Advantages of traditional lactic acid bacteria fermentation of food in Africa

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Lactic acid bacteria (LAB) are a large group of closely related bacteria that have similar properties such as lactic acid production, which is an end product of the fermentation. LAB include *Lactobacillus, Lactococus, Streptococcus and Leuconostoc* species. LAB fermentation is a common way of preparing food traditionally in Africa. Some of the traditionally fermented foods in Africa include maize porridge, alcoholic beverages and dairy products. Some of the main reasons for the fermentation practice using LAB is to increase food palatability and improve the quality of food by increasing the availability of proteins and vitamins. Furthermore, LAB confer preservative and detoxifying effects on food as well. When used regularly, LAB fermented foods boost the immune system and strengthen the body in the fight against pathogenic bacterial infections. Thus, LAB fermentation is not only of a major economic importance, but it also promotes human health in Africa.

Keywords: lactic acid bacteria; fermentation; proteins; vitamins; food quality; traditional.

1. Introduction

Traditional fermentation is a form of food processing, where microbes, for example, lactic acid bacteria (LAB) are utilized. The bacteria use food as a substrate for their propagation. This is a form of food preservation technology, used from ancient times. Over the years, it became part of the cultural and traditional norm among the indigenous communities in most developing countries, especially in Africa. The rural folk have come to prefer fermented over the unfermented foods because of their pleasant taste, texture and colour. This popularity has made fermented foods one of the main dietary components of the developing world [1-3].

Different types of food fermentations have been suggested and are classified based on the major products of the fermentation process. These include alcoholic fermentation, lactic acid (non-alcoholic) fermentation, acetic acid fermentation, alkaline fermentation and amino acid/peptide sauce fermentations [4-6]. Since lactic acid is the main by-product of the fermentation process, the pH of the ferment is always lower than 5 (in the acid range) [7] . In this article, LAB fermentation will be the major subject of review. The types of foods processed using fermentation technology include beverages, dairy products, cereals and even meat products [8].

2. Types of foods fermented in Africa

Several types of foods are traditionally fermented and this contributes substantially to the daily diets of rural communities. These indigenous foods are locally prepared in small scale, in the village homes; and their quality depends on the skills of the household occupants, as inherited over the years. These include alcoholic and non-alcoholic beverages, which are mainly cereal-based [3, 9-10]. Moreover, alcoholic traditional maize-based beverages have been produced at home-level and at a commercial scale [11]. Fermentation of fruits, vegetables and fish is also practiced in different countries of Africa [12], although fermented fish products are not very common. While some of the foods constitute the main form of daily diet, some are used as light meals, for example, in breakfast.

2.1 Cereal-based foods

The authors have been focusing mainly on fermented maize meal research over the years, as maize is a staple diet of the majority South Africans. The two main products that have been the centre of their focus are *amahewu* and *incwancwa* and these will be highlighted in this review. *Amahewu* is a sour maize-based fermented gruel or beverage consumed mainly by the indigenous people of South Africa. Maize is the main substrate used in its fermentation. *Amahewu* can be kept in a cool place for many days and serves as a refreshing energy drink both for adults and children. Figure 1 is a flow diagram showing how this product is traditionally prepared.

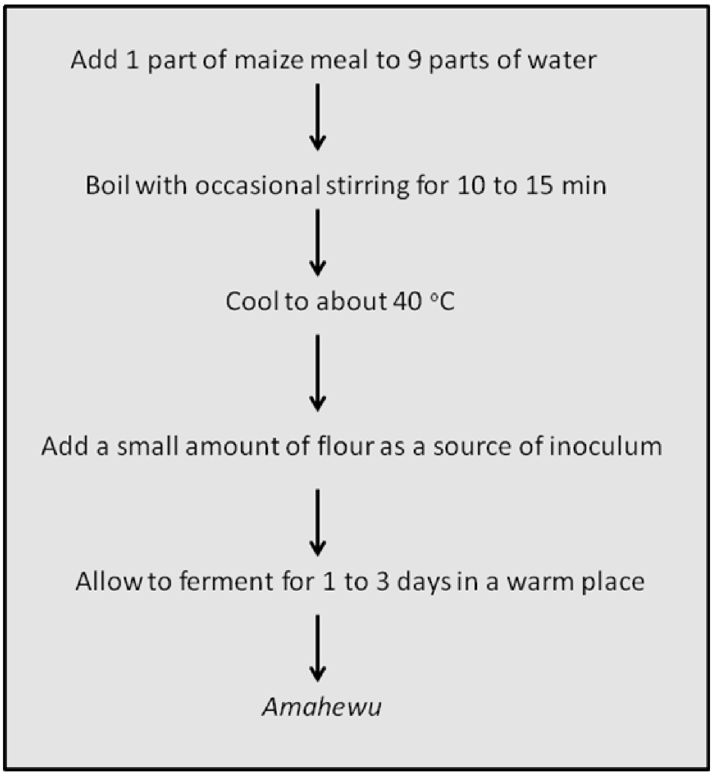

Fig. 1. Preparation of home-made *amahewu,* a South African fermented maize beverage.

