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Nigerian Indigenous Fermented Foods: Processes and Prospects

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Additional information is available at the end of the chapter

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1. Introduction

The deliberate fermentation of foods by man predates written history and is possibly the oldest method of preserving perishable foods. Evidence suggests that fermented foods were consumed 7,000 years ago in Babylon (Battcock and Aza-Ali, 1998). Scientist speculates that our ancestors possibly discovered fermentation by accident and continued to use the process out of preference or necessity. Preserving by fermentation not only made foods available for future use, but more digestible and flavourful. The nutritional value produced by fermenting is another benefit of fermenting.

Fermented foods are generally produced using plant or animal ingredients in combination with fungi or bacteria which are either sourced from the environment, or carefully kept in cultures maintained by humans. Just as living organisms cover the surface of the earth, fermentation microbes cover the surface of the organisms. Wild yeasts are found living on grapes (Chamberlain et al. 1997), and bacteria line the human digestive tract.

Fermented foods, whether from plant or animal origin, are an intricate part of the diet of people in all parts of the world. Fermented food plays a very important role in the socio-economics of developing countries. Each nation has its own types of fermented food, representing the staple diet and the raw ingredients available in that particular place. It makes major contributions to the protein requirements of the rural population. The preparation of many indigenous or “traditional” fermented foods and beverages remains a household art today.

2. Purpose and benefits of food fermentation

The primary benefit of fermentation is the conversion of sugars and other carbohydrates to usable end products. According to Steinkraus (1995), the traditional fermentation of foods

serves several functions, which includes: enhancement of diet through development of flavour, aroma, and texture in food substrates, preservation and shelf-life extension through lactic acid, alcohol, acetic acid and alkaline fermentation, enhancement of food quality with protein, essential amino acids, essential fatty acids and vitamins, improving digestibility and nutrient availability, detoxification of anti-nutrient through food fermentation processes, and a decrease in cooking time and fuel requirement.

2.1. Nutritional benefits

Fermentation can produce important nutrients or eliminate anti-nutrients. Food can be preserved by fermentation, since fermentation uses up food energy and creates conditions unsuitable for spoilage microorganisms. For instance, in pickling, the acid produced by the dominant organism inhibits the growth of all other microorganisms.

Fermenting makes foods more edible by changing chemical compounds, or predigesting, the foods for us. There are extreme examples of poisonous plants like cassava that are converted to edible products by fermenting. Some coffee beans are hulled by a wet fermenting process, as opposed to a dry process (Battcock and Aza-Ali, 1998).

Reduction in anti-nutritional and toxic components in plant foods by fermentation was observed in a research which showed " Cereals, legumes, and tubers that are used for the production of fermented foods may contain significant amounts of antinutritional or toxic components such as phytates, tannins, cyanogenic glycosides, oxalates, saponins, lectins, and inhibitors of enzymes such as alpha-amylase, trypsin, and chymotrypsin.

- These substances reduce the nutritional value of foods by interfering with the mineral bioavailability and digestibility of proteins and carbohydrates. In natural or pure mixed-culture fermentations of plant foods by yeasts, molds, and bacteria, antinutritional components (e.g. phytate in whole wheat breads) can be reduced by up to 50%; toxic components, such as lectins in tempe and other fermented foods made from beans, can be reduced up to 95%. (Larsson and Sandberg, 1991)

Fermentation increases nutritional values of foods, and allows us to live healthier lives. Here are a few examples:

- The sprouting of grains, seeds, and nuts, multiplies the amino acid, vitamin, and mineral content and antioxidant qualities of the starting product (Wigmore, 1986).
- Fermented beans are easier for the bodies to digest, like the proteins found in soy beans that are nearly indigestible until fermented (Katz, 2003).
- Fermented dairy products, like, cheese, yogurt, and kfir, can be consumed by those not able to digest the raw milk, and aid the digestion and well-being for those with lactose intolerance and autism.
- Porridge made from grains allowed to ferment increases the nutritional values so much that it reduces the risk of disease in children (Battcock and Aza-Ali, 1998).
- Probiotic supplements (beneficial bacterial cultures for microbial balance in the body) are capable of fighting cancer and other diseases.

- Vinegar is used to leach out certain flavours and compounds from plant materials to make healthy and tasty additions to the meals.

2.2. Health benefits

Fermented food, enjoyed across the globe, conveys health benefits through lactic acid fermentation. The fermentation process can transform the flavour of food from the plain and mundane to a mouth-puckering sourness enlivened by colonies of beneficial bacteria and enhanced micronutrients.

- Studies have revealed that *Lactobacillus rhamnosus* and *L. reuteri* which are common organisms in Nigerian fermented foods like ogi and kunun-zaki could colonize the vagina, kill viruses, and reduce the risk of infections, including bacterial vaginosis (Reid *et al.*, 2001a; Cadieux *et al.*, 2002). The potential therapeutic effects of Lactic Acid Bacteria (LAB) and *ogi*, including their immunostimulatory effect, are due primarily to changes in the gastrointestinal (GI) microflora to suppress the growth of pathogens. Increase in population of LAB in the intestinal or vagina reduces the cause of bacterial vaginosis, which is a major risk factor for the contraction of HIV (Reid, 2002a). It also reduces the occurrence of gonorrhoea, chlamydia, and other sexually transmitted diseases (Reid *et al.*, 2001b) and diarrhoea (Adebolu *et al.*, 2007).
- All lactic acid producing bacteria (E.g *Lactobacillus acidophilus*, *L. bulgaricus*, *L. plantarum*, *L. caret*, *L. pentoaceticus*, *L. brevis* and *L. themophilus*) produces high acidity during fermentation. The lactic acid they produce is effective in inhibiting the growth of other bacteria that may decompose or spoil the food. Despite their complexity, the whole basis of lactic acid fermentation centres on the ability of lactic acid bacteria to produce acid, which then inhibits the growth of other non desirable organisms. Other compounds are important as they improve particular tastes and aromas to the final products. The *L. mesenteroides* initiates growth in vegetables more rapidly over a range of temperatures and salt concentrations than any other lactic acid bacteria. It produces carbon dioxide and acids which rapidly lower the pH and inhibit the development of undesirable micro organism.
- Over 200 species of bacteria live in gut of humans. These microbes help break down food in the intestines, aid in the digestion process, help fight off disease, and boost the immune system. A good balance of intestinal flora is very important to the overall health. If we eat nothing but overly processed and hard to digest foods, then the fermentation process occurs within the GIT resulting into gas, bloating, diarrhoea, and constipation might possibly lead to other diseases like cancer. However, providing the body with predigested foods such as fermented foods will help the existing microbes within to do the job they need to do.
- Fermentation is not only a way to preserve certain foods, in some cases it actually adds to the nutrient value of it. Fermented vegetables contain more vitamin C and fermented milk products have ample amounts of B vitamins. The bioavailability of these vitamins also increases with fermentation. Probiotics, or "good bacteria" are also formed through the process of fermentation. Fermented soy products contain more vitamin B₁₂ (Chung *et al.*, 2010)

- The desirable bacteria cause less deterioration of the food by inhibiting the growth of the spoiling types of bacteria. Some fermenting processes lower the pH of foods preventing harmful microorganisms to live with too acidic an environment. Controlled fermentation processes encourage the growth of good bacteria which starves, or fights off, the bad microbes.
- The fermentation process can be stopped by other means of preserving, such as, canning (heating), drying, or freezing. Heat (pasteurization, 63°C), and low temperatures (freezing, 0°C or below) stops the fermenting process by slowing, or killing, the preferred microorganisms, and other bacteria. A few undesirable bacteria are not killed by either means, and continue to grow. When the beneficial bacteria are gone, the unfavorable bacteria take over, growing exponentially! This causes rotting, disease, illness, and inedible foods. When the good guys are present and happy, the food remains edible.
- Phytates (phytic acid) are the storage form of phosphorus [a mineral] bound to inositol [a B vitamin] in foods high in fiber (all plant foods), and particularly the fiber of raw whole grains, legumes, seeds, and nuts. Although these foods have high phosphorus content, the phosphates in phytates are not released by human digestion. Phytates, particularly in such raw foods as bran, are a concern because they can bind a portion of the iron, zinc, and calcium in foods, making the minerals unavailable for absorption. When bread is leavened (fermented) by yeast, enzymes degrade phytic acid, and phytates pose no problem. Enzymes, called phytases, destroy phytates during fermentation processes such as: the yeast-raising of dough, Even a small amount of phytates in food can reduce iron absorption by half (by 50%), but the effect is less marked if a meal is supplemented with ascorbic acid (Vitamin C) which also helps the absorption of zinc and calcium.
- Fermented food, enjoyed across the globe, conveys health benefits through lactic acid fermentation. The fermentation process can transform the flavor of food from the plain and mundane to a mouth-puckering sourness enlivened by colonies of beneficial bacteria and enhanced micronutrients. While fermented food like yogurt, sauerkraut and kefir are well-known many other lesser-known foods also benefit from the lactic acid fermentation process. Indeed, virtually every food with a complex or simple sugar content can be successfully fermented.
- Born of both necessity and practicality, lactic acid fermentation proved to be not only an efficient method of preserving food for our ancestors, but also a critical one. Indeed, fermented food like sauerkraut, cheese, wine, kvass, soured grain porridge and breads often sustained tribes and villages during harsh winters when fresh food simply wasn't available let alone plentiful.
- In many societies including our own where yogurt has been heralded as a health food since the 19th century, fermented food has gained a reputation for its beneficial effects on immunity, intestinal health and general well-being. Modern researchers are just beginning to understand what the sages of old were tuned in to: fermented food conveys clear and calculable health benefits to the human diet. Lactic acid fermentation in and of itself enhances the micronutrient profile of several foods.

2.3. Detoxification

Detoxification of anti-nutrients through food fermentation processes. The renewal of anti-nutrient from the Nigerian fermented food is an important step in ensuring that the fermented food is safe to eat. Many fermentation foods contain naturally accruing toxins and anti-nutritional compounds. These can be removed or detoxified by the action of micro-organism during fermentation for instance, the fermentation process that produces the Sudanese product, kawal, removes the toxins from the leaves of *Cassia obtusifolia* and fermentation is an important step in insuring that the fermentation foods are safe to eat.

