International Journal of Food Microbiology 250 (2017) 27–36

Contents lists available at ScienceDirect

International Journal of Food Microbiology

journal homepage: www.elsevier.com/locate/ijfoodmicro

Review

African fermented dairy products – Overview of predominant technologically important microorganisms focusing on African *Streptococcus infantarius* variants and potential future applications for enhanced food safety and security

Christoph Jans [a], Leo Meile [a], Dasel Wambua Mulwa Kaindi [b], Wambui Kogi-Makau [b], Peter Lamuka [b], Pierre Renault [c], Bernd Kreikemeyer [d], Christophe Lacroix [a], Jan Hattendorf [e,f], Jakob Zinsstag [e,f], Esther Schelling [e,f], Gilbert Fokou [g], Bassirou Bonfoh [e,f,g,]*

[a] *Laboratory of Food Biotechnology, Institute of Food Nutrition and Health, Department of Health Science and Technology, ETH Zurich, LFV C22, Schmelzbergstrasse 7, 8092 Zurich, Switzerland*
[b] *Department of Food Science, Nutrition and Technology, College of Agriculture and Veterinary Sciences, University of Nairobi, P.O. Box 29053, 00625 Nairobi, Kenya*
[c] *Micalis Institute, INRA, AgroParisTech, Université Paris-Saclay, 78350 Jouy-en-Josas, France*
[d] *Institute of Medical Microbiology, Virology, Hygiene and Bacteriology, Rostock University Medical Center Rostock, Schillingallee 70, 18055 Rostock, Germany*
[e] *Swiss Tropical and Public Health Institute, Socinstrasse 57, Basel, Switzerland*
[f] *University of Basel, Petersplatz 1, 4003 Basel, Switzerland*
[g] *Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), Km 17, Adiopodoumé, Rte Dabou, 01 BP 1303 Abidjan 01, Côte d'Ivoire*

ARTICLE INFO

Article history:
Received 17 November 2016
Received in revised form 16 March 2017
Accepted 20 March 2017
Available online 21 March 2017

Keywords:
Food fermentation
Lactic acid bacteria
Microbiota
Streptococcus bovis/Streptococcus equinus complex
Streptococcus infantarius
Milk production system

ABSTRACT

Milk is a major source of nutrients, but can also be a vehicle for zoonotic foodborne diseases, especially when raw milk is consumed. In Africa, poor processing and storage conditions contribute to contamination, outgrowth and transmission of pathogens, which lead to spoilage, reduced food safety and security. Fermentation helps mitigate the impact of poor handling and storage conditions by enhancing shelf life and food safety. Traditionally-fermented sour milk products are culturally accepted and widely distributed in Africa, and rely on product-specific microbiota responsible for aroma, flavor and texture. Knowledge of microbiota and predominant, technologically important microorganisms is critical in developing products with enhanced quality and safety, as well as sustainable interventions for these products, including Africa-specific starter culture development.

This narrative review summarizes current knowledge of technologically-important microorganisms of African fermented dairy products (FDP) and raw milk, taking into consideration novel findings and taxonomy when re-analyzing data of 29 publications covering 25 products from 17 African countries. Technologically-important lactic acid bacteria such as *Lactococcus lactis* and *Streptococcus infantarius* subsp. *infantarius* (*Sii*), *Lactobacillus* spp. and yeasts predominated in raw milk and FDP across Africa. Re-analysis of data also suggests a much wider distribution of *Sii* and thus a potentially longer history of use than previously expected. Therefore, evaluating the role and safety of African *Sii* lineages is important when developing interventions and starter cultures for FDP in Africa to enhance food safety and food security. In-depth functional genomics, epidemiologic investigations and latest identification approaches coupled with stakeholder involvement will be required to evaluate the possibility of African *Sii* lineages as novel food-grade *Streptococcus* lineage.

Contents

Abbreviations: FDP, fermented dairy products; GRAS, Generally Recognized as Safe; LAB, lactic acid bacteria; MLST, multi locus sequence typing; QPS, qualified presumption of safety; SBSEC, *Streptococcus bovis/Streptococcus equinus* complex; *Sgg*, *Streptococcus gallolyticus* subsp. *gallolyticus*; *Sgm*, *Streptococcus gallolyticus* subsp. *macedonicus*; *Sgp*, *Streptococcus gallolyticus* subsp. *pasteurianus*; *Sii*, *Streptococcus infantarius* subsp. *infantarius*.

* Corresponding author at: Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), Km 17, Adiopodoumé, Rte Dabou, 01 BP 1303 Abidjan 01, Côte d'Ivoire.
E-mail address: bassirou.bonfoh@csrs.ci (B. Bonfoh).

