African Food Tradition Revisited by Research

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Kenkey

Background information and Literature review

Wisdom Kofi Amoa-Awua and Charlotte Oduro-Yeboah

Food Research Institute,
Council for Scientific and Industrial Research,
Post Office Box M.20, Accra, Ghana

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Abstract

Traditional processing of foods including the production of indigenous fermented foods is an important activity in the informal sector of the Ghanaian economy. It provides a means of livelihood for a large number of traditional food processors in the rural areas and increasingly in urban areas in recent times. One of the most important of these indigenous Ghanaian fermented foods is kenkey which is a sour stiff gruel or dumpling made from fermented maize dough which is wrapped in leaves and boiled. Kenkey is consumed all over Ghana but especially in the southern coastal areas where it has originated from. There are two main types of kenkey produced from maize and these are Ga Kenkey and Fanti Kenkey. Both are cooked sour tasting stiff porridges with a pH of about 3.7, moisture level of between 52-55% and usually eaten with sauce and fish. 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 boiled. It is interesting to note that kenkey varieties vary widely throughout Ghana. Ga kenkey is fermented for 2-3 days, salted , cooked, wrapped in maize husks and has a shelf-life of about 3 to 4 days. Fanti kenkey which has a shelf-life of about one week is fermented for 3 -4 days, not salted and cooked wrapped in plantain leaves. In addition to Ga and Fanti kenkey. There are also a few other types of kenkey produced but these are mainly produced from dehulled rather than whole maize grains. Two of such products are *Nsiho* and *Fomfom*

Kenkey's importance in modern-day life is underlined by the wide spectrum of fermented foods marketed both in developing and industrialized countries, not only for the benefit of preservation and safety, but also for their highly appreciated sensory attributes. Fermented foods are treasured as major dietary constituents in numerous developing countries primarily because of their keeping quality under ambient conditions, and also for their safety and traditional acceptability.

Several studies have been carried out to upgrade and mechanize some of the unit operations involved in the production of kenkey, including the development of shelf- stable dehydrated fermented maize meal flour as a convenience intermediary product.

1.0 Introduction

Kenkey is an indigenous fermented product commonly produced in Ghana, West Africa, especially in the coastal areas. Traditionally it has been produced by two ethnic groups, the Gas in the Greater Accra region and the Fantis in the Central and Western regions. The production of fermented maize products might have developed either from a definite attempt of the local population to produce food with a more pronounced flavour than the relatively bland tubers such as yam. Just as bread in Europe, kenkey is of particular importance amongst the poorer people and more so in cities than in country communities. In Accra, Kenkey is only second in importance to fresh cassava. In Western and Central regions of Ghana it falls into third place after plantain. It decreases in importance in the Eastern , Ashanti and Brong Ahafo regions and in the North, where sorghum rather than maize is grown, little kenkey is consumed (Muller and Nyarko-Mensah, 1972).

There are two types of kenkey, Ga-kenkey (also called *Komi*) and Fanti-kenkey (also called *dokono*). Slight differences exist in the organoleptic quality and the processing procedure for the two types of kenkey. Both are produced by the fermentation of maize dough into a sour dough that is subsequently cooked—wrapped in maize husks in the case of Ga-kenkey or plantain leaves in the case of Fanti-kenkey. Fanti-kenkey is fermented for a slightly longer period than the Ga-kenkey, and salt is also added to the latter during processing. In addition to Ga and Fanti kenkey, there are also a few different types of kenkey produced but these are mainly produced from dehulled or polished maize rather than the whole grains. *Akporhi* or *Nsihu* is one such type of polished kenkey produced mainly in the Central, Western and Volta regions of Ghana. It is prepared by dehulling the maize, the dehulled maize is then milled and reconstituted with water to form a dough which is left to ferment for only 24h. Balls are made from this dough and steamed (Whitby 1968; Dovlo, 1970; Sefa- Dedeh, 1993). Fomfom is yet another type of kenkey produced from dehulled maize and is mainly produced in the Western Region of Ghana (Johnson and Halm, 1998).

Traditional processing of Kenkey

Raw materials used in the production of kenkey

Maize is the main raw material used to produce kenkey. It is principal cereal produced in Ghana and is grown in varying quantities throughout the country as shown in Fig 1. Maize is also consumed as a staple crop in most parts of the country. Its annual production is currently 1,034,200 metric tons, accounting for 3% of the Agricultural Gross Domestic Product. The bulk of the maize produced is consumed in the form of kenkey (Hayford, 1998; Halm *et al.* 2003).

Processing of maize into kenkey

The traditional method for the production of both Ga and Fanti kenkey is shown in the flow diagram in Fig. 2 and involves cleaning, steeping, milling, dough fermentation, *aflata* preparation, mixing of *aflata* and raw dough, moulding and packaging, and cooking into kenkey.

Cleaning

Maize for processing into kenkey is cleaned to remove all foreign matter. This is done by one or a combination of several processes including winnowing, handpicking, sieving, and sedimentation. These operations remove dust, chaff, stones, insect-damaged grains, and other debris. The sedimentation process involves pouring the grains into a big basin of clean water, stirring with a wooden ladle to allow the mature and good-quality grains to settle at the bottom while the less dense immature, some insect damaged, and diseased grains float on the surface. The latter are collected with small baskets or sieves and used as animal feed. The good maize is then washed again in water before steeping (Halm et al. 2003).