Removing cyanide by fermentation: Cassava contains naturally occurring chemicals, cyanogenic glycoside. When eaten raw or improperly processed, this substances releases cyanide into the body, which can be fatal, correct processing removes this chemicals. The cassava is first peeled (as about 60-70% of the poison is in the peel) and then soaked in stagnant water or fermented in sacks for about three days. It is sometimes grated or rasped as this helps to speed up the fermentation process. At the beginning of the fermentation, *Geotricum candidia* acts on the cassava. This helps to make the product acidic, which finally kills off the microorganisms as they cannot exist in such a medium. A second strain of microorganisms (*corynebacteriumlactis*) which can tolerate the acidic environment then take over and by the third day 90-95% of the dangerous chemicals would have been hydrolyzed. The cassava also develops its characteristic flavour. The product is then sieved and the fine starch particles are fried in an iron pan over aflame or with some oil. During this process most, if not all the remaining toxins are given off. The liquor from a previous fermentation is used as a starter, thereby reducing the period of fermentation to about 6-8hours.

3. Nigerian fermented foods

3.1. Fermented tubers

These include mainly cassava and yam used in the production of foods such as garri, fufu, lafun and elubo etc.

Nigeria is one of the leading producers of cassava in the world with an annual production of 35-40 million metric tons. Over 40 varieties of cassava are grown in Nigeria and cassava is the most important dietary staple in the country accounting for over 20% of all food crops consumed in Nigeria (IITA, 2004). Cassava tubers are rich in starch [20-30%] and with possible exception of sugar cane; cassava is considered the highest producer of carbohydrates among crop plants. Despite its vast potentials, the presence of the two gynogenic glycosides, linaman calculating for 93% of total content (Okafor *et al.*, 1984) and lotaustralin or methyl linamarin, hydrolysis by the enzymes linamarase to release toxic HCN, is the most important problem limiting cassava utilization. Generally cassava contains 10-500 mg HCN/KG of root depending on the variety, although much higher levels, exceeding 1000 mg HCN/kg, may be present in unusual cases. Cassava varieties are frequently described as sweet or bitter. Sweet cassava varieties are low in cyanogens with most of the cyanogens present in the peels. Bitter cassava varieties are high in cyanogens

that tend to be evenly distributed throughout the roots. Environmental (soil, moisture, temperature) and other factors also influence the cyanide content of cassava. Low rainfall or drought increase cyanide level in cassava roots due to water stress on plant. Apart from acute toxicity that may result in death, consumption of sub-lethal dose of cyanide from cassava production over a long period of time results in chronic cyanide toxicity. That increases the prevalence of goiter and cretinism in iodine deficient area. Symptoms of cyanide poisoning from consumption of cassava with high level of cyanogens include vomiting, stomach pains, dizziness, headache, weakness and charkha. Chronic cyanide toxicity is also associated with several pathological conditions including konzo, an irresistible paralysis of the legs reported in eastern, central and southern Africa. And tropical ataxic neuropathy, reported in west Africa, characterized by lesion of the skin, mucous membranes, optics and auditory nerves, spinal cord and peripheral nerves and other symptoms. Without the benefits of modern science, a process for detoxifying cassava roots by canvassing potentially toxic roots into garri and fufu was developed, presumably empirically in West Africa.

a. Gari

Gari is a creamy-white, granular flour with fermented flavour and a slightly sour taste made from fermented, gelatinized fresh cassava tubers. Gari is widely known in Nigeria and other West African countries. It is commonly consumed either by being soaked in cold water with sugar, coconut, roasted groundnuts, dry fish, or boiled cowpea as complements or as a paste made with hot water and eaten with vegetable sauce. There are basically three types of gari

1. Rough-sour gari which is preferred for soaking with sugar and sometimes roasted peanut or coconut.
2. Medium gari is usually cooked by adding to boiling water and stirred. This is usually eaten with stew or soup.
3. Smooth gari which could be mixed with pepper and other spicy ingredients. A small amount of warm water and palm oil is added and mixed with the hand to soften. This type of gari is served with fried fish.

b. Fufu

Fufu is a fermented white paste made from cassava it is ranked next to gari as an indigenous food of most Nigerians in the South. Fufu is made by sleeping whole or cut peeled cassava roots in water to ferment for maximum of three days, during the steeping, fermentation decrease the pH, softens the roots and help to reduce the potentially toxic cyanogenic compound (Agbor-Egbe and Lape Mbome, 2006)

c. Lafun

Lafun is a fibrous powdery form of cassava similar to fufu in Nigeria. The method of producing lafun is different from that of fufu in the traditional preparation; fresh cassava roots are cut into chunks and steeped for 3-4 days or until the roots become soft. The fermented roots are peeled, broken up into small pieces and sun dried on mats, flat rocks, cineol flours, or the roofs of houses. The dried pieces are milled into flour. Alternatively, chips are made directly from fresh roots, cut into chunks and sun dried. Drying takes 2-4

days, depending on weather. Unlike fufu, the fiber is the related root for lafun are dried along with the mash and later sieved out. The flour is made into dough with boiling water before consumption. When properly stored, it has a shelf life of six months or more.

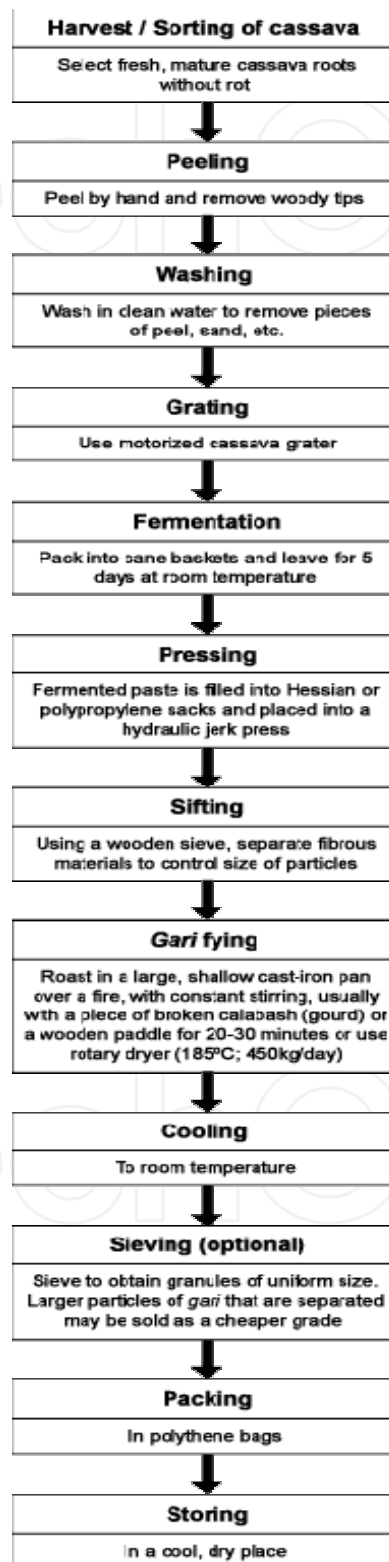


Figure 1. Process flow chart for Gari.

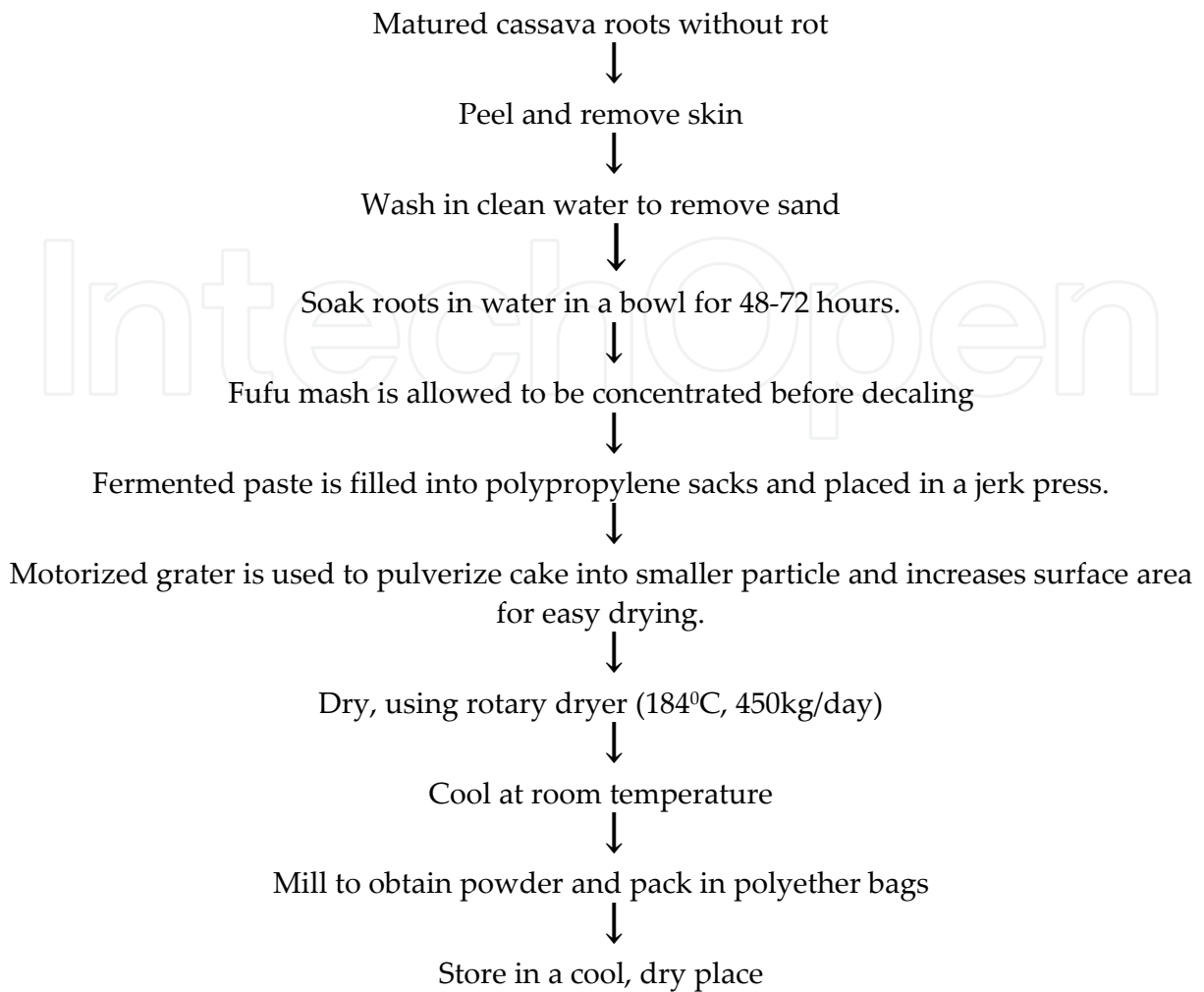


Figure 2. Process flow chart for fufu.

