PROCESS OPTIMIZATION AND PRODUCT CHARACTERISTICS
OF WHITE KENKEY (nsiho)

THIS THESIS IS SUBMITTED TO
THE UNIVERSITY OF GHANA, LEGON

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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF THE PhD FOOD SCIENCE DEGREE

NUTRITION AND FOOD SCIENCE DEPARTMENT

June, 2015
DECLARATION

I do hereby declare that this thesis is the result of my own research except for references to works of others that have been duly cited under the supervision of Prof. F.K. Saalia, Dr. Wisdom Amoa-Awua, Dr. Christian Mestres and Prof. E. Sakyi-Dawson. This work either in whole or part has not been presented for another degree elsewhere.

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ABSTRACT

*Kenkey*, is a maize based sour, stiff dumpling, and it is among the most common fermented cereal food products in Ghana. There are several types of *kenkey*, and while some are made from whole maize grains others are produced using degermed/and dehulled maize grains. The *kenkey* types made using dehulled maize grains are less popular and have largely remained at the level of “ethnic food”, restricted to very few socio-cultural communities. Current trends in urbanization, and the increasing popularity of *kenkey* among consumers, require larger scale production with consistent quality. The study was carried out to examine the traditional white *kenkey* process and to optimize the key processing variables in order to obtain reproducible quality white *kenkey* that will be acceptable to native and non-native consumers.

A survey was conducted in three white *kenkey* production districts to collate information on production, vending and consumption practices. The sensory profile and consumer acceptance of different types of *kenkey* and other fermented maize products in Ghana were investigated. A total of two hundred consumers including 110 Ghanaians and 90 internationals were used for the consumer test. Traditional white *kenkey* types were analyzed for their physicochemical, textural, microstructure and sensory characteristics. Physicochemical analysis involved determination of pH, titratable acidity, sugars, lactic acids, minerals, vitamins and amino acids using high performance liquid chromatography procedures. The textural characteristics of white *kenkey* randomly obtained from traditional processors were determined using instrumental (texture analyser) and consumer assessments.

The effects of processing variables of steeping time (12, 30 and 48 h) and dough fermentation time (0, 12 and 24 h) on the physicochemical properties of white *kenkey* were
determined. A (three variable) Box-Behnken design was used to optimize the processing variables of steeping time, steeping temperature, and fermentation time on white kenkey quality parameters of moisture, pH, titratable acidity, glucose and lactic acid content. The optimum region of the process variables was obtained by hedonic tests on the white kenkey using balanced incomplete block design (for k= 5, b= 21, λ=2, r =7)

Quantitative Descriptive Analysis (QDA) was conducted on white kenkey made from within and outside the optimum region of the process variables, as well as white kenkey obtained from vendors using a panel of 18 trained members. Consumer acceptance study was conducted using 65 consumers for white kenkey obtained from the optimum region and traditionally processed white kenkey obtained from vendors.

The results of the survey showed that there were two main types of white kenkey, non-sweetened white kenkey and sweetened white kenkey to which sugar is added during production. All three procedures involved steeping of dehulled maize grains which is then milled into a meal. In the (procedure at Atimpoku), the meal was not fermented any further but precooked, moulded into balls wrapped in leaves and steamed. In the (procedure at Anum), the meal was kneaded into dough and allowed to ferment for 12 hours, the fermented dough (70%) is precooked and mixed with the remaining dough, moulded into balls and steamed. Three classes of behaviours of consumers were identified. Those who liked all the products ‘all likers’ (36%), those who preferred the white kenkey ‘white likers’ (30%) and those who preferred Banku ‘banku likers’ (34%). Sensory attributes important for the white likers were whitish colour, fruity odour, smooth and non-sticky texture, a less sour product without a pronounced fermented odour, and a bland taste. The white kenkey samples randomly obtained from vendors contained 70 – 77 % moisture, 0.58-0.88 g/100 g ash, 0.09-0.19 g/100 g fat, 2.45-2.84 g/100 g protein, vitamin
B1 of 17-47 g/100 g, had pH of 4.07 –4.54, titratable acidity 0.42-0.60% lactic acid, 2-28 mg/g glucose, and 0.6-2 mg/g lactic acid. The amino acids lysine, methionine, Gaba and Ornitine values were less than 0.2 g/100g. Steeping time of maize was complimentary to fermentation time since both influenced the conversion of glucose by lactic acid bacteria into lactic acid. Generally, the longer steeping and fermentation times gave higher levels of glucose and lactic acid in the white kenkey. However, whilst steeping increased glucose level, dough fermentation reduced it. The intensity of whiteness (L) in white kenkey diminished as steeping time increased. On the other hand, fermentation time improved whiteness of kenkey. High aflata (i.e ratio of precooked to uncooked dough) produced kenkey with softer texture, whilst reducing the aflata ratio increased the hardness and stickiness of white kenkey. Consumers preferred white kenkey made using high aflata ratio and steamed for longer periods.

The optimization studies showed that processing variables had significant effects on the physicochemical and sensory characteristics of white kenkey. The optimum region for the process variables at which the most acceptable kenkey was obtained were steeping time of 30-45 h at 30-35°C temperature followed by 12 h dough fermentation. Consumer acceptance test indicated no significant difference in acceptance between the traditionally processed white kenkey samples and those obtained from the optimum region. White kenkey samples of higher quality potential has been identified. The process for production of white kenkey has been standardized, saving production time.
DEDICATION

I dedicate this work to my dear husband Rev. Joseph Oduro-Yeboah, my lovely kids, Joshua, Yacoba and Caleb and my father Mr. James Tete-Marmon for their care and understanding throughout this programme. A special dedication to my late mum, Yacoba Tete-Marmon who really sacrificed for me.
ACKNOWLEDGMENTS

This work was facilitated by financial support from the European Union under the project African Food Tradition Revisited by Research (AFTER) KBBE-20009-2-3-02.

I wish to honestly thank my supervisors, Prof. F. K. Saalia, Professor E. Sakyi-Dawson, all from Department of Nutrition and Food Science, Legon and Dr. W. Amoa-Awua, Chief Research Scientist and former Head of Food Microbiology Division, Food Research Institute, Accra, Dr. Christian Mestres of CIRAD, Montpellier-France for their constructive criticisms, guidance and mentorship which have brought this work to a successful completion.

I am grateful to Dr. Christian Mestres and Dr. Genevieve Fliedel of CIRAD for helping and accommodating me in their laboratory for analysis. I am appreciative to Mr. Job Barwuah and Miss Gloria Adjei for their selfless help during my analysis. I am highly indebted to Messrs. Papa Toah Akunnor, Hayford Ofori, Apolonius Nyarko, Solomon Douwona and Dr. Margaret Owusu for their assistance and interest in this work. I would also thank Messrs’ Gariba and Safo for driving me to the field to collect my samples.

A big thanks to all the AFTER team members for their support. Finally, I am most grateful to my husband for his support and encouragement.

I am above all most grateful to God almighty for giving me strength and wisdom to carry out this work.
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LIST OF ABBREVIATIONS

SRID- Statistical Research Information Directorate
FAO- Food and Agriculture Organization
GGDP- Ghana Grains Development Project
QPM- Quality Protein maize
LAB- Lactic acid bacteria
USDA- United States Department of Agriculture
AFTER- African Food Tradition Revisited by Research
FRI- Food Research Institute
CSIR- Council for Scientific and Industrial Research
GMP- Good Manufacturing Practices
HACCP- Hazard Analysis Critical Control point
GHP’S- Good Hygienic Practices
TTA- Titratable acidity
JHS- Junior High School
UNDP- United Nations Development Programme
PCA- Principal Component Analysis
AACC- American Association of Cereal Chemist
FCC- Federal Communication Commission
RSM- Response Surface Methodology
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CHAPTER 1

1.0 Introduction

Indigenous or traditional foods form the bulk of staples consumed in Ghana and their processing techniques are still strongly rooted in culture and tradition (Sefa-Dedeh, 1993). The indigenous foods are produced using simple technologies which have been handed down from ancestral generations and form an important part of the cultural heritage of Ghana. The same principles and unit operations are used as in modern food technology but their scale and method of application are different because they are largely artisanal in nature. All most all products require simple techniques and implements and the operations are home based (Sefa-Dedeh 1993). Inspite of their rudimentary nature these technologies are used to produce a wide variety of processed and semi-processed traditional staples to meet the demands of consumers of various socio-economic groups. The processors are predominantly women, almost no formal education, who carry out their operations purely from experience usually acquired through apprenticeship with relatives or friends.

Maize is the main cereal produced in Ghana and also one of the crops that is most extensively processed into a wide variety of traditional food products. The annual maize production in 2012 was 1.95 million metric tonnes and this accounted for 3% of Ghana’s Agricultural Gross Domestic Product (SRID, 2011). Maize is essential for the survival and food security for most Ghanaian population, contributing over 55% of the total energy intake (Alderman and Higgins, 1992). A nationwide survey carried out in 1990, revealed that 94 % of all households had consumed maize during an arbitrarily selected two-week period (Alderman and Higgins, 1992). An analysis based on 1987 data indicated that maize and maize-based foods accounted for 10.8 % of household
food expenditures by the poor, and 10.3% of food expenditures by all income groups (Morris et al., 1998; Boateng et al., 1990). Maize is utilized in several forms but mostly it is first processed into a fermented sour meal which is used directly for some food products, or further processed into traditional foods such as *kenkey*.

*Kenkey* is a sour dumpling very common food produced by traditional food processors. It has moisture content between 52-55%, its pH is 3.7 and a shelf life of 3-4 days (Halm et al., 2004a). Kenkey’s socio-economic importance is as a source of livelihood for many families engaged in its production and retailing, and also an affordable principal meal consumed regularly by a large segment of the population. It is an important part of diet in the food-eating habits of low-income workers. It is an affordable heavy meal which provides a feeling of satiety (Halm et al., 2004b).

The basic steps in the production of *kenkey* are steeping and milling of maize grains which is then mixed with water and kneaded into a stiff dough. The dough is left to ferment spontaneously into sour dough, which is further processed into *kenkey*. The further processes that the dough is taken through in *kenkey* making depend on the type of *kenkey*. Two main types of *kenkey*, namely Ga and Fante-kenkey, are indigenous to two different ethnic or socio-cultural groups located on the coastline of Ghana: the Ga and Fante. Both types of *kenkey* have become so popular that they are now eaten throughout Ghana. Other types of *kenkey* are known, but they are less popular. These include *nsiho* which is produced after the maize grains have been dehulled or polished and also sweet kenkey to which sugar is added during processing to sweeten the product. Commercial production and street vending of the different types of *kenkey* make a sizeable aspect to the rural and urban economy (Tortoe et al., 2008). As a street-vended
food, *kenkey* is convenient, ready-to-eat, inexpensive and affordable for the poor and provides informal and self-employment opportunities and supplementary income. Vending of *kenkey* contributes immensely to the food security of all actors in the value chain including maize farmers, input suppliers, *kenkey* processors and vendors. The *kenkey* vending business starts from the house. A woman with a little capital puts up a structure and *kenkey* prepared in the home is sold (Tortoe *et al*., 2008).

