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Full Length Research Paper

Physical and nutritive properties of fermented cereal foods

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Fermented cereal porridge, "Ogi" is made from maize, sorghum or millet. Fermented cereal porridges (and gels) are important staple food items for people of the West African sub- region and are also important weaning foods for infants. The qualities of these foods are measured in terms of their nutritive values evidenced in the biochemical properties and the textural characteristics. These qualities are influenced by many factors of types of cereal grains and the kind of treatments these grains undergo during processing. Many workers seeking to enhance Ogi nutritional status have investigated the ways in which these factors influence its physical and biochemical properties. This review attempts to bring into focus these various efforts.

Key words: Fermented cereal porridges, physical and nutritional properties.

INTRODUCTION

Cereal grains had been one of man's earliest sources of food (Matz, 1971). One way of processing the grains into food is through fermentation (Akinrele, 1970; Akingbala, et al., 1981; Fields et al., 1981; Adeyemi and Beckley, 1986). The grains are fermented, milled and mixed into a starch mush by mixing with water and then cooked. When diluted to thinness, the mush is a drink or porridge; 8-10% total solids, and is eaten with beans cake or other protein rich foods (Oke, 1967: Osungbaro, 1990[b]). Cereal food dough is obtained when the fermented cereal starch mush is boiled and on cooking forms a stiff gel (Amoa and Muller, 1976; Osungbaro, 1990[a]).

Fermented cereals are very widely utilized as food in African countries and in fact cereals account for as much as 77% of total caloric consumption (Chavan and Kadam, 1989). A majority of traditional cereal based foods consumed in Africa are processed by natural fermentation and are particularly important as weaning foods for infants and as dietary staples for adults (Akobundu, 1982; Umoh and Fields, 1981). These fermented cereal based food products can be classified on the basis of either the raw cereal ingredients used in their preparation or the texture of the fermented products.

The major cereal based foods are derived mainly from maize, sorghum, millet, rice, or wheat. In terms of texture, the fermented cereal foods are either liquid (porridge) or stiff gels (solid). The cereal porridges include *ogi, mahewu* and *mawe*, which are prepared from maize, millet, or sorghum. The cereal gels are *agidi, kenkey, bogobe, banku, injera and kisra* (Table1). Pre-fermentation treatments of cereals are largely dependent on the type of cereal and on the end product desired. Generally, treatments such as drying, washing, steeping, milling, and sieving are some of the processing steps applied in the preparation of these fermented cereal foods (Akinrele, 1970; Muller, 1980; Akingbala et al., 1981; Adeyemi, 1983; Adeyemi and Beckley, 1986; Osungbaro, 1990[a]). During manufacture of these fer-mented cereal foods, nutrients including protein and minerals are lost from the grains thereby affecting nut-ritional quality adversely (Aminigo and Akingbala, 2004). Such foods are often of poor protein qualities and have high paste properties. Efforts to improve the nutritional status of these staples have been based on fortification with legumes to provide the deficient amino acids (Osundahunsi et al., 2003). Various attempts that have been made for nutrient restoration and fortification of *ogi* include blending with fermented and unfermented legumes (Otunola et al., 1998; 2006), and addition of pawpaw slurry at various levels of substitution (Otunola et al., 2006).

A lot of other attempts have been made by various workers to investigate and improve the physical and biochemical nature of a number of these traditionally fermented cereal based foods. *Ogi*, being an important cereal porridge in the West African sub-region, has for sometime been a subject of scientific evaluations. This paper is an overview of the numerous attempts at

Table 1. Some fermented non-alcoholic cereal-based foods in Africa.

Product name	Countries of production	Substrate	Fermenting Microorganism	Textural characteristics
Ogi	Nigeria, Benin	Maize, Sorghum or Millet	Lactobacillus Sp; Aerobacter; Corynebacterium; yeast moulds.	Liquid (porridge)
Mahewu	East African Countries	Maize, Sorghum and Millet	Lactobacillus delbrukii; L.bulgarius; Streptococcus lactis.	Liquid (porridge)
Mawe	South Africa, Benin	Maize	Lactobacillus fermentum; Candida krusei; S. cerevisae	Liquid (porridge)
Agidi	Nigeria, Benin	Maize	Lactobacillus sp., Aerobacter; Corynebacterium; Yeast; moulds.	Dough (solid)
Kenkey	Ghana, Botswana	Sorghum, Maize, Millet	Lactobacillus Sp; Yeasts.	Dough (solid)
Bogbe	Ghana, Botswana	Sorghum, Millet, Maize	Lactobacillus sp. Yeasts.	Dough (solid)
Banku	Ghana	Maize	Lactobacillus sp.Moulds.	Dough (solid)
Injera	Ethiopia, Sudan	Sorghum	Yeasts, Lactobacillus sp.	Dough (solid)
Kisra	Sudan, Ethiopia	Sorghum	L.bulgaricus, yeasts.	Dough (solid)

Sources: (Biosing and Nancy, 1982; Hounhouigan et al., 1993; Gebrekidan and Gebretivat, 1982**)**.

investigating the biochemical nature of *ogi* with the aims of improving its nutritional properties.

