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# Pearl millet grain: A mini-review of the milling, fermentation and brewing of *ontaku*, a non-alcoholic traditional beverage in Namibia

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**Pearl millet is a cereal that grows and produces grains in arid areas where other cereals may not survive. It has the potential to become a global food crop as the world experiences climate change. Pearl millet is a staple food for more than 60% of the Namibian human population. It is processed into flour, porridge and a daily-consumed fermented acidic beverage, known as *ontaku or oshikundu*. This drink comprises pearl millet meal, sorghum or pearl millet malt and water. *Ontaku* has a heterogeneous composition and a short shelf life, usually of less than a day at ambient conditions. Its brewing processes are various but all are not standardised. Freshest *ontaku* is non-alcoholic, but over time it can have an alcohol content of up to 1.6%. The quality and phenolic content of the malt and the composition of congeners and fermentation metabolites such as methanol and butyrate in *ontaku* have not been investigated. The production of *ontaku* with improved safety and of predictable, consistent and consumer-acceptable qualities requires the standardisation and control of ingredients and processing conditions. This contribution provides a mini-review on the malting, fermentation and milling processing steps and the underlying basic science involved in the production of the ingredients used in the brewing of *ontaku.* It also highlights gaps in knowledge to aid future research in the field of African traditional fermented cereal foods.**

**Keywords:** pearl millet; *ontaku*; sorghum malt; milling; fermentation

## INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br) is a cereal grain with the potential to become a global food crop (Taylor, 2016a). It is cultivated in arid and semiarid regions in Asia and Africa. This ability gives it a competitive advantage in the era of climate change. India in Asia and Nigeria, Niger and Mali in West Africa are some of the major producers of pearl millet. In southern Africa, pearl millet is domestically produced in countries such as Zimbabwe, Mozambique and Namibia (Taylor, 2016a). It is regarded as one of the most hypoglycaemic cereals (Annor *et al.*, 2017), which has potential in the management of Type 2 diabetes. In Namibia, it is a staple food to over 60% of the human population.

Pearl millet grain is usually processed by malting, fermentation and milling. The grain can also be boiled as a whole or following decortication and then consumed. One of the uses of pearl millet in Namibia is in the brewing of a drink known as *ontaku or oshikundu* (Figure 1) in Oshiwambo languages. It is a non-alcoholic, fermented and acidic beverage comprising of pearl millet (*Pennisetum glaucum* (L.) R. Br.) meal (Taylor, 2016a), sorghum (*Sorghum bicolor*) or pearl millet malt, water and/or pearl millet bran (Embashu *et al.*, 2013; Hepute *et al.*, 2016; Taylor, 2016b; Mallet & Du Plessis, 2001). It is brewed almost daily for immediate consumption in more than half of Namibian households, primarily as a source of energy and hydration. This is because, under the current processing methods, it has a short shelf life of about 10–14 hours at ambient conditions.

The cultural importance of *ontaku* in the majority of Namibian households cannot be overemphasised. For instance, unlike in many societies where one would be commonly offered a cup of coffee or tea, *ontaku* is the first food/beverage offered to visitors in most households in Namibia. Furthermore, *ontaku* is also used as a weaning food and is often frequently fed to children, the sick, lactating mothers and the elderly. Although *ontaku* is currently not produced for formal commercial markets, it is sold to low income earners at the informal markets and labourers at construction sites in most towns in Namibia. Essentially, *ontaku* is important to the food security of Namibia. With modernisation, via rapid urbanisation in most developing nations (Watson *et al.*, 1996), the indigenous traditional techniques of food processing can be easily lost and die together with the current rural elders if not documented. Contrast this with developed nations where fermented foods are becoming fashionable in Western diets, where there is an emphasis on artisanal food processing. One reason for this is the health-promoting potential of fermented foods. Scientific publications have even appeared lately suggesting the inclusion of fermented foods in national dietary



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**Figure 1.** (a) Fresh *ontaku* and (b) expired *Ontaku*.

recommendations (Chilton *et al.*, 2015; Bell *et al.*, 2017). Currently, there is limited documentation on the brewing processes and characteristics of *ontaku*, a popular fermented beverage in Namibia. To document the traditional techniques involved in the processing of pearl millet in Namibia, this contribution collates and provides a mini-review on the available pertinent information on the malting, fermentation and milling processes involved in the production of the ingredients used in the brewing of *ontaku*. It also discusses the flow processes commonly followed by brewers of this non-alcoholic African beverage. Furthermore, the brief basic science underlying the key processing steps has been included. The information presented in this contribution should aid future research in the field of functional cereal foods.

