Fermentation: Assessment and research

Report of a Joint FAO/WHO Workshop on fermentation as a household technology to improve food safety

in collaboration with the Department of Health, Republic of South Africa

Pretoria, South Africa, 11–15 December 1995

FOOD SAFETY UNIT
DIVISION OF FOOD AND NUTRITION
WORLD HEALTH ORGANIZATION
We would like to thank Dr Robert Nout, Wageningen Agricultural University, The Netherlands, for his contribution in the preparation of this report. Also, we would like to extend our thanks to Dr Michiel van Schothorst, Secretary of the International Commission on Microbiological Specifications for Foods, who reviewed the HACCP studies in this report.
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(ii)
1. INTRODUCTION

Fermentation is one of the oldest technologies used for food preservation. Over the centuries, it has evolved and has been refined and diversified. Today a large variety of foods are derived from this technology which is used in households, small-scale food industries and large commercial enterprises. Foods so produced form a major part of the human diet all over the world, and in some regions, mainly in African countries, the technology is also used to prepare foods for infants and young children.

In the past, traditional fermentation technologies were based on experiences accumulated by consecutive generations of food producers, as a result of trial and error. Only recently has science and technology started to contribute to a better understanding of the underlying principles of fermentation processes and of the requirements for quality and safety. However, in many instances, food fermentation practices, especially at the household level, do not benefit yet from advances in science and technology. Since the days of Louis Pasteur who pointed out the importance of hygiene in relation to fermentation, it is known that this technology is readily influenced by various factors during processing, and that if it is not applied correctly the safety and/or quality of the final product may be jeopardized. Because of the ineffective foodborne disease surveillance programmes in most countries, in particular developing countries, many cases of foodborne diseases do not come to the notice of public health authorities. Nevertheless, it has been possible to trace some foodborne disease outbreaks to fermented foods and to the inappropriate application of this technology.

On the other hand, fermentation is of economic importance as a method of food preservation in areas where preservation techniques such as cold storage (refrigeration) or hot-holding cannot be used due to lack of facilities and resources. For such situations, fermentation has been considered as an affordable technology for the safe preservation of foods, in particular weaning foods. In developing countries, as a result of poor hygienic handling and inadequate preservation, weaning foods are often contaminated and are a major cause of diarrhoea and associated malnutrition.

With these considerations in mind, the Food and Agriculture Organization of the United Nations and the World Health Organization organized a Workshop to assess fermentation as a household technology for improving food safety. The Workshop was held in Pretoria from 11-15 December 1995 in collaboration with the Department of Health of the Republic of South Africa (RSA). The aims of the Workshop were: (i) to assess the risk and benefits associated with current household fermentation practices, with specific emphasis on the food safety aspects; (ii) to outline improvements which can be achieved by process development and education of food handlers; and (iii) to identify gaps in the existing knowledge and priorities for research.
The Workshop was opened by Dr Jocelyn Webster from the Division of Food Technology of the Council for Scientific and Industrial Research (CSIR), Republic of South Africa, who welcomed the participants to Pretoria. Dr Webster emphasized the need for collaboration between international organizations and South African research organizations, universities and government departments to ensure information, research and technology transfer which address key health, nutritional and food security issues in South Africa. Dr Theo van de Venter, Director of Food and Chemicals, Department of Health, RSA then gave a brief overview of the country’s Programme for Reconstruction and Development which places specific emphasis on the underdeveloped and underprivileged communities.

The objective of the Workshop, therefore, met one of the current concerns in the RSA, that is, to meet the basic needs of the population.

Dr D.L. Tembo, the WHO Liaison Officer ad interim in the RSA, welcomed the participants to the Workshop on behalf of the Directors-General of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO). Dr Tembo stated that FAO and WHO were particularly pleased to organize the Workshop in Africa. He pointed out that the International Conference on Nutrition (Rome, December 1992) had expressly recommended that high priority be given to problems encountered in the African continent, and it had recommended that action should be taken to promote sound weaning practices by encouraging the use of nutritionally adequate, safe and appropriately processed, locally-available foods. He added that fermentation is a common practice in the preparation of weaning foods in many African countries, and said that the problem of diarrhoeal diseases in infants and young children is also a dominant problem and one of massive proportions.

Dr Tembo thanked the participants and representatives of international organizations for having accepted the invitation of FAO and WHO to participate in the Workshop and gratefully acknowledged the contribution of the International Foundation for Science which supported several participants. Special recognition was also given to the Department of Health of the RSA and the CSIR for hosting the Workshop.

Dr Olusola Oyewole was elected Chairman of the Workshop, Dr Fernando Quevedo as Vice-Chairman and Dr Robert Nout as Rapporteur. The deliberations of the Workshop were based on a number of background papers (listed in Annex 1) and the work carried out by Working Groups, under the leadership of Drs Richard Fuchs, Alex von Holy and Wilhelm Holzapfel. The full list of participants is given in Annex 2.

In closing, Dr G. Kouthon of FAO, on behalf of WHO and FAO, thanked all participants, the Chairman, the Chairman of the Working Groups and the Rapporteur for their thorough work during the Workshop.
2. BACKGROUND

Foodborne diseases are a major health and economic problem in both industrialized and developing countries. The incidence of foodborne diseases in the industrialized countries has been estimated to be as high as 10% of the population. In some countries the trend is on the increase. The developing countries bear the biggest burden of foodborne diseases in the world (Table 1). Although reliable statistics on the incidence of diarrhoeal diseases are not available due to lack of, or poor reporting systems in most countries, the high prevalence of diarrhoeal diseases in these countries, particularly in infants and children, is evidence of this tremendous problem. Annually, some 1500 million episodes of diarrhoea occur in children under the age of five, and over 3 million children die as a direct result. Indirectly, diarrhoeal diseases kill many more children, as they are one of the major underlying factors of malnutrition. It is estimated that annually some 13 million children under the age of five die from the associated effects of malnutrition and infections.

Table 1. Examples of pathogenic organisms of public health importance which may be transmitted through food

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Protozoa</th>
<th>Trematodes</th>
<th>Cestodes</th>
<th>Nematodes</th>
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<tbody>
<tr>
<td>Bacillus cereus</td>
<td>Cryptosporidium spp.</td>
<td>Clonorchis sinensis</td>
<td>Diphyllobothrium latum</td>
<td>Anisakis spp.</td>
</tr>
<tr>
<td>Brucella spp.</td>
<td>Entamoeba histolytica</td>
<td>Fasciola hepatica</td>
<td>Echinococcus spp.</td>
<td>Ascaris lumbricoides</td>
</tr>
<tr>
<td>Campylobacter jejuni</td>
<td>Giardia lamblia</td>
<td>Fasciolopsis buski</td>
<td>Taenia solium; T. saginata</td>
<td>Trichinella spiralis</td>
</tr>
<tr>
<td>Clostridium botulinum</td>
<td>Toxoplasma gondii</td>
<td>Opisthorchis felineus</td>
<td></td>
<td>Trichuris trichiura</td>
</tr>
<tr>
<td>Clostridium perfringens</td>
<td></td>
<td>Opisthorchis viverrini</td>
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<tr>
<td>Escherichia coli spp.</td>
<td></td>
<td>Paragonimus westermani</td>
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<tr>
<td>(pathogenic strains)</td>
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<tr>
<td>Listeria monocytogenes</td>
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<tr>
<td>Mycobacterium bovis</td>
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<tr>
<td>Salmonella typhi and paratyphi</td>
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<tr>
<td>Salmonella (non-typhi) spp.</td>
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<tr>
<td>Shigella spp.</td>
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<tr>
<td>Staphylococcus aureus</td>
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<tr>
<td>Vibrio cholerae</td>
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<td>Vibrio parahaemolyticus</td>
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<tr>
<td>Vibrio vulnificus</td>
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<tr>
<td>Yersinia enterocolitica</td>
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<tr>
<td>Viruses</td>
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<tr>
<td>Hepatitis A virus</td>
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<td>Hepatitis E virus</td>
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<tr>
<td>Norwalk agents</td>
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<tr>
<td>Poliovirus</td>
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<td>Rotavirus</td>
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Pathogens identified as the cause of diarrhoeal diseases include bacteria such as *Escherichia coli*, *Shigella* spp., *Salmonella* spp., *Vibrio cholerae O1* and *Campylobacter jejuni*; protozoa such as *Giardia lambia*, *Entamoeba histolytica*, *Cryptosporidium* spp.; and enteric viruses, such as rotavirus. Infections due to pathogenic strains of *E. coli* are probably the most common cause of diarrhoea in developing countries. They constitute up to 25% of diarrhoeal diseases in infants and children and have been associated, among others, with weaning foods. The distribution of other pathogens, as observed among cases of diarrhoeal diseases seen at treatment centres in developing countries, is shown in Table 2.

Contaminated food is a major cause of diarrhoeal diseases; it is estimated that up to 70% of all cases are of foodborne origin. The sources of contamination are numerous and include night soil, polluted water, flies, pests, domestic animals, dirty utensils and pots, food handlers (e.g. soiled hands), dust and dirt. Raw foods themselves are frequently the source of contamination, as some may naturally harbour pathogens, or come from infected animals. Moreover, during food preparation and storage there is an added risk of cross-contamination. However, one of the major factors leading to food contamination is time-temperature abuse during preparation, with the resultant survival and/or growth of pathogens or production of toxin (Figure 1).

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Rotavirus</td>
<td>15-25</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td></td>
</tr>
<tr>
<td>- enterotoxigenic</td>
<td>10-20</td>
</tr>
<tr>
<td>- enteropathogenic</td>
<td>1-5</td>
</tr>
<tr>
<td><em>Shigella</em> spp</td>
<td>5-15</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>10-15</td>
</tr>
<tr>
<td><em>Vibrio cholerae O1</em></td>
<td>5-10</td>
</tr>
<tr>
<td><em>Salmonella</em> (non typhi) spp</td>
<td>1-5</td>
</tr>
<tr>
<td><em>Cryptosporidium</em> spp</td>
<td>5-15</td>
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</tbody>
</table>

Applying basic rules for safe food preparation (Annex 3) will help to prevent the contamination, growth and survival of pathogens in foods and will reduce the incidence of diarrhoeal diseases. However, application of these rules can be sometimes hampered by socioeconomic constraints, such as an inadequate supply of safe water, lack of facilities for safe preparation and storage of food (e.g. refrigerators, fuel for hot-holding or thorough reheating), and lack of time to prepare food properly prior to each meal. As a result, poor householders are simply not able to apply certain essential food safety principles, such as feeding infants with freshly prepared food, refrigeration (below 10°C), hot storage (above 60°C), or reheating of stored food (Annex 3).

In some countries, fermentation (lactic acid fermentation in particular) is traditionally used as a household technology for preservation of foods. For example, in some African countries it is customary to give infants fermented cereal or root crop products such as *ogi* (Nigeria) or *ugali* (United Republic of Tanzania, Uganda, Kenya). In addition to nutritional benefits, such fermented foods offer a good keeping quality as a result of acidity produced by lactic acid bacteria (pH <4.5). Therefore, lactic acid fermentation has been considered as an alternative to what are presently regarded as conventional methods of food preservation (i.e. cold storage, dehydration or canning). It is also a belief that fermented products can
Figure 1. Sources of food contamination
be consumed without further reheating, and using this technology therefore overcomes fuel problems. In addition, some nutritional benefits have been attributed to fermented foods. However, four important questions arise when considering the safety implications of the application of fermentation at household level. Firstly, what kind of hazards can be controlled by the application of such a technology? Secondly, what kind of risks are associated with the actual application of the technology due to food handlers' lack of knowledge, or poor hygienic conditions during food preparation? Experience has shown that when this technology has been applied improperly, fermented products were the source of foodborne illness. Thirdly, what kind of considerations of a sociocultural nature should be taken into account in order to successfully apply or transfer fermentation technology to another region? And finally, considering the risks and benefits, should such a technology be promoted at all?

**Figure 2.** Interrelation of care, foodborne infections and nutrient intake on the health and nutritional status of infants and children

(source: Svanberg, U. and Lorri, W. Fermentation and Nutrient Availability. Background paper presented at the Workshop)
3. DEFINITION OF FERMENTATION

Fermentation is defined as a desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes. Fermentation is purposely carried out to enhance properties such as taste, aroma, shelf-life, texture and nutritional value. Fermentation is often part of a sequence of food processing operations, including cleaning, grinding, soaking, salting, cooking, packaging and distribution. Therefore, the potential of fermentation to enhance food safety or nutritional value should be assessed in the light of the total manufacturing sequence.

From a microbiological point of view, it is tempting to distinguish food fermentations according to the organisms responsible for the desired modification, i.e. filamentous fungi, yeasts and bacteria.

However, for the purpose of this commodity-oriented Workshop it appeared more appropriate to distinguish several characteristic groups of fermented products, as follows:

- Textured vegetable protein meat substitutes made from legumes and/or cereals using mixed starter cultures of filamentous fungi, bacteria and yeasts; the fungal mycelium keeps the food particles together in a sliceable cake, whereas various enzymatic degradations contribute to enhanced flavour and digestibility.

- Food-flavouring sauces and pastes (protein hydrolysates) with high salt content made from proteinaceous seeds, fish or fishery by-products, using combinations of filamentous fungi, yeasts, bacteria, as well as fish intestinal proteolytic enzymes; the resulting peptides and amino acids have a flavour enhancing effect.

- Lactic acid fermented preserved foods, characterized by a significant acidity caused by the production of lactic acid by lactic acid bacteria. Foods of plant origin (vegetables, cereals, roots, legumes) as well as animal-derived foods (milk, meat, fish) are transformed into relatively shelf-stable, refreshing and nutritious, sour-tasting products worldwide.

- Alcoholic beverages, including beers, wines and spirits made from starchy or sugary substrates using yeasts and occasionally bacteria for alcohol formation. In several alcoholic beverages a sour taste is produced by simultaneous activity of lactic acid bacteria.

- Vinegars characterized by a significant acetic acid content, made from various alcoholic products using acetic acid bacteria. Vinegar is not a food of major importance to the diet, but plays an important role as a highly effective food preservative and flavouring agent of biological origin.

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1 Steinkraus, K.H. Classification of Fermented Foods. Background paper presented at the Workshop (see Annex 1).
* Alkaline food condiments made from proteinaceous seeds. As a result of bacterial proteolytic action on the seed protein, nitrogenous degradation products are released resulting in a strong ammoniacal flavour and an alkaline reaction.

* Breads made from cereal meal or flour, leavened by the action of yeasts or yeast-lactic acid bacteria mixed populations. The fermentation of bread dough contributes to the texture, taste and shelf-life of baked bread.

4. **SCOPE AND OBJECTIVES**

It is essential that public health and food authorities concerned with nutrition, food safety and prevention of diarrhoea consider the advantages and disadvantages with regard to the application and promotion of fermentation at household level. These considerations should also be included in programmes for the education of consumers, food handlers and manufacturers.

After reviewing some traditional fermented foods (particularly those consumed in Africa, Asia and Latin America), the effects of fermentation on different foodborne hazards and nutritional quality, and the potential use of starter cultures on a household scale, the Workshop decided to focus the scope of its discussions on:

- food safety problems as related to feeding of infants and children under the age of five, as the occurrence of under-five diarrhoea poses a serious public health problem;
- fermented foods worldwide, with particular reference to African fermented weaning foods;
- food commodities such as cereals, dried legumes, root and tuber crops, fruits and vegetables, and milk;
- lactic acid fermentation; and
- production at household level, which will also be of relevance to cottage industries.

The following three objectives were adopted:

a) to review the current "state of the art" with respect to the benefits and the risks of fermentation;

b) to develop practical interventions for improving the safety and nutritional quality of fermented foods; and

c) to identify gaps in knowledge and establish where additional research is needed.
5. FERMENTATION: CURRENT HOUSEHOLD PRACTICES

Fermentation is a common traditional household technology in many parts of the world. Regional differences occur in manufacturing practices, consumption habits, quality, and level of acceptability of fermented foods for weaning purposes. These will depend on such factors as the availability of raw materials, the laborious processes involved, and changing patterns in society. Fermented foods intended for infants and young children consist mainly of lactic acid fermented cereals (e.g. maize, sorghum, millet), root crops (e.g. cassava), milk, and to a lesser extent fish, meat and vegetables.

Lactic acid fermentation at the household level is a natural process brought about by the lactic acid bacteria present in the raw food, or those derived from a starter culture. The following representative examples of fermentation practices serve to illustrate the variety of techniques employed in Africa.