In view of the socio-economic importance of *kenkey* and its standing among other traditional foods, it is critical that *kenkey* does not become marginalized in the face of economic development, modernization and the advent of foreign fast foods. Consequently, a great deal of in-depth scientific investigations has been directed on indigenous African fermented foods in the last few decades. Much of the research effort on *kenkey* have focused on the microbiological and physicochemical changes that occur during fermentation and at other stages of processing as well as management of the safety of the product during processing (Amponsah, 2010; Nche *et al*., 1996; Amoa-Awua, 1996; Halm *et al*., 1996; Ackom-Quayson, 1992; Sefa-Dedeh and Plange, 1989; Bediako-Amoa and Austin, 1976, Halm, 2006, Annan, 2002, Kpodo, 2000, Hayford, 1998). Some of these have led to recommendations for improved methods for steeping, fermentation, cooking and packaging of *kenkey* (Nche *et al*., 1996). *Kenkey* processing is largely artisanal and the operations are not formally standardized, the important areas for ensuring compliance with HACCP and Good Manufacturing Practice (GMP) have also been identified (Amoa-Awua *et al*., 2007).

Most of these studies have been carried out with the view to upgrading the procedures for the standardization of *kenkey* production, even targeting industrial production to
satisfy its high demand. According to Halm et al. (2004), development of scientifically-based and controlled industrial operations for kenkey fermentation process will be a huge advancement as it could position the kenkey industry for global recognition and acceptance.

Despite the socio-economic importance of kenkey and other indigenous foods, several factors threaten their continued socio-economic importance and relevance in the Ghanaian society and economy. This includes changing trends in the food habits of the younger urban population who are attracted to trendy fast food restaurants. Additionally, it should be possible to expand the market for traditional foods beyond the borders of Ghana if they can be further developed to be acceptable to non-Ghanaian consumer demands. Based on these considerations this work was carried out to optimize processing of kenkey such that it would have both local and international consumer appeal and acceptability.

1.1 Main Objective

The main objective of the study was to examine the traditional white kenkey process and optimize the key processing variables to obtain reproducible quality in white kenkey that would be acceptable to native and non-native consumers.

1.1.1 Specific objectives

1. To evaluate traditional production, distribution practices and consumption patterns of different types of white kenkey.
2. To determine the sensory profile and consumer acceptability of fermented maize products.

3. To evaluate the physico-chemical, rheological and microstructural characteristics of non-sweetened and sweetened white kenkey.

4. To evaluate the effect of unit operations in the production of white kenkey (nsiho) and determine the drivers for consumer acceptability.

5. To optimize the white kenkey production process using Response Surface Methodology.

6. To conduct sensory profiling and consumer acceptability test on white kenkey using the optimized processing conditions.
CHAPTER 2

2.0 Literature review

2.1 Maize (Zea mays)

Maize (zea mays) is the American-Indian word for corn which literally means "that which sustains life". It is the third most important cereal grain in the world, after wheat and rice, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil, protein, alcoholic beverages, food sweeteners and more recently, fuel (FAO, 1992). About half of the maize available worldwide is grown in developing countries, where it is a staple food and the stalks provide feed for farm animals (Ofori and Kyei- Baffour, 2009).

In West Africa, maize is consumed in several forms following various units of operations such as soaking, milling, fermentation, boiling and packaging (Sefa-Dedeh et al., 2003; Sefa-Dedeh, 1993). In Ghana, particularly, the 2012 total maize production was 2 million metric tons, accounting for 3% of the Agricultural Gross Domestic (SRID, 2011). Maize is vital to the survival and food security of a large segment of the population, contributing over 55% of the total energy intake (Sefa-Dedeh and Mensah, 1989).

2.2 Origin of maize

The origin of maize is thought to be the Mesoamerican region, probably in the Mexican highlands from where it spread rapidly. It spreads around the world, particularly to the temperate zones after European discovery of the Americas in the 15th century, (Farnham et al., 2003, Paliwal, 2000). Maize was an important item in Mayan and Aztec civilizations and occupied an important role in their religious beliefs, festivities and
At the end of the fifteenth century, after the discovery of the American continent by Christopher Columbus, maize was introduced into Europe through Spain. It then spread through the warmer climates of the Mediterranean and later to northern Europe (FAO, 1992).

### 2.2.1 Structure and chemical composition

The maize kernel has a complex structure as it consists of pericarp, endosperm and germ components (Boyer and Hannah, 1994). The typical mature kernel is composed of 70-75% starch, 8-10% protein and 4-5% oil (Boyer & Hannah, 1994). However, there are large differences in the relative concentrations of these macromolecules in the different structural components of the kernel. The two major structural components of the kernel are the endosperm and the germ (embryo), constituting about 80% and 10% respectively of the mature kernel dry weight. The endosperm largely consists of starch (approximately 90%) while the germ contains high levels of fat (approximately 33%) and protein (approximately 18%) (Boyer & Hannah, 1994). These differences in the composition of the structural components become a significant consideration when maize is processed for consumption. The pericarp or hull of the maize grain is the thin covering enclosing the kernel. The endosperm is the largest portion of the kernel and represents about 82.3 percent of the weight of the grain. It consists largely of the starch (87.6%). The average energy content of the whole meal from maize is 3,578 calories per kilogram (FAO, 1992).
Table 2.1: Distribution (%) of nutrient components in maize kernel*

<table>
<thead>
<tr>
<th>Component</th>
<th>Pericarp (seed coat)</th>
<th>Endosperm</th>
<th>Germ (embryo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>3.7</td>
<td>8</td>
<td>18.4</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>86.7</td>
<td>2.7</td>
<td>8.8</td>
</tr>
<tr>
<td>Crude fat</td>
<td>1.0</td>
<td>0.8</td>
<td>33.2</td>
</tr>
<tr>
<td>Starch</td>
<td>7.3</td>
<td>87.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.34</td>
<td>0.62</td>
<td>10.8</td>
</tr>
</tbody>
</table>

*Data taken from FAO (1992)

2.2.2 Maize Production in Ghana

Maize is an important cereal crop in Ghana. It is grown by most rural households in all parts of the country (Morris et al., 1998). Its production has increased steadily since 1991 as compared to other cereals grown in the country. A total annual maize production as of 2012 was 2 million metric tons, accounting for 3% of the Agricultural
Gross Domestic Product (SRID, 2013) (Figure 2.2). Figure 2.2 shows five (5) year production rates of cereals in Ghana.

![Figure 2.2 Cereal productions in Ghana](image)

Source: Statistics, Research and Information Directorate (SRID), Min. of Food & Agric. - February, 2013

Dent maize is the most commonly grown type in the country. Normal dent maize is a variety of maize with a high soft starch content. It received its name because of the small indentation at the crown of each kernel on a ripe ear of maize (Shukla and Cheryan, 2001). According to the Ghana Grain Development Project (GGDP, 1991), about 12 different varieties of maize have been developed in the country. These varieties include aburotia, dobidi, kawanzie, golden crystal safita-2, okomasa, abeleehi, dorke, obatanpa, mamaba dadaba and cidaba. Some of the varieties (obatanpa,
mamaba dadaba and cidaba) have been nutritionally enhanced such as quality protein maize or QPM to help improve the nutritional status of consumers.

2.2.3 Maize consumption trends in Ghana

Maize is the most widely consumed staple food in Ghana (SRID, 2011). A nationwide survey in 1990 revealed that 94% of all households consumed maize during an arbitrarily selected two-week period (Alderman and Higgins, 1992). An analysis based on 1987 data showed that maize and maize-based foods accounted for 10.8% of household food expenditures by the poor, and 10.3% of food expenditures by all income groups (Morris et al., 1998; Boateng et al., 1990). In 1996, a survey in Accra by Allotey (1996) showed that about 0.05 to 1.2 metric tons of maize was processed weekly at most production sites in the country.

Maize is consumed in a variety of forms in Ghana, many of which require considerable time and skill to prepare. This explains why a significant proportion of all maize products consumed in Ghana are purchased from street food vendors (Alderman and Higgins, 1992; Morris et al., 1998). Some of the many traditional food products that are made using maize include banku, koko, and aboloo but the most popular product is kenkey, a sour stiff dumpling made from fermented maize dough, wrapped in leaves and boiled (Johnson and Halm, 1998). The process of kenkey-making is lengthy (6 days) and laborious and therefore, it is more often purchased from commercial producers (Halm et al., 2004).
2.3 Traditional food processing

Traditional processing of foods, including the production of indigenous fermented foods, is an important activity in the informal sector of the Ghanaian economy and perhaps in many African countries as well. It provides a means of livelihood for a large number of traditional food processors in the rural areas and increasingly in urban areas too. Despite the importance of traditional food processing in the food delivery system, several issues including both the safety of the food and their operations are of concern to the regulatory authorities and attempts are being made to improve them (Amoa-Awua et al., 2007).

According to Sefa-Dedeh (1993), 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, et al., (2004), the underlying fermentation processes of 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 traditional processing technologies employed for maize and other cereals in the developing world include cooking, sprouting, milling, fermentation and combinations of

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these (Nche, 1995). Of these, fermentation is the most commonly practiced, although the type of raw material, type and conditions of fermentation and sensory qualities of the finished products may vary from culture to culture. Fermentation is especially important to the developing world because it is an inexpensive and simple method of improving the nutritional and organoleptic qualities of otherwise bland cereal products (Hesseltine, 1983; Cooke et al., 1987; Chavan and Kadam, 1989). It does not require expensive equipment or special expertise and can be achieved in a very short period of time (Lay and Fields, 1981). Pre-fermentation treatments of cereals are largely dependent on the type of cereal and on the end product desired. Generally, treatments of grain before fermentation involve simple units operations such as drying, washing, steeping, milling, and sieving (Akinrele, 1970; Muller, 1980; Akingbala et al., 1981; Adeyemi, 1987; Adeyemi and Beckley, 1986; Osungbaro, 1990).

Fermented cereals are very widely utilized as food in Africa 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 using natural fermentations and are particularly important as weaning foods for infants and as dietary staples for adults (Akobundu and Hoskins, 1982; Umoh and Fields, 1981). The fermented cereal products can be classified on the basis of either the raw cereal ingredients used in their preparation or the texture of the fermented products (Blandino et al., 2003). The major cereal 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 koko, ogimahewu and mawe, which are prepared from maize, millet or sorghum (Blandino et al., 2003). The cereal gels are agidi, kenkey, bogobe, banku, injera and kisra (Blandino et al., 2003).
2.4 Lactic acid fermentation

Different types of food fermentations have been classified based on the major products of the fermentation process. These include alcoholic fermentation, lactic acid (non-alcoholic) fermentation, acetic acid fermentation, alkaline fermentation and amino acid/peptide sauce fermentations (Anukam and Reid 2009; Blandino et al., 2003, Steinkraus, 1997). Lactic acid is the main by-product of fermentation process, the pH of the ferment is always lower than 5 (in the acid range) for lactic acid fermentation (Mokoena et al., 2005).