http://dx.doi.org/10.1016/j.ijfoodmicro.2017.03.012

1. Introduction

Milk is a very important source of nutrients. Historically, milk was mainly a key component in the diets of pastoral communities in Africa and particularly in sub-Saharan Africa, but increasingly milk also plays an important role in the diets of the growing population of sedentarized pastoralists as well as urban communities (Dirar, 1993; Fratkin et al., 2004; Wurzinger et al., 2009). Milk delivers high quality proteins, micronutrients, vitamins and energy-containing fat (Schönfeldt and Gibson Hall, 2012; Wuehler et al., 2011). The total annual consumption and demand for milk and animal products is increasing across sub-Saharan Africa due to population growth and changes in lifestyle such as urbanization (The World Bank, 2015). Products are often consumed raw, as well as in the form of traditional fermented dairy products (FDP) for extended shelf life. The microbiota of FDP greatly influences spoilage, food safety, food security and product characteristics. However, despite the long tradition of FDP in Africa (Franz et al., 2014), general knowledge of the unique aspects of the fermentative microbiota of these products has only recently been obtained. While the knowledge on zoonotic and foodborne diseases and hygiene aspects of dairy production in Africa is profound, a comprehensive overview of the fermentative and technologically important microorganisms of the microbiota of milk and FDP in Africa is lacking. This knowledge is pivotal to designing local, adapted starter cultures that could assist in enhancing food safety, food quality and eventually food security through FDP. Thus, this review is intended to provide the current status of knowledge of fermentative and technologically important microorganisms in African milk products, with a focus on the most recent developments and novel emerging *Streptococcus infantarius* subsp. *infantarius* (*Sii*) variants in sub-Saharan Africa. The review also envisages steps to evaluate the role and safety of the novel (*Sii*) variants in food fermentation. These findings are discussed within the context of recent changes in taxonomy, advances in microbiological tools, and laboratory technologies to provide recommendations for future work on microbiota analysis of novel fermented products in other settings based on the lessons learnt from *Sii* in African FDP. The findings are also embedded in the context of foodborne infectious diseases and the socioeconomic aspects of dairy production systems in Africa that are the basis of livelihoods for a large number of communities.

2. The various roles of livestock milk in Africa

Milk in Africa has a strong connection to pastoralists, who have a long tradition in dairy production (Ranciaro et al., 2014). An estimated 20 million pastoralists and 240 million agro-pastoralists live in sub-Saharan Africa (FAO, 2001); such pastoralists often have a mobile way of life to make new pastures available to their livestock. For pastoralists, milk is an important source of micronutrients, vitamins and energy-containing fat. Milk contributes 10% of the energy and more than 50% of the micronutrients, including vitamins A, B12 and C, to their diets (Iannotti and Lesorogol, 2014). In Chadian mobile pastoralists, milk was identified as the primary source for vitamin A (Bechir et al., 2012; Zinsstag et al., 2002). Milk further serves as a source of animal fat and thus provides energy to consumers (Schönfeldt and Gibson Hall, 2012), which highlights the importance of dairy livestock and their primary products to human nutrition in Africa.

In 2013, Africa was home to an estimated 304 million cattle, 333 million sheep, 364 million goats and 23 million camels of which an estimated 294 million cattle, 262 million sheep, 328 million goats and 22 million camels where located in sub-Saharan Africa (FAOSTAT, 2015). This visualizes the important contribution of sub-Saharan Africa to the African livestock sector. Livestock production is dominated (70–90%) by small scale and extensive livestock production systems (Bosire et al., 2015) in arid and semi-arid land areas (Bosire et al., 2015; Ndambi et al., 2008). Approximately 80–90% of the milk volume is produced and marketed through informal channels by smallholder dairy units and pastoral communities (Grimaud et al., 2009; Kamana et al., 2014; Noor et al., 2013). Total milk production in Africa was 49 million tons in 2013 and nearly doubled in sub-Saharan Africa during the last two decades to 33 million tons in 2013, with the majority being produced in East Africa (FAOSTAT, 2015). However, productivity per animal is significantly lower compared to industrialized countries; the increased production volume was mainly due to larger animal populations (Cardoso, 2012). In parallel, approximately 25–30% of the milk produced in sub-Saharan Africa is lost because of spillage and spoilage prior to reaching the consumer (Gustavsson et al., 2011). Local production is not sufficient to provide adequate milk for all consumers, and thus does not sufficiently contribute to food security or to meet the increasing demand. Thus, many sub-Saharan countries depend on imported milk or powdered milk, which account for 24–60% of the milk quantity consumed (Ayenew et al., 2009; Bayemi and Webb, 2009; Bosire et al., 2015; Kamana et al., 2014; Mapekula et al., 2009; Sanogo et al., 2013). This highlights the need to optimize local milk production and decrease losses along the milk value chain.

Milk is prone to microbial spoilage and can harbor a wide variety of foodborne and zoonotic agents (Quigley et al., 2013b). Sub-Saharan Africa and other less developed regions share a significantly higher burden of diseases by zoonotic agents than industrialized countries (Kirk et al., 2015). Key zoonotic and foodborne pathogens in milk such as *Staphylococcus aureus*, *Campylobacter* spp., *Clostridium perfringens*, *Clostridium botulinum*, *Bacillus cereus*, *Brucella* spp., *Listeria monocytogenes*, *Mycobacterium bovis*, *Salmonella* spp. and Shiga-toxin producing *Escherichia coli* are important contributors to the high foodborne disease burden in sub-Saharan Africa (Havelaar et al., 2015; Jans et al., 2017; Kirk et al., 2015).

Raw milk is a major contributor to humans contracting bovine tuberculosis and brucellosis (Dean et al., 2012; Müller et al., 2013). Bovine tuberculosis caused by *M. bovis* is estimated to yield seven cases per 100,000 population/year in developing countries. This is significantly higher compared to 1 case per 100,000 population/year in developed countries (Müller et al., 2013). Similarly, brucellosis caused by *Brucella* spp. has an estimated 34 cases per 100,000 person years among mobile pastoralists vs. 0.02–0.09/100,000 in developed countries (Dean et al., 2012; Dean et al., 2013). *Streptococcus agalactiae*, a pathogen less recognized for its zoonotic potential, was detected in Kenyan camel milk at 10^7 CFU/mL at the consumer level, which might pose additional health