Review on African traditional cereal beverages

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Abstract

Spontaneous fermentation typically result from the competitive activities of different microorganisms; strains best adapted and with the highest growth rate will dominate during particular stages of the process. Microorganisms involve usually in spontaneous fermentation belong mainly lactic acid bacteria and yeast. Production of African traditional cereal non or alcoholic beverages need two spontaneous fermentations steps : a lactic acid fermentation which is carried out by a complex population of environmental microorganisms and an alcoholic fermentation which is usually initiated by pitching sweet wort with a portion of previous brew or dried yeast harvested from previous beverage. This review deals of the raw materials used for production of non and alcoholic beverages, their technologies production, their importance and risks associated with consomption of these beverages. The review focuses also on the role of spontaneous fermentations in the improving of preservation, nutritional value and sensory quality of these cereal beverages. The socio-cultural and economic aspects, nutritional aspect, sensory characteristics, preservative properties and health benefit aspects of these beverages and microflora involve during spontaneous fermentations will also be reviewed.

Keywords. African beverages; cereals; spontaneous fermentation; alcoholic fermetation; preserving; nutritional quality

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Introduction

In the developing world, fermentation is one of the oldest technologies used for food processing and preservation. On this technology depend up millions of people for preserving and often enhancing organoleptic and nutritional qualities of their food at costs available to the average consumer (Gotcheva *et al*., 2001; Tamang *et al*., 2005; Kalui *et al*., 2010). Fermentation can be described as a desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes. These microorganisms are associated with raw material and/or utensils, or they may be added as starter cultures (Nout and Motarjemi, 1997; Tamminen *et al*., 2004). Raw materials included milk, meat, fish, fruits and cereals. In some African countries in particular, cereals are used to produce indigenous fermented foods, non alcoholic and alcoholic beverages. These beverages are popular because of the social, religious and therapeutic values associated with them (Aka *et al*., 2008 ; Djè *et al*., 2009 ; Nwachukwu *et al*., 2010). Indeed, spontanous fermentations improve nutritional value of beverages that contributes significantly to improve the diet of consumers. They improve also sensory quality which is very important in the beverage acceptance. Non-alcoholic beverages are consumed by all population specialy by children, pregnant women, sick and old people. They are also used as weaning infants. While, alcoholic beverages are usually preferred by men. These beverages are different names in different countries and regions where they are produced. Their production varie from one region to another, but essentially include malting, brewing and fermentation feedstock for millet, maize and mainly sorghum. Their are managed by women at househome and or small scale and involves one or two steps of fermentation : lactic acid fermentation for non alcoholic beverages and lactic acid fermentation and alcoholic fermentation for alcoholic beverages. The lactic acid fermentation is carried out by a complex population of environmental microorganisms; it confers souring taste and storage longevity. On the other hand, the alcoholic fermentation is usually initiated by pitching sweet wort with a portion of previous brew or dried yeast harvested from previous beverage (Maoura *et al*., 2005 ; Aka *et al*., 2009 ; N'Guessan *et al*., 2012). It is one of the steps in the traditional process which mainly determines the quality of the beverage (N'Guessan *et al*., 2012). In the last years, the number of books and articles dealing with african fermented beverages found around the whole world have rapidly increased (Blandino *et al*., 2003). This review deals of the raw materials used for production of non and alcoholic beverages, their technologies production, their importance and risks associated with consomption of these beverages. This review focuses also on the role of spontaneous fermentations in the improving of preservation, nutritional value and sensory quality of these cereal beverages. The socio-cultural and economic aspects, nutritional aspect, sensory characteristics, preservative properties and health benefit aspects of these beverages and microflora involve during spontaneous fermentations will also be reviewed.

Raw materials used in the production of African traditional cereal beverages

A wide range of cereals raw materials are used for fermented foods and beverages. Cereal grains such as sorghum (*sorghum bicolour* (L.) *Moench*), millets (pearl and finger millets (*Pennisetum glaucum* (L) and *Eleusine coracana*) and maize (*Zea mays* (L.) are common substrates usually used in Africa for produce a wide variety of beverages (Sekwati-Monang, 2011). Raw materials used in the production of African traditional cereal beverages are listed in Table 1.

Sorghum (sorghum bicolour (L.) Moench

Sorghum is a cereal widely grown for food use in Africa and as a feed grain in some parts of the world. It is eaten as flat bread prepared from fermented dough (*kisra*), thin or thick fermented or unfermented porridges (*ting, togwa, uji*) and alcoholic and non-alcoholic beverages (*burukutu, pito, dolo, tchapalo* and *bushera, gowè, kunun-zaki* respectively). The composition of sorghum grain depends on the variety and cultural venues. According to FAO (1995), sorghum consists essentially of starch, its protein content is almost equal and comparable to that of maize and wheat, its fat content is higher than that of wheat but less than the maize. Sorghum is also characterized by its high fiber content and poor digestibility of nutrients. Its energy value is 1374kj/100g. Sorghum is a rich source of vitamin B group, especially thiamine, riboflavin and niacin (Table 2). It contains detectable amounts of vitamins D, E and K. Some varieties of sorghum yellow endosperm contain β -carotene or provitamin A. Sorghum also contains minerals such as phosphorus, iron, zinc, potassium and copper (Glew *et al*., 1997; Anglani, 1998). However, its nutritional quality is poor. In fact, sorghum contains anti-nutritional factors such as tannins and phytates. They can form complexes with proteins, vitamins and minerals and therefore decrease the bioavailability of nutrients. To improve his nutritional quality, germination, fermentation and cooking methods are used (FAO, 1995; Anglani, 1998; Michodjèhoun *et al*., 2005; Dicko *et al*., 2006).

Table 1. Raw materiel and location of African traditional cereal beverages

Raw Materials	Name of beverages	Class	Location	References
Sorghum	*Amgba*	Alcoholic beverage	Cameroon	Chevassus-Agnes, 1979
	Bushera	Non-alcoholic beverage	Uganda	Muyanga *et al*., 2003
	Bili-bili	Alcoholic beverage	Tchad	Maoura *et al*., 2006
	Burukutu	Alcoholic beverage	Northern part of Nigeria	Achi, 2005; Sunday and Aondover, 2013
	Dolo	Alcoholic beverage	Burkina Faso	Sawadogo-Lingani *et al*., 2007
	Gowé	Non-alcoholic beverage	Benin	Michodjèhoun-Mestres *et al*., 2005
	Ikigage	Alcoholic beverage	Rwanda	Lyumugabe *et al*., 2010
	Kaffir beer	Alcoholic beverage	South Africa	Tamang, 2010
	Kunun-zaki	Non-alcoholic beverage	Northern part of Nigeria	Amusa and Odunbaku, 2009; Nyanzi and Jooste, 2012
	Oti-oka	Alcoholic beverage	South-Western Region of Nigeria	Ogunbanwo and Ogunsanya, 2012
	Pito	Alcoholic beverage	Nigeria, Ghana	Duodu *et al*., 2012; Fadahunsi *et al*., 2013
	Chakpalo	Alcoholic beverage	Benin, Togo	Kayodé *et al*., 2007 ; Osseyi *et al*., 2011; Baba-Moussa *et al*., 2012
	Tchapalo	Alcoholic beverage	Côte d'Ivoire	Aka *et al*., 2008a
	Tchoukoutou	Alcoholic beverage	Benin, Togo	Kayodé *et al*., 2007 ; Osseyi *et al*., 2011; Baba-Moussa *et al*., 2012
	Gowé	Non-alcoholic beverage	Benin	Michodjèhoun-Mestres *et al*., 2005
Maize	*Burukutu*	Alcoholic beverage	Northern part of Nigeria	Achi, 2005; Sunday and Aondover, 2013
	Busaa	Alcoholic beverage	Kenya	Katongole, 2008
	Kaffir beer	Alcoholic beverage	South African	Tamang, 2010
	Kunun-zaki	Non-alcoholic beverage	Northern part of Nigeria	Nyanzi and Jooste, 2012
	Mahewu	Non-alcoholic beverage	South Africa	Sekwati-Monang, 2011
	Pito	Alcoholic beverage	Nigeria, Ghana	Duodu *et al*., 2012; Fadahunsi *et al*., 2013
	Tchapalo	Alcoholic beverage	Côte d'Ivoire	Aka *et al*., 2008a
	Gowé	Non-alcoholic beverage	Benin	Michodjèhoun-Mestres *et al*., 2005
Millet	*Bushera*	Non-alcoholic beverage	Uganda	Muyanja *et al*., 2003
	Gowé	Non-alcoholic beverage	Benin	Michodjèhoun-Mestres *et al*., 2005
	Mangisi	Non-alcoholic beverage	Zimbabwe	Zvauya *et al*., 1997
	koko sour water	Non-alcoholic beverage	Northern part of Ghana	Lei and Jakobsen, 2004
	Kunun-zaki	Non-alcoholic beverage	Northern part of Nigeria	Obadina *et al*., 2008; Adeleke and Abiodun, 2010
	Malwa	Non-alcoholic beverage	Uganda	Muyanja *et al*., 2010
	Masvusvu	Non-alcoholic beverage	Zimbabwe	Zvauya *et al*., 1997
	Oti-oka'	Alcoholic beverage	South-Western Region of Nigeria	Ogunbanwo and Ogunsanya, 2012
	Tchapalo	Alcoholic beverage	Côte d'Ivoire	Aka *et al*., 2008a
	Burukutu	Alcoholic beverage	Northern part of Nigeria	Achi, 2005; Sunday and Aondover, 2013
Sorghum and millet	*Obiolor*	Non-alcoholic beverage	Nigeria	Sekwati-Monang, 2011
	Pito	Alcoholic beverage	Nigeria, Ghana	Duodu *et al*., 2012; Fadahunsi *et al*., 2013
	Burukutu	Alcoholic beverage	Northern part of Nigeria	Achi, 2005; Fadahunsi *et al*., 2013
Sorghum and Maize	*Kwete*	Alcoholic beverage	Uganda	Namugumya and Muyanja, 2009
	Pito	Alcoholic beverage	Nigeria, Ghana	Achi, 2005; Fadahunsi *et al*., 2013
	Umqombothi	Alcoholic beverage	South African	Katongole, 2008
Maize, sorghum, wheat, finger millet and *tef* and Barley	*Borde*	Non-alcoholic beverage	Ethiopia	Kebede, 2007

Sorghum is also vulnerable to fungal growth and mycotoxin production depending on environmental conditions. Lefyedi *et al.* (2005) and N'Kwe *et al.* (2005) report, in fact, that during storage, the seeds may be contaminated with *Aspergillus*, *Penicillium*, *Fusarium* and *Rhizopus*. Their toxins are not only harmful to health but also affect the nutritional quality of sorghum. When sorghum is planted, the roots and shoots contain very large amounts of hydrocyanic acid (FAO, 1995; Traoré *et al.*, 2004). This acid is a poison to the hemoglobin in red blood cells. In addition it causes thyroid disorders by preventing iodine from binding and causing goiter, slow growth in children. However, it can easily be removed by manual degerming germinated seeds, drying in the sun, cooking and fermentation (Traoré *et al.*, 2004). Sorghum grain contains many enzymatic activities involved in the degradation of the endosperm. Red sorghum has a very high enzyme activity compared to white sorghum; it what explains its use in the manufacture of beer as well as industrial traditional sorghum (Dufour *et al.*, 1992; Taylor and Robbins, 1993).

Pearl millet Pennisetum glaucum (L.) and finger millet (Eleusine coracana)

Millets are the most widely grown varieties for food use in Africa. Millet is used in preparation of various kinds of beverages (*koko* sour water, *obiolor*, *kunun-zaki*) and porridges (*koko* and *kirario*). Millet has nutritive value, which resemble that of sorghum. However, pearl millet has slightly lower starch contents, higher protein and lipid content than sorghum and most other common cereals. This makes the energy yield of millet higher than that of sorghum. Millet contains lysine and sulphur containing amino acids, threonine and tryptophan and therefore millet has a better amino acid balance than sorghum (Sekwati-Monang, 2011). In general, millet contains similar amounts of vitamins as sorghum, especially the B vitamins, which is concentrated in the aleurone layer and germ. Malting and fermentation of millet lead to an increased amount of vitamins B and their availability (Nout and Motarjemi, 1997; Léder, 2004). Mineral content of millet vary according to soils and conditions where the plants are grown. Generally, the mineral content of millets is higher than that of sorghum and other cereals.

Among millets, finger millet and tef are good sources of dietary calcium (Table 2). Pearl millet contains low concentration of calcium, as compared to tef and finger millets and this is due to the fact that pearl millet, together with other grains, contain oxalic acid which binds with calcium to form insoluble complexes and thus reducing its bioavailability. Also, the high phytate and phenolic compounds in the pericarp of millet limits the absorption of the minerals, especially calcium. Many of the finger millets contain tannin levels of up to 3.5%

comparable to brown sorghum (Ramachandra *et al*., 1997). Tannin quantity is associated with low in vitro protein digestibility. Unlike sorghum and finger millet, pearl millet varieties do not contain tannins and this explains differences in the nutritional content between pearl and finger millet (Sekwati-Monang, 2011).

Maize (Zea mays L.)

Maize is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages and food sweeteners. Maize grain accounts for about 15 to 56% of the total daily calories in diets of people in about 25 developing countries, particularly in Africa and Latin America (Prasanna *et al*., 2001). Maize is processed into various products such as porridges/gruels (*uji, ogi, mawe*), flat breads (*kenkey*) and beverages (*obiolor, kwete*, kaffir beer). Many of the traditional foods in Africa are produced from fermented or geminated maize, which increases the vitamin content, mineral bioavailability and the quality of protein (Sekwaté-Monang, 2011). Like other cereals, maize is an excellent source of carbohydrates, which accounts for about 72-73% of the kernel (Wilson, 1987). Maize also contains protein, but it is regarded as inferior because of its low content of lysine and tryptophan. It is considered to be rich in vitamin B and minerals, especially, phosphorus, magnesium, manganese, zinc, iron and small amounts of potassium (Table 2). Maize is deficient in niacin, which is found in the outer layer and often removed with the pericarp during dehulling. Maize compares well with other cereals as energy source. However, maize contains no tannins as compared to some sorghum and finger millet cultivars.

Traditional technologies for production of fermented cereal beverages

Non-alcoholic beverages

Bushera

Bushera is the most common traditional non-alcoholic beverage prepared in theWestern highlands of Uganda **(**Muyanja *et al*., 2003). It is prepared from sorghum and millet. Low-income women at village level produce *bushera* for home consumption and sale. The product is consumed by both young children (only 1-day fermented *bushera*) and adults. In brief, to prepare *bushera*, sorghum or millet flour from germinated sorghum and millet grains is mixed with boiling water and left to cool to ambient temperature. Germinated millet or sorghum flour is then added and the mixture is left to ferment at ambient temperature for 1–6 days

(Muyanja *et al*., 2003). Traditional preparation of *bushera* is presented in Figure 1. In production of sour *bushera*, fermentation time is prolonged to 2-4 days as compared to 1 day for sweet *bushera*. Sour buchera is mostly for adults, while the sweet version is fed to children. Back-slopping is also practiced in the production of *bushera*, but this has been considered to lead to fast production of acid and hence excessive sourness. Therefore, back-slopping is practiced in households where they prefer sour *bushera* over sweet one (Muyanja *et al*., 2003 ; Sekwati-Monang, 2011).