## PEARL MILLET NUTRIENT COMPOSITION

The nutrient composition of the pearl millet grain can be affected by among others the soil, environmental conditions and variety of grain. The nutrients are distributed variably in the different anatomical parts (pericarp, endosperm and germ) of the grain (Serna-Saldivar & Espinosa-Ramírez, 2019). The pericarp (8.4%) of pearl millet contains mostly insoluble fibres, proteins, minerals and phenolic compounds. For pearl millet, like sorghum, the pearl millet pericarp may contain starch granules. The endosperm that is 75.1% of the grain anatomy comprises primarily of starch and proteins (prolamins). It also contains B-vitamins, phytic acid and phenolic compounds. Pearl millet has the largest germ of all the cereals, about 16.6%. This is where the oil, proteins (albumins and globulins), soluble sugars, minerals and vitamins are found. Removal of some of these anatomical parts during the milling of the grain adversely affects the original nutrient content of the grain.

The content of some nutrients present in the variously milled pearl millet meals are given in Table 1. The energy content of whole pearl millet grain is between 1646 and 1691 g/100 g dry weight (Taylor, 2004, 2016a, b). These amounts decrease during milling. For instance, the energy content was reported to be 1381 g/100 g dry weight in pearl millet meal obtained from service millers (Mallet & Du Plessis, 2001). Some components, such as fat, that contribute to the overall energy content of the grain are usually removed during milling for shelf-life extension and phenolics are removed for palatability (Taylor, 2016a).

**Table 1.** Comparison of some nutrients of pearl millet meals obtained through different ways of milling and from different millers.

| Nutrient on dry basis | Whole pearl millet grain[a] | Commercial milling service pearl millet meal[b] | Commercial milling service pearl millet meal[c] | Industrial milled pearl millet meal[b] |
|---|---|---|---|---|
| Food energy (kJ/100 g) | 1646 - 1691 | | 1381 | |
| Protein (g per 100 g) | 8.6 - 19.4 | 13.2 | 12.4 | 13.4 |
| Carbohydrate (g per 100 g) | 63.1 - 78.5 | 70.8 | 72.8 | 69.8 |
| Dietary fibre (g per 100 g) | 8.0 - 9.0 | 11.4 | 7.5 | 11.7 |
| Fat (g per 100 g) | 1.5 - 6.8 | 3.8 | 5.8 | 4.1 |
| Ash (g per 100 g) | 1.6 - 3.6 | 0.76 | 1.5 | 1.12 |
| Total polyphenols (mg per 100 g) | | 80 | | 140 |
| Phosphorus (mg per 100 g) | 373 | | 226 | |
| Calcium (mg per 100 g) | 41 | | 188 | |
| Magnesium (mg per 100 g) | 125 | | 73.4 | |
| Potassium (mg per 100 g) | 460 | | 204 | |
| Zinc (mg per 100 g) | 2.4 | | | |
| Copper (mg per 100 g) | 0.5 | | | |
| Iron (mg per 100 g) | 10.8 | | | |
| Niacin (mg per 100 g) | 2.9 | | 1.32 | |
| Riboflavin (mg per 100 g) | 0.2 | | 0.064 | |
| Thiamin (mg per 100 g) | 0.3 | | 0.25 | |

[a]Taylor, 2016a, [b]Barrion, 2008, [c]Mallet & Du Plessis, 2001

The protein content of the various pearl millet meals ranges from 8.6 to 19.4 g/100 g dry weight.

