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Review Article

A Compilation of the Traditional Processing Techniques and Microbiome in Ghanaian Fermented Milk Products

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Abstract

Traditional milk fermentation is an integral part of Ghana's food heritage, contributing to both the nutrition and cultural identity of the people. Fermented milk products are of great importance in that they help in alleviating lactose intolerance, have social value and serve as a means of generating income for the producers. The benefits of fermenting foods nowadays extend to inhibiting pathogenic microorganisms while also enhancing the nutritional value and digestibility of foods. Various traditional fermented milk products are produced and consumed in Ghana. These include *nunu*, *wagashi* (soft cheese), *brukina*, and *nyarmie*. Milk fermentation in Ghana is usually by spontaneous fermentation and these fermented products contain rich and valuable microbial diversity, dominated by lactic acid bacteria and yeasts. A Comprehensive knowledge of the traditional production processes and microbiological aspects of these products is critical for the development of products with enhanced quality, safety and health benefits for sustainable food security in Ghana and elsewhere. This review aims to provide a comprehensive compilation of the fermentation processes of these products and the associated microbiome. The documentation of these products will go a long way to establish a foundational reference point, providing a basis for future research in Ghanaian milk processing and standardization efforts.

Keywords

Fermented Milks, Ghana, *Brukina Nunu*, *Wagashi*, *Nyarmie*

1. Introduction

Fermentation is an age-old food processing method that modifies food materials. Due to its ease of use, low cost, and limited environmental impact, fermentation has been widely used in almost all countries in the world [1, 2]. Food fermentation, as a processing technique, involves transforming raw food ingredients into various value-added products through the processes of microbial growth and their activities on different substrates. The benefits of food fermentation now extend to inhibiting pathogenic microorganisms while also enhancing the nutritional value and digestibility of foods [1].

Milk has been preserved since ancient times through the process of fermentation. Before the introduction of modern refrigeration, milk and other raw food products were preserved by fermentation [3, 4]. Fermented milk products are of great importance in that they help in alleviating lactose intolerance, have social value and serve as a means of generating income for the producers [5]. The art of making these products is handed down from generation to generation from mother to daughter [6].

Various traditional fermented milk products are produced

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and consumed in Ghana. These are *nunu*, *wagashi* (soft cheese), *brukina*, and *nyarmie* [6-8]. A thorough understanding of the production processes and microbiological aspects of these products is essential for developing high-quality, safe, and health-promoting products that contribute to sustainable food security. This review seeks to provide a compilation and overview of the fermentation processes of these products, and their associated microbial communities.

2. The Traditional Processing of Ghanaian Fermented Milk Products

2.1. Nunu

Akabanda et al. (2010, 2013) described *nunu* as the generic Hausa term for spontaneously fermented, yoghurt-like milk product in Ghana, made exclusively from cow's milk. It can be consumed on its own or enjoyed with sugar and *fura* [9].