Cereal grains are dry, and can be fermented only after the addition of water. Thus in most cases, after manual cleaning, grains are soaked in water. During soaking for a period of a few days, a succession of naturally occurring microorganisms will result in a population dominated by lactic acid bacteria. It is also possible to first grind the grains to a meal and then moisten to obtain a dough. If the dough is kept for a few days, a similar succession will take place.

Fermentation may be "fuelled" by the endogenous grain amylases which generate maltose (fermentable sugar) from starch, a type of fermentation which is very common; it can be accelerated by adding a simple starter culture containing a large number of active lactic acid bacteria. This can be some of the previous batch of fermented dough (a practice referred to as "back-slopping"), or a carrier material to which lactic acid bacteria attach (such as the porous wall of a gourd or vessel, or the "inoculation belt" used in Ghana). The resulting fermented dough can be cooked with water to make a beverage, such as Kenyan uji, or a product such as Ghanaian kenkey.

Sometimes a mixture of cereal meal and water is cooked first and fermented afterwards. The endogenous amylases have then been inactivated, and less fermentable sugar will be available for lactic acid bacteria. Household experience has taught that the addition of an enzyme rich material is required to bring about the fermentation. For this purpose the use of germinated grain (such as malted sorghum) is common, although some people use plant juices or saliva. The germinated grain will act as a source of maltose-generating enzymes, and also as a starter culture, although of a less homogeneous type than the back-slopping starter culture mentioned above. In the fermentation which follows, lactic acid bacteria should quickly colonize the substrate by rapid acidification. Often, some yeasts will also develop. The latter are not dangerous, but in weaning foods their activity must remain limited because of undesirable gassiness and alcohol production. This type of fermented beverage is exemplified by Tanzanian togwa.
Cassava is a staple food for about 500 million people in developing countries, and bitter varieties are potentially toxic because of their cyanide content. However, fermented cassava products are generally introduced to children after one year of age, and soon form a major part of their daily diet. The addition of water is not usually necessary when processing cassava because of its high moisture content. However, the peeled roots, either whole or cut into pieces, are often fermented submerged in water. This soaking process is also called “retting” and is common in Africa and Latin America in the household production of sour cassava starch products such as lafun and farinha de mandioca. Under water, the facultative anaerobic lactic acid bacteria will dominate within a day and acidify the product. After several days of retting, the pieces of tuber are removed from the water and sun-dried. After grinding, the flour is used for porridge preparation. Usually a starter culture is used by way of adding some water from a previous batch, or from the wall of the vessel. Another way of cassava fermentation is by grating the peeled and washed roots into pulp, and pressing the pulp in jute or polypropylene bags. The pressure ensures drainage of excess fluid, and in a few days a thorough acidification is the result of lactic acid fermentation. The starter culture is usually present on the grater and in the previously-used bags. The fermented pulp is crumbled and roasted in a hot cast-iron pan to a pregelatinized and shelf-stable product called gari. It can also be steamed after sun-drying for about one day to a more perishable product called attiéké. A third option for cassava fermentation is to stack the peeled and washed whole or cut roots under a plastic sheet to avoid dehydration. After a few days “sweating”, moulds will grow. Research has shown that the desirable moulds are Mucor, Rhizopus and Neurospora spp., and that during the “solid substrate fermentation” moulds overgrow the bacterial species, causing flavour production and root softening. After the “sweating” stage, the plastic sheet is removed and the roots are gradually dried in the sun. The dried material is ground to a meal, which is used for porridge preparation. This practice is common in Mozambique and Uganda.

Lactic acid fermentation of milk usually takes place with raw (unpasteurized) milk, by keeping it in a gourd which is always used for that purpose. The lactic acid bacteria present in the cavities of the gourd’s wall act as a starter culture. Fermentation is usually rapid, and adequate acidification should be obtained within a few hours. The fermented product usually has a semi-liquid consistency due to the coagulation of casein. Often, bigger coagulated casein lumps are strained off prior to consumption or sale, as these can be used as starter cultures for succeeding batches.

The common denominator of lactic acid fermentations of fish, meat and vegetables is that in most cases, salt (kitchen salt, or rock salt) is added in varying quantities (1-25% w/w). Many lactic acid bacteria have a better tolerance to salt than most pathogenic bacteria. Salt is also effective in protecting the product against some spoilage bacteria, and in the case of vegetable fermentation, it makes fermentable plant sugars available by osmotic extraction of juices. Lactic acid fermented foods with a high salt content are not normally given to children.
6. FERMENTATION: ASSESSMENT OF BENEFITS AND RISKS

Food can act as a vehicle for illness in a number of ways. Figure 1 illustrates the various potential sources of contamination. Contamination of food with enteropathogenic microorganisms may result in foodborne infections, whereas growth of toxigenic microorganisms may give rise to toxin accumulation in the food and, consequently, foodborne intoxications. The single most effective way of controlling most of these microbial hazards is to cook foods thoroughly. The effect of lactic acid fermentation on some food hazards has been studied, and its potential for improving safety noted. Microbial fermentation is often just one step in a food preparation process. Usually, other operations, such as size reduction (grating, cutting, grinding), salting and heating, are also involved. Where the reduction of a hazard has been observed, this may be the result of other unit operations or their combination with fermentation rather than the fermentation step alone.

6.1 Benefits

6.1.1 Biological

There is considerable evidence showing that lactic acid fermentation inhibits growth and survival of and toxin production by a number of pathogenic bacteria. In the latter case, rapid growth of lactic acid bacteria and decrease in pH inhibits growth of the toxin-producing organisms, or inhibits toxin production by competition. A summary of recent published data for the principal foodborne bacterial pathogens is presented in Annex 7.

A number of antimicrobial factors associated with lactic acid fermentation have been identified, but the most important is the production of lactic acid itself. The extent to which bacteria are inhibited will depend on the organism concerned, the temperature, the amount of acid produced and the properties of the food, i.e. its buffering capacity. In cereal and vegetable products which are weakly buffered, an efficient lactic acid fermentation will produce a pH of 4.0 or less, at which the growth of bacterial pathogens is inhibited, and many bacteria will die at a rate which increases with increased ambient temperature.

The potential of lactic acid fermentation for controlling food contamination will depend on factors that are difficult to quantify, such as initial level of contamination, which in turn will depend on local conditions, levels of hygiene and sanitation, and the degree of acidification achieved. Therefore, it should be noted that fermentation cannot replace the need for observing rules of hygiene. There is, though, recent evidence to suggest that prevalence of diarrhoea in young children is reduced by consuming lactic acid fermented cereal gruels.³

6.1.2 Chemical

Lactic acid fermentation has been associated with the reduction of certain naturally-occurring toxins in plant foods. For example, levels of cyanide from cassava, which has been implicated in a number of health problems, are reduced in several traditional fermented products. Although cassava can be fermented in different ways, experimental evidence shows that in at least one of these, acid fermented grated roots (e.g. gari), cyanide removal is a consequence of the activity of naturally-occurring plant enzymes rather than microbial activity. In other cassava products, microorganisms play an essential role in softening the plant tissues thus facilitating the reduction in cyanogen content. Microbial fermentation also contributes to the keeping quality and desirable sensory properties.

6.1.3 Nutritional

Change in nutrient composition. Carbohydrates, particularly starch and soluble sugars, are the principal energy source of fermenting microorganisms. The level of these compounds as well as non-digestible oligosaccharides decrease during the microbial fermentation. Certain amino acids may be synthesized during fermentation. Lactic acid fermentation of cereals and cereal-legume blends improve the availability of certain B-group vitamins, although variation has been observed. The major organic acids produced are lactic acid and acetic acid; these and other metabolites contribute to the rich variety of taste and aroma of the fermented products.

- Carbohydrate digestibility. There is an enhanced nutritional quality through better digestibility by reduction of certain oligosaccharides particularly prevalent in legumes. This reduces side effects, such as abdominal distention and flatulence, which customarily occur among people eating a diet which is high in oligosaccharides, such as raffinose, stachyose and verbascose.

- Nutrient density - dietary bulk. Fermentation techniques which involve a combination of amylase rich flour (ARF or power flour) and a small amount of a lactic starter culture provide a considerable opportunity for increase of the nutrient density. The decrease in viscosity enables the addition of more dry matter while maintaining a semi-liquid consistency. The ARF must be added after cooking the gruel; the flour concentration can be increased by more than 100% while still maintaining a semi-liquid consistency regarded as preferable for feeding young children. This thinning effect is partly due to the low pH of the fermented gruels but is mainly due to the effect of the amylase activity of the germinated cereals.

Effect on anti-nutritional factors. Some cereal-based diets have restricted bioavailability of nutrients as a result of the presence of anti-nutritional factors such as phytates and polyphenols (tannins).

- Phytate (or inositol hexaphosphate) is an abundant plant constituent and accounts for 60-90% of the total phosphorus content of the product. This is necessary for the energy metabolism of the plant itself. Phytate content in fruits and vegetables is
generally lower than in cereals and is decreased by enzymes (phytases) and high-temperature processing. Phytate is normally found in the form of complexes with polyvalent cations, e.g. iron, zinc, calcium and magnesium, and proteins. The inhibition of non-haem iron absorption by phytates is dose dependent and even low levels (less than 90% of whole wheat flour phytate content) are inhibitory. Phytases are present in most cereals and active at a pH of around 5.0. The ideal fermentation process provides optimum pH conditions for degradation of phytate. This is obtained by initial soaking of the flour in water for about 12-24 hours. Such a reduction in phytate increases the amount of soluble iron several-fold. There are similar benefits for zinc and calcium. Thus, lactic acid fermentation of maize or sorghum changes a diet of "low iron bioavailability" into a diet of "intermediate to high iron bioavailability".

- Tannins (or polyphenols) are plant components which contribute to protection against plant disease and predators. They also inhibit dietary mineral absorption and protein digestibility. The galloyl groups of polyphenols are mainly responsible for the inhibiting effect on iron absorption. The tannin content of cereals is reduced by lactic acid fermentation. In some high-tannin cereals, however, there seems to be little or no improvement in iron availability after lactic acid fermentation. This is presumably due to production of metabolites of tannins which are inhibitory to iron absorption. Microbial fermentation improves protein digestibility of high-tannin cereal varieties. The greatest increase in digestibility is observed in high-tannin sorghum gruels fermented with a natural starter culture. Tannins have also an inhibiting effect on the growth of lactic acid bacteria, thereby slowing the process of microbial fermentation.

**Presence of promotors.** Vegetables generally contain low but sufficient amounts of phytate to have an inhibitory effect on iron absorption. During lactic acid fermentation, e.g. in "sauerkraut", phytate may be completely degraded. The amount of iron absorbed is increased when fermented vegetables are added to a phytate-rich diet. This indicates the presence of iron-promoting factors in lactic acid fermented vegetables. Vitamin C is such an iron-promoter; it is well-known that it is preserved in lactic acid fermented vegetables because of the prevailing reducing conditions.

### 6.2 Risks

The aspects listed below are generally supported by published experimental evidence. However, in some cases the evidence is fragmentary and rather reflects a lack of clearly established scientific evidence.

#### 6.2.1 Biological

A certain number of agents appear not to be affected by lactic acid fermentation. However, they may be adequately destroyed by other processing operations involved in the preparation of the food, such as cooking.
• There are emerging patterns of acid resistance in some enteropathogens such as *E. coli* O157:H7, where for example, fermented meats and yoghurt have been vehicles of infection and this should be monitored closely.

• Foodborne viruses are recognized as a significant cause of gastroenteritis, and rotavirus has been identified as one of the most common causes of diarrhoea in childhood. Enteric viruses are necessarily relatively acid stable to survive passage through the stomach’s acidity, and unlike bacteria do not have greater sensitivity to weak organic acids, such as lactic acid. Simian rotavirus has been shown to survive at high levels of acidity during 24 hours storage in a model fermented weaning food. They did, however, show increased heat sensitivity at low pH.

• The diseases produced by parasites such as *Cryptosporidium*, *Giardia lamblia*, and trematodes transmitted by foods are varied and widely distributed in all parts of the world. There is little information on the effects of fermentation on these parasites. The cysts of these organisms often show resistance to adverse conditions although they are generally killed by adequate cooking. For example, there are indications that cysts of many foodborne trematodes may survive 70°C and further studies are required to define the precise time/temperature combinations to assure safety from these organisms, and to assess whether the fermentation step will have an effect on their infectivity.

6.2.2 Chemical

Certain algae, bacteria and moulds can produce toxins that may be transmitted by foods. Many of these are heat resistant and will survive normal cooking temperatures. Generally, lactic acid fermentation will not eliminate the risk posed by these preformed toxins.

• Mycotoxins are toxic secondary metabolites that are produced during the growth of certain moulds on foods. They may be present in the food material as a result of mould contamination in the field or during storage in uncontrolled, hot and humid conditions. The risk of contamination by mycotoxins of raw materials used in fermented foods is a serious food safety hazard. Some studies have reported no reduction in the level of mycotoxins by fermentation while others have reported appreciable decreases (Annex 7). Other processing steps, such as cleaning, milling, dehulling and cooking will contribute to the reduction in mycotoxin levels. However, the precise role of microbial fermentation in reducing the concentration of mycotoxins in foods is not well established. From these data, it is clear that fermentation cannot be relied upon as a means of detoxifying mycotoxin-contaminated foods.
Bacteria can cause foodborne illness either as a result of ingestion of preformed bacterial toxins with a food (intoxication) or the ingestion of live organisms (infection). There is no evidence to suggest that microbial fermentation alone will eliminate risk by removing preformed bacterial toxins from food. A final cooking stage will eliminate heat labile toxins, such as those produced by Clostridium botulinum, but cannot be relied upon to destroy the heat stable toxins produced by other bacteria such as Staphylococcus aureus and Bacillus cereus.

6.2.3 Physical

There is no evidence to suggest that lactic acid fermentation reduces the level of contamination with extraneous matter. On the other hand, in certain cases fermentation follows a steeping step which might contribute to the removal of dirt.

6.2.4 Nutritional

Microbial fermentation has a minimal effect compared with cooking in reducing the anti-nutritional effects of protease inhibitors, and the toxic effects of lectins on the intestinal epithelium.

Microbially-produced lactic acid is usually a mixture of the optical isomers L-(+) and D-(−) lactic acid. D-(−) lactic acid cannot be metabolized by humans. Excessive intake of D-(−) lactic acid may result in acidosis, a disturbance of the acid-alkali balance in the blood. Little is known about the "toxicity" of D-(−) lactic acid for malnourished or sick children. In addition, relatively little data is available about the D-(−) lactic acid content of fermented foods prepared at the household level.

7. PRACTICAL INTERVENTIONS FOR IMPROVING THE SAFETY AND NUTRITIONAL QUALITY OF FERMENTED FOODS AND TECHNOLOGY TRANSFER

7.1 Weaknesses in present practices of fermentation, and considerations for improvement

The constraints and shortcomings related to traditional fermented weaning foods can be threefold: technical and safety, nutritional, and social. The complexity of the problems necessitates a multidisciplinary approach to improve fermentation practices.

7.1.1 Food safety constraints

The time necessary for food processing in the traditional household fermentation process is a constraint on the hours available to women who, as mothers and food processors, are also engaged in child care and other household activities. Lack of time may have
significant implications regarding safety and nutritional quality of fermented foods because any time saved by cutting down on fermentation periods may jeopardize the effectiveness of acidification by lactic acid bacteria, or the degradation of plant toxins and anti-nutritional factors by the relevant enzymes.

Reduction of time expenditure may be achieved by accelerating the process, or by a different distribution of labour. In the latter case, foods might be produced by entrepreneurs. Care should be taken that no unjustified shortcuts are employed in the process which might jeopardize the safety and nutritional value of the product.

Other food safety problems arise from shortcomings in handling/processing of foods, resulting in different types of hazards (e.g. phytotoxins or anti-nutritional factors in the raw materials, survival and/or growth of pathogenic organisms, contamination from the environment). Improvement of product quality and safety could be achieved by Good Manufacturing Practice (GMP) and Good Hygienic Practice (GHP), and by using the Hazard Analysis Critical Control Point (HACCP) system. The latter is aimed at identification, assessment and control of hazards throughout the process from raw material to packaging and consumption.

7.1.2 Nutritional constraints

The limitations related to many currently-used weaning foods include:

a) low content and limited quality of protein in raw materials, mainly cereals and root crops;
b) low nutrient density of the prepared foods; and,
c) poor or low bioavailability of proteins and minerals in the finished product.

The following measures for improvements may be considered:

Macronutrients: The viscosity of starchy and bulky products could be reduced in order to enable an increased nutrient density while maintaining an acceptable viscosity. In addition, the protein quantity and quality could be improved by protein supplementation, e.g. by adding legumes.