The ranges of carbohydrate, dietary fibre, fat, and ash contents (g/100 g dry weight) are as follows, respectively, 63–78.5, 7.5–11.7, 1.5–6.8 and 0.76–3.6. During the milling process, decortication reduces the amount of nutrients such as the fat, mineral (ash) and fibre contents in the resulting meal or flour. These nutrients are often removed as part of bran (pericarp and germ) during decortication (Taylor, 2004; Barrion, 2008). This loss of outer layers of the grain "concentrates" the amount of starch. Thus, the starch content is higher 71 g/100 g dry weight in service milled pearl millet meal than in the raw grain (59.8 g/100 g dry weight) (Barrion, 2008). Steeping of the grain can also possibly cause a reduction of some nutrients through the leaching of water soluble proteins and phenolics, minerals and vitamins into the steeping water.

It is noteworthy that whole unprocessed pearl millet grain contains compounds that adversely affect mineral bioavailability, those implicated in goitre and those with a disagreeable effect on the sensory quality of some pearl millet products (Taylor, 2016a). Phytate present in pearl millet represents the reserve of phosphorus like in other cereal grains but it binds minerals such as Cu (II), Fe (II) and Zn (II), rendering them bio-unavailable. C-glycosyl flavones in pearl millet such as vitexin, glucosyl vitexin and glucosyl orientin are not only responsible for the grey/brown colour of pearl millet grain, but they are also implicated in the goitre incidents reported in the Sudans. This should, however, be noted together with the fact that the communities where the incidents were reported apparently have a very limited diet that might simply be deficient of iodine (Taylor, 2016a). The C-glycosyl flavones have also been attributed to the mousy or mouse-dropping-like flavour associated with damp, improperly dried pearl millet flour. The phytate and the C-glycosyl flavones are concentrated in the outer layers of the grain. They therefore significantly reduce together with the minerals by decortication. Malting and fermentation free the minerals through enzymatic hydrolysis of phytate.

## MILLING OF PEARL MILLET IN NAMIBIA

The ingredients used in the making of *ontaku* are water, pearl millet meal and malted sorghum meal or malted pearl millet meal. Pearl millet meal (locally known as *uusila/oufila* [Taylor, 2016b; Mallet & Du Plessis, 2001] *woMahangu* in Oshiwambo, a local language in Namibia) can be obtained from traditional domestic milling (Taylor, 2004) (Figure 2(a)) or from service millers (Figure 2(b)) or from industrial milling (Figure 2(c)) (Barrion, 2008). The industrial milling process includes conditioning of the grains with water, abrasive decortication and roller milling of the decorticated grain. The traditional and service milling processes are generally similar. They both usually (but not always) include a decortication, fermentation, partial drying of fermented grain and size-reduction and then solar-drying of the flour steps. Service milling refers to milling services that reduce the size of the grain using a hammer mill, whereas laborious traditional milling uses a wooden pestle and mortar and then sieving (Taylor, 2004; Barrion, 2008). Customers can buy pearl millet meal from service millers and/or can deliver their own grain (decorticated and fermented or whole grains fermented by steeping) for milling at a fee.

Pearl millet meal used in brewing of *ontaku* can either be fermented or unfermented. This often depends on the brewer's and consumers' preference and/or on the availability of the ingredients. The first step in the traditional and the service milling processes is decortication (Taylor, 2004; Barrion,

