme added	Soft fresh cheese, no rind, slight salty and sour taste	Drained overnight	< 7 days
Mudafara cheese	Middle East, Sudan	Cow milk	No	Natural bacteria and rennet	Semi-hard, no rind, slightly salty taste and plaited	Unripened, stored in brine in welded tins at 21 °C	3 - 6 months
Takammart	Southern Algeria	Goat milk	No	Kid dry abomasum	Dry hard cheese, flat square shape, dark brown in colour	Sun dried for 2–3 days and kept in shade afterwards	3 - 6 months
Tchoukou	Niger	Cow, sheep, goat or camel milk	No	Rennet from lamb or kid's abomasum or industrial	Hard milky-white, no rind, thin dry rectangle with close texture, mild taste	Sun dried, preserved in aerated baskets (Aznam) for 3 to 6 mnths	6 - 12 months
Wagashi	Mali, Niger, Burkina Faso, Ghana and Mauritania	Cow milk	Boiled for 3 to 5 min	Juice from crushed Bryophyllum stems	No rind, white with small eyeholes, slightly sour and salty	Unripened, kept in brine with 25% salt	3 days out of brine, 14 days in brine
Wagassirou	Northern Benin	Cow milk	Boiled for 1 hour	No	Soft fresh whitish, curved disk shape, close texture & slightly acid and salty	Unripened, preserved by salting, smoking or drying	1 mnths
Hodzeko	Zimbabwe	Cow milk	No	Fermentation by natural milk microbiota	Fresh cottage cheese-like	Unripened	< 7 days

Table 1 Prominent cheese varieties that are indigenous to Africa (continued)

Name	Area of origin	Raw materials	Pasteurization	Starter culture	Characteristics	Ripening	Shelf life
Ras	Egypt	Cow and/or buffalo milk	No	Fermentation by native microflora	Hard cheese	Ripened for few months	-
Wara	Nigeria	Cow milk	N	Extract of <i>Calotropis procera</i> or <i>Carica papaya</i> leaves	Soft fresh cheese	Unripened	2 - 3 days or 4 - 5 days in cool water
Karish	Egypt	Cow or a mixture of cow and buffalo milk	No	Natural acid coagulation	Soft fresh white cheese	Unripened	7 - 11 days, immersed in whey
Domiaty	Egypt	Cow or buffalo or mixture	Raw or pasteurized milk	Rennet and starter cultures are added	Pickled soft white cheese, salty	Consumed fresh or after pickling for 4 - 8 months	-
Klila	Algeria	Cow or sheep milk	Heated to 55–65 °C until whey is separated	Natural fermentation for 24 to 48 hours	White soft cheese	Consumed fresh or dried in open air for 2 - 3 days	< 7 days
Traditional Bouhezza	Eastern Algeria	Goat, sheep, cow milk or mixture	No	Natural fermentation for 24 to 72 hours	Soft, smooth, and spreadable texture: flavours are slightly salty, spicy, and acidic	Ripened in a natural and permeable goat skin bag (<i>chekoua</i>) for 2 to 3 months	-
Huguenot	South Africa	Cow milk	Pasteurized milk	Non-animal rennet	Semi-hard, brushed rind style moulded into huge golden cartwheels, nutty flavour	Minimum of 6 months	-

Adapted from FAO (1990), O'Connor (1993), McSweeney *et al.* (2004, 2017), Ramalho Ribeiro *et al.* (2006), Benkerroum (2013), Ibrahim *et al.* (2015), Benlahcen *et al.* (2017)

In some African regions, cheese is still produced as a farm-based operation under artisanal conditions, but information about the volume is limited. Artisanal cheeses such as Wara (Omemu *et al.*, 2014), Ayib (O'Connor, 1993), and Karish (Ombarak *et al.*, 2016) are produced on-farm on a small scale and mainly for family consumption or vending on the streets. Most artisanal cheese varieties are now produced in large highly mechanized factories to meet the growing demand in urban areas (Gadaga *et al.*, 1999; Beukes *et al.*, 2001).