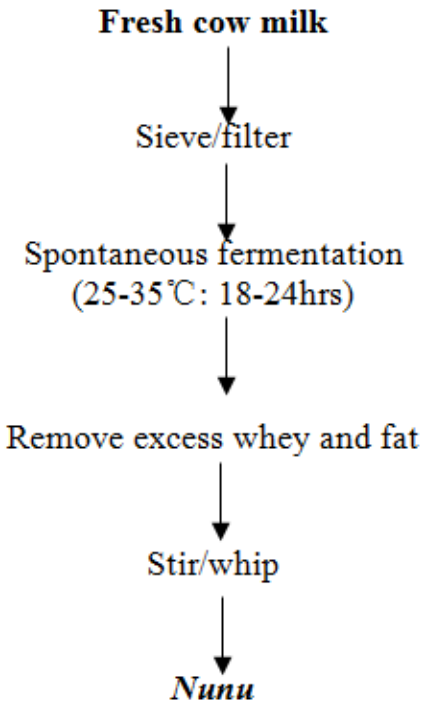

Figure 1. *Traditional processing of Ghanaian Nunu.*

During the traditional processing of milk into *nunu* (Figure 1), fresh cow's milk is collected in calabashes or plastic containers. It may be sieved or filtered to remove animal fur and other impurities that may have entered the milk during collection and handling on the farm. The sieved milk is then allowed to spontaneously ferment. The duration of the milk fermentation varies depending on seasonal temperature fluctuations. During the hot season, typically from March to June, ambient temperatures reaching approximately 35 ℃ accelerate acidification, allowing the fermentation process to be completed within 12 to 24 hours. Conversely, in the colder months from October to February, when temperatures range between 15 and 17 ℃, fermentation can extend up to 48 hours. Additionally, during the dry season, when limited grazing results in reduced milk production, smaller quantities of milk are often added to the previous day's batch, illustrating a traditional back-slopping technique. The fermented milk is churned using a wooden ladle, causing the fat to separate and accumulate, which is then removed. Excess whey is drained off, resulting in a thick, creamy product known as *nunu*. The consistency of *nunu* varies from smooth and uniform to a product containing suspended milk curds. It typically exhibits a viscous texture with a white-to-yellowish appearance [7, 10]. *Nunu* remains consumable for 4–5 days at ambient temperature without refrigeration or can be stored at 4 ℃ for several weeks. It is commonly consumed as a standalone beverage or combined with *fura*, a fermented cereal-based dough, to form a nutritionally balanced meal [8, 11]. The demand for *nunu* usually peaks during the muslin month of Ramadan, as it effectively quenches thirst and provides nourishment, particularly in hot climates [1, 7, 8, 12].

2.2. Nyarmie

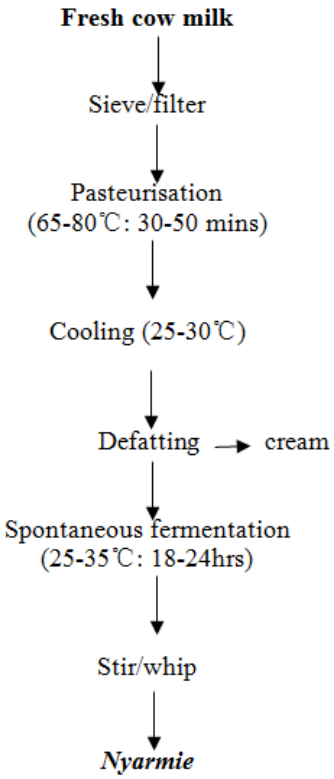

Figure 2. *Traditional processing of Ghanaian Nyarmie.*

In the traditional processing of nyarmie (Figure 2), fresh cow's milk is collected and passed through an aluminum

strainer or cheesecloth to eliminate animal fur and other impurities. The milk is then pasteurised by cooking in aluminium pots at 65–75 ℃ for 30–50 min, following pasteurisation, the milk is allowed to cool at room temperature, after which the fat accumulating on the surface is collected. The pasteurised milk is transferred into calabashes or plastic containers, covered with a lid, and left to undergo spontaneous fermentation at ambient temperatures ranging from 28 to 35 ℃ for approximately 18 to 24 hours. This natural fermentation process leads to the formation of curdled milk. Excess whey may be removed, after which the curd is vigorously stirred or whipped using a wooden stirrer, resulting in a thick, creamy, and slightly sour yoghurt-like product with a set-style consistency [6, 12].

2.3. *Brukina*

Brukina is a traditional Ghanaian beverage made from fermented milk and millet. *Brukina* has gained significant popularity in Ghana and is regarded as one of the most successful Indigenous dairy-based beverages. It competes favorably with yoghurt and other widely consumed local drinks [13, 14].