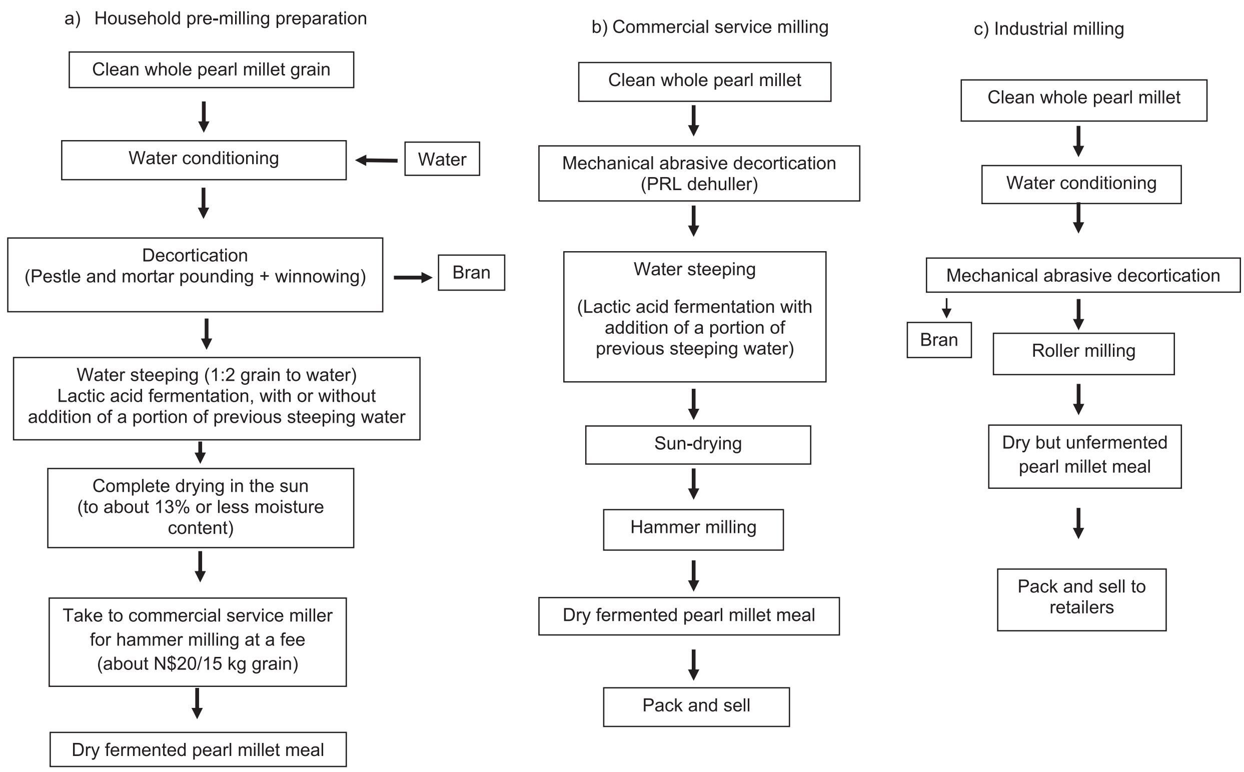


**Figure 2.** General flow processes of (a) traditional pre-milling processing and by (b) commercial hammer milling service providers and (c) industrial milling.

2008). Using the pestle and mortar or a mechanical dehuller, between 10 and 30% of the grain may be removed during this step. The pericarp and germ and thus their chemical components such as oil, fibres and phenolics are lost into the bran. The removal of the germ during decortication reduces the oil content in the resulting flour. The oil, which is rich in unsaturated fatty acids, is prone to rancidity via oxidation. Its removal therefore positively contributes to the shelf stability of the meal. The decorticated grain can then be directly milled into a meal or it can be subjected to fermentation before milling.

Different techniques of fermentation can be applied during traditional milling at household level or applied by service millers (Figure 3(a) and (b)) to produce fermented meals. One of the techniques involves steeping of the grain in water (1:2 parts, respectively) and the other involves the use of *oomuma/eendjeke*, which are grain remnants from previously fermented grain when milled using the pestle and mortar (Shimbwadala *et al.*, 2018). The duration of steeping of cleaned pearl millet grain in water is variable. It can be allowed for several hours or days. This depends among other factors on the ambient temperature, availability of money for service millers or of labour to pound using the wooden pestle and mortar, need of the meal and/or desired whitening of grain. The steeping step brings about lactic acid fermentation, which brightens (Taylor, 2004) the grain and subsequently yields a less dark meal. Lactic acid fermentation can occur spontaneously but often a backslopping technique is employed. This involves the use of a previous portion of steeping water, which contains a relatively high load of fermenting microorganisms, mostly lactic acid bacteria (Shimbwadala *et al.*, 2018), to inoculate the new steep water. Alternatively, the new steeping process may be carried out in the same container as the previous steeping but intelligently washed to leave portions of previous dry or semi-wet deposits in it. These deposits possibly carry a lactic acid "starter culture".