Traditionally, the milk is fermented with natural native bacteria, animal rennet or plant extracts as coagulants (O'Connor, 1993; Mulder & Wasserfall, 2013). Karish cheese from Egypt is an example of a traditionally manufactured cheese using natural native bacteria, mainly the lactic acid in raw cow or buffalo milk (Ombarak *et al.*, 2016). The non-starter lactic acid bacteria in ripening cheese are responsible for flavour development (McSweeney *et al.*, 2004) and are found mainly in raw milk (Terzic-Vidojevic *et al.*, 2007). This gives artisanal cheeses a unique taste, which is not found in industrial cheeses. Kupiec and Revell (1998) noted that artisanal cheese consumers seek premium quality, uniqueness, and superiority in their food. Several studies regarding artisanal cheese sensory properties have been conducted (Awad, 2006; Hussein *et al.*, 2016; Shams *et al.*, 2020) and they show that their distinctive characteristics come partly because of raw material quality and processing technologies used. Traditional processing technologies are reported to give handmade cheese unique organoleptic attributes. Since production is done by hand, there is great variability in texture and flavour and little product standardization (Bemfeito *et al.*, 2016).

In some African regions, plant extracts from papaya (*Carica papaya*), pineapple (*Ananas comosus*), lemon juice (*Citrus limon*), castor oil seeds (*Ricinus communis*), fig trees (*Ficus carica*) and Sodom apples (*Calotropis procera*) are used as coagulants (Mikkelsen, 2014; Agossou Yao *et al.*, 2015). For example, Wara from West Africa is an unripened cheese that is coagulated with leaf extract from *C. procera* or *C. papaya* (Adetunji *et al.*, 2008). These plant extracts contribute to the sweeter flavour. However, industrial use of these plant extracts is practically non-existent because of the associated lower cheese yields and higher bitterness compared with commercial rennet (Amira *et al.*, 2017).

In addition, traditional cheeses can be found in colours that are unique to that variety. Prior to the use of annatto, an extract from achiote trees (*Bixa Orellana*) in Latin American countries and the Caribbean, in commercial factories cheese makers used vegetable dyes such as *S. bicolor* and olives (*Olea europaea*) to enhance the appearance (Mulder & Wasserfall, 2013). These natural food colourants are preferred as they offer health benefits such as antioxidative and antimicrobial properties (Sharma *et al.*, 2019).

The availability of local ingredients suggests that cheese could be produced successfully in rural communities. However, lack of standardization and poor hygiene standards present obstacles to the commercialization and export of most artisanal cheeses. To date, developments in the cheese industry include improved hygiene protocols and the use of commercial starter cultures, rennet and colourants (Johnson, 2017). These have resulted in the production of microbial safe products with a more consistent quality. Nevertheless, consumers in regions with a tradition of on-farm cheese processing favour their local products because of their nutritional benefits, palatable taste and affordability (Hammad *et al.*, 2015).

In rural areas, livestock rearing is still important in most people's livelihoods, with milk consumption forming an important part of their diets. Livestock are regarded as a measure of wealth in these communities (Bettencourt *et al.*, 2015). However, milk and cheese production are low, especially in developing countries (OECD-FAO, 2015). Focus must be put on greater milk and cheese production in these regions to promote and increase consumption, which depends partly on availability. South African (Kgatla & Moremi, 2013) and Nigerian (Yunusa *et al.*, 2012) governments tried to improve availability with schemes such as school feeding programmes with milk from local producers. These programmes promote healthy feeding for school children and support dairy farmers by creating niche markets.

Throughout history, cheese has been appreciated for its taste and benefits as a source of essential amino acids (López-Expósito *et al.*, 2012; Jerónimo & Malcata, 2016). Conjugated linoleic acid (CLA) has anticarcinogenic, anti-obese, antidiabetic and antihypertensive properties (Koba & Yanagita, 2014). Tchoukou cheese, which is produced by local people in Niger, is a good source of protein, zinc and calcium (Seini *et al.*, 2018). The high concentration of calcium in cheese contributes to the formation and maintenance of strong bones and teeth and shows a positive effect on blood pressure (Walther *et al.*, 2008). Thus, cheese has the potential to improve people's long-term health.