Studies by Hirayama and Rafter, (1999), indicated that Lactic Acid Bacteria fermentation products (organic acid, hydrogen peroxide, acetic acid) have anti-tumour effects. It has been reported that moulds and aerobic mesophilic bacteria present at start of steeping are not detectable after 24 hours of fermentation (Halm et al., 1993). In inoculation studies, the numbers of enteric pathogens were markedly reduced in maize fermentations (Mensah et al., 1991; Simango and Rukure, 1992). Mensah, (1997), demonstrated that fermentation is more effective in the removal of gram-negative than the gram-positive bacteria. These apparent strong antimicrobial activities of the dominant lactic acid bacteria could be explained by the decrease of pH from 6.5 to 3.7 within 24 hours of fermentation (Halm et al., 1993) and specific effects of compounds like organic acids, hydrogen peroxide and bacteriocins produced by the lactic acid bacteria during fermentation (Piard and Desmazeaud, 1992).

LAB fermentation is thought to prevent diarrheal diseases because they modify the composition of intestinal microorganisms, and suppress the growth of pathogenic
enteric bacteria. LAB bacteria also produce fungal inhibitory metabolites, which are mainly organic acids, including propionic, acetic and lactic acids (Huwig et al., 2001). The production of bacteriocins has been reported for microbial species found in fermented maize, such as *Lactobacillus fermentum*, *Lactobacillus reuteri* (Toba et al., 1991), *Lactobacillus plantarum* (Lewus and Montville, 1992; Daeschel et al., 1990; West and Warner, 1988) and *P. pentosaceus* (Spelhaug and Harlander, 1989; Daeschel and Klaenhammer, 1985). It has also been reported that *L. reuteri* produces reuterin, a derivative of 3-hydroxypropionaldehyde, which has a broad antimicrobial spectrum (Olsen et al., 1995; Axelsson et al., 1989).

Fermented cereal products may not only be microbiologically safe, but they may also be devoid of minimum levels of mycotoxins. Steinkraus, (1997), Chelule, (2010) and Mokoena et al., (2005) demonstrated that detoxification of mycotoxins (fumonisins, ocratoxin A, zearalenone and aflatoxins) in food occurs through LAB fermentation. LAB fermentation irreversibly degrades mycotoxins without leaving any toxic residues. The detoxifying effect is believed to be through toxin binding (El-Nezami et al., 2002). Apart from its antibiotic properties, lactic fermentation makes the food palatable by enhancing its aroma and flavor (Leroy and De Vuyst, 2004). These organoleptic properties make fermented food more popular than the unfermented one in terms of consumer acceptance (Blandino et al., 2003).

### 2.5. Microbiology of fermented dough and kenkey

The microbiology of fermented maize dough used for production of kenkey has been investigated in detail (Jespersen, 2003; Halm et al., 1993). Olsen et al. (1995) indicated that each processing stage has its own micro-environment with strong antimicrobial
activity. It has also been confirmed that the process for the production of Ga kenkey include four different microbiological environments which include the maize grains, steeping of the maize grains in water for 48 hours, milling of the steeped maize as well as preparation and fermentation of the dough for about 48 hours (Halm et al., 1993). On the maize and early phase of steeping, the microbial flora consists of a mixed population of lactic acid bacteria, aerobic mesophilic bacteria, yeasts, and moulds. The flora rapidly changes towards a more uniform population of heterofermentative lactic acid bacteria, mainly *Lactobacillus fermentum* and *Lactobacillus reuteri* (Halm et al., 1993; Hounhouigan et al., 1993). Other lactic acid bacteria associated with fermented maize are *Lactobacillus plantarum* (Fields et al., 1981), *Pediococcus pentosaceus* and *Pediococcus acidilactici* (Halm et al., 1993). It has been reported (Nche et al. 1994) that *L. plantarum* and *Pediococcus* spp. dominate the latter stages of maize dough fermentation. *Lactobacillus fermentum* has been reported to play a dominant role in fermented maize dough (Sefa-Dedeh et al., 2003; Halm et al., 1993). Lactic acid bacteria (LAB) are historically defined as a group of micro-aerophilic, gram-positive organisms that ferment hexose sugars to produce primarily lactic acid. This functional classification includes a variety of industrially important genera, including *Lactococcus*, *Enterococcus*, *Oenococcus*, *Pediococcus*, *Streptococcus*, *Leuconostoc*, and *Lactobacillus* species.

Apart from lactic acid bacteria, yeasts also form an important part of the microbial flora in fermented maize (Jespersen et al., 1994; Halm et al., 1993; Hounhouigan et al., 1993). A mixed flora comprising the species of *Candida*, *Saccharomyces*, *Trichosporon*, *Kluyveromyces* and *Debaryomyces* has been isolated from raw maize, during steeping and early phases of fermentation. After 24 to 48 hours of fermentation
S. cerevisiae dominated and the number of *Candida krusei* was found to increase during the fermentation and after 72 hours, *C. krusei* was the dominant yeast species. The microbial succession for *C. krusei* at the advanced stage of fermentation is likely to be due to this species’ greater tolerance of high levels of organic acids (Jespersen, 2003). In other studies by Obiri-Danso, (1994) and Akinrele (1970) the main yeasts isolated from maize dough and during the fermentation of a Nigerian maize-fermented food (ogi) respectively, were *Saccharomyces* and *Candida*. The presence of this variety of microorganisms in the steep water and in the dough may result in the production of a foul smell in the steeped maize water and/or the fermented dough (Jespersen, 2003).

### 2.6 Small Scale fermented foods in Africa

Small scale fermented foods are foods which are produced using traditional fermentation techniques. Some foods are fermented using cereals while others are fermented using tubers, stems and using cow milk. Popular fermented cereal products include ‘ogi’, ‘kenkey’, ‘injera’, ‘pito’, and ‘kunu-zaki’. On the other hand, ‘gari’, ‘lafun’ and ‘fufu’ are fermented using cassava while ‘Wara-kisi’ is fermented from cow milk. Locust beans are used in the fermentation of ‘iru’ (Ijabadeniyi and Omoya, 2006).

#### 2.6.1 Ogi

‘Ogi’ is a porridge prepared from fermented maize, sorghum or millet. It is a staple in West Africa and serves as a weaning food for infants. The traditional preparation of ‘ogi’ involves soaking of maize kernels in water for 1 – 3 days followed by wet milling and sieving to remove bran, hulls and germ (Akinrele, 1970; Odunfa, 1985). The filtrate, mainly white starchy sediment is fermented (for 2-3 days) to yield a sour
product locally known as ‘ogi’. ‘Ogi’ is often marketed as a wet cake wrapped in leaves or transparent polyethylene bags. It is diluted to a solids content of 8 to 10 % and boiled into pap, or cooked and turned into stiff gel called ‘agidi’ or ‘eko’ or ‘kafa’ prior to consumption (Ijabadeniyi and Omoya 2006).

2.6.2 Banku

Banku is a popular staple consumed in Ghana. It is prepared from maize and or from a mixture of maize and cassava (Owusu- Ansah et al, 1980). The preparation of banku involves steeping the raw material (maize or a mixture of maize and cassava) in water for 24 h followed by wet milling and fermentation for 3 days. The dough is then mixed with water at a ratio of 4 parts dough to 2 parts water; or 4 parts maize dough to 1 part cassava dough and 2 parts water. Continuous stirring and kneading of the fermented dough is required to attain an appropriate consistency during subsequent cooking.

2.6.3 Kunu-Zaki

This is a millet – based non-alcoholic fermented beverage widely consumed in the Northern parts of Nigeria and Ghana (‘zunkuang’). It is however becoming more widely consumed in Southern Nigeria, owing to its refreshing qualities. Adeyemi and Umar (1994) described the traditional process for the manufacture of kunu-zaki. This process 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 over 8- 48 hour period is known to involve mainly lactic acid bacteria and yeasts (Obadina et al., 2008).
2.6.4 Kenkey

This is fermented maize dough product 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 (Blandino et al., 2003). There are several types of kenkey throughout Ghana, but the most commonly occurring are the Ga-kenkey, the Fante kenkey and the nsiho types.

2.7. Production of Kenkey

Kenkey is one of the most important fermented products in Ghana (Halm et al., 2004; Nche et al., 1996). It is largely produced traditionally by two ethnic groups, the Gas and the Fantes. Ga kenkey or komi and Fante kenkey or dokono are the two main types of kenkey in Ghana. Both types of kenkey are produced using fermented maize dough that is subsequently cooked and wrapped in maize sheaths (Ga kenkey) or in plantain leaves as in the case of Fante kenkey (Halm et al., 2004). Kenkey has been described as one of the best examples of traditional African foods which through history has played a significant role in food safety as well as food security (Amoa-Awua et al., 2007).

Kenkey forms an important part of the food-eating habits of low income workers who may consume it as breakfast, lunch or dinner (Halm et al., 2004). Its production also serves as a source of income for the producers who are mainly women with little or no formal education. They carry out this commercial production as a family-acquired art either individually or as a family business in the household, often depending on family labour to produce and retail the product (Halm et al., 2004).
During Ga *kenkey* production, the preparation of fermented maize dough goes through a number of units operations, which include cleaning and steeping of maize kernels for 24 to 48 hours, milling, mixing with measured amounts of water to the maize meal to form dough, and fermentation of the dough for 48 to 72 hours (Jespersen, 2003). The fermented maize dough is mainly the raw material for a number of traditional fermented maize dough, including *kenkey*. In the *kenkey* process, part of the fermented maize dough (usually half) is slurried with water (to about 15-20% solids) and cooked into a thick and sticky paste, called *aflata* (Nche et al., 1994; Muller and Nyarko-Mensah, 1972).

A more detailed analysis of some of the critical units of operations of the *kenkey* process is important in understanding the state of research and to help in identifying important parameters for modeling and scale up operations for industrial production.

2.7.1 **Raw material cleaning**

This is usually the first step in *kenkey* production. Maize intended for production of *kenkey* is cleaned to remove all foreign matter. This is done by one or a combination of several processes including winnowing, hand picking, sieving and sedimentation. These operations remove dust, chaff, stones, insect-damaged grains and other debris (Halm et al., 2004). The sedimentation process involves pouring the grains into a big basin of clean water and stirring with a wooden ladle. This is to allow the mature and good quality grains to settle at the bottom while the less dense immature, 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 before steeping (Halm et al., 2004)
2.7.2 Steeping of maize

Soaking or steeping of the cleaned maize is a very important unit operation that greatly affects the quality characteristics of the final product (kenkey). Steeping of maize is known to facilitate smooth milling, and is considered crucial to the aflata binding characteristics when mixed with non-cooked maize dough (Nche et al., 1996). The steeping process causes the uptake of water and results in swelling and softening of the kernels. It also results in the incubation of native microorganisms from the maize thus causing the initiation of fermentation and subsequently influences the taste, texture and flavour of the final product (Sefa-Dedeh and Plange, 1989; Muller and Nyarko-Mensah, 1972). When genetically improved maize grains were steeped in water (1:4, w/v) for 0 h, 12 h, 24 h, 48 h and 72 h at 30 ± 2°C, it resulted in increases in microbial load of both steep water and maize grains. During soaking of maize grains, pH decreased with steeping time, whilst the titratable acidity increased (Ingbian and Agwu, 2010).