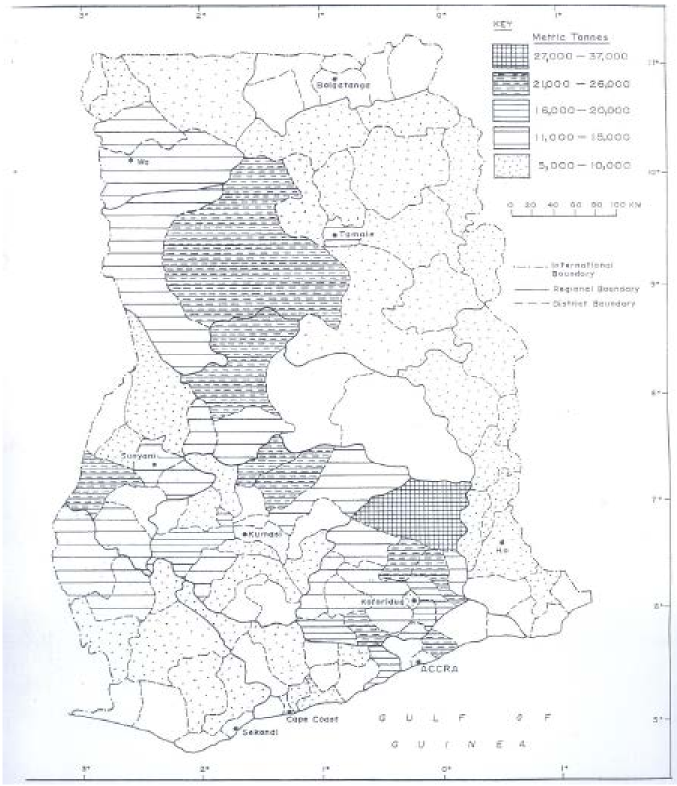

Fig 1. Map of Ghana showing major maize producing areas

Plate 1. Bags of maize to be processed into kenkey at a large traditional production site.

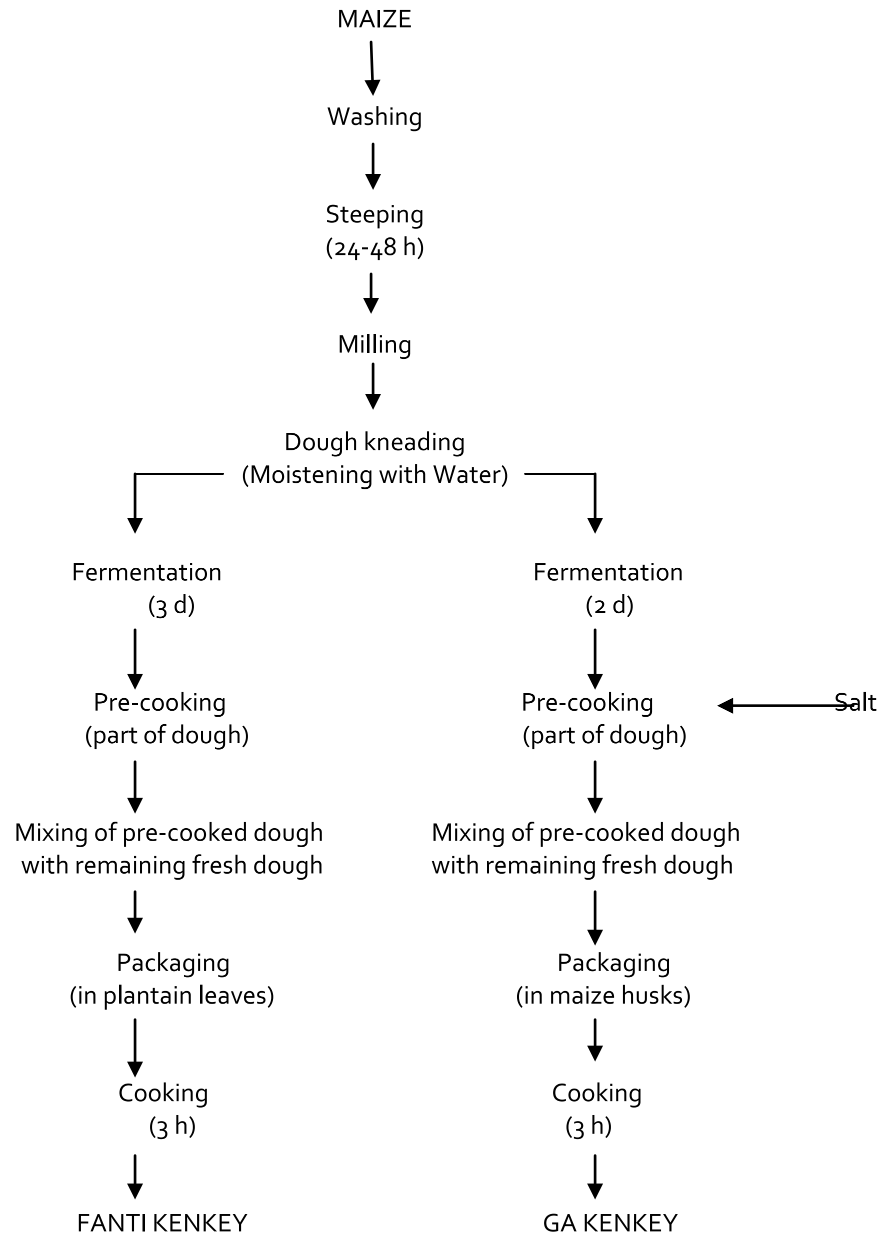

Fig 2. Process flow diagram showing various unit operations in the production of kenkey from maize (Source: Amoa-Awua et al. 1998)

Steeping

This involves the steeping of the maize grains in clean water for 1 to 3 days depending on the initial moisture content and hardness of the grains. Most local varieties are steeped for 1 day, but some hybrid maize with very hard kernels and high portion of testa are steeped for up to 3 days to soften the kernels and facilitate milling. It has been confirmed that soaking of whole maize before milling remains the best option for developing the necessary dough textural characteristics (Akingbala *et al*. 1987; Niche *et al*. 1996). The steep water is drained off and the maize washed before milling.

Plate 2. Maize being steeped in large aluminium containers at the large traditional kenkey production site

Milling and Doughing (Kneading)

The steeped maize is milled in a plate mill popularly known in Ghana as corn mill into a very smooth meal; which is then mixed with water to form a dough with a moisture content of about 50–55%. The amount of water used to form the dough is very important as this affects the rate of fermentation as well as the quality and shelf life of the dough. This amount varies widely from one producer to another, between 17 and 44 liters of water to 100 kg of maize (Allotey, 1996). Plahar and Leung (1982) demonstrated that low moisture content of 45% reduced the rate of acid production and early onset of mould growth, while high moisture content of 65% and 80% developed high concentration of acids and subsequently a high degree of sourness.

