Review

Possible microbial and biochemical contaminants of an indigenous banana beer 'Urwagwa': A mini review

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Indigenous traditional beers play an important role in the daily social, economic, nutritional and cultural life of the people especially in developing countries. Bananas and banana beer remain very popular in Rwanda and they continue to be an important source of income. Banana cultivation forms an essential part of the socio-economic life of Rwandan communities, and the fruit has a long and widespread history in the production of alcoholic beverages. However, there is very little documentation on this product. Although, methods of manufacture have been passed through generations in Rwanda, little is reported in the literature, and research has been minimal. As a result of increased rural-urban migration, and the adoption of Western culture by the younger generation, most of these fermentation techniques will die off, and remain history to the next generation while many other countries are expanding and scaling up the processing of their respective indigenous fermented foods and beverages. Therefore, the objective of this mini-review was to document the traditional processing techniques, characteristics of the product, traditional culture associated with this beverage and to trace its origin and the problems which farmers might be facing during processing in order to identify research topics that can alleviate some of the problems and constraints identified.

Key words: Biochemical, bananas, contamination, indigenous banana beer, urwagwa.

INTRODUCTION

Consumption of home-brewed traditional alcoholic beverages and fermented foods is one main characteristic feature, deeply rooted in African culture, as part of daily lives (Haggblade and Holzapfel, 1989). In Africa, there are numerous traditional alcoholic beverages, made from many types of agricultural sources such as: sorghum, maize, barley, wheat, millet, palm trees, bananas and/or plantains. Examples of these traditional beers are: ‘thobwa’ in Malawi (Matumba et al., 2010) ‘burukutu’ in Nigeria (Sawadogo-Lingani et al., 2010), ‘sekete’ in Ghana and Nigeria (Blandino et al., 2003), ‘tonto’ in Uganda (Mwesige and Okrutu, 1995), ‘mbege’ in Tanzania (Shayo et al., 1998), ‘muratina’ in Kenya (Bahiru et al., 2006), ‘talla’ in Ethiopia (Shale and Gashe, 1991), ‘umqombothi’, ‘maiza’, ‘imfulamfula’, ‘isiquatha’ and ‘utshwala’ in South Africa (Odhav and Naicker, 2002;
Table 1. The examples of indigenous traditional African beers.

<table>
<thead>
<tr>
<th>Product</th>
<th>Raw material</th>
<th>Region/origin</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agadagidi</td>
<td>Plantain</td>
<td>Nigeria</td>
<td>Iwuoha and Eke, 1996</td>
</tr>
<tr>
<td>Borde</td>
<td>Maize or wheat</td>
<td>Ethiopia</td>
<td>Tadesse et al., 2005</td>
</tr>
<tr>
<td>Chikokiyana</td>
<td>Maize and Millet</td>
<td>S.Africa/Zimbabwe</td>
<td>Gadaga et al., 1999</td>
</tr>
<tr>
<td>Dolo</td>
<td>Sorghum</td>
<td>Togo/Burkina Faso</td>
<td>Jespersen, 2003</td>
</tr>
<tr>
<td>Doro</td>
<td>Sorghum</td>
<td>Zimbabwe</td>
<td>Gadaga et al., 1999</td>
</tr>
<tr>
<td>Ikigage</td>
<td>Sorghum</td>
<td>Rwanda/Burundi</td>
<td>Lyumugabe et al., 2010</td>
</tr>
<tr>
<td>Kaffir beer</td>
<td>Sorghum</td>
<td>South Africa</td>
<td>Blandino et al., 2003</td>
</tr>
<tr>
<td>Merissa</td>
<td>Sorghum and Millet</td>
<td>Sudan</td>
<td>Blandino et al., 2003</td>
</tr>
<tr>
<td>Palm wine</td>
<td>Palm trees</td>
<td>West Africa</td>
<td>Olawale et al., 2010</td>
</tr>
<tr>
<td>Pito</td>
<td>Sorghum/maize</td>
<td>Ghana/Togo</td>
<td>Glover et al., 2005</td>
</tr>
<tr>
<td>Tchapalo</td>
<td>Sorghum</td>
<td>Cote d’Ivoire</td>
<td>Koffi et al., 2009</td>
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Shephard et al., 2005; Ikalafeng, 2008; Ikalafeng, 2008; Lues et al., 2011, ‘chibuku’ in Zimbabwe (Kutyauroipo et al., 2009), ‘bouza’ in Egypt (Blandino et al., 2003) and ‘tchoukoutou’ in Benin (Nout, 2009). Other examples of indigenous traditional African beers are summarized in Table 1.