During steeping, changes that occur in the maize kernel may be bio-chemical (enzymatic, pH, acidity), microbiological or physical (water uptake). It results in the extraction of water-soluble components and dissolves salts, soluble carbohydrates, and protein in the maize (Hull et al., 1996). There is rapid uptake of water by the maize kernel at the initial stages of steeping via its tip cap and pericarp. This is then followed by a slow process associated with the uptake of water by the endosperm through the testa (Akom-Quayson, 1992, Oguntunde and Adebawo, 1989). Obiri-Danso et al., (1997) observed that the moisture content increased significantly (p < 0.05) from 15% for both obatanpa and okomasa dry grains to 46.6 and 45.35% for obatanpa and okomasa maize cultivars respectively on steeping due to absorption of water.
According to Akinrele (1970) and Ackom-Quayson (1992), most of the absorption of moisture by the kernel and the bulk of the swelling of the grain occur during the first 24 hours of steeping. Further steeping only resulted in the depletion of limited supply of fermentable carbohydrates especially sucrose in the maize.

Microorganisms, especially lactic acid bacteria (LAB), that are also detected during the steeping process produce lactic acid which may help soften the kernel and degrade the protein matrix surrounding starch granules (Roushdi et al., 1981). However, these effects may be due to a variety of catabolic indigenous enzymes of the kernel and/ or exogenous bacterial enzymes rather than the lactic acid. Wahl (1971) determined that indigenous proteolytic enzymes reach maximum activities during steeping (Steinke and Johnson, 1991). LAB may also contribute to the fermentation of the maize during steeping and possibly to the production of the foul smell characteristic of most steep water. They may also contribute to fermentation of the dough after the maize has been milled. These microorganisms are able to thrive due to the presence of soluble sugars and amino acids that leach out of the maize kernel during steeping (Ackom-Quayson, 1992; Watson, 1984).

If the traditional kenkey process is to be scaled up to the industrial level, then the long steeping times for the grains could be a disincentive. Consequently methods to reduce production time have been explored. The time required for hydration of maize to 40% (w/w) moisture content was shortened from 48 to 10 hours by pre-cracking the kernels (Nout et al., 1996). Terna and Ayo, (2002) shortened the usual 24 hours steeping time to 12 hours by steeping the grains in warm water with 5% sodium meta-bisulphite. Apart from softening of the grain quite rapidly, development of the foul odour of steep water
was also averted by steeping in dilute sodium metabisulfite, thus providing a solution to steep water disposal management.

2.7.3 Milling and dough preparation

Milling is a very important unit operation in the processing of cereals in general. In the production of *kenkey*, this operation is performed in a disc attrition mill often referred to as corn mill in Ghana. The performance of the mill in terms of efficiency is not uniform and thus yields maize meal with a wide range of particle sizes (Sefa-Dedeh and Plange, 1989). The physical, chemical and structural properties of the maize usually tend to affect the efficiency of the plate mill. Small and soft-textured kernels are often more amenable to milling than large and hard-textured kernels (Vivas *et al.*, 1987). After milling, the maize meal is mixed with water to form dough with moisture content between 50% and 55% (Halm *et al.*, 2004). The dough moisture content is critical since it affects the rate of fermentation as well as the quality and shelf-life of the dough (Halm *et al.*, 2004).

2.7.4 Dough fermentation

The maize dough obtained after mixing the milled steeped maize with clean water (to about 40-50% db) is left to undergo a spontaneous lactic acid fermentation. The final pH reduces to below 4 due to the production of organic acids (Blandino *et al.*, 2003) predominant among which is lactic acid. Lactic acid fermentation of cereal-based foods is a very popular traditional technology in Africa (Mensah, 1997; Oyewole, 1997).

During maize dough fermentation, the freshly prepared dough is packed tightly into wooden vats, aluminium pots, plastic containers, and enamel or aluminium basins and allowed to spontaneously ferment for up to 3 days at ambient temperature. The size of the commercial fermenter is variable but it will not normally exceed one capable of
holding 50 kg of dough (Halm et al., 2004). During the fermentation period, a series of complex reactions usually involving carbohydrates, proteins and fats are triggered off and sustained by microorganisms. This often leads to the development of desired physicochemical and organoleptic qualities (Akom-Quayson, 1992; Sefa-Dedeh and Plange, 1989). In the fermentation process, some degree of safety and storage stability is also imparted. The production of organic acids makes it difficult for spoilage organisms to survive (Blandino et al., 2003, Oyewole, 1997). Apart from their ability to produce organic acids that act as antimicrobials, the LAB also produce hydrogen peroxide, which is inhibitory to some microorganisms (Caplice and Fitzgerald, 1999).

Mensah et al., (1990) researched on the microbiological quality of fermented and unfermented dough and found out that some of the unfermented dough samples contained Escherichia coli (E. coli) carrying plasmids bearing genes for enterotoxins but none was found on the fermented dough samples (Akom-Quayson, 1992). Although fermentation imparts some degree of shelf stability to maize dough, it still has a very short shelf-life of up to about 5 days (Bediako-Amoa, 1973). Producers usually begin to use the dough after 24 hours of fermentation to produce kenkey, and this continues until it is used up (between 3 to 4 days). Ofosu (1971) showed that while dough fermented for 24 hours may be used in preparing kenkey, the kenkey prepared in this way lacks the sourness and characteristic aroma associated with that prepared with well fermented dough.

On the other hand, extended periods of dough fermentation beyond 4 days sometimes lead to the development of undesirable flavours and high acidity (Halm et al., 2004). Bediako-Amoa, 1973 reported that the best kenkey is obtained from 48 hour fermented
dough and that further fermentation adversely affects consumer acceptance. According to some commercial kenkey producers, however, the shelf-life of the fermenting dough can be extended without adverse effects on consumer acceptance if less water is used in making the dough (Halm et al., 2004). Fermentation as has been described also affects the rheological properties of maize dough. Anim (1991) showed that the gelatinization temperature of dough prepared from maize steeped for 24 hours at different steeping temperatures increased with increase in fermentation time and steeping temperature. Furthermore, studies on solid-state fermentation of millet showed increase in cooked paste viscosity of dough with increase in fermentation time (Osa-Mensah, 1991).

2.7.5 Aflata preparation and mixing

Aflata is the sticky gelatinous paste prepared from cooking the slurry made by mixing two or three parts of water to a portion of fermented dough (Halm et al., 2004; Nche et al., 1994). During cooking of the aflata for Ga-kenkey salt is added to taste (Ofosu, 1971). When the aflata is well cooked, it is mixed thoroughly with a portion of non-cooked fermented dough while still hot, moulded into balls wrapped in banana leaves or maize sheaths as the case may be, and subjected to intense cooking for about three hours (Halm et al., 2004). The difference between Fante kenkey and Ga-kenkey apart from the wrapping material, is that little or no salt is added during the aflata cooking of Fante kenkey (Ofosu, 1971). Aflata serves as a binding agent and moisturizer when it is subsequently mixed with the non-cooked dough (Nche et al., 1996). When kneaded the aflata holds the non-cooked dough together in a dumpling which can then be shaped, wrapped and boiled to give kenkey (Nout et al., 1996). Nche et al. (1996) reported that a dough with a high starch gelatinisation index during cooking and a high set-back viscosity, on cooling, is required to give an aflata of adequate binding and moisturizing.
capacity. This is very important in determining the desired textural characteristics of cooked kenkey, which is a cohesive mass of coarse particulate matter cemented by the aflata.

The ratio of aflata mixed with non-gelatinized dough depends on the preference of processor/consumers. Amongst indigenous Ga people, who consume kenkey as a major staple, the ratio is usually, one to one (Halm et al., 2004). Some producers however, mix two-thirds of aflata with one-third of uncooked dough and vice versa. In a sensory evaluation of the texture of kenkey, the highest score given by panelists was for kenkey prepared from a one to one ratio of aflata and non-cooked dough (Bediako-Amoa and Austin, 1976). Good kenkey is neither too sticky nor crumbly. The choice of ingredients and the pre-treatment of maize and dough for aflata production are, therefore, crucial to the achievement of these properties. Local kenkey producers therefore prefer maize with a high swelling index (Nche et al., 1996).

2.7.6 Moulding, packaging and cooking of kenkey
Moulding of the aflata-dough mixture into balls of about the same sizes is the next step after the preparation and mixing of aflata. The balls which weigh approximately 300 g are wrapped in cleaned maize husks and cooked (Halm et al., 2004). During cooking, clean maize husks are placed at the bottom of the cooking pot and the balls of kenkey packed on them. This is to ensure that the kenkey does not stick to the bottom during cooking. Enough water, based on judgement of the producer is then poured into the pot and allowed to boil for between 2 to 3 hours depending on the aflata-dough ratio (Halm et al., 2004).
The lower the aflata content of the mixture, the longer the cooking period. The cooking water left in the pot; often referred to as “kenkey water” is also consumed as a thin porridge by most people (Halm et al., 2004). According to Yartey et al. (1993), the carbohydrate and electrolyte levels of “kenkey water” are comparable to those of the UNICEF/WHO Oral Rehydration Salts and therefore suitable for use in oral rehydration in Ghana.

2.7.7 Comprehensive description of white kenkey

Apart from Ga- and Fanti-kenkey other types of kenkey exist, though less known. Such products are however important in some parts of the country. One of such products is nsiho or apkorhie, and is kenkey produced from dehulled or degermed maize grains and is consequently more whitish in colour. Compared to Ga- and Fantekenkey, nsiho or white kenkey is less sour in taste, hence blander, and less sticky in texture (Obodai et al., 2014). There are two types of white kenkey, non-sweetened (nsiho) and sweet kenkey which is essentially nsiho to which sugar is added during processing to give a sweet product. Production of nsiho involves dehulling maize grains which are then steeped in water for 48 h and milled into a meal. The meal is kneaded with water into a dough and left to ferment spontaneously for 12 to 24 h. Some producers however do not carry out dough fermentation. The dough is now pre-cooked, moulded into balls, wrapped in maize husks and steamed for 1 to 2 h. Some producers do not pre-cook the dough whilst others pre-cook two-thirds of the dough and mix it with one-third of uncooked dough before moulding and steaming into nsiho (Annan et al., 2015; Obodai et al., 2015). Figure 2.3 shows the flow diagram for the production of white-kenkey (nsiho).
Maize grains

Cleaning
(Sorting, sieving, winnowing)

Dehulling

Steeping (48 h)

Washing

Milling

Kneading into dough

Fermentation (12 h)

Pre-cooking of 2/3rd of dough (30-60 mins)

Mix ohu is with remaining fresh dough

Mould and package in maize husks

Steaming (1-2 h)

Nsiho (white kenkey)
(Procedure at Anum)

Source: (Halm et al., 2004) with modification

Figure 2.3: Flow diagram for the production of Nsiho (white-kenkey).
2.8 Nutritional value of kenkey and fermented cereal products

Maize is poor in nutritional value, yet they constitute the main staple diet of the low income populations. The nutritive value of kenkey is basically dependent on the maize from which it is made and the processing technique used in production. Maize, provides an estimated 15% of the world’s protein and 20% of the world’s calories (Brown et al., 1988). It is a dietary staple for more than 200 million people. This number can be expected to grow as the world’s population approaches 8 billion in 2025 (Lutz et al., 2001; USDA, 2009), indicating maize’s status as a paramount crop in the context of global nutrition.