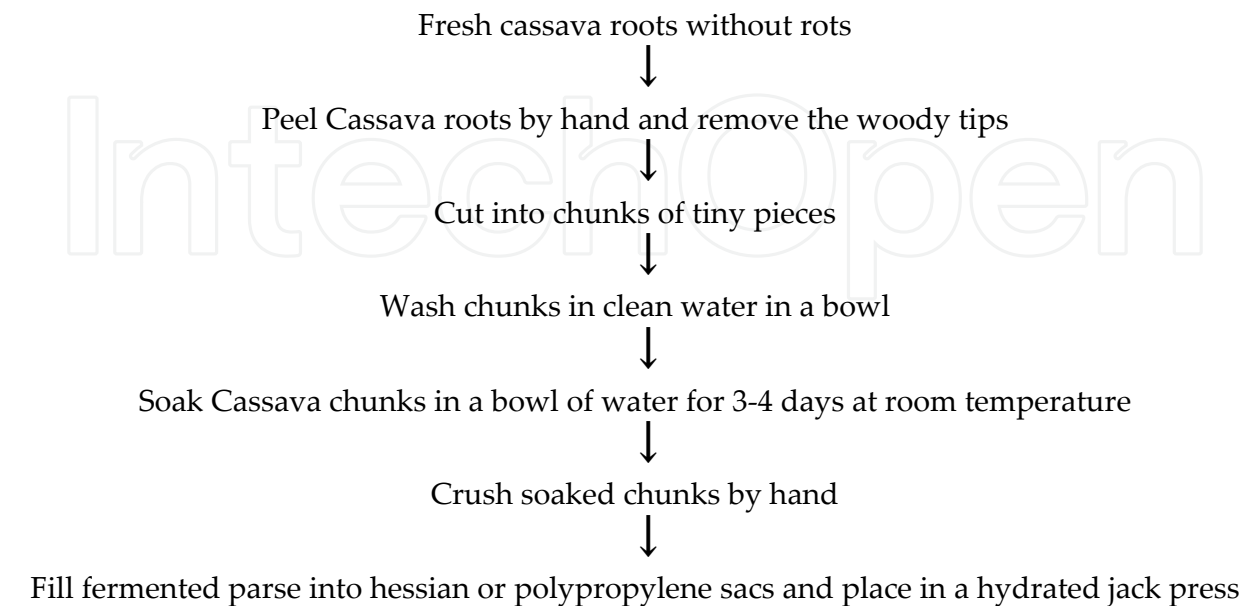


Figure 3. Process flowchart for the production of lafun.

3.2. Fermented cereals

Cereals which include maize (*Zea mays*), Sorghum (*Sorghum bicolor*), millet (*Peninselum americanum*) and acha etc. are used in the production of gruels which is used as complementary food for babies and serves as breakfast for adults.

Maize, millet, rice and sorghum cereals provide mainly carbohydrates and low quality protein. The generation and fermentation of cereals enhance the availability of elemental iron, the deficiency of which is responsible for the high incidence of anaemia in tropical countries. It is estimated that about 50% of perishable food commodities including fruits, vegetables, roots and tubers and about 30% of food commodities including maize, sorghum millet, rice and cowpeas are lost after harvest in Nigeria. Nigerian in fact experience a slower growth rate and weight gain during the weaning period than during breastfeeding, due primarily to the poor nutritional qualities of traditional Nigerian complementary food such as "Ogi" which are mainly produced from cereal fermentation. Apart from their poor nutritional qualities, traditional Nigerian cereal based gruels used as complementary foods have high paste viscosity and require considerable dilution before feeding; a factor that further reduces energy and nutrient density.

Although nutritious and safe complementary foods produced by food multinationals are available in Nigeria, they are far, too expensive for most families. The economic situation in these country necessitate the adoption of simple, inexpressive processing techniques that result in quality improvement and that can be carried out at household and community levels for the production of nutritious, safe and affordable complementary foods which is the leading cause of protein-energy malnutrition in infants and preschool children in Nigeria.

a. Ogi

This is an example of traditional fermented food, it is a staple cereal of Yorubas of Nigeria and is the first native food given to babies at weaning. It is produced generally by soaking corn grains in warm water for one to two days followed by wet milling and sieving through a screen mesh. The sieved material is allowed to sediment and fermented, and is marketed as wet cake wrapped in leaves. Various food dishes are made from the fermented cakes or ogi. During the steeping corn, *Corynebacterium* spp. become prominent and appears to be responsible for the diastolic action necessary for the growth of yeast and lactic acid bacteria. Along with the corn in bacteria, *S. cerevisiae*, *Enterobacter cloacae* and *L.plantarum* have been found to be prominent in traditional ogi fermentation.

In Nigeria, the first weaning food is called pap, akamu, ogi, or koko and it is made from maize (*zea mays*), millet (*Pennisetum americanum*), or guinea corn (*Sorghum spacers*). In Anambra state most mothers introduce the thin gruel at three to six months of age. The baby is fed on demand with a spoon or a few mothers used the traditional forced hand-feeding method. After the successful introduction the thin gruel, other staple foods in the family menu are given to the child. These food include yam (*Dioscoria spp*) rice (*oriza sativa*) gari (fermented cassava grit) and cocoyam (*xanthosoma sagitifolium*), which may be eaten with

soup. These foods are usually mashed thinned or pre-chewed. As soon as a child can chew, he or she is given pieces of from the family pot.

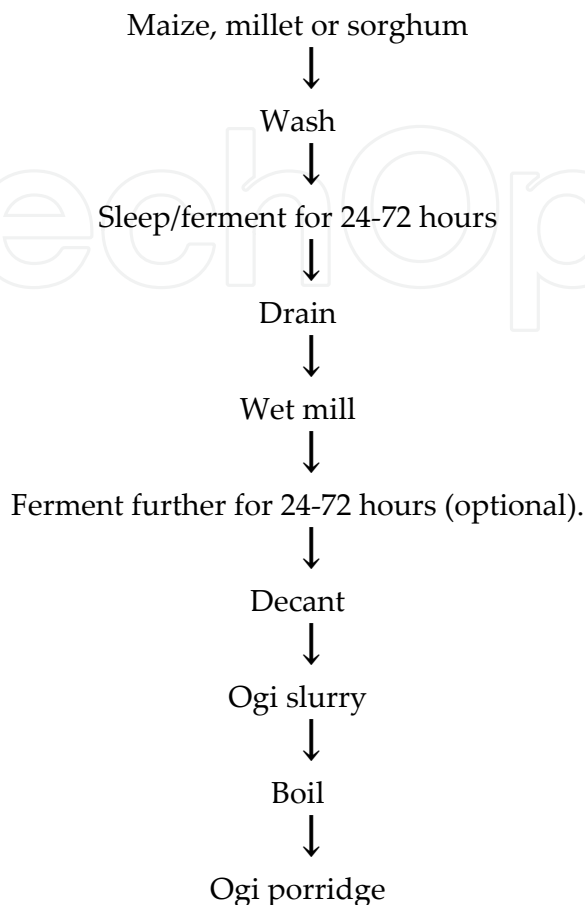


Figure 4. Process flow chart for ogi.

b. Masa

Masa (waina) is a fermented puff batter of rice, millet, maize, or sorghum cooked in a pan with individual cup like depressions. It resembles the Indian idli in shape and dosa in test. Masa is consumed in various forms by all groups in the northern States of Nigeria and other North African countries (Mali, Burkina Faso, Niger and Chad.) It is the principal ingredients of a variety of cereal-based foods and is a good source of income for the women who prepare the traditional product for sale. Though, masa is as popular as a Nigeria ogi, it has received very little attention. The problem of masa, apart from the short shelf keeping quality, is that of low protein content and inconsistency in the use of varied cereals and spices has resulted in variation in the quality of the products.

The addition of cowpea, groundnut or soybeans flour into masa during preparations improves the nutritional quality of masa. Groundnut-maize enriched masa could be a source of protein to the consumer particularly in developing countries like Nigeria where cost of feeding on animal sourced protein is unaffordable. The high calorie content of

groundnut-maize masa could be due to the high fat content of the added paste. The decrease in the weight of masa with addition of groundnut paste could be due to increase in the oil content in the paste which has been proofed to be relatively lighter. Masa formulation containing millet or rice blended with cowpea or groundnut was prepared and sodium concentrations were high. Significant improvements in lysine (9-75%), threonine (16-25%) and Isoleucine(10-28%) were observed from masa samples. The biological value (81-93%), apparent digestibility (82-88%) and net protein utilization (74-79%) of all masa samples showed improved nutritional qualities. Supplemented masa was nutritionally better than masa made from millet or rice alone.