Incwancwa is another South African non-alcoholic fermented beverage. It is prepared by fermenting maize meal over a one to three-day period using spontaneous fermentation by LAB, originating from the maize. Future fermentation can be carried out by back-slopping, using the previous fermented maize meal as source of inoculum. Once fermented, the maize meal is cooked to boiling, adding salt and sugar as preferred by the consumer [9].

In West Africa *ogi* is a staple porridge prepared from fermented maize, sorghum or millet [13]. It is a popular breakfast gruel and a complementary food for young children [14]. Its consumption rate has been on the increase. It is traditionally prepared by soaking maize kernels for 1 to 3 days, followed by wet milling and later sieving to remove the bran, hulls and germ. This fermented maize product is fortified by blending it with bambara groundnut to increase its protein and fat content [15-16].

Togwa is fermented maize–sorghum gruel prepared and consumed by the Tanzanian people [17]. The difference between this gruel and mahewu for example, is that it can be prepared either from cassava, maize, sorghum, millet or their combinations. The other cereal fermented preparations include *kisra*, a Sudanese fermented sorghum [18], *hussuwa*, a traditional African fermented sorghum food from Sudan [19]. *Hussuwa* is a semi-solid, dough-like fermented food which ferments for up to a month. *Munkoyo* is a traditional Zambian maize fermented gruel [11], prepared with addition of *Rhynchosia heterophylla* root extract. The extract has amylase enzyme that digests starch, which is a part of the fermentation process.

2.2 Dairy Products

Milk is a globally known nutritious food, not only for the infants, but for human adults as well. However, it often gets contaminated by pathogenic bacteria and easily gets spoilt if kept for too long at ambient temperature. It also may contain residual toxins from the food consumed by the cows prior to milking, for example aflatoxin M1. Dairy products such as yoghurt, cheese and sour milk are fermented, protein-rich milk products. Several probiotics in use today are obtained from fermented milk products [20]. Yoghurt, a fermented milk product, offers other benefits such as the ability to kill pathogens as well as modulate the immune system [20-21].

Fermented milk is common all over Africa for example, *sethemi* is a South African fermented milk prepared by naturally fermenting milk [22]. *Kule naoto* is a traditionally fermented milk by the Maasai of Kenya [23-24]. It is spontaneously fermented from raw milk in traditionally prepared calabashes. The calabashes are first treated with burnt smoky twigs of a traditional plant. The milk is further pre-treated by adding fresh cow's blood, before initiating the fermentation process. *Lactococcus* and *Lactobacillus spp.* were the main isolated bacteria from the fermented product. *Suusac*, is another Kenyan traditional fermented camel milk product [25]. This is usually prepared and consumed by the Somali people in the semi-arid areas of northern Kenya. It is prepared by spontaneously fermenting unboiled milk in calabashes treated with smoky, burnt traditional plant twigs. *Amasi*, is a traditional fermented milk consumed both in South Africa and Zimbabwe [26-27]. It has been shown to experimentally inhibit the growth of pathogens, such as *Salmonella enteridis* and *Escherichia coli*, that usually contaminate raw milk [27]. Traditional preparation of *amasi* is similar in both countries where raw milk is poured into calabashes made of gourd or into stone jars. It is then left to ferment for several days. *Amasi* is now available in commercial outlets in South Africa.

2.3 Cassava products and legumes

Similarly, cassava which can grow in poor, acidic soils, is drought resistant and therefore readily available to the poor living in semi-arid areas with minimal rainfall. It is nutritionally deficient in terms of carbohydrates, protein and can cause cyanide poisoning in its raw state. Furthermore, it cannot be stored for long periods after harvest, as it is a perishable product [28]. Many countries in Africa use cassava as a staple diet but it presents a number of problems. It is low in dietary content, short-term storage following harvest and has cyanogenic toxins. However, it is nutritionally enhanced when fermented. The foods made from cassava include *gari* produced in West Africa [29]. This food is prepared from grated cassava tubers, left to ferment for 2-3 days at ambient temperature. After this, it is dried by heating and then mixed with palm oil. *Agbelima* is another West African cassava fermented food [30]. Like *gari*, this food is prepared by fermenting grated cassava, after inoculating it with old traditional cassava ferment, as a starter culture. In Tanzania, a cassava fermented food product named *kivunde* [31], is prepared in the same manner as *gari* but is left to spontaneously ferment.

Soybean is a widely distributed and easily available product which is a good source of protein and other nutrients. It has found wide application in the production of confectionery foods, weaning diets and reduction of malnutrition. Another interesting application in Africa is the use of soymilk in the production of yoghurt, which can serve as a simple low cost food product to combat malnutrition [21].

