Industrialization of Fermented Food Processes: How Far in Nigeria?

Ayoade Kaye
Department of Chemical Engineering, University of Port Harcourt, PMB 5323, Port Harcourt, Rivers State, Nigeria
and
Lateef Oladimeji Sanni*
Department of Food Science and Technology, University of Agriculture, Abeokuta, Ogun State, Nigeria

Studies on selected fermented foods, indigenous to Nigeria, viz. ogi, gari, fufu, lafun, iru, ogiri, ugba and okpeye, are reviewed. A brief description about their production process is presented. The evaluation about their commercialisation is given. It is observed that only iru, ogi and gari have been commercialised to some extent, the other products are still made as a traditional family art. Efforts made so far towards identifying the microorganisms implicated and the biochemical changes that occur, are described. It is pointed out that areas such as development of appropriate starter cultures, effect of process variables and scale-up strategies need further investigations.

1. Introduction

Fermentation is indigenous to the Nigerian culture and is being used for centuries to produce various foods in this country. There are over 20 fermented foods and beverages in the country; some are served as main meals, while others are used as condiments. The art and production style for these products originated from different traditional family settings. With increase in the level of scientific awareness, efforts are being made to explain the underlying principles involved and in some cases, to also improve upon the production technique.

During the fermentation of foods, several chemical compounds are formed. These include steam volatile acids (formic, acetic and propionic); non-volatile acids (lactic and succinic); volatile neutral compounds (ethanol, acetone and isopropanol); non-volatile neutral compounds (glycerol and 2,3-butanediol); butyric, butanediol, acetoin and some gases. In natural fermentation, the relative amounts of various products formed change, depending upon the prevailing environmental conditions like pH, water potential ($\psi_w$) and temperature.

Fermentation offers a number of advantages including food preservation, improved food safety, enhanced flavor and acceptability, increased variety in the diet, improved nutritional value, improved functional properties and reduction in anti-nutritional compounds.

For instance, it has been shown that certain strains of Lactobacillus plantarum and Leuconostoc mesenteroides, isolated from cassava have the abilities to produce the linamarase enzymes. These linamarase enzymes break down the toxic cyanogenic glucosides contained in cassava.

Although a number of workers have done research on the various fermented foods in Nigeria, the industrial production of these foods has not been encouraging. Thus, the purpose of this paper is to review the available literature with emphasis on those factors that are necessary for industrial application. Furthermore, we shall restrict the presentation to some of the products that are widely consumed in Nigeria. These are, 'Ogi', made from cereals such as maize or sorghum, 'Gari', 'fufu' and 'lafun', which are products from cassava as well as Iru or Dawadawa, Ogiri-igbo, Ogiri, Ugba and Okpeye which are products from legumes. A description of the production process for these foods is given in Section 2. In Section 3, we have presented the microorganisms that have been implicated during the fermentation, while Section 4 discusses process parameters that could influence the fermentation process.

2. Processing of Fermented Foods

The common fermented foods that are indigenous to Nigeria are mainly from legumes, cereals and root fibres. While Iru, Ogi and Gari have been commercial-
Table I—Selected fermented foods in Nigeria

<table>
<thead>
<tr>
<th>Fermented product</th>
<th>Raw material</th>
<th>Microorganisms implicated</th>
<th>Stage of development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ogi</td>
<td>Maize</td>
<td>Lactobacillus plantarum, L. fermentum, S. cerevisiae, Candida krusei, Corynebacterium spp, Acetobacter spp</td>
<td>1, 2, 3, 5</td>
</tr>
<tr>
<td>Gari</td>
<td>Cassava</td>
<td>Leuconostoc mesenteroides, L. plantarum, Bacillus subtilis, Candida krusei</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Fufu</td>
<td>Cassava</td>
<td>L. plantarum, L. brevis, B. subtilis, C. krusei</td>
<td>1, 2, 4</td>
</tr>
<tr>
<td>Lafun</td>
<td>Cassava</td>
<td>L. plantarum, B. subtilis, C. krusei</td>
<td>1, 2, 4</td>
</tr>
<tr>
<td>Iru</td>
<td>Seeds of Parkia</td>
<td>Bacillus spp, Staphylococcus sp</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Ogiri</td>
<td>Seeds of castor oil</td>
<td>B. subtilis, Alcaligenes sp, Streptococcus sp, Staphylococcus sp.</td>
<td>1</td>
</tr>
<tr>
<td>Ugba</td>
<td>Seeds of oil-bean</td>
<td>Leuconostoc mesenteroides, Bacillus sp, Staphylococcus sp, Micrococcus sp.</td>
<td>1</td>
</tr>
<tr>
<td>Okpeye</td>
<td>Seeds of Prosopsis africana</td>
<td>L. plantarum, L. bulgaricus, Micrococcus sp, B. subtilis.</td>
<td>1</td>
</tr>
</tbody>
</table>

Key: 1 = Organisms isolated and identified 2 = Roles of organisms determined 3 = Starter cultures development attempted 4 = Process optimization 5 = Semi-industrialization of process

ized to some extent, the other products are still made as a traditional family art. The basic raw materials required for these foods are listed in Table 1 and the production process is described below. It should be noted that some of these products are consumed in other African countries, also.