Fermentation

The dough is packed tightly into wooden vats, aluminum pots, enamel or aluminum basins or plastic containers and allowed to ferment spontaneously for up to 3 days at ambient temperature (i.e., 25–30°C). The size of the fermenter is variable but it will normally not exceed 50 kg of dough. Normally, after 2 days of fermentation, the dough is ready for use in making different products including kenkey, *banku*, and *koko*. Dough fermented for 24h

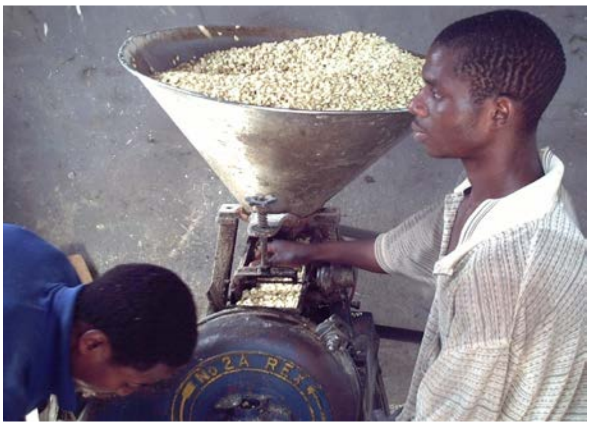

Plate 4A. Milling of steeped maize

Plate 4B. Kneading of milled maize into dough does not give a good-textured product, but this can be mixed with older dough to obtain the desired texture. Sometimes the traditional processors hasten the fermentation by back-slopping with old dough. With back slopping, fermentation can be shortened to 24 hr.

Usually the processors use up all the fermenting dough between the second and third day, but if fermentation is prolonged beyond the third day it might lead to the development of undesirable flavours and high acidity. However, according to some commercial producers, the shelf life of the dough can be extended without adverse effect on consumer acceptance if less water is used in making the dough. The dough may also be sun-dried after the desired acidity has been obtained within 2 days. Commercial producers of kenkey do not advice 24h dough kenkey, however, this can be mixed with over fermented dough (3 days) and used for kenkey to give the desired characteristics (Halm et al. 2003). Some large scale producers encourage "back sloping" as means of facilitating fermentation, by adding old dough to fresh dough. This leads to shorter fermentation time of 24h, and the dough seems to attain all the desired characteristics within this time (Nout *et al*. 1996). Three days seem to be the maximum time for the fermentation. Extended times often results in undesirable characteristics such as undesirable flavours and high acidity with extreme sourness (Halm et al. 2003).

Plate 5. Fermenting maize dough

Aflata Preparation and Mixing

A portion of the fermented dough is made into a slurry by adding two or three parts of water and cooked with continuous stirring into a sticky gelatinous paste known as *aflata*. During this process, salt is added in the case of Ga-kenkey. The *aflata* is mixed thoroughly with a portion of the uncooked fermented dough using wooden ladles and allowed to cool. The ratio of *aflata* mixed with uncooked dough depends on the type of kenkey being produced and the preference of the consumers. Amongst the indigenous Ga people who consume kenkey as a major staple, the ratio of *aflata* to the uncooked dough is usually 1 to 1. However, some producers mix two-thirds of *aflata* with one-third of the uncooked dough, and others mix one-third *aflata* with two-thirds uncooked dough. The ratio of *aflata* mixed with the uncooked dough determines the texture of the kenkey that will be produced. In a sensory evaluation of the texture of kenkey, the highest score was given by panellists for kenkey prepared from a 1-to-1 *aflata* to uncooked dough mixture (Bediako-Amoa 1976). The study confirmed that aflatalisation is necessary to produce kenkey of the desired texture. *Aflata* is reported to act as a binding agent , giving kenkey its firm and semi-sticky consistency (Sefah Dedeh 1993). When mixed with uncooked fermented dough and enables the product to be moulded into balls and other shapes (Sefa-Dedeh and Plange 1989).

Moulding and Packaging

For Ga-kenkey the mixture is moulded into balls of uniform sizes of about 300 g weights and wrapped in clean prewetted maize husks. Fanti-kenkey is moulded into rectangular shapes, placed in a polyethylene bag and then wrapped with plantain leaves(Halm et al. 2003).

Plate 6. Moulding of Ga-kenkey into balls

Cooking

Some clean maize husks or plantain leaves are placed at the bottom of large aluminum cooking pots and the balls of kenkey are packed on top to prevent the balls from sticking to the pots during cooking. Boiling water is poured into the pot to cover the balls and the top covered with a piece of cloth or polythene sheet to conserve steam. The kenkey is cooked for about 3 to 3.5hours. The length of cooking depends on the ratio of *aflata* to the uncooked dough and how well the *aflata* was cooked. For kenkey containing less *aflata*, boiling lasts longer. After the balls are well cooked, they are removed from the pots and placed in large bowls lined with polythene sheets, which are also used to cover the balls of kenkey to keep them hot until they are all sold for consumption. The cooking water left in the pot, referred to as kenkey water is collected and drunk as a thin porridge and is believed to have curative properties against malaria, diarrhea and jaundice. It has been reported that the carbohydrate and electrolyte levels of kenkey water are comparable to the UNICEF/WHO Oral Rehydration Salts and therefore suitable for use in oral rehydration in Ghana (Yartey *et al*. 1993).

Plate 7. Traditional cooking of Ga-kenkey

Plate 8. Cooked Ga-kenkey

Processing of maize into Nsiho or Akporhi

Nsiho or *Akporhi* is a dumpling similar in consistency to kenkey. It is a popular product in the Western and Central regions of Ghana made from dehulled maize. The process flow diagram for the production of nsiho is shown in Fig 3. In the processing of *nsiho* dry maize is cleaned of foreign matter and tempered with a little quantity of water. The conditioned maize is then dehulled and winnowed to remove the hulls and chaff. The dehulled maize is washed and steeped in water for 24 h. The steep water is drained off and the maize is milled into a smooth meal in a disc attrition mill, mixed with water to form a dough and allowed to ferment for 6 to 24h. The period of fermentation can be reduced to 6 hours when the steep water is used in forming the dough. After fermentation, one half of the dough is cooked into a paste known as *aflata*, which is mixed with the remaining half uncooked dough, and moulded into balls. The balls are packaged in plantain leaves and cooked for up to 2 h or more to give *nsiho* (Whitby, 1968; Dovlo, 1970; Sefa-Dedeh, 1993; Johnson and Halm, 1998).

