

**Locally Fermented Foods in Nigeria and their Significance to
National Economy: a Review**

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Abstract

Locally fermented foods are produced by the activities of microorganisms, which while forming only a small proportion of the total weight of the foods, have profound effects on the character of the food. Locally fermented foods in Nigeria are grouped into tubers (e.g. gari, and fufu), cereals (e.g. ogi and pito), legumes (e.g. dawadawa and iru), milk (e.g. local cheeses) and beverages (e.g. palm wine). The mechanism of fermentation is biochemical and it involves lactic acid fermentation to yield products such as organic acids, alcohols, aldehydes and ketones. Some species of microorganisms involved in fermentation are *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Enterococcus*, *Streptococcus*, *Penicillium* and *Saccharomyces*. Locally fermented foods are significant in provision of employment opportunities, market improvement, availability of food supplement and poverty alleviation. Some advantages of locally fermented foods are enhancement of organoleptic and preservative properties, provision of nutritional quality, detoxification and production of antibiotics. However, they contribute to food spoilage and health defects. Some factors influencing production of locally fermented foods are temperature, water activity, hydrogen ion concentration (pH), oxygen availability and substrate used for food fermentation process.

Key words: Fermented foods, locally, fermentation, microorganisms, lactic acid

Introduction

Locally fermented food is a form of food processing, where microbes, for example, lactic acid bacteria (LAB) are utilized for food production via the process known as fermentation (Chelule *et al.*, 2010). Fermentation in food processing is the conversion of carbohydrates to alcohol and carbon dioxide or organic acids using yeast and/or bacteria, under anaerobic conditions (William and Dennis, 2011; Wikipedia, 2012). Fermentation is one of the classic methods to preserve foods. Lactic acid bacteria (LAB) and yeasts are responsible for most of these fermentations (Adenike *et al.*, 2007; Adeleke *et al.*, 2010). The weight of the microorganisms in the food is usually small, but their influence on the nature of the food, especially in terms of flavour, and other organoleptic properties, is profound (Okafor, 2009).

Nigeria has a variety of people and culture that it is difficult to pick one national dish. Each area has its own regional favorite food that depends on customs, tradition and religion (Abdel *et al.*, 2009; Adebayo *et al.*, 2010). The fermentation processes for these foods constitute a vital body of indigenous knowledge used for food preservation, acquired by observations and experience, and passed on from generation to generation (Aworh, 2008; Chelule *et al.*, 2010). Lactic acid bacteria (LAB) isolated from these foods displayed probiotic properties such as hypolipidemic, hepatoprotective and antibacterial and had been found to be effective in treating gastroenteritis in man and animals (Aderiye *et al.*, 2007). The fermentation techniques are often a small scale and household basis, characterized by the use of simple non-sterile equipment, chance or natural inoculums, unregulated conditions, sensory fluctuations, poor durability and unattractive packing of the processed products resulting in food of unpredictable quality (Olanrewaju *et al.*, 2009). With increasing industrialization and urbanization, efforts are presently geared towards the development of large-scale factory production facilities for these foods where the quality of the finished product will be assured (Agarry *et al.*, 2010).

This review article focuses on the various changes of fermented food products in Nigeria and their significance to national economy.

Mechanism of Food Fermentation by Lab

During fermentation, pyruvate is metabolized to various compounds (Wikipedia, 2012). To extract chemical energy from glucose, the glucose molecule must be split into two molecules of pyruvate (Wikipedia, 2011). This process generates two molecules of reduced nicotinamide adenine dinucleotide (NADH) and also four molecules of adenosine triphosphate (ATP), yet there is only net gain of two ATP molecules considering the two initially consumed by the reaction (Wikipedia, 2012). Most cells will carry out further reactions to 'repay' the used NAD^+ and produce a final product of ethanol or lactic acid (Wikipedia, 2012). This is performed by the lactic acid bacteria through homofermentative or heterofermentative pathway.

