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Review article

Traditional fermented foods and beverages of Namibia

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ABSTRACT

Background: Although traditional fermented foods and beverages play an important role in contributing to the livelihoods of Namibians through enhanced food security and income generation, there is a scarcity of information regarding their traditional production methods, microbiological and biochemical characteristics, nutritional value, and safety. Research into the processing technologies of these foods and beverages is still in its infancy; thus, there is a need to document their traditional production methods, microbiology, and biochemistry in order to evaluate their nutritional value and safety, standardize and industrialize them, where possible, and preserve them for future generations.

Methods: The socioeconomic importance, traditional production methods and, where available, microbiological, biochemical, and nutritional properties and safety evaluation of commonly consumed fermented foods and beverages in Namibia are documented. Recommendations are made for potential research areas.

Results: Commonly produced fermented foods and beverages in Namibia include milk-based products (*omashikwa*, *mashini ghakushika*, *mabisi*, and *âudaï*), cereal-based beverages (*oshikundu*, *omalodu*, *otombo*, *epwaka*, *okatokele*, *oshafuluka*, *maxau*, and */Ho ≠Goas*), vegetable-based fermented food, *mudhika*, and fruit-based beverages (*ombike*, *omagongo*, and *omalunga*).

Conclusion: Fermented foods and beverages play a major role in the diet, socioeconomic, and cultural activities of the Namibian population. Most are spontaneously fermented. Research is scarce and should be conducted on the microbiology, biochemistry, nutritional value, and safety of the fermented foods and beverages to ensure the health of the population.

1. Introduction

Fermentation, being an inexpensive technology, plays an important role as the major biotechnological application of food processing in many developing countries. A wide range of fermented foods and beverages are produced in Africa from foods, such as milk, cereals, fruits, and starchy root crops [1–3]. Benefits associated with fermentation include enhancement of the sensory properties and nutritional value of the foods, reduction in toxic and anti-nutritional factors, and improvement in the shelf life of the foods [4–6]. Traditional fermented foods are primarily produced at household level using largely uncontrolled spontaneous inoculation methods in which microorganisms associated with the raw food material and the processing environment serve as inoculants [6]. Major limitations of spontaneous fermentation processes include their inefficiency, low yields of product, and variable product quality.

In Namibia, traditional fermented foods and beverages produced mainly from milk, wild fruits, cereals, and cassava are of sociocultural and nutritional value and are marketed for income generation. Fig. 1 shows the distribution of the various fermented foods and beverages in the various regions of Namibia. The fermented foods and beverages provide an affordable source of food and make a substantial contribution to the food and nutritional security of the rural population. In rural communities, the foods and beverages are generally produced under relatively poor hygienic conditions at the household level, and consumers place very little importance on the safety and quality of the foods. Only a few of these foods have been industrialized to meet the demand for traditional products by the urban dwellers.

Despite the importance of traditional fermented foods in the lives of Namibians, very little research has been conducted on the

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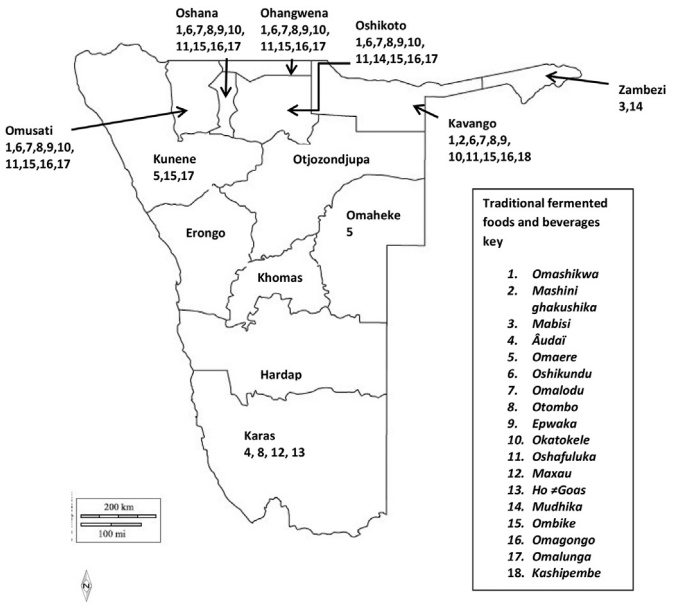

Fig. 1. Distribution of traditional fermented foods and beverages in Namibia.

foods, probably due to scarcity of information on the foods. This paper reviews available information and documents information regarding traditional production methods, microbiological, biochemical, nutritional, and safety properties of commonly consumed fermented foods and beverages in Namibia in an effort to provide useful information in the identification of potential research areas and prioritization of research to assure the safety, quality, and availability of the foods.