To express the significant role of traditional beer in African societies, in the Karamoja sub-region of north-eastern Uganda, sorghum traditional beer is termed as ‘beer is the cattle of women’, an explanation encompassing at once its ritual, nutritional, social and economic value. In this society, the wealth of men, relationships among families and the authority of elders are expressed through cattle (Dancause et al., 2010). In other words, cattle are an indication or a symbol of wealth.

In the olden days, indigenous traditional beers were mainly brewed for important social and cultural gatherings, such as seasonal rituals, funerals, marriage ceremonies, communicating with the ancestors, harvest gatherings and all other kinds of celebrations depending on ethnic group (Dancause et al., 2010; Lyumugabe et al., 2010).

In Rwandan culture, traditional banana beer has been given first preference in various social and ceremonial roles, where no ceremony is complete without banana beer. Custom demands it in dowries, at weddings, funerals, births and celebrations of all kinds. In welcoming visitors, Rwandans offer them banana beer and reciprocal exchanges of banana beer are the preferred means of strengthening relationships (Rukazambuga, 2008).

The offering of banana beer is considered essential before advancing any request for small favours or any kind of assistance. Mobilizing communal labour (or any social work), for clearing fields, building homes or other labour-intensive tasks, normally requires that the beneficiary provide banana beer to those who assist. In Rwanda banana plantations are more valued because they serve as an important dietary staple food and source of income to the farmers, through the selling of traditional banana beer and banana fruits at the farm level (Mpawenimana, 2005). Not only in Rwanda, even in other parts of the world, bananas are considered a significant staple food to many people, especially in developing countries in Africa, Asia and Latin America (Aurore et al., 2009), thus serving as a base for food security. To many farmers, banana plantations are a sign of wealth, security and social status, where brewing banana cultivars are mainly grown for beer production and sharing of banana beer and/or other traditional beer, serves as a mediating symbol in resolving conflicts among relatives, friends and neighbours.

The African continent has many different indigenous fermented foods and beverages (Campell-Platt, 1994), but the absence of a written culture in most countries makes the origin difficult to trace. The lack of written documents, archives and reliance on oral history, makes some of the information unreliable. For example, there is no clear origin of the banana beer produced in Rwanda; historical literature does not tell exactly the time when and where banana beer was produced for the first time. The origin of bananas as the main raw material in the production of banana beer is placed in Southeast Asia and is likely to have been first domesticated in Papua New Guinea (Nsabimana and van Staden, 2007; Venkatachalam et al., 2008, Boonruangrod et al., 2009; Donohue and Denham, 2009). Areas of secondary diversity are found in East Africa, indicating a long history of banana cultivation in the region between the 5th and 10th centuries (Onguso et al., 2004). Phytolith http://en.wikipedia.org/wiki/File:Bananas_Muslim_world.JPG discoveries in Cameroon, dating to the first millennium BC, triggered an yet unresolved debate about the date of first cultivation in Africa (Leju et al., 2006).

In addition to the above, there is linguistic evidence that bananas were known in Madagascar around first millennium BC. The earliest prior evidence indicates cultivation dates no earlier than late 6th century AD (Leju et al., 2006). The dates and route of bananas from their native centre of origin (South East Asia) to Africa, remains
a subject of speculation. However, banana beer is believed to have been produced after the domestication of brewing-banana cultivars into Africa. The processing of juice, from matured, green beer-bananas, for alcoholic beverages was noted to be the main characteristic feature of East African countries, such as Rwanda, Uganda, Burundi, Kenya, Tanzania and Eastern Congo, where the majority of farmers in these banana-growing regions (East African highlands) mainly cultivate banana juice-yielding cultivars (Kyamuhangire et al., 2002; Byarugaba-Bazirake, 2008; Aurore et al., 2009) as compared to the rest of the world. In addition, Palmer (1971), quoted Baker and Grant (1864 and 1886), who described the processing of banana beer in the Kagera region (currently Tanzania) and in West-Central Uganda. Mulumba et al. (2004) also added that Uganda has a long history of cultivation of banana plantations, dating back to the 13th century.