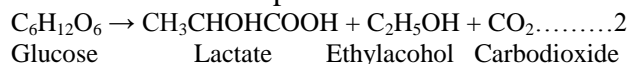
a) Homolactic acid fermentation

Lactate Dehydrogenase catalyzes reduction of the keto group in pyruvate to a hydroxyl, yielding lactate, as NADH is oxidized to NAD^+ . In homolactic acid fermentation, both molecules of pyruvate are converted to lactate as shown in equation (1) (Wikipedia, 2012). An example of homolactic acid fermentation is production of gari.



b) Heterolactic acid fermentation

NADH is converted to NAD^+ in the reaction catalyzed by Pyruvate and Alcohol Dehydrogenase. Other Lactic acid bacteria use alternative pathways (pentose phosphate pathway) to generate lactate from glucose. In heterolactic acid fermentation, one molecule of pyruvate is converted to lactate; the other is converted to ethanol and carbon dioxide as shown below in reaction equation (2) (Wikipedia, 2012). An example of heterolactic acid fermentation is production of burukutu.



Production of Locally Fermented Foods in Nigeria

Production of Fufu

To prepare fufu, fresh cassava tubers are peeled, washed, and made ready for soaking (Aworh, 2008). The peeled and washed tubers are cut into chunks of different sizes and soaked into drums or earthen pot of water for three to five days to undergo fermentation. The lactic acid fermentation reduces the pH value, tubers are softened and this facilitates the reduction in potentially toxic cyanogenic compounds (Uyoh, *et al.*, 2009). When sufficiently soft, the roots are taken out, broken by hand, and sieved to remove the fibers. The sieved mass is allowed to sediment in a large container for about 24 hours, the water is poured off while the fine, clean sediment (mainly starch) is dewatered using a high powered press and the cake is then sifted before drying.

Production of Gari

To prepare gari, fresh cassava tubers are peeled, washed, and grated (Chelule, 2010). The resulting pulp is put in a cloth bag or porous sack and weighted down with a heavy object at ambient temperature for two to four days to remove effluent (waste material) from the pulp while it is fermenting. The de-watered and fermented lump is pulverized, sieved and the resulting semi-dry fine pulp is toasted in a pan. The grating, effluent expressing, pulverization, toasting, and the addition of palm oil as some processors do are adequate to reduce hydrogen cyanide (HCN) to a safe level (Aworh, 2008). Fermentation imparts a sour taste to gari while toasting extends its shelf-life. During fermentation, endogenous linamarase present in cassava roots hydrolyze linamarin and lotaustralin releasing hydrogen cyanide (HCN) (Aworh, 2008; Wikipedia, 2011).

Production of Burukutu and Pito

The production involves the processes of malting, mashing, boiling, fermentation and maturation (Yabaya, 2008). Sorghum or millet grains are washed and soaked in water for a few minutes. They are removed, spread on mats or trays placed on a bare ground and covered with banana leaves for 2-5 days to enhance germination or sprouting. The grains are sun-dried. A portion of the sprouted grains are wet-milled, mixed with cold

water and filtered. The filtrate is boiled in water for a day or 12 hours until a properly cooked, dark sweet concentrate is obtained. The sweet concentrate is left to cool and regarded as 'malt' (Egbere, 2008). The rest of the sprouted bulk is wet-milled, mixed with water and filtered. The filtrate is boiled for 3-4 hours after which it is left to cool. The malt was added to inoculate the bulk with the fermenting micro flora. At this stage burukutu is sweat. The non-alcoholic liquor is left at room temperature for 24 hours to enhance alcoholic fermentation. The final product, buraleutic is obtained by sieving out the liquor (Achi, 2008).

Pito is obtained by getting out the supernatant of the buraleutic or diluting the buraleutic with water to a normal viscosity (Sade, 2010). In some place gar or grinded roasted maize is added as an adjunct (Egbere, 2008; Sade, 2010).

Production of Daddawa (Iru)

Daddawa (Iru), an African locus bean (*Parkia biglobosa*) is the most important food condiments used to flavor soups and stews in Nigeria (Odebunmi *et al.*, 2010; Onyenekwe *et al.*, 2012). According to Aworh (2008), African locust bean seeds are first boiled for 12-15 hours or until they are tender, this is followed by dehulling by gentle pounding in a mortar or by rubbing the seeds between the palms or trampling under foot and sand or other abrasive agents may be added to facilitate dehulling. The dehulled seeds are boiled for 30 minutes to 2 hours, molded into small balls and wrapped in paw-paw leaves or banana leaves. A softening agent called 'kuru' containing sunflower seed and trona or 'kaun' (sodium sesquicarbonate) may be added during this second boiling to aid softening of the cotyledons, then covered with additional banana leaves or placed in raffia mats and allowed to ferment for 2-3 days been covered with jute bags.