The forecast increase in demand for milk and cheese products in developing countries should be harnessed by small-scale farmers to raise production and their market share. Small-scale farmers produce milk for family consumption or sell to local communities at a relatively low price. This milk could be spared for cheese making, which would result in higher profit margins for these producers. Processing value-added products gives a better income than selling raw milk (Cornelisse & Hyde, 2017). Cheese can be processed from small quantities of milk. For example, 100 litres of milk can produce about 10 kg of a hard cheese (Fox *et al.*, 2017). If farmers are not able to produce at least 50 litres of milk for cheese making, they could work

as a cooperative. However, factors such as milk composition, the cheese-making process and time and size of curd cutting are linked to cheese yield (Janhoj & Qvist, 2010). Cheese yield per unit of milk processed is a key factor in the profitability of an individual business, thus improving milk yield would make cheese making more economically sustainable.

In regions that produce artisanal cheeses, there has been an increase in demand because of their taste, higher nutritional value and low prices (Hammad *et al.*, 2015). Moreover, tourists who visit African countries such as South Africa, Malawi, Mozambique, Rwanda, Uganda, and Tanzania have been reported to enjoy local cheeses (Mulder & Wasserfall, 2013). This opens up opportunities for local dairy producers. On the other hand, farmers should be able to meet the growing demand at minimum production costs for reasonable profits. Cheese production with cheaper local resources and ingredients could be used as a model to ensure sustainability. Several reports confirmed the practice of on-farm artisanal cheese making with local resources and ingredients in countries such as Egypt (Ombarak *et al.*, 2016), Nigeria (Omemu *et al.*, 2014), and Algeria (McSweeney *et al.*, 2004). Financial support should not present a major barrier to dairy farmers who want to venture into cheese making or to grow bigger to enter larger formal markets. On-farm cheese production does not require sophisticated machinery or equipment, which are usually out of reach of most farmers. Simple equipment such as firewood, ordinary pots and cutlery is enough. Stainless steel material is recommended, whereas wood and plastic materials are not recommended as they are difficult to clean (Vazquez-Fontes *et al.*, 2010). The milk pasteurizer is one of the largest and most expensive items of equipment for cheese processing (Bouma *et al.*, 2014). To overcome this challenge, in countries such as Zimbabwe, small-scale dairy farmers were grouped in milk collection centres where donor-funded pasteurizers were installed (Netherlands Development Organization (SNV), 2012). Alternatively, small-scale producers could use raw milk if they maintain proper hygiene standards to produce microbiologically safe products.

Another advantage in rural communities is the ability to use family labour. This reduces costs because small-scale artisanal cheese entrepreneurs could use family labour for building, processing, and management. However, as the business grows larger, family resources, particularly land and labour, may become insufficient (Ndambi & Hemme, 2009). Running a business as a family could be a problem because of poor planning, since a family is ruled mainly by emotions and equality, whereas a business should be economics and profit directed (Kgatla & Moremi, 2013). Therefore, proper management and planning strategies are important to maximize production and profits. Provision of technical expertise and indigenous knowledge development would help to open opportunities for successful cheese-making enterprises.

Milk production is seasonal, which affects farmers who cannot afford to buy animal feed supplements or have effective irrigation systems for their pastures. During peak production, small-scale farmers who lack electricity and facilities to preserve the milk are at a disadvantage and are forced to sell their milk at a lower price. Furthermore, they would have too little or no milk production in the low season (Holmann, 2001). In this situation the disadvantage is double, namely loss of nutritious food and of potential income. As was seen in South Africa, small-scale farms without cooling facilities cannot compete with commercial dairy farms, or influence the milk price, which is often established by the big distributors. The development of a small-scale artisanal cheese processing factory might be the key to sustainable production. To overcome milk price competition in favour of small-scale local producers, government empowered programmes or policies could be designed and implemented effectively.

Cheese plays a significant role in many cultures and economies. In Egypt, Nigeria and Algeria there are reports of ancient and current small-scale artisanal cheese processing (Akinyosoye, 2006; Nouani *et al.*, 2009; Ombarak *et al.*, 2016). Indigenous or artisanal cheeses in these regions are usually vended by women at local produce markets or sold at locations such as livestock markets (Omemu *et al.*, 2014). In Benin, the popular Peulh cheese is manufactured and sold mostly by women, while men are responsible for taking care of the animals in the fields (Kees, 1994). Cheese processing seems to open up opportunities for women empowerment, which increase income and influence over household expenditure, boosting social and economic capital. In Mozambique, Malawi, Rwanda, Uganda and Tanzania, artisanal cheese making has been reported to be a powerful tool to double family income and improve quality of life (Mulder & Wasserfall, 2013).