2.4 Meat products

Meat and meat products are consumed in almost all communities of the African World. It is one of the richest food sources of protein [32]. However, it gets easily contaminated by pathogenic microorganisms present in animals prior to being slaughtered. It is therefore important to make meat safe for consumers in terms of stability, transportation and storage. One of the preferred methods used to achieve these qualities is meat fermentation [33-35]. Fermentation of meat sausages, for example, using selected LAB strains, strongly inhibited the spoilage bacterial growth but left the organoleptic properties of the products intact [36]. Thus, LAB strains can be effectively used to preserve meat products for quality purposes. *Lanhouin*, a fermented fish product consumed by the locals in the West African country of Benin [37], is processed by spontaneous and largely, uncontrolled fermentation. The product was found to be safer and free of pathogenic bacteria such as *Salmonella*. It has also been demonstrated that fish products, which were LAB fermented could be stored for longer periods, free of the fishy odor and taste [38]. Furthermore, the nutritional quality of fish remained intact.

3. Fermenting organisms

The indigenous natural fermentation takes place in a mixed colony of microorganisms such as moulds, bacteria and yeasts [39]. Thus, fermentation products in food substrates are based on the microorganisms involved in the fermentation. Some of the compounds formed during fermentation include organic acids (e.g., palmitic, pyruvic, lactic, acetic, propionic and butyric acids), alcohols (mainly ethanol) aldehydes and ketones (acetaldehyde, acetoin, 2-methyl butanol) [40]. The bacteria are not harmful to the consumer and have enzymes such as proteases, amylases and lipases that hydrolyze food complexes into simple nontoxic products with desirable textures, aroma that makes them palatable for consumption [6].

The fermenting organisms include LAB such as, *Leuconostoc, Streptococcus, Lactobacillus, Enterococcus, Aerococcus* and *Pediococcus* spp. [5, 39, 41-42]. The yeasts isolated are mainly of the species, *Saccharomyces, Candida, Kluyeromyces and Debaryomyces* [14, 43]. Moulds have been used mainly in milk and cheese fermentation and include, *Penicillium, Mucor, Geotrichium,* and *Rhizopus* species [43-45]. Some of the microorganisms isolated from fermented food are, however, yet to be identified. In all the foods and beverages examined, LAB are the dominant microorganisms, and therefore, lactic acid fermentation is considered as the major contributor to the beneficial characteristics observed in fermented foods. Thus, lactic acid bacteria are the main subject of this review.

4. What fermentation does to food

4.1 Flavour enhancement

Fermentation makes the food palatable by enhancing its aroma and flavor. These organoleptic properties make fermented food more popular than the unfermented one in terms of consumer acceptance [5]. The agents responsible for these properties have been described [46]. However, the specific mechanisms by which flavour is generated are still subject to investigation. Addition of other ingredients like citric acid in lemon juice, to imitate the low pH of fermented products failed to give the same desired results. Furthermore, food acidification does not result in improvement of food texture and quality. Thus, fermentation is unique in that it modifies the unfermented food in diverse ways, resulting in new sensory properties in the fermented product [47]. However, not all bacteria and moulds are beneficial in enhancing food flavor. In some instances, they may cause food spoilage since their enzymes may lead to generation of fermentation digests that have offensive odours or flavours, making food to be entirely unpalatable.

4.2 Nutritional quality

A number of foods especially cereals are poor in nutritional value, and they constitute the main staple diet of the low income populations. However, LAB fermentation has been shown to improve the nutritional value and digestibility of these foods [48-49]. The acidic nature of the fermentation products enhances the activity of microbial enzymes at a temperature range of 22-25 ºC [7]. The enzymes, which include amylases, proteases, phytases and lipases, modify the primary food products through hydrolysis of polysaccharides, proteins, phytates and lipids respectively. Thus, in addition to enhancing the activity of enzymes, LAB fermentation also reduces the levels of antinutrients such as phytic acid and tannins in food leading to increased bioavailability of minerals such as iron, protein and simple sugars [50-51]. The amount of vitamins is also increased in the ferment [50, 52-54]. A number of techniques such as nutrient supplementation have used in the past to improve the nutritional value of food. However, these are inadequate and often unaffordable in meeting the demands of the low-income populations.

4.3 Preservative properties

The preservative activity of LAB has been observed in some fermented products such as cereals. The lowering the pH to below 4 through acid production, inhibits the growth of pathogenic microorganisms which can cause food spoilage, food poisoning and disease [55]. For example, LAB bacteria have antifungal activities [56-59]. By doing this, the shelf life of fermented food is prolonged. This is because the sheer overgrowth of desirable edible bacteria in food outcompetes the other non-desirable food spoilage bacteria. Thus LAB fermented foods have lactic acid as the main preservative since lactic acid bacterial growth is accompanied by the production of lactic and acetic acids with decrease in pH and increase in titratable acidity. The process of fermentation usually takes 4-5 days. The bacterial population stabilizes at around 48 hours.

