Lactic fermented foods in Africa and their benefits

Olusola B. Oyewole

Lactic acid fermentation is an important food processing technology in Africa. This technology is indigenous and is adaptable to the culture of the people. This paper reviews the different raw materials and microorganisms which are used in producing lactic fermented food products in Africa. The beneficial aspects of this technology for improving food safety in Africa as a low-cost method of food preservation and in improving the nutritional quality of the food raw materials are discussed. Areas of research needs to enhance further the benefits of this technology are highlighted. © 1997 Published by Elsevier Science Ltd.

INTRODUCTION

African countries require food processing technologies that will meet the challenges of the peculiar food security problems in the continent. Such a technology should be low-cost to be affordable by the poor sectors of the community and should be able to address the problems of food spoilage and foodborne diseases which are prevalent in the continent. Fermentation is one important food processing technology that meets these challenges. Fermentation is indigenous to the African cultures and has been used in many of these countries for centuries.

Among the various fermentation processes in Africa, lactic acid fermentation is one of the oldest and most widespread (Dirar, 1992a). Lactic fermentation technology can be defined as the fermentation process involving the activities of a group of Gram-positive, non-sporing, non-motile, catalase-negative, non-aerobic organisms, which ferment carbohydrates to produce lactic acid as the sole or major organic acid. In Africa, lactic fermentation technology has developed indigenously for an extensive range of raw materials yielding an extensive range of products.

This paper presents the status of lactic acid fermentation as a household technology in Africa and the role of this technology in meeting the challenges of food security in the continent.

THE RAW MATERIALS

The range of raw materials that are used in lactic fermentation processes include cereals, root crops and milk. Tables 1 and 2 show the categories of lactic fermented raw materials, their products and the area of consumption. Unlike in other parts of the world, lactic fermentations of vegetables, fish and meat are not common in Africa.

A large number of lactic fermented products in Africa are cereal-based and the products include porridges, bread and both alcoholic and non-alcoholic beverages (Table 1). Common cereals which are fermented in Africa include maize, sorghum, millet, teff and occasionally rice and wheat. Table 2 shows the non-cereal-based lactic fermented products in Africa. Cassava is the major root crop that is processed through lactic fermentation and a wide range of lactic fermented cassava products such as ‘gari’, ‘fufu’ and ‘kokonte’ are common throughout Africa. Milk from goats, sheep and cows forms the major raw material for the fermented milk products in the continent.

Lactic fermented food products constitute the bulk of foods given to children and generally form part of the daily main dishes of the average individual in Africa. For example, ‘ogi’, a lactic fermented maize-based gruel is the major indigenous traditional weaning food common in the whole of West Africa. ‘Ogi’ is also consumed as a breakfast meal by many and it serves as the food of choice for the ‘sick’.
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Table 1  Cereal-based lactic acid fermented products in Africa

