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Towards valorisation of indigenous traditional fermented milk: mabisi as a model

Himoonga Bernard Moonga[1,2,3,4], Sijmen E Schoustra[3,4], Anita R Linnemann[2], John Shindano[4] and Eddy J Smid[1]

Africa has a rich cultural heritage that is accompanied by rich traditional foods. Some of these foods are preserved by traditional fermentation processes, which are transferred from one generation to another. Fermentation is a low-cost technology, which converts raw materials into final products with improved nutritional value, organoleptic properties and extended shelf life. These traditional fermented foods are widely consumed in both rural and urban areas. This review uses mabisi, a traditional fermented milk product from Zambia to demonstrate the importance of indigenous knowledge of mabisi processing in the valorisation process with a view towards upscaling of not only mabisi but also other similar traditional food products. It highlights the different types, product characteristics and microbial communities of mabisi.

Addresses
[1] Laboratory of Food Microbiology, Wageningen University and Research, P.O. Box 17, 6700 AA Wageningen, The Netherlands
[2] Food Quality and Design, Wageningen University and Research, P.O. Box 17, 6700 AA Wageningen, The Netherlands
[3] Laboratory of Genetics, Wageningen University and Research, P.O. Box 17, 6700 AA Wageningen, The Netherlands
[4] Department of Food Science & Nutrition, School of Agricultural Sciences, University of Zambia, P.O. Box 32379, Lusaka, Zambia

Corresponding author:
Himoonga Bernard Moonga (bmoonga@unza.zm)

Abbreviations: LAB, Lactic acid bacteria; TMPR, Traditional mabisi production regions; TFMP, Traditional fermented milk products

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Introduction

Traditional fermented milk products play an important role in the diet and nutritional security of not only rural households but also an increasing number of urban households in Africa. Just like other fermented dairy products, such as cheese, are important in the western diets, so is mabisi in Zambia. Cheese has been studied extensively and has many varieties, which can be differentiated in geographical indications (GI) (Emmentaler cheese, Parmigiano reggiano, Gouda cheese, Cheddar, etc.) or as a function of production method/kind of cheese (soft or hard cheese, unripened or ripened cheese) [1–3]. Moreover, research has been carried out on the development of starter cultures, aroma and texture, as well as production process optimisation, which has resulted in more assorted cheeses that are standardised and meet consumer's expectation [3–7].

Traditional fermented milk products in Africa have similar potential. There are several types of these products in sub-Saharan Africa, which include amasi, argo, omashikwa, mursik, kivuguto, lait caille, nunu and mabisi [8–17]. Unlike cheese, most of these are fermented milk products that flow, do not require brine for fermentation and are more comparable to yoghurt and kefir than to cheese. The market penetration of fermented products such as yoghurt in Africa suggests that the market possibilities for newly developed or optimised unique African fermented dairy products are high.

This opinion paper describes the application of indigenous knowledge of traditional fermented foods towards process optimisation and upscaling production using mabisi, a traditional fermented milk from Zambia as a model. Mabisi is an archetypical example of a milk-based traditional fermented food. Using this as a model in describing how its traditional processing could be optimised and valorised, such as for the development of (mixed) starters, will be of relevance to many other traditional fermented foods.

Types of mabisi and its uses

Mabisi is a product made through a spontaneous fermentation process of raw milk at ambient temperature for about two days (Figure 1) [18,19]. The product is stable for several days at room temperature. It is a popular product consumed by all age groups in both rural and urban households in Zambia.

The indigenous knowledge of mabisi production practices and the uses of the product were investigated

Figure 1

Images of: **(a)** calabash (gourd), a container traditionally used for mabisi fermentation, **(b)** a metal container with mabisi and **(c)** mabisi in a cup and plastic bottle.

through a countrywide survey by Moonga, Schoustra [18], in which it was discovered that there were seven different methods of production as opposed to the suggestion that one unique method exists as earlier reported by Schoustra, Kasase [19]. These methods were coined as tonga, barotse, backslopping, creamy, cooked, illa and thick-tonga types, with tonga type identified as the most popular. The names: tonga, barotse and illa relate to either the tribe or location mostly associated with the type of mabisi while the other names are associated with either a brief description of how the mabisi type is produced or with a key sensory property. This study further identified the key production parameters as type of fermentation container, backslopping, alternate removal of whey and addition of raw milk, agitation (churning), boiling and cooling, and fermentation temperature. Mabisi was found to be a versatile product with a wide range of uses, that is, mostly consumed with maize porridge, boiled grain or tubers, fruits, as a beverage or used for cooking (Table S1).