Ogi fermentation

Ogi is traditionally made from maize, sorghum or millet. It is prepared by steeping clean grains in water at room temperature (25+2^{0}C) for 48-72 h (Banigo and Muller, 1972; Akingbala et al., 1981). The steep water is decanted and the fermented grain is washed with clean water and then wet-milled. The bran is removed by wet sieving and the sievate is allowed to settle for 24-48 h, a process referred to as souring during which time fermentation also proceeds and the solid starchy matter, *ogi*, sediments (Akinrele, 1970; Akingbala et al., 1981). The physical and biochemical qualities of *ogi* are influenced by the type of cereal grain, fermentation or souring periods and the milling method (Banigo and Muller, 1972; Da et al., 1982; Akingbala, 1981; Fields et al., 1982; Osungbaro, 1990[a]; Hounhouigan et al., 1993). Fermentation studies on cereal grains revealed important microorganisms in *ogi* manufacture. Those isolated and identified include moulds like *Fusarium, Aspergillus* and *Penicillum*. Other moulds associated with surface microfloral of fermenting maize include *Cephalosporium sp, O'ospora sp, Cercospora sp,* all which are eliminated within 6 hof steeping (Ohenhen, 2002). Aerobic bacteria isolated include *Corynebacterium Sp; Aerobacter* and Lactic acid bacteria (Fields, 1981; Akinrele, 1980; Banigo, 1972). The yeasts implicated in the fermentation are *Candida mycoderma, Saccharomyces cerevisae* and *Rhodotorula* (Andah and Muller, 1973; Fields et al., 1981).

Major fermentation products include lactic, acetic and butyric acids, all contributing to the flavour of *ogi*. Odunfa (1985) determined that *L. plantarium* was the predominant organism in fermentation responsible for lactic acid production. Corynebacterium hydrolysed maize starch to organic acids while *S.cerevisae* and *C. mycoderma* contributed to flavour development. Periods of fermentation or souring had been found to significantly affect titrable acidity of *ogi*, which increases with periods of fermentation (Adeyemi and Beckley, 1986; Osungbaro, 1990[a]). Attempts have been made to modify the traditional methods of fermenting cereal grains for *ogi* manufacture. Such attempts involved inoculating dry milled cereal grains with starter cultures of micro- organisms. *Ogi* had been successfully prepared using dry milled sorghum and maize flours (Umoh and Fields, 1981; Adeyemi, 1983; Osungbaro, 1990[a]). The dry milling was considered more convenient than wet milling process, since the flour could be dispensed and packaged to consumers for subsequent steeping and fermentation.

Ogi fermentation by traditional methods has been observed to have shelf life of 40 days (Ohenhen and Ikenebomeh, 2007) . In an attempt to prolong the shelf life of *ogi,* these two workers modified the fermentation method of *ogi* preparation. This was done by steeping maize grains in previous steep water with an innoculum load of 2.60 x 10^6 cfu /ml for 72 h at 28 + 2^{0}c, and grains were wet milled and wet sieved. The result of the investtigation showed that the shelf life of inoculated fermented *ogi* was well over 60 days as compared with the shelf life of 40 days for uninoculated fermented *ogi*.

Nutritional properties of *ogi*

A lot of nutrient losses occur during processing of cereals for *ogi* manufacture. These losses include fibre; protein; calcium; iron phosphorous and vitamins; such as thiamin; riboflavin; niacin; folic and panthotenic acids (Adeniji and Porter, 1978). According to Lagunna and Carpenter (1951), considerable nutrient losses take place during processing steps such, as steeping, milling and sieving. Aminigo and Akingbala (2004), working on nutritive composition of *ogi*, also confirmed this view. These losses are inevitable because much of the protein in cereal grains is located in the testa and germ, which are usually sifted off during processing (Oke, 1967; Banigo et al., 1974; Chavan and Kadam, 1989) . Reductions in net protein utilization, protein efficiency ratio and biological values have also been reported during *ogi* processing of maize or sorghum (Akobundu and Hoskins, 1982). Discarding steeping water over tails and *ogi* wash water leads to serious losses in minerals and other nutrients (Muller, 1980). A minimal use of water in wet sieving is recommended to minimize losses of soluble nutrients during *ogi* preparation (Amoa and Muller, 1976).