An increase in household income tends to encourage the consumption of milk and dairy products (Akaichi & Revoredo-Giha, 2014). This suggests that policies aimed at improving the income of poor people may boost their demand for dairy products and support their nutritional needs. In South Africa, demand for cheese has increased significantly because of expansion of income and urbanization (Ronquest *et al.*, 2015), resulting in greater social impact, and growing demand for cheese and wine from local consumers and tourists (Mulder & Wasserfall, 2013). Homemade cheese recipes are trending on national television (South African Broadcasting Cooperation), for example making ricotta with lemon juice or vinegar as coagulants. In addition, there seems to be an increase in small companies in South Africa (e.g., Finest Kind

Plettenberg Bay, Western Cape) that offer cheese-making courses, equipment and supplies for household cheese making. This has contributed to the growth of the South African cheese industry and many producers have received prizes at international level (Mulder & Wasserfall, 2013).

In other regions, dairy markets are reported to be changing rapidly, mainly because of increased exposure to a wider variety of food products. For example, people in Zimbabwe used to focus on making sour milk because it is consumed with their staple *sadza*, but now production of value-added dairy products such as cheese, yoghurt and ice cream has become popular (Brits, 2014). In Algeria, Kemaria cheese has a social impact as it is consumed at religious events such as Mawlid and Ramadan (Nouani *et al.*, 2009). These significant social roles played by traditional cheeses and their availability in African communities guarantee their potential to be developed. However, smallholder farmers in most developing countries face challenges that make it difficult to excel in the dairy industry.

Artisanal cheese entrepreneurs lack access to economic data for developing a credible business plan to help make decisions and profits (Bouma *et al.*, 2014, Durham *et al.*, 2015). Common financial problems include operational costs, poor record keeping, poor profit management, incorrect pricing, over-spending and too many debts and creditors (Axtell *et al.*, 2008). Kgatla and Moremi (2013) stated that it was difficult to convince smallholder farmers in South Africa to see dairy farming as a business because most of them did it informally. This suggested that if small-scale farmers were given access to business plans and finance they would excel in the cheese-making industry.

In African countries little work has been done to evaluate individual small-scale on-farm cheese-making plants from the start, with close monitoring and management of production costs. More studies need to be conducted with local facilities and equipment to have affordable estimates. Estimates for start-up and production costs for a cheese plant referred to developed countries such as the USA with more highly modified technology, equipment and expensive labour (Bouma *et al.*, 2014). Costs of dairy production must be low enough to eliminate foreign competition, and profit needs to be satisfactory so that farmers stay in business. To balance on-farm costs, producers could use whey, a by-product of cheese and casein production. Whey could be used as a nutritive animal feed supplement and producers could generate extra income by selling the product to other dairy farmers. Feeding whey on-farm improved animal water intake and provided energy, protein and minerals (El-Tanboly *et al.*, 2017). Care must be taken when handling whey to reduce chances of contamination and whey should be introduced gradually to animals to avoid digestive disorders, which would affect productivity. Additionally, farmers should have good marketing channels for their products.

Most small-scale artisanal cheese producers have limited access to better markets (International Fund for Agriculture and Development (IFAD), 2008). Markets can be a problem when a business is established in areas with low demand for cheese or with no tradition of including cheese in daily dishes. In Zimbabwe, when Kefalos Cheese was first established, the small artisanal family business faced market-related challenges and routine power cuts. The factory was based in an area where people viewed cheese as an expensive luxury (Brits, 2014). Their milk suppliers faced infrastructure challenges, such as poor road networks. This affected their initial growth significantly, but the company now produces much of the cheese in Zimbabwe (Kagoro & Chatiza, 2012). Small-scale and emerging producers need to be supported and well connected to commercial retailers in cities to overcome market-related challenges. Otherwise, these producers lack the technical know-how needed to be successful (FAO, 2018). Success stories include strong policy development components that allow links of small-scale dairy producers to inputs, capacity-building measures, and markets. In South Africa, the number of small-scale milk producers has decreased since 1997 because of market challenges and lack of support from authorities (Milk South Africa, 2014). When farmers have well established markets and financial guarantee, there is room for them to expand properly. However, farmers must have a more consistent milk and cheese supply. For the first few months, farmers will not receive an income from cheese making, since aged cheese is sold after at least 60 and 90 days. Nevertheless, significantly lower profits can be experienced during the dry season when milk production is lower (Holmann, 2001). In such cases, cooperative marketing would enable local small-scale producers to have a more consistent supply (Musemwa *et al.*, 2008). In addition, producers should be involved in the dissemination of information, which plays a critical role in access to formal markets. Success would be linked to good-quality nutritious and safe products. Care must be taken during processing to maintain the physicochemical and microbiological quality of the products.