Micronutrients: Micronutrient fortification could improve the nutritional quality of the product, provided that their bioavailability is ensured. At the household level, however, fortification seems of lesser relevance as it might not be affordable or practicable. At all levels of production, the bioavailability of macro- and micronutrients could be improved by strategic use of germination and fermentation techniques.
7.1.3 Sociocultural constraints

The major social constraint related to fermented foods for weaning is one of poor image when compared to industrial preparations which are considered superior and associated with progressiveness in some countries. Fermented foods are often poorly perceived and poorly accepted by mothers whose responsibility it is to prepare and feed them to the children. Another constraint here is that of a socioeconomic nature where sophisticated processing equipment is not affordable at the household level. In other words, the sophistication level of the fermentation method must fit the socioeconomic framework.

The Workshop identified several areas requiring attention:

- The public image of some traditional fermented foods is poor, and should be improved.
- An important aspect is to educate the mother or child carer, as well as the food manufacturer, about the optimum conditions for the preparation of specific fermented foods.
- The involvement of food manufacturers in terms of training and experimenting with new or upgraded techniques is important. Participatory research has benefits for the manufacturer as well as the researcher.
- The present exchange of information between mothers, manufacturers, scientists, government and non-governmental organizations needs to be improved.

7.2 Model approaches for improvement of fermentation

Interventions for improving the safety and nutritional adequacy of traditional fermented food should take into account:

- traditional, technical and socioeconomic aspects; and
- the needs and realistic prospects to achieve this aim.

In assessing the safety and nutritional value of weaning foods produced by a fermentation process, either at household or cottage level, the Workshop considered that the assessment of socioeconomic and cultural aspects is essential to enable the optimum utilization of this technology for the preparation of these weaning foods. The socioeconomical and cultural considerations should be integrated with key concepts of food safety, nutrition, household food security, and prevention and control of infection, if an improvement is to be achieved in the nutritional status of infants and young children.
Therefore, where fermented foods already form part of the diet of infants and young children, it is important to examine the existing socioeconomic and cultural relations and patterns, and identify the type of support which is needed to improve the safety and nutritional value of the fermented foods.

7.2.1 Technical and safety aspects

Reduction in the processing time can be attempted using fermentation starter cultures. In principle, starter cultures contain a high concentration of live microorganisms which are added to raw materials with the aim of achieving the desired fermentation as rapidly as possible. At the household level several starter cultures are practicable. These include using batches of previously fermented products (also referred to as back-slopping), or specially prepared dry starter cultures such as the Ghanaian inoculation belt or the Indonesian *rugi* and *usur*.

The Hazard Analysis Critical Control Point (HACCP) system could be used in order to identify and evaluate hazards and control measures. The application of the HACCP concept to a few selected but representative processes of African fermented foods, e.g. *gari* (Nigeria), *togwa* (Tanzania) and *ujji* (Kenya) is illustrated in Annexes 4-6. The schematic presentation of the production processes for these products are shown in Figures 3-5.

Some important safety considerations which derive from the application of HACCP to cassava and cereal for production of *gari*, *togwa* and *ujji* are:

- Rapid and adequate acidification (a combination of low pH and sufficient titratable acidity to result in an inhibitory level of undissociated weak organic acid (mainly lactic and some acid acetic).

- Sufficient cooking for rendering food safe, particularly in terms of parasites and viruses. If starchy meals are cooked for palatable purposes, the importance of adequate thermal processing for elimination or reduction of hazards should nevertheless not be overlooked.

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5 A prerequisite for the application of the HACCP system in food processing/preparation is that the principles of Good Hygienic Practice (GHP) or Good Manufacturing Practice (GMP) are adhered to. In principle, Critical Control Points (CCPs) should be restricted to steps in a food operation which, if not controlled properly, may lead to significant food safety problems. In a newly-developed HACCP plan, more CCPs may be included than are perhaps necessary. Based on a review of the monitoring and verification results, CCPs may be deleted from the HACCP plan, if they turn out to be sufficiently covered by GHP/GMP. The HACCP studies presented in Annexes 4-6 are models for the application of the HACCP system to fermented foods, based on a worst case scenario, thus many steps have been identified as CCPs. Depending on the situation, some of these steps may not need to be considered as CCPs. It should also be noted that model HACCP plans are not appropriate for use until validated for a specific food and food process.
• Sufficient size reduction in cassava to enable enzymatic degradation of toxic cyanogenic glycosides.

• Avoidance of mouldy raw materials in view of possible mycotoxin contamination.

• Using safe water.

Togwa preparation is associated with a higher food safety risk than fermented ugi, as the first involves the addition of power flour (or ARF) and togwa after the food has been cooked (see Annexes 4 and 5). There is thus a risk of post-cooking contamination, particularly with acid-resistant pathogens. For example by the addition of power flour and if the lactic acid fermentation fails, the proliferation of bacterial pathogens may occur. Possible options to minimize the safety risks of togwa preparation include quick (accelerated) fermentation by back-slopping or use of other starter cultures; using ARF of high (hygienic) quality; and avoiding post-cooking contamination.
Maize (Sorghum, millet) \[\text{CCP}\]

Grind to flour

Dough (30% solids) \[\text{CCP}\]

Ferment \[\text{CCP}\]

Dilute to 4-5% solids in boiling water \[\text{CCP}\]

Boiling \[\text{CCP}\]

Sweeten

Serving \[\text{CCP}\]

Water \[\text{CCP}\]

Sugar \[\text{CCP}\]

Figure 3. Application of the HACCP system to preparation of uji in households. The numbers refer to the steps described in Annex 4.
*Although this step was not part of the original *t*ogwa preparation, it was added after the HACCP study because boiling water was identified as being essential and needed to ensure the hygienic quality of power flour.

**Figure 4.** Application of the HACCP system to preparation of *t*ogwa in households. The numbers refer to the steps described in Annex 5.
Figure 5. Application of the HACCP system to preparation of *gari* in households. The numbers refer to the steps described in Annex 6.
7.2.2 Nutrition

At the household level, it is technically feasible to increase the nutrient density of foods while maintaining a semi-liquid consistency. It is possible to prepare porridges containing 20-25% (w/w) dry matter (about 1 kcal or 4 kJ per gram of porridge) which can still be swallowed easily by a small child, using 1-5% (w/w) ARF after having cooked the starchy cereal or root crop based food.

Likewise, it is technically feasible to enrich the protein content of such porridges using legumes such as soya beans or cowpeas. As a rule of thumb, a 70:30 weight ratio of starchy staple versus protein-rich legume will be adequate.

7.3 Alternative options in household food technologies

As a single unit operation, lactic acid fermentation provides acidity and flavour and contributes to the nutritional value. The acidity provides a significant microbiological stability enabling storage at ambient temperature for a day without risking associated microbiological hazards. If combined with an appropriate heat treatment, a fermentation-based process will also minimize hazards (e.g. viruses, parasites or some anti-nutritional factors) which cannot be reduced by the fermentation process alone.

Alternative options to fermentation-based food processing in households in developing countries include:

1) Consumption of fresh food raw materials without fermentation or cooking. This is the cheapest way. The risk of foodborne infections may be high, particularly for foods of animal origin or made with crops grown in contaminated environments. In some foodstuffs, natural toxins may pose a severe threat to human health. The characteristic fermentation flavour will be absent.

2) Cooking of fresh (non-fermented) food. More energy is required to cook fresh rather than fermented food to achieve the required palatability/digestibility. Some of the natural toxins and anti-nutritional factors cannot be adequately removed by cooking alone. The biological safety of cooked fresh food is adequate, provided that it is consumed immediately after cooking, and post-contamination is avoided. Left-overs need to be refrigerated (<10°C) or kept hot (>60°C) as the neutral pH allows proliferation of surviving or post-cooking contaminating microorganisms. Re-heating prior to consumption is highly recommended. The characteristic fermentation flavour will be absent.

3) The use of non-fermented (ready-to-consume) food, preserved by canning. Generally, the safety of canned food is high, if the product is consumed immediately after opening the can and, in principle, no thermal energy is required at the household level. Left-overs require refrigeration and re-heating, as in option 2 above.
4) Dehydration (e.g. using solar energy) of non-fermented fresh produce, followed by reconstitution and cooking. This option provides a relatively cheap way to preserve perishable raw food materials such as roots and vegetables. Adequate solar dehydration requires appropriate climatic conditions and hygienic practices to avoid contamination via soil, insects, rodents, other animals and humans. The resulting dehydrated food would require processing as in option 2 to render it palatable and safe.

However, if fermentation is culturally acceptable and desirable, it provides a valuable and relatively cheap option, even when combined with a cooking step, as cooking a fermented product requires less energy.

7.4 Technology Transfer

7.4.1 Target groups

Where fermentation is not commonly practised and its introduction is being considered (or being revived), the study of the socioeconomic and cultural factors is important in order to assess the feasibility of application of the technology. In this case, the need to educate those who will apply the technology should be particularly emphasized with respect to the factors determining the safety and nutritional adequacy of the food.

Social and cultural patterns vary tremendously from one place to another and are subject to change over time. The impact of these patterns on food safety and nutrition as well as solutions to the problems encountered are therefore location and time-specific. Perhaps the only common thread is that, in all cultures and at all times, women have played and will continue to play a prominent role in infant and young child care. Women are the key players, either as mothers preparing food, or as decision-makers in selecting infant food. The children play a role as consumers, but not as decision makers. Therefore, gender relations have to be addressed in attempts to improve food safety and nutrition.

Issues to be considered when recommending the use of fermented foods are:

- Know-how, education and practices of food handlers / households in the preparation of fermented foods;
- Facilities for hygienic preparation of fermented foods (e.g. starter cultures, materials, fuel);
- Environmental conditions, such as the quantity and quality of water and the sanitary conditions;
- Environmental pollution, detrimental ecological conditions and biological changes in the environment, e.g. the emergence of resistance of pathogens;
• Agronomic, food storage, food processing, and food marketing practices;
• Consumers’ purchasing power, and their access to markets;
• Family and social structures;
• Caring capacity for the infant, e.g. time available to mothers;
• Food choice and acceptability of fermented foods; and
• The level of education in general, and as related to food safety and nutrition in particular.

7.4.2 Policies

The introduction of food and nutrition know-how should be seen in the light of a country’s overall development. Important issues at stake are access to shelter, safe drinking-water, wholesome food and education. Appropriate policies should be developed, supported and implemented by relevant government agencies. Specific technologies should be tested in multifaceted pilot projects, during which implementation is closely monitored with a continued feedback from the community.

Transfer of know-how is a continuous process, and one in which the following parties play an important role:

Government authorities especially those responsible for public health and food control:

- to adopt and implement policies, where appropriate, regarding the improvement of water quality, control of agricultural residues, promotion of improved crop cultivars (acceptable to subsistence agriculture) at the level of the household; and
- to develop and implement a two-way communication mechanism between the central government offices and the household to facilitate education.

International agencies: to participate in the development and introduction of policy and in the implementation of projects.

Non-governmental organizations: to contribute to the process of policy making and implementation of policies.

Public educators: including teachers and consumer groups engaged in food and nutrition and health care education. This includes formal and non-formal education structures (community forums, newspapers and media).

Scientists/academia: to assist in research and education in food technologies, and fermentation in particular.
8. RESEARCH NEEDS

A comprehensive overview of the research on fermented foods used throughout the world was presented during the Workshop. The current status of research was assessed with particular emphasis on understanding the potential and effects of using fermented foods as weaning foods. The crucial questions addressed were:

- With our current knowledge of fermented foods, can the use of these foods be promoted as safe and nutritional foods, particularly for infants and young children?

- Whether future research is required to improve the safety of fermented foods used at the household level?

- With the worldwide importance of small-scale food processing enterprises (i.e. cottage industries), what are the research priorities to ensure that fermented foods are safe for the consumer?

- What are the socioeconomic and cultural issues that need to be addressed to ensure that fermentation is adopted both at the household and cottage levels?

Each identified research need was analysed to determine the relative research priority, taking into account the state of the current knowledge and the severity of the problem. It will be essential in any of these studies to take into account differences between rural and urban dwellers.

Research issues in four areas were considered, namely: food safety, nutritional value, technology development, and technology transfer and related socioeconomic aspects.

8.1 Food Safety

8.1.1 Efficiency of fermentation in biological safety

A considerable amount of work has been done on the effectiveness of lactic acid bacterial fermentation for the inhibition of a wide range of pathogenic bacteria. A meta-analysis would enable a quantitative analysis of these data for trends. Mathematical models describing the survival of pathogens in lactic acid fermentation would have a useful predictive value without recourse to challenge testing. A few research opportunities exist in this area specifically related to the survival of sub-lethally injured organisms and certain acid-tolerant pathogens such as Escherichia coli O157:H7.

Little information exists on the destruction of parasites (such as trematodes) during fermentation. Limited information is available on the fate of viruses during fermentation, but there is still need for some further studies on their survival. Part of the reason for the lack of information on viruses and parasites is associated with the problems of enumerating them.
It is essential that a multidisciplinary approach to these problems is taken. It is very unlikely that the growth of mycotoxigenic fungi represents a problem in anaerobic fermentations.

In studies on the efficiency of fermentation in the inhibition of pathogenic microorganisms, it is important to distinguish between those present in raw materials and those introduced into the product during and after processing (for example, after cooking).

Laboratory observations of the inhibition of pathogenic organisms need to be verified under household conditions.

Research is needed on the epidemiology of diarrhoea among infants and young children who are receiving fermented or non-fermented foods. Such studies will require very careful control of epidemiological design for the confounding variables and the differences that might occur between experimental and control groups. It is recommended that a carefully produced protocol is subjected to widespread critical peer review before the implementation of the studies.

Research needs:

- To determine effects of lactic acid fermentation on parasites and undertake more confirmatory studies on the effect of the process on viruses. [High priority]
- To establish the effect of fermentation on sub-lethally injured pathogenic bacteria and certain pathogens such as Escherichia coli O157:H7. [High priority]
- To determine the effect of the consumption of fermented foods on the incidence of diarrhoea by studying the epidemiology of diarrhoea among infants and young children receiving fermented or non-fermented foods. [High priority]
- To undertake a meta-analysis of current literature on the inhibition of pathogenic bacteria and the development of appropriate mathematical models for assessing safety. [Medium priority]
- To verify laboratory observations of the inhibition of pathogenic organisms under household conditions. [Medium priority]

Overall, research in this area is considered to have a high priority
8.1.2 Effect of fermentation on biochemical/chemical toxicants in raw materials

Fermentation cannot be seen as a means of cleaning up contaminated raw materials. However, recognizing that contaminated raw materials are frequently used, further research on a number of issues is justified. The importance of water quality in the fermentation processes must also be addressed.

Limited information is available on the effect of fermentation on mycotoxins. Some information exists with respect to aflatoxin. Very little is known about the effect on bacterial toxins that might be present. Toxicity of mycotoxin breakdown products is largely not understood. Further work is justified in these areas, but the long-term solution lies in improving raw material quality.

Consideration needs to be given to the effect (including changes to bioavailability) of fermentation on environmentally-acquired (in food and soil) chemical contaminants, such as heavy metals, trace elements, herbicides, and pesticides.

**Research needs:**

- Effect of fermentation on mycotoxins and on the toxicity of breakdown products. [High priority]
- Effect of fermentation on environmental contaminants. [Medium priority]
- Effect of fermentation on bacterial toxins. [Low priority, because of focus on dried grains]

**Overall, research in this area is considered to have a medium priority**

8.1.3 Additional considerations in the promotion of fermentation

The extent of knowledge on the potential problem of D-lactate acidosis is limited. Studies need to be undertaken to determine whether a problem with D-(−) lactate acidosis exists or potentially exists when fermented foods are consumed. There is a need to specifically consider the situation with regard to malnourished children who may have impaired buffering capacity.

Care should be exercised to ensure that the generation of biogenic amines or other toxic materials such as ethyl carbamate does not occur. This could be done by the optimization of the various processing steps involved in the preparation of fermented foods. This is considered to have low to medium priority because of the reported lack of a problem with fermented cereal and legume foods.
Research needs:

- Investigation into the significance of D-(−) lactate acidosis associated with the consumption of fermented foods. [High priority]
- Optimization of processing with respect to biogenic amines and ethyl carbamate (ethylurethane). [Low to medium priority]

Overall, research in this area is considered to have a high priority

8.2 Nutritional value

A major objective is to provide infants and young children with products of high nutritional value. It is important to consider the whole process in relation to nutritional value and not just the fermentation step.