Fermentation is usually carried out in a moist solid state involving contact with appropriate microorganism at the ambient temperatures; the completion of fermentation is indicated by formation of mucilage and overtones of ammonia produced as a result of breakdown of amino acids during fermentation (Onyenekwe *et al.*, 2012). The fermented product is salted, molded into various

shapes and dried (Aworh, 2008). Okpehe from (*Prosopis africana* seeds), 'dawadawa' from soybeans (*Glycine max*), Ogiri from water Melon seed (*Citrullus vulgaris*) 'Ugba' using the African oil beans (*Pentaclethra macrophylla*) are processed in a similar way (Enujiugha *et al.*, 2008; Ogueke *et al.*, 2010; Jonathan *et al.*, 2011).

Production of local Cheese (Wara)

The traditional cheese-making process was developed by the nomadic Fulani and is based on the milk-coagulating properties of juice from the leaves of the sodom apple plant (*Calotropis procera*) or pawpaw leaves (Aworh, 2008). The juice, obtained by crushing sodom apple leaves, is mixed with fermented cows' milk gently heated in a pot over a wood fire. Following coagulation, the loose curd pieces are poured into small raffia baskets and allowed to drain (Osuntoki, 2010).

Production of Banda, Suya and Kilishi

Banda (kundi), Suya (tsire or balangu), and kilishi are the most important traditional processed meats in Nigeria where they provide valuable animal protein in the diets of the people (Aworh, 2008).

Banda is a salted, smoke-dried meat product made from chunks of cheap, low quality meat from various types of livestock including donkeys, asses, horses, camel, buffalo and wild life. The meat chunks are pre-cooked before smoking or kiln drying or sun drying. The traditional smoking kiln for banda is usually an open-top, 50-gallon oil drum fitted with layers of wire mesh that hold the product, and fired from the bottom. Banda is a poor quality product, stone-hard and dark in color (Aworh, 2008).

Unlike banda, Kilishi is made by roasting spiced, salted slices or strips of meat (usually beef), but different from suya in that a two-stage sun-drying process proceeds roasting. Consequently, kilishi has lower moisture content than suya and a longer shelf life. Application of spice (e.g. ginger, chillies, melegueta pepper, onion, *Piper guineense*, *Thonningia sanguinea*, *Fagara santhoxyloides* and defatted peanut cake powder) is one of the most important stages during the production of kilishi because it is a critical control point (Shamsuddeen

and Ameh, 2008). Kilishi consists of about 46% meat and about 54% non-meat ingredients, with defatted peanut powder accounting for about 35% of the ingredient formulation (Aworh, 2008). These spices do not have a marked bacteriostatic effect in the concentrations used in meat products and they may even serve as source of contamination of processed product which causes gastrointestinal disturbances resulting from the consumption of suya in Nigeria (Shamsuddeen, 2009).

Microorganisms Involved in Fermented Food Production

Microorganisms are living creatures that are microscopic in size and are heterogeneous organisms that can be in form of plant or animal such as algae, fungi (mould and yeasts), and bacteria (Wikipedia, 2011). The multiplication of microorganisms in food is greatly influenced by the inherent (intrinsic factors) and environmental characteristics of the food (Onyenekwe *et al.*, 2012). In general, microorganisms multiply mostly rapidly in moist, nutritionally-rich, pH-neutral and warm, oxygen-rich environment (Nester *et al.*, 2007).