There are many potential sources of microbial contamination during artisanal cheese processing, and bacterial load levels vary significantly according to animal health, microbial metabolic potential, environmental conditions, farm practices, personal hygiene and processing conditions (Montel *et al.*, 2014). These sources can be grouped as direct and indirect. Direct sources include the raw milk, animal teat, personnel hygiene, and dairy equipment. Indirect sources include animal feed, faeces, the milking parlour, and drinking and washing water (Montel *et al.*, 2014). These reservoirs interact with the microbial populations

from raw milk and starter cultures during processing, contributing to the overall microbial quality of cheese. Studies have assessed the microbiological quality of these sources (Scatassa *et al.*, 2015; Calasso *et al.*, 2016). Calasso *et al.* (2016) identified *Streptococcus thermophilus*, *Lactobacillus casei* and *Lactobacillus plantarum* as the most abundant bacteria on equipment used to process Caciotta and Caciocavallo Pugliese.

Milk microbiota is influenced strongly by overall farm management systems and processing conditions, which make it difficult to identify the influence of a single practice. For direct sources, teat care and sterilization of the equipment are of primary importance. Traditional cheese makers managed safety empirically by taking extra care, especially when using hand milking and wooden equipment (Montel *et al.*, 2014). But these processes do not guarantee safe hygienic products, thus posing human health risks and limiting the commercialization and export of artisanal products. Small-scale farmers who still use such practices need to be well trained and informed about food safety (Belli *et al.*, 2013). It is also important to monitor and maintain hygiene during ageing and storage. This is more important for producers that use raw milk, which has been reported to have bacterial populations such as *E. coli*, *Staphylococcus aureus* (Jakobsen *et al.*, 2011) and *Listeria monocytogenes* (Fox *et al.*, 2011; Lahou & Uyttendaele, 2017). Raw milk cheeses should not have *E. coli*, coliforms and aerobic colony counts that exceed 2.0, 4.0 and 7.0 Log₁₀CFU/g (Commission Regulation, 2005). *Salmonella*, *Staphylococcal enterotoxins*, and *Listeria monocytogenes* should not be present in a 25 g sample.

Small-scale processing plants usually apply improper hygiene processing procedures, which can lead to microbial spoilage of milk and dairy products (Belli *et al.*, 2013). Unhygienic practices were reported during handling and processing of Wara cheese in Nigeria, resulting in higher counts of pathogenic bacteria (Omemu *et al.*, 2014). Heating treatments such as pasteurization are commonly applied to the milk used in cheese-making to reduce or eliminate the risk of food poisoning, but may result in loss of authenticity in taste, aroma, flavour, and texture (Cilliers *et al.*, 2014). Besides making the milk safe for consumption and increasing shelf-life, Cilliers *et al.* (2014) found that heat treatment could result in changes in the nutritional value. Claeys *et al.* (2013) postulated that heat treatment resulted in negligible changes in essential amino acids, vitamins, and minerals of raw milk, but concluded that consumption of raw milk posed a realistic health threat because of possible contamination from human pathogens, and recommended heating milk before consumption.