The reduction in the levels of anti-nutritional factors is important, but it is important to understand the mechanism by which changes occur. For the purpose of this review of research needs, cyanogenic glucosides are considered in this section.

<table>
<thead>
<tr>
<th>Anti-nutritional factors</th>
<th>Present status of knowledge</th>
<th>Severity of problem</th>
<th>Research need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytate</td>
<td>good (some gaps)</td>
<td>high</td>
<td>medium-high</td>
</tr>
<tr>
<td>Tannins</td>
<td>moderate</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Protein inhibitors</td>
<td>moderate</td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>Others (lectins, saponins)</td>
<td>poor</td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>Oligosaccharides</td>
<td>moderate</td>
<td>high</td>
<td>medium-high</td>
</tr>
<tr>
<td>Cyanogenic glucosides</td>
<td>good</td>
<td>medium</td>
<td>relatively low</td>
</tr>
</tbody>
</table>
Of equal importance to reduction of anti-nutritional factors is the improvement of the bioavailability of micro-nutrients. It is important to compare the micro-nutrient status and growth of infants and young children fed fermented and non-fermented cereals.

There is a need to investigate the mechanisms in the fermentation process that influence the bioavailability of nutrients, especially iron, zinc, calcium and protein.

Research needs:

- Reduction in levels of anti-nutritional factors focusing specifically on the mechanisms of change during the whole process. [Medium to high priority]
- Investigation of the mechanisms in the fermentation process that influence the bioavailability of nutrients, especially iron, zinc, calcium and protein. [Medium to high priority]
- Comparison of the micronutrient status and growth of children under five fed fermented and non-fermented cereals. [Medium priority]

Overall, research in this area is considered to have a medium-high priority

8.3 Technology development

8.3.1 Characterization of fermentations

There has been a large amount of work on the microbiological characterization of fermented foods. Justification for future work is relatively low with the exception of the need to understand the dynamics of natural fermentations. Those fermentations that have not been studied should be considered.

Extensive documentation exists on the methods of processing fermented foods. There are some gaps in the literature and there is a need to verify the existing data. The dissemination of currently available information has a high priority.

Research need:

- Characterization of previously uninvestigated fermentations, especially where they are used or could be used for feeding infants and children. [High priority]
8.3.2 Development/improvement of fermentation systems

It is recommended that research on starter cultures adopt the following approaches:

a) **Determination of the need for and feasibility of using starter cultures.** Specific attention should be given to cost:benefit analyses and processor/consumer requirements. The level of knowledge in this area is low and hence the priority for research is high.

b) **Establishment of the appropriate level of technology.** This might range from the use of back-slopping to the use of defined starter cultures with specific biochemical properties. The approach taken is dictated by the needs of the target groups (a) and an understanding of the scale and nature of operation. There is a reasonable level of knowledge on some aspects of this subject and hence research is given medium priority.

c) **Development of appropriate starter culture delivery mechanisms.** Mechanisms for the distribution and maintenance of starter cultures must be developed with a good understanding of the conditions under which they will be used and their cost. Little work has been done in this area and the need for research is high, provided that the selected level of technology demands it.

d) **Selection of microorganisms with desirable properties.** Such properties might include the possession of phytase active at low pH values and high levels of acid production. Whereas there is a moderate amount of knowledge on this subject, further research should receive high priority where issues a, b, and c above have been properly addressed.

Based on a sound understanding of the changes that occur during fermentation and knowledge of consumers and/or processor requirements, there is the potential to optimize fermentation conditions to provide a range of benefits. This provides an alternative to the development of starter cultures.

<table>
<thead>
<tr>
<th>Research needs:</th>
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<tbody>
<tr>
<td>• Development of appropriate starter cultures for lactic acid bacterial fermentations, according to the sequence of activities mentioned above. [High priority]</td>
</tr>
<tr>
<td>• Optimization of fermentation conditions to achieve specific benefits. [High priority]</td>
</tr>
</tbody>
</table>
8.3.3 Probiotics

The consumption of live lactic acid bacteria (such as *Lactobacillus acidophilus*) is thought to help prevent diarrhoeal disease. Such effects are desirable for weaning foods. The feasibility of using microorganisms as probiotics should be assessed. It will be important to take into account problems of starter culture development (see above), acceptability to the consumer, distribution and maintenance of starters, and the fact that many gruels are boiled before consumption.

**Research need:**

- Determination of the feasibility of the use of specific microorganisms with probiotic activities. [High priority]

8.3.4 Effects of each processing stage on food safety

It is important to understand the role that individual and combinations of processing stages play in the safety of the final product. Such processing operations include cooking, washing, peeling, grinding, dehydration, packaging and fermentation. An example of this is the order of cooking and fermentation in the preparation of weaning gruels. Changing the order of these stages has implications for food safety.

**Research need:**

- Investigation (HACCP studies) into the role of individual processing steps and combinations of steps in ensuring food safety. [High priority, but only where there are specific gaps in knowledge]

8.3.5 Application of quality and safety systems (including HACCP)

Few studies have assessed fermentation as a household level technology in terms of food quality and safety. The application of the HACCP approach and the principles of good manufacturing practice offer great potential for focusing education and extension programmes.
Research needs:

- To assess the hazards and risks associated with the household preparation and processing (biological, chemical, physical) of infant foods. [High priority]

- To determine the Critical Control Points in the processing and preparation of fermented weaning foods at the household level with respect to food safety and quality. [High priority]

- To determine the most appropriate means of transferring knowledge of improved procedures in safety and quality. [High priority]

Overall, research in this area is considered to have a high priority

8.4 Technology transfer and related socioeconomic aspects

8.4.1 Consumer and producer perception and needs

Research is needed to understand consumer and producer (processor) perception of food safety and specifically of fermentation. It is not known whether food safety is a significant enough issue in its own right for these target groups to adopt fermentation or change traditional practices. For example, if fermented food is being promoted as a means of reducing the incidence of diarrhoeal diseases in children, the benefits to the household have to be obvious if change is going to take place.

There are many reasons and advantages for using fermentation, including extending shelf-stability, addition of variety to the diet, as an income generating activity, nutritional benefits, and processing otherwise unusable raw materials. Even with these advantages, there are some communities that have discontinued using fermentation processes.

The initial stage in safety improvement of a fermentation process is understanding why that process is used. This would be an important part of a needs assessment, which should be carried out as an initial step in any research programme. The needs assessment should also determine what the perceived issues and problems are for both the processor and the consumer.

It may be possible to make changes to existing fermentation systems or introduce a fermentation process for food safety purposes if one can also demonstrate advantages such as extended shelf-life, cost savings, reduction in processing time, and improvement in taste or in nutritional quality. This requires an understanding of consumer and processor needs and perceptions. If fermented products are to be promoted as safe weaning foods, it is particularly important to evaluate the contribution that these foods make to the nutritional needs of the child.
During the implementation of any research project, it is crucial to have continuing interaction between scientists, processors and end-users to ensure that any changes to the process or product are acceptable, practical and cost-effective.

**Research needs:**

- To gain a greater understanding of consumer perceptions of food safety and the significance of this with respect to modifying food processing practices. [High priority]

- To gain an understanding of the needs and perception of processors in relation to their use of fermentation and potential adoption of the technology. [High priority]

- To evaluate the potential contribution of fermented foods to the daily nutritional requirements of weaning infants and children. [High priority]

- To determine why the use of a particular food fermentation has been discontinued, or continued in certain communities. [Medium priority]

**Overall, research in this area is considered to have a high priority**

8.4.2 **Transfer of information and technology to meet the needs of the target groups in relation to food safety**

The requirement for needs assessment studies was emphasized elsewhere in this Report. It is essential that such studies form an integral part of any project and are carried out not only at the beginning, but also during and after project activities. It is important to include target groups in the research exercise thereby considering them as partners rather than observers. Monitoring and evaluation are essential parts of the project cycle to determine whether or not an approach is effective and allows for corrective measures.

Adaptive research (pilot studies) is required to develop and modify technologies in partnership with target groups. Pilot studies can also be a useful tool in assessing the most appropriate means of technology and information transfer. It is important to recognize that different approaches will be required according to the scale of operation, for example the dissemination of fermentation and associated training may be appropriate at the household level. There is a need to understand the most appropriate mechanisms of education and communication to facilitate rapid and sustainable technology adaptation. In the transfer of technology/information on food fermentation, there might also be an opportunity to transfer other information such as that related to health, hygiene, food safety and nutrition.
Research needs:

- Adaptive research to develop and adapt processes. [High priority]
- Determination of appropriate mechanisms of education and communication. [High priority]

8.4.3 Research issues relevant to the household

The driving force behind the adoption of fermentation for domestic use, including infant feeding, is food security. Safety issues are important, but probably have a lower profile from the mother’s perspective than from the commercial perspective. Key issues will include quality of raw materials, ease of processing, energy use, and the extension of shelf-life for use within the home. The role of women is a specific issue that will determine the nature of the technology and how it is transferred. It will be important to make changes in small incremental steps so that the development is sustainable. One suitable approach may be the development and dissemination of fermentation kits.

8.4.4 Research priorities relevant to cottage industry

The adoption of fermentation at the commercial level is driven by the need to make a profit. Food regulation is a significant consideration in some countries. The research priorities of relevance are dictated by these issues. Starter cultures may be more relevant in this case than for domestic use, and the application of the principles of good manufacturing practice and other quality/safety criteria should be appropriate. Safety will have a high profile since it contributes to a commercial reputation. Product distribution issues are critical, and this would be expected to be a driving force behind the need to extend shelf-life.
9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

9.1.1 General

Lactic acid fermentation can contribute towards the safety, nutritional value, shelf-life and acceptability of foods for infants and young children. 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.

On its own, fermentation cannot eliminate all food-related health risks, but its benefits can be enhanced when combined with other unit process operations such as soaking, grinding and particularly cooking. Though shortcomings in the use of fermentation as a household food technology exist, options and solutions have been identified and proposed. There is a great need to ensure that existing knowledge of the fermentation technology is used for the maximum benefit of households and cottage industries.

The education of food handlers and consumers about the proper application of fermentation as part of the total food preparation process is essential.

The assessment of socioeconomic and cultural aspects is essential to enable the optimum utilization of fermentation technology for the preparation of weaning foods. The socioeconomic and cultural considerations should be integrated with key concepts of food safety, nutrition and household food security, and prevention and control of infection and care, if improvement is to be achieved in the nutritional status of infants and young children.

9.1.2 Safety

Major benefits include the inhibition of growth of most pathogenic bacteria, the inhibition of formation of bacterial toxins, and the degradation of some plant toxins e.g. cyanogenic glycosides.

In combination with other regular food preparation operations such as cleaning, cooking and appropriate hygiene, adequate protection is provided against most foodborne diseases of microbial and chemical origin. An exception should be made for pesticide and mycotoxin contamination occurring in the raw food materials. These are mostly not affected by fermentation or other process operations usually accompanying the fermentation step.

The prevalence of diarrhoea among infants and young children is influenced by the interaction of organisms in the environment (water, food, soil), hygienic behaviour, the virulence and number of organisms and prior health and nutritional status of the host. Despite the favourable effect of fermentation on contamination levels in food, it is not yet known whether the use of fermented food will additionally protect against diarrhoea when all the above variables are controlled.
9.1.3 Nutritional value

Preparation of foods of plant origin by processes involving fermentation contributes to
the degradation of some anti-nutritional factors, e.g. phytate, thus increasing mineral
bioavailability, to the improvement of the protein digestibility of tannin-rich cereals, and to
the improvement of carbohydrate tolerance by degradation of flatulence causing oligo-
saccharides. When germinated cereal grains are included as an ingredient in fermented
weaning foods, reduction of viscosity enables the preparation of semi-liquid porridges with
increased nutrient density.

9.1.4 Shelf-life

In the absence of facilities for refrigeration and/or hot-holding, lactic acid
fermentation provides an affordable method to extend the shelf-life of food. However, good
care should be taken to ensure that fermentation results in rapid and adequate acidification.

9.1.5 Acceptability

Lactic acid fermentation provides a variety of tastes to otherwise bland foods.

9.1.6 Research needs

High priority research needs were formulated within the areas of food safety,
nutritional value, technology development, and technology transfer and related socio-
economic aspects. Some major questions to be resolved include the effect of lactic acid
fermentation on the fate of parasites, viruses and certain pathogenic bacteria; the effect of
fermentation on mycotoxins and the toxicity of breakdown products; the significance of
D-(−) lactate acidosis associated with the consumption of fermented foods; the effect of
fermentation on the anti-nutritional impact of tannins on nutrient bioavailability;
characterization of hitherto uninvestigated fermentations; development of appropriate starter
cultures; optimization of fermentation conditions to achieve specific benefits; feasibility of
the use of probiotic microorganisms; development and application of quality and safety
systems (including IIACCP); assessments of consumer and producer perception of
fermentation and needs; assessment of appropriate mechanisms of communication and
education; and transfer of information and technology to households and cottage industries
through adaptive and participatory pilot projects.

9.2 Recommendations

9.2.1 Policy matters

The present exchange of information between mothers, manufacturers, scientists,
government and non-government organizations needs to be improved.
It is recommended that medical, health, technological and sociological services are integrated to coordinate efforts against foodborne diseases, with food fermentation as an integral part of this action.

Safety considerations should be integrated when fermentation is advocated and promoted for nutritional purposes.

In communities where lactic acid fermentation is usually carried out, this practice should be encouraged while educating the food handlers, in line with the HACCP approach, about the critical points in the process for controlling the safety of the products. Existing socioeconomic and cultural relations and patterns should be examined, and the type of support which is needed to improve the safety and nutritional value of fermented foods should be identified. Appropriate communication strategies and means should be developed and applied, to inform households about the appropriate food processing techniques with respect to fermentation.

If lactic acid fermentation is not known or used, a sociocultural assessment should be made of the appropriateness and feasibility of fermentation practice in that community, and its food safety and nutrition implications, prior to any attempt to formally introduce fermentation technology.

Education or development of communication strategies should be based on KAP (a methodology for the assessment of Knowledge, Attitudes, and Practices) and HACCP studies, from which community needs will be derived. On the basis of these identified needs, information can be disseminated, preferably utilizing existing and already well-established strategies.

9.2.2 Research

Research in the high priority areas as mentioned above and listed in more detail in section 8 should be promoted and supported. The execution should preferably have a collaborative and multidisciplinary character.

A follow-up to this Workshop, e.g. in the form of a “forum”, touching on all the matters referred to in these recommendations should be planned in the near future.

A network of scientists should be established to facilitate exchange of information, coordination of research efforts, and dissemination of results. Such a “food fermentation network” should be adequately affiliated with international professional organizations, governments and NGO's.
GLOSSARY

Acidosis
A pathologic condition resulting from accumulation of acid or loss of base in the body, and characterized by increase in hydrogen ion concentration (decrease in pH).

ARF
Amylase Rich Flour. See also: Power Flour.

Back-slopping
The practice of employing material from previous successful batches as a fermentation starter culture. In fermentation of cereals, root crops and leguminous seeds (beans, pulses), back-slopping usually results in a gradual dominance of lactic acid bacteria.

Contaminant
Any biological or chemical agent, foreign matter or other substance present in the food - not intentionally added - which may compromise food safety or suitability.

Control (verb)
To take all necessary actions to ensure and maintain compliance with established criteria.

Control (noun)
The state wherein correct procedures are being followed and criteria are being met.

Control measure
An action or activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Corrective action
A type of action to be taken when the results of monitoring the CCP indicate a loss of control.

Critical Control Point (CCP)
A step at which control is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Critical limit
A value which separates acceptability from unacceptableness.

ERF
Enzyme Rich Flour. See also: Power Flour.
Fermentation
A desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes. Fermentation is purposely carried out to enhance taste, aroma, shelf-life, texture, nutritional value and other attractive properties of food. Fermentation is often part of a sequence of process operations including one or more of the following: cleaning, grinding, soaking, salting, cooking, packaging, and distribution.

Fermentation (characterization of):
The investigation and description of microbiological, chemical and other relevant changes taking place during a fermentation. Characterization of fermentations is required to understand the factors and substances affecting food quality and safety.

Foodborne disease
A disease, usually either infectious or toxic in nature, caused by agents that enter the body through the ingestion of food. The term ‘food’ includes drinking-water, or water used in food preparation.

Food safety (state)
Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.

Food safety (measure)
All conditions and measures that are necessary to ensure the safety and suitability of food for human consumption at all stages of the food chain.