Dry Maize

Washing
(Optional)

Dehull, Winnow & Wash

Steeping (24 h)

Milling & Kneading into dough

Fermentation (8-24h)

Pre-cook half dough | Mould dough into balls

Mix pre-cooked dough with remaining half of dough | Ist Cooking & Ist Pounding

Mould & Package in plantain leaves | 2nd Cooking & Pounding

Boil (2h) | Mould & Package in banana leaves

NSIHO | *FOMFOM*

Fig 3. Process flow diagram showing the production of *Nsiho* and *Fomfom* from maize. (Source: Johnson and Halm, 1998)

Processing of maize into Fomfom

The traditional procedure for processing maize into fomfom is shown in Fig 3. Fomfom is a stiff porridge similar to *kenkey* in consistency but made from dehulled maize. Maize is dehulled and milled as for *nsiho.* The meal is mixed with water and an inoculum of old dough is added to shorten fermentation period from 24 h to 6 - 9 h. The fermented dough is shaped into balls with holes made in the centre. The balls are cooked twice in boiling water. After each boiling, the balls are pounded in a mortar. After the second pounding, the mass is moulded into balls and packaged in banana leaves ready for consumption. This product is popular in the Western region of Ghana (Johnson and Halm, 1998; Halm 2006).

Major problems associated with processing methods

The major problems with kenkey production and consumption are contamination with aflatoxins and other mycotoxins from maize grains and corn husks used for processing, survival and growth of spoilage during steeping and fermentation, and physical contamination with various foreign materials and items (Kpodo et al. 1996; Amoa-awua et al. 1998.

Maize sold on the open market is often contaminated with moulds, including mycotoxin-producing species such as *Apergillus flavus* and *Aspergillus parasiticus*, which produce aflatoxins, and *Penicillium citrinum*, which produces citrinin. (Jespersen et al. 1994; Kpodo et al. 1996). The occurrence of aflatoxins in maize and maize products in Ghana has been reported by Kpodo et al (1996) and is a matter of public health concern. According to Kpodo et al (1996) contamination of maize with moulds is largely dependent on the moisture content of the grains and storage conditions. Maize sold on the open market is also often contaminated with fumonisis produced by some Fusaria spp. (Kpodo, 2000; Kpodo et al. 2000). Field infestation of maize with moulds may occur if there is intermittent rain during the period that mature maize is left to dry on the field before harvest. However, prompt harvesting of mature grains and mechanical drying to a moisture content of not more than 12% and efficient storage prevents mould growth. The prolonged cooking of kenkey for about 3 hr destroys some mycotoxins which may be present such as citrinin. However aflatoxins are heat- stable and survive the process even though there is reduction in their total level (Kpodo *et al*. 1996).

The second problem encountered in kenkey production is the risk of spoilage of steeped grains and fermented dough due to growth of spoilage microorganisms. Pro-liferation of such microorganisms in the products may result in an economic loss to the producer because the organisms produce strong offensive odors, which are not acceptable to consumers. The growth and survival of the spoilage microorganisms is favored by higher pH values. A rapid drop in pH to acidic conditions as a result of the fermentation during steeping minimizes the occurrence of this problem (Amoa-Awua et al, 1998).

A third problem in kenkey production is the survival and growth of pathogenic microorganisms even though the lactic acid fermentation of maize during kenkey has been shown to have antimicrobial effects against major bacterial food pathogens (Mensah *et al*. 1991; Halm et al 2004; Halm 2006). The prolonged cooking of kenkey for about 3 hr is drastic enough to kill off any surviving pathogenic bacteria and most of their toxins.

Maize purchased in sacks from the open market often contain a lot of debris such as broken cobs, soil, pieces of nylon thread used to knit the open end of the sacks, and other foreign material. Processors handle large quantities of maize, so they find it rather tedious to clean the maize by sifting and picking out unwanted materials manually. Maize cleaning is therefore often carried out inefficiently. Hazardous materials may also occur in the form of metal pieces broken off the grinding plates of the plate mill during milling.

Storage methods, maximum duration and problems associated with storage

Cooked kenkey balls are placed in a big container lined and covered with polyethylene sheets to preserve heat until sold. Kenkey has a moisture content of about 62-68%, ph 3.7, and shelf-life of about 3 to 4days with no refrigeration (Hayford 1998). Fanti kenkey however has a slighly longer shelf life and can be stored for about 5 to 9 days under ambient conditions (Atople 2006)

Socio-economic importance

Production, processing, handling and storage zones identified in the country

The process of kenkey-making is lengthy and laborious, therefore it is more often purchased from a commercial kenkey producer rather than cooked at home. The producers who are mainly women with little or no formal education–carry out commercial production as a family-acquired art. The small-scale processors carry out their activities either as individuals or as a family business in the household often depending on family labor to produce and retail the product. In a survey conducted in Accra, Allotey(1996) found that at most production sites the amount of maize processed weekly ranged from 0.05 to1.2 metric tons with an average of 0.3 tons of maize processed into 0.5 tons of kenkey. There are however, a few large production sites with weekly capacities of several tons (up to 5 tons) of maize. Such large production sites do not only produce kenkey for sale but also sell the intermediate product, the fermented dough, which is also used to prepare other products such as *koko* and *banku*. The production of kenkey is based on traditional technologies, that have been handed down in generations. Production costs, apart from the raw material, maize, are minimal because the family labor employed is often not perceived as costs. This makes the product affordable, providing food for a large part of the urban population especially the low-income group.