In Africa, up to 30% of the harvested banana fruits are squeezed to produce juice that can be taken fresh, or fermented with sorghum flour, to make banana beer and wine. The idea of ‘rubisi’ (traditional banana beer) produced in Tanzania has records from about 300 years ago (Rivard, 2009), which started with the production of banana juice, ‘mulamba’. ‘Mulamba’ became sour after storage for only two days and had no alcohol content. On the other hand, farmers were drinking sorghum beer with a bitter taste. After finding that ‘mulamba’ was non-alcoholic and sweet, while sorghum beer was bitter with alcohol, farmers tried to make a balance by sweetening sorghum beer with ‘mulamba’ (Rivard, 2009). However, to date, there is still a gap in the historical literature about the origin of this beer, although production and consumption of traditional banana beer is a unique feature of many African countries.

Production of traditional banana beer serves as an important source of income and employment among many farmers. Processing this traditional banana beer employs rudimentary methods, such as the use of feet, hands and spear grass to extract juice (Kyamuhangire et al., 2002; Byarugaba-Bazirake, 2008) (Figure 1A and B). Its production has remained mainly by home-based brewers in rural areas. Although the traditional methods are still preferred, improved processing techniques are indispensable to add value to beer products, particularly banana beverages, which still pose processing challenges in Rwanda and many other developing countries (Byarugaba-Bazirake, 2008; Mukantwali et al., 2008; Lues et al., 2011).

However, apart from its informal manufacturing in Rwanda, commercial production of this traditional banana beer has been developed as a business through the establishment of considerable processing plants, such as Urwibutso (local medium enterprise, owned by an individual) and COVIBAR (Compagnie de Valorisation Industrielle de la Banane au Rwanda). The latter plant was initially owned by the government but recently, through a Rwandan government initiative to promote the private sector, the plant has been privatized. The current owners have targeted exploring wider regional markets such as Common Market for Eastern and Southern Africa (COMESA) and East African Community (EAC), to which Rwanda belongs, with the aim of making more profit (Mpawenimana, 2005).

In the commercial production, improved processing technologies are employed, such as; mechanical extraction of juice, use of enzymes to facilitate ripening and extraction of juice (Mukantwali et al., 2008). The final beer products are bottled for sale within the country and a surplus is being exported to neighbouring countries and regional markets. However, many households in the country of Rwanda are involved in the production of traditional banana beer at home level, from which they get substantial cash income, similar to the South African situation as reported (Ikalafeng et al., 2009; Lues et al., 2011). To date, indigenous traditional beers are no longer produced for cultural purposes, as in the past, due to developments and western influence.

In most countries, especially in rural areas and some of the urban centres, traditional beer remains the backbone of the economy, mainly for the poor segment of the population (Kebede et al., 2002; Shackleton, 2003; Dancause et al., 2010). The income generated is used to pay school fees, medical treatment and other day-to-day home expenses (Muyanja et al., 2003; Choma and Alberts, 2007). Home-brewed banana beer and other traditional beverages like ‘ikigage’, ‘ubushera’, ‘mokoko’ and ‘maiza’, are mainly consumed in rural areas and in poor urban places, because of its affordable price as compared to commercially produced beer. This means that it is mostly the poorer segments of society who consume most of the local beverages (Kebede et al., 2002; Kayodé et al., 2007; Lues et al., 2011), except in the case of some culturally important functions, in which local beverages might have important ceremonial value. The Rwandan local banana beer, in rural areas and townships, is known to control large business markets for various reasons inspired by its need (Mpawenimana, 2005).

Even in other African societies, home-brewed traditional beverages are produced mainly for home consumption and/or for sale by low-income earners, who have no other alternative source of income to sustain their families (Dancause et al., 2010). Shackleton (2003) reported the selling of marula beer as the main source of income for many poor families in the Bushbuckridge community in South Africa. Ikalafeng (2008) also indicated a similar trend in the production of local traditional beers in the Northern Cape. It is believed that income is highly seasonal but it comes at time when money is needed for school fees, uniforms and purchase of books for students, especially after Christmas and new year celebrations, when there is shortage of money (Shackleton, 2003; Choma and Alberts, 2007).
The processing of traditional beers varies from region to region and/or from country to country. The generic way for production of traditional beers and other indigenous, cereal-based fermented foods or beverages, involves many similar, common steps which are: malting (soaking, germination, sun drying), brewing (mashing, boiling, filtration) and fermentation (Gadaga et al., 1999; Blandino et al., 2003; Kayodé et al., 2007; Nzigamasabo and Nimpagaritse, 2009; Sawadogo-Lingani et al., 2010). In contrast, the preparation of traditional banana beer, is mainly carried out in different ways, as compared to many other traditional African beers except, ‘tonto’, ‘mbege’, ‘agadagidi’ (Mwesigye and Okurut, 1995; Iwuoha and Eke, 1996; Shayo et al., 1998). In the processing of traditional banana beer, juice obtained by crushing and squeezing peeled ripe bananas, is mixed with water in desired proportion and crushed roasted sorghum grains. The mixture is allowed to ferment for 2-4 days in a warm pit, covered with banana leaves to provide a conducive environment for the growth of fermenting organisms (Mwesigye and Okurut, 1995; Nzigamasabo and Nimpagaritse, 2009). The major difference in traditional banana beer-making is that sorghum grain, used as an adjunct in the banana brewing process, does not undergo a malting stage, like cereals used in the preparation of other traditional beers. Figure 2 outlines generic steps involved in the production of traditional banana beer.