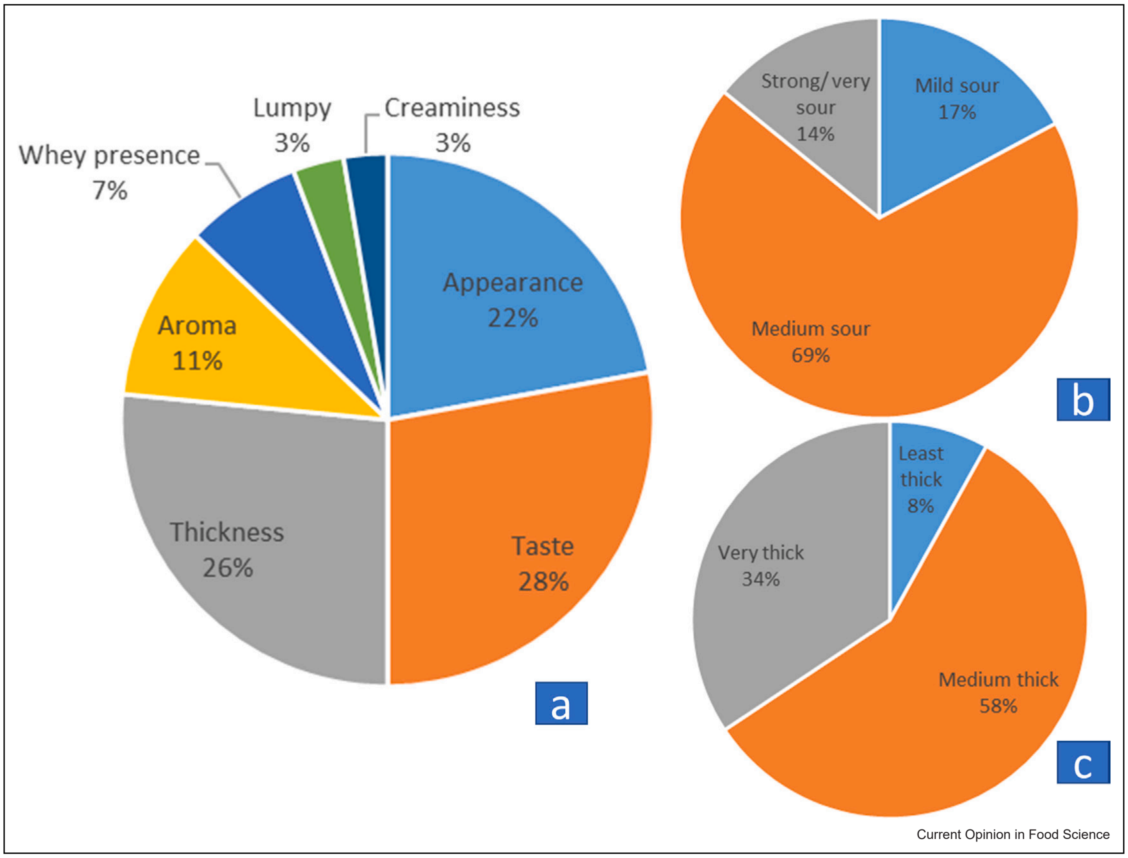
Product quality and consumer preferences and perceptions

Product quality is a critical aspect of product optimisation as it defines the key attributes of the product, which are important to the consumer. A study by Moonga [20] found that the quality attribute which was ranked highest by consumers in determining the best quality of mabisi was taste, followed by thickness (consistency) and then appearance (Figure 2a). Others were aroma, whey presence (syneresis), lumpiness and creaminess. The taste was evaluated on the basis of the degree of sourness, which was divided into three categories: mild, medium and strong (Figure 2b) as well as the consistency (Figure 2c).

The findings from another countrywide study on the pH of mabisi samples showed that the pH ranged from 3 to 5 with an overall mean of 4.16 ± 0.31, which is similar to amasi [21–23]. Using these data, the three levels of sourness can be divided into three pH ranges (Table 1), which, when combined, gives more information about the consumer preferences of the product and can be used as a target for production protocol or standard development. This table provides the basis for the classification of mabisi based on acidity which is associated with taste and can be used for product differentiation and description.