Table 2. Nutritional composition of cereals in 100/ g serving portions

Parameters Cereals	Starch (g)	Protein (g)	Fat (g)	Crude Fiber (g)	Ash (g)	Food Energy (kJ)	Calcium (mg)	Iron (mg)	Thiamin (mg)	Niacin (mg)	Riboflavin (mg)
Sorghum	77	10.9	3.4	2.3	1.6	1374	29	4.3	0.3	3.0	0.14
Pearl millet	69	11.0	5.0	2.2	2.3	1443	36	9.6	0.3	2.5	0.15
Finger millet	75	6.0	1.5	3.6	2.6	1396	358	9.9	0.3	1.4	0.10
Maize	77	9.2	4.6	2.8	1.2	1498	26	2.7	0.4	3.6	0.2
Tef	77	11.0	2.3	3.3	2.9	1389	167	150	0.5	2.5	0.1
Wheat	71	11.6	2.0	2.0	1.6	1389	30	3.5	0.4	5.1	0.1

Source: FAO, 1995; Léder (EOLSS), 2004; Sekwaté-Monang, 2011

Borde

Borde is an Ethiopian spontaneously fermented, low or non-alcoholic cereal beverage. It is produced from a variety of locally available cereal ingredients using traditional techniques. The adjunct (all unmalted cereal ingredients) and each malt can be from one type or a mixture of cereals. *Borde* is an opaque, effervescent, whitish-grey to brown colour and has a thick consistency and sweet-sour taste. It must be consumed while actively fermenting within a day due to its poor keeping quality. It is widely consumed by adults and children mainly in southern and western parts of Ethiopia. *Borde* is often consumed as a low-cost meal replacement for many poor people (Kebede, 2007). The production of *borde* is a laborious and complex technology and is exclusively carried out by women. As shown in the flow chart of Figure 2, the production of *borde* has four major phases, which are marked by the introduction of fresh ingredients into the fermentation vessel. In Phase I, maize grits are mixed with water enough to immerse them and allow to ferment for 44 to 72 h. The content is apportioned into three parts at different periods (44-48 h and 66-72 h), is cooked with other non-fermented ingredients and is used at Phase II, III and IV of main fermentation. In Phase II, a portion of 44-48 h fermented mass from Phase I is roasted at about 90°C for 30-45 min and is cooled and fresh malt flour are blended with water in a cleaned and smoked to a light brown thick mash. The brewers mix the ingredients using their hands and adjust the consistency of the mash. This mixture is called *tinsis* and is allowed to ferment for about 24 h. During preparation of unmalted ingredients for the third phase, a second portion of the fermented mass (now about 66 h old) from Phase I is slightly roasted, cooled, thoroughly kneaded with more flour and water and then is moulded into dough balls. They are then steam-cooked for 1-1.5 h to give *gafuma*. The *gafuma* is broken into pieces, cooled and blended with the fermented *tinsis* and water to a thick brown mash called *difdif*. The *difdif* is then allowed to ferment for 18 h. In Phase IV, the last portion of fermented mass (about 72 h) from Phase I is mixed with a boiling porridge prepared from flour or grain. The content is maintained with continuous stirring at about 90°C for 1-1.5 h into a very thick porridge. The cooled thick porridge is blended with the fermented *difdif*, along with some additional malt and water. This mixture is then sieved using a *wonfit* (about 1 mm pore size). The residue is wet-milled using grinding stones and then sieved again by slurrying with more water. The wet-milling and -sieving operations are repeated up to 3 times. All the three fractions of filtrate are collected together, poured back into the rinsed main fermentation vessel and the consistency adjusted if necessary. This filtrate is allowed to ferment for a further 4-6 h. The actively fermenting, effervescent *borde* is then ready for consumption.

Gowé

Gowé is a homogenous gelatinized, malted, fermented and cooked paste prepared from sorghum, millet or maize. It is consumed as a beverage after dilution in water and the addition of ice, sugar and sometimes milk. It is the preferred beverage of children, pregnant women, sick and old people. All types of sorghum, millet and white maize can be used to make acceptable gowé but colored sweet *gowé* is preferred (Michodjèhoun-Mestres *et al.*, 2005 ; Vieira-Dalodé *et al.*, 2007). According to Michodjèhoun-Mestres *et al.* (2005), *gowé* preparation starts by dried grains steeping overnight in a plastic container in 3 volumes of tap-water at room temperature (28-30°C), without changing the water. The soaked grains are washed and drained. They are uniformly spread on a wet piece of thin cloth placed in a traditional wicker basket, then they are covered with another piece of cloth to reduce deshydration. The grains are kept wet by frequent spraying with tap-water. Germination is done at room temperature (28- 30°C), over a 48h period. The germinated grains are sun-dried (4 days) but the roots are not removed, in accordance with local practice. The malt is milled in the community plate disc mill to get a fine flour, passing through a 0.5 mm sieve. Then 1 kg of malted sorghum flour is mixed with 2 kg of non-malted sorghum flour and 3 L of water. The sample is divided between 7 lidded plastic buckets marked with different fermentation times (0, 4, 8, 12, 24, 48 and 72 h). The first fermentation is carried out at room temperature (28-30°C). After 12 h fermentation, non-acid thick porridge (prepared by mixing 1 kg of whole sorghum flour and 10 L of water and cooking at 100°C for 10 min) is added to the samples in the buckets marked 12, 24, 48 and 72 h. The temperature of the mixture is 50-60°C when added to the samples and decreased to room temperature (28-30°C) during the following (or second) fermentation period. After second frmentation, raw *gowé* obtained is cooked, then packaging in leaves. It is consumed after dilution in water and the addition of ice, sugar and sometimes milk (Figure 3).

Kunun-zaki

Kunun zaki is a traditional non-alcoholic fermented beverage widely consumed in the northern part of Nigeria (Obadina *et al.*, 2008 ; Adeleke and Abiodun, 2010 ; Agarry *et al.*, 2010 ; Nwachukwu *et al.*, 2010 ; Sekwati-Monang, 2011). It is however becoming widely consumed in the southern parts among low and middle income workers who cannot afford industrially produced beverages like Coca-cola, Pepsi etc. Its popularity is due to its characteristic sweet-sour taste, its refreshing quality as well as the creamy or milky appearance and also its flowing consistency. The beverage is a millet based food drink which is consumed within few hours of its production. For preparation of *Kunun-zaki* (Figure 4), 500 g of dehulled millet grains are cleaned and washed, weighed and steeped in 1000 ml of water at room temperature for 48 h. The same procedure was repeated four times after steeping each sample is milled with 3.25 g ginger, 0.25 g cloves, 1.25 g red pepper and 0.25 g black pepper. The resulting slurry is sieved using a sterile sieve until all the starch is extracted, the shaft are then discarded. The filtrate is allowed to settle, the supernatant decanted and the sediment is divided into 2 parts (ratio 3:2). The larger portion is cooked by the addition of 500 ml boiling water for 5 min while 500 ml cold water is added to the second part. The two slurries are thoroughly mixed and allowed to ferment for 6 h at ambient temperature following which it is sieved, and sweetened with 50 g granulated sugar (i.e. 10% sugar w/w millet used).

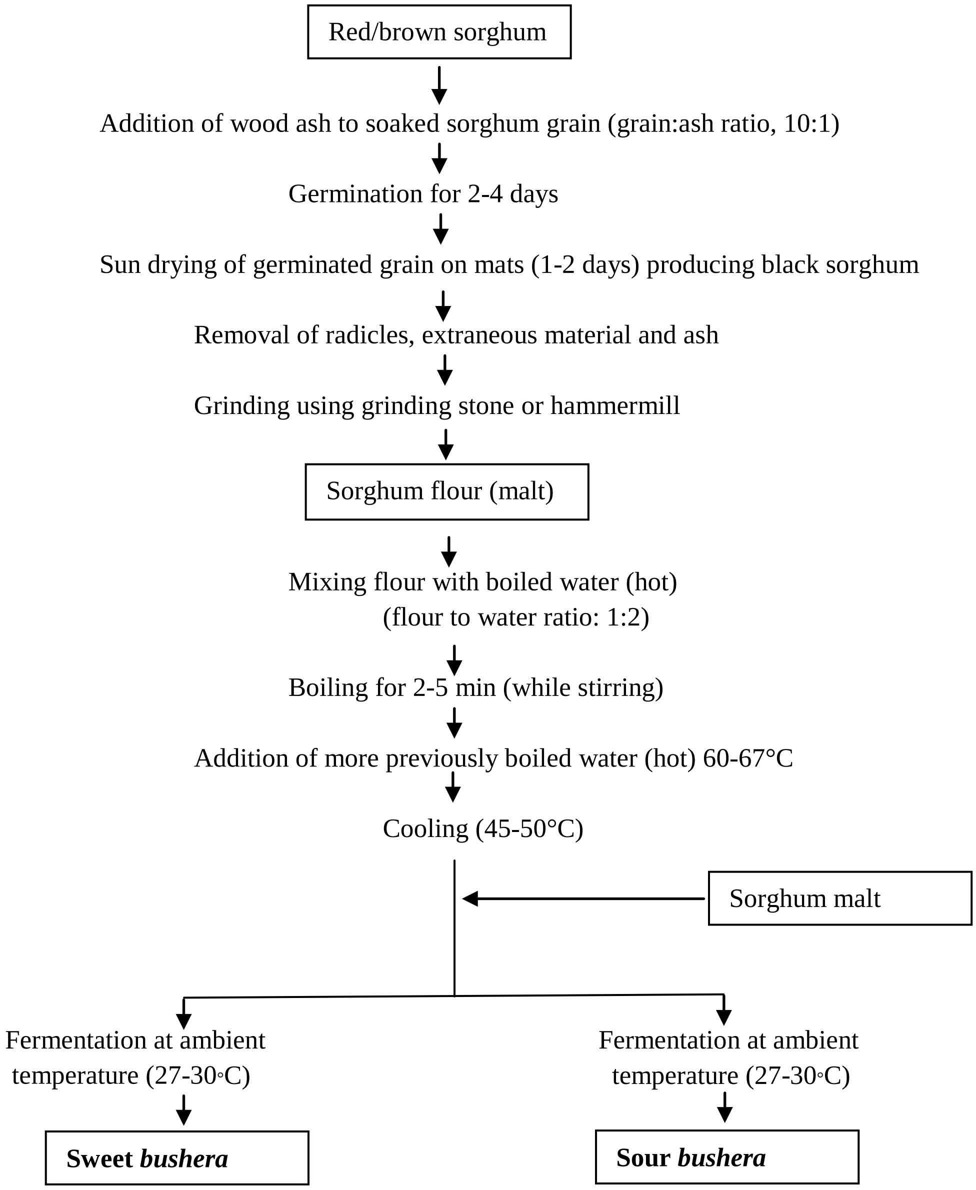

Figure 1. Production of sweet and sour sorghum *bushera.*

Source : Sekwati-Monang, 2011

Mahewu

Mahewu (*amahewu*) is a non-alcoholic South Africa sour beverage makes from maize meal. It is an adult type of food, although it is commonly used to wean children and is introduced to infants between 4–18 months (Katongole, 2008). It is known by various names. In Zulu it is known as ‘*amahewu*’, the Xhosas call it ‘*amarehwu*’, the Swazis, ‘*emahewu*’, the Pedis, ‘*metogo*’, Sothos, ‘*machleu*’, while the Vendas call it ‘*maphulo*’ (Katongole, 2008). The most commonly used term is *mahewu*. *Mahewu* is traditionally prepared by boiling thin maize porridge containing 12-14% meal gruel. After boiling, the porridge gruel is cooled to ambient temperature and transferred into a fermentation vessel, 2-4% of wheat flour is added to provide an inoculum and the inoculated gruel is spontaneously fermented in a warm place for 24-48 h (Figure 5). Alternatively it can be prepared by mashing left over pap into a slurry and then ferment it overnight (Gadaga *et al.*, 1999). The fermentation is a spontaneous process carried out by the natural flora of the malt at ambient temperature (Gadaga *et al.*, 1999). The drink is consumed after standing for about 24 h (Katongole, 2008 ; Blandino *et al.*, 2003 ; Sekwati-Monang, 2011).

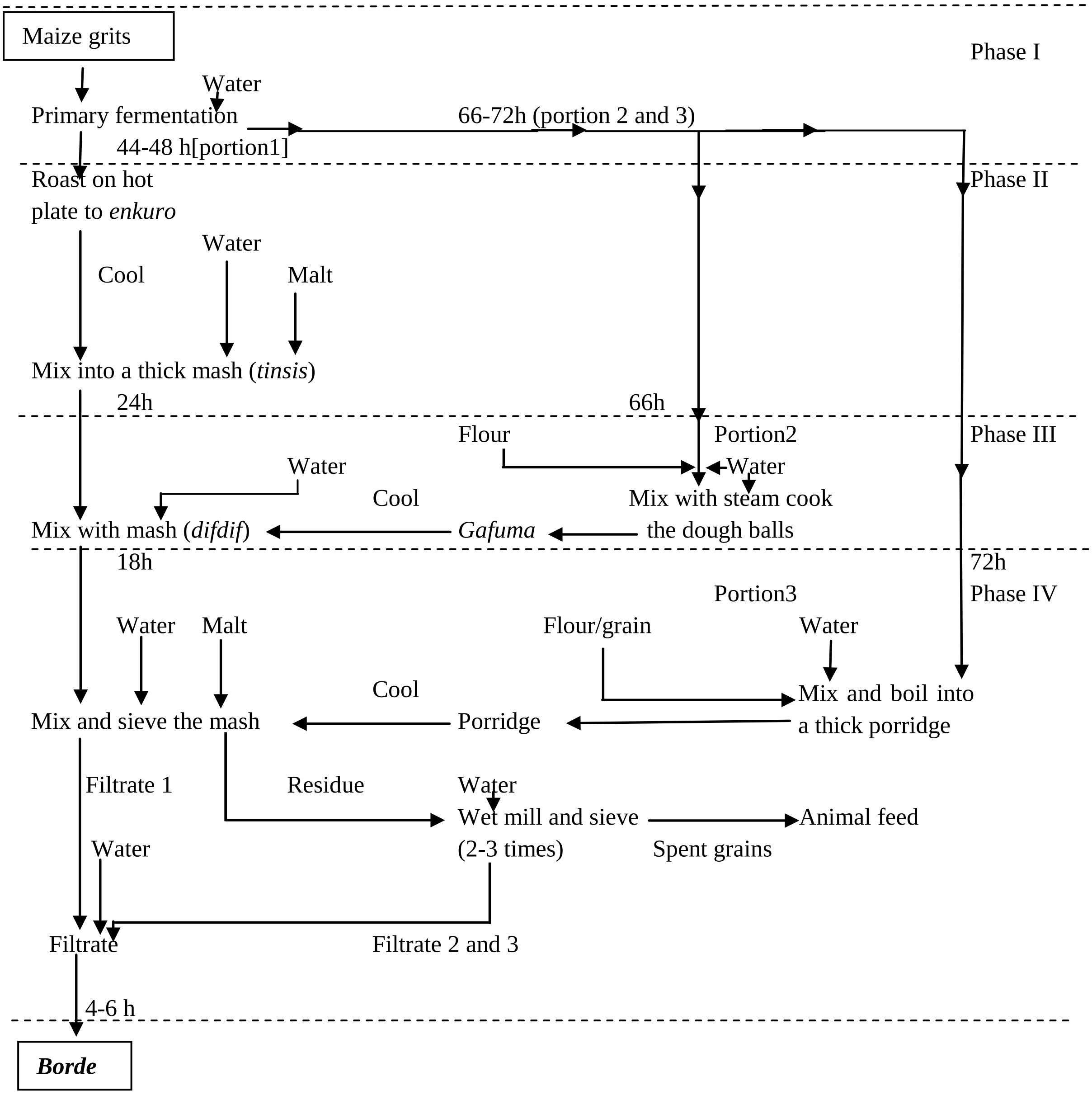

Figure 2. Traditional production of *Borde*.