Table 2 gives a detailed list of the prevalence of pathogenic bacteria in prominent artisanal cheeses sampled from retail shops and production factories across Africa. In addition, higher levels of *Enterococcus spp* (Hammad *et al.*, 2015) and *E. coli* (Omarak *et al.*, 2016) were reported in artisanal raw milk Karish cheese. Fox *et al.* (2011) noted that about 80% of selected farmhouse cheese-making facilities had samples (cheese, raw milk, processing, and external environment) that were positive for *L. monocytogenes*. Table 2 shows a higher prevalence of *Enterobacteriaceae*, *E. coli* and *S. aureus*, with a wide variation in numbers across studies. These variations can be attributed to factors such as milk quality and hygiene implementation during manufacturing, packaging, and handling (Belli *et al.*, 2013; Laba *et al.*, 2015). Precautions must be taken to improve hygiene and manufacturing techniques. This would help to improve domestic public health and enhance opportunities for international trade.

Best strategies for improving dairy farming lie in improved farmer education and engagement in training programmes for dairy product processing (FAO, 2018). These programmes should incorporate indigenous knowledge. Education could encourage farmers to work as cooperatives. This would help farmers who are struggling to produce enough milk for cheese making. Similar milk collection centres work well in Zimbabwe (SNV, 2012). Cooperation projects could expand internal market and export opportunities for African dairy products (Mattiello *et al.*, 2018). Agricultural cooperatives for cheese production could enable farmers to improve the product and quality of service and reduce risks. But small-scale milk production is characterized by low productivity because of genetic and nutritional constraints (Khan *et al.*, 2009). These affect cheese yields significantly. Therefore, general animal management schemes to improve productivity are important tools to help small-scale dairy farmers. These include animal nutrition in the form of feed and concentrates and pasture management to improve feed intake, milk yield and cheese products. Feed management should be improved so that animals are able to express their genetic superiority. The use of natural grazing and supplements rich in oils is one of the best and cheapest strategies to modify the milk fatty acid profile, resulting in cheese with higher α -linolenic acid and beneficial isomers of CLA and antioxidants compared with conventional production (Butler *et al.*, 2011).

Breeds play a significant role in animal performance and the quality of dairy products. Most communal and emerging farmers in South Africa use local cattle breeds such as Nguni and Afrikaner for dairy farming (Grobler *et al.*, 2008). Although these breeds are well adapted to the harsh local environment (Scholtz *et al.*, 2010), they are seldom suitable for dairy farming because of lower milk production compared with established dairy breeds such as the Jersey and Holstein. Muchenje *et al.* (2007) noted that smallholder milk production

Table 2 The prevalence of pathogenic bacteria in some prominent artisanal cheeses from selected African countries

Cheese type	Pathogen	Country	No of samples	% positive samples	Reference
Ras	<i>Enterobacteriaceae</i>	Egypt	60	51.7	Nosir <i>et al.</i> , 2014
Karish	<i>Enterobacteriaceae</i>	Egypt	60	100	Nosir <i>et al.</i> , 2014
Mudaffara	<i>Coliform</i>	Sudan	54	>50.0	Abdalla <i>et al.</i> , 2013
Ras	<i>E. coli</i>	Egypt	60	21.7	Ombarak <i>et al.</i> , 2016
Karish	<i>E. coli</i>	Egypt	55	74.5	Ombarak <i>et al.</i> , 2016
Artisanal Mozzarella	<i>E. coli</i>	Cameroon	42	>50.0	Belli <i>et al.</i> , 2013
Wara	<i>E. coli</i>	Nigeria	45	72.0	Laba <i>et al.</i> , 2015
Wagashi	<i>E. coli</i> O157:H7	Ghana	17	5.9	Kunadua <i>et al.</i> , 2018
Domiaty	<i>E. coli</i> O157	Egypt	50	4.0	Ibrahim <i>et al.</i> , 2015.
Klila	<i>Salmonella</i>	Algeria	8	0.0	Benlahcen <i>et al.</i> , 2017
Cottage cheese	<i>Salmonella</i>	Ethiopia	Unknown	0.0	Ejo <i>et al.</i> , 2016
Gibna	<i>Salmonella</i>	Sudan	24	0.0	Omer <i>et al.</i> , 2007
Tchoukou	<i>Salmonella</i> spp	Niger	13	0.0	Seini <i>et al.</i> , 2018
Domiaty	<i>Salmonella</i> spp	Egypt	50	4.0	Ibrahim <i>et al.</i> , 2015.
Wagashi	<i>S. enterica</i>	Ghana	17	17.7	Kunadua <i>et al.</i> , 2018
Wara	<i>Salmonella typhimurium</i>	Nigeria	45	10.0	Laba <i>et al.</i> , 2015
Klila	<i>S. aureus</i>	Algeria	8	0.0	Benlahcen <i>et al.</i> , 2017
Hodzeko	<i>S. aureus</i>	Zimbabwe	Unknown	19.0	Chimuti <i>et al.</i> , 2016
Gibna	<i>S. aureus</i>	Sudan	24	79.2	Omer <i>et al.</i> , 2007
Hodzeko	<i>Bacillus cereus</i>	Zimbabwe	Unknown	2.8	Chimuti <i>et al.</i> , 2016
Ayib	<i>Listeria</i> spp	Ethiopia	100	4.0	Gebretsadik <i>et al.</i> , 2011