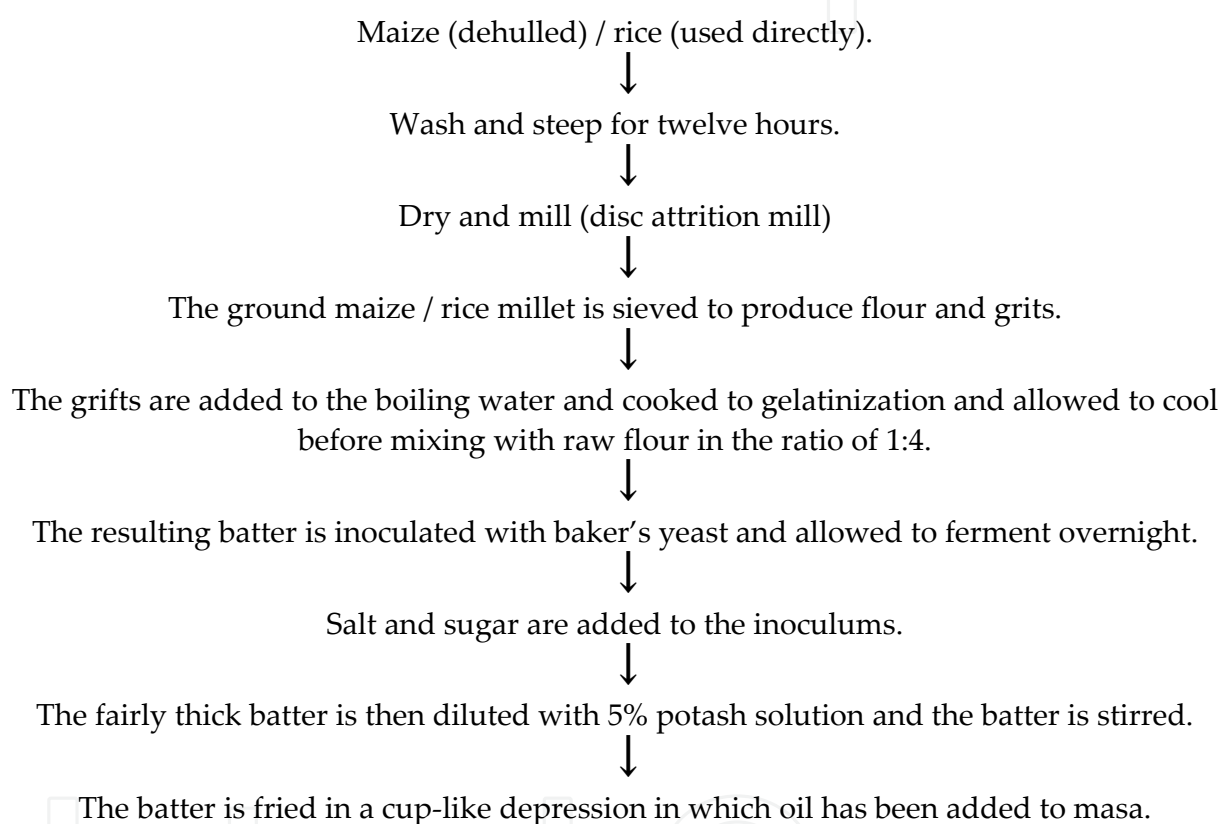


Figure 5. Process flow chart for the production of masa.

c. Pito

Pito is the traditional beverage drink of the Benins in the Mid- West part of Nigeria. It is however popularly consumed throughout Nigeria owing to its refreshing nature and low price. Pito is also widely consumed in Ghana. The preparation of pito involves soaking the cereal grains (maize, sorghum, or combinations of both) in water for two days, followed by malting and allowing them to sit for five days in basket lined with moistened banana leaves. The malted grains are ground mixed with water and boiled. The resulting mash is allowed to cool and later filtered through a fine mesh, allowed to cool and later filtered through a fine mesh basket. The filtrate thus obtained is allowed to stand overnight or until it assumes a slightly sour flavour, following which it is boiled to concentrate.

A starter from the previous brew is added to the cool concentrate which is again allowed to ferment overnight. Pito, the product obtained thus is dark brown liquid which varies in taste from sweet to bitter. It contains lactic acid, sugars and amino acids and has an alcoholic content of about 3%. Organisms responsible for souring include *Geotricum candidum*, and *Lactobacillus species*, while *Candida species* are responsible for the alcoholic fermentation.

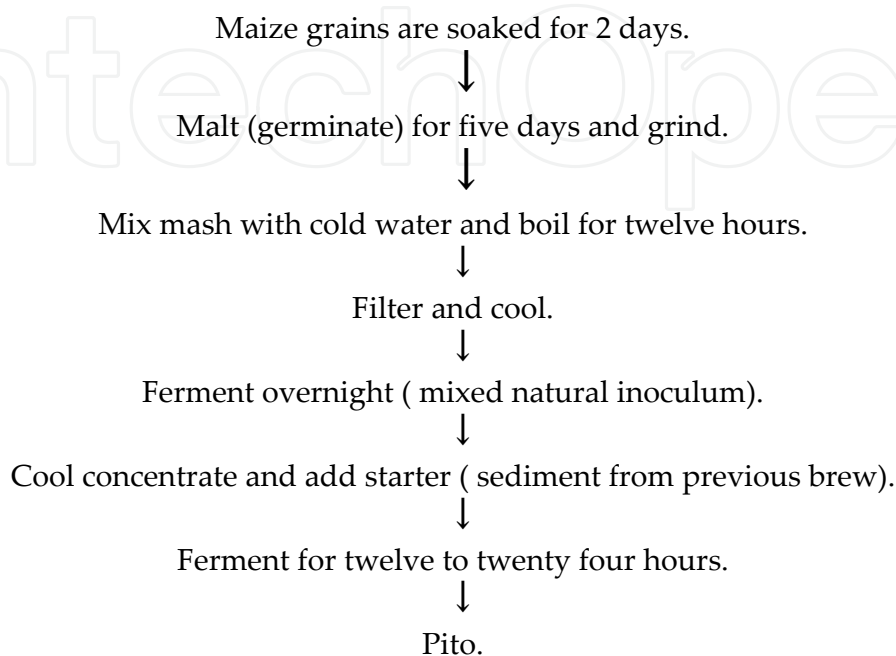


Figure 6. Process flowchart for production of pito.

d. Burukutu

This is a popular alcoholic beverage of vinegar-like flavour, consumed in Northern Guinea Savannah region of Nigeria, in the republic of Benin and Ghana. The preparation of burukutu involves steeping sorghum grains in water overnight, following which excess water drained. The grains are then spread out onto a mat or tray, covered with banana leave and allowed to germinate. During the germination processes, the grains were watered on alternate days and turned over at intervals. Germination continues for four to five days until the plumule attain a certain length. The malted grains are spread out in the sun to dry for one to two days, following which the dried malt is ground to powder. Garri (a farinaecious fermented cassava product) is added to the mixture of the ground malt and six parts water. The resulting mixture is allowed to ferment for two days, following which it is boiled for two days. The resulting product is cloudy alcoholic beverage.

The pH of the fermenting mixture decreases from about 6.4 to 4.2 within 24 hours of fermentation and decreases further to 3.7 after 48 hours. At the termination of the 2-days maturing period, *Acetobacter species* and *Candida species* are dominant microorganisms. Boiling prior to maturation eliminates lactic acids and other yeast. Fully matured burukutu beer has an acetic acid content which varies between 0.4 to 0.6%.

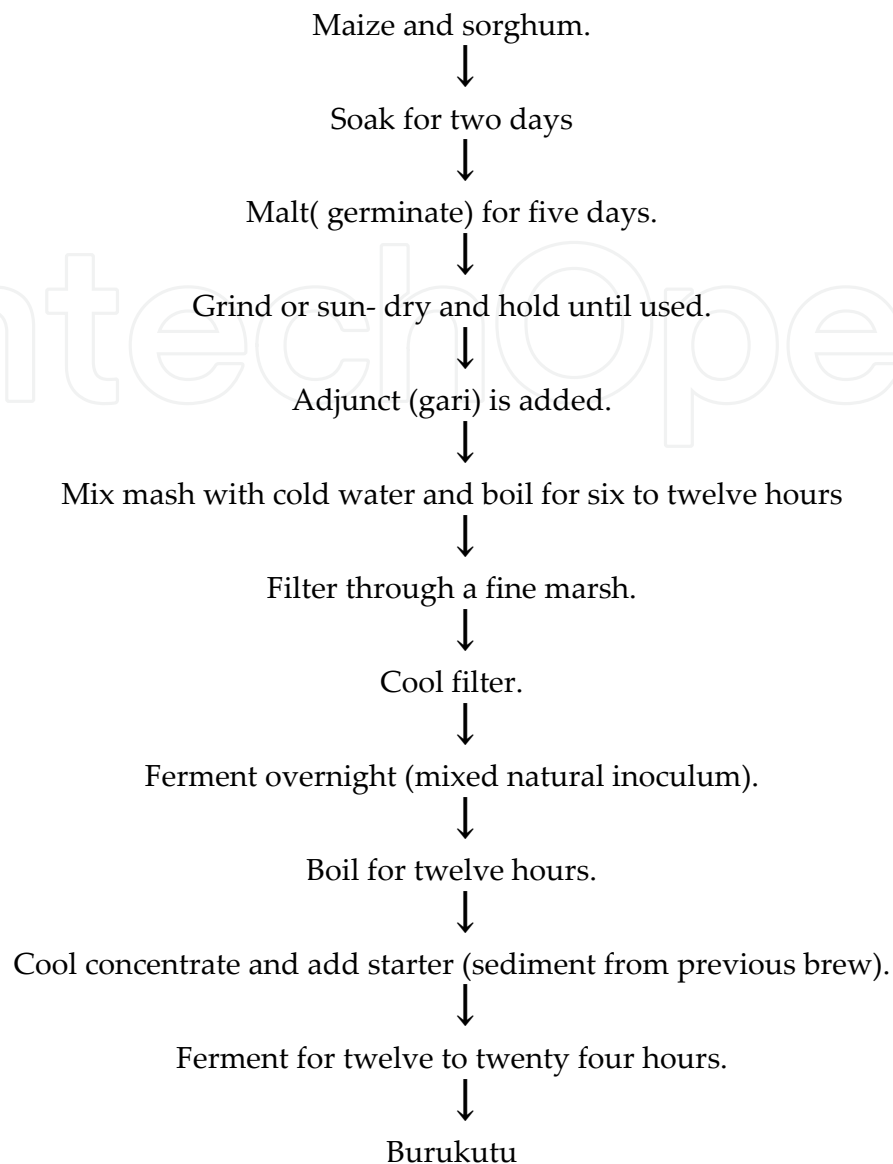


Figure 7. Process flowchart for production of burukutu.

e. Kunun-zaki.

Kunun-zaki is a non-alcoholic fermented beverage widely consumed in Northern part of Nigeria. This beverage is however becoming more widely consumed in southern Nigeria, owing to its refreshing qualities. Kunun-zaki is consumed anytime of the day by both adult and children as breakfast drink, food supplement. It is a refreshing drink usually used to entertain visitors, appetizers and is commonly used / served at social gathering. Although, there are various types of kunun processed and consumed in Nigeria which include; kunun-zaki, kunun-gyada, kunun-jiko, and amshau and kunun-gayamba. However, kunun-zaki is mostly consumed. The traditional process for the manufacture of kunun-zaki involves the steeping of millet grains, wet milling with spices (ginger, cloves and pepper) ,wet sieving and partial gelatinization of the slurry, followed by the addition of sugar and bottling.

