**CEREAL FERMENTATION**

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**INTRODUCTION**

Major cereals grown in Africa include maize, rice, sorghum and millet. Cereals are more widely utilized as food in African countries, than in the developed world. In fact, cereals account for as much as 77 % of total caloric consumption in African countries and contribute substantially to dietary protein intake in a number of these countries. Majority of traditional cereal-based foods consumed in Africa are processed by natural fermentation. Fermented cereals are particularly important as weaning foods for infants and as dietary staples for adults.

**CLASSIFICATION OF FERMENTED CEREALS**

Fermented cereal-based food products produced in African countries can be classified on the basis of either the raw cereal ingredients used in their preparation, or the texture of the fermented product.

**Classification on the basis of raw cereal ingredients:**

a) wheat-based foods e.g. bouza, kishk  
b) rice-based foods e.g. busa   
c) maize-based foods e.g. ogi, bread, kenkey  
d) millet-based foods e.g. kunuzaki  
e) sorghum-based foods e.g. pito, ogi, bogobe, kisra, burukutu, kisra, injera  
f) barley-based foods e.g. beer

**Classification on the basis of texture:**

a) liquid (gruel) e.g. ogi, mahewu, burukutu, pito, uji  
b) solid (dough) and dumplings e.g. kenkey, agidi  
c) dry (bread) e.g. kisra, injera

**PRE-FERMENTATION PROCESSING OF CEREALS**

Pre-fermentation processing of cereals is largely dependent on the end product desired. In most cases, grains are sun-dried prior to fermentation. Treatments such as washing, steeping, milling and sieving are pre-fermentation processing steps applied in the preparation of fermented gruels, while milling and sieving are required as pre-fermentation processing steps in the production of dry fermented foods such as bread.

**FERMENTED CEREAL-BASED FOODS**

Indigenous fermented foods prepared from major cereals are common in many parts of Africa. Some are used as beverages and breakfasts or snack foods while a few are consumed as staples and weaning foods (Tables 2 and 3).

**Fermented Gruels and Non-Alcoholic Beverages**

**Ogi**

Ogi is a porridge prepared from fermented maize, sorghum or millet in West Africa. It is a staple of that region, and serves as a weaning food for infants. The traditional preparation of ogi involves soaking of corn kernels in water for 1 to 3 days followed by wet milling and sieving to remove bran, hulls and germ . The pomace is retained on the sieve and later discarded as animal feed while the filtrate is fermented (for 2-3 days) to yield ogi, the sour, white starchy sediment. Ogi is often marketed as a wet cake wrapped in leaves or transparent polythene bags. It is diluted to a solids content of 8 to 10% and boiled into a pap, or cooked and turned into a stiff gel called "agidi" of "eko" prior to consumption.

Microbiological and nutritional studies showed that the lactic acid bacterium *Lactobacillus plantarum*, the aerobic bacteria *Corynebacterium* and *Aerobacter*, the yeasts *Candidamycoderma*, *Saccharomyces cerevisiae* and *Rhodotorula* and molds *Cephalosporium*, *Fusarium*, *Aspergillus* and *Penicillium* are the major organisms responsible for the fermentation and nutritional improvement of ogi. It was determined by research that *L. plantarum* was the predominant organism in the fermentation responsible for lactic acid production. *Corynebacterium* hydrolysed corn starch to organic acids while *S. cereviseae* and *Candida mycoderma* contributed to flavour development.

Substantial nutrient losses occur during the various steps of ogi processing. Steeping, milling and sieving are the processing steps during which considerable nutrient losses take place. Much of the protein in cereal grains is located in the testa and germ which are usually sifted off during processing.

**Table 2. Fermented Non-Alcoholic Cereal-Based Foods In Africa**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Product name** | **Area of production** | **Substrate** | **Microorganisms  involved** | **Textural  characteristics  of product** |
| Ogi   BogobeKoko and kenkey   Mawe  Mahewu (magou)  Uji  Kisra  Enjara | Nigeria, Benin   BotswanaGhana   Dahomey  South Africa  East Africa  Sudan  Ethiopia | Maize, sorghum or millet   SorghumMaize, sorghum or millet   Maize  Maize sorghum or millet  Maize, sorghum or milletSorghum  Sorghum | *Lactobacillus* sp.  and yeasts  Unknown*Lactobacillus*sp.  and yeasts*L. fermentum*,  L. *cellobiosis*,  L. *brevis*, yeasts –  *Candida* *Krusei*  and *S. cerevisaeL. delbrueckii*,  and *L. bulgaricusLactobacillus*sp.Unknown  *Candida  guilliermondii* | Soft or stiff gel   PorridgeDough   Dough  Liquid  Liquid  Dough  Dough |