2. Milk-based fermented products

Milk-based fermented products are widely produced in different agro-climatic zones for nutrition and income generation, varying according to sociocultural and taste preferences. *Omashikwa*, *mashini ghakushika*, and *mabisi* are popular traditional fermented milk products in the north-central regions of Namibia [7], while *âudaï* is popular in the //Karas region in the southern part of Namibia [8]. The fermented milk products are popular thirst quenchers, condiments for consumption with stiff porridge, and are also mixed with gruel [9,10]. Research on traditional fermented milk products in Namibia has been mainly focused on the physicochemical properties, microbiology, and sensory evaluation and safety of *omashikwa* [7,11–13]. The traditional fermentative flora of *omashikwa*, *mabisi*, and *mashini ghakushika* and their antimicrobial profiles have been studied [7]. The nutrient content of *âudaï* has been documented [8]. *Omashikwa, mabisi*, and *mashini ghakushika* are associated with volatile compounds such as acetic acid, 2,3-butanediol, and lactic acid, which are responsible for the flavor and lowering the pH of the fermented milk products, and compounds such as diacetyl, which impart distinctive aroma [14].

There is a knowledge gap in the nutritional value of *mashini ghakushika* and *mabisi* in Namibia. Risks associated with fermenting and contaminating microorganisms need to be assessed as well.

2.1. Omashikwa

The traditional fermented buttermilk known as *omashikwa* in Oshiwambo, *mpofu* in Rukwangali, and *omaere* in Otjiherero is commonly produced in Oshana, Ohangwena, Oshikoto, Omusati, and Omaheke regions. Traditionally, *omashikwa* is prepared by collecting fresh milk into a calabash, followed by addition of *omunkuzi (Boscia albitrunca)* or *omukwa (Adansonia digitata)* roots, addition of previously prepared *omashikwa* for back-slopping, and then leaving the milk to ferment for 3–4 days at ambient temperatures, commonly ranging from 30°C to 37°C [7,11,14]. Following fermentation, the roots are removed and fermented milk is churned by shaking the calabash for 2–3 hours until butter granules accumulate on top of the sour milk. Butter is then scooped off using a wire mesh or hands, and the butter granules are then washed using clean cold tap water to remove excess milk. The churned milk (*omashikwa*) is usually kept in plastic containers [14]. Fig. 2 shows a calabash (Fig. 2A) and roots (Fig. 2B) used for the traditional production of *omashikwa* and the final ready-to-consume product (Fig. 2C).

In an investigation of the dominant lactic acid bacteria (LAB) and antimicrobial profiles, three LAB species, *Lactobacillus plantarum*, *Lactobacillus rhamnosus*, and *Lactobacillus lactis* ssp. Lactis were isolated from *omashikwa*. LAB of the genera belonging to *Lactococcus* and *Lactobacillus* were also isolated from *omashikwa* in the study of Bille [15]. *Omashikwa* has been reported to have a protein content of about 3.3%, fat 1.6%, moisture 90%, lactose 4.6%, ash 0.7%, total solids 8.7%, lactic acid 0.9%, and a pH of 3.3 [9,11,12]. *Omashikwa* is characterized by a bitter, rancid flavor, rooty taste, and slimy consistency [12]. Bille et al [12] compared laboratory-prepared *omashikwa*, which is made using pasteurized, filtered milk, with traditionally-prepared *omashikwa* and reported significant differences ($p < 0.05$) in descriptive and consumer sensory attributes. Syneresis, filth, rancidity, and bitterness were significantly higher in traditional *omashikwa* than in laboratory-prepared *omashikwa*, whereas aroma, viscosity, and texture were lower in traditional *omashikwa*. Compared with laboratory-prepared *omashikwa*, 80% consumer preference was recorded for traditional *omashikwa* [10]. The researchers proposed heat treatment of milk prior to fermentation, use of lactic acid starter cultures, and maintenance of good hygiene and sanitation as effective methods to improve and sustain the quality and safety of *omashikwa* [10,12]. Commercialized buttermilk branded as *omashikwa* and *omaere* is available in the market in Namibia. Its sensory properties have not been compared to the traditional *omashikwa*.

Omashikwa is associated with volatile compounds, such as acetic acid, 2,3-butanediol, and lactic acid, which are responsible for the flavor and lowering the pH of the fermented milk products, and aromatic compounds such as diacetyl [7]. Furthermore, 2,3-butanediol is responsible for the buttery flavor of milk. *Omunkuzi* root in *omashikwa* is reported to enhance fermentation and churning and impart the sour flavor of *omashikwa* [7,9,15]. The high bitter flavor perceived in the traditional *omashikwa* [13] may be due to the presence of wild microorganisms and enzymes which may hydrolyze fats and proteins into bitter fatty acids, such as butyric, caproic, caprylic, capric, and lauric acids and bitter peptides, such as tryptophan and tyrosine. The higher level of syneresis may be due to the wild microorganisms found in raw milk which may produce gases or rennet-like enzymes, causing wheying-off and make the curds to float including back-slopping contamination.