A number of studies have reported that producers of home-brewed beer are predominantly women and unemployed school leavers (Ikalafeng, 2008; Amusa and Odunbaku, 2009). Most of these people go into alcohol
Figure 2. The generic steps involved in the production of traditional banana beer.

production due to poverty and lack of alternative income-generating choices. The lack of adequate knowledge about food handling, poor personal hygiene, lack of facilities such as clean water, toilets and equipment, sometime results in microbial contamination of traditional beverages during and after processing, as well as the addition of other contaminants, such as battery acids and concoctions known to the brewers only (Ikalafeng, 2008, Amusa and Odunbaku, 2009; Lues et al., 2011).

MICRO-ORGANISMS ASSOCIATED WITH INDIGENOUS BEER

The methods for pathogenic bacteria detection are critical to food safety and human health. Numerous media and molecular-based methods have been developed to detect and identify food-borne pathogens and other organisms from samples of different origins. Culturing and plating is an old technique used for identification of organisms and it is still widely used as a standard method for quantification of micro-organisms (Mugula et al., 2003; Bahiru et al., 2006; Cetinkaya et al., 2008). However, molecular techniques are preferred, as rapid and reliable methods for identifying even non-cultivable organisms. The examples of such molecular-based methods are: Intergenic transcribed spacer-polymerase chain reaction/restriction fragment length polymorphism (ITS-PCR/RFLP) (Glover et al., 2005; Sawadogo-Lingani et al., 2010), real-time PCR assay (Karns et al., 2005), quantitative-polymerase chain reaction (qPCR) (Andorrá et al., 2008), denaturing gradient gel electrophoresis (DGGE) (Díez et al., 2001; Temmerman et al., 2004; Stringini et al., 2009) and several other methods. Micro-organisms, either desirable or undesirable, are ubiquitous in the environment and have a variety of essential
functions. Due to the nature and origin of traditional beer, its processing is prone to microbial contamination through various routes. One aspect is the hygienic handling of raw materials and final product (traditional beer) which, when compromised, leads to contamination before consumption. Although some metabolites, such as organic acids, which are produced during the fermentation process, possess an inhibitory effect against undesirable organisms, the beer should not be assumed to be free of contamination (Holzapfel, 2002; Tetteh et al., 2004). For example, members of the bacteria genera \textit{Staphylococcus}, \textit{Escherichia} and \textit{Salmonella} spp. are microorganisms closely associated with food-borne illnesses relating to poor hygiene, poor sanitation and improper food handling (Roy et al., 2007; Abraham et al., 2009). These microbes, amongst others, have been reported to be present in a number of food products, including traditional beverages (Lues et al., 2011). Protection of all types of foods and beverages from hazardous microbial contaminants is of great importance, as various gastrointestinal illnesses are the most common consequences of consuming contaminated foods and/or beverages.

Indicator microorganisms, such as total coliform bacteria, are a collection of relatively non-pathogenic micro-organisms that live in large numbers in the intestines of man, cold-blooded animals, soil and vegetation (Ksoll et al., 2007). Members of coliforms include genera such as \textit{Citrobacter}, \textit{Enterobacter}, \textit{Escherichia}, \textit{Hafnia}, \textit{Klebsiella} and \textit{Serratia}. Coliforms are Gram-negative bacteria, predominant facultative anaerobes in the bowel (Collins et al., 1995; Haynes et al., 2001), and they are members of \textit{Enterobacteriaceae}. Members of the total coliform group, especially \textit{Escherichia coli}, are used as indicator organisms of faecal contamination (Bell and Kyriakides, 1998; Oyedeji et al., 2010) and their presence in water and/or food indicates the possible presence of pathogenic bacteria, such as \textit{Salmonella} spp., \textit{Shigella} spp. and \textit{Campylobacter} species (Bell and Kyriakides, 1998). Some strains of \textit{E. coli} are human pathogens and are normally associated with diarrhoea, gastroenteritis and urinary infection (Bell and Kyriakides, 1998; Elmahmood and Doughari, 2007). Pathogenic \textit{E. coli} that cause intestinal diseases are categorized into five classes: Enterohaemorrhagic \textit{E. coli} (EHEC), Enteroaggregative \textit{E. coli} (EPEC), Enteroinvasive \textit{E. coli} (EIEC), Enteropathogenic \textit{E. coli} (EPIC) and Enterotoxigenic \textit{E. coli} (ETEC) (Bell and Kyriakides, 1998).