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Fermented product name</th>
<th>Country/region of consumption</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Gruels and Beverages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>Ogi</td>
<td>Nigeria/West Africa</td>
<td>Onyekwere et al. (1989)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Abreh</td>
<td>Sudan</td>
<td>Dirar (1992a,b)</td>
</tr>
<tr>
<td>Miller</td>
<td>Uji</td>
<td>Kenya/East Africa</td>
<td>Mbugua (1981)</td>
</tr>
<tr>
<td>Rice</td>
<td>Kenkey</td>
<td>Ghana</td>
<td>Halm et al. (1993)</td>
</tr>
<tr>
<td>Wheat</td>
<td>Mahewu/Magou</td>
<td>South Africa</td>
<td>Hesseltine (1979)</td>
</tr>
<tr>
<td>[B] Alcoholic Beverages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baka</td>
<td>Humulur</td>
<td>Sudan</td>
<td>Dirar (1992a)</td>
</tr>
<tr>
<td>Mawe</td>
<td>Benin/West Africa</td>
<td>Hounhouigan (1994)</td>
<td></td>
</tr>
<tr>
<td>Busa</td>
<td>Kenya/East Africa</td>
<td>Nout (1980a,b)</td>
<td></td>
</tr>
<tr>
<td>Mbege</td>
<td>Tanzania</td>
<td>Okafor (1990)</td>
<td></td>
</tr>
<tr>
<td>Bouza</td>
<td>Egypt</td>
<td>Okafor (1990)</td>
<td></td>
</tr>
<tr>
<td>Merisa</td>
<td>Sudan</td>
<td>Dirar (1978)</td>
<td></td>
</tr>
<tr>
<td>Kaffir/Keche</td>
<td>North Africa</td>
<td>Novele (1968)</td>
<td></td>
</tr>
<tr>
<td>Leting/Josala</td>
<td>South Africa</td>
<td>Okafor (1990)</td>
<td></td>
</tr>
<tr>
<td>Utshival/aqmombotib</td>
<td>South Africa</td>
<td>Okafor (1990)</td>
<td></td>
</tr>
<tr>
<td>[C] Acid-leavened Breads/Pancakes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baka</td>
<td>Burukutu</td>
<td>West Africa</td>
<td>Faparasi et al. (1973)</td>
</tr>
<tr>
<td>Ensette</td>
<td>Plot</td>
<td>West Africa</td>
<td>Ekundayo (1969)</td>
</tr>
<tr>
<td>Malawa</td>
<td>Samba, Uganda</td>
<td>Lovelace and Nyath (1977)</td>
<td></td>
</tr>
<tr>
<td>Kiara</td>
<td>Sudan</td>
<td>Dirar (1982a,b)</td>
<td></td>
</tr>
<tr>
<td>Enjera/Tef Injera</td>
<td>Ethiopia</td>
<td>Gashe (1985)</td>
<td></td>
</tr>
<tr>
<td>Kish</td>
<td>Egypt</td>
<td>Marcos et al. (1973)</td>
<td></td>
</tr>
<tr>
<td>Laban zeer</td>
<td>Morocco</td>
<td>Faid et al. (1983)</td>
<td></td>
</tr>
</tbody>
</table>

*Superscript on Fermented Product Name refers to raw materials with the same superscript and indicates the raw materials used for the product.

Apart from ‘ogi’, another important lactic fermented product is ‘gari’, which is consumed in a large part of the continent, where it serves as one of the three daily main dishes of most families. Lactic acid fermentation is therefore widespread in the African continent.

To date, lactic fermentation of food is carried out through traditional, village-art methods (Odunfa, 1985). Processing usually involves either soaking of the raw materials, submerged in water contained in a fermenting vat, usually clay pots, for a length of time or an initial size reduction of the raw material by grating or milling in the wet form before being allowed to ferment without being soaked in water. These two fermentation methods have been described by Oyewole and Odunfa (1991a) as traditional submerged and solid-state fermentation processes.

The production of lactic fermented foods in Africa is largely home-based and it is usually left to chance inoculation from the environment. Little or no control is involved in the processing. The fermentation vessels of previous ferments usually serve as the source of inoculum for the initiation of the fermenta-