The fermentation which occurs briefly during steeping of the grains in water for 8 to 48 hours period involves mainly lactic acid bacteria and yeast. Storage studies revealed that the product has a shelf-life of about 24 hours at ambient temperature, which was extended to 8 days by pasteurization at 60 °C for 1 hour and stored under refrigeration conditions.

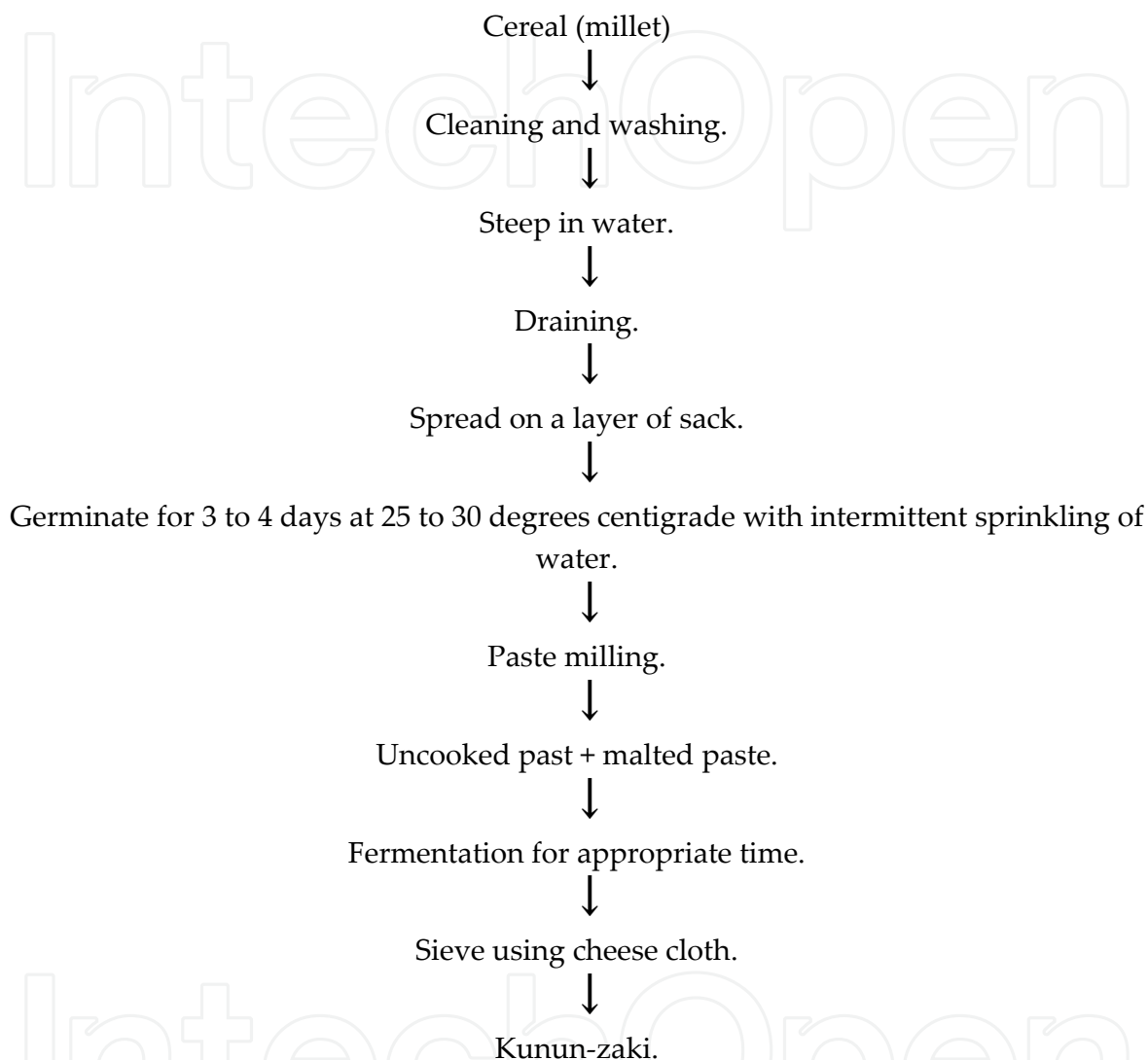


Figure 8. Flowchart for the traditional processes of kunun-zaki.

4. Fruits and vegetables

a. Ogiri

This is a condiments gotten from the fermentation of castor oil seeds. The raw castor oil seed are boiled for two hours until the seed changes colour to brown. The seeds are dehaulled, rinsed in clean water. The boiled seeds are boiled again for one more hour. It is then cooled and wrapped with enough banana leaves, which is then packed in a clean container with cover to ferment at room temperature.

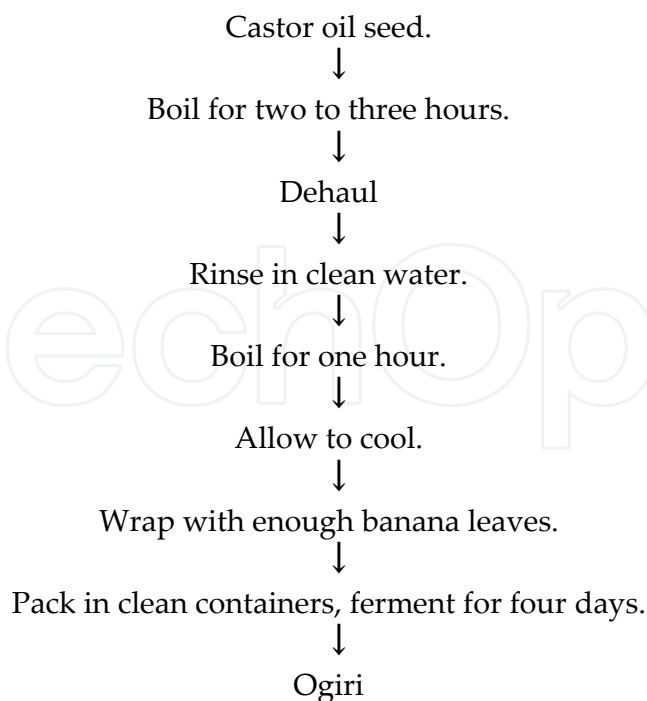


Figure 9. Flow chart for the production of ogiri.

5. Legumes (locust-beans, african oil beans, soya beans) iru, dadawa ugba, afiyo, dangwua)

a. Dadawa/Iru

This is one of the most important food condiments in Nigeria and many countries of West and Central Africa. It is used in much the same way as bouillon cubes are used in the Western world as nutritious flavouring additives along with cereal grains sauce and may serve as meat substitute. Dadawa (Iru) is prepared from the seeds of African locust beans, thus are rich in fat (39 to 40%) and protein (31 to 40%) (Achi, 2005) and contributes significantly to the energy intake, protein and vitamins, especially riboflavin, in many countries of West and Central Africa. Dadawa or iru is made from locust-bean (*Parkia biglobosa*) seed, a leguminous tree found in the Savannah region of Africa, Southeast Asia and South America. Dadawa is produced by a natural un-inoculated solid –substrate fermentation of the boiled and dehaulled cotyledon, the major fermenting organisms are the *Bacillus* and *Staphylococcus*. The beans mass after fermentation is sun-dried and moulded into round balls or flattened cakes. Due to the high protein content, it has a great potential as a key protein source and basic ingredient for food supplement.

Dadawa fermentation is very similar to that of okpehe prepared from the seeds of *Prosopis africana*, ogiri prepared from melon seeds (*Citrullus vulgaris*) and castor oil bean (*Ricinus communis*). Although, the organisms involved in the fermentation of these foods condiments and others have been identified, this has marginal effects as the industrial or commercial production is concerned. Traditionally fermentation of African locust beans involves boiling

the beans for twelve hours in excess water, until they are very soft to allow for hand dehauling after which the separated cotyledon is boiled for another two hours to soften it. The cotyledon is then wrapped with enough banana leaves (*Musa sapientum*) and packed with cover to ferment at room temperature.

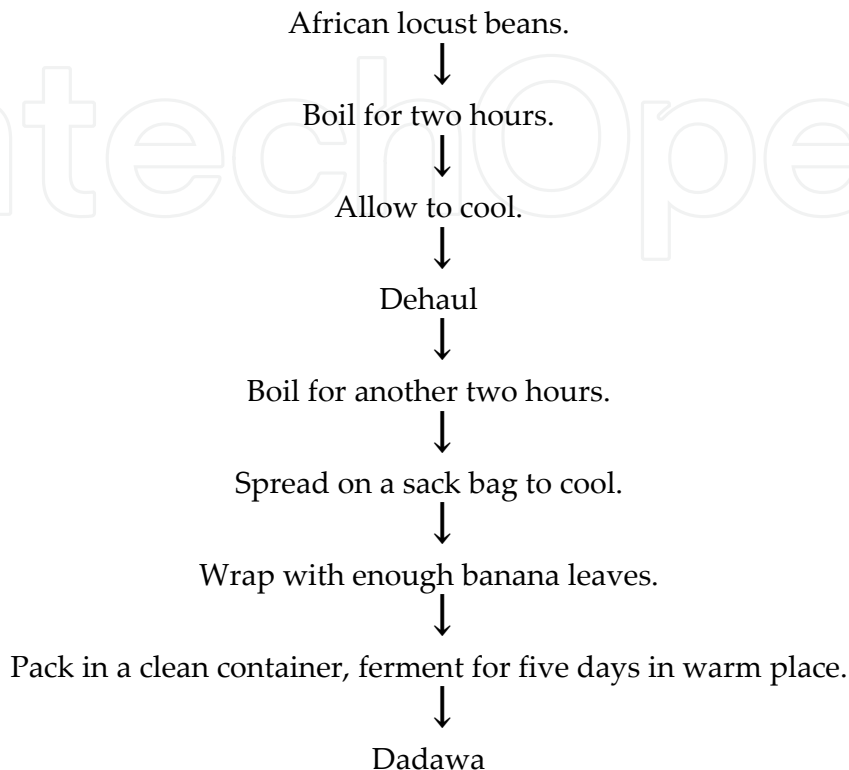


Figure 10. A Flow chart for the production processes of dadawa.