Ogi: Ogi is a fermented product of either maize or sorghum or millet grains. It is obtained by washing the grains followed by steeping or fermentation for 72 h. During steeping, the grains are also fermented. The fermented grains are wet milled, sieved (using muslin cloth) and decanted to get ogi slurry. Optionally, the sieved slurry may be allowed to further ferment for 24–72 h. The slurry is boiled in water to obtain the ogi porridge.

Soy-beans are sometimes added to ogi to yield soyogi (30% soy-beans and 70% corn). It is being produced on a pilot plant scale in Nigeria as a weaning food. The product is fortified with vitamins and minerals, pasteurized, spray-dried and packaged.

Another approach suggested for the production of ogi involves dry-milling of the maize to produce maize flour. It is then mixed with water, inoculated and fermented with a mixed culture of L. plantarum, Streptococcus lactis, and Saccharomyces lactis. Adeyemi also described a method for manufacturing of ogi from sorghum.

Gari: It is also a fermented cassava product. To prepare it, fresh roots are peeled, grated into mash, and then put in sacks. The sacks are pressed, using heavy objects, to extract excess liquid from the pulp during fermentation. After 3–4 days, the dewatered and fermented mash is sieved and garified in a pan. Palm oil is often added during garifying to prevent burning. Addition of oil also changes the color of the product from white to yellow. Many authors have worked on various ways for
mechanizing the processing steps, especially grating, milling and water expressing. Gari is preferred by urban consumers because it is a precooked convenient food. It is commonly consumed either by soaking in cold water with sugar, coconut, peanut, fish, boiled cowpea as complement or as a paste made with hot water and eaten with vegetable sauce.

Gari is probably the only food for which Africa has developed a patented plant. The Federal Institute of Industrial Research, Oshodi, Nigeria, has designed plants with capacities up to 10 tons/day.

Fufu: Fufu is made by steeping whole or cut-peeled cassava or unpeeled cassava water to ferment for 3-5 days. During steeping, the fermentation decreases the pH, softens the roots and facilitates reduction of potentially toxic cyanogenic compounds of the roots. When sufficiently soft, the roots are taken out, broken manually, and the fibres removed by sieving. The sieving is done manually by adding water to the retted mass on a nylon or cloth screen. The sieved mass is allowed to sediment in a large container for about 24 hours. After sedimentation, the water is decanted while the fine, clean filtrate (mainly starch) is dewatered overnight in raffia or cotton bags, using heavy stones as presses. The fufu is collected and sold to the consumers in its wet form in small units packaged in plastic or polypropylene bags. Fufu is consumed as a paste made with boiled water. Cooked fufu is usually eaten warm with fish, meat, and vegetable sauce.

Lafun: Lafun is similar to fufu in Nigeria. The principal difference is that lafun is dried providing enhanced storage characteristics, while fufu has reduced fibre content. Lafun is produced by cutting fresh cassava root into chunks and steeping for 3-4 days or until the roots become soft. The fermented roots are peeled, broken into small pieces and sun-dried. Alternatively, chips are made directly from fresh roots, cut into chunks and sun-dried. The dried pieces are milled into flour, which is made into a dough in boiling water before consumption.

The sun-drying of raw cassava takes 4 days to 3 weeks, depending upon the weather and size of the pieces. Although this approach is very simple and practised in areas where water for fermentation is scarce, the product has been found to contain considerable amounts of cyanides.

Iru: This is a fermented product of African locust bean. It is known by three different names in Nigeria - Iru in the South West, Dawadawa in the North and Ogirigala in the South East. It is widely acceptable for its flavoring characteristics as a condiment. In addition, it also serves as a low cost animal protein substitute. The processing method of iru has been documented by many workers.

The hard, dried locust beans are boiled in water in a covered earthen-wall or metallic pot for 12-24 h to soften the tough, hard testa cotyledons. The black beans testa are then removed by either rubbing between the hands, rubbing against the walls of a basket, under the foot or by pounding gently in a wooden mortar. A little sand or wood ash is often added as an abrasive to aid the removal of the testa. The cotyledons are then washed thoroughly and boiled again for 30 to 120 minutes. During this second boiling, potassium carbonate and potassium bicarbonate (obtained from a native rock called kaun) may be added to aid softening of the cotyledons. The seeds are drained after boiling and spread in calabash trays in layers of about 10 cm deep.