4.4 Detoxification

Food and feeds are often contaminated with a number of toxins either naturally or through infestation by microorganisms such as moulds, bacteria and viruses. Certain moulds often produce secondary toxic metabolites called mycotoxins. These include fumonisins, ocratoxin A, zearalenone and aflatoxins [60]. Several methods are available for degrading toxins from contaminated food, for example, using alkaline ammonia treatment to remove mycotoxins from food. However, these methods are harsh to food as they involve use of chemicals which are potentially harmful to health or may impair/reduce the nutritional value of food. Cooking food does not remove mycotoxins either, as most of them are heat-stable. Detoxification of mycotoxins in food through LAB fermentation has been demonstrated over the years [7, 51, 56, 61-64]. Using LAB fermentation for detoxification is more advantageous in that it is a milder method which preserves the nutritive value and flavor of decontaminated food [65]. In addition to this, LAB fermentation irreversibly degrades mycotoxins without leaving any toxic residues. The detoxifying effect is believed to be through toxin binding effect [66-68]. Other authors allude to a possibility of an enzymatic interaction, although this was not thoroughly investigated [63].

As in the case of mycotoxin detoxification, LAB fermentation has also been successfully used to detoxify cassava toxins (cyanogens) following fermentation of cassava food products [69]. In addition to cyanogen detoxification, cassava fermentation contributes to the preservation and improvement flavour and aroma of cassava ferment [42]. Although cooking has been used as a method of cyanogens detoxification, it has a number of problems as it leaves residual cyanogens in processed cassava, which exist as glucoside, cyanohydrin or free cyanide, which are equally toxic as their parent compounds in uncooked food [70].

4.5 Antibiotic activities

Some of the inhibitory compounds against other bacteria include hydrogen peroxide and bacteriocins [8]. LAB fermentation products have also been shown to have antitumour effects [41]. One of the arguments supporting the use of LAB fermentation to prevent diarrheal diseases is because they modify the composition of intestinal microorganisms, and by this, act as deterrents for pathogenic enteric bacteria. LAB bacteria also produce fungal inhibitory metabolites. These are mainly organic acids, which include propionic, acetic and lactic acids [56, 71]. Thus, LAB are applied as a hurdle against non-acid tolerant bacteria, which are ecologically eliminated from the medium due to their sensitivity to acidic environment [55]. Also, fermentation has been demonstrated to be more effective in the removal of Gram-negative than the Gram-positive bacteria, which are more resistant to fermentation processing [72]. As such, fermented food can control diarrhoeal diseases in children [73-74].

Moreover, LAB are also known to produce protein antimicrobial agents such as bacteriocins [75-76]. Bacteriocins are peptides that elicit antimicrobial activity against food spoilage organisms and food borne pathogens, but do not affect the producing organisms. LAB also synthesises other anti-microbial compounds such as, hydrogen peroxide, reuterin, and reutericyclin [47]. Other applications of LAB include their use as probiotics that restore the gut flora in patients suffering from diarrhea, following usage of antibiotics that destroy the normal flora [1]. In this manner, fermented food is used to prevent and to alleviate diarrhea. In addition, the consumption of food products and beverages rich in LAB helps to alleviate constipation and abdominal cramps.

5. Importance of fermented food in Africa

Fermented food products play a significant socio-economic role in African countries and the developing world. The importance of traditional fermented foods has been reviewed [4-5, 15, 26, 46, 62]. These products also contribute to the protein requirements of the indigenous consumers [77]. Lowering the pH of food products through fermentation is a form of food preservation [55]. This is a self-limiting process in that further reduction of pH may be inimical to the producing organisms. As a result the pH normally stays just below 5. Other benefits of fermentation include improvement of food quality through food digestibility to increase essential amino acids, vitamins and protein [8, 51]. In the era of diminishing food quality, fermentation can play a role in complementing the food fortification programme instituted by the WHO. Cereal grains are also susceptible to contamination by naturally occurring mycotoxins both on the fields and during storage. The fermentation of maize meal has been demonstrated to detoxify these toxins making maize meal safer for human consumption. Children are the hardest hit segment of the population when a nation faces food crisis. Donor countries would normally supply mainly maize to fight off hunger. Fermentation of maize meal makes the final product suitable to serve as weaning food since the bacteria responsible for fermentation also produce vitamins and amino acids during their growth and serve as single cell proteins after cooking [78-79]. Moreover, maize is more likely to be readily available in a poor setting where a balanced diet is not available. Therefore, fermentation technology is of great importance in ensuring food safety, preservation and food flavouring [80].

Fermentation is also known to soften food texture and alter its composition in such a way that it will require minimal energy both in cooking and preservation process. Thus, less fuel will be used for cooking and eliminates the need of preservation as fermentation increases the shelf life of food. These advantages make fermentation a highly desirable technique in the rural communities of the third world where resources for cooking and preservation are scarce. Fermentation technology also has the potential of meeting the world's food supply demand if adequately developed into the industrial scale[80].

In a Joint FAO/WHO Workshop held in Pretoria, South Africa, the importance of antibiotic activity and nutritional benefits of LAB was revisited [79]. In this workshop, a gap of knowledge was identified and the participants were unanimous that further research was required to further expand the usefulness of food fermentation especially its antibiotic activities against parasites, viruses and bacteria. Additionally, assessment of physicochemical effects of fermented foods on consumers and the establishment of starter cultures for commercial market were identified as priorities [79]. The handlers of traditional foods also need to be educated on food hygiene, as there are many instances where food is contaminated by bad handling after cooking. LAB fermentation fits into primary care initiatives and can reduce child mortality by supplying the minimum required nutrients [81]. In addition to its potential use to tackle malnutrition, the technology is a low cost means of food preservation [32, 56].