Maize constitutes a major source of dietary nutrients all over the world despite the deficiency in some essential amino acids such as lysine, tryptophan, methionine, cystosine and phenylalanine and B vitamins (Blandino et al., 2003). 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 of Ghana (Davey, 1962). On a dry basis, the proximate composition of Ga kenkey is approximately 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/100g phosphorus, 6.5-12.6 mg/100g iron and 74.3-87.1% total carbohydrates (Halm et al., 2004). Table 2.2 gives chemical composition of white kenkey (nsiho).
Table 2.2: Chemical Composition of white kenkey (Nsiho)

<table>
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<tr>
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<th>Moisture (g/100g)</th>
<th>Ash (g/100g)</th>
<th>Protein (g/100g)</th>
<th>Total fibre (g/100g)</th>
<th>Crude fat (mg of KOH/100g)</th>
<th>Fe (mg/kg dry basis)</th>
<th>Cu (mg/kg dry basis)</th>
<th>Zn (mg/kg dry basis)</th>
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<td>Mean of duplicate determinations</td>
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Source: African Food Tradition revisited by Research Project (AFTER), Deliverable 1.2.7.1, 2013

Studies by Nout, (1992) and Obiri-Danso et al., (1997), indicated that lactic acid fermentation has been shown to improve the nutritional value and digestibility of these foods. The acidic nature of the fermentation products enhances the activity of microbial enzymes at a temperature range of 22-25 °C (Mokoena et al., 2005). The enzymes, which include amylases, proteases, phytases and lipases, modify the primary food products through hydrolysis of polysaccharides, proteins, phytates and lipids respectively. LAB fermentation also reduces the levels of anti-nutrients such as phytic acid and tannins in food leading to increased bioavailability of minerals such as iron, protein and simple sugars (Sripriya et al., 1997, Chelule et al., 2010). The amount of vitamins is also increased in the ferment (Sripriya et al., 1997, Santos et al., 2008).

2.9 Opportunity for improvement of fermented foods

Indigenous fermented foods like white kenkey (nsiho) are traditionally produced at the household level in Ghana. Their production processes require a great deal of time and effort. Trends in urbanization require the industrialization of traditional fermented foods for larger scale production of consistent quality to meet the increasing demands.
and changing lifestyles of the growing middle class. Upgrading production of fermented foods such as white kenkey from the household to the industrial level will require some improvements in process controls. To achieve this, critical process and environmental factors such as temperature, moisture content, pH, acidity, which influence the activity of microorganisms during the fermentation process, need to be well understood, and modeled on final product quality attributes.

The chemical and functional properties of fermented blends of steeped and nixtamalized maize were investigated (Sefa-Dedeh, et al., 2003). A 3x5 factorial experimental design with fermentation time (0, 24, 48 h) and blends composition (0:100, 25:75, 50:50, 75:25, 100:0 steeped: nixtamalized maize) was employed. Blends were fermented and analysed for pH, titratable acidity, water absorption, texture and viscosity. As fermentation time increased, pH of blends decreased with increase in titratable acidity. Decreases in water absorption capacity, texture, colour and cooked paste viscosity were observed with increased fermentation. It was observed after 48 h of fermentation that cooked paste viscosity of 50:50, 25:75 and 0:100 blends decreased. With increased fermentation, blend derived from 100% steeped maize, showed increases in all parameters.

Nche et al., (1996) studied the effect of water uptake during soaking of whole or dry-milled maize on the extent of starch damage, dough pH, and fermentation time on pasting and set-back viscosities of aflato dough. It was observed that high endogenous activity of proteases and carbohydrases were recorded in both grits and whole maize soaked at 4 °C or 25°C. These were significantly reduced after soaking at 60 °C.
Soaking of grits at 60 °C with a heat-stable protease, or wet fine-milling of fermented grits resulted in significant (P<0.05) increases in pasting viscosities. Peak viscosities increased with fermentation time up to 24 h. Authors concluded that pasting viscosities decreased with repeated wet milling of fermented dough.

The chemical, functional, pasting and sensory qualities of *ogi* (fermented maize porridge) produced from white and yellow maize at different length of fermentation were analyzed. Significant different in protein (10.05-11.00 %), ash (0.86-1.10 %), moisture content (8.88-10-33 %) were observed (Adegunwa *et al.*, 2011). They brought to the fore that significant difference (p<0.05) existed in sensory qualities of *Ogi* powder samples except for texture.

**2.10 Sensory studies on kenkey and similar type Foods**

Studies were carried out by Fadahunsi *et al.*, (2012) to investigate the effect of single and combined starter cultures on fermentation of maize for *kenkey* production. Panel members rated samples for sourness, taste, aroma, appearance and overall acceptability on a nine-point hedonic scale. It came to light that *kenkey* produced using combined starter of *L. Plantarum* and cerevisiae *krusei* was rated best in terms of assessed attributes. Traditionally produced *kenkey* scored the highest sourness value of 4.38. Fadahunsi *et al.*, (2012) concluded that *kenkey* produced using combined starter culture of *L. Plantarum* and cerevisiae *krusei* was highly preferred.

Amponsah, (2010) developed ways of reducing water consumed during *kenkey* production process and to investigate the effect on *kenkey* produced. Maize dough was
prepared using re-used steep water and fresh water, it was fermented for 24 hours and kenkey prepared. Consumer acceptability was conducted for 50 sensory panelists using a 9-point hedonic scale. Taste scores for treatment samples, were not significantly different from the control. Different treatments given to the maize and dough did not significantly influence texture of the kenkey. Smell, colour and overall acceptability of kenkey samples were however significantly affected by the treatments. The author concluded that the primary concern in steep water reuse is the development of undesirable odour or aroma in kenkey, which is a significant risk in the preparation of traditional kenkey.

Aflata was prepared for 8, 10 and 12 mins. Equal amount of uncooked dough was added, mixed and moulded to prepare Ga-kenkey (Dzigbor, 2012). Ga-kenkey samples were evaluated using a 9-point hedonic scale with 50 consumers. In terms of colour and odour, kenkey samples prepared by cooking aflata for various time, were not significantly different from traditional kenkey at (p ≤0.05). Significant differences existed between the samples (P <0.05) in terms of hardness.

Sensory attributes of two traditional ogi (fermented maize porridge) diets enriched with soybeans and crayfish were evaluated (Samuel and Otegbayo, 2006). Authors randomly selected panel of 16 members, who assessed samples in terms of appearance, aroma, consistency and taste using a nine-point hedonic. Sensory evaluation showed that diet A (ogi-soybeans) which contained 14.16 per cent protein, 18.6 per cent fat, 2.0 per cent crude fibre and 2.14 per cent ash was generally more acceptable than diet B (ogi - crayfish) which contained 17.66 % protein, 12.6 % fat, 2.45 % crude fibre and 5.35 % ash in terms of colour, tastes, consistency and aroma.
Color, taste, texture, aroma, and consistency of the *ogi* prepared using seven sorghum varieties were evaluated to determine which sorghums had the best properties for *ogi* preparation (Akingbala *et al*., 1981). It was observed that *ogi* prepared with non-waxy white sorghums was highly rated.

Pastes composed of 100% soybeans, 90% soybeans and 10% maize, and 75% soybeans and 25% maize which were natural (NFP) and lactic acid bacteria (LFP) fermented were evaluated for sensory properties driving consumer liking (Ng’ong’ola-Manani *et al*., 2013). Ten trained panelists evaluated intensities of 34 descriptors, of which 27 were significantly different (*P* < 0.05). The LFP were strong in brown color, sourness, umami, roasted soybean- and maize associated aromas, and sogginess while NFP had high intensities of yellow color pH, raw soybean, and rancid odors, fried egg, and fermented aromas and softness. Ng’ong’ola-Manani *et al*., (2013), revealed that although there was consumer (*n* = 150) heterogeneity in preference, external preference mapping showed that most consumers preferred NFP.

### 2.11 Studies on industrialization of the *kenkey* production process

Nout *et al.* (1996) have observed that in view of facilitating convenience in an era characterized by increasing urban populations, it is realistic to consider options for industrial-scale manufacture of *kenkey*.

The traditional process for the production of *kenkey* is carried out at artisanal level. It takes considerable time (4-6 days), physical labour (*aflata* making, kneading and wrapping of dumplings) and energy (two cooking stages). Several studies have been
carried out to upgrade and mechanize some of the unit operations involved in *kenkey* production (Halm *et al.*, 2004). It has been shown that some parts of the *kenkey* process can be upgraded by shortening the fermentation period using an accelerated fermentation process (Nche *et al.*, 1994) or by reducing physical labour using pre-cooked dehydrated *kenkey* mixes (Nche *et al.*, 1996; Nout *et al.*, 1996).

The traditional 4-6 days *kenkey* manufacturing procedure can be shortened to 24 hours by a combination of reduced soaking time of maize to 12h where pre-cracked maize kernels were used, using starter dough in a dough- aflata mixture, and by cooking in sausage casings (Nout *et al.*, 1996). The cooking time and energy expenditure was reduced from 2 hours to 35 minutes by changing the dimension of the *kenkey* balls from 10-15 cm diameter to 6 cm diameter cylinders. These resulted in considerable savings on cooking time and thermal energy (Nout *et al.*, 1996).

To help lessen fermentation time in the process for industrial purposes, a starter culture containing strains of *Lactobacillus fermentum*, *Saccharomyces cerevisiae* and *candida krusei* were developed for the production of fermented maize dough (Halm *et al.*, 1996; Amoa-Awua, 1996). However, the organoleptic qualities of *kenkey* prepared from this dough were found to be unacceptable (Halm *et al.*, 1996; Amoa-Awua, 1996). To further facilitate industrial production of *kenkey*, the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR) established a pilot plant for semi-industrial scale production of dehydrated fermented maize meal and *kenkey* using modern methods of food processing (Halm *et al.*, 2004; Amoa-Awua *et al.*, 1998). It helped improve the situation at the site.
2.11.1 Quality Management

To manage mycotoxin contamination of a maize product like *kenkey* in Ghana, application of Good Manufacturing Practices (GMPs) and Hazard Analysis and Critical Control Points (HACCP) was proposed for traditional production of *kenkey* (Amoa-Awua *et al.*, 2007). Good Manufacturing Practice or Good Hygienic Practices (GHPs) was considered a requirement for implementing HACCP into the traditional operations to ensure the effectiveness of the quality system. HACCP can be implemented at minimal cost into traditional operations relying on very simple techniques and instruments.

2.11.1.1 Good Manufacturing Practices (GMP)

The *kenkey* production process can be described as tedious and labour intensive. In addition, there is little concern about food safety and Good manufacturing Practices (GMP) during production (Amoa-Awua *et al.*, 2007). However, some form of GMP is observed by *kenkey* producers to ensure the quality of *kenkey*. In order to ensure that the Ga-kenkey was cooked satisfactorily within the expected time frame, most processors (94%) employed addition of water during the *kenkey* cooking process. Other techniques used for ensuring Ga-kenkey cooks fast are increasing the intensity of the fire and increasing the thickness of plastic covering used to cover the *kenkey* during cooking (Owusu-Brafi, 2014).

Amponsah, (2010) observed that all producers who used raw maize as opposed to the already prepared maize meal or dough as a starting point in the production process included some form of cleaning treatment before steeping. Most of them (47%) simply winnowed while others after winnowing, also handpicked unwanted materials (16%),
used sedimentation (15%) or washed (12%) the maize. Most of the respondents believed that irrespective of the method of cleaning before steeping, the cleaning process helped prevent unpleasant smell in the kenkey (33%) or removed any dirt in the maize (26%). Producers (45%) agreed that prolonged steeping also results in foul odour development.