2.2. Mashini ghakushika

Mashini ghakushika is produced in the Kavango region. The production process is very similar to that of *omashikwa*, as shown in Fig. 2, differing only in the type of root used. Milk is commonly collected in 20 L plastic containers or calabashes and left to ferment in the presence of either *omukunzi* root (*Boscia albitrunca*) or *omukwa* root (*Adansonia digitata*). The milk is allowed to ferment for 4–5 days at room temperature of 30–37°C. The milk is then

Fig. 2. Milk-based fermented products. (A) Calabash in which fresh milk is fermented. (B) Root chunks added to the calabash in the traditional production of *omashikwa*. (C) Ready-to-consume *omashikwa* packaged in recycled soft drink bottles. (D) Ready-to-consume *mashini ghakushika* being poured into a recycled soft drink container. (E) Ready-to-consume *âudaï* in plastic containers and the calabash used in production.

churned for 2–3 hours for the butter granules to separate from the milk, which are then washed with water. The churned milk is then stored in plastic buckets or containers [14]. Fig. 2D shows the ready-to-consume *mashini ghakushika*. Two LAB species, *L. plantarum* and *L. rhamnosus*, were isolated from *mashini ghakushika. Omukwa* root may influence the flavoring and souring of *mashini ghakushika*, distinguishing it from *omashikwa*. The nutritional value of *mashini ghakushika* has not been studied.

2.3. Mabisi

Mabisi is commonly produced in the Zambezi region in the north-eastern part of Namibia. The production process differs from that of *omashikwa* and *mashini ghakushika*. *Mabisi* is prepared by collecting fresh milk in a calabash and leaving the milk to ferment spontaneously for about 4 days at ambient temperature [14]. Whey is removed from the fermented milk, and more fresh milk is added. The process is repeated until the container is full of partly-drained curd. The whole process takes about 1 week. The concentrated fermented milk may be shaken before consumption and kept for up to 1 week at room temperature [14]. Four LAB species (*L. plantarum*, *Lactobacillus paracasei ssp*., *L. rhamnosus*, and *Pediococcus pentosaceus*) were isolated from *Mabisi* [7].

2.4. Âudaï

Âudaï is the sour milk produced in southern Namibia, and it is prepared from goat milk. Generally, *Âudaï* is prepared by placing goat milk in a calabash and leaving it to stand overnight to allow fermentation at room temperature. The fermented milk is then poured into plastic bottles the next day for daily use [8]. Fig. 2E shows a calabash used for *Âudaï* preparation and the final ready-to-consume product.

3. Cereal-based indigenous fermented products of Namibia

Most cereal-based fermented beverages in Namibia are prepared mainly from the meals and malts of pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) although maize meal is occasionally used. Therefore, the beverages are commonly produced in the north-central semi-arid regions of Namibia where the cereals are grown. Spontaneous fermentation processes are commonly employed in producing the beverages and the microorganisms responsible for the fermentation may originate from the cereal meals and malts, fermentation pots, and the surrounding environment; thus, variable quality beverages are produced. The microbiological and biochemical characteristics of a wide range of traditional cereal-based beverages have been studied in many African countries, targeting strain isolation and identification, development of starter cultures, and improvement of quality and safety [16–18]. However, very limited studies have been performed regarding traditional cereal-based fermented beverages in Namibia. The production process and physicochemical, nutritional, and microbiological analysis of *oshikundu* have been studied [19–23]. The nutrient content of *maxau* has been studied [8].

3.1. Non-alcoholic fermented beverages

3.1.1. Oshikundu

Oshikundu is a popular non-alcoholic fermented beverage in the north-central and Kavango regions of Namibia which are suitable for pearl millet and sorghum cultivation [9,19]. It is a very

important daily beverage among the *Owambo*-speaking people in northern Namibia, being brewed both for household consumption and for income generation. Culturally, serving of *oshikundu* to visitors is considered as a token of welcome and hospitality, and the beverage is produced as a part of the traditional initiation of young girls into womanhood [19]. *Oshikundu* is served at weddings and other important ceremonies as well as at daily social interactions [21]. The main ingredients for *oshikundu* production include water, pearl millet flour (locally known as *mahangu*), and sorghum flour [19]. Pearl millet bran may be added optionally. It is a perishable beverage with a shelf life under 6 hours [21]. Figs. 3A–3D show the ingredients used in *oshikundu* production and the final ready-to-drink product (Fig. 3E).