Table 2  Non-cereal-based lactic fermented foods in Africa

<table>
<thead>
<tr>
<th>Raw material categories</th>
<th>Fermented product name</th>
<th>Country/region of consumption</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Root Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td>Gari</td>
<td>Africa</td>
<td>Okafor (1977)</td>
</tr>
<tr>
<td></td>
<td>Fufu</td>
<td>West Africa</td>
<td>Oyewole and Odunfa (1990)</td>
</tr>
<tr>
<td></td>
<td>Lafun/Kokonte</td>
<td>West Africa</td>
<td>Oyewole and Odunfa (1988)</td>
</tr>
<tr>
<td></td>
<td>Chikawangue</td>
<td>Zaire</td>
<td>Odunfa (1985)</td>
</tr>
<tr>
<td></td>
<td>Cingwada</td>
<td>East and Central Africa</td>
<td>Okafor (1985)</td>
</tr>
<tr>
<td></td>
<td>Kocho</td>
<td>Ethiopia</td>
<td>Gashe (1987)</td>
</tr>
<tr>
<td>Goat Milk</td>
<td>Leben/Lben</td>
<td>Zimbabwe, Morocco</td>
<td>Hamama (1982)</td>
</tr>
<tr>
<td>Cow Milk</td>
<td>Leban rayeb/Raib</td>
<td>Egypt/Morocco</td>
<td></td>
</tr>
<tr>
<td>Sheep Milk</td>
<td>Jben</td>
<td>Morocco</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yogurt/Zabadi</td>
<td>Egypt/North Africa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>West Africa</td>
<td>Akinyanja (1989)</td>
</tr>
<tr>
<td>[C] Vegetables</td>
<td>Cassia obtusifolia</td>
<td>Kaval</td>
<td>Dirar et al. (1985)</td>
</tr>
<tr>
<td>[D] Others</td>
<td>Palm Wine</td>
<td>West Africa</td>
<td>Okafor (1975)</td>
</tr>
</tbody>
</table>

*Superscript on Fermented Product Name refers to the raw materials with the same superscript and indicates the raw materials used for the product.
tion. Starter cultures are not available but old stocks of previous ferments are used in some cases to initiate fermentation in new batches.

MICROORGANISMS INVOLVED IN THE FERMENTATIONS

The microorganisms implicated in the lactic fermentation of foods in Africa belong to four major genera, namely *Lactobacillus*, *Lactococcus*, *Leuconostoc* and *Pediococcus*. These form part of the major group of microorganisms referred to as the lactic acid bacteria. According to Aguirre and Collins (1993), the term 'lactic acid bacteria' is used to describe a broad group of Gram-positive, catalase-negative, non-sporing rods and cocci, usually non-motile, that utilize carbohydrates fermentatively and form lactic acid as the major end product. These are categorized into 'homo' or 'hetero' according to the metabolic routes they use (Embden-Meyerhof or Phosphoketolase pathways) according to the resulting end products. The lactic acid bacteria and other microorganisms implicated in various African lactic acid fermented foods are shown in Tables 3 and 4. The fermentation processes, being by chance inoculation, are usually initiated by a mixed microbial flora (Odunfa, 1985).

- Non-lactic acid microorganisms are eliminated with increasing acid production in the medium (Oyewole and Odunfa, 1990).
- There is a microbial succession trend among the lactic acid bacteria which survive in the acidic medium. For example, *Leuconostoc mesenteroides* does not survive in very high acidic environments which *Lactobacillus plantarum* strains can tolerate (Olasupo et al., 1997; Oyewole and Odunfa, 1990; Sanni, 1993).

The following observations were found to be common to these lactic fermented foods of Africa:

- The fermentation processes, being by chance inoculation, are usually initiated by a mixed microbial flora (Odunfa, 1985).
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The following observations were found to be common to these lactic fermented foods of Africa:

- While the microorganisms involved in many of the lactic fermentation processes had been isolated

The status of the various microorganisms and the various food fermentation processes have been reviewed recently (Sanni, 1993; Okafor, 1992). Tables 3 and 4 show the updated status on the stage of development of the various lactic fermented foods in Africa. The following could be inferred:

**Table 3**  Lactic acid bacteria involved in cereal-based African fermented foods

<table>
<thead>
<tr>
<th>Fermented product</th>
<th>Lactic acid bacteria implicated</th>
<th>Stage of development</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Gruels and Beverages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ogi</td>
<td><em>Lactobacillus plantarum</em></td>
<td>1,2,6</td>
<td>Onyekwere et al. (1989)</td>
</tr>
<tr>
<td>Abrew</td>
<td><em>Lactobacillus fermentum</em></td>
<td>1.2</td>
<td>Dirar (1992a,b)</td>
</tr>
<tr>
<td>Uji</td>
<td><em>Lactobacillus plantarum</em></td>
<td>1,2,4,5,6</td>
<td></td>
</tr>
<tr>
<td>Kenkey</td>
<td><em>Leuconostoc mesenteroides</em></td>
<td>1.2</td>
<td>Mbugua (1987, 1990)</td>
</tr>
<tr>
<td>Mahewu</td>
<td><em>Lactobacillus delbrueckii</em></td>
<td>1,2,4,5,6</td>
<td>Hahn et al. (1993)</td>
</tr>
<tr>
<td>Mawe</td>
<td><em>Lactobacillus fermentum</em>, <em>Pediococcus pentosaceus</em>, <em>Lactococcus lactis</em></td>
<td>1</td>
<td>Dirar (1992a)</td>
</tr>
<tr>
<td>[B] Alcoholic Beverages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Busaa</td>
<td><em>Lactobacillus helveticus</em>, <em>Lactobacillus salivarius</em>, <em>Lactobacillus casei</em></td>
<td>1.2</td>
<td>Iounhouigan (1994)</td>
</tr>
<tr>
<td>Mbege</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merisa</td>
<td><em>Lactobacillus delbrueckii</em></td>
<td>0</td>
<td>Okafor (1990)</td>
</tr>
<tr>
<td>Kaffir</td>
<td><em>Lactobacillus salivarius</em>, <em>Lactobacillus casei</em></td>
<td>1,2,4,5,6</td>
<td>Okafor (1990)</td>
</tr>
<tr>
<td>Leiting/Joala</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utshival — Amqumboti</td>
<td><em>Pediococcus pentosaceus</em></td>
<td>1</td>
<td>Dirar (1992a)</td>
</tr>
<tr>
<td>Burukutu</td>
<td><em>Lactobacillus fermentum</em></td>
<td>1,2,4,5,6</td>
<td>Sanni (1993)</td>
</tr>
<tr>
<td>Pito</td>
<td><em>Lactobacillus fermentum</em></td>
<td>1</td>
<td>Lovelace and Nyathi (1977)</td>
</tr>
<tr>
<td>Malawa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[C] Bread</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kiswa</td>
<td><em>Lactobacillus spp.</em></td>
<td>1</td>
<td>Mohammed et al. (1991)</td>
</tr>
<tr>
<td>Njiga</td>
<td><em>Leuconostoc mesenteroides</em></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Kishk</td>
<td><em>Lactobacillus plantarum</em></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ladan zeer</td>
<td><em>Lactobacillus spp.</em></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

KEY: 1 = Organisms isolated and identified; 2 = roles of organisms determined; 3 = genetic improvements on organisms; 4 = starter cultures developed; 5 = process optimization; 6 = semi-industrialization; 7 = process fully industrialized; 0 = information not available.
Lactic acid fermentation technology as a household technology for improving food safety in Africa

Diarrhoea due to poor hygienic condition has long been recognized as a major health hazard for infants in Africa. It is estimated that 1400 million episodes of diarrhoea occur annually in children under the age of 5 years and in 1990 over 3 million of such children died as a result (Motarjemi et al., 1993). Many studies have shown that contamination of infant weaning food formulas constitutes a potential source of diarrhoea diseases in African children (Rowland et al., 1978; Barre! and Rowland, 1979). Most of these weaning foods are milk-based and their reconstitution using contaminated water and utensils as a result of poor sanitation and low knowledge of personal hygiene by many mothers in the developing countries encourage a high number of diarrhoea cases (Roland et al., 1978). A possible solution to this problem is the promotion of lactic fermented weaning foods.