Socio-economic profile of kenkey processors and retailers

Traditional processing of foods including the production of indigenous fermented foods, is an important activity in the informal sector of the Ghanaian economy. It provides a means of livelihood for a large number of traditional food processors in the rural areas and increasingly in urban areas in recent times. Despite the importance of traditional food processing, several issues including the food safety aspects of their operations are of concern to the regulatory authorities and attempts are being made to improve their operations (Amoa-Awua et al. 2007). According to Sefa-Dedeh (1993), these traditional food processing technologies have strong links with the rural traditional environment and even though they employ the same principles and unit operations as those found in modern food technology, their mode of application may be different. For most products the processing technologies may be at a rudimentary stage using simple techniques and implements and the operations are home based with women as the major executors (Sefa-Dedeh, 1993). Lartey (1975) lists the disadvantages of the indigenous technologies to include high labour input, uneconomical operations, low efficiency, time consuming nature of the processes, and lack of quality assurance. According to Halm, Amoa-Awua, and Jakobsen (2004), the underlying fermentation processes of the indigenous African fermented foods, provide foods of highly appreciated properties and represent an art of food preparation and preservation, which has substantial socio-economic impact in West African societies.

The informal food processing sector in Ghana including kenkey production is dominated by traditional food processors who operate on a cottage level or rural /small-scale level. These traditional food processors produce the bulk of processed foods consumed in Ghana using traditional methods to produce indigenous foods. However their operations are being increasingly mechanized to overcome labour intensive activities (Amoa Awua *et al*. 1998). These kenkey processors make an effort to control factors that affect the quality of kenkey since their share of the market depends upon the quality and reputation of kenkey. For management of the quality of kenkey, traditional processors rely on their own experiences and factors which they are able to control during processing. The traditional kenkey processor plays an invaluable role in maintaining the cultural and social integrity of the Ghanaian society and their activities need to be supported , upgraded and promoted for the social and economic advance of Ghana (Amoa Awua *et al*. 1998).

Kenkey plays an important socio-economic role in African economies in terms of employment potential. Although Kenkey vendors come from diverse backgrounds, the majority are female heads of households. Most of these vendors employ other people to assist with the business and thus consider themselves as employers. A study by Tomlins and Johnson (2004) showed trends in terms of the participation of the different groups of people, with women constituting the majority of vendors. However, men are now playing an increasingly prominent role in this lucrative business.

Kenkey vendors operate from various places including municipal markets, cooperative markets, industrial sites, vacant bus shelters and other undesignated sites. Kenkey vending takes place alongside other activities such as the sale of haberdashery and clothes, commuter omnibus ranking, push cart operations, cleaning of commuter omnibuses and the hawking of other items including sweets, tobacco and cigarettes, thereby exposing the food to multiple sources of contamination.

Socio-economic importance of kenkey

Commercial production and street vending of kenkey is the source of livelihood for many traditional food processors and food vendors in Ghana and these activities make a sizeable contribution to the rural and urban economy in Ghana. Kenkey as a street food is convenient, cheap and affordable for the poor and provides informal and self-employment opportunities as well as supplementary income for the households. The vending of kenkey contributes positively to the food security of all the actors in the chain including maize farmers, input suppliers, kenkey processors and vendors. The kenkey vending business in Ghana starts from the house. A woman with a little capital sets up a structure and kenkey prepared in the home is sold. Kenkey contributes significantly to food security and nutrition and is physically and economically accessible to most people. It is an activity which provides employment to many while providing nutritious, inexpensive and tasty foods to millions of women, men, children and students (Tortoe *et al*. 2008). Kenkey is now a widely eaten food all over Ghana. It is also eaten across other parts of West Africa including the people of Lagos State in Nigeria.

Commercialisation of kenkey

An indigenous fermented food like kenkey has several in built advantages such as anti-microbial properties due to the lactic acid fermentation and needs to be patronised and the production methods upgraded to withstand competition with fast foods which continue to gain popularity in urban areas in Ghana. There is therefore a threat posed by the food industries and multi-national corporations, which have the facilities to totally dominate the food processing sector. Since these companies produce mainly international, foreign or non-traditional foods, it is important that the quality and production methods of kenkey is upgraded to a level where it will be absorbed into the formal food sector (Amoa Awua *et al*. 1998).

Quality characteristics of the product

Nutritional quality

Maize contributes significantly to the total calorific and protein content of the diet of people who consume it as a staple in Ghana and is richer in protein than other staples such as cassava, cocoyams, yams, and plantain. However, the traditional maize varieties are deficient in lysine, tryptophan, and B vitamins (Mertz 1970). It has been estimated that maize accounts for 90–95% of the total calories and over 70% of the dietary proteins of some people in parts of the coastal areas (Davey 1962). On a dry-matter basis the proximate composition of Ga-kenkey is roughly 8.9–9.8% protein, 1.3–3.2% fat, 0.5–1.9% ash, 10.6–78.6 mg/100g calcium, 202.4–213.8 mg/100 g phosphorus, 6.5–12.6% mg/100 g iron, and 74.3–87.1% total carbohydrate (Eyeson and Ankrah 1975), (Ahemkora *et al*. 1995), (Obiri-Danso *et al*. 1997) (Annan- Prah 1997).

Maize as a cereal is low in protein and deficient in lysine and tryptophan. The nutritional value of maize product kenkey is basically dependent on the variety of maize and the processing technique applied. Processing methods such as soaking, milling, packaging material, cooking and fermentation may either reduce or increase one nutrient depending on the susceptibility of the nutrient in question (Ankrah 1972). High lysine variety of maize known as " *Obantanpa*" and developed locally are being introduced to raise the level of the nutritive value in maize products (Ahenkore *et al*. 1995; Obiri-Danso *et al*. 1997). However, soaking, fermentation and cooking all had an additional increase in available lysine in maize and maize-cowpea femented dough and, consequently an improved nutrient quality of kenkey (Niche *et al*. 1995a, 1995b). Calcium losses occur during kenkey production, phosphorus content however increases but due to anti-nutritive factors such phytic acid which bound this mineral, there is a reduction in bioavailability of both phosphorus and calcium.

Kenkey is rich in high fiber desirable low glycaemic Index carbohydrates advocated for use in diabetics because it slowly releases its carbohydrate content over a long time, helping the body handle its carb requirement for a perfect glycaemic index control. Kenkey is nutritionally rich and especially a good inclusion in diets for diabetics, those with high abdominal fat, and indeed any who wants to control their weight and shape (http://www.africanfoods.co.uk/buy-ga-kenkey.html).