The traditional production process of *oshikundu* has been documented [19–21]. Two main traditional production processes have been documented [20,21]. The first stage of traditional *oshikundu* production involves the addition of boiled water to pearl millet flour and stirring in one procedure and addition of warm water to pearl millet flour and sorghum malt followed by stirring in the second procedure. The mixture is left to cool at room temperature after which sorghum malt is added to the mixture and thoroughly stirred in the first procedure. Pearl millet bran can be added optionally at this stage in either the first or second procedure. Cold water is added to the mixture to the desired volume and consistency. Previously fermented *oshikundu* is added for backslopping, and the mixture is left to ferment for 4–6 hours in a shaded area [19].

The physicochemical, biochemical, and microbiological properties of traditional *oshikundu* have been studied and documented [20–22]. *Oshikundu* has been reported to have a moisture range of approximately 95–97%, total solids range of 2–4.2%, and ash range of 0.07–0.11%. The approximate ranges for pH are 3.3–3.7, titratable acidity 1.2–1.7%, acetic acid 0.1–0.3%, protein 0.13–0.18 mg/mL, insoluble fiber 0.025–0.031 wet basis, viscosity 23–48 mPa, torque 15–28%, alcohol 1–1.6%, and energy 47–59 kJ/100 mL dry weight basis [20]. Organic acids commonly detected in traditional *oshikundu* were acetic acid, lactic acid, shikimic acid, maleic acid, phytic acid, and succinic acid. Vitamins B_1 and B_2 and the minerals B, Ca, Cu, Fe, K, Mg, Mn, Na, S, Zn, and P were detected in *oshikundu.*

Six predominant LAB, *L. plantarum, L. lactis ssp. lactis, Lactobacillus delbrueckii* ssp. *delbrueckii, Lactobacillus fermentum, Lactobacillus pentosus*, and *Lactobacillus curvatus* ssp. *cuvatus* were identified from *oshikundu*. Five bacterial species likely to be spoilage microorganisms were identified as *Enterobacter cloacae, Enterobacter sakazakii, Pseudomonas luteola, Pseudomonas aeruginosa*, and *Serratia ficaria* [20]. The researchers proposed further studies on the rheological properties and product quality evaluation of traditional *oshikundu*. Back-slopping in *oshikundu* has been in practice for many generations, but this also has its disadvantages. The inconsistency in the organoleptic properties of *oshikundu* is considered to be one major drawback in the product characteristics and form a major challenge to develop *oshikundu.* To prolong the shelf life of *oshikundu*, more research can be done by using plant or traditional fruit-based tissues to increase the number of beneficial microorganisms and in the process inhibit the growth of the harmful and spoilage bacteria. Industrial marketing of *oshikundu* ingredients has been successfully implemented in Namibia. Packaged cereal meals and malts which can be used to prepare *oshikundu* following simple instructions on the package can be purchased from retail outlets in Namibia. Comparison of the sensory properties of *oshikundu* produced from industrially marketed ingredients and traditionally produced *oshikundu* has not been researched.

3.1.2. *Maxau*

Maxau is a non-alcoholic, fermented maize-based beverage produced by the *Damara/Nama* people in the //Karas region of Southern Namibia. In a similar production method to *mageu* produced in Southern Africa [24], *maxau* is made from fermented maize meal and sugar is added for taste. Slurry of *maxau* is prepared by mixing water with maize meal. First, water is boiled separately before it is added to the slurry while mixing to produce a thin mixture. This mixture is then boiled for 5–10 minutes after which sugar and wheat flour is