6. The future of traditionally fermented foods

There is need to educate the African citizens on the need of consuming fermented foods and food safety. Although fermented foods are generally safe, and in the view that certain antimicrobial factors are present, lack of standardization in the methods used, the environment and the hygiene of the people that prepare them, will determine the quality of the product. Safety is of paramount importance. Personal hygiene should be practiced to complement the overall benefits of fermented foods. The greatest drawback in the development of fermented food products in Africa is that many products are produced under primitive conditions, resulting in low yield and poor quality, including short shelf-life [77]. Other problems include the lack of appeal in the presentation and marketing of the food products, as well as the fact that the processes are often laborious and time-consuming [82]. The technology needs to be improved through research to advance its potential for food safety and nutritional value. Imported products should not stifle the development of traditional food products at a national and international level.

With the current technologies, it should be possible to be innovative about many of the foods produced using fermentation and indigenous knowledge systems. The challenge is to ensure that technology is used to add value to such products, such as increased shelf-life, flavour and appealing packaging and labeling. Old ferments are not an efficient way of preserving the LAB probiotic organisms as poor survival has been reported in these products. Microencapsulation technology is a new technique which can be used to preserve and propagate LAB cultures for mass production of fermented foods [83]. Current research conducted by our group include the isolation and identification of the microorganisms associated with *amahewu* and *incwancwa* production. This is hoped to preserve the cultures for future use as starter cultures and as a base to extend the product-range of fermented foods. In addition, antimicrobial peptides produced by some LAB can be used as lead compounds in drug discovery.

It is also important to document these traditional indigenous technologies in order to preserve them for future generations, as the old days practices keep changing from time to time. This will also create a reference database for future generations of food research scientists, nutritionists and food regulatory bodies and policy makers in different ladders of government.

7. Conclusion

Fermentation of traditional foods, as a hurdle technology, is profitable in terms of food quality, preservation and decontamination of toxins, often found in food. Together with food safety, the nutritional and flavour profile of the products need to meet the expectations of modern consumers. Education of communities about benefits of consuming fermented foods needs to be part of health education. This technology needs to be further developed to enhance safety and ease of application in a rural poor-resource setting. Development of convenient starter cultures and processing methods will ensure that many people in Africa will reap the benefits of indulging in fermented foods and beverages both during cultural ceremonies and during their normal daily activities.

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References

[1] Aderiye BI and Laleye SA. Relevance of fermented food products in southwest Nigeria. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum)*. 2003;3:1-16.
[2] Mosha TCE and Vicent MM. Nutritional value and acceptability of homemade maize/sorghum-based weaning mixtures supplemented with *rojo* bean flour, ground sardines and peanut paste. *International Journal of Food Sciences and Nutrition.* 2004;55(4):301 - 315.
[3] Nout MJR and Sarkar PK. Lactic acid food fermentation in tropical climates. *Antonie van Leeuwenhoek.* 1999;76(1):395-401.
[4] Anukam KC and Reid G. African Traditional Fermented Foods and Probiotics. *Journal of Medicinal Food.* 2009;12(6):177-1184.
[5] Blandino A, Al-Aseeri ME, Pandiella SS, Cantero D and Webb C. Cereal-based fermented foods and beverages. *Food Research International*. 2003;36(6):527-543.
[6] Steinkraus KH. Classification of fermented foods: worldwide review of household fermentation techniques. *Food Control.* 1997);8(5/6):311-317.
[7] Mokoena MP, Chelule PK and Gqaleni N. Reduction of Fumonisin B1 and Zearalenone by Lactic Acid Bacteria in Fermented Maize Meal. *Journal of Food Protection.* 2005;68:2095-2099.
[8] Oyewole OB. Lactic fermented foods in Africa and their benefits. *Food Control.* 1997;8(5-6):289-297.
[9] Gqaleni N, Shandu NR, Sibiya P and Dutton MF. *Indigenous non-alcoholic fermentations and mycotoxin degradation. Le Baars ed. International Symphosium on mycotoxins in the food chain: IUTOX 8th International Congress in Toxicology, Toulouse, France*, 1998.
[10] Katangole JN. *The microbial succession in indigenous fermented maize products*. University of the Free State Bloemfontein, 2008.
[11] Zulu RM, Dillon VM and Owens JD. Munkoyo beverage, a traditional Zambian fermented maize gruel using Rhynchosia root as amylase source. *International Journal of Food Microbiology*. 1997;34(3):249-258.
[12] Essuman KM. *Fermented Fish in Africa: A study on processing, marketing and consumption. FAO, 329*. FAO, City, 1992.
[13] Nago CM, Tétégan E, Matencio F and Mestres C. Effects of Maize Type and Fermentation Conditions on the Quality of Beninese Traditional Ogi, a Fermented Maize Slurry. *Journal of Cereal Science.* 1998;28(2):215-222.
[14] Omemu AM, Oyewole, OB and Bankole MO. Significance of yeasts in the fermentation of maize for ogi production. *Food Microbiology.* 2007;246:571-576.
[15] Haard NF, Odunfa SA and Lee CH. *Fermented Cereals. A global perspective*. FAO, Rome, Italy, 1999.
[16] Mbata TI, Ikenebomeh MJ and Ezeibe S. Evaluation of mineral content and functional properties of fermented maize (Generic and specific) flour blended with bambara groundnut (Vigna subterranean L). *African Journal of Food Science.* 2009;34(4):107-112.
[17] Mugula JK, Nkko SAM and Sorhaug T. Changes in quality attributes during storage of *togwa*, a lactic acid fermented gruel. *Journal of Food Safety.* 2001;21(3):181-194.
[18] Ali AA and Mustafa MM. Use of Starter Cultures of Lactic Acid Bacteria and yeasts in the preparation of *Kisra*, a Sudanese fermented food. *Pakistan Journal of Nutrition.* 2009;8(9):349-353.
[19] Yousif NMK, Huch M, Schuster T, Cho GS, Dirar HA, Holzapfel WH and Franz CMAP. Diversity of lactic acid bacteria from *Hussuwa*, a traditional African fermented sorghum food. *Food Microbiology*, In Press, Corrected Proof2010).
[20] Katz F. Active cultures add function to yoghurt and other foods. *Food Technology*, 55, 3 2001), 46-49.
[21] Ashaye O A, Taiwo LB, Fasoyiro SB and Akinnagbe CA. Compositional and shelf-life properties of soy-yogurt using two starter cultures. *Nutrition and Food Science.* 2001;31:247-250.
[22] Kebede A, Viljoen BC, Gadaga TH, Narvhus JA and Lourens-Hattingh A. The effect of container type on the growth of yeast and lactic acid bacteria during production of Sethemi, South African spontaneously fermented milk. *Food Research International.* 2007;40(1):33-38.
[23] Mathara, JM, Schillinger U, Guigas C, Franz C, Kutima PM, Mbugua SK, Shin HK and Holzapfel WH. Functional characteristics of Lactobacillus spp. from traditional Maasai fermented milk products in Kenya. *International Journal of Food Microbiology.* 2008;126(1-2):57-64.