Source: Kebede, 2007

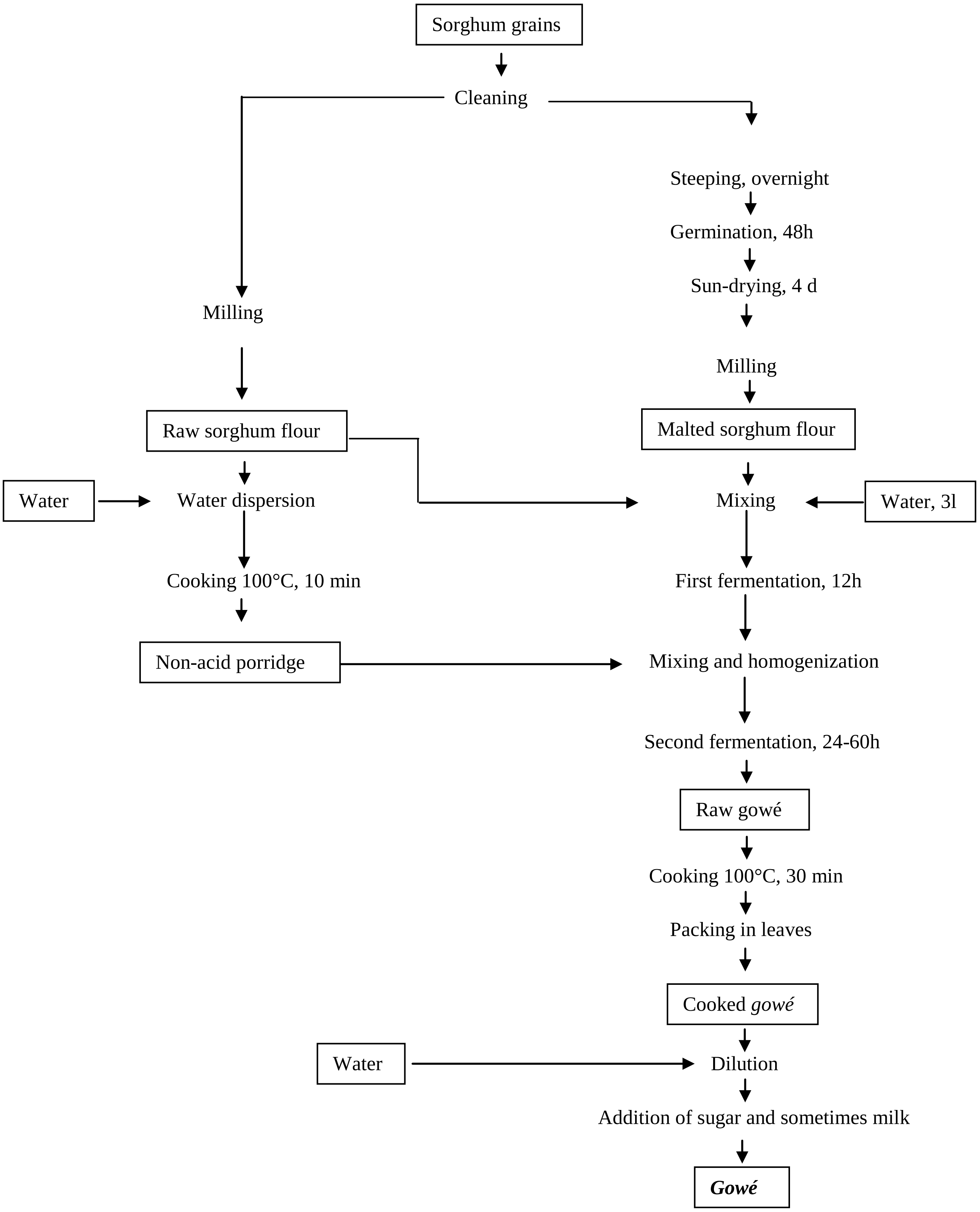

Figure 3. Production of traditional *gowé*.
Source : Adapted of Michodjèhoun-Mestres *et al.*, 2005

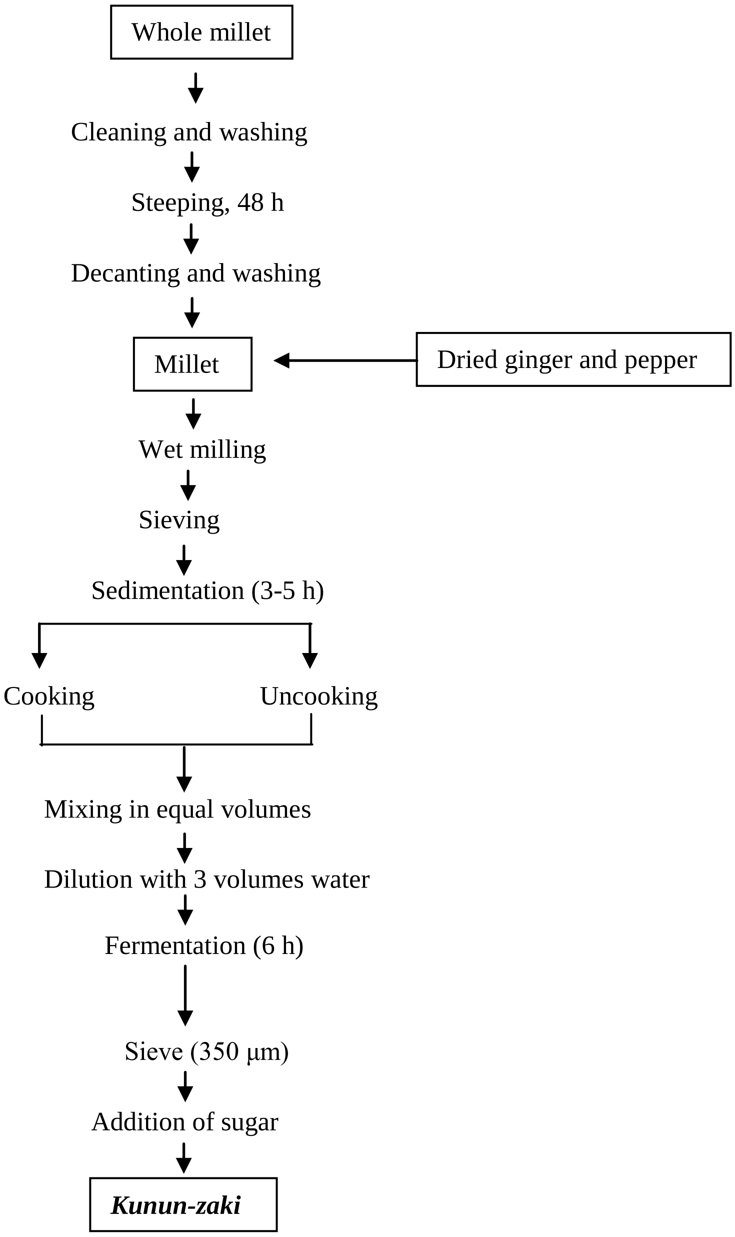

Figure 4. Traditional production of *Kunun-zaki*
Source : Agarry *et al*., 2010 ; Sekwati-Monang, 2011

Malwa

Malwa is a fermented beverage that is valued for its taste, flavour and aroma and is mainly produced at the household level in eastern and north eastern region of Uganda (Muyanja *et al.*, 2010). The *malwa* is served in clay pot and consumed while being diluted with hot water using locally made straws. Consumers preferred sour *malwa* to the sweet one (1-2 days old). Finger millet is used in the production of this beverage. Typically, clean millet grain is sprinkled with water and put in a gunny bags and soaked overnight (12 h). One portion of grains are germinated during 2 to 3 days. After germination, the grains are sun dried for 1-2 days. The dried grains are either hand or hammer milled to produce ground green malt. Another portion of ungerminated millet grain is ground into flour and mixed with a small amount of water to produce stiff dough. The stiff dough is then placed in plastic sheets and buried in the soil to undergo solid pit fermentation for 10-14 days. The stiff dough is subjected to solid state pit fermentation to impart desirable changes in the dough. The sour dough is roasted at around 72°C on cut metallic metal drums under open fire with continuous stirring to avoid undesirable burnt flavour. The roasted sour dough is sun dried for 1-2 days. Water is added to the mixture at a ratio of l Kg of grist to 1.5-3 Litres and mashed by boiling. The mixture is left to cool at ambient temperature before green malt is added. The mixture is fermented at ambient temperature for 2-4 days. During the second day more green malt is added on to accelerate the fermentation process. After fermentation, *malwa* is obtaind (Figure 6).

Masvusvu and Mangisi

Masvusvu is a sweet beverage made traditionally from malted finger millet (*Elusine coracana* (L.) Gaertn) in many villages of Zimbabwe. *Mangisi* is a sweet sour product which results from natural fermentation of sieved *masvusvu* (Zvauya *et al*., 1997). Both products are light brown in color, they are consumed as either food or drink and are popular refreshments during village gatherings or when people are working in the fields. *Masvusvu* is also used as an adjunct during opaque beer brewing. The preparation of both products is still basically a family art that is passed on from generation to generation orally. The traditional brewing process *of masvusvu* and *mangisi* has been described by Zvauya *et al.* (1997) in Figure 7. Water (6 liters) is added to 1.6 kg of malted millet mealy-meal in a pot. The mixture is heated while slowly stirring at intervals for 80 minutes to almost boiling. The slurry mixture is turned brownish in color, viscosity increased and it has a sweet taste. The product is now *masvusvu*. It is left to cool at room temperature for 30 minutes, then diluted by adding 2 liters of fresh clean tap water to reduce viscosity and sweetness. Straining is done using a 425 µm size sieve. One earthenware pot is reserved for *mangisi* preparation and is not washed with any detergent after each fermentation as is practiced traditionally. The filtrate is left to ferment spontaneously at room temperature for 8 hours in this earthenware pot. The product becomes sweet sour with time. The product is now *mangisi*. Some people prefer to drink the product soon after cooking before straining (*masvusvu*), others prefer the diluted, strained product and some prefer the product after if has been left to ferment for a few hours at room temperature (*mangisi*).

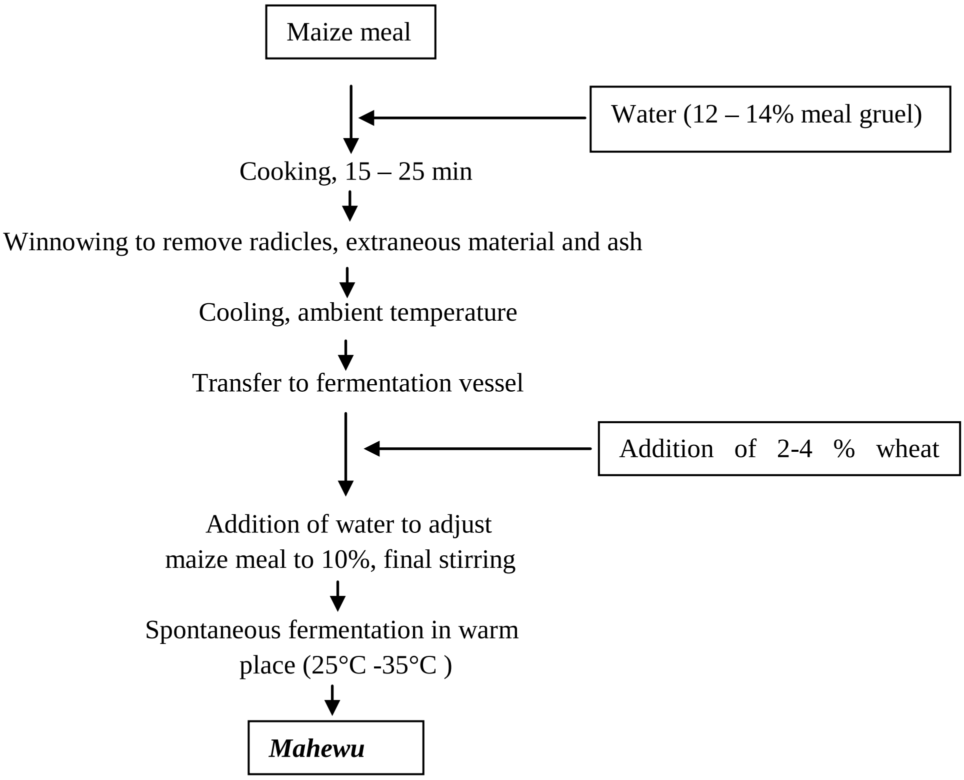

Figure 5. Production of *mahewu*
Source : Sekwati-Monang, 2011

Obiolor

Obiolor is a non-alcoholic beverage produced from fermented sorghum and millet malts in Nigeria. *Obiolor* is consumed daily by the Igala tribe in Nigeria and highly associated with good health. It is a thin gruel with sweet taste. The sweet taste is attributed to sorghum and millet malt. Traditional preparation of *obiolor* is presented in Figure 8. It is produced by steeping sorghum and millet grains in water overnight, after what, the grains are wrapped in fresh banana leaves and allowed to germinate for 3 days. The germinated grains (80% sorghum + 20% millet) are wet milled and prepared into slurry. The slurry is mixed with boiled water (ratio 1:4 v/v). The mash is cooled, filtered and the residue discarded, while the filtrate is concentrated by boiling for 30 min with continuous stirring. The resulting gruel is cooled rapidly and allowed to spontaneously ferment for 24 h at ambient temperature, after which it is ready for consumption (Sekwati-Monang, 2011).

