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PAPER

Lactic fermented foods in Africa and their benefits

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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 food-borne 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.

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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, tef and occassionally 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'.

Table 1 Cereal-based lactic acid fermented products in Africa

Raw materials	Fermented product name*	Country/region of consumption	Reference
[A] Gruels and Beverages			
Maize[a]	Ogi[a,b,c]	Nigeria/West Africa	Onyekwere *et al.* (1989)
Sorghum[b]	Abreh[b]	Sudan	Dirar (1992a,b)
Millet[c]	Uji[a,b,c]	Kenya/East Africa	Mbugua (1981)
Rice[d]	Kenkey[a]	Ghana	Halm *et al.* (1993)
Wheat[e]	Mahewu/Magou[a]	South Africa	Hesseltine (1979)
Tef (*Eragrotis tef*)[f]	Humulur[b]	Sudan	Dirar (1992a)
	Mawe[a]	Benin/West Africa	Hounhouigan (1994)
[B] Alcoholic Beverages	Busa[a,b,c,d]	Kenya/East Africa	Nout (1980a,b)
	Mbege[c]	Tanzania	Okafor (1990)
	Bouza[e]	Egypt	Okafor (1990)
	Merisa[b,c]	Sudan	Dirar (1978)
	Kaffir/Kefir[a,b]	North Africa	Novelle (1968)
	Leting/Joala[a,b]	South Africa	Okafor (1990)
	Utshival amqomboti[b]	South Africa	Okafor (1990)
	Burukutu[b]	West Africa	Faparusi *et al.* (1973)
	Pito[b,c]	West Africa	Ekundayo (1969)
	Malawa[a]	Zambia, Uganda	Lovelace and Nyath (1977)
[C] Acid-leavened Breads/Pancakes	Kisra[b,c]	Sudan	Dirar (1992a,b)
	Enjera/Tef Injera[f]	Ethiopia	Gashe (1985)
	Kishj[e]	Egypt	Morcos *et al.* (1973)
	Laban zeer	Morocco	Faid *et al.* (1983)

*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

Raw material categories	Fermented product name*	Country/region of consumption	Reference
[A] Root Crops			
Cassava[a]	Gari[a]	Africa	Okafor (1977)
	Fufu[a]	West Africa	Oyewole and Odunfa (1990)
	Lafun/Kokonte[a]	West Africa	Oyewole and Odunfa (1988)
	Chikawangue[a]	Zaire	Odunfa (1985)
	Cingwada[a]	East and Central Africa	Odunfa (1985)
Ensette[b]	Kocho[b]	Ethiopia	Gashe (1987)
[B] Milk			
Goat Milk[c]	Ayib[c]	Ethiopia	Ashenafi (1992)
Cow Milk[d]	Leben/Lben[d]	Zimbabwe, Morocco	Hamama (1982)
Sheep Milk[e]	Leban rayeb/Raib[d,e]	Egypt/Morocco	
	Jben[e]	Morocco	
	Yogurt/Zabadi[c,d,e]	Egypt/North Africa	
	Nono[d,e]	West Africa	Akinyanju (1989)
[C] Vegetables			
Cassia obtusifolla	Kawal	North Africa	Dirar *et al.* (1985)
[D] Others			
Palm	Palm Wine	West Africa	Okafor (1975)

*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 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).
- 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 lactic acid bacteria that survive the fermentation processes usually do this in association with some yeasts (*Saccharomyces* spp. and *Candida* spp.) (Faid *et al.*, 1993; Sanni, 1993; Oyewole, 1992).

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:

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

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

Fermented product	Lactic acid bacteria implicated	Stage of development	Reference
[A] Gruels and Beverages			
Ogi	*Lactobacillus plantarum*	1,2,6	
	Lactobacillus fermentum		Onyekwere *et al.* (1989)
Abrew	*Lactobacillus* spp.	1,2	
	Lactobacillus plantarum		Dirar (1992a,b)
Uji	*Lactobacillus plantarum*	1,2,4,5,6	
	Lactobacillus plantarum		
	Leuconostoc mesenteroides		Mbugua (1987, 1990)
Kenkey	*Lactobacillus* spp.	1,2	Hahn *et al.* (1993)
Mahewu	*Lactobacillus delbrueckii*	1,2,4,5,6	
	Lactobacillus bulgaricus,		Dirar (1992a)
	Hulumur Lactobacillus spp.	1	
Mawe	*Lactobacillus fermentum*,	1,2	
	Pediococcus pentosaceus,		
	Lactococcus lactis		Hounhouigan (1994)
[B] Alcoholic Beverages			
Busaa	*Lactobacillus helveticus*,	1,2	
	Lactobacillus salivarius, Lactobacillus casei		Okafor (1990)
Mbege		0	
Merisa	Lactic acid bacteria	1	Dirar (1992a)
Kaffir	*Lactobacillus delbrueckii*	1,2,4,5,6	Okafor (1990)
Leting/Joala	*Lactobacillus delbrueckii*	1,2	
Utshival — Amqumboti	*Lactobacillus delbrueckii*	1,2	
Burukutu	*Lactobacillus* spp.	1	
Pito	*Lactobacillus* spp.	1,2,4,5,6	Sanni (1993)
Malawa	*Lactobacillus* spp.	1	Lovelace and Nyathi (1977)
[C] Bread			
Kisra	*Lactobacillus* spp.	1	Mohammed *et al.* (1991)
Enjera	*Leuconostoc mesenteroides*	1	
	Lactobacillus plantarum		
Kishk	*Lactobacillus* spp.	1	
Laban zeer		0	

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.

Table 4 Lactic acid bacteria involved in the fermentation of non-cereal-based African fermented foods

Fermented products	Lactic acid bacteria involved	Stage of development	References
[A] Root crops			
Gari	*Leuconostoc mesenteroides* *Lactobacillus plantarum*	1,2,4,5,6	Okafor (1992)
Fufu	*Lactobacillus plantarum* *Lactobacillus brevis*	1,2,5	
Lafun/Konkote	*Lactobacillus plantarum*	1,2,5,6	Oyewole (1992)
Chikawangue		1	
Cingwada		0	
[B] Milk products			
Ayib	*Lactobacillus* spp. *Lactococcus* spp.	1	Ashenafi (1992)
Leben/Lben		0	
Yogurt/Zabadi	*Lactobacillus bulgaricus* *Lactococcus bulgaricus*	1,2,4,5,7	
Nono	*Lactobacillus acidophilus* *Lactococcus cremoris*	1,2	Akinyanju (1989)
Kishk		0	
[C] Vegetable			
Kawal	*Lactobacillus plantarum*	1	
[D] Others			
Palm Wine	*Lactobacillus plantarum* *Leuconostoc mesenteroides*	1,2,5,6	Okafor (1990)

KEY: 1 = Organisms isolated and identified; 2 = roles of organisms identified; 3 = genetic improvements on organisms; 4 = starter cultures developed; 5 = process optimization; 6 = semi-industrialization; 7 = process fully industrialized; 0 = information not available.

and identified, a few cases still need to be investigated.

- Investigations on the microorganisms involved in most of the fermentation processes appear to terminate at the isolation and identification of the microorganisms involved.
- Only a few efforts have been made at developing appropriate starter cultures for these processes.
- Little or no work is being done on the genetic improvements of the microorganisms involved in the lactic fermentation processes.
- The quality of the various fermented products still varies from one processor to the other and with seasons and locations.
- Where the fermentation processes appear to have been industrialized as in the cases of 'gari' and 'ogi', the fermentation processes are still being affected by chance inoculation from the environment. Only the non-microbial aspects of the processing appear to have been industrialized.

IMPORTANCE

In Africa, lactic acid fermentation processes have survived throughout the centuries because of the following benefits of this technology:

- It serves as a household technology for improving food safety in Africa.
- It serves as a low-cost method of food preservation in Africa.
- It contributes to the improvement of the nutritional value and digestibility of food raw materials in Africa.

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; Barrel 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

Shigella-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 paratyphii* 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 Njenga (1991) reported the inhibition of the growth of *Staphylococcus aureus*, *Salmonella typhii*, 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 proferred 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*, *Pleisiomonas*, enteropathogenic and enterotoxigenic *Escherichia coli*, *Yersinia enterolytica* and *Vibrio cholerae*. As part of a programme to formulate foods to aid the control of diaarhoel 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 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 cyanogenic glucoside breakdown, suggesting that the endogenous linamarse 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 (Gilooly *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 nutritional quality of these products by either decreasing the number of inhibitors or releasing the nutrients for absorption (Svanberg 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 microoganisms, 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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