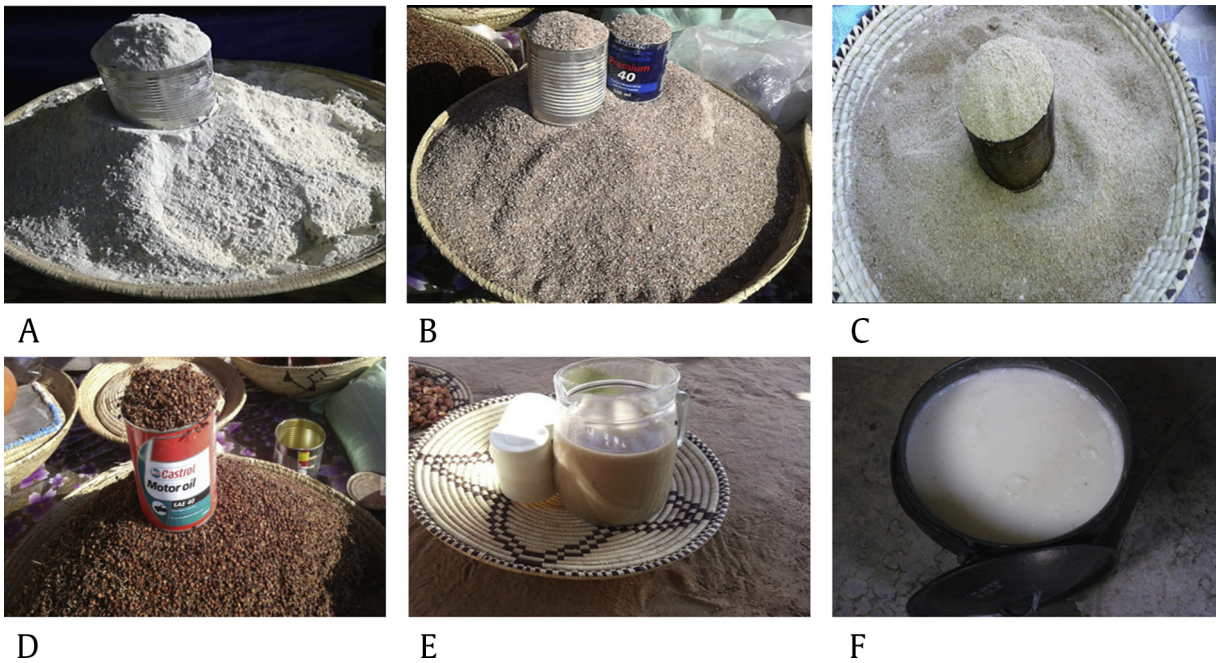

Fig. 3. Non-alcoholic cereal-based fermented beverages and ingredients. Ingredients used in the production of *oshikundu* include: (A) pearl millet meal. (B) and (D) Sorghum malt. (C) Pearl millet bran. (E) Ready-to-drink *oshikundu* in a jug. (F) Ready-to-consume *maxau* made from fermented maize meal.

added to the *maxau* pot, allowed to stand for 24 hours, and then kept at room temperature [8]. For the next *maxau* preparation, a small amount of the previously prepared *maxau* is added for back-sloping. Fig. 3F shows ready-to-consume *maxau*.

3.2. Alcoholic fermented beverages

3.2.1. Omalodu

Omalodu is a popular traditional beer among *Oshiwambo* and *Rukwangali* speaking Namibians [9]. Ingredients for *omalodu* production are sorghum and pearl millet flours. In *Oshiwambo* communities, the beer is of sociocultural importance, being prepared during traditional ceremonies, such as weddings or to welcome new born babies, visitors, and at traditional dancing ceremonies. It is usually consumed in traditional cups known as *omaholo*.

The production of *omalodu* involves mixing sorghum malt with cold water and then boiling the mixture for about 2 hours (Fig. 4A). The boiled mixture is poured onto a big sieve with very fine pores where the mixture is filtered (Fig. 4B). The filtered solution is left to cool, poured into a traditional pot known as *oshitoo*, covered, and left to ferment for 6–24 h. Next, a small amount of pearl millet flour is added, and the mixture is left for about 1 hour to ferment, following which *omalodu* is ready to drink. No research has been carried out to determine the physicochemical, biochemical, nutritional, and microbiological properties and safety of *omalodu*.

3.2.2. Otombo

Otombo is a traditional alcoholic beverage brewed in the north-central regions of Namibia and popular among the elderly. The beverage is commonly marketed at "Cuca" shops for income generation. *Otombo* is brewed using malted sorghum (Fig. 4C). The malting process is traditionally carried out by soaking the sorghum grains in water for 3–4 days, letting them germinate on a wet cloth or sack for about 4 days, and then drying in the sun. Malted grains are put in plastic buckets with water and sugar. The mixture is then left to ferment for 10–24 hours. The grains are then separated from the beverage which is now ready-to-drink *otombo*. Ingredients used in the production process of *otombo* and the final ready-to-drink product are shown in Figs. 4C and 4D. Although no research has been carried out to determine the alcohol content of *otombo*, it is assumed to contain high alcohol levels since consumption of the beverage is associated with drunkenness and women are not encouraged to partake of the beverage. There is a knowledge gap in the physicochemical, biochemical, microbiological, nutritional, and safety properties of *otombo*.

3.2.3. Oshafuluka

Oshafuluka is an alcoholic beverage commonly associated with drunkenness, alcohol abuse, and ill health in the north-central region of Namibia. The beverage is thought to have very high alcoholic content and possibly toxic metabolic products. The beverage is produced from sorghum malt (Fig. 4C). The initial steps for *oshafuluka* production are similar to those for *omalodu* production. Sorghum malt is mixed with water by stirring. Then, the mixture is boiled for about 2 hours. The mixture (*oshixupaela*) is poured into plastic buckets, filtered, and sugar is added to the solution. The solution is then left to ferment at room temperature for 2 days, after which *oshafuluka* will be ready to drink. No information has been documented on *oshafuluka*. The beverage is likely to contain very high alcohol levels and toxic metabolites as it has been reported to be associated with liver damage among long-term consumers.