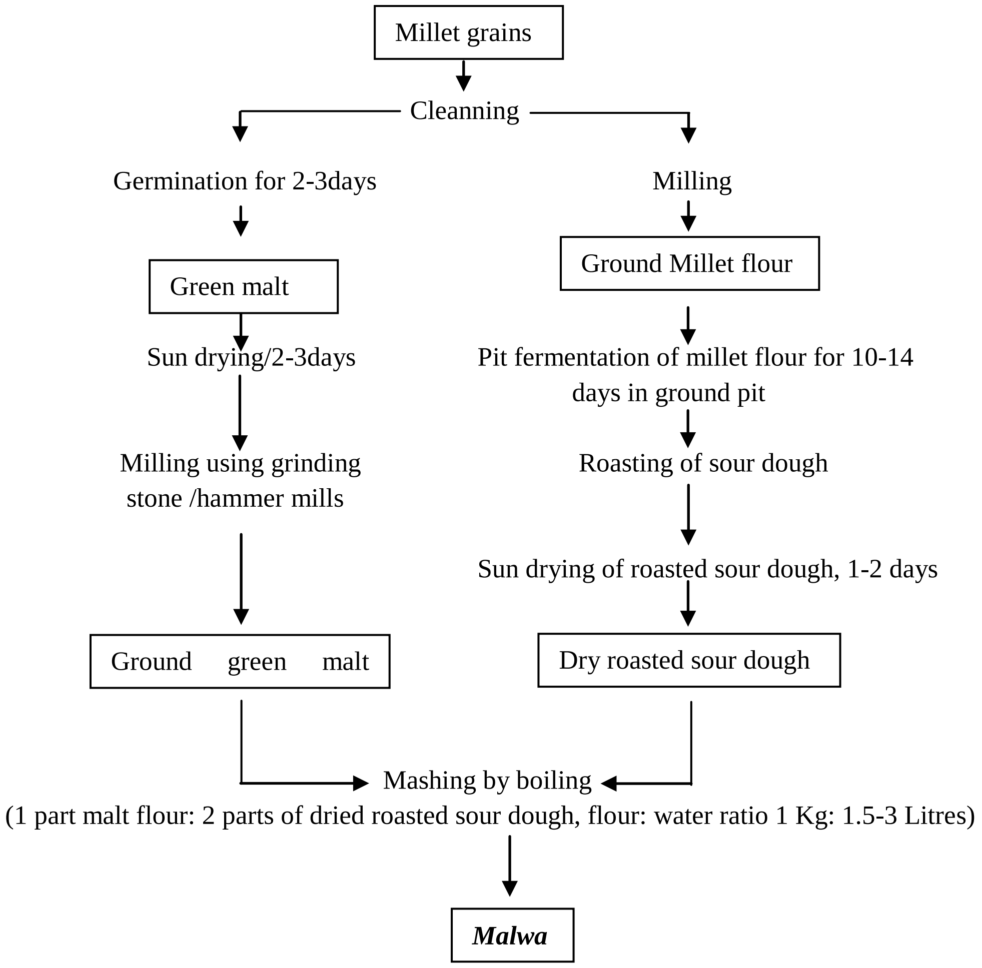

Figure 6. Traditional preparation of *malwa.*
Source : Muyanja *et al.*, 2010

Alcoholic beverages

African cereal alcoholic beverages are empirically derived from the spontaneous alcoholic fermentation of sweet wort from germinated cereals. Their processing is similar to that of modern beer in their outline. The differences relate to the final processing of modern beer (which does not exist in the traditional beverages manufacturing) and in the obligatory spontaneous lactic acid fermentation of traditional beverages processing (which does not exist in the manufacturing of modern beer). Their processing varies from one region to another, but includes essentially malting, mashing, souring, straining, boiling and fermentation.

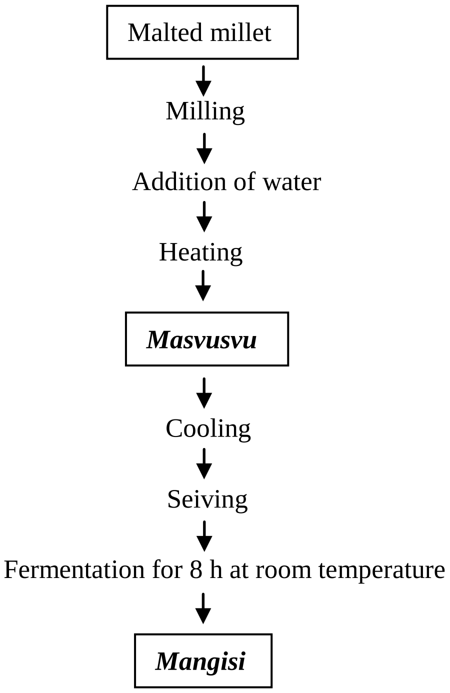

Figure 7. Traditional preparation of *masvusvu* and *mangisi.*

Source : Adapted of Zvauya *et al.*, 1997

Amgba and bili bili

Amgba and *bili bili* are traditiona opaque beers resulting from fermentation of sorghum and millet in Chad and Cameroon. Like most indigenous African beer made from millet or sorghum, *amgba* and *bili bili* are seen both as a food and drink and thus is sometimes referred under the name "eat drink" by some consumers (Chevassus *et al*., 1979 ; Maoura *et al.*, 2005, 2006). They are rich in calories, B-vitamins and essential amino acids such as lysine, which make them a nutritional supplement booster. These beverages are also a significant source of income for women and producers of sorghum and millet. For their production (Figure 9), briefly, sorghum grains are soaked in water and then left to germinate, sun dried and ground into fine flour. This malt flour is then mixed with water containing a sticky substance and left in decantation.After 1 to 2 h of decantation, the supernatant is collected, while the settled residue is cooked during then mixed with the previous supernatant. The mixture is then left during 9h for a spontaneous lactic fermentation to acidify the wort, filtered and the wort obtain is boiling during 5h. After boiling, the wort is cooled and then inoculated with traditional yeast for alcoholic fermentation to obtain *amgba* or *bili bili* depending countries (Chevassus *et al*., 1979 ; Maoura *et al*., 2006).

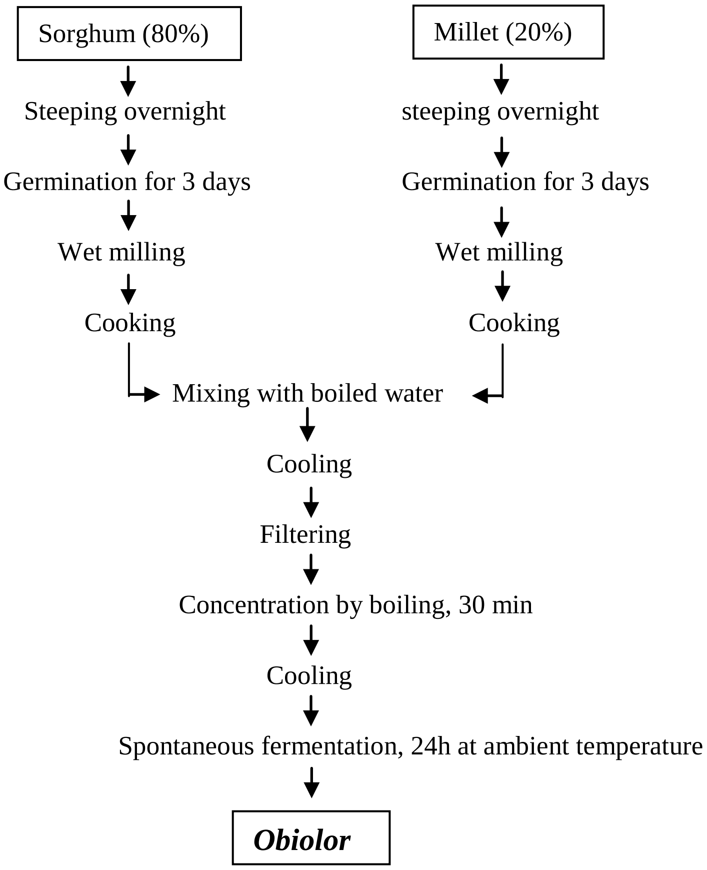

Figure 8. Production of *Obiolor*
Adapted of Sekwati-Monang, 2011

Burukutu and Pito

Burukutu and *pito* are an ethnic light brown, alcoholic, slightly bitter, sweet sour beverages from Nigeria and Ghana with a fruity flavor made by fermentation of malted, mashed maize or sorghum (Achi, 2005 ; Glover, 2007 ; Mbajiuka *et al*., 2010 ; Tamang and Kailasapathy, 2010 ; Sunday and Aondover, 2013). *Burukutu* and *pito* are usually consumed as a nutritious beverages daily and in various festivals and ceremonies (marriage, birth, dowry and so on) and constitute a source of economic return for the women producers. The production process is illustrated in Figure 9. During their production, maize and/or sorghum grains are soaked in water for 2 days, drained, and held in a moist chamber for germination for 5 days. The sprouted grains are sun dried before grinding. The malt flour is mixed with water and then, boiled for 6-12 h, cooled and filtered. During the mashing stage of *burukutu* production, adjuncts are added in the form of *gari* (a farinaceous starchy powder produced from cassava, *Manihot esculenta*). However, adjuncts are not added during the production of *pito*. The filtrate is again fermented overnight and becomes slightly sour due to microbial action. It is then boiled for 12 h to concentrate it and is again cooled. The starter (sediment) from a previous brew is added to the cooled concentrate and is incubated for 12-24 h to get *Burukutu* and *pito*.

Dolo and Tchapalo

Dolo and *tchapalo* are traditional opaque, sour alcoholic beverage produce in Burkina Faso and Côte d'Ivoire respectively. They contain a large amount of insoluble material and are always fermenting (Yao *et al.*, 1995; N'Da et Coulibaly, 1996; Sawadogo-Lingani *et al.*, 2007; Aka *et al.*, 2008a; Dje *et al.*, 2008). In addition to therapeutic properties assigned, they have nutritional value contributing significantly to improve the diet of consumers. *Dolo* and *tchapalo* is generally consumed during rural work, popular festivities, and funerals. They are also used to welcome and to cool down somebody. These beverages production is rooted profoundly in ethnics tradition of Northeast and North of Côte d'Ivoire and all part of Burkina Faso. They are essentially managed by women. For these women, tchapalo production is today a real economic activity productive of revenue. *Dolo* and *tchapalo* are brewed from sorghum, maize and/or millet. Their processing startes by the malting of sorghum grain, sun-drying and milling to give malted sorghum flour (Figure 9). This flour is mixed out with water containing a sticky substance. The mixture obtained called mash is separated from supernatant and sediment. The sediment is cooked during 2-2 h 30 min; later mixed with the supernatant to give wort. The wort is left for a spontaneous fermentation during the night to give after percolation the sour wort. The sour wort is then cooked during 4-6 h to give sweet wort which is cooled and inoculated with dried yeast harvested from previous brew for alcoholic fermentation during 9-12 h. The product obtained after alcoholic fermentation is called *dolo* or *tchapalo* depending countries.

Tchoukoutou and Chakpalo

Tchoukoutou and *chakpalo* or *Tchakpalo* are fermented alcoholic beverages obtained from malted sorghum and consumed as a refreshing drink in Benin and Togo (Kayodé, 2006 ; Osseyi *et al.*, 2011; Baba-Moussa *et al.*, 2012). They are daily life of people and take a place of choice because of important, number of women who devote to their production, selling their and participate to their distribution all along countries. *Tchakpalo* and *Tchoukoutou* are distinguishable by both their appearance and taste. *Chakpalo* is a clear and sweet fluid, while *tchoukoutou* is an opaque (turbid) and acidic beer. Beers are originally prepared with sorghum (Guinea corn; Sorghum bicolor), but other starch sources like millet or maize can be used as adjunct or as substitutes (Kayode, 2006). *Chakpalo* is prepared in the same way as *tchoukoutou* except that the filtered final wort is not inoculated and is allowed to undergo a natural fermentation for 2 to 24 h. The traditional preparation method of beer has described in Figure 9. Sorghum grains are cleaned, soaked and allowed to germinate; this is followed by sun drying in order to stabilize the obtained malt. Germinated grains are ground and mashed with water, decanted and divided into slurry and supernatant. The slurry is mashed by gradually heating until the boiling point is reached after 2h, mixed with supernatant and allowed to sour during overnight fermentation, filtered and boiled. The wort obtained is cooled, inoculated with starter harvested from previous batch and fermented overnight (13-14 h) to obtain *tchoukoutou* or not inoculated and is allowed to undergo a natural fermentation for 2 to 24 h to obtain *Chakpalo*.

Bantu beer or kaffir beer or sorghum beer

Bantu beer or *kaffir* beer or *sorghum* beer is an ethnic beer of the Bantu tribes of South Africa and is an alcoholic, effervescent, pinkish-brown beverage with a sour flavor, having the consistency of a thin gruel and an opaque appearance (Tamang and Kailasapathy, 2010). Maize is also used for *Bantu* beer production. In the traditional method of production of *Bantu* beer (Figure 9), sorghum malt is produced by soaking the grain in water for 1 days, draining, and then allowing the seeds to germinate for 5-6 days at 20°C to 25°C. The sprouted grain is sun dried. The malt is slurried to a thin gruel, boiled, cooled, and a small amount of fresh, uncooked malt is added. The mixture is kept for 1 day during which lactic acid fermentation occurs. On the second day, it is boiled in a cooking pot and returned to a brewing pot for the alcoholic fermentation. On the third and fourth days, more pulverized uncooked malt is added, and on the fifth day the brew is strained through a coarse basket to remove the husks. The *Kaffir* beer is then ready to drink (Tamang and Kailasapathy, 2010 ; Sekwati-Monang, 2011).