could be improved by using Jersey and Tuli F₂ crosses. On the other hand, yield efficiency of cheese making comes from the use of milk with higher protein content and is achieved mainly through the promotion of cross breeds (Holmann, 2001), which would improve productivity and not through the introduction of established dairy breeds in African communities. The use of local breeds in extensive systems could promote the production of natural products and reduce the problem of protein intake in communities. The local cheese produced from three Nigerian cattle breeds (White Fulani, Muturu, and Red Borori) was noted as a good source of protein with good sensory properties that were acceptable to consumers (Yunusa, 2011). However, the main problem with these local breeds is low milk yield under low-input production systems (Muchenje *et al.*, 2007; Mapekula *et al.*, 2011). But farmers could use cooperative marketing to meet the higher volumes required for cheese production using local breeds (Musemwa *et al.*, 2008). Mapiye *et al.* (2007) concluded that in future group marketing and organic certification could result in higher profit margins for small-scale dairy producers. Feed supplementation with grown mixed crop silage improved milk yield (Muchenje *et al.*, 2007). However, the development of local dairy processing industries still needs a great deal of attention to improve the viability and sustainability of the sector.

In cheese production, the retail price, production scale and cheese type determine profit margins (Durham *et al.*, 2015). New producers should start by manufacturing cheese types that have lower production costs. Durham *et al.* (2015) suggested fresh high moisture cheeses, such as Mozzarella, have lower costs of production and can be sold faster at lower prices thus helping with cash flow. Aged cheeses require an additional investment for ageing space, making the payback period longer. In some regions, for example Ragusa (Italy), local producers transport their cheeses to a central ageing centre. The owner of the centre pays the farmers for fresh cheese and takes all the risk of ageing and selling (Licitra *et al.*, 1998). Besides helping to market the product, ageing cheese in the same environment produces more consistent and unique products specific to that area. Good-quality products are easier to market and build a stronger customer base to help grow internationally.

Small-scale cheese producers should use good marketing strategies including the use of social media to open market opportunities for their local products. The product information should be packaged in accessible and user-friendly forms (Musemwa *et al.*, 2008). This would improve sales and reach all classes of consumers. For example, the goat cheese from Jamtland was labelled 'local cheese' with a red heart, which marketed the product effectively in Sweden, although it was more expensive than industrial cheeses (Eriksson & Bull, 2017). The labels 'local' and 'small-scale' imply that the product is genuine, produced with care, and has local identity. Similarly, Kefalos Cheese rebranded many of its products and motivated people to buy 'Proudly Zimbabwean' (Brits, 2014).

Conclusion

The potential for expansion of the dairy sector through artisanal cheese making with small-scale farmers is significant. It is an opportunity for African communities to fight malnutrition and meet the nutritional requirements of people in rural areas at low cost. Artisanal value-added products are attractive because they would find a market for so-called natural products. Small-scale farmers fit this market well because consumers tend to favour local products as they are viewed as having local identities, possessing favourable sensory properties, and as being affordable. Lack of economic information and knowledge pose barriers to entry into small-scale artisanal cheese production. More research should focus on designing a cheese-making model for small-scale producers and disseminating the information properly. Although the farmers might face challenges, if supported with proper technical training and knowledge development, they could adopt the artisanal cheese-making model effectively.

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Authors' Contributions

FN, ER, and GE conceptualized and designed the work. FN carried out the literature search, wrote the article and revised it for intellectual content. KD read and commented on the whole text.

Conflicts of Interest Declaration

The authors declare there is no conflict of interest.

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