**Table 3: Alcoholic beverages produced from cereals in Africa**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Product name** | **Area of Production** | **Substrate** | **Starter** | **Mestrum** |
| Burukutu  PitoKaffir beer  Busaa (maize beer)  Malawa beer  Zambian opaquemaize beer  Merissa  Seketeh  Bouza  Talla  Kishk | Ethiopia Nigeria (north) Northern Ghana  Nigeria (Bendel) Ghana  South Africa  East Africa  Uganda  Zambia  Sudan  Nigeria (south)  Egypt  Ethiopia  Egypt | Guinea corn and cassava  Guinea corn and maize  Kaffir corn (or maize)  Maize  Maize  Maize  Sorghum  Sorghum  Maize  Wheat or maize  Sorghum  Wheat and milk | Yeasts and lactic acid bacteria  Moulds, yeast and *Lactobacillus* sp.  *Lactobacillus* spp. and yeasts  Yeasts and *Lactobacillus* spp.  *Candida krusei*  Yeasts  Lactic acid bacteria, acetic acid bacteria  Unknown  Unknown  Unknown  *Lactobacillus* spp., yeasts and *Bacillus*spp. | Liquid  Liquid  Liquid  Liquid  Liquid  Liquid  Liquid  Liquid  Liquid  Liquid  Liquid |

Corn  
   
Soak in water for 2 to 3 days  
   
Wet mill  
   
Sieve and discard pomace  
  
Ferment filtrate and allow to sediment for 1-3 days  
   
**OGI**

**Figure 1: Flow diagram for the preparation of ogi.**

**Kunu-Zaki**

This is a millet-based non-alcoholic fermented beverage widely consumed in the Northern parts of Nigeria. This beverage is however becoming more widely consumed in southern Nigeria, owing to its refreshing qualities. Production of kunu-zaki involves the steeping of millet grains, wet milling with spices (ginger, cloves, pepper), wet sieving and partial gelatinization of the slurry, followed by the addition of sugar, and bottling (Figure 12). The fermentation which occurs briefly during steeping of the grains in water over a 8-48 hr period is known to involve mainly lactic acid bacteria and yeasts.

Dehulled millet grains  
http://www.fao.org/3/x2184E/x2184e28.gif  
Clean  
http://www.fao.org/3/x2184E/x2184e28.gif  
Steep  
http://www.fao.org/3/x2184E/x2184e28.gif  
Wet mill with the addition of spices  
http://www.fao.org/3/x2184E/x2184e28.gif  
Wet-sieve  
http://www.fao.org/3/x2184E/x2184e28.gif  
Allow to settle  
http://www.fao.org/3/x2184E/x2184e28.gif  
Decant supernatant and retain slurry  
http://www.fao.org/3/x2184E/x2184e28.gif  
Slurry in cold water + Slurry in boiling water  
http://www.fao.org/3/x2184E/x2184e28.gif  
Add sweetener and mix  
http://www.fao.org/3/x2184E/x2184e28.gif  
Bottle  
http://www.fao.org/3/x2184E/x2184e28.gif  
**KUNU-ZAKI**

**Fig. 12: Flow Chart for the Traditional Process of Kunu-zaki**

**Burukutu**

This is a popular alcoholic beverage of a vinegar-like flavour, consumed in the Northern Guinea savanna region of Nigeria, in the Republic of Benin and in Ghana. The preparation of burukutu involves steeping sorghum grains in water overnight, following which excess water is drained. The grains are then spread out on to a mat or tray, covered with banana leaves and allowed to germinate. During the germination process, the grains are watered on alternate days and turned over at intervals. Germination continues for 4-5 days until the plumule attains a certain length. The malted grains are spread out in the sun to dry for 1-2 days, following which the dried malt is ground into a powder. Gari, (a fermented cassava product) is added to a mixture of the ground malt and water in a ratio of one part gari to two parts malt and six parts water. The resulting mixture is allowed to ferment for 2 days, following which it is boiled for approximately 4 hrs and allowed to mature for a further 2 days. The resulting product is a cloudy alcoholic beverage.

Sorghum malt contains primarily yeasts and moulds as the indigenous microflora. Microorganisms associated with the fermentation include yeasts mainly *Saccharomyces cerevisiae* and *S. chavelieri* and the bacteria, *Leuconostoc meseteroides*. The pH of the fermenting mixture decreases from about 6.4 to 4.2 within 24 hrs of fermentation and decreases further to 3.7 after 48 hrs. At the termination of the 2-day maturing period *Acetobacter sp*. and *Candida sp*. are the dominant microorganisms. Boiling prior to maturation eliminates lactics and other yeasts.

**Pito**

Pito is the traditional beverage drink of the Binis in the mid-western part of Nigeria. It is now 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 cereal grains (maize, sorghum or a combination of both) in water for 2 days, followed by malting, and allowing them to sit for 5 days in baskets 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 basket. The filtrate thus obtained is allowed to stand overnight, or until it assumes a slightly sour flavour, following which it is boiled to a concentrate. A starter from the previous brew is added to the cooled concentrate which is again allowed to ferment overnight. Pito, the product thus obtained, is a dark brown liquid which varies in taste from sweet to bitter. It contains lactic acid, sugars, amino acids and has an alcohol content of about 3%. Organisms responsible for souring include *Geotrichum candidum*and *Lactobacillus* sp. while *Candida* sp. are responsible for the alcoholic fermentation.