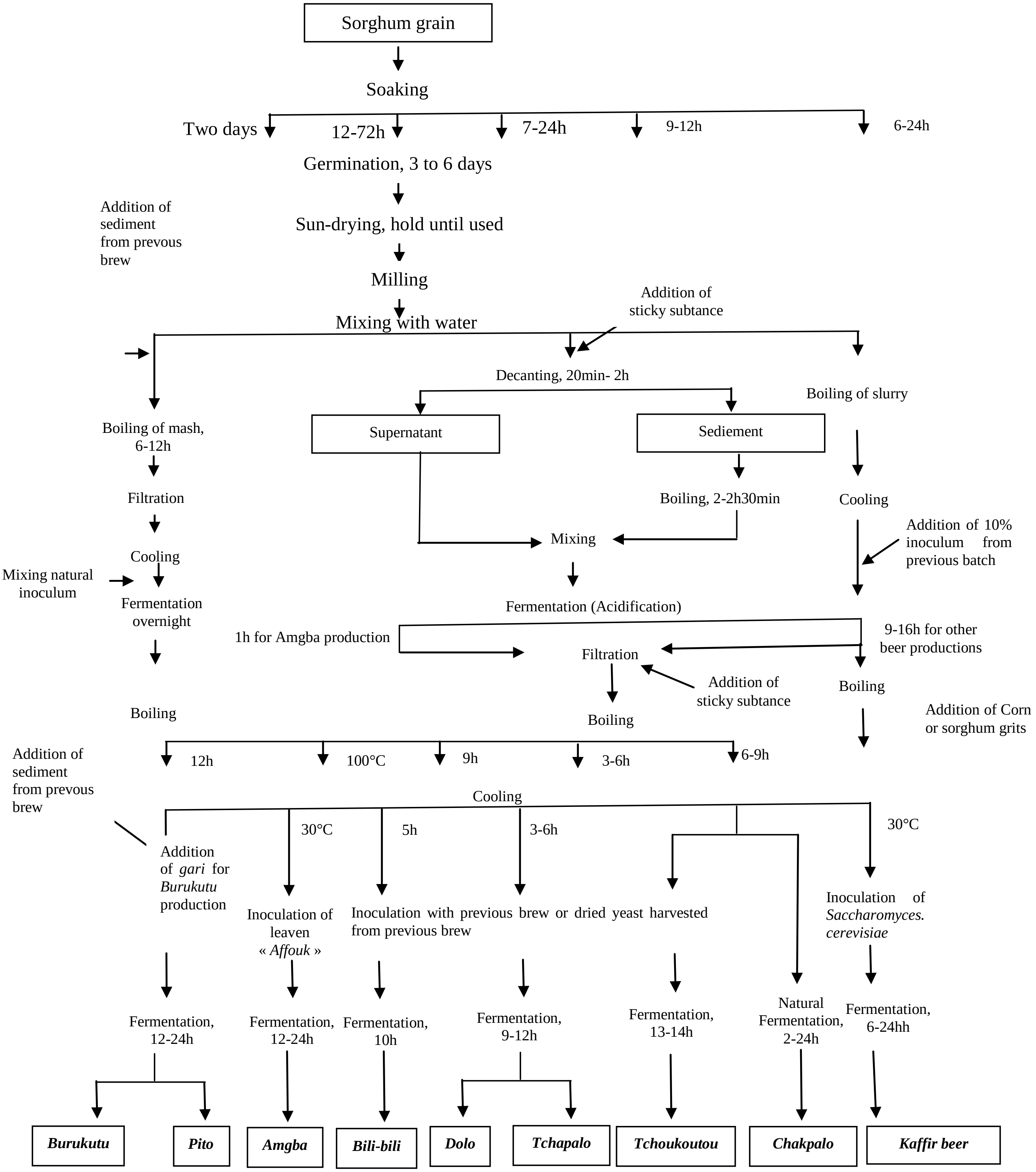

Figure 9. Diagram of some traditional African beers similar processing

Busaa

Busaa is a Kenyan opaque maize beer. It is similar to the *malwa* beer in Uganda and the *kaffir* beer in South Africa. It nutritional value is considered superior to that of clear lager beer due to higher content of crude protein, thiamine and riboflavin. Busaa is a very popular drink among the low income workers (Katongole, 2008). *Busaa* is commonly prepared from maize endosperm grits and finger-millet malt (*Eleusine coracana*). On average, it *busaa* contains 2 to 4 % ethanol.The traditional process for the manufacture of *Busaa* has described in Figure 10. Maize meal is mixed with water to make a paste. The water used is about 45 per cent on a weight for weight basis. Place the paste in a container and allow to ferment at about 25°C (or room temperature in the tropics) for about 7-8 days to obtain *matzo*. Fry the fermented product on an open charcoal fire for about 30 min. During this period the desirable alcoholic flavour and brown colour develops. The millet grains are soaked in water and then placed in open pans which are well ventilated and allowed to germinate. This stage lasts for 7 days. The germinated millet malt is then dried in the sun and is now called *kimera*. The kimera is then coarsely ground, either manually between two stones or by the use of a hammer-mill. Then mixed with the *matzo* at the rate of 2kg *kimera* to 20 kg of maize. This is then thoroughly mixed. Place the mixture in large open drums and add water to a ratio of one part of water to three parts of solids. The slurry is allowed to ferment for 2 days at about 25°C (or room temperature in the tropics). The product is then sieved through a cloth. The filtrate obtained is the *busaa* which may be served hot or cold (ITDG, 1994).

Ikigage

Ikigage is a traditional alcoholic beverage manufactured in Rwanda with malted sorghum. *Ikigage* is consumed in various festivals and Rwandese ceremonies (marriage, birth, baptism, dowery, etc.) and constitutes a source of economic return for the women manufacturers. The traditional process of *ikigage* manufacture has been described by Lyumugabe *et al.* (2010). After washing, sorghum grains are immersed in water (*kwinika*) for 24 h, then drained in a bag with a stone top during 24 h so that the process of germination is completed and rootlets appear (*kumera*). After germination, the malted grains are sun dried. When the grains were quite dry, the rootlets are removed *(kuyavunga)*.Then malt grains are ground or crushed. Then, warm water (20 L) is mixed with ground malt (16 kg) in a large container. After the decoction, cool water is added (40 L) to bring temperature back to between 34 and 40°C. After cooling, certain brewers leave this mixture to rest approximately 3 h in order to eliminate the draffs *imvuzo*. After cooling, the traditional leaven (*umusemburo*) is inoculated in order to start the fermentation process. The fermentation container is covered with leaves of the banana tree, and then by a cloth and a lid. After 12 to 24 h of fermentation, *ikigage* is ready for consumption (Figure 11).

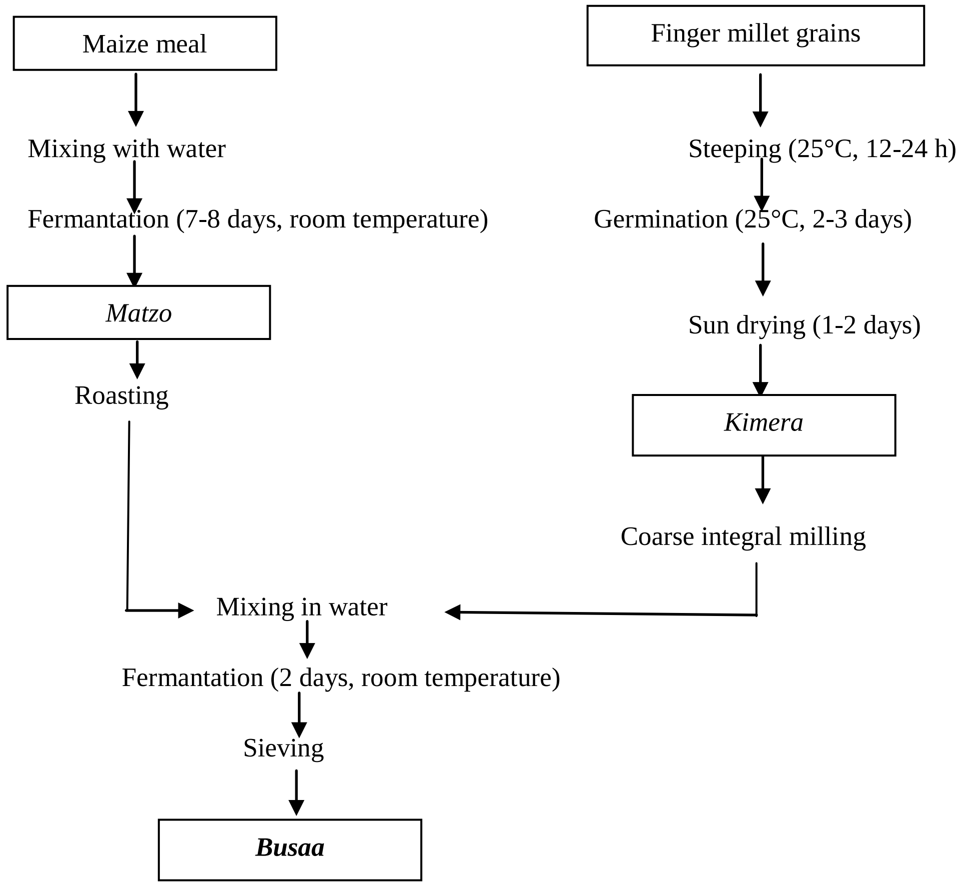

Figure 10. Production of *Busaa*.

Kwete

Kwete is a common traditional fermented beverage mainly produced from a mixture of maize and malted millet flour. It is largely consumed in Uganda and it is a preferred thirst quenching beverage during hot days (Namugumya and Muyanja 2009). *Kwete* is consumed within 24 h of fermentation, so it has a short shelf life. Women and children prefer sweet sour *kwete*, which is considered highly nutritious at that stage, while men prefer alcohol containing *kwete* which has been fermented for 72 h (Namugumya and Muyanja, 2009). Figure 12 below shows the production phases for *kwete*. The production process of *kwete* involves, cleaning, milling to produce maize grits /flour. The millet grains are soaked (24-48hrs), germinated (2-3days) and sun dried (1-2 days) and malted millet flour. Maize flour is fermented to give a raw sourdough, which is roasted in drums on open fire to give a golden brown colour desirable for *kwete* production. The roasted dough is allowed to cool for 6 h followed by addition of *kimera* (dried millet malt), mashing and fermentation for 24-72 h. The final product is strained using a bag woven from grass or cheese-cloth (Namugumya and Muyanja 2009).

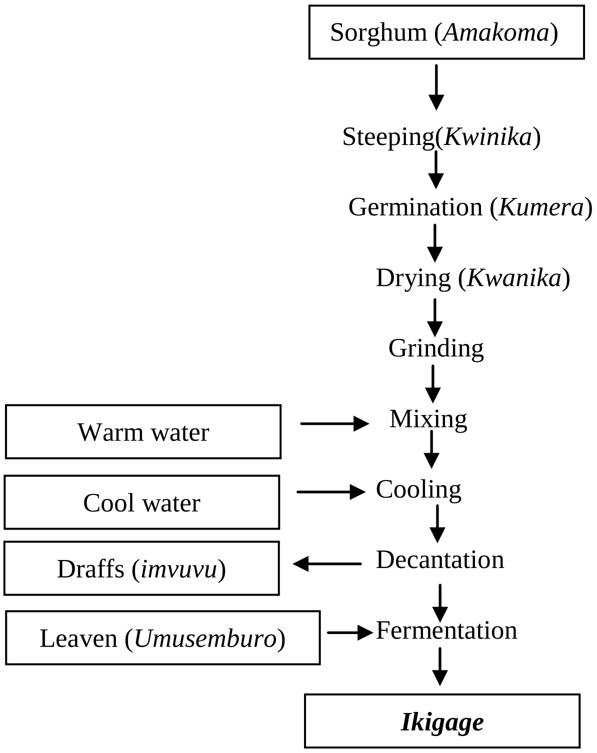

Figure 11. Production of *Ikigage*
Source : Lyumugabe *et al.*, 2010

Oti-oka

Oti-oka is an indigenous alcoholic beverage produced originally from sorghum and pearl millet. It is a fermented cereal gruel whose production is carried out using indigenous fermentation technology in the South-Western region of Nigeria. It has a good flavor; it is sweet, slightly sour with a brownish-opaque colour and has a pleasant taste during the third day of fermentation (Ogunbanwo and Ogunsanya, 2012). Traditional preparation of *Oti-oka* like beverage from pearl millet has described by Ogunbanwo and Ogunsanya (2012) in Figure 13. The cleaned grains are steeped in water for 18 h after which they are rinsed thrice and the grains drained. The hydrolyzed drained grains are spread evenly on a clean trays lined with cloth and kept wet by frequent spraying of water for 36 h at 25°C after which the germinated grains is sundried for 48 h and ground to pass a 0.4 mm sieve. One hundred and Fifty (150) g of ground germinated pearl millet is weighed and 50g each is distributed into 3 portions. Each portion is mixed with water (1:5), sieved with muslin cloth and allowed to boil for 3h. The boiled mixture is allowed to cool to 30°C and fermented naturally at 30°C for 72 h.

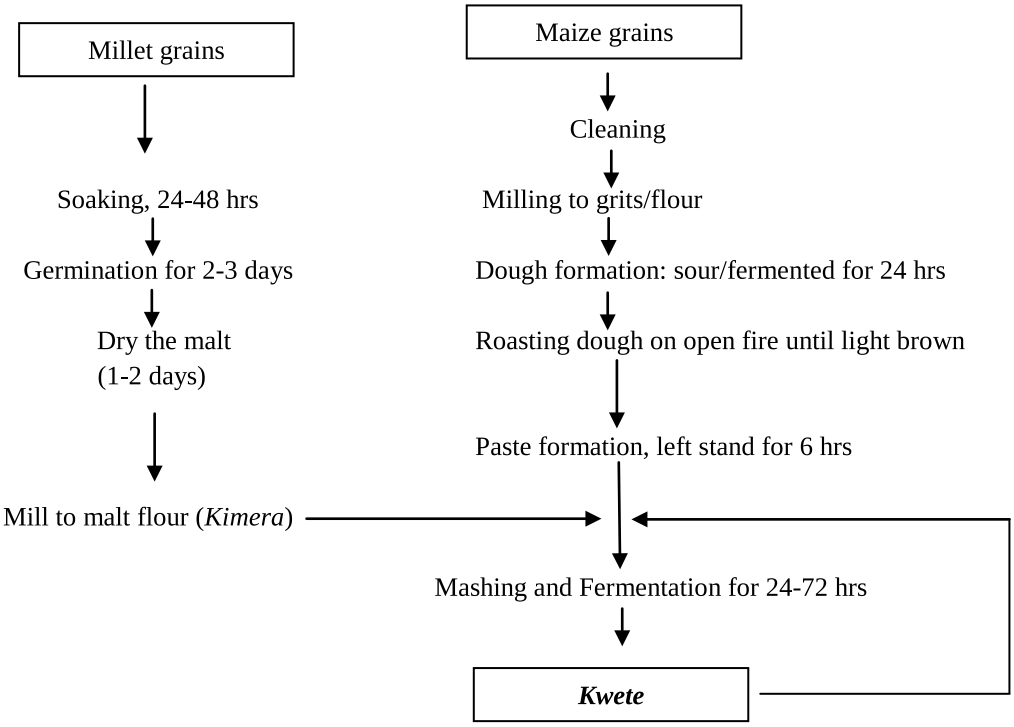

Figure12. Production of *Kwete*
Source : Namugumya and Muyanja, 2009

Umqombothi

Umqombothi is popular among the black South African population. It is pink, opaque, has a yoghurt-like flavour, a thin consistency, and is effervescent and alcoholic (3 %). It is consumed in the active state of fermentation and therefore has a short shelf life of 2-3 days (Katongole, 2008). Although it is produced commercially on large scale using new techniques, the old traditional way of making *umqombothi* still exists. In the townships, women still brew *umqombothi* either for social gatherings or for sale using the age-old techniques and village art methods. Maize and sorghum, used in combination, are the most common cereals used in South Africa to make *umqombothi*. The production process is illustrated in Figure 14. Briefly, maize flour (1 kg) is inoculated with a hand-full of sorghum malt and soaked in water for 24 h. The mixture is then cooked into a soft porridge and allowed to stand for 6 h to cool to room temperature. Additional sorghum malt (0.25 kg) is then added to the porridge and thoroughly stirred. This is then inoculated with a small portion of *umqombothi* (20 ml) from a previous batch. The mixture is then left to ferment for 18 h and then strained through a sieve with a pore size of 0.5 mm. Then *umqombothi* is obtained.