The fermentation of maize during processing into kenkey may improve the nutritional status of the product by increasing synthesis of B vitamins (e.g., thiamine), protein digestibility, and bioavailability of nutrients, among others. It has been reported that soaking of maize resulted in significant increases in lysine availability by about 20%. (Nche *et al*. 1996). Cooking of soaked samples further improved lysine availability by 68%. Fermentation for 2 days further increased lysine availability by 22%. Prolonged fermentation and cooking effected further significant improvements in lysine availability. Maize dough fermented for 4 days and cooked for 3 hr achieved a value of 3.42 g N (Nche *et al*. 1995). The increased availability of essential amino acids resulting from lactic acid fermentation may be related to a reduction in proteinase inhibitors (e.g., trypsin inhibitor) in legumes and a reduction of tannins (Hamaker *et al*. 1987, Khetarpaul and Chauhan 1989). Lactic acid bacterial strains isolated from kenkey and other Ghanaian fermented foods have been found to show different abilities to degrade or inactivate trypsin inhibitor under defined conditions (Holzapfel 1997). *Lactobacillus plantarumstrain* 91 and *Leuconostoc* sp. 106 isolated from kenkey were able to degrade trypsin inhibitor by about 50%.

Very little or no change occurs in the level of riboflavin in maize dough during fermentation, whereas cooking maize dough into *banku* and Ga-kenkey results in a mean loss of 33% and 36% riboflavin, respectively (Ankrah 1972, Andah and Muller 1973). The thiamine content, however, is reported to increase considerably during fermentation of maize dough from 339.1 g/100g maize to 389.3 A g/100 g fermented dough (Andah and Muller 1973).

Microbiological quality

In kenkey production, fermentation occurs during the steeping of maize and the fermentation of the dough. Earlier studies on the microbiology of maize dough fermentation during kenkey production carried out in 1970 reported the presence of a mixed population of lactic acid bacteria and yeasts at the advanced stage of fermentation (Christian 1970). The bacteria consisted of homo fermentative *Pediococcus cerevisiae* and the heterofermentative species *Leuconostoc mesenteroides* and *Lactobacillus fermentum.* Other investigators (Fields *et al*. 1981) identified the dominating lactic acid bacteria in spontaneous fermentations of whole maize meal under laboratory conditions as heterofermentative *L.fermentum*, *lactobacillus cellobiosus*, and *Pediococcus acidilactici*.

Studies carried out by Halm *et al*. (1993) identified the dominant lactic acid bacteria responsible for maize fermentation during kenkey production to be closely related to *L. fermentum* and *Lactobacillus reuteri* based on the pattern of carbohydrate fermentation. Other fermentative organisms identified were *Pediococcus pentosaceus* and *P*. *acidilactici*. In a later study Hayford *et al*. (1999) confirmed the dominant lactic acid bacteria to be *L. fermentum* using molecular methods.

Some authors have reported the dominance of *Lactobacillus plantarum* in the later stages of maize dough fermentation during kenkey production (Niche *et al*. 1994, Olasupo *et al*. 1997). Olasupo *et al*. (1997) have reported *L. plantarum*, *L. fermentum*, *Lactobacillus brevis,* Lactobacillus *delbrueckii* as, was reported as the dominant organism but using biochemical profiling.

With regards to yeasts involved in maize dough fermentation during kenkey production Jespersen et al (1994) reported the presence of *Candida*, *Saccharomyces*, *Trichosporon*, *Kluveromyces*, and *Debaryomyces.* The species of the dominant yeasts involved in the fermentation of maize during processing into kenkey have been confirmed by molecular methods to be *Saccharomyces cerevisiae* and *Candida kusei* (Hayford and Jakobsen 1999; Hayford and Jespersen, 1999).

The presence of moulds during the initial stages of maize dough fermentation has also been reported (Jespersen *et al*. 1994). These moulds — *Penicillium*, *Aspergillus*, and *Fusarium* species, including potential mycotoxin producers — were isolated from raw maize, but during the maize dough fermentation the initial high counts disappeared within 24hr of fermentation.

Physico-chemical and sensory characteristics

Aroma compounds present in fermented maize dough to be used for kenkey production has been determined by Annan, 2002; Annan et al. (2003); Annan and Agbemavor 2003 and include the following compounds as shown in table 1.

Aroma compounds present in fermented maize dough		
Ethanol Ethyl propionate Butanal, 3-methyl Propanol Hexanal 2-methyl-1-propanol Isopentyl acetate 2-Heptanone Heptanal 3-methyl butan-1-ol Furan, 2-pentyl Ethyl hexanoate 1-Pentanol Octanal 2-Heptenal, (Z) 4-methyl-1-pentanol Ethyl lactate Hexanol Nonanal Hexanol	Nonanal 2-Octenal, (E) trans-2-Octenal 1-Octanol Octanoic acid, ethyl ester 1-Octen-3-ol Heptanol 2-Nonenal, (E) 1-Octanol 2-Decenal (E) Nonanol (5-Ethylcyclonpent-1-enyl) methanol 2,4-Nonadienal, (E,E)- 2,4-Decadienal trans-trans-2,4-decadienal Tetradecanoic acid, ethyl ester Octanoic acid Hexadecanoic acid,methyl ester Hexadecanoic acid,ethyl ester	7-Octadecanoic acid, methyl ester Octadecanoic acid, ethyl ester Ethyl oleate 8-Octadecanoic acid, methyl ester 10,13-Octadecadienoic acid, methyl ester 9,12-Octadecadienoic acid (z, z), methyl ester 9,12,15-Octadecatrienoic acid, ethyl ester 9-Hexadecanoic acid Ethyl-9-hexadecanoate gamma-Dodecalactone 2(3H)-furanone, dihydrodihydro-5-(2-octane)

Table 1. Aroma compounds present in fermented maize dough (Annan, 2002; Annan et al. 2003; Agbemavor 2003)

A complex combination of factors during steeping, milling and dough fermentation contribute to the final pasting characteristics of kenkey (Nche *et al*. 1996). Endogenous enzymatic activity, hydration, and grain softening during soaking combine to facilitate the release of starch during milling, thus ensuring better hydration and swelling of granules, to achieve a high degree of gelatinization and set back viscosity necessary for good *aflata* quality. In kenkey production, the aflatalization (gelatinization) process is crucial for the texture of the kenkey and the gelatinization properties are described in terms of viscosity and studied by amylographic measurements (Hayford 1998). A dough with a high starch gelatinization index (during cooking) and a high set back viscosity on cooling is required to give an *aflata* of adequate binding and moisturizing ca- pacity important in determining the desired textural characteristics of cooked kenkey (Nche *et al*. 1996).