About two or three trays are stacked together and wrapped in many layers of jute sacks and coarse cotton cloth to provide warm and humid atmosphere. During this period, the seeds ferment, the color changes to dark brown/black and become softer. The odor of the fermented beans also changes from initial sweet bean to a strong proteolytic ammoniacal.

Ogiri: Ogiri is obtained from water melon seeds. The seeds with the hulls removed, are boiled until soft. The pulpy melon seeds are wrapped in blanched plantain leaves and cooked again for 2-3 h. After draining off the associated water and oil, the seeds are pre-fermented at ambient temperatures for 3 days. At the end of this period, the seeds are ground in a sterile mortar and some salt is added. The resulting paste is rewrapped in plantain leaves and fermented for an additional 4 days at ambient temperature. Like iru, ogiri is used as a food condiment.

Ugba: Ugba is made from oil bean seeds. The seeds are obtained from a perennial legumes tree, Pentaclethra macrophylla Benth, commonly called the oil bean tree, Congo acacia, or Atta bean tree. The oil bean seeds are boiled in water for about 4-12 h. The cotyledons (kernels) are separated from the cooked seeds by removing the seed coats and washing. The separated cotyledons are boiled again in water to remove bitter components in the cotyledons. The bitter components of the oil bean seeds are water soluble. The washed cotyledons are cut into thin slices which are mixed with salt, put in a clean pot without water, covered and fermented for about 5 days at room temperature. Ugba is consumed as a basic food or used as a flavoring agent.
Okpeye: The production of okpeye, a condiment produced from the seeds of *Prosopis africana* by fermentation is similar to other Nigerian condiments produced from plant seeds. The seeds are boiled in water to remove the seed coats. The seeds, which become light brown, are spread in a layer roughly 2-cm thick on washed leaves of *Alchornea cordifolia* in a basket tray and covered with more leaves. Clean pieces of broken clay pots are placed on the top to hold the leaves in position. The baskets tray is incubated at room temperature for 96 h to give okpeye.

3. Microorganisms Involved in the Fermentation Process

A large number of references are available in the literature on the microorganisms implicated during the fermentation process. According to Oyewole, these microorganisms belong to four major groups, namely Lactobacillus, Lactococcus, Leuconostoc, and Pediococcus. Some of the specific studies on each of the products mentioned in Section 2 are discussed below. A summary is also included in Table 1.

For ogi production, Akinrele found that *Corynebacterium*, *S. cerevisiae*, Enterobacter cloacae and *L. plantarum* were prominent. Adegoke and Babalola also showed that *K. oxytoca* dominated the fermentation of ogi (24-48 h) after which *S. cerevisiae* took over the fermentation processes.

Collard and Levi in their study on the cassava fermentation for Gari production, reported a two-stage process in which the fermentation was said to be started by *Corynebacterium manihot*. It breaks down starch and releases organic acids within the first 48 hours of fermentation. The acid produced and the lowered pH condition that developed in the first stage was said to create favorable conditions for the growth of a fungus called *Geotrichum* sp. This latter organism then proliferates into the second stage, producing a variety of aldehydes and factors. The...
*circulans* and *B. macerans* in the ugba fermentation. *Bacillus* sp was reported to be responsible for the characteristic aroma of ugba\(^4\). The microorganisms involved in ugba are natural contaminants from the air, handling and utensils used in slicing the cooked cotyledons. *Staphylococcus* sp is associated with handling since it commonly occurs on the skin. The salt added before the fermentation selects the *Staphylococcus* and *Micrococcus* sp\(^5\). This probably confirms the observation that *Staphylococcus* spp were present only during 24 h of fermentation\(^4\).

The microorganisms isolated from fermenting melon seeds to produce Ogiri include *Bacillus* sp, *Alcaligenes* sp, *Streptococcus* sp and *Staphylococcus* sp. While *Bacillus* sp and *Alcaligenes* sp have been documented with fermenting of seeds\(^52,55\), the presence of *Staphylococcus* sp. could hardly be associated with the fermentation and hence the need for improved processing techniques. Barber and Achinewhu\(^56\) suggested that a combination of *Bacillus* sp and *Alcaligenes* sp. was necessary for melon seed fermentation, since neither organism gave the typical characteristics of ogiri when used. Further research is still needed to determine the specific roles of these organisms in melon seed fermentation and to fully identify the species of these organisms, best suited for the fermentation.