Microflora involved in traditional fermented beverages

'Spontaneous' fermentations typically result from the competitive activities of different microorganisms; strains best adapted and with the highest growth rate will dominate during particular stages of the process. Traditional beverages are typical examples of lactic fermentation followed by alcoholic fermentation in which initially lactic acid bacteria and later yeasts play the dominant role (Holsapfel, 1997). Indeed, different studies on traditional fermented beverages, it appears that the predominant microorganisms in these beverages belong mainly lactic acid bacteria and yeast (Table 3 and 4). Lactic acid bacteria in the mash before spontaneous fermentation consist mainly of *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Enterococcus* (Djè *et al*., 2009). During the production of *tchapalo*, spontaneous fermentation is mainly provided by the lactic acid bacteria (99.73%) with a predominance of *Lactobacilli*. Furthermore *Lactobacillus* (1.2×10^9 cfu/mL), other lactic acid bacteria present at the end of spontaneous fermentation are: *Leuconostoc* (3.4×10^6 cfu/mL), *Pediococcus* (9.8×10^7 cfu/mL) and *Enterococcus* (1.5×10^7 cfu/mL). On the other hand, after alcoholic fermentation, lactic flora isolated *tchapalo* belongs to the genus *Lactobacillus* (1.5×10^3 cfu/mL) and *Leuconostoc* (7.4×10^2 cfu/mL). The combination of phenotypic and genotypic methods identified *Lactobacillus* species involved in the production of *tchapalo* which 82.88% and 17.12% of hetero-and homofermentative. These are: *L. fermentum*, *L. brevis*, *L. plantarum*, *L. hilgardii*, *L. coprophilus* and *L. cellobiosus* with a predominance of *L. fermentum* (Djè *et al*., 2009; Aka *et al*., 2010).

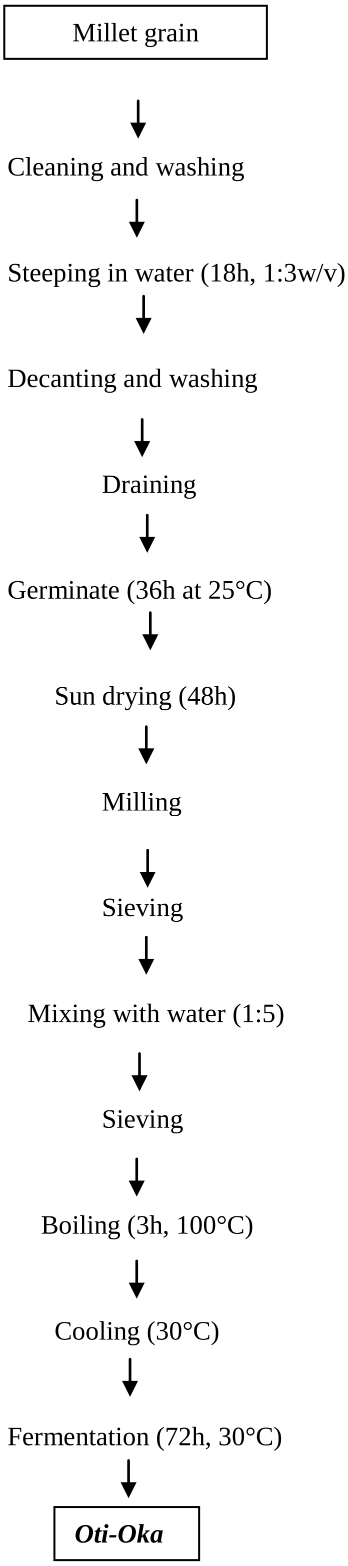

Figure 13. Production of *oti-oka*

Source : Adapted of Ogunbanwo and Ogunsanya, 2012

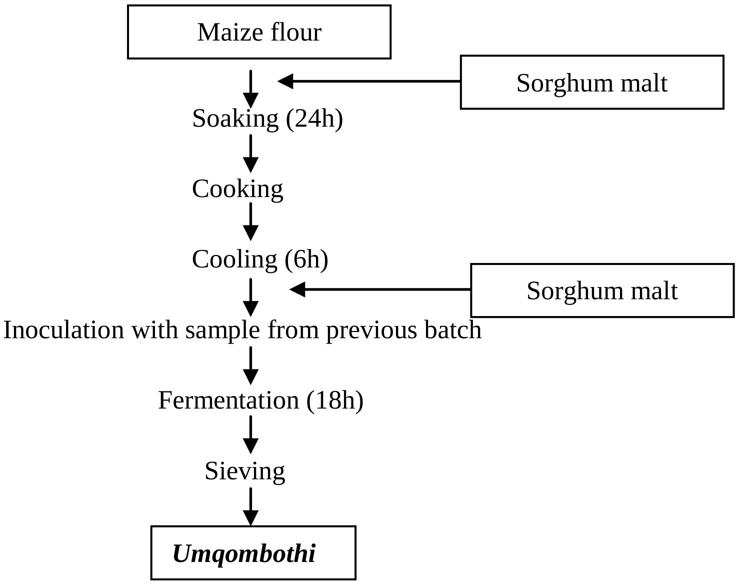

Figure 14. Production of *umqombothi*
Source : Katongole, 2008

In the household *bushera* production, lactic acid bacteria isolated belonged to *Lactobacillus, Streptococcus* and *Enterococcus* genera. Tentatively, *Lactobacillus* isolates were identified as *Lactobacillus plantarum, L. paracasei subsp. paracasei*, *L. fermentum*, *L. brevis* and *L. delbrueckii* subsp. *delbrueckii*. *Streptococcus thermophilus* strains were also identified in household *bushera* (Muyanja *et al*., 2003). On the other hand, throughout *borde* fermentation, the frequency of dominating strains were: *W. confusa* (30.9%), *Lb. viridescens* (26.5%), *Lb. brevis* (10.3%) and *P. pentosaceus* (7.4%) and *P. pentosaceus* subsp. *intermedius* (8.8%), while sporadically isolated species of *Lactobacillus curvatus*, *P. acidilactici*, *Lactobacillus collinoides*, *Lactobacillus sanfrancisco*, *Lactobacillus pontis* and *Lactobacillus delbrueckii* subsp. *delbrueckii* were 16.3% (Kebede *et al*., 2007). Togo *et al.* (2002) reported that in sorghum beer, 35% of strains belong to the *Lactobacillus* genus, 25% *Lactoccocus* genus, 15% *Leuconostoc* genus, 15% *Enteroccocus* genus and 10% *Streptococcus* genus. The species commonly encountered in these beverages are: *L. plantarum*, *L. fermentum*, *L. brevis*, *L. delbrueckii*, *Lc. Lactis subsp. Lactis*, *Lc. raffinolactis*, *Ln. mesenteroides subsp mesenteroides* (Sanni *et al*., 1999; Togo *et al*., 2002.). Sawadogo-Lingani *et al.* (2007) essentially identified through molecular biology techniques, strains of *L. fermentum* as the predominant species of lactic acid bacteria in *dolo* and *pito* produced respectively in Ghana and Burkina Faso. These data show that the majority of the genus *Lactobacillus* are the heterofermentative types (*L. fermentum*) unlike *L. plantarum* is homofermentative. LAB are the dominant microorganisms isolated from fermented beverages, and therefore, lactic acid fermentation is considered as the major contributor to the beneficial characteristics observed in fermented foods (Chelule *et al*., 2010).

Majority yeasts involve in alcoholic fermentation belong to the genus *Saccharomyces* (Table 3 and 4). Demuyakor and Ohta (1991) reported that *Saccharomyces cerevisiae* is the predominant species (33%) in *pito* produced in Ghana followed by *Candida spp* (17%) and *Kluyveromyces spp* (23%). Similar results on the prevalence of *S. cerevisiae* (38%) in the *pito* produced in Ghana were also observed by Sefa-Dedeh *et al.* (1999) also isolated in addition, *Candida tropicalis* (19%) and *Torulaspora delbrueckii* (14%). In the Benin opaque sorghum beer *Saccharomyces cerevisiae* (68%) is predominated; but *Candida albicans, Torulaspora delbrueckii, Saccharomyces pastorianus, Candida kunwiensis, Dekkera anomala, Candida etchellsii* were also found (Kayodé *et al*., 2011). These authors have identified these strains by conventional bacteriological techniques (biochemical and physiological characterizations). However, other authors have used the techniques of molecular biology have shown that yeasts involved in the fermentation of traditional African beverage made from sorghum are exclusively dominated by strains of *S. cerevisiae* (Van der Aa Kühle *et al*., 2001. Naumova *et al*., 2003. Maoura *et al*, 2005.). N’Guessan *et al.* (2012) used also molecular methods to identify yeasts species in *tchapalo* production. They have found that, the most frequent species associated with fermentation was *S. cerevisiae* (87.36%), followed by *Candida. tropicalis* (5.45%) and *Meyerozyma caribbica* (2.71%).

Importance of African cereal fermented beverages

Socio-cultural and economic aspect

African cereal beverages are empirically derived from the spontaneous non or alcoholic fermentation of wort from germinated cereals (sorghum, maize, millet). They are produced and consumed in most parts of Africa where sorghum, maize and millet grow. The preparation of many traditional fermented foods and beverages remains as a household art. They are produced in homes, villages and small scale industries. Their production is deeply rooted in the tradition of people in African countries where they play a significant socio-cultural and economic role. The importance of traditional fermented beverages has been reviewed (Chelule *et al*., 2010). Indeed, they are often attached to the traditions of hospitality and friendliness and are part of the etiquette of most families. They serve to seal harmonious relationships between individuals (Enou, 1997; De Lemps, 2001; N’kwe *et al*., 2005).

Table 3. Microflora involved in spontaneous fermentations during African non-alcoholic beverages processing

Traditional non-alcoholic beverages	Substrats	Microorganisms		References
		Lactic acid bacteria	Yeasts	
Bushera	Sorguhm	*Lactobacillus plantarum, L. paracasei subsp. paracasei, L. fermentum, L. brevis and L. delbrueckii subsp. delbrueckii, Streptococcus thermophilus, Enterococcus*	Unknown	Muyanja *et al.* (2003)
Borde	Maize, sorghum, wheat, millet and tef, barley	*Weissella confusa, Lactobacillus brevis, Lactobacillus viridescens, Pediococcus pentosaceus* and *P. pentosaceus* subsp *intermedius*	Yeasts	Kebede, 2007
Gowé	Sorghum	*Lactobacillus fermentum, Weissella confusa,*	*Kluyveromyces marxianus* and *Pichia anomala*	Vieira-Dalodé *et al.*, 2008
Kunun-zaki	Millet	*Lactobacillus plantarum, L. pentosus, L. cellbiosus, Pediococcus pentosaceus* and *Leuconostoc Mesenteroides*	*Candida mycoderma* and *S. cerevisiae*	Nwachukwu *et al.* (2010) ; Amusa and Odunbaku, 2009
Mahewu	Maize	*Lactococcus lactis* subsp. *Lactis*	*Candida haemuloni, Candida sorbophila, Debaryomyces hansenii, Saccharomyces capsularis* and *Saccharomyces*	Gadaga *et al.*, 1999 ; Katongole, 2008
Malwa	Millet	*Lactobacillus spp* and *Lactococcus spp*	*S. cerevisiae*	Muyanja *et al.*, 2010
Mangisi	Millet	Lactic acid bacteria	Yeasts and Molds	Zvauya *et al.*, 1997
Masvusvu	Millet	Lactic acid bacteria	Yeasts and Molds	Zvauya *et al.*, 1997
Obiolor	Sorghum and millet	*L. plantarum, Lactococcus lactis, Bacillus* species	Unknown	Sekwati-Monang, 2011

Table 4. Microflora involved in spontaneous fermentations during African alcoholic beverages processing

Traditional alcoholic beverages	Substrats	Microorganisms		References
		Lactic acid bacteria	Yeasts	
Bili-bili	Soghum	Lactic acid bacteria	*Saccharomyces cerevisiae, Kluyveromyces maxianus*	Maoura *et al.*, 2005
Burukutu	Sorghum, millet	*Leuconostoc mesenteroides, Lactobacillus*	*S. cerevisiae, Rhodotorula glutinis, C. pelliculosa, Cryptococcus albidus*	Blandino *et al.*, 2003 ; Jimoh *et al.*, 2012
Busaa	Maize	*L. casei* var. *rhamnosus, L. helveticus, L. salivarius, Pediococcus damnosus, P. partulus*	*Candida krusei* and *S. cerevisiae*	Katongole, 2008
Chakpalo	Sorghum	*Lactobacilli*	Yeasts	Baba-Moussa *et al.*, 2012
Dolo	Sorghum	*L. fermentum, L. delbrueckii ssp. delbrueckii, L. delbrueckii ssp. bulgaricus, P. acidilactici*	*Saccharomyces cerevisiae*	Sawadogo-Lingani *et al.*, 2007; Lyumugabe *et al.*, 2012
Ikigage	Sorghum	*Lactobacillus fermentum, L. buchneri*, and *Lactobacillus* sp.	*S. cerevisae, Candida inconspicua, Issatchenkia orientalis, Candida magnolia* and *Candida humilis*	Lyumugabe *et al.*, 2010
Kaffir beer	Maize	*Lactobacillus spp.*	Yeasts	Achi, 2005 ; Sekwati-Monang, 2011
Kwete	Maize and millet	*Lactobacillus, Lactococcus*	Yeasts	Namugumya and Muyanga, 2009
Oti-oka	Millet	*Lactobacillus fermentum*	*S. cereviseae*	Ogunbanwo and Ogunsanya, 2012
Pito	Sorghum	*Pediococcus halophylus, Laactobacillus plantarum*	*S. cerevisiae, Rhodotorula glutinis, Candida pelliculosa, Cryptococcus albidus, Candida utilis*	Orji *et al.*, 2003 ; Jimoh *et al.*, 2012
Tchapalo	Sorghum	*L. fermentum, L. brevis, L. plantarum, L. hilgardii, L. coprophilus, L. cellobiosus, Leuconostoc*	*S. cerevisiae, Candida. tropicalis, Meyerozyma caribbica*	Aka *et al.*, 2010 ; N'Guessan *et al.*, (2012)
Tchoukoutou	Sorghum	*Lactobacillus divergens, Lactobacillus fermentum, Lactobacillus fructivorans, Lactobacillus* sp.	*S. cerevisiae, C. albicans, Torulaspora delbrueckii, S. pastorianus, C. kunwiensis, Dekkera anomala, Candida etchellsii*	Kayodé *et al. 2011 ;* Lyumugabe *et al*. 2012
Umqombothi	Sorghum and maize	Lactic acid bacteria	*Candida ethanolica, C. haemuloni, C. sorbophila, Dekkera anomala, Dekkera bruxellensis, Saccharomycopsis capsularis* and *S. cerevisiae*	Katongole, 2008

They are also used to welcome and to cool down somebody. Traditional African beverages are generally consumed during the fieldwork, popular festivities (marriage, naming, and initiation), and funerals. The fermented beverages serve as food supplement like the use as a weaning food to supplement breastfeeding. They made available the diet required in human body (Oyewole and Isah, 2012). Beverages are sometimes consumed in an environment and a specific social setting. This consumption is most popular in cabaret and used together in a "community of consumers' governed by rules of conviviality, sociability and sociality that induce a perception of product quality and its consumption patterns. They are usually consumed when they are fermenting and near the place of production. All social strata consume fermented beverages.

Today, traditional African beverages production is became a very important economic activity carried out by women. The sale of these products allows them to generate income for their families. Despite the technology that differs from one country to another and from one region to another, traditional African beverages have almost the same characteristics: a short shelf-life, a non or low alcohol, an sour aspect, solids and microorganisms in suspension, as well as taste and color characteristics with the low cost and the widespread availability in some populations (FAO, 1995; De Lemps, 2001).