Food hygiene, Food sanitation
For the purpose of this Report, these terms are considered as synonymous to food safety (measure).

Good Manufacturing Practice
Practices employed by food manufacturing enterprises that are necessary to produce quality food products conforming to food laws and regulations.

Good Hygienic Practice
Practices during food handling that are necessary to conform with basic food hygiene rules.

HACCP system
A scientific and systematic way of enhancing the safety of foods from primary production to final consumption, through the identification, evaluation and control of hazards which are significant for food safety.

Hazard
A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.
Household technology
The combination of methods, utensils and manual labour, as are available in the average home. It may happen that certain steps in food preparation, e.g. grinding, need to be performed for a fee, using equipment and know-how from outside the household. Household technology is primarily used to feed the household, i.e. a family group eating from the same pot. In this case, a direct link exists between the person preparing the food and the family consuming it. The risk of adulteration is low, and usually the products are not subject to official food inspection.

When food is prepared on a large scale for commercial purposes, the term ‘enterprise’ is used. This may mean a single entrepreneur, small cottage- or village-based enterprises, or even semi-industrial ones, all depending on the scale of production, the number of employees and the level of capital investment. Even in an industrial setting much of the technology employed could still be regarded as “household technology”, as described above in terms of methods, equipment and low degree of technical sophistication. However, commercial production activities may involve more complicated channels leading from producer to consumer. This increases the risk of adulteration; thus such products are, or should be, subject to official food inspection.

Inoculation belt (as used in Ghana)
Belt of woven plant fibre used as a fermentation starter culture, e.g. in the traditional brewing process of “pito”, a maize-sorghum beer. The belt is held suspended in the vessel during fermentation and serves as an attachment site for the predominant microorganisms, in this case lactic acid bacteria and yeasts. Towards the end of the fermentation, the belt is removed, gently dried and kept until required for the next fermentation.

L-(+) and D-(−) Lactic acid
Lactic acid is optically active as it contains an asymmetric carbon atom. The two mirror-image optical isomers L-(+) and D-(−) lactic acid are rotating the axis of polarized light to the right and left, respectively. L-(+) lactic acid can be metabolized by man, whereas D-(−) lactic acid is absorbed by the human body but not metabolized. Consequently, if consumed in large quantities it may result in acidosis. Lactic acid bacteria produce a mixture of the two optical isomers in a ratio characteristic for their species.

Monitor
The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.

Power flour
Germindented cereal grain (mostly sorghum or millet), either dried in the sun or artificially at temperatures not exceeding 50°C, and ground to flour. This material, also referred to as malt, contains active starch degrading enzymes which enable the liquefaction of a stiff gelatinized gel of cooked starch (such as cooked cereal or root crop-based food). The sudden change in viscosity explains the name of the product.
Ragi (as used in Indonesia)
A common name for a dried and shelf-stable rice flour-based fermentation starter culture. For example, *ragi tapé* is used as a starter culture to ferment glutinous rice to *tapé ketan*; this particular ragi contains a mixed starter culture of an amylolytic mould (*Amylomyces rouxii*), a yeast (*Hyphopichia burtonii*) and some lactic acid bacteria. The starter culture is prepared in the household or in cottage industry, in the shape of coin-sized tablets, which can be crushed and sprinkled on the material to be fermented.

Starter culture
A starter culture is defined as material containing a high concentration of live microorganisms which is added to raw food materials with the intent of speeding up the process of fermentation. Lactic acid fermentation is often promoted by adding large numbers of active lactic acid bacteria. Most simply this could be done by back-slopping.

Step
A point, procedure, operation or stage in the food chain, including raw materials, from primary production to final consumption.

Usar (as used in Indonesia)
A dried and shelf-stable starter culture used to ferment soya beans to *tempe kelele*, a mould-fermented soya bean cake. Plant leaves (such as *Hibiscus tiliaceus*) which have a rough surface, to which the fermentation microorganism (moulds such as *Rhizopus oligosporus* in this case) are able to attach are used. After growing the mould sandwiched between leaves, the latter are sun-dried. The material to be fermented (cooked soya beans) is rubbed between some leaves of usar in order to transfer the mould spores from the starter culture to the beans. The used usar leaves are then discarded.

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6 In relation to the HACCP system
## ANNEX 1

### LIST OF BACKGROUND PAPERS

The following is a list of papers presented by the some of the participants at the Workshop. Copies can be obtained by writing to the authors. The address given here is that of the first author.

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
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<tbody>
<tr>
<td>Review of the sensitivity of different foodborne pathogens to fermentation</td>
<td>M.R. Adams and L. Nicolaides, School of Biological Sciences, University of Surrey, Guildford, Surrey GU2 5XH, UK</td>
</tr>
<tr>
<td>Use of Starter Cultures in Fermentation on a Household Scale</td>
<td>W. Holzapfel, Institute of Hygiene and Toxicology, Federal Research Centre for Nutrition, Engesserstrasse 20, D-76131 Karlsruhe, Germany</td>
</tr>
<tr>
<td>Household Food Safety in Developing Countries with regard to Fermented Foods</td>
<td>Z. Merican, Senior Research Officer, Food Technology Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), P.O. Box 12031, G.P.O., 50774 Kuala Lumpur, Malaysia</td>
</tr>
<tr>
<td>Lactic fermented foods and their benefits in Asia</td>
<td>C.-H. Lee, Department of Food Technology, College of Natural Resources, Korea University, 1 Anam-dong, Sungbuk-ku, Seoul, 136-701 Korea</td>
</tr>
<tr>
<td>Fermentation - The key to food safety assurance in Africa?</td>
<td>P. Mensah, Noguchi Memorial Institute for Medical Research, P.O. Box 25, Legon, Ghana</td>
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<td>Title</td>
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<td>Technological aspects of preparing affordable fermented weaning foods</td>
<td>M.J.R. Nout and P.O. Ngoddy&lt;br&gt;Department of Food Science,&lt;br&gt;Agricultural University, Bomenweg 2,&lt;br&gt;6703 D Wageningen,&lt;br&gt;The Netherlands</td>
</tr>
<tr>
<td>Lactic fermented foods in Africa and their benefits</td>
<td>O.B. Oyewole, Department of Food Science and Technology, University of Agriculture, P.M.B. 2240, Abcokuta, Ogun State, Nigeria</td>
</tr>
<tr>
<td>Food Safety and Fermented Foods in Latin America</td>
<td>F. Quevedo, Food Quality and Safety Assurance International, Las Petunias,&lt;br&gt;140, Dpto 201, Lima 12, Peru</td>
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<tr>
<td>Socio-economic pitfalls of enhancing indigenous capabilities in household fermentation</td>
<td>T. van de Sande, Socraan 17, 1185 JG Amstelveen, The Netherlands</td>
</tr>
<tr>
<td>Classification of fermented foods: Worldwide review of household fermentation techniques</td>
<td>K.H. Steinkraus, Cornell University,&lt;br&gt;15 Cornell Street, Ithaca, New York 14850 USA</td>
</tr>
<tr>
<td>Fermentation and nutrient availability</td>
<td>U. Svanberg and W. Lorri,&lt;br&gt;Chalmers University of Technology, c/o SIK; Box 5401,&lt;br&gt;40 229 Göteborg, Sweden</td>
</tr>
<tr>
<td>Review of the effect of fermentation on naturally occurring toxins</td>
<td>A. Westby, A. Reilly and Z. Bainbridge&lt;br&gt;Natural Resources Institute, Overseas Development Administration, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK</td>
</tr>
</tbody>
</table>
ANNEX 2

LIST OF PARTICIPANTS

Prof. John W. Hastings, Department of Genetics, University of Natal, Pietermaritzburg, Republic of South Africa

Prof. Alex von Holy, Department of Microbiology, University of the Witwatersrand, Johannesburg, Republic of South Africa

Dr Cheri-Ho Lee, Professor of Food Engineering, Department of Food Technology, College of Natural Resources, Seoul, Korea

Dr Wilbald Lorri, Managing Director, Tanzania Food and Nutrition Centre, Dar es Salaam, Tanzania

Prof. S.K. Mbugua, Department of Food Technology and Nutrition, College of Agriculture and Veterinary Sciences, University of Nairobi, Kabete, Kenya

Dr Patience Mensah, Head Bacteriology Unit, Noguchi Memorial Institute for Medical Research, University of Ghana, Legon, Ghana

Dr M.J. Robert Nout, Department of Food Science, Agricultural University, Wageningen, The Netherlands (Rapporteur)

Dr Olusola B. Oycwole, Department of Food Science and Technology, College of Agricultural Management, Rural Development and Consumer Studies, University of Agriculture, Abeokuta, Ogun State, Nigeria (Chairman)

Prof. Fernando Quevedo, Executive Director, Food Quality & Safety Assurance International, Lima, Peru (Vice-Chairman)

Dr Theo van de Sande, Vrije Universiteit, Amsterdam, The Netherlands

Dr Morenike O. Sanni, Department of Human Nutrition, College of Medicine, University of Ibadan, Ibadan, Nigeria

Prof. Keith H. Steinkraus, Professor Microbiology emeritus, Cornell University, Ithaca, New York, USA

Dr Ulf Svanberg, Department of Food Science, Chalmers University of Technology, Göteborg, Sweden

Prof. Andrew Tomkins, Director, Centre for International Child Health, Institute of Child Health, University of London, London, UK

Dr Jocelyn Webster, Division of Food Science and Technology, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa
Representatives of Other Organizations

Association of African Universities (AAU): Prof. O. Onayemi, African Universities House, Accra-North, Ghana
[unable to attend]

European Union (EU), Brussels, Belgium
[unable to attend]

Industry Council for Development (ICD): Ms Zahara Merican, Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia

International Commission on Food, Microbiology and Hygiene (ICFMH):
Dr Wilhem H. Holzapfel, Institute of Hygiene and Toxicology, Federal Research Centre for Nutrition, Karlsruhe, Germany

International Commission on Microbiological Specifications for Foods (ICMSF):
Ms Zahara Merican, Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia

International Foundation for Science (IFS): Dr Richard Fuchs, Scientific Secretary, Stockholm, Sweden

International Life Sciences Institute (ILSI), Washington, USA
[unable to attend]

International Union of Food Science and Technology (IUFoST): Dr Lilian Marovatsanga, Institute of Food, Nutrition and Family Sciences, Harare, Zimbabwe

International Union of Nutritional Sciences (IUNS): Dr M.J. Robert Nout, Department of Food Science, Agricultural University, Wageningen, The Netherlands

Overseas Development Administration (ODA): Dr Andrew Westby, Natural Resources Institute, Kent, UK

South African Association for Food Science and Technology (SAFST): Prof. Alex von Holy, Department of Microbiology, University of the Witwatersrand, Johannesburg, Republic of South Africa


United Nations Industrial Development Organization (UNIDO): Vienna, Austria
[unable to attend]
Observer

Mrs Ina Willken, Consumer Council, Pretoria, Republic of South Africa

Secretariat

Dr Gabriel Kouton, Senior Officer (Food Industries), Food and Agricultural Industries Service, Agricultural Support Systems Division, FAO, Rome, Italy (Co-Secretary)

Dr Yasmine Motarjem, Food Safety Unit, WHO, Geneva, Switzerland (Co-Secretary)

Mr Alan Reilly, Food Safety Unit, WIPO, Geneva, Switzerland

Dr Martin Adams, School of Biological Sciences, University of Surrey, Guildford, UK (Temporary Adviser)

Local Organizers

Ms Leoni Bosman, Division of Food Science and Technology, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa

Mr Dave Harcourt, Division of Food Science and Technology, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa

Ms Brenda Liebenberg, Dietitian, Directorate Nutrition, Department of Health, Pretoria, Republic of South Africa

Ms Ilze Meyer, Division of Food Science and Technology, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa

Ms F W J van Rijssen, Deputy Director, Food and Chemicals, Department of Health, Pretoria, Republic of South Africa

Dr Theo van de Venter, Director of Food and Chemicals, Department of Health, Pretoria, Republic of South Africa

Dr Jocelyn Webster, Division of Food Science and Technology, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa

Mr Johan de Wet, Division of Food Science and Technology, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa
ANNEX 3

BASIC PRINCIPLES FOR THE
PREPARATION OF SAFE FOOD FOR INFANTS AND YOUNG CHILDREN

• **Cook food thoroughly**
  Many raw foods, notably poultry, raw milk and
vegetables, are very often contaminated with disease-
causing organisms. Thorough cooking will kill these
organisms. For this purpose, all parts of the food must
become steaming hot, which means they must reach a
minimum temperature of 70°C.

• **Avoid storing cooked food**
  Prepare food for infants and young children freshly, and
give it to them immediately after preparation when it is
cool enough to eat. Foods prepared for infants and
young children should preferably not be stored at all. If
this is impossible, food could be stored only for the next
meal, but kept cool (at temperatures below 10°C) or hot
(at temperatures near or above 60°C). Stored food
should be reheated thoroughly. Again, this means that
all parts of the food must reach at least 70°C.

• **Avoid contact between raw foodstuffs and cooked foods**
  Cooked food can become contaminated through even the
slightest contact with raw food. This cross-
contamination can be direct, as, for example, when raw
food comes into contact with cooked food. It can also be
indirect and subtle: for example, through hands, flies,
toilets or utensils surfaces. Thus, hands should be
washed after handling high-risk foods, e.g. poultry.
Similarly, utensils used for raw foods should be
carefully washed before they are used again for cooked
food. The addition of any new ingredients to cooked
food may again introduce pathogenic organisms. In this
case, food needs to be thoroughly cooked again.

• **Wash fruits and vegetables**
  Fruits and vegetables, particularly if they are given to
infants in raw form, must be washed carefully with safe
water. If possible, vegetables and fruits should be
peeled. In situations where these foods are likely to be
heavily contaminated, for example when untreated waste
water is used for irrigation or untreated night soil is used
for soil fertilization, fruits and vegetables which cannot
be peeled should be thoroughly cooked before they are
given to infants.

• **Use safe water**
  Safe water is just as important in preparing food for infants
and young children as it is for drinking. Water used in
preparing food should be boiled, unless the food to which
the water is added has subsequently been cooked (e.g., rice,
potatoes). Remember that ice made of unsafe water will also
be unsafe.

• **Wash hands repeatedly**
  Wash hands thoroughly before you start preparing or
serving food and after every interruption - especially if you
have changed the baby, used the toilet, or been in contact
with animals. It should be remembered that household
animals often harbour germs that can pass from hands to
food.

• **Avoid feeding infants with a bottle**
  Use a spoon and cup to give drinks and liquid foods to
infants and young children. It is usually difficult to get
bottles and teats completely clean. Spoons, cups, dishes and
utensils used for preparing and feeding infants should be
washed right after use. This will facilitate their thorough
cleaning. If bottles and teats must be used, they should be
thoroughly washed and boiled after every use.

• **Protect foods from insects, rodents and other animals**
  Animals frequently carry pathogenic organisms and are
potential sources of contamination of food.

• **Store non-perishable foodstuffs in a safe place**
  Keep pesticides, disinfecting agents or other toxic chemicals
in labelled containers and separate from foodstuffs. To
protect against rodents and insects, non-perishable foodstuffs
should be stored in closed containers. Containers which
have previously held toxic chemicals should not be used for
storing foodstuffs.

• **Keep all food preparation premises meticulously clean**
  Surfaces used for food preparation must be kept absolutely
clean in order to avoid food contamination. Scraps of food
and crumbs are potential reservoirs of germs and can attract
insects and animals. Garbage should be kept in safe,
covered places and be disposed of quickly.

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1 Adapted from *Golden Rules for Safe Food Preparation: health surveillance and management procedures for food-
Series, No. 785).
ANNEX 4

APPLICATION OF THE HACCP SYSTEM TO UJI

a. Product description

Preparation of uji varies depending on the region. The following description is one example of uji preparation as practised in Kenya.

The basic cereal in uji production is maize, but at times a mixture of maize, sorghum and millet is used. The raw cereal is finely ground and mixed with water in a concentration of about 30% solids. The dough, without inoculation, is fermented for 2-5 days at ambient temperature, and it is then diluted to about 4-5% solids in boiling water, and sweetened with crystalline sugar.

b. Intended use

Uji is consumed by adults as well as children. For the purpose of this Report, its use as a weaning food is considered.

c. Flow diagram

Figure 3 shows the flow diagram of uji.

d. Hazards of concern

Hazards considered in this context include biological (e.g. bacteria, viruses, parasites), chemical (e.g. contaminants, mycotoxins) and physical agents.

e. Identification of hazards, control measures and Critical Control Points

Table 3 shows hazards associated with each step in the preparation of uji, and some possible measures for their control.