2.11.1.2 Hazard Analysis Critical Control Point (HACCP)

HACCP was implemented at a semi-commercial kenkey production plant to manage the hazards, aflatoxins and enteric pathogens, associated with production (Amoa-Awua et al., 2007). The facility was upgraded and GMP was implemented before HACCP. Effectiveness of GMP and HACCP was assessed by monitoring the environment and kenkey production, as well as auditing and verification (Amoa-Awua et al., 2007). Air sampling and swabbing of equipment surfaces revealed microbiota which was consistent with the fermented product. Monitoring showed that raw materials, products processing parameters, conformed to the critical limits within which the safety of the food product would be ensured. This was confirmed by the results of laboratory analysis of raw materials, intermediary and final products.

Escherichia coli, Staphylococcus aureus, Enterococcus, Salmonella, Bacillus cereus, and Vibrio cholera were not detected in any of the finished products and the level of total aflatoxins in the kenkey samples ranged between 17.2 and 14.5μg/kg. Aflatoxins levels in kenkey samples reported at the plant before implementation of GMP and HACCP were between 64.1 and 196μg/kg. Authors concluded that application of GMP and HACCP were effective as a quality management system for assuring the safety of kenkey in the traditional processing of maize into kenkey.
2.12 Physicochemical properties of kenkey

Fadahunsi et al., (2012) investigated physiochemical changes during fermentation of maize using single and combined starter culture to produce kenkey. pH, titratable acidity and nutritional analysis of kenkey were measured. pH decreased throughout 72 h fermentation for treatments. The mixed starter of *L. plantarum* and *C. krusei* recorded the highest decrease. pH decreased from 4.6 at 0 h to 3.8 at 72 h. An inverse relationship with pH was observed for titratable acidity of kenkey. Combined starter of *L. plantarum* and *C. krusei* recorded the highest increase in titratable acidity. Authors observed highest values for moisture, crude protein, crude fat and low carbohydrate contents for kenkey produced using mixed starter of *L. plantarum* and *C. krusei*.

The effect of water uptake during soaking of whole or dry-milled maize, the extent of starch damage, dough pH, fermentation time, and added enzymes on pasting and setback viscosities of aflata dough used for kenkey production was studied (Nche et al., 1996). Soaking of grits at 60 °C with a heat-stable protease, or wet fine-milling of fermented grits resulted in significant (P<0.05) increases in pasting viscosities. Peak viscosities increased with fermentation time up to 24 h. Pasting viscosities decreased with repeated wet milling of fermented dough (Nche et al., 1996).

Dough prepared from both fresh and steep water were not different in pH and titratable acidity. Amylograph pasting characteristics revealed that steeping maize with SO₂ resulted in significantly higher peak and setback viscosities (Amponsah, 2010). Kenkey was prepared on a laboratory scale from a 4:1 mixture of maize (*Zea mays*) and red or white cowpea (*Vigna unguiculata*) and compared with an all-maize product. Parameters
measured were fermentation profile of doughs, colour and fracture profiles. No significant difference existed between fermentation profiles after 4 days' fermentation at 30°C, with final dough pH values reaching 4.07 and 4.08 for all-maize and maize/cowpea mixtures, respectively (Nout et al., 1994).

Cabinet and drum-drying were used to prepare dehydrated kenkey flour and pre-gelatinised aflato. Drum-drying was an effective method for preparing pre-gelatinised aflato, but it resulted in a 34% reduction in the titratable acidity (TA) of fermented dough. Cabinet-drying, had a less drastic effect on the TA of fermented dough, suggesting the possible use of a mixture of drum-dried aflato and uncooked cabinet-dried flour for convenient preparation of kenkey at household level (Nche et al., 1994). Dry-milled maize flours had pasting and set-back viscosities that were inferior to those of the traditionally prepared dough.

A study was carried out to identify the microorganisms responsible for nsiho fermentation and to develop a starter culture for its controlled fermentation in order to improve the safety and quality of nsiho. (Annan, 2014).

Samples for laboratory analysis were obtained from two districts in the Eastern Region. The population of aerobic mesophiles, lactic acid bacteria (LAB) and yeasts were enumerated on Plate Count Agar, de Man Rogosa Sharpe Agar and Oxytetracycline Glucose Yeast Extract Agar respectively. The species of the LAB and yeasts were tentatively identified by phenotypic characterization based mainly on their pattern of carbohydrate assimilation and fermentation. Lactic acid bacterria isolates were screened for rate of acidification, production of exopolysaccharides (EPS), amylase and protease activity as well as antimicrobial activity against some common enteric pathogens using the Agar Well Diffusion Assay. Starter culture was developed through combination of
dominant strain of lactic acid bacteria and yeasts in production trials. Survival of four enteric pathogens \((\text{Salmonella typhimurium}, \text{NCTC 12023}, \text{Staphylococcus aureus}, \text{NCTC 657}, \text{Vibrio cholerae NCTC 11348 and Escherichia coli. NCTC 9001})\) were also studied during steeping enriched with the starter cultures (Annan, 2014).

2.13 Conclusions

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 food processors in the rural areas and increasingly in urban areas as well. Despite the importance of traditional food processing in the food delivery system, several issues relating to the safety of the food and process operations still need to be addressed. Some of the other key issues are that the production processes require a great deal of time and effort. A majority of indigenous cereal based foods are processed using simple technologies, including natural fermentations. Even though it requires a great deal of time, fermentation is employed in producing weaning foods for infants and many dietary staples for adults. The fermented cereal foods are either liquid or stiff gels and popular among them are ‘ogi’, ‘kenkey’, ‘pito’, and ‘kunu-zaki’.

Maize is among the most widely used cereals in Ghana as it is the main ingredient for many indigenous fermented foods. Kenkey is a very popular indigenous Ghanaian fermented maize dough product. Its production serves as an important income commercial activity for the producers who are mainly women with little or no formal education. There are several types of kenkey but the most popular are the Ga and Fante kenkey. Lesser known types are the white (non-sweetened) kenkey (locally called nsiho)
and the sweetened white *kenkey*. Current trends in urbanization, and the increasing popularity of *kenkey* among consumers, require larger scale production. Upgrading production from the artisanal to industrial level entails improvements in process controls to ensure products of consistent quality.

Analyses of some of the critical units of operations of the white *kenkey* process are important to help identify important parameters for modeling and scale up operations for industrial production. Much of the research effort on *kenkey* has focused on the microbiological and physicochemical changes that occur during fermentation and at other stages of processing. Physicochemical, rheological and microbiological information have concentrated largely on *kenkey* produced from whole grain maize (*Ga* and *Fante kenkey*) but not white *kenkey*. Even though it is very popular among its consumers, white *kenkey* (*nsiho*) has remained an “ethnic food”, and its processing is largely restricted to specific ethnic groups. The technological processes for obtaining reproducible quality white *kenkey* that will be acceptable to native and non-native consumers need to be well established. Widening of its international appeal will greatly improve the chances of success for production at the industrial level. To achieve this, critical process factors need to be well understood, and modeled on final product sensory and other quality attributes.
CHAPTER 3

OBJECTIVE 1: To evaluate traditional production, distribution practices and consumption patterns of different types of white kenkey.

3.0 Introduction:

Kenkey is one of the most popular Ghanaian fermented maize foods produced by traditional food processors. The production of kenkey is based on traditional technologies that have been handed down in generations. According to Sefa-Dedeh (1993), even though they employ the same principles and unit operations as those found in modern food technology, their mode of application may be different. Production of kenkey is usually at the small scale artisanal level. 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 (Halm et al., 2004). 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.

The socio-economic importance of kenkey is as a source of livelihood for many families engaged in its production and retailing, and also as an affordable principal meal consumed regularly by a large segment of the population (Halm et al., 2004).

There are two very popular types of kenkey, which include the Ga and Fante-kenkey. These are indigenous to two different ethnic or socio-cultural groups located on the coast line of Ghana: the Ga and Fante. Both types of kenkey have become so popular that they are now eaten throughout Ghana and beyond. Other types of kenkey are also known, but they are less widespread, and are found in communities in which they are traditionally associated with. Among these lesser known kenkey types is white kenkey
produced after the maize grains have been dehulled, and it may be sweetened (by the addition of sugar). Consequently, the two types of white kenkey are the non sweetened (nsiho) and the sweetened (asikyere dokono).

Similar to the Ga- and Fante kenkey types, commercial production of white kenkey and street vending make a sizeable contribution to the rural and urban economy (Tortoe et al., 2008) and provides informal and self-employment opportunities. Unlike the major kenkey types, the production of white kenkey is limited to certain communities, particularly in the Eastern Region and to a lesser extent in the Central Region of Ghana. It is produced at the artisanal level, and varies widely in quality from one producer to the other and even with the same producer. The effect of the various production steps on the quality of kenkey, has however not been addressed (Amponsah, 2010). The aim of this study was to evaluate traditional production, distribution practices and consumption patterns of different types of white kenkey.

3.1 Methodology

A survey of white kenkey (nsiho) processors, retailers and regular consumers was done in the Eastern Region of Ghana, specifically in the following districts: Asuogyaman (Atimpoku, South Senchi, and Anum), Manya Krobo (Kpong, Somanya) and Fanteakwa (Osino). These sites were chosen because white kenkey is predominantly produced in the area. Three different questionnaires were designed to obtain information on the production, retailing and consumption of both non-sweetened white kenkey (nsiho) and sweet kenkey which are produced from dehulled or degemmed maize grains. The first questionnaire was administered to kenkey producers, the second to kenkey retailers or vendors and the third questionnaire to consumers (Appendix 1, 2,3).
questionnaires sought to obtain information on the socio-cultural characteristics of the producers including age group, gender, marital status, educational background, position in household, ethnic group and religion. The questionnaire also gathered information on quantity of maize processed per batch, yield of kenkey, production methods, and source of knowledge, problems encountered, labour intensive operations and assessment of kenkey quality.

For vendors, it sought information on sociocultural characteristics, quantity bought and sold, quality attributes of good kenkey, cost of transportation, unit price of kenkey, packaging materials used for selling, quantity of kenkey sold, daily income and shelf-life of kenkey. The third questionnaire sought to obtain information on the socio-cultural characteristics of consumers together with age group, gender, marital status, ethnic group and religion. The questionnaire also collated information on reasons for consumption, frequency of consumption, type of fish and sauces used in consumption, time of the day for consumption, places of consumption and attributes of good quality kenkey.

3.2 Pretesting of Questionnaires

The questionnaires were pre-tested with twenty (20) producers, twenty-one (21) vendors and twenty-eight (28) consumers. Pre-testing was done at the Madina market, Atimpoku, South Senchi and Tema station, Accra. Based on the responses obtained, the questionnaires were modified to make it suitable as a research tool for gathering the relevant data.
3.3 Sample size

The total sample size of the respondents to be interviewed for the whole geographical region was calculated using

\[ N_i = 4X p_i(1-p_i)/d^2 \]

Ni being the total number of respondents to be surveyed for the study (Chadare et al, 2008).

\[ P_i = n_p/N_t \]; the proportion \( n_p \) of the product producer, vendors and consumer among the \( N_t \) randomly interviewed and \( d \) the expected error margin fixed at 0.05. Dagnelie (1998).