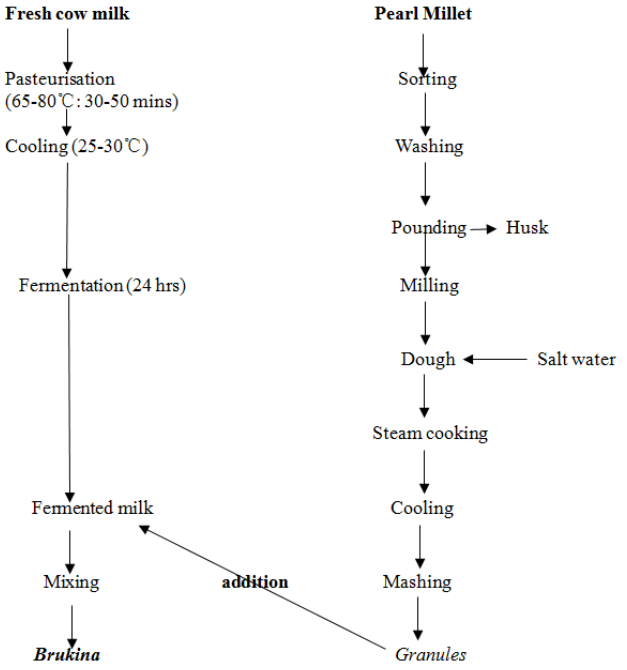

Figure 3. *Traditional processing of Ghanaian Brukina.*

In the traditional processing of *Brukina* (Figure 3), pearl millet undergoes careful sorting to remove stones and other debris. The millet is then thoroughly washed, air-dried, and pounded in a mortar to remove the outer husk (epidermis) before being ground into a fine powder. A salt solution is prepared and evenly sprinkled over the millet flour to ensure uniform mixing. The milled millet is then subjected to steam cooking until it forms a compact dough. Once cooled, the dough is manually mashed using a masher to break it into smaller, coarse granules. Margarine is incorporated into the granules to enhance uniformity and improve taste. The prepared granular millet is then stored in a container to be added to the fermented milk [15, 16, 21]. The milk used in the processing of *Brukina* may be sourced from fresh cow's milk or reconstituted from imported milk powder. Regardless of the source, the milk is first boiled to eliminate potential contaminants before being transferred into a plastic basin. It is then allowed to cool at room temperature, and then fermented spontaneously or inoculated with starter cultures derived from previously fermented milk for 24 hours. Once fermentation is complete, the granulated millet is incorporated into the cultured milk and mixed to achieve the desired consistency, yielding the final *Brukina* product.

2.4. *Wagashi* (Soft Cheese)

The processing of *Wagashie* (Figure 4) involves the use of extracts from the Sodom apple plant (*Calotropis procera*) as a natural coagulant. Fresh milk is first filtered and gently heated to a temperature range of 50–70 ℃. The extract from *C. procera* leaves or stems is then added to the warmed milk, stirred thoroughly, and further heated at the same or slightly elevated temperature until coagulation occurs. The curd formed is allowed to boil for about 20 min before draining in a raffia or plastic basket, or mesh strainers, to facilitate the separation of the whey. The resulting milk curds are then moulded into round or oval shapes ready for consumption and can be eaten in raw form, fried, or cooked, often serving as a substitute for meat in various dishes [17, 18].

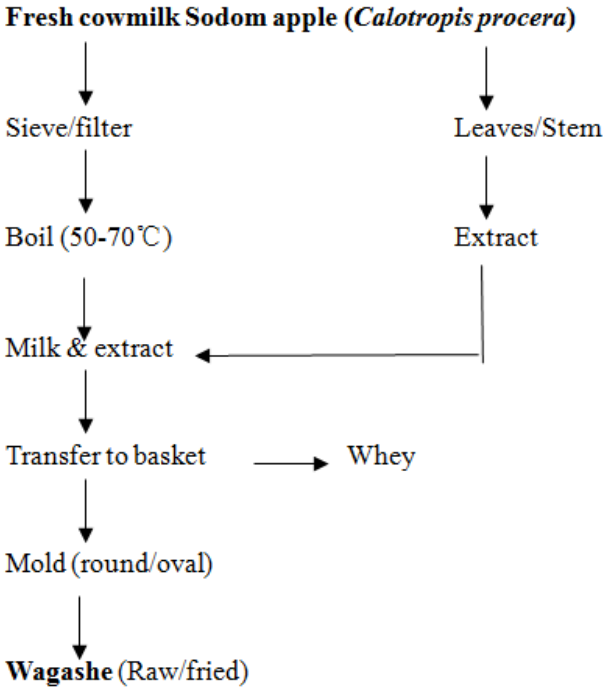

Figure 4. *Traditional processing of Ghanaian Wagashi.*

3. Microbial Communities in Ghanaian Fermented Milk Products

Research utilizing both culture-dependent and culture-independent approaches has identified a diverse range of microbial communities in Ghanaian fermented milk products. These microorganisms play a crucial role in acidification, flavor development, and texture modification during fermentation [6-8] which ultimately shapes the quality, safety, and overall characteristics of the final product [1].

Since milk fermentation in Ghana depends on natural fermentation or back-slopping, various external factors—such as regional and local climatic conditions (season and temperature), the quality and composition of the raw material, and the fermentation duration—affect the composition and activity of the microbial community during the process [7, 19], These factors, in turn, contribute to the distinct organoleptic [1] and functional properties of the final products.

Table 1 presents the microorganisms isolated and identified in traditional fermented milk products from Ghana.

Arthur et al., (18) 16S rRNA sequencing of bacterial communities in *brukina*, revealed the abundant presence of *Firmicutes* followed by *Proteobacteria*. Other phyla present were *Deinococcus Thermus*, *Bacteriodetes*, and *Actinobacteria*.