For consistency, a classification system was developed to grade mabisi into four different classes of thickness: class 1 ('very thick'), class 2 ('thick '), class 3 ('medium') and class 4 ('thin') [24]. This classification was based on the diameter of spread of mabisi in centimetres using the Adam's consistometer (Table S2). Recent studies show that barotse mabisi is either 'very thick or thick', tonga mabisi is 'thick to medium', backslopping mabisi is 'medium to thin' while illa mabisi is 'thin' [20,24]. Thus, when describing the most preferred type of mabisi that has a medium sour taste and consistency, this implies a product with pH 4.4–4.0 and consistency 7–8 cm diameter of spread (class 3). This kind of information is crucial for the development of standards for mabisi as well as for product and price differentiation, which will in the long term, improve the regulation of mabisi production and trade. However, these proposed pH ranges and consistency classes still need to be validated by sensory evaluation to ensure that they are realistic. Consistency could also be validated with viscosity measurements, so that more precise and accurate information can be used. It should be noted that both pH and consistency can be influenced by fermentation temperature and raw milk composition [24].

Figure 2



(a) Consumer ranking scores of the most important quality attributes of mabisi, and consumer preference for three levels of mabisi: **(b)** sour taste and (c) consistency (thickness).
Source: [20].

Table 1

Classification of mabisi acidity/sournes.

Acidity class	Mild	Medium	Strong
pH	4.7–4.5	4.4–4.0	< 4

Source: [20]

The nutritional composition of tonga mabisi has been determined (Table S3) [25]. In view of the different types of mabisi that exist, there is a need to ascertain their respective nutritional composition to be able to estimate their nutritional contribution to the diet. The potential health benefits of mabisi have been demonstrated in a study where mabisi intake by children under the age of five showed positive effects on their gut microbiota [26,27].

Microbial community composition of mabisi

Mabisi is made by a spontaneous fermentation process that is dominated by species of lactic acid bacteria (LAB) and acetic acid bacteria [19]. In studies involving over 170 samples of mabisi, it was established that the microbes were mostly from two phyla, Firmicutes and Proteobacteria [21]. At genus level, the top 10 most abundant genera were *Lactococcus*, *Lactobacillus*, *Streptococcus*, *Kluyvera*, *Klebsiella*, *Enterobacter*, *Citrobacter*, *Buttiauxella*, *Aeromonas*, and *Acinetobacter*. The most dominant genera were *Lactococcus* and *Lactobacillus*. The mabisi samples showed differences in the microbial community composition and microbial diversity as a function of geographical location, production methods, producer, container, fermentation temperature and pH of the product [20,21,24].

The geographical locations that were sampled around the country were divided into two main regions: the traditional mabisi production region (TMPR) with more cattle, milk and mabisi production (Western, Southern and Central provinces) and the non-TMPR (Eastern, North-western, Northern, Muchinga and Copperbelt provinces) [28,29]. Products from the TMPR, were found to be dominated by (LAB), *Lactococcus*, *Lactobacillus* and *Streptococcus*, while products from the non-

Table 2

Proposed starter culture composition and product characteristics of six types of mabisi.

Type of mabisi	Product characteristics	Candidate LAB genera
Tonga mabisi	• pH: 4.2–4.5 • Acidic taste: medium • Consistency: medium • Syneresis: < 30%	*Lactococcus, Streptococcus*
Thick-tonga mabisi	• pH: 4–4.5 • Acidic taste: medium • Consistency: thick • Syneresis: < 5%	*Lactococcus, Streptococcus & Lactobacillus*
Strong barotse mabisi	• pH: 3.8-4.3 • Acidic taste: strong • Consistency: very thick • Syneresis: < 5%	*Lactococcus, Streptococcus, Lactobacillus* & *Leuconostoc*
Regular barotse mabisi	• pH: 4–4.5 • Acidic taste: medium • Consistency: very thick • Syneresis: < 5%	*Lactococcus, Streptococcus*
Illa mabisi	• pH: 4–4.5 • Acidic taste: medium • Consistency: thin • Syneresis: < 35%	*Lactococcus, Streptococcus, Lactobacillus* & *Leuconostoc*
Backslopping mabisi	• pH: 4–4.5 • Acidic taste: medium • Consistency: medium • Syneresis: < 30%	*Lactococcus, Streptococcus, Lactobacillus* & *Leuconostoc*

Source: Adapted from [20].

TMPR had a more complex and diverse microbial composition with *Lactococcus* as the main LAB genus driving the fermentation process and a high relative abundance of non-LAB, which has also been reported for amasi [21,23]. Geographical location also influenced microbial communities in 'lait caille' [30]. Similarly, the production methods showed a more complex and diverse microbial composition for tonga mabisi than the rest of the other types [21,31]. Furthermore, a temperature of 25 °C favoured the relative abundance of *Lactococcus* while a higher temperature of 30 °C favoured *Lactobacillus*. The latter also dominated low pH (< 4) mabisi, whereas the former dominated moderate pH (4.1–4.6) [21,24]. It should be noted that most of these studies were conducted before the reclassification of the genus of *Lactobacillus* and were not species specific. Thus, under the new taxonomy, some of the new genera that maybe considered part of this genus based on their metabolism and habitat include: *Lacticaseibacillus*, *Limosilactobacillus*, *Levilactobacillus*, *Lactiplantibacillus* and *Lentilactobacillus* [32].