**Kenkey**

This is a fermented maize dough which is popularly consumed in Ghana. During the production of kenkey, the dough is divided into two parts: one part, the ‘aflata’ is cooked into a thick porridge, while the other uncooked part is later mixed with the ‘aflata’. The resulting mixture is moulded into balls and wrapped in dried maize husk or plantain leaves, after which it is steamed. It is interesting to note that kenkey varieties vary widely throughout Ghana. In northern Ghana, sorghum is sometimes used instead of maize for preparation of the dough.

Maize  
  
Clean  
  
Steep (24-48 hrs)  
  
Mill  
  
Dough formation  
  
Ferment for 72 hr

Cooked dough                             Raw dough

Mix (Aflatasation)  
  
Mould into balls  
  
Wrap with maize husks  
  
Boil for about 3 hrs  
  
**KENKEY**

**Fig. 3: Flow chart for the traditional preparation of kenkey**

**Mahewu**

This is a fermented maize meal commonly consumed as a staple among black South Africans. It is traditionally prepared by adding one part of maize meal to 9 parts of boiling water. The suspension is cooked for 10 minutes, allowed to cool and then transferred to a fermentation container. At this stage, wheat flour (about 5% of the maize meal used) is added to serve as a source of inoculum. Fermentation occurs in a warm sunny place within 24 hrs. *Streptococcus lactis* is the main fermenting organism in traditionally prepared mahewu.

Mahewu is known to offer some advantages over ogi in that the initial wild fermentation by fungi is eliminated by boiling both the maize meal and water for steeping. Furthermore, it is pre-cooked and requires only mixing prior to consumption. Mahewu consists of coarse maize particles while ogi contains very fine pasty maize particles.

Mahewu is currently produced on an industrial scale as a pre-cooked ready-mix powder. The industrial production of mahewu therefore spurs the need for the development of starter cultures. Research has evaluated the use of various lactic acid bacteria as starters in mahewu fermentation and determined that *Lactobacillus delbruckii* and *Lactobacillus* *bulgaricus* produced the most acceptable mahewu at a temperature of 500 C, which was determined to disallow the growth of unwanted microorganisms. In South Africa, a more acceptable mahewu was produced at room temperature using a combination of starters including an acid-producing bacterium, a yeast and a non-acid producing bacterium. The identity of the various organisms used was not however disclosed by these workers.

Maize meal  
  
Mix in warm water to give 8% solids content  
  
Cook at 121oC for 15 minutes  
  
Cool  
  
Inoculate  
(5% wheat flour or an adapted pure culture of *Lactobacillus delbrueckii*)  
  
Incubate at 30-50oC for wheat innoculum, or at 45oC for *L. delbrueckii* innoculum   
  
Ferment for 36 hrs with mixing only at the beginning of fermentation  
  
Heat for 10-15 mins under pressure (7 psi)  
  
Spray or drum dry  
  
**MAHEWU**

**Fig. 4: Industrial preparation of mahewu**

**Injera**

Injera is the most popular baked product in Ethiopia. It is a fermented sorghum bread with a very sour taste (Stewart and Getachew, 1962) and is the undisputed national bread of Ethiopia. The baked product is referred to by different names depending on the locality of production in Ethiopia. It is referred to as ‘bidena"in Oromigua, ‘taeta’ in Giragigua, and ‘solo’ in Walaytigna. According to a report by Gebrekidan and Gebrettiwat (1982) over 8% of total sorghum production in Ethiopia is used for ‘injera production. The sorghum grains are dehulled manually or mechanically and milled to flour which is subsequently used in the preparation of injera (Figure 8).

Sorghum flour  
http://www.fao.org/3/x2184E/x2184e28.gif  
Mix with water, 4:1 *w/v*http://www.fao.org/3/x2184E/x2184e28.gif  
Knead to form a dough  
http://www.fao.org/3/x2184E/x2184e28.gif  
Mix with starter  
(Fermented yellowish liquid saved from previously fermented dough)  
http://www.fao.org/3/x2184E/x2184e28.gif  
Knead   
http://www.fao.org/3/x2184E/x2184e28.gif  
Add water  
http://www.fao.org/3/x2184E/x2184e28.gif  
Ferment for 48 h  
http://www.fao.org/3/x2184E/x2184e28.gif  
Add water and allow to stand for 1 h  
http://www.fao.org/3/x2184E/x2184e28.gif  
Bake on hot  
greased clay griddle metal till holes begin to form on top  
http://www.fao.org/3/x2184E/x2184e28.gif   
**INJERA**

**Fig. 8: Flow diagram for the preparation of injera**

On the basis of production procedures three types of injera are distiguishable: (i) thin injera which results from mixing a portion of fermented sorghum paste with three parts of water and boiling to yield a product known as ‘absit’’ which is, in turn, mixed with a portion of the original fermented flour (ii) thick injera, which is reddish in color with a sweet taste, is a ‘tef’ paste that has undergone only minimal fermentation for 12-24 hours; (iii) komtata-type injera, which is produced from over-fermented paste, and has a sour taste. The paste is baked or grilled to give a bread-like product. Yeasts are the major microorganisms involved in the fermentation of the sweet type of injera.There is little variation in the nutrient composition of injera prepared from different cereals, which indicates the potential for the use of cereals other than sorghum in the production of injera.