In the other technique, fermentation of pearl millet is sped up by the use of *eendjeke/oomuma*. Like backslopping (Taylor, 2004; Barrion, 2008), *eendjeke* also contains live microorganisms. They act as a source of "starter culture". The isolation, identification and characterisation of the microorganisms in *eendjeke* are not clearly documented. The practice of using *eendjeke* in

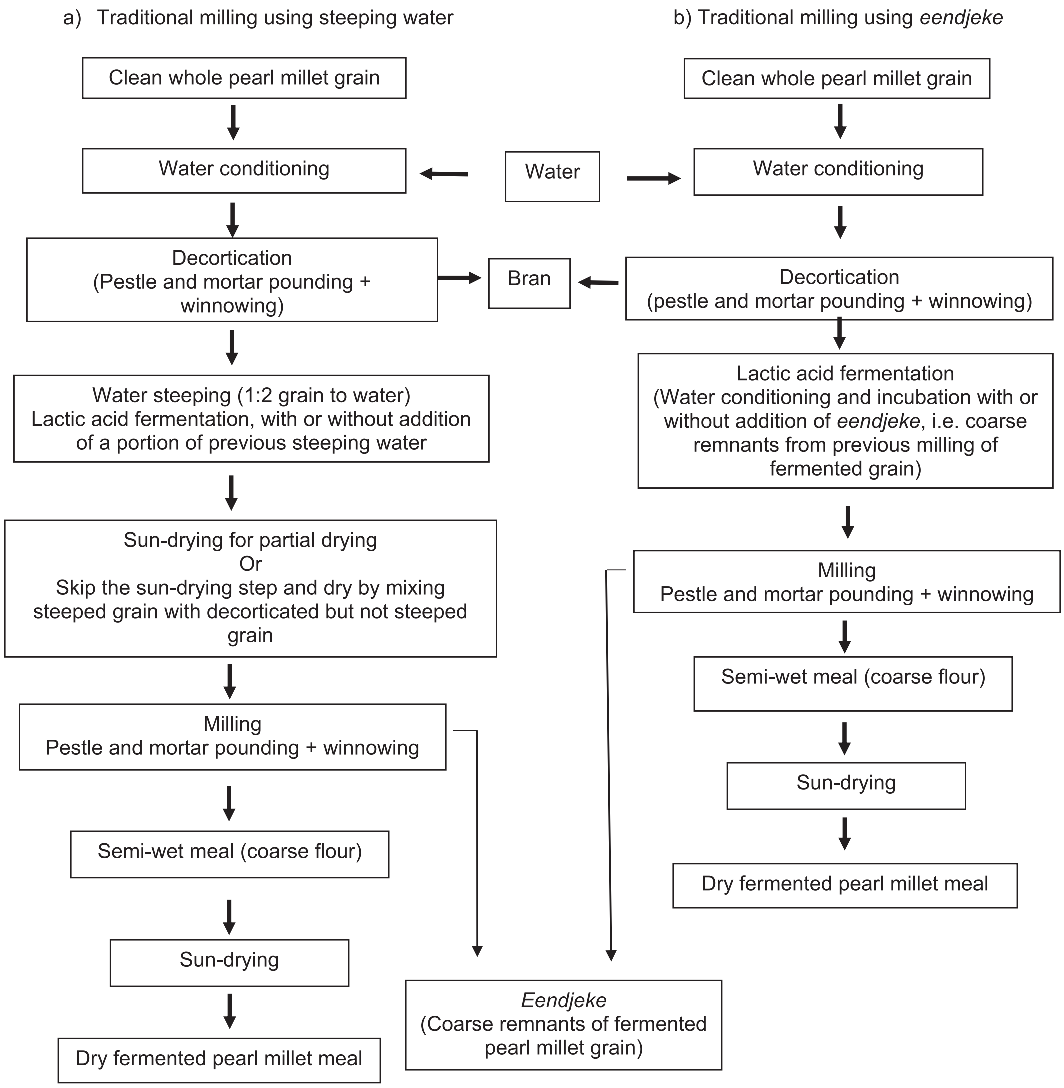


**Figure 3.** Common processing steps involved in the production of traditional fermented pearl millet meal. These are currently carried out domestically only.

the fermentation of pearl millet meal is currently limited to households.