\textit{E. coli} has been reported to be present in the following traditional beers and other fermented food products and/or beverages amongst others. Lyumugabe et al. (2010), reported the occurrence of \textit{E. coli} at level of 21.90 x 10^3 cfu ml^{-1} in traditional sorghum beer (‘ikigage’) marketed in Rwanda, and these organisms are said to originate from water used for cooling and leavens. Roy et al. (2007), also reported the presence of \textit{E. coli} at level ranging from 10^2-10^4 cfu g^{-1} in Indian traditional fermented foods. Coliforms were detected in ‘bushera’, a non-alcoholic sorghum beverage, initially at higher level followed by progressive decrease in numbers until day 4 of fermentation, when they were no longer detected (Muyanja et al., 2003). Several reports have indicated the presence of coliform counts in various fermented beverages at low level or undetectable level as pH drops (Kunyanga et al., 2009; Namugumaya and Muyanja, 2009).

One of the virulent genera, \textit{Salmonella}, is ubiquitous and found in both cold and warm-blooded animals, including domestic and wild birds, reptiles and mammals (Pasmans et al., 2005). \textit{Salmonella} spp. are pathogens but can frequently live in animals as transient members of the intestinal population, without causing disease. Callaway et al. (2008) stated that approximately 2 to 4 million people annually, in the United States, are affected by \textit{Salmonella} spp. and salmonellosis is believed to be the second most common food-borne illness worldwide (Karns et al., 2005; Juneja et al., 2007). \textit{Salmonellae} are Gram-negative, rod-shaped bacteria, facultative anaerobes, which move by means of peritrichous flagella. They have an optimum temperature of 35 to 37°C and can also survive at low temperatures of 5°C, with a maximum growth temperature of 45 to 47°C. These bacteria have an optimum pH of 6.5 to 7.5 and a water activity of a_w 0.999 and 0.945. They are generally contracted by humans through the consumption of contaminated food of mainly animal origin (meat, poultry, eggs and milk), although other foods such as green vegetables have been implicated in their transmission (Bemis et al., 2007). The common symptoms associated with \textit{Salmonella} are: nausea, intestinal cramps, diarrhoea, vomiting and sometimes arthritic (Bemis et al., 2007).

On the other hand, \textit{Staphylococcus} is another bacterial type most often implicated in the contamination of traditional beverages (Tadesse et al., 2005; Lues et al., 2011). It has been reported as the causative agent of gastrointestinal illness world-wide, due to the production of heat-stable toxins. Staphylococcal toxins are resistant to heat and cannot be destroyed by cooking (Adams and Moss, 1997; Jørgensen et al., 2005). Staphylococci are normal microbiota of the human skin, nose, fingernails, palms, hair, throat and mucus membrane of healthy individuals. One study reported humans as being the main reservoir of \textit{Staphylococcus cohnii} while \textit{Staphylococcus aureus} can be found in both humans and animals (Plaatjies et al., 2004). Abraham et al., (2009) also reported that \textit{S. aureus} are commonly present in nasal passage, skin and hair of up to 30-50% of the human population. The most common way for food to be contaminated with \textit{Staphylococcus} spp. is through contact with food workers, who carry the bacteria on their skin and/or under the fingernails. Staphylococcal toxins are fast-acting, sometimes causing illness in as little as
Apart from the above-mentioned organisms, mainly associated with contamination of traditional beverages, other organisms such as lactic acid bacteria, yeasts and moulds have been isolated in a number of traditional beers (Jespersen, 2003; Kutyauripo et al., 2009). In traditional fermented foods and beverages, lactic acid bacteria are mainly responsible for the inhibition of undesirable microorganisms (Tadesse et al., 2005; Kebede, 2007); while the main function of yeasts (Saccharomyces cerevisiae) is the formation of alcohols and other aroma compounds (Jespersen, 2003). Cereal grains, like sorghum are frequently colonized by fungal contamination while in the field and during storage (Nkwe et al., 2005). Some of these moulds can produce mycotoxins, which may be transferred from contaminated grains into beer during brewing process (Bullerman and Bianchini, 2007).