3.2.4. Okatokele

Okatokele is commonly brewed among the *Oshiwambo* speaking people, and the main ingredients are pearl millet flour (Fig. 3A),

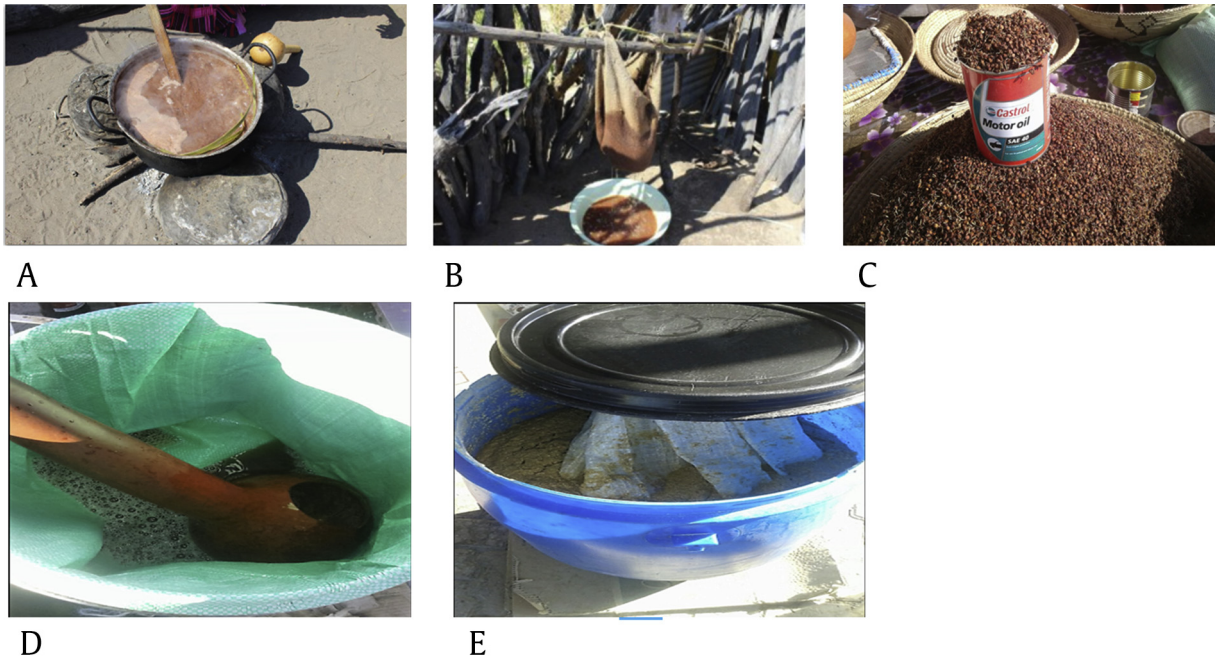

Fig. 4. Alcoholic fermented beverages made from the cereals pearl millet and sorghum. (A) Boiling of sorghum malt and water in a metal pot on a fire while stirring using a wooden stick. (B) Sieving of boiled sorghum malt and water mixture using a sack to collect the dregs and a dish to collect the filtrate (http://preservenamibia.org/drinks/omalodu/). (C) Unground sorghum malt, the ingredient used to make *otombo*. (D) The beverage *otombo* in a plastic bucket with a sieving sack used to collect dregs and a traditional cup used for serving. (E) The beverage *epwaka* in a bucket with a sieving sack to collect the dregs from the pearl millet bran.

sugar, and water. Pearl millet flour is mixed with water and stirred thoroughly. Sugar is added to the mixture. The mixture is then left to ferment in plastic buckets for 8–24 hours at room temperature, following which *okatokele* is ready to drink. No research is conducted on *okatokele* yet; therefore, there is an information gap in the nutritional value and the fermenting microbes involved.

3.2.5. Epwaka

Epwaka is a cereal-based fermented beverage made from pearl millet bran (*onghundu*) (Fig. 3C) obtained after pounding and sifting pearl millet grains. It is perceived to contain moderate alcohol levels in comparison to *otombo*. *Onghundu* is mixed with water and sugar. The mixture is left to ferment at room temperature for 8–24 hours and subsequently *epwaka* is ready to drink. No research is conducted yet on *epwaka*; therefore, there is an information gap in the nutritional value and the fermenting microbes involved. Fig. 4E shows *epwaka* being produced in a plastic container.

3.2.6. /Ho ≠Goas

The brown wheat beer */Ho ≠Goas* is produced in the //Karas Region in southern Namibia. Fig. 5 shows the ingredients used for production of *Ho ≠Goas* and the final product. Brown wheat flour (150–200 g; Fig. 5A) is placed in a pot and covered for 2–3 days outdoors. An unpleasant smell is an indication that the fermentation process has started. The fermented wheat is then placed in another pot and *//Kuni* (rubber grass; Fig. 5B) and 500 g of brown sugar are added. Next, a powdered form of *!Khuxā* (coffee root; Fig. 5C) is added together with 5 L of warm water. Raisins can be added as a flavoring agent. The brew is left for 24 hours at room temperature for the fermentation to complete, and then it is ready for serving (Fig. 5D).