Product quality perception/requirement by consumers

The requirement of kenkey by consumers may be attributed to several factors. To an extent it may be due to

- convenience, accessibility and affordability
- habit ("we have always eaten it and nothing has happened")
- psychological attitude i.e. resignation or fatalism of consumers ("there is nothing we can do about it anyway")
- the inability of consumers to associate safety of the food with its overall quality since many consumers may confuse taste with quality
- lack of alternatives or options
- poverty or budget constraints

Kenkey is consumed principally in the coastal areas. It is consumed as a main meal served with fried or grilled fish and an accompanying sauce or soup. The sauce is usually a blend of onions, tomatoes, pepper, and salt, which is freshly ground and uncooked Kenkey forms an important article of diet in the food- eating habits of low income workers who may eat it as breakfast, lunch or dinner. Kenkey is a heavy meal because it is bulky, so when eaten as breakfast, it carries through to dinner thus making it economical (Halm *et al.* 2003).

Consumption forms of the product

Food forms

There are different types of kenkey. Some are sweetened with sugar, some have sweet potatoes or salt added. Some are wrapped in maize sheaves while others are wrapped in dried plantain leaves. Some are made from wholesome maize flour and dark in colour, others are white and made from high extraction flour. The three common types of kenkey are the Fanti kenkey wrapped in plantain leaves, and Ga-kenkey and Nsiho or Akphorhe wrapped in corn husks (see Plates 8 & 9). The corn husk wrapping is typically pushed into the dumpling from below, leaving part of it exposed at the top. The further the corn husks are pushed into the bottom of the dumpling, the more ample its appearance (Muller and Nyarko-Mensah 1972).

Plate 8. Ga-kenkey

Plate 9. Fanti Kenkey

There are numerous other types of *kenkey*, including a type where the skins of the corn are removed before grinding it. A sweet version is called *dokompa*, and it is one of the few instances where sugar is added to a main carbohydrate (sweet potatoes or yam are also added). *Kenkey* can also be made from plantains, where very ripe plantains are pounded and mixed with green plantain meal (*amada kokonte*). Plantain *kenkey* is known as *brodokono* in Twi, *afanku* in Ga, and *ahyenku* or *asenku* in Fanti (www.betumi.com).

Period of the day for consumption (breakfast, lunch, dinner)

Kenkey forms an important article of diet in the food-eating habits of low-income workers who may eat it as breakfast, lunch, or dinner. Kenkey is a heavy meal because it is bulky, so when eaten as breakfast, it carries through to dinner thus making it economical. It may also be mashed with water into a thin porridge, a sort of refreshing drink to which sugar and milk are added (Halm *et al*. 2003).

Research activities and new development on technology and product

Several studies have been carried out to upgrade and mechanize some of the unit operations involved in the production of kenkey, including the development of shelf- stable dehydrated fermented maize meal flour as a convenience intermediary product. Spontaneously fermented maize dough has been successfully dehydrated in a hot air tray dryer (Fig. 5) at temperatures of 60° C, 120°C, and 200° C to produce acceptable product

(Andah and Osei-Yaw 1979). Dehydration at a temperature range of 60–70° C did not affect total acid content of the product, and taste panel evaluations found products such as *akasa*, *koko*, and *banku* made from the dehydrated dough acceptable. Dehydrated fermented maize meal made by this method can be reconstituted into fresh dough by adding water and is now produced on commercial basis for sale in Ghana and also for export.

An accelerated option for industrial production of kenkey flour was developed by inoculating dry-milled maize flour with dough containing an enrichment of lactic acid bacteria to accomplish fermentation within 24 hr of incubation at 30° C to obtain the required level of acidification (Nche *et al*. 1994). Subsequently, the dough was dehydrated into kenkey flour and pregelatinized *aflata* using cabinet and drum drying. Although the two methods were effective in preparation of pregelatinized *aflata*, drum drying caused a 34% reduction in titratable acidity of the fermented dough whereas cabinet drying had a less drastic effect. The possibility of using a mixture of drum-dried *aflata* and uncooked cabinet dried flour for convenient preparation of kenkey at domestic level was demonstrated. However, dry- milled maize flour had inferior pasting and setback viscosities as compared to the traditionally prepared dough and was not suitable for the production of pregelatinized the use of a starter dough. The cooking time and energy expenditure was reduced from 2 hr to 35 min by changing the dimensions of the kenkey balls from 10–15 cm diameter to 6 cm diameter cylinders. Due to the different processing conditions, yeasts were found to be more active than in traditional fermentation, resulting in higher alcohol levels. However, these alcohol levels remained low and ethanol disappeared after cooking. The combination of lactic acid fermentation and cooking resulted in a microbiologically stable product even after the dumpling had been deliberately contaminated. This study concluded that the traditional kenkey-making process could be shortened to 24 hr by a combination of reduced steeping time, use of starter dough in a dough-*aflata* mixture, and packaging in sausage casings. However, it should be noted that the traditional packaging of kenkey in maize husks or plantain leaves gives it a unique sensory characteristic that consumers associate with the product.

Attempts have also been made to increase the protein content of kenkey by fortification of the dough with amino acids, soybeans (Plahar *et al*. 1983, Plahar *et al*.1997), cowpeas (Nche *et al*. 1994) and also by the development of Quality Protein Maize (QPM) varieties (Eyeson and Ankrah 1975, Ahenkora *et al*. 1995). In addition to increasing the protein content, addition of boiled whole soybeans to soaked maize before milling and fermentation reduced the fermentation time by 60% (Plahar *et al*. 1997). A lactic acid bacteria–enriched starter dough has been developed by back-slopping. Initially, a previous batch of acceptable-quality spontaneous fermented dough was used to inoculate fresh dough at a level of 10%. The procedure was repeated every 24 hr at 30°C until a stable culture indicated by pH, titratable acidity, and viable microbial numbers was obtained. This was then used successfully to ferment dough within 24 hr at 30°C to the required level of acidification, a total titratable acidity value of 1.24%, calculated as lactic acid on a wet-weight basis, and a pH of 3.79 (Nche *et al*. 1994).