Lactic acid bacteria (LAB) and yeast species dominate *nunu* in Ghana [7, 8]. Akabanda et al. (8) investigated the taxonomic diversity of LAB and yeasts in nunu fermentation using both phenotypic and genotypic methods. Their study revealed that *Lactobacillus fermentum* is the dominant species throughout the fermentation process, while *Lactobacillus plantarum* and *Leuconostoc mesenteroides* also play significant roles. Less commonly isolated LAB included *Lactobacillus helveticus*, *Enterococcus faecium*, *Enterococcus italicus*, and *Weissella confusa*. The yeasts associated with nunu fermentation comprised *Candida parapsilosis*, *Candida rugosa*, *Candida tropicalis*, *Galactomyces geotrichum*, *Pichia kudriavzevii*, and *Saccharomyces cerevisiae*, with *P. kudriavzevii* and *S. cerevisiae* being the predominant yeast species.

PCR-DGGE analysis of nyarmie samples revealed that LAB dominated the microbial community, with *Leuconostoc mesenteroides ssp. mesenteroides*, *Streptococcus thermophilus*, *Lactobacillus delbrueckii ssp. bulgaricus*, *Lactobacillus helveticus*, *Lactobacillus delbrueckii ssp. lactis*, *and Lactococcus lactis* being the most prevalent. Among the yeast species, *Saccharomyces cerevisiae* was the dominant species. [6].

Basic microbiological assessment of *wagashe* indicates the presence of Bacillus *cereus*, *E. coli*, Coliforms, and Enterobacteriaceae [1].

During the fermentation process, these microbial species interact with each other to positively contribute to products. The production of essential growth metabolites, such as amino acids and vitamins, or through lactose and galactose metabolism, proteolysis, lipolysis, and enzymatic degradation, contributes to flavor development [1, 20].

Table 1. *Microorganisms From Fermented Milk Products in Ghana.*

Product name	Microorganisms	Method of identification	Reference
Brukina	*Firmicutes (Lactobacillus, Streptococcus, Leuconostoc, Lactococcus and Weisella, Sarcina, Geobacillus), Proteobacteria (Enterobacter and Yersinia), Deinococcus-Thermus, Actinobacteria, Bacteriodetes*	16S rRNA sequencing technique	(21)
Nunu	*Lactobacillus fermentum*, *Lactobacillus plantarum*, *Lactobacillus helveticus*, *Leuconostoc mesenteroides*, *Enterococcus faecium*, *Enterococcus italicus*, *Weissella confusa*, *Candida parapsilosis*, *Candida rugosa*, *Candida tropicalis*, *Galactomyces geotrichum*, *Pichia kudriavzevii*, *Saccharomyces cerevisiae*	Basic phenotypic characterization followed by GTG-5 fingerprinting and 16S rRNA gene/26S rRNA gene sequencing	(8)
Nyarmie	*L. mesenteroides* ssp. *mesenteroides*, *Staphylococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *L. helveticus*, *L. delbrueckii* ssp. *lactis*, *Lactococcus lactis*, *L. delbrueckii* ssp. *delbrueckii*, *S. cerevisiae*, *Trichosporon cutaneum*	16S and 18S rRNA gene DGGE, API 50 CHL, API 20 STREP, API 20C AUX	(6)
Wagashe	*Bacillus cereus*, *E. coli*, *Coliforms*, *Enterobacteriaceae*, yeasts and molds	Basic phenotypic characterization	(18)

4. Conclusion

This review presents an overview of the traditional production processes and microbiological composition of Ghanaian fermented milk products. These products are usually process via spontaneous fermentation and so contain rich and valuable microbial diversity, dominated by lactic acid bacteria and yeasts. There has been detailed molecular characterization of the microbiota in some of the products but there need to be further research on the others and also research to development permanent starter cultures for these products.

The consumption of these fermented milk products can contribute significantly to lifelong health and help combat protein-energy malnutrition in infants. They serve as valuable sources of minerals, vitamins, essential amino acids, and probiotics, particularly benefiting underprivileged communities in Ghana.

Abbreviations

LAB	Lactic Acid Bacteria
rRNA	Ribosomal Ribonucleic Acid
PCR-DGGE	Polymerase Chain Reaction-Denaturing Gradient Gel Electrophoresis
DGGE	Denaturing Gradient Gel Electrophoresis
API	Analytical Profile Index

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Author Contributions

Fortune Akabanda is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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