Nutritional aspect

In several African countries, traditional cereal fermented beverages are consumed as either food or drink because they satisfy hunger, and also because of their high nutritional value. They are as a source of energy providing important nutrients to contribute to the diet of the population (Van der Aa Kühle *et al.*, 2001; Achi, 2005; Amane *et al.*, 2005; Maoura *et al.*, 2006; Aka *et al.*, 2008a; Abdoul-Latif *et al.*, 2013). Thus, they contain a high proportion of starch, sugars and proteins (Table 5). They are also sources of B-group vitamins (thiamine, riboflavin and niacin) and minerals such as iron, manganese, magnesium, phosphorus, calcium, potassium and copper (FAO, 1995; Michodjèhoun *et al.*, 2005; Lyumugabe *et al.*, 2012). Traditional sorghum beverage also contains vitamin C. This vitamin is synthesized during seed germination and during alcoholic fermentation; there is a further increase in the content of vitamin C (Taur *et al.*, 1984; Aka *et al.*, 2008a). In Cameroon, Chevassus-Agnes *et al.* (1979) showed that the beer *amgba* prepared from sorghum proved nutritionally superior to sorghum flour because they provide more riboflavin, thiamine and lysine. Derman *et al.* (1980), meanwhile, reported that iron absorption from sorghum beverage was more than 12 times what it was from its components. Kayodé (2006) shows that the levels of Fe, Zn, ash and crude protein have almost doubled after fermentation giving *tchoukoutou*.

Apart from Chevassus-Agnes study on physico-chemical and nutritional analyses of *amgba*, no detailed study on traditional beverage was conducted.

Sensory characteristics

Fermentation makes the beverages palatable by enhancing its aroma and flavor. These organoleptic properties make fermented beverages more popular than the unfermented one in terms of consumer acceptance (Chelule, 2010). African traditional cereal fermented beverages keep the same characteritics. They are opaque containing suspended solids, with sweet-sour taste and odours or flavours characteristic, pinkish–brown colour, whitish-grey to brown or light brown colour, creamy or milky appearance following raw materials. Moreover, alcoholic beverages are effervescent aspect refreshing quality. During cereal fermentations several organic acid and volatile compounds are formed, which contribute to a complex blend of flavours in the products. Indeed, these fermented beverages contain lactic acid in high concentration (Zvauya *et al*., 1997 ; Maoura *et al*., 2006 ; Djè *et al*., 2008). Organic acids identified in household *bushera* included citric, pyruvic, succinic, acetic, lactic and pyroglutamic acids. While, volatile organic compounds identified in the same *bushera* included acetaldehyde, acetone, acetoin, diacetyl, 2-methyl-propanol, 2-methyl-propanal, 2-methyl-butanal, 3-methyl-butanal, 2-methyl-butanol, and 3-methyl-butanol (Muyanja *et al*., 2003). Aka *et al.* (2008b) have found oxalic, citric, malic, lactic, fumaric and propionic acids in the sweet wort (intermediary product) and *tchapalo*. These authors have found also volatile compounds such as ethanol, acetaldehyde, methyl ethyl ketone and ethyl acetate in the sweet wort (intermediary product) and *tchapalo*. Furthermore, Sanni *et al.* (1999) also determined the lactic and malic acids in *sekete*, *pito* and *burukutu*, traditional alcoholic beverages in Nigeria. These organic acid and volatile compounds enhance the flavour and taste of beverages. However, African fermented cereal beverages are consumed while it is still fermenting ; so the sensory quality can often varied. Fadahunsi *et al*. (2013) have showed the fresh both *Burukutu* and *Pito* samples were accorded better acceptability in all tested sensory parameters than the stored samples by the consumers.

Table 5. Biochimical composition of some African fermented cereal beverages

Parameters	*Amgba* (/100 g of beverage)	*Pito* (% of beverage)	*Burukutu* (% of beverage)	*Dolo* (/100 g of beverage)	*Tchapalo* (/100 g of beverage)	Sweet wort of *tchapalo* (/100 g of beverage)	*Kunun-zaki* (% of beverage)
Calories (Kcal/100 ml)	42.08	-	-	21.8	-	-	-
Moisture (g)	90.7	96.56	92.35		-	-	86.3
Dry matter (%)	9,3	-	-	5.9	-	-	-
Density	-	-	-		1.01	1.05	-
Protein (g)	0.7	5.42	2.75	0.65	0.03	2.7	3.83
Lysine (g/100 of proteins)	7,2	-	-	-	-	-	-
Fat (g)	0.02	-	-	0	-	-	-
Total sugars (g)	6.1	3.4	5.83	0.77	0.53	3.6	13.55
Soluble Solids (°Brix)	-	4.2	-	-	7.94	15.2	5.5
Ash (g)	0.3	0.001	1.05	-	0.27	0.3	0.16
Calcium (mg)	1.8	-	1.47	-	-	-	-
Total phosphorus (mg)	46	-	0.61	-	-	-	-
Ca2++/P	0.021	-	-	-	-	-	-
Phytic phosphorus (mg)	10	-	-	-	-	-	-
Potassium (mg)	94	-	1.08	-	-	-	-
Sodium (mg)	2.3	-	1.41	-	-	-	-
Thiamine (µg)	390	-	-	-	-	-	-
Riboflavine (µg)	55	-	-	-	-	-	-
Niacin (mg)	0.6	-	-	-	-	-	-
Vitamin C (mg/100mL)	-	-	-	-	1.48	1.1	15
Alcohol (%)	2.13	3.09	1.63	2.3	5.22	-	0.2
pH	3.5	3.66	3.94	3.5	3.34	-	5.65
References	a	B	C	d	e	F	g

- : Not determinated ; a: Chevassus-Agnes *et al.* (1976) ; Fadahunsi *et al.* (2013) ; c : Eze *et al.*, 2011 ; d : Abdoul-Latif *et al.* (2013) ; e and f : Aka *et al.* (2008a) ; g : Amusa and Odunbaku, 2009 ; Adeleke and Abiodun, 2010.

Preservative properties

Fermented foods, unlike non-fermented foods, have a longer shelf-life, making fermentation a key factor in the preservation. African fermented cereal beverages contains organic acids (e.g. lactic, acetic, propionic and butyric acids) produced during fermentation. These acids prolong beverags shelf-life by lowering the pH to below 4 or 3 and this restricts the growth and survival of spoilage organisms and some pathogenic organisms such as *Shigella, Salmonella* and *E. coli* (Zvauya *et al*., 1997 ; Muyanja *et al*., 2003 ; Michodjèhoun-Mestres *et al*., 2005 ; Vieira-Dalodé *et al*., 2007 ; Muyanja *et al*., 2010 ; Chelule *et al*. 2010 ; Nyanzi and Jooste, 2012). In addition to acids, during fermentation, lactic acid bacteria can produce a range of other antimicrobial metabolites such as ethanol from the heterofermentative pathway, CO_2, H_2O_2 produced during aerobic growth and diacetyl (Ross *et al*., 2002 ; Ogunbanwo and Ogunsanya, 2012). These components improve preservative of beverages. However, The shelf life of African fermented cereal beverages is limited. In fact, the preserving of tradition beverages does not usually exceed more than 3 to 5 days. Because the metabolic activities of mesophilic lactic acid bacteria are entraine the deteriorating beverages. Then, other undesirable bacteria such as *Acetobacter aceti*, *A. hansenii*, *A. pasteurianus*, *Alcaligenes*, *Flavobacterium* produce acetic acid, volatile off-flavors which render the taste and odor of the beverages unacceptable to consumers (Sanni *et al*., 1999 ; Lyumugabe *et al*., 2012 ; Fadahunsi *et al*., 2013). The short shelf-life of traditional beverages has been reported as the major problem confronting African brewers.

Health benefit aspects

Many of African fermented beverages consumed have therapeutic values. The health benefits of these beverages are expressed either directly through the interaction of ingested live microorganisms (bacteria or yeast) or indirectly because of ingestion of microbial metabolites produced during the fermentation process (Tamang and Kailasapathy, 2010 ; Oyewole and Isah, 2012). Some studies have demonstrated that the beneficial bacteria contained in fermented foods support and help the digestive system assimilate food, providing for better nutrition and thus increase the effectiveness of the immune system. Other studies have found that fermentation increases acidity of beverages and inhibits spoilage and can rid the food of poisonous bacteria. Certain lactic acid bacteria and moulds have been found to produce antibiotics and bacteriocins which inhibited spoilage and pathogen bacteria causing disorders (Marshall and Mejia, 2011). According for Lei *et al.* (2006), it is likely that traditionally fermented drinks have an important role in preventing acute diarrhoea because *koko sour wort* could help reducing persistent diarrhoea of young children. *Kunun-zaki* is also popularly believed to enhance lactation in nursing mothers (Nyanzi and Jooste, 2012). Sour wort and *thapalo* consumers attributed to these beverages the laxative, anti-malarial and anti-hemorrhoid properties (Enou, 1997; Aka *et al*., 2008b). Futhermore, studies showed that traditional fermented beverages contained antioxidant components, such as vitamin C (**Table 5**) and phenolic compounds. The importance of antioxidant are maintaining health and protection from coronary disease and cancer. The presence of organosulfur compounds of garlic inhibit the peroxidation of lipids and possess antioxidant and free-radical-scavenging activity (Tamang and Kailasapathy, 2010). Abdoul-latif *et al.* (2012) are found that *dolo* constitutes a potential source of phenolic comparable to other industrial alcoholic beverages. Nowadays, there is a prominent interest on food and drinks that contain antioxidant molecules such as phenolic compounds. Indeed, phenolic compounds have been reported to inhibit the development of cancerous tumours, and to have anti-bacterial, anti-inflammatory, antispasmodic and anti-diarrhoeic properties (Abdoul-latif *et al.*, 2012). Several vitamins B including niacin (B3), panthothenic acid (B5), folic acid (B9), and also vitamins B1, B2, B6 and B12 are released by lactic acid bacteria in fermented foods. These vitamins are co-factors in some metabolic reactions, for instance, folates prevent neural tube defects in babies and provide protection against cardiovascular disease and some cancers (Nyanzi and Jooste 2012).

Role of spontaneous fermentations in the processing of African cereal beverages

Improving of the preserving

Food preservation by freezing, refrigeration and irradiation is known in developed countries. But these methods of preservation are very expensive for millions of low-income consumers in Africa. Lactic acid fermentation is by far the least expensive method and widely used in Africa for food storage (Tamang *et al*., 2005). In general, the fermentation occurs naturally under the action of microorganisms in the environment and microorganisms associated with the raw material (Tamminen *et al*., 2004; Lefyedi *et al*., 2005; Bahiru *et al*., 2006). It leads to acidification and to extend the shelf-life of traditional alcoholic beverages. Lactic acid fermentation reduces the pH and prevents the growth of pathogens and spoilage microorganisms. Blandino *et al.* (2003) reported the role of lactic acid fermentation in beverages preserving and noted that it is due to the production of organic acid and hydrogen peroxide in the activities of lactic acid bacteria. In fact, lactic acid bacteria are able to convert carbohydrates into organic acids (lactic, acetic, propionic and butyric acids) which lower the pH of the product at a level where the pathogens and / or spoilage cannot survive (Oyewole, 1997; Aka *et al*., 2008b). The pH decreased from 3.51-3.72 in the sweet wort (final wort) to 3.31-3.63 in the alcoholic beverages (Maroura *et al*., 2006; Sawadogo-L. *et al*., 2008; AKa *et al*., 2010). The undissociated forms of the acetic and lactic acids at low pH exhibit inhibitory activities against a wide range of pathogens. This, improves food safety by restricting the growth and survival, in fermented cereal beverages, of spoilage organisms and some pathogenic organisms such as *Shigella, Salmonella* and *E. coli* (Nyanzi and Jooste, 2012). A part from their ability to produce organic acids, the lacti acid bacteria posses the ability to produce hydrogen peroxide through the oxidation of reduced nicotin-amide adenine dinucleotide (NADH) by flavin nucleotides, which react rapidly with oxygen. As lactic acid bacteria lack true catalase to break down the hydrogen peroxide generated, it can accumulate and be inhibitory to some microorganisms and improved beverages preserving and their shelf-life (Caplice et Fitzgerald, 1999 ; Blandino *et al.*, 2003).

Some lactic acid bacteria isolated in the processing beverages have antibacterial activities against *S. aureus*, *E. coli*, *L. innocua*, *B. cereus* and *P. aeruginosa* (Sawadogo-L *et al*., 2008; Aka *et al*., 2010; Okereke *et al*., 2012). Indeed, lactic acid bacteria are known for their production of antimicrobial compounds, including bacteriocins or bacteriocin-like peptides. Bacteriocins of lactic acid bacteria are defined as ribosomally synthesized proteins or protein complexes usually antagonistic to genetically closely related organisms. Bacteriocins are generally low molecular weight proteins that gain entry into target cells by binding to cell surface receptors. Their bactericidal mechanism varies and may include pore formation, degradation of cellular DNA, disruption through specific cleavage of 16S rDNA, and inhibition of peptidoglycan synthesis **(**Heu *et al*., 2001 ; LeBlanc and Todorov, 2011). Production of antimicrobial compounds by starter cultures in beverages is important in the control of food-borne pathogens and is significant for the safety of the Consumer. Alcohol production during alcoholic fermentation improved also the microbiological safety and stability of beverages (Mugala *et al*., 2003, Okereke *et al*., 2012).

Improving the sensory quality

Another important property of the fermentation described in the literature is to improve the organoleptic quality of beverages (Van der Aa Kühle *et al*., 2001; Maoura *et al*., 2005). The products formed during biochemical reactions occurring beverages fermentation are at the origin of the flavor, taste and aroma of these beverages, decisive in the acceptability and preference of a food to another (Chelule *et al*., 2010). The conversion of carbohydrates into organic acids, alcohols and other flavoring such as esters and carbonyl compounds was studied in lactic acid fermentation and alcoholic fermentation appearing in beverages processing. Aka *et al*. (2008b) reported that during the production of *tchapalo*, the spontaneous fermentation determines the subsequent of operations. Indeed, this spontaneous fermentation leads to the production of sour wort. It is very important and necessary because it greatly influences the sensory characteristics and preservation of the finish product. It ends only if, at taste the brewer believes that the wort is sufficiently sour; otherwise, the fermentation continuous. These authors showed that the organic acids synthesis occurs mainly during spontaneous fermentation that takes place during the production of *tchapalo* while the volatile compounds occurs during alcoholic fermentation. Thus, during the spontaneous fermentation, lactic and acetic acids are synthesized. Their mean values were 12.38g/L and 1.83g/L respectively in the sweet wort. While during alcoholic fermentation, volatile compounds such as ethanol (4.06% alc vol), acetaldehyde (0.3 mg/L), methyl ethyl ketone (0.26 mg/L) and ethyl acetate (1.74 mg/L) were synthesized. Moreover, Djè *et al.* (2008) highlighted the organic acids found in the sweet wort (intermediary product) and *tchapalo*. There are oxalic, citric, malic, lactic, fumaric and propionic that improved the sensory quality of these beverages. The sweet wort is highly appreciated by women and children (Nout and Motarjemi, 1997 ; Kalui *et al*., 2010). The lactic acid content of sour mash was observed also by Maoura *et al.* (2006) during the preparation of the *bili bili*. These authors found the lactic acid concentration of 12.69 g/L in the *bili bili*. Sanni *et al.* (1999) also determined the lactic and malic acids in *Sekete*, *pito* and *burukutu*.