The role of lactic acid bacteria in health and in disease control has been documented (Sandine, 1979). Yogurt and other milk ferments have been reported to be effective in the treatment of a variety of disorders, including colitis, constipation and diarrhoea (Sanders, 1993). The in vitro inhibition of growth of pathogenic microorganisms by lactic acid bacteria has encouraged investigations into its use as a prophylactic and therapeutic means of treating gastrointestinal and other diseases. Lactobacillus acidophilus has been found to be effective in the treatment of different types of diarrhoea in humans and chicks (Beck and Necheles,, 1961; Watkins and Miller, 1983). Acidophilus milk, which is yogurt produced by fermenting milk with Lactobacillus acidophilus, is now being used to treat Escherichia coli, Salmonella and...
Salmonella-mediated diarrhoea and dysenteries in infants in some parts of Europe (Alms, 1983; Zychowicz et al., 1974). Other investigations, though few, have been carried out on some lactic acid fermented African foods which are used for feeding infants. Odugbemi et al. (1991) confirmed that enteropathogenic Escherichia coli, Salmonella typhii and Salmonella paratyphi were incapable of multiplying in ‘ogi’, a lactic fermented maize product used for feeding infants in West Africa. In other studies on South African ‘mahewu’ (Simange and Rukure, 1991) and the Ghanaian maize dough (Mensah et al., 1988) disease-causing Campylobacter, Escherichia coli and Shigella were not able to survive or multiply on the lactic fermented products on inoculation. Mbugua and Ngjega (1991) reported the inhibition of the growth of Staphylococcus aureus, Salmonella typhi, enteropathogenic Escherichia coli and Shigella dysenteriae in ‘uji’, a traditional weaning food of Kenya. Mensah et al. (1988, 1991) in their investigations simulated the unhygienic conditions of a typical rural community in a developing country by inoculating fermented maize dough porridge with Shigella flexneri and enteropathogenic Escherichia coli and found that the fermented dough inhibited the growth of these pathogens. They concluded that fermentation of maize dough is a useful strategy for reducing contamination of weaning foods in developing countries. Similar findings were obtained by Nout et al. (1989) using accelerated fermentation of some cereals used for weaning in Africa.

Various explanations have been proffered on the inability of various pathogens to survive in or grow in lactic fermented African foods. While some noted that the acidic media generated by the lactic acid bacteria were not conducive to the survival of the organisms (Gibbs, 1987), others were of the view that the lactic acid bacteria involved play some very important roles (Olukoya et al., 1993a; Steinkraus, 1983). Studies carried out by Olasupo et al. (1994) and Olukoya et al. (1993a) have confirmed that various lactic acid bacteria isolated from fermented African foods produce the antimicrobial chemicals called bacteriocins and many of these bacteria have some plasmid-borne characteristics (Olukoya et al., 1993b).

Probiotic products

In spite of the antimicrobial effects of the lactic acid bacteria from African fermented foods, the use of these organisms and their fermented products as probiotics is not common. The term ‘probiotic’ refers to a product containing mono or mixed cultures of live microorganisms which when applied to animal or man will improve the health status and/or affect beneficially the host by improving its microbial balance. Olukoya et al. (1994) reported the isolation of a Lactobacillus starter with antimicrobial activities against some diarrhoeagenic bacteria, including Salmonella, Shigella, Campylobacter, Aeromonas, Plei-
siomonas, enteropathogenic and enterotoxigenic Escherichia coli, Yersinia enterolytica and Vibrio cholerae. As part of a programme to formulate foods to aid the control of diarrhoeal diseases, an improved ‘ogi’ named ‘Dogik’ was developed using this lactic starter. A similar probiotic product was developed by Alms (1981) in Sweden with Acidophilus yogurt where yogurt was developed for treating diarrhoea cases with infants.

Lactic acid fermentation technology as a low-cost method of food preservation in Africa

Food preservation is a major problem contributing to the food crisis in Africa. The costs and infrastructural requirements of many advanced food preservation methods such as refrigeration, freezing, canning and irradiation, which are common in industrialized countries, greatly reduced their applications in the developed world (Cooke et al., 1987). The inhibitory effects of lactic acid bacteria, which are used in the fermentation production of many foods in Africa, have made this technology a low-cost means of preserving food in Africa (Gibbs, 1987).