1) Raw material: Major hazards in maize, millet and sorghum are toxins, e.g. aflatoxin produced by moulds, and agrochemicals. For prevention of toxigenic moulds during storage, the raw material should, as far as possible, be stored under appropriate ambient conditions. When the ambient temperature and humidity are high, storage time should be limited. In so

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1 This study has been carried out by the Joint FAO/WHO Workshop Secretariat.

2 Application of the HACCP system has been simplified and adapted to household conditions. Although the same approach can be used for production on a cottage and industrial scale, the requirements in terms of Critical Control Points, critical limits, and monitoring procedures may be different and more severe.

3 Model HACCP plans are not appropriate for use until validated for a specific food and food process.
far as agrochemicals are concerned, households cannot do much except to get assurance from suppliers about the safety of the products. The possibility of accidental contamination of grains during storage with agro-chemicals should be prevented. The grains may also contain foreign matter such as stones and insect fragments. These will not be eliminated or controlled at a later step, so it is important that households thoroughly clean the raw material.

Cereals may also be contaminated with pathogens. These will be eliminated at subsequent steps of preparation, i.e. fermentation and boiling.

Water may be contaminated with pathogens. As part of a good hygienic practice, safe water should be used, particularly for washing hands and utensils. As the fermented dough is subsequently boiled, the quality of water used for its preparation is not considered as a Critical Control Point with regard to pathogens. However, with respect to chemical contaminants, the quality of water is a Critical Control Point as chemical contaminants will not be removed during later stages of preparation.

Crystalline sugar may contain foreign matter. Some foreign matter, e.g. glass, constitutes a health risk. Care should be taken to see that sugar does not contain any foreign matter.

2) **Grinding:** This step may introduce dirt and foreign matter. As part of a good hygienic practice this should be avoided as far as possible by using clean and properly maintained equipment. However, it is unlikely that this step will introduce any major health hazard.

3) **Dough preparation:** Except for the quality of water (see step 1), this step does not present a specific hazard. As a part of a good hygienic practice, households should use safe water, as far as possible.

4) **Fermentation:** This step is important for preventing the growth of undesirable bacteria and moulds. However, microorganisms (vegetative form) surviving this step will be eliminated during the subsequent boiling step. The major hazards associated with this step are microorganisms producing thermostable toxins, e.g. *Staphylococcus aureus*, or moulds, as the toxins will not be destroyed later by boiling. Fermentation is therefore a Critical Control Point for these hazards. To prevent these hazards, the fermentation process should be rapid, i.e. characteristic odours and smell of fermentation should appear within 24 hours.

5) **Boiling water:** All pathogens (vegetative form) are killed during this step.

6) **Dilution in continuously boiling water:** This step is a critical point for ensuring the biological safety of *agi*, as pathogens existing in the raw material or introduced during previous steps will be killed at this step. It should, however, be noted that spores of bacteria, e.g. *Bacillus cereus*, may survive.
7) **Sweetening:** Provided that sugar or utensils used for sweetening are clean, no major hazard is associated with this step.

8) **Serving:** Care should be taken to ensure that pathogens are not re-introduced into the prepared uji by dirty hands or utensils. Therefore, these have to be washed carefully with safe water. This is particularly important with regard to pathogens of a low-infective dose, e.g. *Shigella*. The prepared uji should be consumed as soon as possible. Although the acidity of the product discourages spore germination, a significant delay in serving may give an opportunity for the growth of bacterial spores which have survived previous steps (e.g. spores of *Bacillus cereus*) or microorganisms which may have been introduced by dirty hands or utensils.
<table>
<thead>
<tr>
<th>Step</th>
<th>Hazards</th>
<th>Control Measures</th>
<th>CCPs</th>
<th>Critical Limit</th>
<th>Monitoring Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
</table>
| 1.   | Raw material  
   i) Maize  
   Sorghum  
   Millet | a. Mycotoxins  
   i) Obtain assurance from supplier of adequate preharvest and post-harvest handling of the grains  
   ii) Store grains in dry (and if possible cool) area, limit storage time | a. Yes | a. No mouldiness, good smell | a. Observation, smelling | a. Discard the raw material and change supplier |
|      |         | b. Agrochemicals | b. No | | | |
|      |         | c. Pathogens:  
   Bacillus cereus,  
   Salmonella, E.coli | c. Heat treatment, correct fermentation | c. No | | |
|      |         | d. Physical:  
   insects and stones | d. Manual cleaning | d. Yes | d. No visible insect fragments or stones | d. Re-clean |
<p>| | | | | | | |
|      |         |                  |      | | | |</p>
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<tr>
<th>Step</th>
<th>Hazards</th>
<th>Control Measures</th>
<th>CCPs</th>
<th>Critical Limit</th>
<th>Monitoring Procedure</th>
<th>Corrective Actions</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>b. Pathogens, e.g. <em>E. coli</em>, <em>Campylobacter</em>, <em>V. cholerae</em>, <em>Salmonella</em>, <em>Cryptosporidium</em>, <em>Giardia lamblia</em>, <em>Entamoeba histolytica</em>, <em>Rotavirus</em></td>
<td>b. Use safe water (i.e. filtered and disinfected) or boil the water</td>
<td>b. No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Raw material iii) Crystalline sugar</td>
<td>Filth, dirt, insect, glass</td>
<td>Use clean sugar</td>
<td>Yes</td>
<td>No visible foreign matter</td>
<td>Observation</td>
<td>Clean the sugar (e.g. sieve) and if cleaning is not possible, discard the sugar</td>
</tr>
<tr>
<td>2. Grinding</td>
<td>Introduction of filth, dirt, and foreign matter</td>
<td>Use clean and properly maintained equipment</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Dough preparation</td>
<td>Contamination with water</td>
<td>Use safe water</td>
<td>No</td>
<td></td>
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<tr>
<td>Step</td>
<td>Hazards</td>
<td>Control Measures</td>
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</table>
| 6. Dilution  
(to 4-5% solids in continuously boiling water) | Survival of non-spore forming pathogens | Continuous boiling | Yes | Gelatinization, well cooked | Observation | Keep boiling |
| 7. Sweetening  
(in hot ḋjī) | No hazard  
(for hazards associated with sugar see step 1(iii)) | | | | | |
| 8. Serving | a. Re-contamination by hands, utensils, environment  
b. Growth of pathogens and spores of Bacillus cereus, if consumption delayed for more than four hours | a. Wash hands and use clean utensils  
b. Consumption without delay | a. Yes  
b. Yes | a. Washing with soap and thorough rinsing with clean water  
b. Use within four hours | a. Observation  
b. Time keeping | Thorough reheating  
(steam, bubbles) |
ANNEX 5

APPLICATION OF THE HACCP SYSTEM TO TOGWA\textsuperscript{1,2,3}

a. Product description

\textit{Togwa} is prepared by many tribes in Tanzania, and there are many variations in its production. The preparation involves mixing cooked cereals (e.g. maize, sorghum) with germinated cereals, e.g. finger or bulrush millet or sorghum. Fermentation takes about 9-12 hours, depending on whether or not an old batch is used as a starter culture. If an old batch or power flour is used, the fermentation is completed in about 6-9 hours.

b. Intended use

Most fermented gruels in Tanzania remain edible for 1-2 days. Beyond this period, the product is too sour, or gives off an unpleasant odour. Fermented gruels are traditionally given to children under five years of age.

c. Flow diagram

Figure 4 shows the flow diagram of \textit{togwa}.

d. Hazards of concern

Hazards considered in this context include biological (e.g. bacteria, viruses, parasites), chemical (e.g. contaminants, mycotoxins) and physical agents.

e. Identification of hazards, control measures and Critical Control Points

Table 4 shows hazards associated with each step in the preparation of \textit{togwa} and of power flour which is an essential ingredient in this gruel.

1) Raw material: Major hazards in maize, millet and sorghum are toxins, e.g. aflatoxin produced by moulds, and agrochemicals. For prevention of toxigenic moulds during storage, the raw material should, as far as possible, be stored under appropriate ambient conditions. When the ambient temperature and humidity are high, storage time should be limited. In so far as agrochemicals are concerned, households cannot do much except to get

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\textsuperscript{1} This study has been carried out by the Joint FAO/WHO Workshop Secretariat.

\textsuperscript{2} Application of the HACCP system has been simplified and adapted to household conditions. Although the same approach can be used for production on a cottage and industrial scale, the requirements in terms of Critical Control Points, critical limits, and monitoring procedures may be different and more severe.

\textsuperscript{3} Model HACCP plans are not appropriate for use until validated for a specific food and food process.
assurance from suppliers about the safety of the products. The possibility of accidental contamination of grains during storage with agro-chemicals should be prevented.

The grains may also contain foreign matter such as stones and insect fragments. These will not be eliminated at a later step, so it is important that households thoroughly clean the raw material.

Water used in the preparation of slurry may be contaminated. Boiling the slurry (see step 9) will eliminate eventual pathogens. Therefore, water used for the preparation of slurry is not a Critical Control Point, although as part of a good hygienic practice, safe water should be used as far as possible in the preparation of *tögwa* and for washing hands and utensils. On the other hand, the safety of water used in the production of power flour does not include a step which would ensure the elimination of pathogens introduced through the raw material, i.e. water, sorghum or millet. In addition, pathogens introduced through the raw material may proliferate during the soaking and germination periods and also survive the sun-drying stage. Therefore, the safety of water used for the preparation of power flour is critical for minimizing the contamination of power flour. The hygienic quality of the power flour is particularly important for the safety of the final product, as once the power flour has been added there is no step which would ensure the killing of acid resistant pathogens.

2) **Soaking:** During the soaking period, bacterial growth will occur. Use of safe water may minimize final bacterial load. If at all possible, soaking should take place at low temperatures to minimize the growth of microorganisms.

3) **Germination:** This usually takes place in layers a few centimetres thick, spread on mats or leaves, and covered with leaves, mats or gunny sacks to avoid excessive dehydration. From time to time, the material must be aired and mixed while checking and adjusting the degree of grain humidity. Further contamination by mats and microbial growth can occur at this stage. Microbial growth, particularly with respect to toxigenic moulds, can also occur. As far as possible, germination should be carried out in cool conditions to minimize microbial growth.

4) **Sun-drying:** The cover is removed, the sprouted grains are spread on mats or bamboo trays to dry in the sun. This may take a few days. All kinds of contaminants and foreign matter can fall into the sprouted grains, if not well protected. Insufficient drying may lead to a microbiologically unstable product during subsequent storage. Thorough drying is critical for the stability of the product.

5) **Storage of sun-dried germinated grains:** Hazards associated with this step are contamination, for example by rodents and other animals during storage, and microbial growth, particularly toxigenic moulds, if the germinated grains are not properly dried or are kept in humid conditions.
6) **Grinding to power flour:** This step may introduce dirt and foreign matter. As part of a good hygienic practice this should be avoided as far as possible by using clean and properly maintained equipment. However, it is unlikely that this step will introduce any major health hazard.

7) **Grinding:** Same as step 6

8) **Preparation of slurry:** Except for the safety of water and cleanliness of utensils, no other major hazard is associated with this step. As the subsequent boiling step will kill the pathogens which may have been introduced at this step, it is not considered a Critical Control Point. Nevertheless, as a part of a good hygienic practice, households should use clean utensils and safe water as far as is possible.

9) **Boiling:** Boiling should be thorough to fully gelatinize all starch. This step is also essential to kill all pathogens (bacterial spores may nevertheless survive).

10) **Cooling:** The pot should be covered to protect against dirt or other foreign matter falling in. It is important that cooling is carried out as fast as possible. Prolonged cooling may give an opportunity for bacterial spores to grow. When large quantities of togwa are prepared, the cooling time can be reduced by dividing the togwa into small recipients.

11) **Addition of power flour and togwa:** Two ingredients may be added here to initiate the fermentation, i.e. power flour and previously fermented togwa. The contamination brought about by power flour is diverse and difficult to control. Viruses and other acid-tolerant agents are of particular concern here. The togwa starter culture is quite acid, and will thus contain only those contaminants which are acid-tolerant in nature.

During the fermentation which follows, acid-sensitive pathogens may be killed. However, acid tolerant pathogens may survive in togwa. A power flour, prepared under hygienic conditions may minimize the contamination of togwa. **However, in the absence of a final killing step, e.g. thorough reheating, the presence of acid tolerant pathogens in the final product may not be excluded.**

12) **Fermentation:** During fermentation a rapid dominance of lactic acid bacteria may be expected. This is supported by the short fermentation time to reach acidity. A rapid fermentation is critical for killing acid-sensitive pathogens and for the prevention of bacterial growth and production of toxin. Addition of togwa enhances fermentation and may be beneficial provided that it does not introduce acid-resistant pathogens.

13) **Serving:** It is important to ensure that pathogens are not re-introduced into togwa by dirty hands and utensils. Therefore, these have to be washed carefully with safe water. Depending on the hygienic measures taken to prepare togwa, the final product could be more or less contaminated, as there is no final Critical Control Point which would ensure the killing of acid-resistant pathogens. Thorough reheating greatly contributes to the safety of the final product. However, implications in terms of textural and other changes should be considered, as the final product may become unacceptable to the consumer.
<table>
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<tr>
<th>Step</th>
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<th>Control Measures</th>
<th>CCPs</th>
<th>Critical Limit</th>
<th>Monitoring Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Raw material</td>
<td>a. Mycotoxins</td>
<td>a. Obtain assurance from supplier of adequate pre-harvest and post-harvest handling of grains</td>
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<td></td>
<td></td>
<td>i) Store grains in dry (and if possible cool) area, limit storage time</td>
<td></td>
<td>a. Yes</td>
<td>a. i) Adequate time, temperature, humidity of storage area</td>
<td>i) No mouldiness, good smell</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Agro-chemicals</td>
<td></td>
<td>b. No</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>b. Agro-chemicals</td>
<td>b. Obtain assurance from supplier of adequate pre-harvest and post-harvest handling of grains</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>c. Pathogens:</td>
<td>c. Heat treatment, fermentation</td>
<td></td>
<td>c. No</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bacillus cereus,</td>
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<tr>
<td></td>
<td>Salmonella, E.coli</td>
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<tr>
<td></td>
<td>insects and stones</td>
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</tr>
</tbody>
</table>
| 1. Raw material i) Water | a. Chemical contaminants, depending on the source  
    b. Pathogens, e.g. *E. coli*, *Campylobacter*, *V. cholerae*, *Salmonella*, *Cryptosporidium*, *Giardia lambia*, *Entamoeba histolytica*, *Rotavirus* | a. Obtain assurance about the source of water; use only safe water  
    b. If safe water (i.e., filtered and disinfected) is not available, boil the water | a. Yes  
    b. Yes for step 2 | a. Clear, free of odour and off-taste  
    b. Bubbles | a. Observation, smelling and tasting  
    b. Observation | a. Use another source of water  
    b. Re-boil |
| 2. Soaking | Growth of microorganisms | As far as possible at low temperatures | Yes | Water should remain free from odour or foam | Observation, smelling | Refresh water |
| 3. Germination | Growth of microorganisms: e.g. toxigenic moulds | As far as possible at low temperature | Yes | Grains should remain free of mouldiness | Observation | Remove mouldy grains |
| 4. Sun-drying | a. Contamination  
    b. Inadequate drying may lead to growth of microorganisms during storage | a. Protect the sprouts  
    b. Ensure thorough and fast drying | Yes | a. No foreign matter  
    b. Sufficient time, adequate exposure to sun, dry ambient conditions, adequate air circulation, no mould | a. Observation  
    b. Time keeping, observation | a. Clean if possible. If not, discard  
    b. As long as there is no mould growth, re-dry under proper conditions, otherwise discard |
<table>
<thead>
<tr>
<th>Step</th>
<th>Hazards</th>
<th>Control Measures</th>
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<th>Monitoring Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b. Growth of toxigenic moulds, if the moisture content is high</td>
<td>b. Keep dry</td>
<td></td>
<td>b. Dry conditions of storage, no mould</td>
<td></td>
<td>b. Discard</td>
</tr>
<tr>
<td>6. Grinding to power flour</td>
<td>Introduction of filth, dirt and foreign matter</td>
<td>Use clean and properly maintained equipment</td>
<td>No</td>
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<td></td>
<td></td>
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<tr>
<td>7. Grinding</td>
<td></td>
<td></td>
<td></td>
<td>same as step 6</td>
<td></td>
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</tr>
<tr>
<td>8. Slurry preparation</td>
<td>Contamination through utensils and/or water</td>
<td>Use clean utensils and safe water</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Boiling</td>
<td>Survival of pathogens</td>
<td>Thorough boiling</td>
<td>Yes</td>
<td>Bubbles</td>
<td>Observation</td>
<td>Re-boil</td>
</tr>
<tr>
<td></td>
<td>b. Contamination</td>
<td>b. Protect the porridge during the cooling process</td>
<td></td>
<td>b. No foreign matter</td>
<td>b. Observation</td>
<td>b. Depending on the nature of contamination, either clean, re-boil or discard</td>
</tr>
<tr>
<td></td>
<td>b. Togwa</td>
<td>b. Ensure the safety of previously prepared togwa</td>
<td></td>
<td>b. Absence of disease upon consumption of togwa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step</td>
<td>Hazards</td>
<td>Control Measures</td>
<td>CCPs</td>
<td>Critical Limit</td>
<td>Monitoring Procedure</td>
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</table>
| 12. Fermentation | a. Growth and formation of toxin by *Staphylococcus aureus*  
   b. Survival of acid-tolerant pathogens | a. Rapid fermentation  
   b. Minimize contamination with acid-tolerant pathogens (see step 11) | a. Yes | a. Acid taste and characteristic odour within 24 hours | a. Observation | a. Discard the material |
| 13. Serving | Recombination by hands, utensils, environment  
   Wash hands and use clean utensils | Yes | Washing with soap and thorough rinsing with clean water | Observation | Thorough reheating |