Improving the nutritional value

Lactic acid fermentation also improves the nutritional quality of traditional African cereal beverages (Steinkraus, 1997). Some authors have indeed observed that the traditional fermentation of cereals reduced the content of phytic acid and polyphenols to significantly improve protein quality while increasing the lysine content, the availability of essential amino acids, the in vitro protein digestibility, the carbohydrates digestibility, the availability of iron, minerals and B-group vitamins including thiamine, niacin, folic acid (Thaoge *et al.*, 2003; Kayodé, 2006; Katongole, 2008 ; Chelule *et al.*, 2010; Lyumugabe *et al.*, 2012). Fermentation also provides optimum pH for enzymatic degradation or reduction of phytates, tannins and oxalate content in cereals and form complexes with polyvalent cations such as iron, zinc, copper, calcium, magnesium, protein and B-group vitamins. In general, natural fermentation also leads to a decrease in the content of carbohydrates, trace and non-digestible polysaccharides (Katongole, 2008 ; Tamang and Kailasapathy, 2010 ; Chelule *et al.*, 2010; Lyumugabe *et al.*, 2012). Lactic acid bacteria also activate the synthesis of vitamin C. Moreover, the minerals are better assimilated in the presence of lactic acid.

Risks associated with traditional African fermented cereal beverages

Like other products, cereals (Sorghum, maize, millet) contain antinutritional factors, such as tannins and phytate that may form stable complexes with proteins, vitamins and minerals restricting their bioavailability. The above factors contribute to anemia and other nutritional disease in developing countries where the consumption of these products and the foods prepared therefrom is high (Eze *et al.*, 2011 ; Marshall and Mejia, 2011). It reported that, the antinutritional factors contribute to malnutrition and reduced growth rate due to the promotion of poor protein digestibility and by limiting mineral bioavailability (Nyanzi and Jooste, 2012). In fact, phytic acid in cereals affects the nutritional quality due to chelation of phosphorus and other minerals such as Ca, Mg, Fe, Zn, and Mo. Hence, deficiency in a mineral such as iron can result in anaemia, a decrease in immunity against disease and impaired mental development. On the other hand, poor calcium bioavailability prevents optimal bone development and can cause osteoporosis in adults. Insufficient zinc also brings about recurring diarrhoea and retarded growth (Nyanzi and Jooste, 2012).

Various techniques including malting, fermentation and cooking can improve the protein digestibility and mineral availability of cereal grains by reducing its tannin and phytate content. However, some African traditional fermented cereal beverages contain tannins and phytate. Adewara and Ogunbanwo (2013) are observed 9.15mg/100L, 3.75mg/100L and 6.40mg/100L of polyphenols, phytate and tannins respectively in burukutu produced using germinated grains. Muyanja *et al*. (2003) and Kayodé (2006) are also mentionned respectively tannin and phytate contents in *malwa* and *tchoukoutou*.

The health risk associated with the consumption of African traditional fermented cereal beverages can be due to also heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd) and arsenic (As) which are generally regarded as environmental contaminants and their presence in drinks can have some toxic effects on human. High levels of Pb in foods may result to food poisoning in humans either in acute or chronic exposure. Accumulation of lead produces da-maging effects in the hematopoetical, hematic, renal, gastrointestinal systems (Duodu *et al*., 2012). Duodu *et al.* (2012) are found detected concentrations of Ni, Pb and Cd in the *pito* samples above the respective maximum WHO guideline in water. According for these authors, *pito* is susceptible to metal contamination due to poor handling and primitive equipment used in the production.

In developing countries, most food borne illnesses are of a bacterial nature (Katangole, 2008). Beverages are prepared in the homes usually under unhygienic conditions and thus are prone to contamination by the micro flora. The main sources of contamination include humans, sewage, raw materials, utensils, processing equipment and environment, poor handling and storage conditions and rodents (Osuntogun and Aboaba, 2004 ; Eze *et al*., 2011). Some pathogenic microorganisms susceptible to contamine beverages are *Staphylococcus aureus*, *Esherichia coli*, *Bacillus* species, *Streptococcus* species, *Proteus* species, *Rhizopus stolonifer*, *Aspergillus flavus, Aspergillus niger* (Nout and Motarjemi, 1997 ; Osuntogun and Aboaba, 2004 ; Amusa and Odunbaku, 2009 ; Eze *et al.*, 2011 ; Duodu *et al.*, 2012 ; Fadahunsi *et al.*, 2013). *Staphylococcus aureus* is the major cause of staphylococcal food poisoning. The poisoning is characterized by diarrhea and vomiting. *Escherichia coli* can cause gastroenteritis and urinary tract infection as well as diarrhea in infants and young children. Its presence is an indication of faecal contamination of the samples. This may be attributed to improper sanitary condition during processing. Most members of the *Bacillus* genus are saprophytic organisms prevalent in soil, water, air and on vegetation. *Bacillus cereus* and *Bacillus subtilis* are the most encountered in the group. *Bacillus cereus* when grown on food causes food poisoning by the production of an enterotoxin. These pathogenic microorganisms could be harmful to man and pose a serious public health hazard to the consumers and economic loss to the producer (Eze *et al.*, 2011 ; Fadahunsi *et al.*, 2013). The microbes found associated with hawked kunun-zaki are *Bacillus subtilis*, *B. cereus*, *Staphylococcus aureus*, *Micrococcus acidiophilis*, *E. coli*, *Pseudomonas aeruginosa*, *Streptococcus faeceaum*, *S. lactis*, *Lactobacillus plantarum*, *Saccharomyces cerevisiae*, *Candida mycoderma*, *Aspergilluus niger*, *Penicillium oxalicum* and *Fusarium oxysporum* (Amusa and Odunbaku, 2009). While Lyumugabe *et al.*, (2010) have showed *Ikigage* marketed contains also *Staphylococcus aureus*, *E. coli*, Coliform, fecal *Streptococci* and moulds.

In malwa, coliforms were still detectable after 72 h fermentation (Muyanja *et al.*, 2003). Study of microbiological quality of the *Tchakpalo* revealed presence of pathogenic microorganisms and worse hygienic indicators like the genera *Staphylococcus*, Coliforms and *Salmonella* which have been identified in many samples of *Tchakpalo* (Baba-Moussa *et al.*, 2012). Eze *et al.* (2011) have analysed the microbiological qualities of burukutu sold in Nigeria some State. The bacterial genera isolated were *Staphylococcus aureus*, *Streptococcus* species, *Bacillus* species and *Escherichia coli*, while the fungal genera were *Aspergillus* species, *Fusarium* species, *Penicillum* species. Fadahunsi *et al.* (2013) are also identified *Staphylococcus aureus*, *Pseudomonas fragilis*, *Bacillus megaterium*, and *Lactobacillus brevis*, *Torulopsis sp*, *Saccharomyces cerevisiae*, *Candid krusei and Aspergillus niger* in the both fresh and stored samples of *Burukutu* and *Pito*. The genera *Aspergillus*, *Fusarium* and *Penicillium* produce mycotoxins such as aflatoxins and fumonisins. Aflatoxin B1 (AFB1) is toxic, carcinogenic, mutagenic and teratogenic. Fumonisins have been linked to oesophageal cancer in South Africa and liver cancer in China. Kwashiorkor in children is aggravated by long term exposure to aflatoxin (Nyanzi and Jooste, 2012). The presence of pathogenic microorganisms and mycotoxins in beverages constitutes a hazard for the consumers and economic loss for the producers (Katongole, 2008). It is of paramount importance that these fermented products be prepared under good sanitary and hygienic conditions including application Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP).

Use starter cultures for the production of traditional fermented cereal beverages

All of the traditional fermented cereal beverages are originally fermented by natural microorganisms which has been transferred from generation to generation. Hence, Preparation procedures for these beverages are still traditional arts and the fermentation is, by and large, uncontrolled. Starter cultures are not normally used and therefore, variations in the quality and stability of the products are often observed. Isolation, selection, preservation or collection and starter making of a high efficient microbial strain for use as an inoculum has to be passed before industrialized large-scale production (Mugala *et al*., 2003 ; Achi, 2005 ; Viera-Dalodé *et al*., 2007). Lactic acid bacteria and yeasts are the most important groups of organisms in fermented beverages. Several investigations have been carried out in order to understand the role of LAB and yeasts in traditional African fermented foods (Viera-Dalodé *et al*., 2007). Mugala *et al*. (2003) have noted that the proliferation of yeasts in foods is favoured by the acidic environment created by LAB while the growth of bacteria is stimulated by the presence of yeasts, which may provide growth factors, such as, vitamins and soluble nitrogen compounds. The association of LAB and yeasts during fermentation may also contribute metabolites, which could impart taste and flavour to beverages. The use of starter cultures would be an appropriate approach for the control and optimisation of the fermentation process in order to alleviate the problems of variations in organoleptic quality and microbiological stability observed in African traditional fermented beverages (Holsapfel, 1997 ; Achi, 2005 ; Viera-Dalodé *et al*., 2007 ; Mugala *et al*., 2003). Different species of LAB and yeasts have been used successfully as starter cultures to ferment traditional products from cereals (Viera-Dalodé *et al*., 2008 ; Glover *et al*., 2009 ; Agarry *et al*., 2010 ; Ogunbanwo *et al*., 2013). Ogunbanwo and Ogunsanya (2012) have tested the effects of single and co-cultures of predominant lactic acid bacteria and yeast as starters on the nutritional, anti-nutritive component and physical properties of *oti-oka* using pearl millet as substrate. They have concluded that the use of *L. fermentum* in coculture with *S. cereviseae* enhances the nutritional, sensorial attributes and brought about a significant decrease in the anti-nutritive content of the *oti-oka* like beverage produced from pearl millet compared to the spontaneously produced *oti-oka* beverage form fermented sorghum. Furthermore, single of *L.*

fermentum and *S. cerevisiae* have been used successfully to produce *burukutu* ; however, the combined use of the both starter cultures have given better organoleptic properties similar to that of the commercial product (Ogunbanwo *et al*., 2013). For *gowé* production Vieara-Dalodé *et al.* (2007) have found that an accelerated fermentation was obtained when *Lactobacillus fermentum* was used individually or in combination with *Kluyveromyces marxianus* during the controlled fermentation of a mixed malted and non-malted sorghum flour. *Gowé* obtained within 7 h of controlled fermentation was judged to be similar to the product obtained by spontaneous fermentation by sensory evaluation. This improved process required a 2 h saccharification of the malted flour at 40°C instead of 12 h of primary fermentation at 30°C. Consequently, *gowé* can be obtained by controlled fermentation, using *L. fermentum* as inoculum enrichment, in a small scale industry. The dominant lactic acid bacteria (*Lactobacillius plantarum*, *L. fermentum* and *Lactococcus lactis*) isolated from fermenting Kunun-zaki have used as starter cultures in its production. This affected the sensory and nutritional qualities of the product positively. Use of starter cultures in the production of *Kunun-zaki* would encourage the industrialisation of the production process on sound scientific principle conclude by Agarry *et al*. (2010).

Starter cultures of *Candida tropicalis* and *Saccharomyces cerevisiae* isolated from *tchapalo* were tested in pure culture and co-culture of four ratios [2:1, 25:4, 1:4, 2:3 (cells/cells)] for their ability to ferment sorghum wort to produce *tchapalo* (N'Guessan *et al*, 2010). Starter cultures with large ratio of *C. tropicalis* produced a higher organic acids and 2-butanone than *S. cerevisiae* in pure culture. However, co-culture *C. tropicalis* and *S. cerevisiae* (2:1) was the alone starter which produced higher ethanol than *S. cerevisiae* in pure culture. Hence, *C. tropicalis* contribution to the quality of sorghum beer depends on its ratio. But further investigations are required before the definitive conclusion. Glover *et al.* (2009) have found also that *dolo* produced with double strain combinations of *Lactobacillus fermentum*s and *Saccharomyces cerevisiae* under laboratory conditions possessed consistent organoleptic quality and stability comparable to the commercial product. Indeed, single-strain and double-strain combinations of lactic acid bacteria and yeast starter cultures could be used successfully to produce *dolo* of different quality indices. Combinations of either *Lactobacillus fermentum*s strain with one *Saccharomyces cerevisiae* strain AC17 produced *dolo* that is more comparable to the commercial product than combinations with the other *Saccharomyces cerevisiae* strain TK25. *Lactobacillus fermentum*s strain ZN4.1 in combination with *Saccharomyces cerevisiae* strain AC17 give better *dolo* in all attributes evaluated. Varied combinations of these starters should be investigated in order to determine a suitable combination for producing *dolo* possessing all the desired organoleptic qualities and consistency. In their study on use *Lactobacillus sake* as a starter culture to produce *pito*, Okoro *et al.* (2011) have found that the various characteristic parameters investigated in a locally fermented *pito* drinks showed that this local drink can serve as a potential probiotic food for the indigenous native when it is hygienically produced. Therefore, Kayodé *et al*. (2012) have developed granule starter of yeasts and lactic acid bacteria to produce African opaque sorghum beer, particulary *tchoukoutou*. This starter has probiotic properties. So, the optimal drying conditions providing a stable granule starter with its optimum viability are established to 43°C and 24 h.

Conclusion and perspectives

In several African countries, cereal fermented beverages are produced. The tradition of these fermented beverages is long embedded in many cultures. Cereal raw materials usually used for beverages production are sorghum, millets and maize. Despite production technologies which are different between countries and regions where they are produced, their processing involves spontanous fermentations steps : lactic acid fermentation for non alcoholic beverages and lactic acid fermentation and alcoholic fermentation for alcoholic beverages. The lactic acid fermentation is carried out by a complex population of environmental microorganisms; it confers souring taste and storage longevity. On the other hand, the alcoholic fermentation is usually initiated by pitching sweet wort with a portion of previous brew or dried yeast harvested from previous beverage. This steps determines also the beverage preserving. Spontanous fermentations improve nutritional value of beverages that contributes significantly to improve the diet of consumers. They improve also sensory quality which is very important in the beverage acceptance. Lactic acid fermented beverages are also the traditional means for weaning infants in many African countries, as they improve both beverages safety and digestibility. Thus, the beverage quality depends of these fermentations. Microorganisms involve in cereal African beverages belong mainly lactic acid bacteria and yeast. According to regions where they are produced, genus of lactic acid bacteria varies but *Lactobacillus* appears the predominant genus in these beverages and *L. fermentum*, *L. brevis*, *L. plantarum* are predominant species. On the other hand, yeasts involve in majority of beverages are dominated by *Saccharomyces cerevisiae* strains. Hazards which may be associated with the traditional beverages can be effectively managed or controlled by Application Good Manufacturing Practice (GMP) and Good Hygienic Practices (GHP). Therefore, the use of starter cultures obtained with predominant lactic acid bacteria species and yeasts species will be stabilize the organoleptic quality of these beverages and improve its hygienic quality and the safety of the Consumer.

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