The preservative role of lactic acid fermentation technology has been confirmed in the following products:

- Fermented cassava products. Cassava is an important staple food for over 500 million people in Africa (Cock, 1985). However, after harvesting, the shelf life of cassava is less than 5 days as it starts to deteriorate within 24 h of harvesting. The ease of its spoilage is an important limitation to cassava production and utilization. However, when cassava is subjected to lactic fermentation to yield products like fufu, the shelf life of the product is prolonged. The major microorganism in the fermentation of cassava is Lactobacillus plantarum, which has been found to be inhibitory to many spoilage moulds and bacteria.

- Fermented cereal products. The preservative role of lactic acid fermentation technology has been confirmed in some cereal products, including the Nigerian ‘ogi’ and the Kenyan ‘uji’. The fermentation process has been found to reduce the pH to below 4.0, making it difficult for some spoilage organisms that are present in maize, sorghum or millet to survive (Akinrele, 1970; Mbugua, 1981). Dirar (1992a) reported that in the traditional production of sour bread called kisra, local women occasionally used some traditional devices to discourage the growth of lactic acid bacteria. Where this is done, the dough that develops has a bad odour in a defect caused by spore forming proteolytic Bacillus species. This spoilage organism is effectively inhibited where lactic production of kisra is carried out.

- Milk products. Dirar (1975) reported local findings that where lactic fermentation of milk in Sudan is suppressed in very hot climates, coliform bacteria
such as *Aerobacter aerogenes* and *Klebsiella pneumonia* develop in fermented milk yielding frothing products with low acidity. The growth of these spoilage organisms is, however, not detected when milk products are produced through lactic fermentation processes.

Gibbs (1987) and Steinkraus (1983) reviewed the preservative roles of lactic acid fermentation technology and noted that it is due to acid production, and the hydrogen peroxide and antibiotics which are produced through the activities of the lactic acid bacteria. Lactic acid bacteria are capable of converting the carbohydrate substrate to lactic acid, which lowers the pH of the fermenting medium to levels that cannot support the growth and activities of many spoilage microorganisms. Apart from their ability to produce organic acids, the lactic acid bacteria possess the ability to produce hydrogen peroxide through the oxidation of reduced nicotinamide adenine dinucleotide (NADH) by flavin nucleotides which react rapidly with gaseous oxygen. Dahiya and Speck (1968) confirmed that *Staphylococcus aureus* was inhibited by hydrogen peroxide produced by some lactic acid bacteria. The ability of many lactic acid bacteria, including those involved in the fermentation of African fermented foods, to produce bacteriocins and other antibiotics has been noted previously. These antibiotics were found to be inhibitory to many spoilage organisms.

**Nutritional benefits of traditional lactic acid fermentation of African foods**

Lactic acid fermentation technology has been found to be a very effective way by which Africans for centuries have improved their food raw materials to make them palatable and safe for consumption. Lactic fermentation improves the nutritional status of food in the following basic ways:

- by the detoxification of food raw materials to make them safe for consumption;
- by improvements of functional properties;
- by improving the digestibility and nutritional value of food products.

**Food detoxification by lactic acid bacteria**

Cassava is one important crop for which the potential roles of lactic acid bacteria have been confirmed. For centuries, native Africans have subjected cassava to lactic acid fermentation before consumption. Various workers have confirmed that cassava needs to be processed before consumption in order to remove the potentially toxic cyanogenic glucosides which cassava contains. In cassava processing involving the grating of the cassava root as in 'gari' production, it has been found that rupturing of the cassava tissues would release the linamarase enzymes embedded in the root tissues and would break down the glucosides sufficiently. This endogenous linamarase activity has been found to be sufficiently capable of the detoxification where cassava root is grated, and for this the lactic fermentation process is said to serve purposes other than detoxification. This, however, cannot be said to be the situation of the cassava fermentation process where the root is not grated.