A statistical power of 80% was achieved based on the equation and its parameters used in the sample size calculation.

3.4 Survey Area

The study sites were located in the Eastern Region of Ghana, specifically in the three districts listed in Table 3.1. The choice of study locations was informed because white kenkey is predominantly produced in that region (Table 3.1). A total number of eighty-two (82) producers, seventy-one (71) vendors and one hundred and thirty-five (135) consumers were interviewed. The number of questionnaires administered at each site as detailed in Table 3.1 was proportional to the population of the community.
Table 3.1: Study towns and districts in the Eastern Region

<table>
<thead>
<tr>
<th>Eastern Region</th>
<th>Producers</th>
<th>Vendors</th>
<th>Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asuogyaman district</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Towns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Senchi</td>
<td>24</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Atimpoku</td>
<td>10</td>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td>Anum</td>
<td>21</td>
<td>18</td>
<td>38</td>
</tr>
<tr>
<td><strong>Manya Krobo district</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Towns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Somanya</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Kpong</td>
<td>4</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td><strong>Fanteakwa district</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Towns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osino</td>
<td>20</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>82</strong></td>
<td><strong>71</strong></td>
<td><strong>135</strong></td>
</tr>
</tbody>
</table>

Producers were interviewed at their production sites whereas consumers and vendors were selected randomly on the streets and market places. Each respondent was given information and consent form to sign to seek their approval before administering the questionnaire. The interviews were conducted in English and the local dialect depending on the respondent’s preference. Answers were translated and recorded in the English language.

The map of Ghana indicating the study districts is shown in figure 3.1.
3.5 Statistical analyses of survey data

Completed questionnaires were coded into the Statistical Package for Social Scientists (SPSS) for windows, version 16.0. Frequencies and percentages of both sociocultural and the actual questions were analyzed and charts developed. Frequencies were generated for variables and significant associations were tested at $p \leq 0.05$.

3.6 Results and Discussion

3.6.1 Demographics and socio-cultural characteristics of Producers

All the white *kenkey* producers were females and they were generally elderly, with nearly 60% of them over 40 years old (Figure 3.2). This was rather surprising since *kenkey* production is considered to be a labour intensive operation (Halm *et al.*, 2004).
Figure 3.2: Age group of producers of white kenkey

White kenkey production is dominated by processors who learned the trade from their ancestors. About three quarters of the producers had learnt kenkey production within the family, whilst 11% had learned it through training or apprenticeship (Figure 3.3). This suggests that as the female children grew up in the household, they offered inexpensive labour and in the process learnt and engaged in the white kenkey business at the expense of formal education.
Consequently, the majority of *kenkey* producers had little or no formal education and the few most educated ones had only up to senior High school education. Indeed, while about half of the producers had either completed the primary or junior high school, 27% had no formal education and only 4.9% had attended senior High School. Halm *et al.*, (2004) observed similar characteristics among traditional foods processors in Ghana. They reported that traditional food processing was mainly done by women with little or no education, who learnt their trade as a family acquired art and carried out their processing activities in home-based operations. Work done by other workers have also reported that *kenkey* production is predominantly family based vocations undertaken by women with little or no education (Akom-Quayson 1992, Halm *et al* 2004, Amponsah 2010 and Dzigbor 2012).
Table 3.2 Districts and towns in Eastern Region in which producers were interviewed

<table>
<thead>
<tr>
<th>Districts</th>
<th>Number</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asuogyaman</td>
<td>55</td>
<td>67.1</td>
</tr>
<tr>
<td>South Senchi</td>
<td>26</td>
<td>31.7</td>
</tr>
<tr>
<td>Atimpoku</td>
<td>8</td>
<td>9.8</td>
</tr>
<tr>
<td>Anum</td>
<td>21</td>
<td>25.6</td>
</tr>
<tr>
<td><strong>Manya Krobo</strong></td>
<td><strong>7</strong></td>
<td><strong>8.5</strong></td>
</tr>
<tr>
<td>Kpong</td>
<td>4</td>
<td>4.9</td>
</tr>
<tr>
<td>Somanya</td>
<td>3</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Fanteakwa</strong></td>
<td><strong>20</strong></td>
<td><strong>24.4</strong></td>
</tr>
<tr>
<td>Osino</td>
<td>20</td>
<td>24.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

3.6.2 Ethnic backgrounds and marital status of white kenkey producers

Unlike Ga and Fante-kenkey, which are the very popular types of kenkey, the enterprise of white kenkey (nsiho) processing has remained as “ethnic food”, and is closely associated with specific ethnic groups. Tables 3.3a-c, show the socio-cultural characteristics of white kenkey producers.

Table 3.3a Ethnic groupings and educational level of white kenkey producers

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ewe</td>
<td>38</td>
<td>37.8</td>
</tr>
<tr>
<td>Twi</td>
<td>23</td>
<td>26.8</td>
</tr>
<tr>
<td>Krobo</td>
<td>6</td>
<td>8.5</td>
</tr>
<tr>
<td>Others</td>
<td>23</td>
<td>26.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educational level</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>22</td>
<td>26.8</td>
</tr>
</tbody>
</table>
Non-formal 10 12.2
Primary 22 26.8
Middle 4 4.9
JHS 22 26.8
SHS 4 4.9
Total 100

Table 3.3b: Marital status of white kenkey producers

<table>
<thead>
<tr>
<th>Marital status</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>13</td>
<td>29.3</td>
</tr>
<tr>
<td>Married</td>
<td>42</td>
<td>58.5</td>
</tr>
<tr>
<td>Divorced</td>
<td>6</td>
<td>7.3</td>
</tr>
<tr>
<td>Widowed</td>
<td>4</td>
<td>4.9</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.3c Role and persons in household and religion of white kenkey producers

<table>
<thead>
<tr>
<th>Role in Household</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>35</td>
<td>61</td>
</tr>
<tr>
<td>Dependent</td>
<td>30</td>
<td>39</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Persons in Household</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤3</td>
<td>2</td>
<td>13.4</td>
</tr>
<tr>
<td>3.5</td>
<td>18</td>
<td>23.2</td>
</tr>
<tr>
<td>6.9</td>
<td>28</td>
<td>41.5</td>
</tr>
<tr>
<td>10-13</td>
<td>11</td>
<td>14.6</td>
</tr>
<tr>
<td>&gt;14</td>
<td>6</td>
<td>7.3</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>100</td>
</tr>
</tbody>
</table>

Over one-third of white kenkey producers were of the Ewe ethnic group. This was probably because that part of Eastern region where the survey was carried out share a
border with the Volta Region, the home region of the Ewe ethnic group. The next dominant socio-cultural group was Twi and about 27% of the producers interviewed belonged to other ethnic groups. Over half of the producers were married, less than a third, (29.3%) were single, 7.3% divorced and about 5% widowed. Most producers seemed to belong to large households. More than 40% of them had 6-9 persons as average household size. About 60% of the producers were the head of their households. The great majority of the respondents (90%) were Christians whilst 8.5% practiced the traditional religion.

3.6.3 Types of white kenkey

Two types of white kenkey were encountered during the survey; nshio (non-sweetened) and the sweetened kenkey (asekyere dokono). Both are whitish in colour, and the main difference between the two is that sugar is added to the sweet kenkey during production. The packaging material for both types of white kenkey is also different. While the sweetened white kenkey is packaged in awurom (M. cuspidata) leaves, the packaging material for nsiho is maize husk. Different production sites showed different interests and emphasis on the different types of white kenkey. Processors in the Asuogyaman district produced mainly the nsiho type of kenkey whilst sweet kenkey is produced in the Fanteakwa district. Non-sweetened white kenkey (nsiho) producers either fermented or did not ferment the meal obtained from milling the steeped grains. Producers of white kenkey (nsiho) at Anum (Asuogyaman district) indicated that they fermented dehulled maize dough for about 12 hours.
3.6.4 White kenkey producers’ motivations

The producers had various reasons for engaging in the commercial activity of white kenkey (nsiho). From the list of reasons for their motivation in Table 3.4, the main reasons may be deduced to include (a) that it was a family business, hence they had grown up into it, (b) that they engaged in it in order to earn a living (c) that it was a profitable business and hence had learnt the trade.

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>24</td>
<td>29.3</td>
</tr>
<tr>
<td>Family trade</td>
<td>20</td>
<td>24.4</td>
</tr>
<tr>
<td>Profitability</td>
<td>19</td>
<td>23.2</td>
</tr>
<tr>
<td>Profitable plus employment</td>
<td>10</td>
<td>12.2</td>
</tr>
<tr>
<td>Family trade/profitable/employment</td>
<td>6</td>
<td>7.3</td>
</tr>
<tr>
<td>Family trade plus employment</td>
<td>3</td>
<td>3.7</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>100.0</td>
</tr>
</tbody>
</table>

These reasons reflect both their demographic profiles (Table 3.3a-c) and socio-cultural backgrounds. Most of the producers had none or very little formal education, were generally elderly with large family sizes, and in many cases (60%) were heads of household. Consequently, enterprises such as production and vending of white kenkey that brought “quick income” were worth undertaking to support their families.

3.6.5 Size of operations

White kenkey productions were generally small operations based in households, and entailed small quantities at a time since production equipment were simple traditional tools. Figure 3.4 shows the quantity of maize processed into white kenkey.
3.4 Quantity of maize processed weekly into white *kenkey*

A good majority of producers (54%) processed only 10-50 kg of maize into white *kenkey* weekly, and just under a third (28%) of producers processed up to 50-100 kg of maize per week into product. Maize dough obtained after milling of soaked dehulled maize is the base raw material for white *kenkey* (sweetened or non-sweetened). Regardless of the size of operation, all the maize dough may be used up per batch of process. One third of producers used the dough in less than a day (Table 3.5).

<table>
<thead>
<tr>
<th>Days</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>31.7</td>
</tr>
<tr>
<td>3-4 days</td>
<td>1.2</td>
</tr>
<tr>
<td>5-7 days</td>
<td>11.0</td>
</tr>
<tr>
<td>&gt;7 days</td>
<td>4.9</td>
</tr>
<tr>
<td>Other</td>
<td>51.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Table 3.5 Estimated days dehulled maize dough is used to produce *kenkey*.
Because white *kenkey* production is largely done on small scale, the frequency of production by some processors is high. The weekly production of *kenkey* by respondents is shown in figure 3.5. More than half of producers processed 1-3 times per week, while twenty (20%) produced 7-10 times weekly (figure 3.5).

![Figure 3.5: Weekly production of white kenkey](image)

3.6.6 Production of white *kenkey*

The main raw material for white *kenkey* production is the whole maize, maize husk and table salt (for non-sweetened white *kenkey*) and *awurom* leaves and sugar for sweet *kenkey*. All these materials are purchased locally. The process flow chart for white *kenkey* is shown in Figure 3.6. Processing involves winnowing and sorting of the maize to remove dust, chaff and stones. The cleaned maize is dehulled in an Engelberg mill (similar to a rice mill) and steeped in water for 48 hours. After steeping, the grains are washed and milled using a disc attrition mill into a smooth meal. Two different procedures were observed for further processing after production of the smooth meal and this depended on the
Fig 3.6 Flow diagram for the production of White Kenkey (Nsiho) and sweet white kenkey
Source: Survey data
locality. At Atimpoku and South Senchi all the milled meal is pre-cooked for about 30-60 minutes into a thick gelatinous paste \((aflata)\). The stiff porridge \((aflata)\) is moulded into balls and wrapped in clean maize husks. The balls are packed into a pot containing small amount of water lined with sticks and maize husk and steamed for 1-2 h.