**TOXIN PROFILES OF TRADITIONAL BEER IN GENERAL**

**Mycotoxins and cytotoxicity**

Rapid urbanization and rural reforms in developing countries have shifted the brewing and selling of traditional beers into commercial activity and this has resulted in increased consumption of these beverages, both in rural and urban areas (Choma and Alberts, 2007). Besides the risks related to ethanol consumption, home-brewed beverages contain other forms of contaminants that expose consumers to great potential health risks (Nikander et al., 1991). Raw materials frequently used in beer brewing activity, such as cereal grains, fruits and other plant materials, are vulnerable to fungal infestation in field, storage and/or during malting stages (Mbugua and Gathumbi, 2004; Nkwe et al., 2005). The use of raw materials contaminated with mycotoxins in the production of beer and other fermented foods, is a serious food safety hazard, due to their severely toxic effects on human health (Westby et al., 1997; Fernández-Cruz et al., 2010).

Numerous studies have reported the incidence of mycotoxins in both traditional and commercial beer, in different parts of the world where, for example, zearalenone, deoxynivalenol, fumonisin B₁ have been detected in Kenyan lager beer (Mbugua and Gathumbi 2004), and South African commercial and home-brewed traditional beer (Odhav and Naicker, 2002; Shephard et al., 2005; Ikafafeng, 2008). The presence of such undesirable toxic metabolites (mycotoxins) in traditional beer or other food products is a concern, as it exposes the consumer to high risk of illnesses (Westby et al., 1997). Mycotoxins are able to cause damage in different ways and these include: cytotoxic, immunosuppressive, neurotoxic, teratogenic or estrogenic, mutagenic, carcinogenic effects on humans and animals (Bennett and Klich, 2003).

These mycotoxins are toxic secondary metabolites, produced by many filamentous fungi, and contaminate various agricultural commodities in pre-harvest, harvest, post-harvest and storage conditions (Kumar et al., 2008; Wagacha and Muthomi, 2008; Pietri et al., 2009). Cereals are very susceptible to fungal infection in the field and/or inappropriate storage conditions. It is estimated that mycotoxins are responsible for the spoilage of approximately 25% of cereal crops worldwide (Prieto-Simón et al., 2007; Prieto-Simón and Campàs, 2009). Cereals that are particularly associated with mycotoxic contamination are: barley, maize, oats, sorghum and rye. Fungal species predominantly associated with sorghum, belong to the genera Fusarium, Penicillium and Aspergillus (González et al., 1997). There are about 300-400 known mycotoxins (Abdulkadar et al., 2004), but the most important common mycotoxins are: aflatoxins, fumonisin, deoxynivalenol, ochratoxins, zearalenone, T-2 toxin and T-2-like toxins (Bullerman and Bianchini, 2007). However, food-borne mycotoxins that occur frequently and are of the greatest importance in tropical developing countries, are the aflatoxins, ochratoxin, deoxynivalenol, fumonisins and zearalenone (Kumar et al., 2008; Shephard, 2008; Fernández-Cruz et al., 2010).

Mycotoxins are of concern due to their acute, potentially cytotoxic, effect on both human health and animals (Prieto-Simón and Campàs, 2009), as they are toxic to cells. Toxicological effects caused by ingestion of mycotoxins include: weakened immune system, decreased resistance to infection, reduced growth, allergens or irritants. Some have no known effect on humans and animals (Oswald et al., 2005; Wachè et al., 2009), but chronic or long-term exposure to mycotoxin doses may result in reproductive disturbances, leukoencephalomalacia, pulmonary oedema, impairment of the humoral and cellular immune responses, nervous disorders, myocardial hypertrophy and several cancers (Champeil et al., 2004). Some of the mycotoxins are discussed below.