Investigations by workers in Nigeria (Oyewole and Odunfa, 1991b; Okafor and Ejiofor, 1985, Okafor and Ejiofor, 1986) and in France (Giraud et al., 1992, 1993) have confirmed that certain strains of *Lactobacillus plantarum* and *Leuconostoc mesenteroides* isolated from cassava have the ability to produce linamarase enzymes useful for hydrolysing the potentially toxic components of cassava. However, because these microorganisms have linamarase activity it does not mean that this is the main detoxification method. Giraud et al. (1995) used a linamarase-producing *Lactobacillus plantarum* as a starter culture for 'gari' fermentation and there was no difference in the rate of cyanoxygenic glucoside breakdown, suggesting that the endogenous linamarase release in the ruptured tissues of the grated cassava as in 'gari' production is sufficient for the detoxification. However, in cassava fermentation processes where the root is soaked unpeeled and not grated, the linamarase produced by the lactic acid bacteria have potential roles to play in the detoxification process. There is need for further investigations into the potential detoxification roles of lactic acid bacteria.

**Improvement of functional properties**

Not much information is available on the effect of lactic acid fermentation on the functional properties of African foods. Available information shows that lactic acid bacterial fermentation has little or no effect on the viscosity of fermented porridge from sorghum (Westby and Gallat, 1991) but effected an increase in the viscosity of fermented maize (Banigo and Muller, 1972; Adeyemi and Beckley, 1986).

**Improvement of nutrition and digestibility**

Malnutrition is one of the problems facing babies in many developing countries. While malnutrition is partly due to non-availability of food, it is also due to low energy and nutrient density and low bioavailability of nutrients in the available foods (Ljungqvist et al., 1981). The presence of some antinutritional factors such as phytic acid, tannins and polyphenols in some cereals used as weaning foods is known to be responsible for the low availability of proteins (Maclean et al., 1980) and iron (Gilooy et al., 1984). Household lactic acid fermentation of cereals has been found effectively to reduce the amount of phytic acid, polyphenols and tannins and improved protein availability in sorghum (Chavan et al., 1988) and millet (Khetarpaul and Chauhan, 1990). It has also led to improved iron (Svanberg and Sandberg, 1988), minerals (Khetarpaul and Chauhan, 1989) and sugar (Khetarpaul and Chauhan, 1990) availability.

Lactic acid production of cereal-based weaning foods in Africa has been found to improve the nutri-
ional quality of these products by either decreasing the number of inhibitors or releasing the nutrients for absorption (Swanberg and Lorri, 1991).

CONCLUSION AND RESEARCH NEEDS

Lactic acid fermentation processes contribute towards the safety, nutritional value, shelf life and acceptability of a wide range of foods in Africa. It is an advantageous technology in the sense that extension of shelf life, enhancement of sensory properties, safety and improved nutritional value are achieved by one technique which is affordable at the household level.

In order to enhance further the potentials of this technology, there is need for further research on technology improvement, technology transfer and its socio-economic implications. Investigations are still needed within the areas of food safety, nutritional value and processing. Specifically, research is needed to challenge hitherto uninvestigated lactic fermentations, to determine the need for and feasibility of using starter cultures and probiotic microorganisms, to optimize fermentation conditions for achieving specific benefits. Traditional lactic fermentation processes in Africa will be greatly improved with the development and application of quality and safety systems such as HACCP. Like all foods, lactic fermented foods will need to be made to stand up to the challenges posed by parasites, newly emerging pathogenic bacteria and viruses. All these investigations will need to be done to meet the producers’ and consumers’ specific needs. In order to make for easy transfer of information and technology to household and cottage industries, adaptive and participatory pilot projects will need to be encouraged.

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