A starter culture containing strains of *L. fermentum*, *S. cerevisiae*, and *C. krusei* has also been developed for the production of fermented maize dough. Both in laboratory trials and at a commercial production site, the period of fermentation could be reduced from 48–72 hr to 24 hr. The organoloeptic qualities of the kenkey and *koko* prepared from doughs fermented with the starter for 48 hr were not significantly different from the traditional products. However, kenkey prepared from doughs fermented for 24 hr with starter culture were found to be unacceptable by the taste panel although similarly produced koko was acceptable (Krogbeck 1993, Halm *et al*. 1996, Amoa Awua 1996; Hayford 1998).

At the Food Research Institute of the Council for Scientific and Industrial Research, Ghana, a pilot plant has been established for semi-industrial scale production of dehydrated fermented maize meal and kenkey using modern methods of food processing. The plant layout satisfies the basic elements of Good Manufacturing Practice, whilst the cleaning of maize is mechanized. The maize is steeped in tanks line with porcelain tiles, and dough fermented in small plastic containers. The kenkey is cooked in a small retort and dough dehydrated in a walk in cabinet dryer (Amoa-Awua (1998)

An HACCP system that is suitable for kenkey production at both traditional and upgraded commercial production sites has been published as a manual and been used to train processors, entrepreneurs, etc (Amoa Awua *et al*. 1998). A semi-commercial kenkey production plant in Accra was also upgraded by the Food Research Institute and HACCP implemented at the plant in 1997 (Amoa-Awua et al. 2007). The HACCP Plan developed by Amoa-Awua et al (1998) is presented in table 2

Conclusion (Perspectives on research and innovation needs)

Kenkey is one of the best examples of traditional African foods, which through history have played a significant role in food safety as well as food security. The underlying fermentation process has provided foods of highly appreciated properties and represented an art of food preparation and preservation with substantial socioeconomic impact in West African societies. The raw materials used are all of local origin and the sustainability of this type of food processing is unique. The industrialization of the global agribusiness system has strongly concentrated opportunities for adding value to the process end of the chain. Development of traditional food fermentations, like processing of kenkey, into scientifically based and controlled industrial operations will be a way forward for the food industry in Ghana and beyond. Through recent intensive research activities, the microbiology of kenkey is now very well understood. Effective starter cultures have been identified and shown to improve maize fermentations leading to the preferred characteristics of kenkey. The cultures appear to have desired functional properties and they have been defined by detailed pheno- and genotyping, which can also provide a proper background of patenting of cultures and protecting intellectual rights. It has been demonstrated how traditional production sites can be upgraded to meet the requirements of recognized guidelines of GMP. Local producers, consultants, and organizations have been trained in the use of the HACCP concept for management of food safety in maize processing. Kenkey flour with an extended shelf life has been developed. The final step of development, to achieve a product that is acceptable and attractive to the international market and European consumers, in particular seems no longer to be out of reach. This is the activity to be tackled by the African Food Traditional Revisited by Research project. The next move should be directed toward development of local governmental agencies for independent and qualified verification and validation of the safety and quality of kenkey as well as hygienic conduct and understanding of the basic principles of food hygiene in the complete chain from growing and handling of maize through processing of kenkey. The important role of microbiology in African foods has been demonstrated by the biodiversity and promising properties of the dominating microorganisms in the many different fermented foods, including kenkey, in Africa. It justifies that microbiology be made a high-priority research area in Africa to support a development in biotechnology. Potential biotechnological activities could include, for example, production and sales of starter cultures, probiotic cultures, cultures for biopreservation, and bioactive substances for various purposes.

Table 2. HACCP Plan for kenkey production (Amoa-Awua et al. 1998)

		PROCEDURES			
DATE: June 2, 1995		PAGE	1 of 2	**APPROVED BY**	
		CONTROL OF CCP'S			
PROCESS STEP	HAZARD	CONTROL MEASURE	CRITICAL LIMITS	MONITORING PROCEDURE (each batch)	CORRECTIVE ACTION
MAIZE CCP	. Mycotoxins: Aflatoxins Citrinin fumonisins . Foreign materials	.Purchase good quality material	> .... ppm 13.0% moisture > .... ppm	. Visual inspection	. Reject raw material and inform supplier
STEEPING CCP	. Spoilage and pathogenic microorganisms	. Clean water . pH control to desired level . keep hands off	. Transparent, clear, odourless and colourless . pH 4.2+ 0.1 . Keep hands off	. Visual inspection . Use of pH strips	. Boil water . Educate . Steep longer
DOUGH FERMENTATION CCP	. Mycotoxins . Spoilage and pathogenic microorganisms	. Adherence to fermentation time . Cover dough	. pH not > 3.9 . Titrable acidity Lactic: -1.4-2% Acetic:0.18-023% . Volatile/Non volatile acid ratio about 0.16	. Visual inspection . Use of pH strips	. If fermentation is slow backslop with old dough

PROCEDURE					
DATE: June 2, 1995		PAGE 2 of 2	APPROVED BY:		
PROCESS CONTROL					
PROCESS STEP	HAZARD	CONTROL MEASURE	CRITICAL LIMITS	MONITORING PROCEDURE	CORRECTIVE ACTION
PACKAGING CCP	. Mycotoxins in maize husks	. Selection of non- mouldy maize husks . Good Hygiene	>.......ppm . free from moulds	. Visual inspection	. Reject
. COOKING CCP	. Residual mycotoxins in kenkey: Aflatoxins Citrinin	. Adequate cooking	. not less than 3 hrs cooking > 10 parts per bilion of aflatoxins	. Recording of time	. Heat longer
KENKEY Final product			>100 cfu/g of foreign bacteria (non LAB) >100 cfu/g of moulds >10 parts per billion of aflatoxins		
CLEANING CCP	. Contamination with spoilage and pathogenic microorganisms	. Good housekeeping and personal hygiene . Maintenance of equipment	. Clean premises, processing equipment and vessels and processing staff	. Visual inspection	. Clean premise, hall equipment and vessels . Clean factory coats . Wash hands . Use gloves

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