The commonest organisms responsible for fermentation of foods are acid-forming bacteria such as genera lactic acid bacteria (LAB) such as *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Enterococcus*, *Streptococcus*, *Aerococcus* and *Pediococcus* (Chelule *et al.*, 2010; Agarry *et al.*, 2010; Wikipedia, 2011) known as obligate fermenters, flavorful organisms (aromatic compound microorganisms) and *Propionibacterium* species (Bukola and Abiodun, 2008). The yeasts are mainly of the species *Saccharomyces*, *Candida*, *Kluyveromyces* and *Debaryomyces* (Omemu *et al.*, 2007; Chelule *et al.*, 2010). Moulds have been used mainly in milk and cheese fermentation (William and Dennis, 2011) and these include *Penicillium*, *Mucor*, *Geotrichium*, and *Rhizopus* species (Chelule *et al.*, 2010) of more importance are the LAB. The lactic acid bacteria (LAB) are a group of Gram positive bacteria, non-respiring, non-spore forming, cocci or rods, the genera *Lactobacillus*, *Leuconostoc*, *Pediococcus* and *Streptococcus* are the main species that play a key role in safety and

acceptability of the products of carbohydrates in tropical climate (Nwachukwu *et al.*, 2010). Most pathogenic microorganisms found in food cannot survive the low pH, hence, Lactic acid fermentation of food has been found to reduce the risk of having pathogenic microorganisms grow in the food (Abdel *et al.*, 2009).

Alkaline fermentations cause the hydrolysis of protein to amino acids and peptides and releasing ammonia, which increases the alkalinity by the *Bacillus* species such as *Bacillus subtilis* (dominant species), *B. licheniformis* and *B. pumilius* (Enujiugha *et al.*, 2008; Chelule *et al.*, 2010).

This indigenous natural fermentation takes place in a mixed colony of microorganisms such as moulds, bacteria and yeasts (William and Dennis, 2011). These bacteria are not harmful to the consumers and have enzymes such as proteases, amylases and lipases that hydrolyze food complexes into simple nontoxic products with desirable textures, aroma that makes them palatable for consumption (Nwachukwu *et al.*, 2010). Thus, fermentation products in food substrates are based on the microorganisms involved in the fermentation as shown in Table 1. Some of the compounds formed during fermentation include organic acids (palmitic, pyruvic, lactic, acetic, propionic, malic, succinic, formic and butyric acids), alcohols (mainly ethanol) aldehydes and Ketones (acetaldehyde, acetoin, 2-methyl butanol) (Ari *et al.*, 2012).

Significance of Locally Fermented Foods to National Economy of Nigeria

Locally fermented Foods have a role to play in developing economies like that of Nigeria (Anukam and Reid, 2009). To develop is to conquer nature, to transform citizens to be able to succeed, with small resources in eliminating poverty, ignorance and disease, so that the nation can live in dignity. Fermented food products play a significant socio-economic role in Nigeria (Olanrewaju *et al.*, 2009). The locally fermented foods are a significant item in both local and international trade. Some of these significance of fermented foods are:

Provision of employment opportunities

By generating employment opportunities in the rural areas, small scale food industries reduce rural-urban migration and the associated social problems (Aworh, 2008).

Reduction in mortality rate

It prevents the enlargement of pancreas. "Eating an enzyme-rich diet decreases the load on pancreas, preserving the body's own natural enzyme potential, thereby reducing the risk of chronic diseases". Eat more raw food, fermented food and living food (Kristen, 2011).

Industrialisation

Likewise the locally fermented foods play a unique role in promoting industrial development in Nigeria through employment generation, value-added processing and training of skilled manpower, their impact is felt greatly in the urban areas (Aworh, 2008).

Small-scale food industries that involve lower capital investment and that rely on traditional food processing technologies are crucial to rural development in Nigeria (Aworh, 2008).

Food security:

The locally fermented foods promote and improve food processing and preservation at all levels of operation, which are essential component of national strategic plans for food security aim at achieving national food security (Adeyemi, 2008). Fermentation technology also has the potential of meeting the Nigerian's food supply demand if adequately developed into the industrial scale. Such as condiments which have being increasingly marketed throughout the country and beyond in informal ways. Fermented foods constitute a major portion of peoples' diets all over the world and provide 20 – 40% of the total food supply (Abdel *et al.*, 2009).

Poverty alleviation

It provides a source of income and means of poverty alleviation contributing to food security of Nigeria (FAO, 1997). The preparation of this locally fermented foods like kunun has become technology in many homes in the rural communities and more recently in the urban areas where commercial production due to support from the

government through the poverty alleviation scheme, has helped to alleviate poverty among the people (Essien *et al.*, 2011).