Other biochemical changes that occur during dadawa fermentation include the hydrolysis of indigestible oligosaccharide present in African locust beans notably stachyose and raffinose, to simple sugars by alpha and beta galactosidase, the synthesis of B-vitamins (thiamin and riboflavin), vitamin C and the reduction of anti-nutritional factors (oxalates and phytates). An improved process for industrial production of dadawa involves dehauling African locust bean with ball (disc) mill, cooking in a pressure retort for one hour inoculating with *Bacillus subtilis* culture, drying the fermented beans and milling into a powder. Cadbury Nigeria Plc. In 1991 introduced cubed dadawa but it failed to make the desired market impact and it is withdrawn. It would appear that consumers preferred the granular product to the cubed product.

b. Ugba

Fermented African Oil bean seed, (*Panthalacthra macrophylla benth*) Ugba, is an indigenous fermented food and a popular staple among the eastern part of Nigeria. It is rich in protein and other minerals and is obtained by solid-state fermentation of the African Oil bean seed.

It is gotten traditionally from the fermentation of oil bean seed. It contains up to 44% protein, which comprise of at least 17 of the 20 amino and protein digestibility and

utilization increases with fermentation (Okechukwu *et al*, 2012). The oil bean seeds are boiled for three hours, dehaull and cooked, the cooked seeds are then sliced (0.5 to 1mm thickness) and boiled again for two hours, drained, rinsed thrice in water and steeped in cold water for four hours so as to eliminate the bitter taste. The sliced beans are wrapped with enough banana leaves (*Musca sapientum*), packed in a clean container and covered to ferment at room temperature.

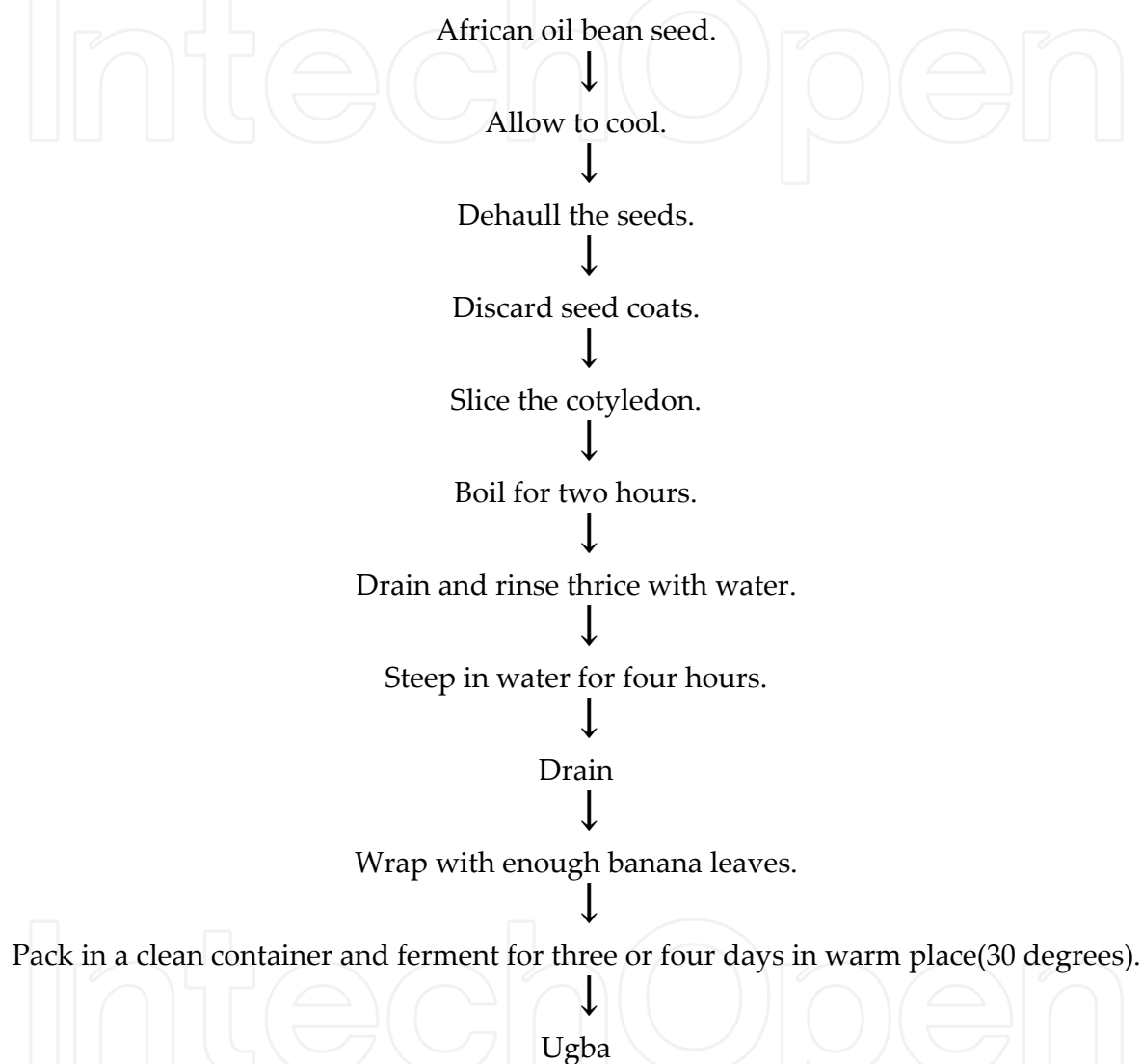


Figure 11. A flow chart for the production process of ugba.

c. Afiyo (Okpehe)

Afiyo as is called by the Hausas or Okpehe as known by the Idomas in Benue state is a fermented food flavouring condiment most popular in the middle belt of Nigeria. It is produced from *Prosopis Africana*, which is a leguminous oil seed, fermented in most part of Benue, Niger, Kaduna states and northern parts of Kwara state. This fermented product of *Prosopis Africa* is a strong smelling mash of sticky browned seed and fermentation is moist solid state by chance inoculation, supposedly by various species of micro-organisms.

Various fermented foods have been recorded and these are highly placed condiments while some serve as main meals. Of the thousands of legumes, less than twenty are used extensively in use. Those in common use include peanuts, soy beans, locust beans, oil beans, cowpea and lentils etc.

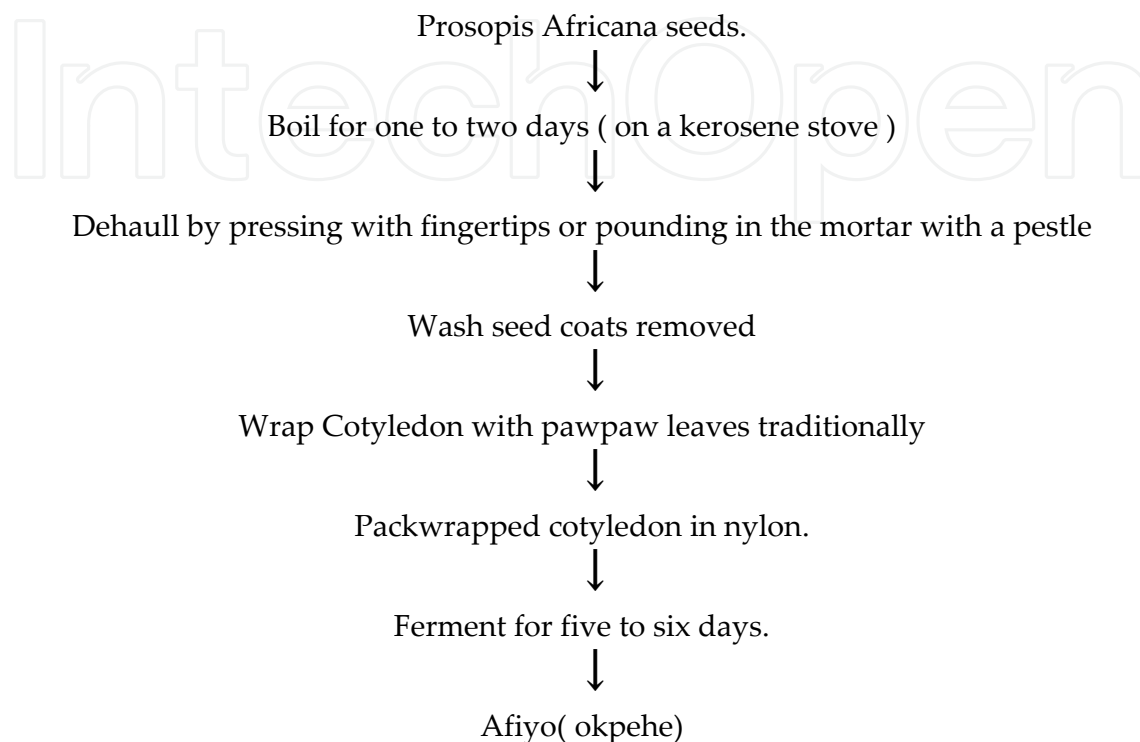


Figure 12. Flow chart for the traditional preparation of okpehe.

Generally, the concentration of amino acids increases during the production of condiments (dadawa, ogiri, ugba) as the fermentation day increases, and it reaches a peak at day four, day three, and day two respectively. This progressive increase in concentration of amino acids in condiments is due to the decrease in total protein as fermentation progresses, which may be attributed to the effect of protease enzymes which result in the hydrolysis of protein molecules to small molecules such as amino acids, such protease activities in the fermenting oil seed increases digestibility than the seed.

Reducing sugar concentration increases with days of fermentation and reaches a peak at the day five, day four, day three for African locust bean, African oil bean seed and castor oil seed respectively. The increase in reducing sugar is due to the hydrolysis of carbohydrates in the presence of certain enzymes such as amylases and galactase. This phenomenon is expected since microbial amylase hydrolyses higher carbohydrates (polysaccharides and disaccharides) to reducing sugars which are then readily digestible by humans. Similarly, galactose softens the texture of the seeds and liberates sugar for digestion. The reduction in the amino acids and the reducing sugar concentration may be due to the presence of some micro-organism that feed on amino acids and reducing sugars.