4. Vegetable-based traditional fermented products

4.1. Mudhika

Fermented cassava (*Manihot esculenta*) flour, commonly known as *mudhika* in the north-central and Kavango regions of Namibia, is commonly used to prepare porridge and sold for income generation. Cassava tubers are cut longitudinally, fully immersed in water in plastic buckets, and then left to ferment in a sunny environment for 7 days, after which the cassava is soft in texture (Fig. 6A). The fermented cassava is then sun-dried for about 2 days (Fig. 6B) and pounded into flour.

Although some varieties of cassava have been reported to contain high levels of toxic cyanogenic glycosides in Africa [25,26], the production, biochemical, microbiological, nutritional, and safety properties of fermented cassava flour and products have not been documented in Namibia.

5. Fermented wild fruit products

Wild fruits whose juices are known to be fermented into alcoholic beverages in Namibia include Marula (*Sclerocarya birrea*), Bird plum (*Berchemia discolor*), Jackal berry (*Diospyros mespiliformis*), Makalani palm (*Hyphaena petersiana*), Manketti (*Schinziophyton rautanenii*), Buffalo thorn (*Ziziphus mucronata*), and Large false mopane (*Guibourtia colesperma*) [27].

5.1. Ombike

Ombike is the generic name for fermented beverages made from wild fruits in the north-central regions of Namibia. In the Kavango

Fig. 5. The alcoholic brown wheat-based fermented beverage *Ho ≠Goas*. Ingredients used for production of *Ho ≠Goas* are: (A) brown wheat flour. (B) *//Kuni* (rubber grass). (C) *!Khuxā* (coffee root). (D) Ready-to-drink *Ho ≠Goas* produced by fermenting a mixture of the dry ingredients in warm water held in a glass bottle.

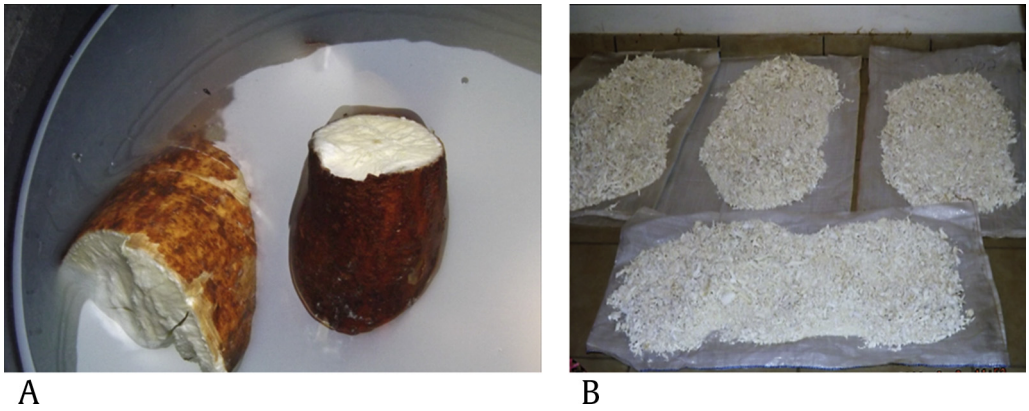

Fig. 6. Vegetable-based fermented product, *mudhika*. (A) Fermentation of cassava tubers submerged in water in a plastic bucket. (B) Sun drying of chipped, fermented cassava on plastic sheets.

region, *ombike* is locally known as *kashipembe* [27]. Wild fruits commonly used to produce *ombike* include Bird plum *(Berchemia discolor),* Jackal berry (*Diospyros mespiliformis*), Makalani palm (*Hyphaena petersiana*), Manketti (*Schinziophyton rautanenii*), Buffalo thorn (*Ziziphus mucronata*), and Large false mopane (*Guibourtia colesperma*). Manketti (*Schinziophyton rautanenii*) fruits are famous for producing the liquor in the Kavango region. Figs. 7A–7F show the stages of production of *ombike* and equipment used. The general traditional procedure for *ombike* production involves addition of water to peeled or unpeeled fruit and leaving the mixture to ferment for a period of a few days up to 2 weeks in a plastic bucket (Fig. 7A). The fermented juice is then heated and distilled to obtain the liquor (Fig. 7B and 7C). Variations exist when different wild fruits are used. The microbiology and biochemistry of *ombike* has not been fully studied and documented; due to excessive and unmeasured amount of alcohol in *ombike*, the government of Namibia does not encourage its production [27].