## MALTING AND MALT QUALITY OF PEARL MILLET OR SORGHUM FOR USE IN THE BREWING OF *OSHIKUNDU*

Malt quality is central to the brewing of beers and other beverages. In Namibia, pearl millet and sorghum can be malted for use to brew *ontaku* (Taylor, 2016a; Embashu *et al*., 2013; Hepute *et al*., 2016; Taylor, 2016b; Mallet & Du Plessis, 2001; Taylor, 2004) or an opaque beer (*omalovu*) (Embashu *et al*., 2019). The traditional malting process and its set-up in Namibia are not controlled, standardised or well documented. Nevertheless, this traditional malting process follows the common malting steps of steeping, germination and drying (Taylor, 2016a). The duration of steeping of pearl millet or sorghum grains in Namibia ranges from 1 to 3 days (Embashu *et al*., 2019). There is generally no temperature control or air rests.

During steeping, the water diffuses into the grain. The grain swells and biochemical changes and germination are induced. The steeped grain is drained and then allowed to germinate for 7 to 14 days with some intermittent watering. The amount and frequency of watering of the germinating grain are mostly subjectively applied. During germination, the seedling grows (Taylor, 2016a). The various endogenous enzymes are activated and mobilised from the germ into the endosperm to modify the grain structure. The most important enzymes in the malting process are the amylases, proteases and peptidases (Taylor & Duodu, 2010). The α- and β-amylases hydrolyse starch, the major component of the grain, into dextrins and fermentable sugars such as maltotriose and maltose. The degree of activity of these two enzymes in the malt is referred to as diastatic power (DP). DP estimates the ability of the malt to solubilise starch during brewing.

The activities of proteases and peptidases cumulatively convert proteins into amino acids. The amino acids are estimated as free amino nitrogen (FAN) content in malts and are utilised by the fermenting microorganisms during brewing (Taylor & Duodu, 2010). The malted grain is then subjected to size-reduction by semi-wet milling, primarily by women using wooden pestle and mortar. The milled malt is then sun dried for up to 3 hours depending on the season, at ambient temperature, usually below 50 °C to conserve the activity of the mobilised enzymes. This also produces a shelf stable malt because of its low moisture content.

There is no literature found on the conditions of malting and on the quality of pearl millet or sorghum malt for use in the brewing of *ontaku*. However, the malting conditions, which give an acceptable amount of free amino nitrogen and α- and β-amylase, for opaque beer brewing, have been reported and reviewed for sorghum (Okafor & Aniche, 1980; Palmer *et al*., 1989; Dewar & Taylor, 1999; Lyumugabe *et al*., 2012) and pearl millet (Pelembe *et al*., 2004) to be generally between 25 and 30 °C and germination time between 1 and 3 days. The quality of traditionally produced malt currently used domestically in Namibia needs to be studied and then relate aspects such as its diastatic power, free amino nitrogen and related parameters to the quality of *ontaku*. Safety aspects of the malt, such as the occurrence of harmful bacteria and mycotoxins, also need to be investigated. Recently, aflatoxin B1 was detected in pearl millet meals and sorghum malts (Misihairabgwi, *et al*., 2018). Sorghum malt had levels above the European Union regulatory limit of 5 parts per billion. Fumonisin B1 is found in pearl millet meals and in sorghum malts. The amount of fumonisin B1 was above the European Union regulatory limit of 2000 parts per billion in pearl millet meal. Interestingly, none of the regulated mycotoxins were detected in *ontaku*. Information on the quality and safety of the malt can be useful in the processes that lead towards the commercialisation of malt for use in the brewing of *ontaku*. Recently, a dry premix of ingredients (pearl millet meal containing sorghum malt) has been produced industrially and is available in the supermarkets in Namibia for use in the brewing of *ontaku*.

## FLOW PROCESS FOR BREWING *ONTAKU*

The traditional brewing methods of *ontaku* have been described (Embashu *et al*., 2013; Hepute *et al*, 2016; Taylor, 2004). The general flow process used in the making of *ontaku* is shown in Figure 4. Pearl millet meal is mixed with boiling water at a ratio of 1:2.5. Pearl millet bran may be used as part of the ingredients (Embashu *et al*., 2013). This paste is stirred until it is relatively homogeneous without lumps. The boiling water partially gelatinises the starch granules of the meal. The paste is then cooled to temperatures below 40 °C.