[24] Patrignani F, Lanciotti R, Mathara JM, Guerzoni ME and Holzapfel WH. Potential of functional strains, isolated from traditional Maasai milk, as starters for the production of fermented milks. *International Journal of Food Microbiology*. 2006;107(1):1-11.
[25] Lore TA, Mbugua SK and Wangoh J. Enumeration and identification of microflora in suusac, a Kenyan traditional fermented camel milk product. *Lebensmittel-Wissenschaft und-Technologie.* 2005;38(2):125-130.
[26] Gadaga TH, Mutukumira AN, Narvhus JA and Feresu SB. A review of traditional fermented foods and beverages of Zimbabwe. *International Journal of Food Microbiology.* 1999;53(1):1-11.
[27] Mufandaedza J, Viljoen BC, Feresu SB and Gadaga TH. Antimicrobial properties of lactic acid bacteria and yeast- LAB cultures isolated from traditional fermented milk against pathogenic Escherichia coli and Salmonella enteritidis strains. *International Journal of Food Microbiology*. 2006;108(1):147-152.
[28] Kostinek M, Specht I, Edward VA, Pinto C, Egounlety M, Sossa C, Mbugua S, Dortu C, Thonart P, Taljaard L, Mengu M, Franz CMAP and Holzapfel WH. Characterisation and biochemical properties of predominant lactic acid bacteria from fermenting cassava for selection as starter cultures. *International Journal of Food Microbiology.* 2007;114(3):342-351.
[29] Kostinek M, Specht I, Edward VA, Schillinger U, Hertel C, Holzapfel, WH and Franz CMAP. Diversity and technological properties of predominant lactic acid bacteria from fermented cassava used for the preparation of Gari, a traditional African food. *Systematic and Applied Microbiology*. 2005;28(6):527-540.
[30] Amoa-Awua WK, Frisvad JC, Sefa-Dedeh S and Jakobsen M. The contribution of moulds and yeasts to the fermentation of 'agbelima' cassava dough. *Journal of Applied Microbiology.* 1997;83(3):288-296.
[31] Kimaryo VM, Massawe GA, Olasupo NA and Holzapfel WH. The use of a starter culture in the fermentation of cassava for the production of "*kivunde*", a traditional Tanzanian food product. *International Journal of Food Microbiology*. 2000;56(2-3):179-190.
[32] Lücke FK. Utilization of microbes to process and preserve meat. *Meat Science.* 2000;56(2):105-115.
[33] Hugas M, Garriga M and Aymerich MT. Functionalty of enterococci in meat products. *International Journal of Food Microbiology.* 2003;88(2-3):223-233.
[34] Hugas M and Monfort JM. Bacterial starter cultures for meat fermentation. *Food Chemistry.* 1997;59(4):547-554.
[35] Jones RJ, Hussein HM, Zagorec M, Brightwell G and Tagg JR. Isolation of lactic acid bacteria with inhibitory activity against pathogens and spoilage organisms associated with fresh meat. *Food Microbiology.* 2008;25(2):228-234.
[36] Metaxopoulos J, Mataragas M and Drosinos EH. Microbial interaction in cooked cured meat products under vacuum or modified atmosphere at 4°C. *Journal of Applied Microbiology.* 2002;93(3):363-373.
[37] Anihouvi VB, Ayernor GS, Hounhouigan JD and Sakyi-Dawson E. Quality characteristics of lanhoun: A tradtionallu processed fermented fish product in the Republic of Benin *African Journal of Food, Agriculture, Nutrition and Development.* 2006;6(1):1-5.
[38] Gelman A, Drabkin, V. and Glatman, L. Evaluation of lactic acid bacteria, isolated from lightly preserved fish products, as starter cultures for new fish-based food products. *Innovative Food Science & Emerging Technologies.* 2000;1(3):219-226.