Microbial functionality and aroma compounds

Fermented dairy products such as cheese have characteristic aroma and flavour, which are mainly volatile compounds that are produced through the enzymatic breakdown of proteins and lipids as a function of the microbes.

In mabisi production, the fermentation process is predominantly spontaneous with a different microbial community composition for different types of mabisi [20,24]. These microbial communities produce different aroma profiles for the different types of mabisi but, overall, when compared to other African Traditional fermented milk products (TFMP), mabisi has more esters than amasi and kivuguto [33,34]. Tonga mabisi has the least number of aroma compounds, compared to the other types of mabisi [20,24].

The barotse, illa and backslopping mabisi all had more esters than tonga mabisi [20,24]. Fermentation temperature had an effect on the microbial community composition of barotse mabisi with *Lactococcus* dominating at 25 °C and *Lactobacillus* dominating at 30 °C after 6 days of fermentation, which resulted in more aroma compounds at the latter higher temperature [24].

Conclusions and prospects of valorisation

In Zambia, about 50% of the raw milk produced annually goes to waste due to an underdeveloped value chain, poor infrastructure and inadequate cold chain systems [29,35]. This milk can potentially contribute to the mitigation of undernutrition (with stunting at 35%) and increased incomes for the farmers by processing it into mabisi [36,37]. Studies have shown that there is vitamin fortification and release of micronutrients through microbial activities during mabisi fermentation

[25]. Moreover, modelling of current diets showed that mabisi is able to optimise the local diet and reduce malnutrition [26].

Mabisi has a natural complex and diverse microbial community which is stable and resilient against invasion by pathogens or spoiler development [38,39]. This gives the product stability at room temperature for several days. These native mabisi microbes can be harnessed into a starter culture which can either be native (autochthonous) or a specially designed one, which can be based on the microbial composition of the different types of mabisi. Several LAB genera candidates have been identified for starter culture development (Table 2). On the other hand, several studies have indicated that the application of native starter cultures allows for the preservation of the characteristics that define the authenticity and uniqueness of traditional foods [40–43]. However, recent findings have also shown that a consistent product can still be produced spontaneously by controlling the process conditions [24]. Moreover, some cheeses use undefined starters [44,45]. These approaches can collectively be used to upscale mabisi production for local and regional markets.

Africa has a lot of unexploited traditional fermented foods, which through the application of indigenous knowledge and scientific approaches can be developed into foods that still retain their unique organoleptic attributes and improved nutritional value. Traditional fermented foods are a promising prospect, as fermentation is low cost and transforms raw materials using microbial activity into nutritious foods with extended shelf-life that are culturally embedded and can reach low-resource urban consumers [46–49]. In these foods, the microbial communities that drive fermentation are more diverse than most industrially fermented foods, which are limited to 1–3 species [50]. Several industrial variants of some traditional fermented foods such as mabisi, munkoyo, mahewu and akpan exist [51–55]. However, they lack the aroma and functional properties of their traditional versions. In contrast, the diverse microbial communities of traditional fermented foods have higher levels of resilience and more diverse functionality [56,57]. Therefore, opportunities for upscaling of traditional fermentation rather than upscaling using few microbial strains are feasible, and some examples of industrially made fermented foods using undefined mixed microbial communities include sourdough breads made with mixed communities of wild yeasts [58]. The upscaling of these traditional fermented foods should be accompanied by promotion and awareness campaigns of their specific nutritional and health benefits to the consumers. Finally, studies have shown an intimate connection between fermented foods and (GI) in the European Union [59]. Mabisi could be used as model for setting up a fermented food GI framework in Zambia.

Conflict of interest statement

Nothing declared.

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Supporting information

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The authors describe the microbial community composition of mabisi and list the top 10 most abundant microbes at genus level. They highlight that tonga mabisi which is the most popular product among producers throughout the country has a complex and diverse microbial community structure compared to the other types of mabisi that are dominated strains of LAB. They further identify the main factors that influence the microbial communities in mabisi as geographical location, type of production method, fermentaton duration and pH. The findings from this study are important for product optimisation and starter culture development which is a crucial component of our opinion paper.

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