Market improvement

The availability of different locally fermented foods displayed on supermarket shelf is the proof of diversity of commodity items, convenience food and prepared food available in the market beautifying it for consumers' satisfaction (Frazier *et al.*, 2008).

Food supplement

The locally fermented foods serve as food supplement like the use of ogi as a weaning food in Southern Nigeria to supplement breastfeeding (Falana *et al.*, 2011). The fermented foods made available the diet required in human body (Egbere, 2008). Traditional fermented protein-rich foods offer excellent opportunities for improving the diets of people in tropical countries providing rich source of starch, vitamins, proteins and minerals (Oladejo and Adetunji, 2012).

Table 1: Some Nigerian locally fermented foods

Product	Substrate	Microorganism involved	Nature of food
Lafun Chips	Cassava	<i>Leuconostoc</i> spp. <i>Lactobacillus</i> spp. <i>Corynebacterium</i> spp. <i>Candida tropicalis</i>	Staple food
Gari Pulp	Cassava	<i>Leuconostoc</i> spp. <i>Lactobacillus</i> spp. <i>Streptococcus</i> spp. <i>Geotrichum candidum</i>	Staple food
Fufu	Cassava	<i>Leuconostoc</i> spp. <i>Lactobacillus</i> spp. <i>Corynebacterium</i> spp. <i>Candida tropicalis</i> <i>Streptococcus</i> spp.	Staple food
Iru	locust bean	<i>Bacillus subtilis</i> <i>B. licheniformis</i> <i>B. pumilus</i>	Condiment
Ogiri	Melon seed	<i>Bacillus</i> spp. <i>Escherichia</i> spp. <i>Pediococcus</i> spp.	Condiment
Okpehe	Mesquite	<i>Bacillus subtilis</i> <i>B. licheniformis</i> <i>B. pumilus</i>	Condiment
Burukutu, Millet Maize	Sorghum	<i>Saccharomyces</i> spp. Lactic acid bacteria	Alcoholic
Waran Milk		Lactic acid bacteria	Meat

Source: Aworh *et al.* (2008).

Food Availability

They are vital to reducing post-harvest food losses and increasing food availability (Aworh, 2008). Fermented foods are of great significant because they provide and preserve vast quantities of nutritious foods in a wide diversity of flavors,

aromas and textures which enrich the human diet (Yabaya, 2008).

Advantages and Limitations of Food Fermentation

Advantages of Food Fermentation

Some advantages of food fermentation include: general improvement in the shelf life, texture, taste and aroma, nutritional value and digestibility and it leads to significantly lowering the content of anti-nutrients of cereal products.

Organoleptic properties enhancement

Fermentation makes the food palatable by enhancing its organoleptic properties; aroma, textures and flavor (Chelule *et al.*, 2010). These organoleptic properties make fermented food more popular than the unfermented one in terms of consumer acceptance (Osungbaro, 2009).

Provision of Nutritional quality

A number of foods especially cereals are poor in nutritional value, which constitute the main staple diet of the low income populations (Chelule *et al.*, 2010). However, Lactic Acid Bacteria fermentation has been shown to improve the nutritional value and digestibility of these foods (Nout, 2009). The enzymes, which include amylases, proteases, phytases and lipases, modify the primary food products through hydrolysis of polysaccharides, proteins, phytates and lipids respectively (Adeyemi, 2008). The quantity and quality of the food proteins as expressed by biological value, and often the content of water soluble vitamins is generally increased, while the antinutrient factors (ANFs) such as phytic acid and tannins in food decline during fermentation leading to increased bioavailability of minerals such as calcium, phosphorus, zinc, iron, amino acids and simple sugars (Santos *et al.*, 2008; Soetan and Oyewole, 2009; Murwan and Ali, 2011).

Preservative properties

The preservative activity of local fermentation has been observed in some fermented products such as cereals and fruits (Adeyemi, 2012). The lowering of the pH to below 4 through acid production inhibits the growth of pathogenic organisms which cause food spoilage, food poisoning and disease and by doing this, the shelf life of fermented food is prolonged (Abdel, 2009; Olukoya *et al.*, 2011). It makes food safe for consumers in terms of stability, transportation and storage (Chelule *et al.*, 2010).