[39] Antony U and Chandra TS. Microbial population and biochemical changes in fermenting finger millet (Eleusine coracana). *World Journal of Microbiology and Biotechnology.* 1997;13(5):533-537.
[40] Campbell-Platt, G. Fermented foods- a world perspective. *Food Research International.* 1994;27:253.
[41] Hirayama, K. and Rafter, J. The role of lactic acid bacteria in colon cancer prevention: mechanistic considerations. *Antonie van Leeuwenhoek*, 76, 1 1999), 391-394.
[42] Holzapfel W. Use of starter cultures in fermentation on a household scale. *Food Control*. 2002;8(5-6):241-258.
[43] Wouters JTM, Ayad EHE, Hugenholtz J and Smit G. Microbes from raw milk for fermented dairy products. *International Dairy Journal.* 2002;12(2-3):91-109.
[44] Steinkraus KH. *Bio-enrichment: production of vitamins in fermented foods*. Thomson Science, City, 1998.
[45] Varga J, Péteri Z, Tábori K, Téren J and Vágvölgyi C. Degradation of ochratoxin A and other mycotoxins by Rhizopus isolates. *International Journal of Food Microbiology.* 2005;99(3):321-328.
[46] Ramaite RAA and Cloete TE. *Traditional African fermentations*. Van Schaik, Pretoria, 2006.
[47] Leroy F and De Vuyst L. Lactic acid bacteria as functional starter cultures for the food fermentation industry. *Trends in Food Science and Technology.* 2004;15:67-78.
[48] Nout MJR. Rich nutrition from the poorest - Cereal fermentations in Africa and Asia. *Food Microbiology.* 2009;26(7):685-692.
[49]Obiri-Danso K, Ellis WO, Simpson BK and Smith JP. Suitability of high lysine maize, Obatanpa for 'kenkey' production. *Food Control*. 1997;8(3):125-129.
[50] Sripriya G, Antony U and Chandra TS. Changes in carbohydrate, free amino acids, organic acids, phytate and HCl extractability of minerals during germination and fermentation of finger millet (Eleusine coracana). *Food Chemistry.* 1997;58(4):345-350.
[51] Chelule PK, Mbongwa HP, Carries S and Gqaleni N. Lactic acid fermentation improves the quality of amahewu, a traditional South African maize-based porridge. *Food Chemistry*. 2010;122(3):656-661.
[52] Santos F, Wegkamp A, de Vos WM, Smid EJ. and Hugenholtz, J. High-Level Folate Production in Fermented Foods by the B12 Producer Lactobacillus reuteri JCM1112. *Applied and Environmental Microbiology*. 2008;74(10):3291-3294.
[53] Slingerland MA, Traore K, Kayodé APP and Mitchikpe CES. Fighting Fe deficiency malnutrition in West Africa: an interdisciplinary programme on a food chain approach. *NJAS - Wageningen Journal of Life Sciences.* 2006;53(3-4):253-279.
[54] Sybesma W, Starrenburg M, Kleerebezem M, Mierau I, de Vos WM and Hugenholtz J. Increased Production of Folate by Metabolic Engineering of Lactococcus lactis. *Applied and Environmental Microbiology.* 2003;69(6):3069-3076.
[55] Ananou S, Maqueda M, Martínez-Bueno M and Valdivia E. *Biopreservation, an ecological approach to improve the safety and shelf-life of foods*. FORMATEX, 2007.
[56] Schnürer J and Magnusson J. Antifungal lactic acid bacteria as biopreservatives. *Trends in Food Science & Technology.* 2005;16(1-3):70-78.
[57] Huwig A, Freimund S, Käppeli O and Dutler H. Mycotoxin detoxication of animal feed by different adsorbents. *Toxicology Letters*. 2001;122(2):179-188.