**Fumonisin B₁ (F B₁)**

Fumonisins are a group of naturally occurring toxic metabolites produced by several Fusarium species (Berek et al., 2001; Rao et al., 2010). These were identified and characterized for the first time in 1988 (Gelderblom et al., 1988). To date, six different fumonisins have been identified as fumonisins A₁, A₂, B₁, B₂, B₃ and B₄ (Pelagalli et al., 1999; Rheeder et al., 2002). Among the numerous members of the fumonisins family, Fumonisin B₁ (FB₁) is the most predominant,
classified by the International Agency for Research on Cancer (IARC) as a group 2B carcinogen (possibly carcinogenic in humans), as shown in Figure 3 (IARC, 2002; Shephard, 2008). The species producing significant quantities of fumonisins are *Fusarium moniliforme* and *Fusarium proliferatum*. They are common contaminants of maize (Fandohan et al., 2005; Halloy et al., 2005; Tardieu et al., 2006), but these strains have been isolated frequently from corn-based food and feedstuffs (Marin et al., 1999; Soriano and Dragicci, 2004), barley, rice and wheat (Munimbazi and Bullerman, 1996), sorghum (Patel et al., 1996) and banana (Jiménez et al., 1997). Amongst the *Fusarium* species, *Fusarium napiforme*, *F. moniliforme*, *Fusarium nygamai* and *F. proliferatum*, are the most common important producers of Fumonisin B₁ (Torres et al., 1998; Soriano and Dragicci, 2004). Fumonisin B₁ (FB₁) is structurally similar to Fumonisin B₂ (FB₂) mycotoxin and, in high concentrations, FB₁ causes a variety of species-specific acute toxicological effects in domestic and laboratory animals.

This mycotoxin has been found to be responsible for the cause of leukoencephalomalacia (ELEM) in horses (Myburg et al., 2009), porcine pulmonary oedema (Fandohan et al., 2005; Voss et al., 2007) and human oesophageal cancer (Cetin and Bullerman, 2005; Presello et al., 2007) especially in the region of South Africa, China and other countries, due to the consumption of heavily *Fusarium*-contaminated local maize (Cetin and Bullerman, 2005; Myburg et al., 2009). It also causes hepatotoxicity in all species thus far examined (Bolger et al., 2001; Haschek et al., 2001). The effects of exposure to low doses of FB₁ mycotoxin are not well documented, but several studies have shown that it does not induce any clinical symptoms in swine or in mice (Bondy et al., 2000; Zomborszky-Kovacs et al., 2002). However, ingestion of low doses of FB₁ revealed pathological alterations of the lungs and an increase of intestinal colonization by opportunistic pathogenic bacteria in piglets (Oswald et al., 2003).

**Deoxynivalenol (DON)**

Deoxynivalenol (DON, Figure 4), also known as vomitoxin, is a member of the trichothecenes group of mycotoxins, mainly produced by numerous strains of *Fusarium* species and some other fungi, such as *Myrothecium, Phomopsis, Stachybotrys, Trichothecium* and *Trichoderma* (Crepp, 2002; Döll et al., 2009; Zinedine and Mañas, 2009). Trichothecenes are a group of closely related poly-cyclic sesquiterpenoids which possesses 12, 13-epoxytrichothene as a common skeleton ring (González-Osanya et al., 2010).

These classes of mycotoxins are well-known to be potent inhibitors of protein synthesis for both RNA and DNA (Eriksen and Pettersson, 2004; Boermans and Leung, 2007). In addition, trichothecenes are toxins of concern in mammals, as they are responsible for haematic, apoptosis, anorexic syndromes, neurotoxic and immunotoxic illnesses (Visconti et al., 2004). Acute and chronic ingestion of these mycotoxins by humans and animals can also result in a diverse toxic effect, which includes impaired immunity, diarrhoea, vomiting, fever, necrosis, anorexia, depletion of bone marrow and haemorrhage (Berthiller et al., 2005; Bimczok et al., 2007).

DON occurs predominantly in grains such as wheat, barley, oats, rye, maize, rice and sorghum. DON poisonings occur both in farm animals and humans and it is highly toxic, producing a wide range of immunological disturbances; it is particularly noted for inducing feed refusal and emesis in pigs, hence its alternative name vomitoxin (Schlatter, 2004; Cetin and Bullerman, 2005; González-Osanya et al., 2010). Most of the time, deoxynivalenol (DON) is noted to co-exist with other *Fusarium* toxins, such as Zearalenone, Nivalenol and its derivates, as well as the group of fumonisins. The presence of this mycotoxin has been documented by Ikalafeng (2008) at levels of concern for the consumers.
Zearalenone (ZEA)

Zearalenone (ZEA, Figure 5) is a non-steroid compound, also known as F-2 mycotoxin, and has frequently been implicated in numerous mycotoxicoses cases involving farm animals especially swine (Zinedine et al., 2007). It is classified as Group 3 (not classified to be carcinogenic to humans) by International Agency for Research on Cancer (IARC) (Azizi and Azarmi, 2009). Moreover, zearalenone is known to be a heat-stable mycotoxin and found worldwide in a number of cereal grains, such as maize, barley, oats, sorghum, rice, wheat, millet and bread (Zinedine et al., 2006), as well as in banana and bean leaves.