Detoxification during food fermentation

Food and feeds are often contaminated with a number of toxins like fumonisins, ocratoxin A, zearalenone and aflatoxins, (mycotoxins) either naturally or through infestation by microorganisms such as moulds, yeast, bacteria and viruses (Ari *et al.*, 2012). Using Lactic acid bacteria in fermentation detoxified toxins and is more advantageous, in that it is a milder method which preserves the nutritive value and flavor of foods (Chelule *et al.*, 2010). In addition to this, fermentation irreversibly degrades mycotoxins without adversely affecting the nutritional value of the food (Ari *et al.*, 2012) and without leaving any toxic residues.

Production of antibiotic

Some of the inhibitory compounds against other bacteria include hydrogen peroxide and bacteriocins (Olanrewaju *et al.*, 2009). A myriad of beneficial activities such as immunomodulatory, antiallergenic, antimicrobial, antihypertensive and antitumourigenic effects have been reported (Osuntoki, 2010). One of the supporting use of LAB fermentation to prevent diarrheal diseases is because they modify the composition of intestinal microorganisms and by this, act as deterrents for pathogenic enteric bacteria (Olukoya *et al.*, 2011). Thus, Lactic Acid Bacteria are applied as a barrier against non-acid tolerant bacteria, which are ecologically eliminated from the medium due to their sensitivity to acidic environment (Agarry *et al.*, 2010). Also, fermentation has been demonstrated to be more effective in the removal of Gram negative than the Gram-positive bacteria, which are more resistant to fermentation processing. As such, fermented food can control diarrhoeal diseases in children.

Moreover, Lactic Acid Bacteria are also known to produce protein antimicrobial agents such as bacteriocins, peptides that elicit antimicrobial activity against food spoilage organisms and food borne pathogens, but do not affect the producing organisms.

A decrease in cooking time and fuel requirement

Processing to destroy any anti-nutrients will facilitate processing and cooking and improve the nutritional quality of fermented foods, such as cereals and legumes, especially sorghum and beans as in the case of fermented soybeans products, or ogi from maize (Egber, 2008; Wikipedia, 2012).

Health benefits of fermented foods

Many of the fermented products consumed by different ethnic groups have therapeutic values, some of the most widely known are fermented milks (i.e., yoghurt, curds) which contain high concentrations of pro-biotic bacteria that can lower the cholesterol level (Jyoti, 2010), improvement of nutrients absorption and digestion, restores the balance of bacteria in the gut to hinder constipation, abdominal cramps, asthma, allergies, lactose and gluten intolerance (Abdel *et al.*, 2009). The slurries of carbohydrate based fermented Nigerian foods such as ogi, fufu and waran have been known to exhibit health promoting properties such as control of gastroenteritis in animals and human (Aderiye *et al.*, 2007;; Olukoya *et al.*, 2011). Raw fermented foods are rich in enzymes. Our body needs enzymes to properly digest, absorb and make full use of food. As you age, your body's supply of enzyme decreases (Egber, 2008).

Limitation of Food Fermentation

Food spoilage

The negative effects include spoilage of food products and contamination by pathogenic microorganisms (Adeyemi, 2012). By increasing their numbers, utilizing nutrients, causing enzymatic changes, and contributing off-flavours through breakdown of a product or synthesis of new compounds, they can spoil a food. Oxidation of food constituents is also a key event in food spoilage which may reduce the nutritional value and safety of the food by producing undesirable flavours and toxic substances while addition of synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) to foods have been reported to have side effects (Osuntoki, 2010).

Health defect

Chronic cyanide toxicity is also associated with several health conditions including konzo, an irreversible paralysis of the legs reported Aworh, (2008), the problem of food-borne diseases like cases of botulism (Wikipedia, 2012) and death due to diarrhea (Oluwafemi *et al.*, 2011). They are labor-intensive: Labor requirements for traditional processing locally fermented foods like cassava into gari, fufu, lafun and other products are huge or cumbersome (Aworh, 2008).

Influence of a western diet and fast foods

However, though most fermented foods have health-promoting benefits; their global consumption is declining as traditional food systems give way to the influence of a western diet and fast foods (Jyoti, 2010).