Extent of nutrient losses depends considerably on the exact method of *ogi* preparation. The traditional process has been shown to result in lower mean protein and fat with a higher mean starch content when compared with *ogi* product obtained by experimental milling (Akingbala et al., 1981). Also dehydration of *ogi* by drum or tray drying has been found to prolong its shelf life, but the method has been found to destroy heat sensitive nutrients in *ogi* (Labuza, 1972). An appreciable loss in the valuable lysine content of drum -dried *ogi* has been reported (Adeniji and Potter, 1978).

From the foregoing, the major drawback to the use of *ogi* as a staple food is its low nutritional value. Several attempts have been made to improve the nutritional status of *ogi*, by fortifying it with protein rich substrates (Anon, 1970; Banigo, 1972; Bamiro et al., 1994; Osungbaro et al., 2000) . A protein-enriched *ogi* containing 10% Soya flour was developed by the Federal Institute of Industrial Research (FIIRO), Lagos, Nigeria (Akinrele, 1970). The utilization of high lysine maize for the manufacture of *ogi* using improved processing system had also been attempted (Banigo et al., 1974; Adeniji and Potter, 1978). The development of an *ogi* (dogit), having the therapeutic properties on the basis of its ability to control diarrhoea among infants has been reported (Olukoya et al., 1994). The use of *ogi* as a popular weaning food for children in the West African sub region makes this finding significant and relevant.

In an attempt to improve the nutritive composition and sensory properties of *ogi*, Aminigo and Akingbala (2004) fortified maize *ogi* with okra seed meal. Okra seed fortification at 20% level using defatted and roasted meals increased crude protein content by 122 and 106%, respectively. These workers were also able to raise ash content by 2 -5 fold and fat content was increased by 1.5-2.2%. Also working on fortification of *ogi*, with okra seed flour, Otunola et al. (2007) were able to achieve substantial increases in the levels of protein in maize *ogi* samples obtaining up to 100% increment.

Microbiological and nutritional studies show that organisms responsible for fermentation of *ogi* could be majorly responsible for its nutritional improvement. Working on *ogi* fermentation, Odunfa et al. (1994) utilized mutants as starter culture, resulting in a threefold increase in the lysine content of *ogi.* Fifty mutants from *L. plantarum* and seven mutants from a yeast strain were selected from thialysine-resistant cultures capable of overproducing lysine. After analysis for lysine production, a 12-fold increase in lysine production was observed for *L. plan-tarum* and a 3-4-fold increase for yeasts was observed.

Heating *ogi* over a period of time impacts greatly on its physical characteristics as the cooked maize starch gels to solid state on cooling. Cooking of white maize *ogi* at concentration of about 15% total solids for 15 min followed by cooling produces the stiff gel, agidi (Osungbaro, 1990 [a]). Agidi is an important food for the people of West Africa and is widely used as weaning solid food and staple breakfast cereal.

The nutritive quality of agidi will definitely be a reflection of the chemical composition of *ogi*, the base material. Deficiency of lysine and tryptophan, in normal maize is well known. Protein losses in traditional processing of maize into *ogi* for agidi manufacture aggravate the situation (Akobundu and Hoskins, 1984). Again the fact that the presence of other non-starch components like fat, protein and crude fibre, reduces the tendency of cereal starches to form gels, limits the inclusion of non-starch nutrients into cereal starches intended for agidi manufacture.

Physical properties of *ogi*

Textural quality of *ogi* porridges depend on many factors, which include the type of cereal grains, variety, milling technique; particle sizes; steeping and fermentation periods (Amoa and Muller, 1976; Klaus and Hinz, 1976; Adeyemi, 1983; Adeyemi and Beckley, 1986; Osungbaro, 1990[a]). Working on maize for *ogi* fermentation, Osungbaro (1990[b]) found that different varieties of maize exhibited different pasting viscosities on the amylograph. This trend was attributed to the fact that these maize varieties were found to contain varying amounts of amylose ranging from 29-34% (Adeyemi and Beckley, 1986). Particle size distribution has been found to be important in cereal porridges because it influences such properties as rheology, heat and mass transfer; mixing and consistency of starchy pastes (Kruger and Murray, 1976). For sorghum *ogi,* the most acceptable sample in terms of consistency and mouth feel was prepared from flour fraction of <125 μm particle size (Adeyemi, 1983). Penetrometer and adhesion tests had been used to evaluate textural qualities of *ogi* and sorghum porridges (Da et al., 1981; Cagampang et al., 1982).