Strains of *B. subtilis* appear to be the most important organisms in Okpeye production. Other organisms include *B. Licheniformis*, *Lactobacillus* sp, *L. bulgaricus* and *L. plantarum\(^25-57\). The absence of fungi in the product excludes the danger of mycotoxins\(^35\).

Jideani and Okeke\(^54\) presented a comparative study of microorganisms involved during the fermentation of seeds of African locust bean, melon, castor oil bean and soybean. Their results indicate that three genera of bacteria (*Bacillus*, *Staphylococcus* and *Pseudomonas*) were isolated. Furthermore, it was shown that *Bacillus* species were present throughout the 72 hour period of fermentation. *Staphylococcus* was not isolated from the melon fermentation. Also, more species of bacteria, especially *Bacillus*, were involved in soybean and castor bean fermentation than in the other two bean-types.

4. Process Factors in Fermentation

Different conditions which affect the fermentation of the different foods have been studied by many authors. The parameters studied include temperature, relative humidity, fermentation period, aeration and mixing. A majority of such studies are for cassava fermentation. For gari production, Akinrele\(^44\) showed that the cassava fermentation was best at 35°C. Also, the flavor of acceptable gari should be made from fermented cassava at pH 3.95. Inoculation of cassava pulp with fermented cassava juice reduces the fermentation period to 15 h, compared to the traditional duration of 3-4 days. It was found that aeration during fermentation was inhibitory.

For fufo production, the effect of processing methods has been studied by a number of authors\(^26,47,58,59\). Akingbala et al.\(^59\) showed that grating the cassava roots before steeping improved the aroma and periodical change of water during steeping improved the taste, color and texture of fufo over that produced by the traditional method. Oyewole and Odunfa\(^59\) as well as Blanshard et al.\(^59\) reported that the retting of cassava occurred after 60 hours of steeping at temperatures 30-35°C. Ampe et al.\(^60\) optimized the retting process in terms of period and the quality of the end-product. It was also shown that small pieces of cassava allowed retting to be completed more quickly than when whole roots were used\(^60,67\).

For the fermentation of legumes, Odunfa\(^61\) showed that the cooking period for dawadawa production could be reduced by first soaking the beans in water for 12 hours before cooking in a pressure cooker for 30 min. However, it took more time to remove seed coats from the beans cooked in this manner. In contrast, Osinowo\(^62\) cooked beans in a pressure cooker for 90 min without presoaking and found that the seed coats were easily removed from the cooked beans. The effects of period, temperature and relative humidity on locust bean fermentation have been reported by Odunfa and Adeyemi\(^51\). The optimal duration was 48 h and the corresponding temperature was 35-40°C. The optimum relative humidity was 51% at 35°C and 71% at 40°C.

For the foods considered in this paper, it is generally agreed that the fermentation process is exothermic. However, we are not aware of any effort to quantify the amount of heat involved.

Some authors have worked on the post-fermentation handling of the foods with a view to improving their shelf-life. The usual approach is to dry the products. Blanshard et al.\(^68\) reported that the storage of wet fufo in plastic bottles at room temperature over eight weeks affected its acidity and microbial qualities. Okpokiri et al.\(^63\) found that good quality dried fufo could be obtained by drying wet fufo in an oven at 55°C for the first 8 hours and thereafter increasing the temperature to 80°C. Drying of fufo at 60°C also reduced the strong odor but the product was not acceptable\(^58\). The effect of different drying methods on the composition and properties of lafun fermented flour, was reported by Sanni et al.\(^64\). Recently, Sanni et al.\(^65-66\) presented the moisture sorption isotherms for fufo.
The provision of pure starter cultures has been attempted by some workers. There are three main approaches, namely natural inoculation, transfer of an old batch of fermented products to a new batch (back-slopping) and indigenous derived culture. The success so far has been limited probably because most of the indigenous fermentation processes are "wild", that is, the effective microorganisms are not controlled.

5. Conclusion

The work done in Nigeria so far on fermented foods is reviewed in this paper. As can be seen, quite a lot has been done in the area of understanding the production process especially that of identifying the microorganisms implicated and the biochemical changes that occur. Also, for gari and dawadawa, attempts have been made towards developing appropriate starter cultures.

Future Studies

To fully commercialize different procedures, more research is still needed. For instance, the effect of various process variables (raw materials, temperature, moisture, fermentation duration, etc.) on the quality of the foods need be investigated to optimize the fermentation process. There is need to develop starter cultures with appropriate carriers so that they can easily be handled and used by local processors without the problem of contamination.

Also, no work seems to have been done on the scale-up strategies for any of the processes described above. Such information is necessary if the resulting fermentation plants are not labor and energy intensive.

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