6. Animal products (milk, meat) nono, cheese, kilishi

a. Nono

Nono is a fermented food drink derivatives gotten from cow milk. As a general practice among Fulani Herdsmen, the milking is done between the third and sixth months of lactation. Until the third month, the calves are left to consume milk. Cows are only milked at night and since no milking is possible during the day calves roam with the dam. Milk, if left untreated, spoils within a short time due to microbial activity; thus, processing of milk improves its storage and diversifies its use.

Traditionally, nono is prepared by inoculating freshly drawn cow milk with a little of the leftover as starter and then is allowed to ferment for twenty four hours at room temperature. During fermentation, some of the lactose is converted to the lactic acid. At the end of the fermentation period, the milk butter is removed by churning for further use and the remaining sour milk, nono is a delicious and refreshing beverage. Most of the organisms involved in the fermentation process are usually of three main groups; bacteria, yeast, and mould. Of these, *Lactobacilli* (*L. acidophilus* and *L.bulgaris*), *Lactococci species* (*L. cremoni*, and *L.lactis*), *Streptococcus thermophilus*, *Leuconostoc species* and *Saccharomyces species* seems to be the most prominent, each giving the product a characteristic flavour.

Nono has yoghurt-like taste (sharp acid taste), and is therefore usually taken with sugar, and fura which is made up of millet flour compressed in balls and cooked for about twenty to forty minutes. The cooked fura is crumbled in a bowl of nono (now called fura de nunu). Nono is an excellent source of protein, rich in essential amino acids and a good source of calcium, phosphorus and vitamin A, B, C, E and B complex. However, like other milk products, it is poor in ascorbic acid and iron. Wives of pastoralist usually process fresh milk into various traditional milk product. These include nono, (sour milk), kindirimo (sour yoghurt), maishanu (local butter), cuku (Fulani cheese) and wara (Yoruba cheese). These products are usually hawked around the local markets in certain towns. These products are usually only available within the walking distance of Fulani settlement. For the same reason, these products are also more readily available in the northern states of the country.

b. Production of kilishi and other processed meats of interest.

Suya (esire or balangu), banda (kundi) and kilishi are the most important traditional processed meats in Nigeria and other West African countries including Chad, Niger and Mali.

Banda is a salted, smoke-dried meat product made from chunks of cheap, low quality meat from various types of livestock including donkeys, horses, camel, buffalo and wild life. The meat chunk is pre-cooked before smoking/ kiln drying or sun-drying. The traditional smoking/ kiln for banda, usually an open top. Fifty-gallon of oil drum fitted with layers of wire mesh that hold the product, and fired from the bottom. Banda is a poor product, stone-hard and dark I and n colour. Unlike banda, suya, and kilishi are made by roasting, spiced, salted, slices,/ strips of meat (usually beef).

Kilishi is different from suya in that a two stage sun-drying process proceeds to roasting. Consequently, kilishi has a low moisture content (6-14%) than suya (25-35%) and a longer shelf- life. A variety of spices and other dried ingredients are used in kilishi processing including ginger (*Zingiberofficinale*), chillies (*Capsicufrtescens*), melegueta pepper (*Aframomum melegueya*), onion (*Allium cepa*) and defatted peanut (*Arachis hypogea*), cake powder, kilishi consist of about 46% meat and 54% non-meat ingredients with defatted powder accounting for about 35% of the ingredients formulation. Other traditional processed meat products in Nigeria include ndariko and jirge.

The summary of micro organism associated with Nigerian fermented foods is shown in table 1

SUBSTRATE	MICROORGANISM	PRODUCT
Cassava	<i>Leuconostoc sp</i> <i>Geotrichum candidum</i> <i>Pseudomonas sp.</i> <i>Scolecotrichum graminis</i> <i>Bacteriodes sp.</i> <i>Tallospora aspera</i> <i>Actinomyces sp.</i> <i>Passalora bacilligera</i> <i>Corynebacterium sp.</i> <i>Varicosporium species</i> <i>Lactobacillus sp.</i> <i>Culicidospora gravida</i> <i>Diplococcium spicatum</i>	Gari
Yam	<i>Streptococcus sp.</i> <i>Articulospora inflate</i> <i>Lactobacillus sp.</i> <i>Aspergillus niger</i> <i>Listeria sp.</i> <i>Aspergillus rapens</i> <i>Aspergillus flavus</i> <i>Lemonniera aquatic</i>	Elubo-isu
African locust beans <i>Parkia filicoida</i>	<i>Lactobacillus sp.</i> <i>Rhizopus stolonifer</i> <i>Streptococcus sp.</i> <i>Aspergillus fumigatus</i> <i>Pediococcus sp.</i> <i>Triscelophorus monosporus</i> <i>Bacillus sp., Coryneform bacteria</i>	Iru
Castor seed <i>Ricinus communis</i>	<i>Bacillus spp., Pseudomonas spp.</i> <i>Micrococcuss spp., Streptococcus</i>	Ogiri-igbo
Fluted pumpkin seeds <i>Telferia occidentalis</i>	<i>Bacillus spp., E. coli, Staphylococcus Spp., Pseudomonas</i>	Ogiri ugu

SUBSTRATE	MICROORGANISM	PRODUCT
African oil beans <i>Pentaclethra macrophylla</i>	<i>Bacillus subtilis</i> , <i>Staphylococcus</i> spp., <i>Micrococcus</i> spp., <i>Corynebacterium</i> spp.	Ugba / Ukpaka
Soya bean	<i>B. subtilis</i> , <i>B. licheniformis</i> , <i>B. megaterium</i> , <i>Staphylococcus epidermidis</i> , <i>Micrococcus</i> spp.	Okpiye/Okphehe
African yam beans <i>Stenophylis stenocarpa</i>	<i>Bacillus subtilis</i> , <i>B. licheniformis</i> , <i>B. pumilis</i> , <i>Staphylococcus</i> sp.	Owoh
Melon seed <i>Citrulus vulgaris</i>	<i>Bacillus subtilis</i> , <i>B. megaterium</i> , <i>B. firmus</i> <i>E.coli.</i> , <i>Proteus</i> , <i>Pediococcus</i> , <i>Alcaligenes</i> spp., <i>Pseudomonas</i> <i>aeruginosa</i>	Ogiri-egusi
Cereals: maize, sorghum, millet	<i>Saccharomyces cerevisiae</i> , <i>Lactobacillus</i> spp., <i>Fusarium</i> spp.	Ogi Agidi
Milk	<i>Lactobacillus</i> spp. <i>Lactococcus</i> spp. <i>Streptococcus</i> spp. <i>Pediococcus</i> spp. <i>Leuconostoc</i> spp. <i>Propionibacter</i> spp.	Wara (Nigerian cheese)
Grain flour	<i>Saccharomyces cerevisiae</i>	Bread
Cereals (Millet, sorghum, maize, rice)	<i>Lactobacillus plantarum</i> , <i>L. fermentum</i> and <i>Lactococcus lactis</i>	Kunun-zaki

Ijabadeniyi(2007), Achi (2005) Agarry, et.al.,(2010) Osho, et, al.,(2010)

Table 1. Role of fermented food in detoxification.

6.1. Mycotoxin detoxification

Food and feeds are often contaminated with a number of toxins either naturally or through infestation by micro-organisms such as moulds, bacteria and virus. Certain moulds often produce secondary toxic metabolites called mycotoxins. These include fumonisins, ochratoxins A, zearalenone and aflatoxins. Several methods are available for degrading toxins from contaminated food. For example, using alkaline ammonia treatment to remove mycotoxins from food. However, these methods are harsh to food as they involve the use of chemicals which are potentially harmful to health or may impair or reduce the nutritional value of foods. Cooking foods does not remove mycotoxins either as most of them are heat stable. Detoxification of mycotoxins in foods through LAB fermentation has been demonstrated over the years (Biernasiak et.al. 2006). Using LAB fermentation for detoxification is more advantageous in that it is a milder method, which preserve the nutritive value and flavour of de-contaminated food. In addition to this, LAB fermentation irreversibly degrades mycotoxins without leaving any toxic residues. The detoxifying effect is believed to be through toxin binding effect.

In mycotoxin detoxification, LAB fermentation has also been successfully used to detoxify cassava toxins (cyanogens) following fermentation of cassava food product. In addition to cyanogens detoxification, cassava fermentation contributes to the preservation and improvement of flavour and aroma of cassava ferment. Although cooking has been used as a method of cyanogens detoxification, it has a number of problems as it leaves residual cyanogens in processed cassava, which exist as glucosides, cyanohydrins or free cyanide which are equally toxic as their parent compounds in uncooked food.

In a review, Bankole and Adebajo (2003), found that the level of aflatoxin B₁, B₂ and

G₁ were significantly higher in corn from the high incidence area for human hepatocellular carcinoma and the average daily intake of aflatoxin B₁ from the high risk area was 184.1 g/kg aflatoxin. Udoh *et al* (2000) reported 33% of maize sample from ecological zones of Nigeria contaminated with aflatoxins.

Fermented maize (Ogi) is a staple cereal in Nigeria and it is a popular weaning food in most rural communities in Nigeria. Oluwafemi and Ikeowa (2005) have reported that in fermenting maize to ogi, aflatoxin B₁ was reduced by about 50% after 72 hours of fermentation. Maize as well as other Nigerian cereals are also important raw materials for both local and commercial beer brewing. Oluwafemi and Taiwo (2003) have shown that the role of *S. cerevisiae* in reducing the pH from 5.2 to 3.7 during fermentation is important in detoxifying aflatoxin B during beer fermentation.

6.2. Cyanide detoxification

Processing of cassava roots improves palatability, reduces or eliminates potential toxicity, transforms raw cassava into other preservable forms which are more beneficial to man. Fermentation is by far the most common method of processing the cassava crop in Africa (Okafor *et al.*, 1984). The rate of detoxification of cyanide by traditional fermentation is

shown in figure 13. Fermentation is a very effective way for detoxification of cyanide in cassava with r^2 of 98%.