1 As there is no Critical Control Point in the subsequent steps which would ensure the killing of acid-tolerant pathogens surviving the fermentation step, the present process of *tugwa* preparation may lead to a high risk product.
ANNEX 6
APPLICATION OF THE HACCP SYSTEM TO GARI

a. Product description

Gari is a granular starchy food made from cassava roots. The processing starts with peeling, washing and grating the tubers. The grated pulp is then put into bags (often jute, or woven polypropylene bags) and left to ferment for several days under weight (pressure), during which time water is also removed. Fermentation is followed by fragmentation, drying and roasting. During the roasting stage, the core temperature reaches 80-85°C, and the starch is gelatinized. Palm oil is sometimes added during roasting. After the roasting process, the gari, as it is now called, is cooled and stored. The final moisture content will determine its shelf-life. When a final moisture content of below 10% is reached, gari may be stored for several months. At higher moisture contents, the shelf-life of gari is reduced to a few weeks, because of potential mould growth.

b. Intended use

Gari is an important part of the staple diet in Nigeria and many other African countries. It is also given to children over one year. Gari can be prepared in many different ways. In the following example, soaking in cold water is used.

c. Flow diagram

The flow diagram of gari is presented in Figure 5.

d. Hazards of concern

Hazards considered in this context include biological (e.g. bacteria, viruses, parasites), chemical (e.g. contaminants, mycotoxins) and physical agents.

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2 Application of the HACCP system has been simplified and adapted to household conditions. Although the same approach can be used for production on a cottage and industrial scale, the requirements in terms of Critical Control Points, critical limits, and monitoring procedures may be different and more severe.

3 Model HACCP plans are not appropriate for use until validated for a specific food and food process.
e. **Identification of hazards, control measures and Critical Control Points**

Table 5 shows hazards associated with each step in the preparation of gari, and some possible measures for their control.

1) **Raw material**: Major hazards of cassava are cyanogenic glucosides (linamarin and lotaustralin), and contamination by agro-chemicals. Cyanogenic glucosides will be hydrolyzed and removed during later stages in the processing and preparation of gari, i.e. grating, fermenting and roasting. However, in regard to chemical contaminants and agrochemicals, households should obtain assurance from the suppliers about the safety of raw products.

Depending on its source, water may be contaminated. While the microbiological safety of water is of lesser importance when washing cassava, as it will be fermented and heat treated, it is critical that safe water is used in the final preparatory stages before consumption.

2) **Peeling**: Some foreign matter and pathogens may be introduced at this step. However, as the cassava will be washed and heat treated, the control of hazards, other than peeling in hygienic conditions, is not critical at this stage.

3) **Washing**: Microbiological hazards may be introduced if the water is not clean. Therefore, as part of a good hygienic practice, safe water should be used. Hazards introduced at this step can nevertheless be controlled during subsequent steps of gari production. Washing can, though, decrease the amount of foreign matter.

4) **Grating**: This is the most important step with regard to detoxification when the cellular disruption results in release of linamarase enzymes, and greater contact of the enzymes with its substrate linamarin. Therefore, grating must be thorough to ensure a fast degradation of linamarin.

Foreign matter and pathogens may also be introduced at this stage. While pathogens can be killed at the roasting step, prevention and elimination of any foreign matter at this step is essential.

5) **Bagging**: Unclean bags may further contaminate the raw material. Chemical contamination is of particular concern at this step. The bags should not have been previously used for purposes which could jeopardize the safety of gari, e.g. for storage of pesticides.

6) **Fermentation**: Rapid fermentation is important to prevent growth of undesirable microorganisms and production of toxins. Fermentation is therefore a Critical Control Point for control of pathogens.
Fermentation also provides the opportunity (contact time) necessary for the action of linamarase on its substrate. During later stages, however, fermentation may have an antagonistic effect on detoxification, as the decrease in pH resulting from fermentation may lead to the stability of cyanohydrins. An optimization of the fermentation process with respect to hydrolysis of linamarin and control of microbial growth is therefore important for ensuring the chemical and microbiological safety of *gari*.

7) **Roasting:** Further detoxification of cassava occurs during roasting. The hydrogen cyanide is evaporated. Thorough drying at this step is also important for the stability of *gari* and prevention of mould growth during storage. It is important to prevent formation of lumps as these may limit drying and evaporation of hydrogen cyanide.

8) **Cooling:** Cooling should take place under hygienic conditions.

9) **Storing:** To prevent mould growth, *gari* should be kept under dry conditions, and protected from animals and rodents.

10) **Serving:** Water used for soaking *gari*, as well as hands and utensils, may re-introduce pathogens. It is critical that the water used at this step is safe, and that utensils and hands are thoroughly washed.
<table>
<thead>
<tr>
<th>Step</th>
<th>Hazards</th>
<th>Control Measures</th>
<th>CCPs</th>
<th>Critical Limit</th>
<th>Monitoring Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>i) Cassava</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>1. Raw material</td>
<td>a. Chemical contaminants, depending on the source</td>
<td>a. Obtain assurance of the source of water; use only safe water</td>
<td>a. Yes</td>
<td>a.</td>
<td>a.</td>
<td>a. Use another source of water</td>
</tr>
<tr>
<td>ii) Water</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>b. Pathogens, e.g. Escherichia coli, Campylobacter, V. cholerae, Salmonella, Cryptosporidium, Giardia lamblia, Entamoeba histolytica, Rotavirus</td>
<td>b. Use safe water (i.e. filtered and disinfected) or if filtered water is not available, boil the water</td>
<td>b. Yes for step 10</td>
<td>b.</td>
<td>b.</td>
<td>b.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i) Boil the water</td>
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<tr>
<td></td>
<td></td>
<td>ii) Boil the water</td>
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<td></td>
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</tr>
<tr>
<td>Step</td>
<td>Hazards</td>
<td>Control Measures</td>
<td>CCPs</td>
<td>Critical Limit</td>
<td>Monitoring Procedure</td>
<td>Corrective Actions</td>
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</tr>
</tbody>
</table>
| 3. Washing | a. Introduction of pathogens through water  
b. Residual foreign matter | a. Use safe water  
b. Thorough washing | a. No  
b. Yes  
|          |                                   |                                       |      | b. As clean as possible     | b. Observation  
b. Observation | b. Re-clean |
| 4. Grating | a. Residual cyanide  
b. Pathogens  
c. Foreign matter |
|          | a. Complete grating  
b. Cleaning the equipment  
c. Use well-maintained equipment | a. Yes  
b. No  
c. Yes | a. Absence of coarse particles  
a. Observation  
|          |                                   |                                       |      | c. Free of visible foreign matter  | c. Observation  
c. Observation | c. Remove foreign material |
<p>| 5. Bagging | Chemical contamination |
|          |                                   | Use clean bags. Obtain assurance from supplier about no previous and hazardous use of the bags |
|          |                                   | Yes | Absence of chemical contaminants | Monitor the source and other uses of bags | Use other bags |
| 6. Fermentation under weight | Growth of pathogens and production of toxin, e.g. Staphylococcus aureus |
|          |                                   | Rapid fermentation | Yes | Acid taste and characteristic odours within 24 hours | Observation smelling and tasting | Discard |</p>
<table>
<thead>
<tr>
<th>Step</th>
<th>Hazards</th>
<th>Control Measures</th>
<th>CCPs</th>
<th>Critical Limit</th>
<th>Monitoring Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
</table>
| 7. Roasting | a. Residual cyanide | a. Thorough roasting  
ii) Breaking up lumps | a. Yes | a. Sufficient time for roasting  
i) Observation | a. Time keeping  
i) Observation | a. Continue roasting  
i) Breaking up lumps |
|          | b. Mould growth during storage, if high moisture content | b. Same as above | b. Yes | b. Same as above | b. Same as above | b. Same as above |
| 8. Cooling | Contamination through environment | Cool under hygienic conditions e.g. put in clean container and clean environment | No | | |
| 9. Storing | Mould growth during storage, if high moisture content | Thorough roasting (see step 7: roasting); and keep in dry conditions | No, see step 7 | | |
| 10. Soaking and serving | a. Recontamination with water | a. Use safe water  
see step 1 | a. Yes  
see step 1 | a. See step 1 (water) | a. See step 1 (water) | a. See step 1 (water) |
|          | b. Recontamination by dirty hands, utensils, environment | b. Wash hands and use clean utensils | b. Yes | b. Washing with soap and thorough rinsing with clean water | b. Observation | b. Thorough heating |
|          | c. Growth of pathogens and spores of Bacillus cereus, if consumption delayed for more than four hours | c. Consumption without delay | c. Yes | c. Use within four hours | c. Time keeping | c. Thorough heating |
## ANNEX 7

### SUMMARY OF SELECTED PUBLISHED DATA DEMONSTRATING PATHGEN INHIBITION BY LACTIC ACID BACTERIA

Excerpt from background paper:
Adams, M.R. and Nicolaides, I. Review of sensitivity of different foodborne pathogens to fermentation