Socio-economics of the consumer base

The consumer base of traditionally fermented foods in most developing countries is largely poor. Price, rather than food safety or nutritional security and quality that make a substantial contribution to their food, is therefore a major preoccupation of this group when purchasing food (FAO, 2010).

Crude handling of traditionally fermented foods

According to Achi (2005), the following factors work against traditional fermented foods: Inadequate raw material grading and cleaning contributing to the presence of foreign matter (such as insects, stones) in final product, crude handling and processing techniques employed, lack of durability (shelf life), lack of homogeneity and unattractive presentation.

These were found as a result from the following limitations associated with different aspects of indigenous fermentation processes, thus: a production environment which fails to observe good manufacturing practice (GMP) or code of hygiene; lack of knowledge of the culture of the processes and their characteristics; absence of any control in the processing variables like pH, temperature, humidity, and quality of water were unknown and were unable to be used to regulate the process; lack of awareness of the nutritional and

toxicological implications of fermentation and its products (Olanrewaju, 2009).

Factors Influencing the Development of Fermented Foods

Temperature

Different bacteria can tolerate different temperatures, which provide enormous scope for a range of fermentations (Lee *et al.*, 2011). While most bacteria have a temperature optimum of between 20 to 30°C, there are some (the thermophiles) which prefer higher temperatures (50 to 55°C) and those with colder temperature optima (15 to 20°C). Most lactic acid bacteria work best at temperatures of 18 to 22°C. The *Leuconostoc* species which initiate fermentation have an optimum of 18 to 22°C. Temperatures above 22°C, favour the *Lactobacillus* species (Food and Drug Administration, FDA, 2011).

Salt concentration

Lactic acid bacteria tolerate high salt concentrations. The salt tolerance gives them an advantage over other less tolerant species and allows the lactic acid fermenters to begin metabolism, which produces acid and further inhibits the growth of non-desirable organisms. *Leuconostoc* is noted for its high salt tolerance and for this reason, initiates the majority of lactic acid fermentations (FDA, 2011).

Water activity

In general, bacteria require a fairly high water activity (0.9 or higher) to survive. There are a few species which can tolerate water activities lower than this, but usually the yeasts and fungi will predominate on foods with a lower water activity (FDA, 2011).

Hydrogen ion concentration (pH)

The optimum pH for most bacteria is near the neutral point (pH 7.0). Certain bacteria are acid tolerant and will survive at reduced pH levels. Notable acid-tolerant bacteria include the *Lactobacillus* and *Streptococcus* species, which play a role in the fermentation of dairy and vegetable products (FDA, 2011).

Oxygen availability

Some of the fermentative bacteria are anaerobes; while others are aerobes require oxygen for their metabolic activities (Wikipedia, 2012). Some, lactobacilli in particular, are microaerophilic. That is they grow in the presence of reduced amounts of atmospheric oxygen. In aerobic fermentations, the amount of oxygen present is one of the limiting factors. It determines the type and amount of biological product obtained the amount of substrate consumed and the energy released from the reaction (Lee *et al.*, 2011; FDA, 2011)).

Nutrients

All bacteria require a source of nutrients for metabolism (Egber, 2008). The fermentative bacteria require carbohydrates – either simple sugars such as glucose and fructose or complex carbohydrates such as starch or cellulose. The energy requirements of micro-organisms are very high. Limiting the amount of substrate available can check their growth (FDA, 2011).

Conclusion

Locally fermented foods are profitable in terms of food quality, preservation and decontamination of food. They play a unique role in promoting industrial development in Nigeria through employment generation, value-added processing and training of skilled manpower. This review suggests proper handling of fermented foods so as to prevent food borne infections, improvement of starter cultures or microbial strains development, test of new substrates for their suitability as fermentation raw materials and advanced techniques for the production of locally fermented food should be encouraged. These methods will ensure that many people in Nigeria will reap the benefits of indulging in fermented foods both during cultural ceremonies and during their normal daily activities.

Recommendations

- Locally fermented food should be given proper handling so as to prevent food borne infections.
- Improved starter cultures or microbial strains should be developed.

- New substrates should be tested for their suitability as fermentation raw materials.
- Advanced techniques for the production of locally fermented food should be encouraged.

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