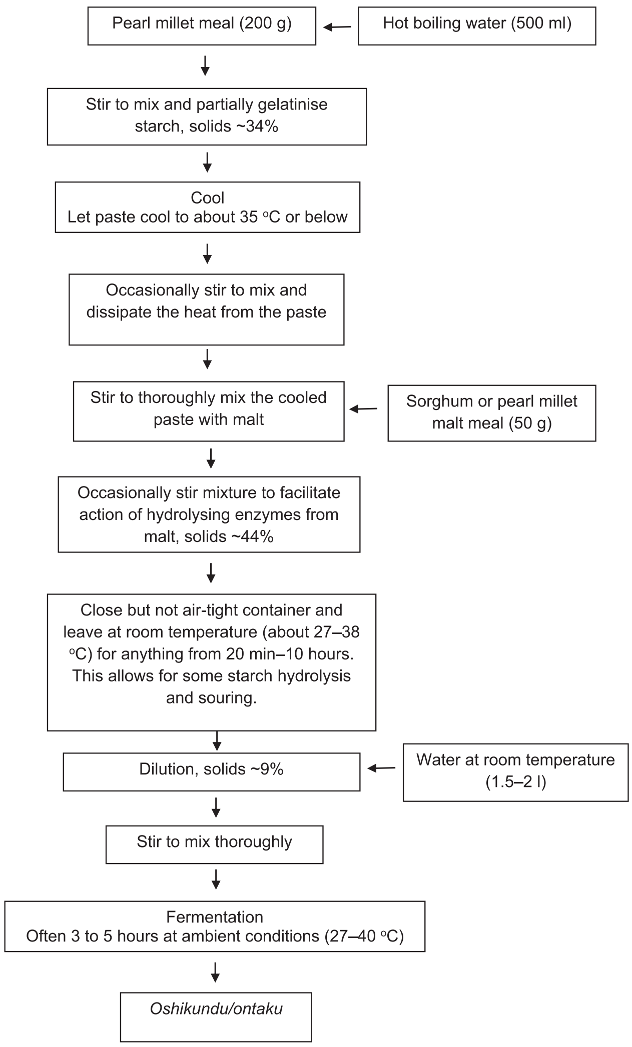


**Figure 4.** *Ontaku* brewing flow process.

Thereafter, pearl millet or sorghum malt, ranging from a quarter to half the amount of the meal is then added and thoroughly mixed. The addition of malt introduces among other soluble sugars, enzymes such as amylases and fermenting microorganisms. The enzymes can act on starch molecules to thin the paste. After some cooling time, the paste is diluted with tap water with about 2 to 3 times the amount of the boiling water that was added. The amount of water added is subject to the consistency desired by the brewer. It is noteworthy that there are no mashing and straining steps in the brewing of *ontaku* that are typical in the brewing of beers. The diluted paste is usually directly allowed to spontaneously ferment at ambient conditions for at least 3 hours before consumption. Backslopping using a previous portion of *ontaku* is also commonly employed. The duration of fermentation is usually overnight but commonly ranges from 3 to 6 hours. Taylor (2016a) suggests that it is the lactic acid bacteria (LAB) that are mostly responsible for the fermentation of soluble sugars in the brewing of *ontaku.* However, some levels (see succeeding text) of alcohol and acidity develop over fermentation time. This suggests that there are different populations of fermenting microoganisms other than LABs.

An alternative but also traditional brewing method of *ontaku* exists. In this method, the dry ingredients (malt and pearl millet meal) are mixed first before the addition of water. Importantly, the water added has to be lukewarm and not boiling water. The exact temperature of the lukewarm water is not determined but is simply described as such based on the experience of the brewers. The addition of lukewarm water to the meal containing the malt is hypothesised to be aimed at not inactivating the enzymes present in the malt. The rest of the processing steps are the same as those described in the first method.