Also the rheological properties of *ogi* measured on the amylograph are well documented (Banigo et al., 1972; Adeyemi and Beckley, 1986; Osungbaro, 1990[a, b] Osungbaro, 1998). The swelling characteristics (thickening) of *ogi* have been found to be influenced by fermentation period. While Banigo et al. (1974) have observed an increase in swelling characteristics of maize flour. Adeyemi (1983) working on sorghum flour observed a corresponding reduction in viscosities on fermentation of samples. It was also established that two-day fermentation of maize is best for *ogi* manufacture in terms of pasting viscosities and consistencies. Fermentation beyond four days was found to result in *ogi* porridge exhibiting poor stability, gelling tendency and consistency (Osungbaro, 1998).

Fortifying *ogi* with protein rich foods has also been found to influence its rheological properties (Edema et al., 2005; Fasasi et al., 2007). Addition of okra seed flour to maize *ogi* samples indicated a reduction in amylograph starch stability values (Otunola et al., 2006) . However, Ogi supplemented with roasted okra seed meal had higher viscosities during heating and cooling cycles than samples fortified with the defatted meals. Also *ogi* fortified with okra seed meals had lower sensory texture ratings as compared to unfortified *ogi*. This is attributed to lower viscosities exhibited by fortified *ogi* sample (Aminigo and Akingbala, 2004). Lowering of viscosities in the process of fortification of fermented cereal foods has implications on the consistency of the gruels prepared therefrom.

Agidi, the stiff gel prepared from *ogi* is traditionally eaten with fingers, and so the main quality for acceptance by the consumer is related to its physical (textural) properties. The textural characteristics used in describing *agidi* quality are firmness, consistency and smooth or gritty appearance. These textural characteristics have been mostly evaluated by subjective methods (Umoh and Fields, 1981; Osungbaro, 1998). Umoh and Fields (1981) observed significant differences in firmness and smoothness of the following *agidi* samples; non-fermented maize meal, fermented maize meal and neutralized fermented maize meal. These workers showed that *agidi* samples produced from wet-milled *ogi* (pH 5.3) were of firmer texture than those produced from dry milled unfermented maize flour (pH 6.7). These findings were corroborated by Osungbaro (1990[a]), while working on the effect of differences in variety and dry milling of maize on textural characteristics of *ogi.* Fermentation therefore plays a prominent role in textural qualities of *agidi*.

As the consuming public becomes more conscious or critical of food texture, the need for better methods of measuring and controlling texture arises. For this reason, *agidi* texture had been evaluated using objective techniques. Working on *agidi* prepared from different *ogi* parti -cle sizes, Osungbaro (1998) measured the consistency and gel strengths of *agidi* samples by comparing values on Brabender amylograph; Adams consistometer; the Ferranti viscometer; and Gel tester.

The amylograph pasting viscosities showed high correlations with Ferranti viscosities but little correlation with Adams consistency measurements. The gel strength values were highly correlated with the amylograph viscosity readings. These findings suggest that viscosity can be used to predict gelling characteristics of maize *ogi* for maize starch

Conclusion

These various works provided an integrated approach to nutritional improvements of fermented cereal porridges. Attempts were made at the utilization of high-lysine maize for the manufacture of *ogi,* while also applying modified fermentation methods for improved processing systems to forestall nutrient losses. Supplementing cereal starches with protein from various sources, different types of protein enriched cereal porridges were developed. Since cereal porridges serve as weaning foods for infants and dietary staples for adults, these improvements in their nutritive properties will go a long way in enhancing the nutritional status and health of the consumers.

The physical properties of these cereal porridges were evaluated by both subjective and objective methods; and the most acceptable rheological characteristics as acceptable to consumers were determined. However, nutritional improvements of these fermented cereal gruels with proteineous foods, lowered their pasting viscosities and sometimes affected their sensory attributes adversely. These factors are likely to influence consumer acceptability. There is therefore the need for investigations into the requirements for appropriate technology to remove such textural and sensory limitations, if consumer acceptability is to be promoted.

The results of the various studies have clearly indicated that supplementation of fermented cereal gruels with protein sources is desirable and could be a viable and sustainable venture if undertaken on a commercial scale using appropriate technology. This is particularly so, as there is the need to improve the nutritional status of a large majority of people in the developing countries, where due to economic reasons, access to animal sources of protein is minimal.

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