<table>
<thead>
<tr>
<th>Species</th>
<th>Level of Inhibition</th>
<th>Lactic Acid Bacteria</th>
<th>Concentration of Lactic Acid</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SALMONELLA spp.</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Fish Sausage</strong></td>
<td></td>
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</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>Limited growth during initial 12 hours, present in end-product.</td>
<td><em>Pedococcus acidilactici</em>, isolated from &quot;Lactacel plus&quot; (p13184) High initial inoculum, &gt;10^6 CFU/g</td>
<td>Aryanta, R.W., Fleet, G.H. and Buckle, K.A., 1991</td>
<td></td>
</tr>
<tr>
<td><em>S. sofia</em></td>
<td>No growth observed.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Fish/Cassava</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>Rapidly disappeared during fermentation at 30°C.</td>
<td>LAB - Lactostart (Chr. Hansen Laboratory, Denmark)</td>
<td>Twiddy, D.R., Cross, S.J. and Cooke, R.D., 1987</td>
<td></td>
</tr>
<tr>
<td>ATCC 1311</td>
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<td></td>
</tr>
<tr>
<td><strong>Cereal Gruels</strong></td>
<td></td>
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</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>Not detected after 48 h in gruel with added starter culture.</td>
<td>LAB</td>
<td></td>
<td>Kingamkono, R. et al., 1994</td>
</tr>
<tr>
<td>No 18375</td>
<td></td>
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</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>Not detected in traditional ogi after 6 h, prepared with added starter culture (Dogik).</td>
<td><em>Lactobacillus acidophilus</em> (DK 77)</td>
<td>Olukoya, D.K. et al., 1994</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lactobacillus plantarum</em> (DK 99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>The higher the proportion of fermented ingredient base (supporting a high level of LAB), the lower the pH of the porridge was after preparation. At pH ≤4.16 a reduction in the level of the pathogen was observed.</td>
<td>LAB</td>
<td></td>
<td>Nout, M.J.R., Rombouts, F.M. and Havelaar, A., 1989</td>
</tr>
<tr>
<td><strong>Rice-based Weaning Food</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>Inhibition occurred only when initial level of LAB were present in comparison with a low contamination level of the pathogen. The pathogen was unable to grow when added to the pre-fermented weaning food (24 h).</td>
<td><em>Lactococcus lactis</em> NCIB 497</td>
<td>Titratable acidity of pre-fermented weaning food 0.23 - 0.26% (96% lactic acid)</td>
<td>Yusof, R.M., Morgan, J.B. and Adams, M.R., 1993</td>
</tr>
<tr>
<td>USCC18375</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Level of Inhibition</th>
<th>Lactic Acid Bacteria LAB</th>
<th>Concentration of Lactic Acid</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dairy</strong></td>
<td></td>
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</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td>Not detected after 30 days in cheese curd nor, at any time, in the corresponding brine in the presence of starter culture.</td>
<td>Cheddar cheese starter culture LAB (Chr. Hansen Laboratory, Denmark.)</td>
<td></td>
<td>Abdalla, O.M., Davidson, P.M. and Christen, G.L., 1993</td>
</tr>
<tr>
<td><em>S. enteritidis</em></td>
<td></td>
<td></td>
<td></td>
<td>Ashenafi, M., 1993</td>
</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><em>S. dublin</em></td>
<td>Readily destroyed during fermentation in Lebanon bologna prepared with starter culture.</td>
<td>LAB</td>
<td></td>
<td>Smith, J.L. <em>et al.</em>, 1975</td>
</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Salmonella spp.</td>
<td>Levels of the pathogen remained constant or increased by 1 log cycle in fermented sausage production.</td>
<td>LAB</td>
<td></td>
<td>Alford, J.A. and Palumbo, S.A., 1969</td>
</tr>
<tr>
<td><em>S. typhimurium</em></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>S. enteritidis</em></td>
<td>Not detected in a mixed culture at pH 3.8.</td>
<td>Lactobacillus acidophilus</td>
<td></td>
<td>Cleplinska, T. and Zychowiec, C., 1974</td>
</tr>
<tr>
<td><strong>Laboratory medium</strong></td>
<td></td>
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</tr>
<tr>
<td><em>S. typhimurium</em></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><em>S. enteritidis</em></td>
<td></td>
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</tr>
<tr>
<td><strong>CAMPYLOBACTER spp.</strong></td>
<td></td>
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<tr>
<td><em>C. jejuni</em></td>
<td>Inhibited after 28 h in fermenting gruels.</td>
<td>LAB</td>
<td></td>
<td>Kingamakomo, R. <em>et al.</em>, 1994</td>
</tr>
<tr>
<td><em>C. jejuni</em></td>
<td>Not detected in traditional <em>ogi</em> after 6 h, prepared with added starter culture (DogiiK).</td>
<td>Lactobacillus acidophilus (DK 77) Lactobacillus pentosus (DK 99)</td>
<td></td>
<td>Olukoya, D.K. <em>et al.</em>, 1994</td>
</tr>
<tr>
<td>Species</td>
<td>Level of Inhibition</td>
<td>Lactic Acid Bacteria LAB</td>
<td>Concentration of Lactic Acid</td>
<td>Reference</td>
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<tr>
<td>----------------------------------------------</td>
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</tr>
<tr>
<td>Y. enterocolitica</td>
<td>Not detected in traditional <em>o.gi</em> after 6 h, prepared with added starter culture.</td>
<td><em>Lactobacillus acidophilus</em> (DK 77)</td>
<td></td>
<td>Olukoya, D.K. et al., 1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lactobacillus pentosus</em> (DK 99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y. enterocolitica, serotype O:5</td>
<td>Antagonistic effect was obtained with both strains of LAB. The pathogen was not detected after day 4 in extract inoculated with LKE 5 or at day 6 in extract inoculated with <em>V. 6</em>.</td>
<td><em>Leuconostoc</em> spp. (V 6)</td>
<td></td>
<td>Jeppesen, V.F. and Huss, H.H., 1993</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lactobacillus plantarum</em> (LKE 5)</td>
<td></td>
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<tr>
<td><strong>ESCHERICHIA COLI</strong></td>
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<tr>
<td>Fish Sausage</td>
<td></td>
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<tr>
<td><em>E. coli</em> (strain 2)</td>
<td>No growth observed.</td>
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<tr>
<td>Fish/Cassava</td>
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<tr>
<td><em>E. coli</em> ATCC 11775</td>
<td>Rapidly disappears during fermentation at 30°C.</td>
<td>LAB - Lactostart (Chr. Hansen Laboratory, Denmark)</td>
<td></td>
<td>Twiddy, D.R., Cross, S.J. and Cooke, R.D., 1987</td>
</tr>
<tr>
<td>Cereal Gruels</td>
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</tr>
<tr>
<td>Enterotoxigenic <em>E. coli</em> STEC No 28662</td>
<td>Reduced to undetectable limits after 32 h of fermentation in the gruel containing starter cultures.</td>
<td>LAB</td>
<td></td>
<td>Kinamkono, R. et al., 1994</td>
</tr>
<tr>
<td>Enteropathogenic <em>E. coli</em> Enteroxigenic <em>E. coli</em></td>
<td>Not detected in traditional <em>o.gi</em> after 6 h, prepared with added starter culture (DogIK).</td>
<td></td>
<td></td>
<td>Olukoya, D.K. et al., 1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lactobacillus acidophilus</em> (DK 77)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td><em>Lactobacillus pentosus</em> (DK 99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rice-based Weaning Food</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><em>E. coli</em> ATCC 25922</td>
<td>Inhibition occurred only when a high initial level of LAB were present in comparison with a low level of the pathogen. The pathogen was unable to grow when added to the pre-fermented weaning food (24h).</td>
<td><em>Lactooccus lactis</em> NCIB 497</td>
<td></td>
<td>Yusuf, R.M., Morgan, J.B. and Adams, M.R., 1993</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lactobacillus plantarum</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microbiology Dept Culture Collection, University of Surrey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Level of Inhibition</td>
<td>Lactic Acid Bacteria (LAB)</td>
<td>Concentration of Lactic Acid</td>
<td>Reference</td>
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</tr>
<tr>
<td><em>E. coli</em> OFC 491</td>
<td>Growth inhibited by the presence of LAB.</td>
<td><em>Lactococcus lactis</em> spp. <em>lactis</em> MOS-11, <em>Lactobacillus confusus</em> NGB-82</td>
<td>Isono, Y., Shingu, I. and Shimizu, S., 1994</td>
<td></td>
</tr>
<tr>
<td><strong>E. COLI 0157:H7</strong></td>
<td></td>
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</tr>
<tr>
<td>Meat</td>
<td>A five strain mix: <em>E. coli</em> O157:H7 (932), <em>E. coli</em> O157:H17 (CL8), <em>E. coli</em> 933,EC 204P and EC 505B</td>
<td>No growth of the pathogens was observed during the manufacture of fermented dried sausage, initial level of 10^6 cfu/g. As bacteriocins offer little or no protection against Gram negative bacteria inactivation of <em>E. coli</em> O157:H7 in this product would be due principally to acidity and drying.</td>
<td>Lactacel 115 (<em>Pediococcus acidilactici</em>). Added as recommended at levels of ca. 10^6 cfu/g.</td>
<td>Glass, K.A. et al., 1992</td>
</tr>
<tr>
<td><strong>SHIGELLA spp.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereal Gruels</td>
<td><em>S. sonnei</em> <em>S. flexneri</em></td>
<td>Not detected in traditional or after 6 h prepared with added starter culture (DogK).</td>
<td><em>Lactobacillus acidophilus</em> (DK 77), <em>Lactobacillus pentosus</em> (DK 99)</td>
<td>Olukeya, D.K. et al., 1994</td>
</tr>
<tr>
<td><strong>S. flexneri</strong></td>
<td>Not detected after 48 h in the fermenting gruel in the presence of starter culture.</td>
<td><em>LAB</em></td>
<td></td>
<td>Kingamikono, R. et al., 1994</td>
</tr>
<tr>
<td>Fermented Maize Dough</td>
<td><em>S. flexneri</em> (20 strains)</td>
<td>14 strains showed complete inhibition, whilst 6 showed partial inhibition in fermented dough.</td>
<td><em>LAB</em></td>
<td>Mensah, P. et al., 1991</td>
</tr>
<tr>
<td>Rice-based Weaning Food</td>
<td><em>S. sonnei</em> USCC 2006</td>
<td>Inhibition occurred only when a high initial level of LAB were present in comparison with a low contamination level of the pathogen. The pathogen was unable to grow when added to the pre-fermented weaning food (24 h).</td>
<td><em>Lactococcus lactis</em> NCIB 497, <em>Lactobacillus plantarum</em></td>
<td>Titratable acidity of pre-fermented weaning food = 0.23-0.27% (96% lactic acid)</td>
</tr>
<tr>
<td>Species</td>
<td>Level of Inhibition</td>
<td>Lactic Acid Bacteria LAB</td>
<td>Concentration of Lactic Acid</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------------</td>
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</tr>
<tr>
<td><em>S. sonnel</em></td>
<td>Not detected in laboratory medium in a mixed culture at pH 3.8.</td>
<td><em>Lactobacillus acidophilus</em></td>
<td></td>
<td>Cieplinska, T. and Zychowicz, C., 1974</td>
</tr>
<tr>
<td><em>VIBRIO spp.</em></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><em>V. cholerae</em></td>
<td>Not detected in traditional <em>ogt</em> after 6 h, prepared with added starter culture.</td>
<td><em>Lactobacillus acidophilus</em> (DK 77)</td>
<td></td>
<td>Ohukoya, D. K. <em>et al.</em>, 1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lactobacillus pentosus</em> (DK 99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>V. parahaemolyticus</em></td>
<td>No growth observed.</td>
<td><em>Pedicoccus acidilactici</em>. High initial inoculum, &gt; 10^7 cfu/g</td>
<td></td>
<td>Aryanta, R. W., Fleet, G.H. and Buckle, K.A., 1991</td>
</tr>
<tr>
<td><em>STAPHYLOCOCCUS AUREUS</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Fish Sausage</em></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Fish/Cassava</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. aureus</em> ATCC 9144</td>
<td>Rapidly disappeared during fermentation at 30°C.</td>
<td>LAB - Lactostart (Chr. Hansen Laboratory, Denmark)</td>
<td></td>
<td>Twiddy, D.R., Cross, S.J. and Cooke, R.D., 1987</td>
</tr>
<tr>
<td><em>Cereal Gruels</em></td>
<td></td>
<td>LAB</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>S. aureus</em></td>
<td>The higher the proportion of fermented ingredient base (supporting a high level of LAB) the lower the pH of the porridge was after preparation. At pH ≤ 4.16 a reduction in the level of the pathogen was observed.</td>
<td></td>
<td></td>
<td>Nout, M.J.R., Rombouts, F.M. and Havelaar, A., 1989</td>
</tr>
<tr>
<td><em>Rice-based Weaning Food</em></td>
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<td><em>S. aureus</em> ATCC 25923</td>
<td>Inhibition occurred only when a high initial level of LAB were present in comparison with a low level of the pathogen. The pathogen was unable to grow when added to the pre-fermented weaning food (24h)</td>
<td><em>Lactococcus lactis NCIB 497</em></td>
<td></td>
<td>Yusof, R. M., Morgan, J.B. and Adams, M.R., 1993</td>
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<td></td>
<td></td>
<td><em>Lactobacillus plantarum</em></td>
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<td>Microbiology Dept. Culture Collection, University of Surrey</td>
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<tr>
<td>Species</td>
<td>Level of Inhibition</td>
<td>Lactic Acid Bacteria LAB</td>
<td>Concentration of Lactic Acid</td>
<td>Reference</td>
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<td><strong>Cabbage salad</strong></td>
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<tr>
<td><em>S. aureus</em></td>
<td>3-4 generations of growth, followed by a gradual decline after 7 hours (change of incubation temperature from 42°C to 7°C). After 2 h at 7°C, a rapid decline observed. An increase &gt; 1 log cycle before decline observed after 100 h. Similar decline (&gt;0.5 log cycle when incubation temperatures changed from 42°C to 7°C).</td>
<td>Lactobacillus piniarum Nos 9 and 20.</td>
<td>1.75 g/kg salad &amp; 2.2 g/kg salad produced after 7 h, 3.0 g/kg salad &amp; 3.5 g/kg salad after 1.5 h at 7°C.</td>
<td>Bonestroo, M.H. et al., 1993</td>
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<tr>
<td><strong>Dairy</strong></td>
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<tr>
<td><em>S. aureus</em></td>
<td>The growth of the pathogen was inhibited by the LAB.</td>
<td>Lactococcus lactis ssp. lactis MOS-11</td>
<td>0.9% (w/v)</td>
<td>Isono, Y., Shingu, I. and Shimizu, S., 1994</td>
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<tr>
<td>ATCC 25923</td>
<td></td>
<td>Lactobacillus confusus NGB-82</td>
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<tr>
<td><em>S. aureus</em></td>
<td>Not detected after 30 days in curd and 20 days in brine solution of corresponding cheese, in the presence of starter culture.</td>
<td>Cheddar cheese LAB starter culture (Chr. Hansen Laboratory, Denmark)</td>
<td></td>
<td>Abdalla, O.M., Davidson, P.M. and Christon, G.L., 1993</td>
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<tr>
<td>NRRL B-4420</td>
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<td><strong>Meat</strong></td>
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<tr>
<td><em>S. aureus</em></td>
<td>Growth and subsequent toxin production by <em>S. aureus</em> is greater at 25°C than at 30°C.</td>
<td>Lactococcus lactis was more inhibitory to <em>S. aureus</em> than <em>Pediococcus cerevisiae</em></td>
<td></td>
<td>Haines, W.C. and Harmon, L.G., 1973</td>
</tr>
<tr>
<td><em>S. aureus</em></td>
<td>The presence of LAB, reduced pH level and anaerobic conditions inhibited the production of enterotoxin.</td>
<td>LAB</td>
<td></td>
<td>Barber, L.E. and Deibel, RH., 1972</td>
</tr>
<tr>
<td><em>S. aureus</em></td>
<td>The presence of LAB, reduced pH level and anaerobic conditions inhibited the growth of the pathogen.</td>
<td>LAB</td>
<td></td>
<td>Peterson, A.C. et al. 1964; Daly, C. et al., 1973</td>
</tr>
<tr>
<td>Species</td>
<td>Level of Inhibition</td>
<td>Lactic Acid Bacteria (LAB)</td>
<td>Concentration of Lactic Acid</td>
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<td><strong>LISTERIA MONOCYTOGENES</strong></td>
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<tr>
<td><em>L. monocytogenes</em></td>
<td></td>
<td><em>Lecconostoc spp., off-odours were produced (diacetyl).</em></td>
<td></td>
<td>Jeppesen, V.F., 1993</td>
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<td><em>Lactobacillus plantarum</em></td>
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<td></td>
<td>The enterococci isolated from &quot;sous-vide&quot; cod fillets</td>
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<tr>
<td>Scott A</td>
<td></td>
<td><em>Lactobacillus plantarum</em> (LKE 5)</td>
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<td><strong>Salads - Fermented Sauce</strong></td>
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<td><em>L. monocytogenes</em>,</td>
<td>Following inoculation, 2-3 generations of growth occurred during fermentation followed by a rapid decline to undetectable levels.</td>
<td><em>Lactobacillus spp.</em></td>
<td></td>
<td>Bonestroo, M.H., et al., 1993</td>
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<tr>
<td>Scott A</td>
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<tr>
<td><em>L. monocytogenes</em>,</td>
<td>For all test strains the level of pathogen increased by 1.0 - 1.7 log units during the initial 12 h souring of <em>Ergo</em>. The counts of the pathogen then decreased to undetectable levels after 48 or 60 h in unsmoked containers. Smoking of the container increased the rate of inactivation when the pathogen was not detected after 36 h.</td>
<td><em>LAB</em></td>
<td></td>
<td>Asenafi, M., 1994</td>
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<td>strains WS2300,</td>
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<td>WS2301 and WS2302</td>
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<td><em>L. monocytogenes</em></td>
<td>Not detected by direct plating in cheese with added starter culture</td>
<td><em>Cheddar cheese LAB starter culture (Chr. Hansen Laboratory, Denmark)</em></td>
<td></td>
<td>Abdalla, O.M., Davidson, P.M., and Christen, G.I., 1993</td>
</tr>
<tr>
<td>Species</td>
<td>Level of Inhibition</td>
<td>Lactic Acid Bacteria LAB</td>
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<tr>
<td>L. monocytogenes, V.7</td>
<td>Growth inhibited but not significantly reduced in Tyndallized skim milk and Tyndallized twofold retentate; level of contamination reduced by 2 log cycles in permeate from UK skim milk</td>
<td>Lactococcus lactis spp. cremoris</td>
<td>El-Gazzar, F.A., Böhner H.F. and Marth, E.H., 1993</td>
<td></td>
</tr>
<tr>
<td>L. monocytogenes Scott A</td>
<td>Eventual decrease in levels of pathogen in presence of starter cultures.</td>
<td>LAB starter culture</td>
<td>Abdalla, O.M., Davidson, P.M. and Christen, G.I., 1993</td>
<td></td>
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<tr>
<td>L. monocytogenes SSICA 38 and SSICA 150, both serotype 1.</td>
<td>The addition of starter culture prevented growth of the pathogen, although low levels were present during fermentation and the subsequent ripening stage. L. monocytogenes was not isolated from the end-product prepared with the bacitracin positive strain (MCS).</td>
<td>Lactobacillus plantarum MCS (bacteriocin positive strain) Lactobacillus plantarum MCS1 (bacteriocin negative strain)</td>
<td>Campanini, M. et al., 1993</td>
<td></td>
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<tr>
<td>L. monocytogenes</td>
<td>Inhibition of the pathogen was demonstrated.</td>
<td>Lactobacillus plantarum Lactobacillus curvatus Leuconostoc spp.</td>
<td>Giraffa, G. et al., 1994</td>
<td></td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>Will survive the fermentation and ripening stages during the manufacture of fermented sausage.</td>
<td>LAB</td>
<td>Buncic, S., Paunovic, L. and Radisic, D., 1991</td>
<td></td>
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<tr>
<td>L. monocytogenes</td>
<td>Greater than 4 log cycles of the pathogen were killed during fermentation and drying (within 5 days after the start of the drying cycle).</td>
<td>LAB</td>
<td>Glass, K.A. and Doyle, M.P., 1989</td>
<td></td>
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</tbody>
</table>

**BACILLUS CEREUS**

**Fish**

<p>| B. cereus No 10781           | No viable cells were detected after 24 h in the gills containing starter cultures. | LAB                      | Kingamkono, R. et al., 1994 |
| B. cereus                   | Not detected after inoculation into salad before fermentation with selected starter cultures. | Lactobacillus spp.       | Bonevstro, M.H. et al., 1993 |</p>
<table>
<thead>
<tr>
<th>Species</th>
<th>Level of Inhibition</th>
<th>Laetic Acid Bacteria LAB</th>
<th>Concentration of Lactic Acid</th>
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<td><strong>CLOSTRIDIUM spp.:</strong></td>
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<td></td>
<td></td>
<td>Fish</td>
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<tr>
<td>C. perfringens</td>
<td>No growth observed</td>
<td>Pediciococcus acidilactici, isolated from &quot;Lactocel plus&quot; (LP13184). High initial inoculum, &gt;10⁷ cfu/g.</td>
<td></td>
<td>Aryanta, R.W., Fleet, G.H., and Buckle, K.A., 1991</td>
</tr>
<tr>
<td>C. perfringens</td>
<td>Inhibition in sous-vide seafood - more detailed work in progress</td>
<td>The enterococci isolated from sous-vide cod fillets</td>
<td></td>
<td>Jeppesen, V. F., 1993</td>
</tr>
<tr>
<td>C. botulinum</td>
<td>Inhibition in sous-vide seafood - more detailed work in progress</td>
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<tr>
<td>C. sporogenes</td>
<td>Rapidly disappear during fermentation at 30°C</td>
<td>LAB - Lactostart (Chr. Hansen Laboratory, Denmark)</td>
<td></td>
<td>Twiddy, D. R., Cross, S. J. and Cooke, R.D., 1987</td>
</tr>
</tbody>
</table>
References to Review of sensitivity of different foodborne pathogens to fermentation


Daly, C., Lachance, M., Sandine, W.E. and Elliker, P.R. (1973) Control of *Staphylococcus aureus* in sausage by starter cultures and chemical acidulation. *Journal of Food Science* **38** 426-430.


Haines, W.C. and Harmon, L.G. (1973) Effect of variations in conditions of incubation upon inhibition of Staphylococcus aureus by Pediococcus cerevisiae and Streptococcus lactis. Applied Microbiology 25 (2) 169-172.