[58] Lind H, Jonsson H and Schnürer J. Antifungal effect of dairy propionibacteria--contribution of organic acids. *International Journal of Food Microbiology*. 2005;98(2):157-165.
[59] Magnusson J, Ström K, Roos S, Sjögren J and Schnürer J. Broad and complex antifungal activity among environmental isolates of lactic acid bacteria. *FEMS Microbiology Letters*. 2003:219(1):129-135.
[60] Sweeney MJ and Dobson ADW. Mycotoxin production by *Aspergillus, Fusarium* and *Penicillium* species. *International Journal of Food Microbiology*. 1998;43(3):141-158.
[61] Gourama H and Bullerman LB. Antimycotic and Antiaflatoxigenic Effect of Lactic Acid Bacteria: A Review. *Journal of Food Protection*. 1995;58):1275-1280.
[62] Dalie DKD, Deschamps AM and Richard-Forget F. *Lactic acid bacteria - Potential for control of mould growth and mycotoxins: A review*. Elsevier, Kidlington, ROYAUME-UNI, 2010.
[63] Zinedine A, Faid M and Benlemlih M. In Vitro Reduction of Aflatoxin B1 by Strains of Lactic Acid Bacteria Isolated from Moroccan Sourdough Bread. *International Journal of Agriculture and Biology*. 2005;7(1):67-70.
[64] Mokoena MP, Chelule PK and Gqaleni N. The toxicity and decreased concentration of aflatoxin B_1 in natural lactic acid fermented maize meal. *Journal of Applied Microbiology*. 2006;100(4):773-777.
[65] Bata Á and Lásztity R. Detoxification of mycotoxin-contaminated food and feed by microorganisms. *Trends in Food Science & Technology*. 1999;10(6-7):223-228.
[66] El-Nezami H, Polychronaki N, Salminen S and Mykkanen H. Binding Rather Than Metabolism May Explain the Interaction of Two Food-Grade Lactobacillus Strains with Zearalenone and Its Derivative {alphaacute}-Zearalenol. *Applied and Environmental Microbiology*. 2002;68(7):3545-3549.
[67] Haskard CA, El-Nezami HS, Kankaanpaa PE, Salminen S and Ahokas JT. Surface Binding of Aflatoxin B1 by Lactic Acid Bacteria. *Appied and Environmental Microbiologyl*. 2001;67(7);3086-3091.
[68] Turbic A, Ahokas JT and Haskard CA. Selective in vitro binding of dietary mutagens, individually or in combination, by lactic acid bacteria. *Food Additives and Contaminants*. 2002;19(2):144 - 152.
[69] Caplice E and Fitzgerald GF. Food fermentations: role of microorganisms in food production and preservation *International Journal of Food Microbiology*. 1999;50:131-149.
[70] Ravi S and Padmaja G. Mechanism of Cyanogen Reduction in Cassava Roots during Cooking. *Journal of Science Food and Agriculture*. 1997;75:427-432.
[71] Sauer M, Porro D, Mattanovich D and Branduardi P. Microbial production of organic acids: expanding the markets. *Trends in Biotechnology*. 2008:26(2):100-108.
[72] Mensah P. Fermentation -- the key to food safety assurance in Africa? *Food Control*. 1997;8(5-6):271-278.
[73] Guandalini S. Probiotics for children: Use in diarrhea. *Journal of Clinical Gastroenterology*. 2006;40(3):244-248.
[74] Szajewska H, Setty M, Mrukowicz J and Guandalini S. Probiotics in Gastrointestinal Diseases in Children: Hard and Not-So-Hard Evidence of Efficacy. *Journal of Pediatric Gastroenterology and Nutrition*. 2006;42(5):454-475
[75] Aymerich MT, Garriga M, Monfort JM, Nes I and Hugas M. Bacteriocin-producing lactobacilli in Spanish-style fermented sausages: characterization of bacteriocins. *Food Microbiology*. 2000;17(1):33-45.
[76] Carolissen-Mackay V, Arendse G and Hastings JW. Purification of bacteriocins of lactic acid bacteria: problems and pointers. *International Journal of Food Microbiology*. 1997;34(1):1-16.
[77] Achi OK. The potential for upgrading traditional fermented foods through biotechnology. *Africa Journal of Biotechnology*. 2005;4(5):375-380.
[78] Motarjemi Y, Käferstein F, Moy G and Quevedo F. Contaminated weaning food: a major risk factor for diarrhoea and associated malnutrition. *Bulletin of the World Health Organization*. 1993;71(1):79-92.
[79] Motarjemi Y and Nout MJ. Food fermentation: a safety and nutritional assessment. Joint FAO/WHO Workshop on Assessment of Fermentation as a Household Technology for Improving Food Safety. *Bulletin of the World Health Organization*. 1996;74(6):553-559.
[80] Nout MJR and Motarjemi Y. Assessment of fermentation as a household technology for improving food safety: a joint FAO/WHO workshop. *Food Control*. 1997;8(5-6):221-226.
[81] Motarjemi Y. Impact of small scale fermentation technology on food safety in developing countries. *International Journal of Food Microbiology*. 2002;75:213-229.
[82] Nout MJR, Kok B, Vela E, Nche PF and Rombouts FM. Acceleration of the fermentation of kenkey, an indigenous fermented maize food of Ghana. *Food Research International*. 1995;28(6):599-604.
[83] Kailasapathy K. Microencapsulation of Probiotic Bacteria: Technology and Potential Applications. *Currrent Issues in Intestinal Microbiology*. 2002:3:39-48.