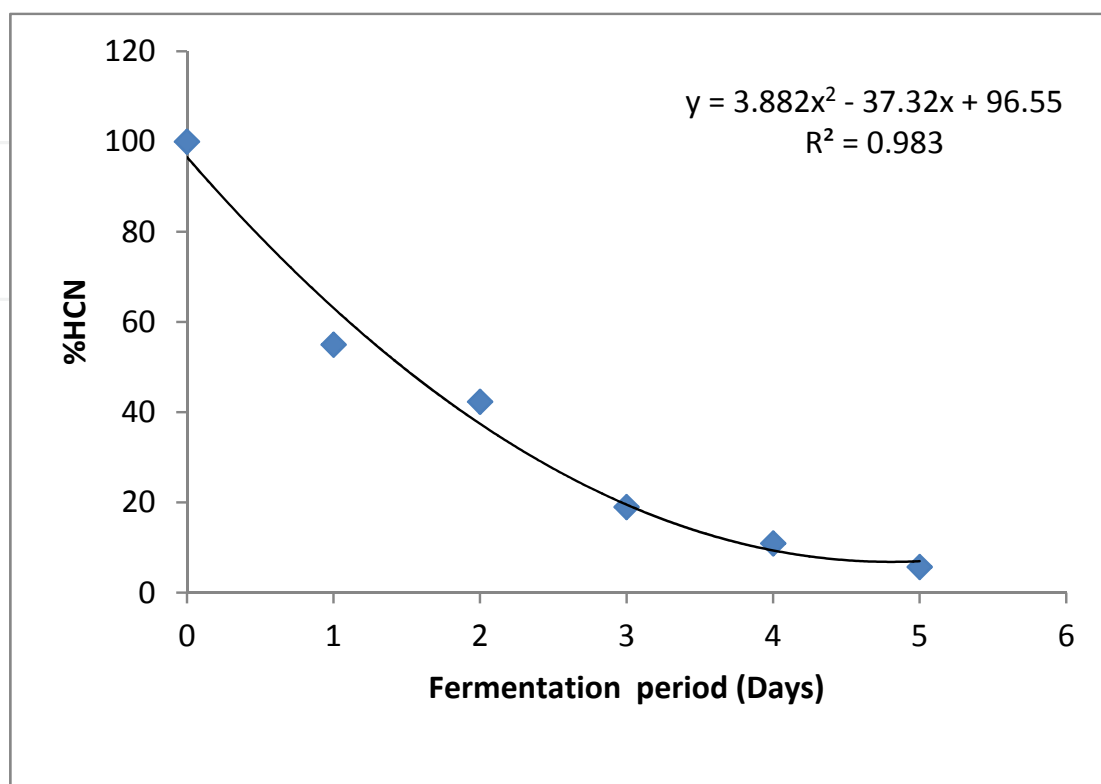


Figure 13. Effect of fermentation on %HCN.

6.3. Loop fermentation

Loop fermentation is achieved by using starter culture from already fermented product to inoculate a fresh batch of fermentation process. Ohenhen and Ikenebomeh (2007) have shown that that loop fermentation can prolong the shelf-life of ogi from about 40days, obtained by traditional fermentation method to well over 60days. We have observed in our laboratory that by using loop fermentation technique in gari processing, fermentation was completed in three days as against five days by the conventional traditional fermentation. Cyanide content also reduced to about 3% with loop fermentation. With a second loop (double loop) ie using products of a first loop fermentation to inoculate a fresh process, fermentation in gari production was completed in 2day with only about 2.6% cyanide remaining. The explanation is that the organisms are “trained” to better utilize the compounds in the fermenting substrate. When the fermenting substrate in the double loop was acidified by squeezing some limes (citrus) juice into it before inoculating, cyanide content was 0% after 3days. The summary is shown in Fig. 14.

6.4. Detoxification of phytates, tannins and oxalates

The anti-nutrients including Phytates, tannins and oxalates interferes with mineral absorption and palatability of the cereals so detoxification is vital to enhance their nutrient

value and organoleptic properties. Several detoxification methods are available, including decortication, malting, fermentation and alkali treatment (Osuntogun *et al.*, 1989; Banda-Nyirenda and Vohra, 1990). Yeast fermentation has proved very effective in the detoxification of antinutrients. The table below summarizes the effectiveness of yeast in detoxification of different anti-nutrient.

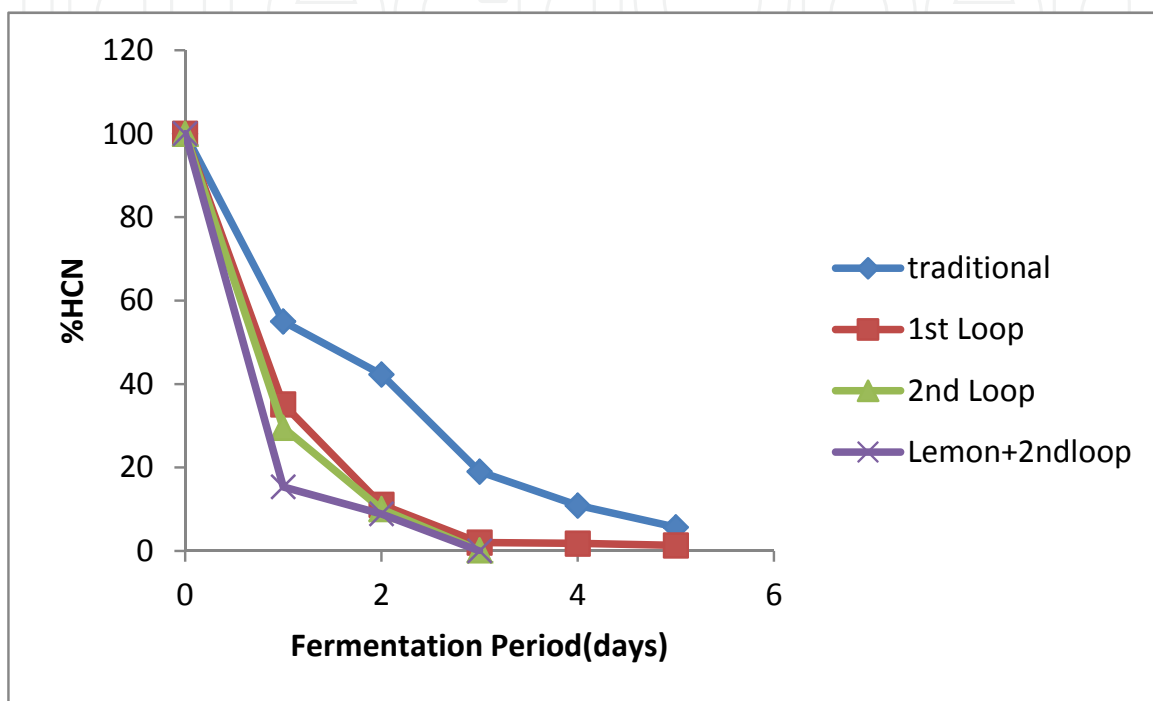


Figure 14. Effect of fermentation loop on Percentage residual HCN

Onyesom *et al.*(2008) have also shown that fermentation of cassava to fufu with lemon grass reduces cyanide to less than 1% after 5days.

Phytic acid is well documented to block absorption of not only of phosphorus, but also other minerals such as calcium, magnesium, iron and zinc. It also negatively affects the absorption of lipids and protein. One reason this is true is because phytic acid also inhibits enzymes that are needed to digest foods such as pepsin (which helps break down protein), amylases (convert starch into sugar for digestion) and trypsin (also used in protein digestion). While whole grains have a much higher mineral content than processed grains, the full benefit of that nutrition is lost if phytic acid blocks the nutrients from being absorbed. It is well known that most cereals and legumes contain high levels of these ant-nutrients. It is also common knowledge that most of the Nigerian staples as in other developing countries constitute mainly cereals and legumes. It is therefore important that these foods staples are fermented as well as improve on the traditional fermentation techniques.

Activity	Yeast species	Effects
Biodegradation of phytate	<i>Saccharomyces cerevisiae</i> , <i>Saccharomyces kluyveri</i> , <i>Schwanniomyces castellii</i> , <i>Debaryomyces castellii</i> , <i>Arxula adeninivorans</i> , <i>Pichia anomala</i> , <i>Pichia rhodanensis</i> , <i>Pichia spartinae</i> , <i>Cryptococcus laurentii</i> , <i>Rhodotorula gracilis</i> , <i>Torulasporea delbrueckii</i> , <i>Kluyveromyces lactis</i> <i>Candida krusei</i> (<i>Issatchenkia orientalis</i>) and <i>Candida</i> spp.	Nutritional importance, i.e., bioavailability of divalent minerals such as iron, zinc, calcium and magnesium
Folate biofortification	<i>S. cerevisiae</i> <i>Saccharomyces bayanus</i> , <i>Saccharomyces paradoxus</i> , <i>Saccharomyces pastorianus</i> , <i>Metschnikowia lochheadii</i> , <i>Debaryomyces melissophilus</i> , <i>Debaryomyces vanriijiae</i> var. <i>vanriijiae</i> , <i>Debaryomyces hansenii</i> , <i>Pichia philogaea</i> , <i>Kodamaea anthropila</i> , <i>Wickerhamiella lipophila</i> , <i>Candida cleridarum</i> and <i>Candida drosophilae</i> <i>Candida milleri</i> and <i>T. delbrueckii</i> <i>Saccharomyces exiguous</i> and <i>Candida lambica</i> <i>P. anomala</i> and <i>Candida glabrata</i> <i>Kluyveromyces marxianus</i> and <i>C. krusei</i> (<i>I. orientalis</i>)	Prevention of neural tube defects in the foetus, megaloblastic anaemia and reduction of the risk for cardiovascular disease, cancer and Alzheimer's disease
Degradation of mycotoxins	<i>. cerevisiae</i> spp <i>Phaffia rhodozyma</i> and <i>Xanthophyllomyces dendrorhous</i>	Antitoxic in some degree

Moslehi-Jenabian, *et al.*, 2010**Table 2.** Overview of yeasts activities in degradation of anti-nutrients.

7. Conclusion

Developing countries like Nigeria require food processing technologies that are appropriate, suitable for tropical regions and affordable to rural and urban economies. Fermentation techniques are one of such technologies that have been developed indigenously for a wide range of food products. These include root crops, cereals, legumes, fruit and vegetables, dairy, fish and meat. As a unit operation in food processing, fermentation offers various advantages, including, improved food safety, improved nutritional values, enhance flavour and acceptability, reduction in anti-nutrients, detoxification of toxigenic compounds, enhanced shelf-life and improved functional properties.

The present review has shown that Nigerian fermented food and food products can be developed into medium or large scale level for standard commercial products. However, there is the need to further optimize the processes.

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