*Ontaku* is greenish brown with a buttery sour taste (Taylor, 2004). It is an effervescent beverage with up to 98% water content on a wet basis. It is generally watery but can have a consistency similar to that of yoghurt. It has a pH of less than 4 and lactic acid content of up to 0.6%. It should be noted that not all *ontaku* beverages are non-alcoholic. The alcohol content that appears over time has been recorded up to 1.6%. For weaning, the freshest and non-alcoholic *ontaku* is commonly used. Upon spoilage (expiration), *ontaku* generally separates into two layers (Figure 1). A more watery layer sits on top of dense solids and the effervescence dissipates. There is little literature (Hepute *et al.*, 2016; Taylor, 2004) found on the nutrient composition and characteristics of *ontaku*. The protein, ash and insoluble fibre content of the watery part (excluding *ontaku* dregs) of ontaku were 0.013–0.018%, 0.07–0.8% and 0.25–0.31%, respectively, on wet basis (Embashu, 2014; Misihairabgwi & Cheikhyoussef, 2017). The energy content was in the range of 0.38–0.58 kJ/mL. While studies on the nutrient composition and safety of the whole *ontaku* need to be conducted, it suffices to note that *ontaku* might not be nutrient dense especially for use as a sole weaning food.

One of the possible major limitations to the commercialisation of this beverage is the absence of standardised production flow processes so that it is safe and has consistent quality and improved shelf life. For instance, the ingredient ratio, mixing regime and processing conditions such as temperature and time at which *ontaku* is brewed are not standardised. Furthermore, with no straining, filtration or other appropriate separation steps and with limited gelatinisation of starch in the flour/meal used, *ontaku* is an unstable suspension that has a large amount of floating particles (flour/meal). It also contains live populations of microbes. Within minutes these particles collect and sediment at the bottom as a denser layer of dregs (*ehete*) (Figure 1) due to gravity. Consequently, *ontaku* has a differential consistency or viscosity. This also results in the differential preferences of these layers or their mixture by consumers.

Currently, the processing conditions for brewing of *ontaku* are as diverse as the brewers. For improved brewing of this beverage, further research needs to be conducted. For example, the quality and amount of ingredients, temperature of water added, the consistency of *ontaku* paste (pearl millet), time of dilution, duration of conversion by the malt are some of the parameters that are not controlled and need investigation The extent of gelatinisation and conversion and extent of dilution during the brewing process of *ontaku* also warrant assessment.

The microflora responsible for the fermentation and their potential health benefits also needs to be explored. The various malting and fermentation processes of pearl millet grain could result in the delivery of populations of different microorganisms involved in the brewing of *ontaku*. Moreover, the use of unfermented whole grain, fermented whole grain or fermented decorticated grain meals presents different substrates for fermentation. This offers opportunities for investigations into possible prebiotics, probiotics and synbiotics which may arise during different stages of brewing and in *ontaku*. Clinical studies on the health effects of consuming *ontaku* in 60% of the Namibian human population may give insight into the functional benefits of this beverage. Understanding the metabolites in *ontaku*, coupled with *ontaku* being a cereal product without complications of coeliac issues presents alternative avenues for the development of new healthy products in the market of functional foods of cereal origin. However, for the improved safety and quality of *ontaku*, there is a need for further investigations into the quality and safety of the ingredients, processing conditions, sensory quality, flavour compounds profile and safety aspects (e.g. methanol level) of *ontaku*.

## CONCLUSIONS

*Ontaku* is a very popular fermented drink in Namibia. It is brewed using pearl millet. It is acidic and has a live culture of fermenting microflora. It has relatively low or no alcohol content. It is currently indispensable to household food security and daily hunger nourishment for the majority of the Namibian people. Improved processing of pearl millet grain and of the *ontaku* brewing process could potentially enhance the utilisation and diversification of high quality fermented products of pearl millet grain. Development of starter cultures for the fermentation steps in the milling of the grain and in the brewing of *ontaku* can result in improved control of product quality and safety. Pearl millet has the potential to become a global staple food crop in many regions that are affected by the effects of climate change. This is because it is well adapted and flourishes in hot and arid regions where most other cereal crops can hardly grow and produce grains.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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