More than 25% of the world’s agricultural production is mainly contaminated with mycotoxins. Apart from aflatoxins, fumonisins, deoxynivalenol and ochratoxin A, which are regarded as important mycotoxins, based on their worldwide occurrences and intoxication (Ayalew et al., 2006; Naicker et al., 2007), zearalenone is also amongst the important mycotoxins implicated in contamination of sorghum grains. Furthermore, it has been reported that Fusarium isolates from bananas can also produce zearalenone (Jiménez et al., 1997). Table 2 indicates a variety of Fusarium strains which are of great concern as they produce zearalenone in sorghum grain (González et al., 1997; Aoyama et al., 2009). Zearalenone is a mycotoxin of low acute toxicity, but some of its metabolites have high binding affinity for oestrogen receptors, which can result in reproductive problems (cause of infertility, affecting ovulation, conception, implantation, fetal development and the newborn’s viability) in all animal species (Aoyama et al., 2009) and can enhance the proliferation of estrogen responsive tumor cells.

In humans, zearalenone is involved in the development of cervical cancer, breast cancer (Abid-Essefi et al., 2004; Boermans and Leung, 2007; Zinedine and Mañes, 2009) and it commonly occurs as a co-contaminant with trichothecenes mycotoxins, more particularly deoxynivalenol.

Lipopolysaccharides and pyrogenicity

Endotoxins (lipopolysaccharides, LPS) are highly pyrogenic components present in the outer membrane of Gram-negative bacteria (Nayak et al., 2008; Nilsson et
Endotoxins are potent fever-inducing agents, hence termed as pyrogens (Gorbet and Sefton, 2005; Schinder et al., 2006). The term pyrogenic directly affect the sensorial quality of the product in a positive or negative way as they greatly enhance beer flavour (Riu-Aumatell et al., 2004, Lui et al., 2005). Flavour is a combination of taste and aroma and it is of particular importance in determining food preferences. It is therefore, necessary to keep the concentrations of volatile compounds of the final product below their taste threshold, so that they do not affect the quality of the product.

Several studies have reported the occurrence of different volatile compounds in commercial beers as well as traditional ones. Three organic acids (lactic, citric and malic acids) were identified during production of ‘tchapalo’, a traditional sorghum beer popular in Côte d’Ivoire, using high-performance liquid chromatography (HPLC) (Aka et al., 2008). Also, using similar methods, Mugulu et al. (2003) reported 7 acids (DL-Lactic, succinic formic, pyruvic, citric, pyrogulatamic and uric acids) from ‘toga’. In addition, Bvochora and Zvauya (2001) identified formic acid and acetic acid in Zimbabwean traditional opaque beer, by HPLC. No propanoic or butyric acid was detected in the same beer sample, using the same technique. Annan et al. (2002), identified 20 alcohols, 22 carbonyls, 11 esters, seven acids, 1 furan and three phenolic compounds by GC-MS in Ghanaian maize dough samples, after 72 h of fermentation. By using gas chromatography (GC), Mugula et al. (2003) detected 5 carbonyls (acetaldehyde, 2-methyl-propanal, 2-methyl-butanal, 3-methyl-butanal), 4 alcohols (ethanol, 2-methyl-propanol, 2-methyl-butanol, 3-methyl-butanol,) plus diacetyl and acetoin in ‘toga’, a Tanzanian traditional popular beverage. Other different methods have been used to identify volatile compounds from beer, wine and other food products, such as capillary zone electrophoresis (CZE) (Cortacero-Ramírez et al., 2003; Santalad et al., 2007) and nuclear magnetic resonance (NMR) (Rodrigues et al., 2010).

**CONCLUSION**

The processing of traditional brew plays a significant role in business, ritual, funerals, wedding feasts and other social gatherings in Rwandan communities and in other African countries. However, the use of low brewing technologies involving uncontrolled fermentation, unsanitary conditions and use of rudimentary methods during processing, packaging and storage can result in beers...
and/or other traditional food products of low quality and short shelf-life. To foster commercial exploitation of the products, there is a need to develop appropriate brewing technologies affordable at farm level that will improve the quality of the traditional alcoholic beverages and extend their shelf-life through hygienic and controlled processing, packaging and storage. However, there is limited literature on this beverage; therefore the aim of this study was first to document the processing method, mode of consumption, traditional association with banana beer and to trace its origin for future generations.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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