5.2. Omagongo and oshinwa

Marula fruit (*Sclerocarya birrea* subsp. *caffra*) is commonly found in the Oshana, Omusati, Ohangwena, Oshikoto, Okavango,

Fig. 7. Fruit-based fermented beverages. (A) Soaking of fruit in a bucket and fermentation to produce *ombike*. (B) Distillation of fermented *ombike* product. (C) Ready-to-drink *ombike* being poured into a recycled glass bottle. (D) Marula fruit and peeling of fruit using a horn, and then separating the fruit pulp from the seeds into different dishes. (E) Pouring marula juice into a traditional earthenware pot (http://www.preservenamibia.org/drinks/omaago). (F) Ready-to-drink *omagongo* in a jug.

Zambezi, and part of Otjozondjupa regions. A popular wine known as *omagongo* in Oshikwanyama is produced from the marula fruit. *Omagongo* is of sociocultural, economical, and nutritional importance, being perceived as a respectable drink as opposed to *otombo*. Traditional communities in north-central Namibia are obliged to take *omagongo* to their senior headman or king every year during a 1-day festival. Production of the wine begins by squeezing juice out of the marula fruits. Once the juice has been collected, it is left to ferment for about 3 days. While it is fermenting, the foam that gathers at the top is removed daily. After fermentation, the liquid becomes clear and is ready for consumption or marketing. Figs. 7D–7F show the ingredients, processing, and ready-to-drink *omagongo*. It has been reported that this drink has a high content of vitamin C and a high alcohol content of up to 15% (v/v), depending on the individual tree and the period the liquid has been fermented for [27]. *Oshinwa*, another fermented beverage from marula fruit is a very sweet, non-alcoholic drink, usually consumed by children. Immediately after the covers of the marula fruits are removed from the seeds, the seeds are put in a container; water is added, and left for about 12 hours. This becomes a very sweet and non-alcoholic drink. There is economic potential from the use of the marula fruits. The microbiology and biochemistry of *omagongo* and *oshinwa* has not been fully studied and documented.

5.3. Omalunga

Makalani palm (*Hyphaena petersiana*) trees are found in many north-central regions of Namibia, and the palm tree sap is used to produce the palm wine known as *omalunga* in Oshiwambo. Sap is extracted and collected by a tapper, accumulating as a white, sweet liquid. The sap is fermented for 3–5 days and then turned into alcohol. Sap extraction involves cutting the terminal bud of the fan palm, resulting in the death of the plant; therefore, *omalunga* production is formally forbidden in the country [27] although people are still violating this regulation.

6. Recommendations

6.1. Starter culture development and improvement

Research directed at the characterization of microorganisms associated with the production of traditional fermented foods in Namibia would be beneficial in enabling starter culture development and improvement. The use of starter cultures would lead to the hygienic processing of traditional fermented foods under controlled conditions and production of consistent quality products with selected desirable properties. Such research would provide useful information that may be useful in designing innovative fermentation equipment, reducing the drudgery associated with the fermentation processes.

6.2. Assessment of safety

6.2.1. Detection of pathogens

While spontaneous fermentations generally enhance the safety of foods owing to a reduction in pH, and through detoxification, in some cases there are safety concerns relating to the bacterial pathogens associated with the raw material or unhygienic practices during processing. Pathogenic organisms are, however, of prime concern in fermented foods. Contamination of the fermentation process can pose a major health risk in the final fermented product. Further research should be directed toward identifying the benefits and risks associated with fermenting and possible contaminating microorganisms. Research is necessary to monitor food safety and prevent food-borne illnesses. The detection of pathogens and other microbial contaminants in food is critical to assess the safety of traditional fermented food products in Namibia.

6.2.2. Detection of mycotoxins, nutritional, and anti-nutritional factors

The problem of mycotoxin contamination in food, including fermented foods, is a global concern, being particularly prevalent in developing countries in tropical areas such as in South Asia and Africa. Contamination of the fermentation process can pose a major health risk in the final fermented product. Anti-nutritional factors such as phytates, tannins, protein inhibitors, lectins, saponins, oligosaccharides, and cyanogenic glycosides are naturally occurring components of raw materials commonly used in food fermentations in developing countries. Research directed at identifying and monitoring the presence of chemical and biochemical hazards in fermented foods is, therefore, a critical need. Nutritional assessment of various fermented foods and beverages would be beneficial in promotion of nutritionally beneficial foods for ensuring food security.

6.2.3. Detection of alcohol and fermentation by-products

The alcohol contents and fermentation by-products of most of the fermented beverages in Namibia are unknown. Therefore, research should be directed at assessment of alcohol levels and by-products of interest to ensure consumer health.

6.3. Screening for probiotics

Development of traditional fermented foods with added probiotic health features would be important in the eradication of poverty and hunger and in health improvement. Research on the isolation, identification, and application of specific probiotic strains with documented health benefits could be developed for household food preparation, making a profound effect on the health and well-being of adults and children.

Conflicts of interest

All authors have no conflicts of interest to declare.

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