In another processing procedure which was observed at Anum, the milled meal is kneaded into stiff dough and fermented spontaneously for 12 hours. After fermentation, a two-third portion of the dough is pre-cooked for about 30-60 minutes into stiff porridge \((ohu)\). The hot \(ohu\) is mixed with the remaining one-third uncooked dough as done for Ga and Fante kenkey (Halm et al., 2004). The mixture formed is moulded into balls and wrapped in clean maize husks. The balls are packed into a perforated pan and placed over a pot of boiling water and steamed for 1 to 2 hours. In the case of the sweet white kenkey, the meal obtained is divided into two; a portion is precooked for 20 mins into \(aflata\). The uncooked dough is reconstituted into slurry and mixed with the stiff porridge \((aflata)\). Sugar is then added. The paste obtained is packaged into aworum leaves \((M.cuspidata)\) and steamed for an hour.
3.6.7. Challenges in process operations of white kenkey

The operations in the white kenkey process are largely manual, and require a great deal of human labour. Consequently, the size of the operations are limited, and within the capability of human labour. The labour intensive unit operations during white kenkey production as identified by the processors are listed in Table 3.6. Most respondents (~28%) considered Aflata preparation as labour intensive. Only 5% considered making slurry for cooking aflata a labour intensive process.

Table 3.6: Labour intensive unit operations during kenkey production

<table>
<thead>
<tr>
<th>Operations</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making of slurry for cooking into aflata</td>
<td>5.1</td>
</tr>
<tr>
<td>Aflata preparation</td>
<td>27.9</td>
</tr>
<tr>
<td>Mixing of Aflata with fresh dough</td>
<td>21.0</td>
</tr>
<tr>
<td>Molding of kenkey</td>
<td>25.6</td>
</tr>
<tr>
<td>Mixing of Aflata with fresh dough +</td>
<td>8.9</td>
</tr>
<tr>
<td>Molding of kenkey</td>
<td></td>
</tr>
<tr>
<td>Aflata preparation + molding of kenkey</td>
<td>11.5</td>
</tr>
</tbody>
</table>

3.6.8 Production practices that affect white kenkey quality

Problems encountered in white kenkey production and solutions proposed by producers are illustrated in Table 3.7.
Table 3.7. Problems encountered in *kenkey* production and solutions proposed by producers

<table>
<thead>
<tr>
<th>Intermediate and final products</th>
<th>Quality assessment of product</th>
<th>Problems encountered with quality</th>
<th>Proposed solution by producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steeped maize</td>
<td>Softness and swelling of grains</td>
<td>Bad odour of maize grains; Meal after milling not smooth</td>
<td>Use sorted grains, clean water; do not put hand in steep water during steeping</td>
</tr>
<tr>
<td>Fermented maize dough</td>
<td>Colour, odour, taste, texture, swelling of dough</td>
<td>Bad odour, dough too sour</td>
<td>Ferment dough for less than a day</td>
</tr>
<tr>
<td>Pre-cooked dough (<em>aflata</em>)</td>
<td>Aroma, colour and textural changes</td>
<td>Poor consistency, too soft, lumps in <em>aflata</em></td>
<td>Good consistency and lump-free <em>aflata</em>, <em>aflata</em> well cooked.</td>
</tr>
<tr>
<td><em>Kenkey</em></td>
<td>Aroma, texture, taste, softness and crumbly <em>kenkey</em></td>
<td>Bad odour, hard texture of <em>kenkey</em>, rough and lumps in <em>kenkey</em></td>
<td>Use only well cleaned maize; do not ferment dough for more than 1 day. Use well-cooked <em>aflata</em>. Mix <em>aflata</em> and fresh dough well.</td>
</tr>
</tbody>
</table>

White *kenkey* producers indicated that *kenkey* would smell and or become discoloured as a result of the following practices were done: use of contaminated maize, dipping hands into maize steeped in water, improper washing of utensils for steeping maize, inadequate pre-cooking of dough or stiff porridge (*aflata*), and inadequate mixing of pre-cooked dough (*aflata*) with uncooked dough. Amponsah (2010) also observed that mixing of the *aflata* with the uncooked dough was one of the causes of variability in *kenkey* quality even between production batches for the same processor. They also attributed the use of over fermented dough, contaminated water, and dirty maize husk to the development of foul smelling *kenkey*. It was observed that producers used sensory attributes like colour, odour, taste, texture through experience to assess quality *kenkey* and intermediates (Table 3.7).
3.6.9. Shelf-life of white kenkey

As a high moisture and fermented product, white kenkey may not keep for long, even though it is expected to keep longer than moist, non-fermented products. Producers’ evaluation of the shelf-life of kenkey is shown in Figure 3.7. Half of the producers acknowledged that the product has a shelf life of 4-6 days, while forty-eight percent (48%) of producers indicated that it does not keep beyond 1-3 days. Producers indicated mouldiness and over fermented odour as the determinants for spoilage. They however stressed that if the kenkey was kept in the refrigerator, the shelf-life of the kenkey was extended.

![Figure 3.7: Producers assessment of shelf-life of white kenkey](image)

3.6.10 Handling of left-over white kenkey

As a result of a weak cold chain, and excess white kenkey is handled differently by different processors in order to extend shelf life. Figure 3.8 shows some of the post retail handling practices of unsold kenkey. While only about 10% are able to sell the entire batch in a day, the majority of producers (about 49%) reheated the left-over kenkey and sold it as a fresh batch. A very small percentage of producers (1%) mash
the left over *kenkey*, and add it to stiff porridge (*aflata*) in the production of a fresh batch of *kenkey*. Other producers (24%) simply keep it and continue sales the next day.

![Figure 3.8 Methods for dealing with unsold white *kenkey* by producers](image)

**Figure 3.8 Methods for dealing with unsold white *kenkey* by producers**

### 3.7 Survey of white *kenkey* vendors

#### 3.7.1 Demographic characteristics

The respondents who were engaged in selling *kenkey* were within the age groups of below 20 year to over 50 years (Table 3.8).

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Vendors interviewed</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>4</td>
<td>4.2</td>
</tr>
<tr>
<td>20-29</td>
<td>14</td>
<td>19.7</td>
</tr>
<tr>
<td>30-39</td>
<td>20</td>
<td>28.2</td>
</tr>
<tr>
<td>40-49</td>
<td>20</td>
<td>28.2</td>
</tr>
<tr>
<td>&gt;50</td>
<td>13</td>
<td>19.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>71</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ethnic groups</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twi</td>
<td>36.60</td>
</tr>
<tr>
<td>Ewe</td>
<td>29.60</td>
</tr>
<tr>
<td>Krobo</td>
<td>7</td>
</tr>
<tr>
<td>Ga</td>
<td>7</td>
</tr>
</tbody>
</table>
Vending of white *kenkey* was dominated by relatively older women with nearly 50% of them above 40 years and only about 4.2% of respondents were below 20 years of age. A study by Tomlins and Johnson (2004) also showed that women constituted the majority of vendors. In a similar study Mwangi (2005), reported that about 81% of street food vendors were women. Though the highest proportion, 37.8% of the producers belonged to the Ewe ethnic group, the highest proportion of vendors (36.6%) belonged to the Twi ethnic group (Table 3.8). Most of the producers were vendors as well, and white *kenkey* was the primary item they sold. They also sold fried fish as a secondary item, since consumers eat white *kenkey* with fried fish.

Generally, the vendors had minimal formal education with majority (41%) being educated only to JHS level. As many as 20% had no formal education, while 23% were educated only to primary school level. Regardless, most of them were able to communicate to an extent in English (Figure 3.8).
Vending of white *kenkey* seemed to be a lucrative trade among the people since they depended on it to support large families. The average size of the household of vendors was 3-9 persons (39.4%). Only a small fraction (1.4%) had more than fourteen persons in their household. Majority of vendors (62%) were heads of households (Table 3.8).

### 3.7.2 Types of white *kenkey* sold.

Most vendors of white *kenkey* sold both the sweetened and non-sweetened types. As observed before, the vending of white *kenkey* was more associated with older women. White *kenkey* (*nsiho*) vendors (18.3%) were in 20-29 and 40-49 age groups. Sweet *kenkey* vendors were even more associated with the older vendors (30-50) group (Figure 3.10).
3.7.3 Ethnic backgrounds of kenkey vendors.

The ethnic groups of the types of white kenkey vendors are shown in Table 3.9. As many as twenty-eight (28) white kenkey vendors and twenty (20) sweet kenkey were associated with the Twi ethnic group, while only two were from the Fante ethnic group. Of all the ethnic groups, it was only the Twi group that sold both the sweetened and non-sweetened white kenkey.

Table 3.9 Ethnic group of types of white kenkey vendors

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>White kenkey (Nsího)</th>
<th>Sweet kenkey</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twi</td>
<td>28</td>
<td>20</td>
<td>48</td>
</tr>
<tr>
<td>Ewe</td>
<td>13</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Ga</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Fante</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Guan</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>51</strong></td>
<td><strong>20</strong></td>
<td><strong>71</strong></td>
</tr>
</tbody>
</table>

3.7.4 Perceptions of quality by vendors

The quality attributes of kenkey that vendors look out for are shown in Figure 3.11. Product crumbliness is a priority quality attribute for white kenkey (nsího) and sweet
kenkey vendors. Of all the attributes, product aroma and appearance were the least appreciated for both white kenkey (nsiho) and sweet kenkey (Figure 3.11).

![Figure 3.11: Quality attributes of different category of white kenkey vendors](image)

3.7.5 Patronage of white kenkey

Vendors’ indications of customers’ patronage of types of white kenkey are given in Table 3.10. The low and middle income group of consumers patronised both types of white kenkey (39.4%), even though the non-sweetened type was more popular with them. The high income group did not seem to patronise white kenkey much, and there was no obvious preference between the sweetened and non-sweetened types.

<table>
<thead>
<tr>
<th></th>
<th>Lower group</th>
<th>Middle group</th>
<th>High group</th>
</tr>
</thead>
<tbody>
<tr>
<td>White kenkey (Nsiho)</td>
<td>16</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Sweet kenkey</td>
<td>6</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td><strong>22</strong></td>
<td><strong>40</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>
3.7.6 Secondary packaging materials

White *kenkey* is usually molded and wrapped in dried maize husk and *awurum* leaves as primary package. After steaming, it is immediately packaged in polythene bag to prevent dehydration, slow down rate of heat loss and facilitate transportation to vending sites.

3.7.7 Transportation costs

The enterprise of producing and vending white *kenkey* is largely run by women who are of very modest circumstances. Just as they employ simple traditional equipment in the manufacture of *kenkey*, they do not have their own means of transportation of raw materials, or finished products to the points of sale. Consequently, they rely on commercial transport services, and depending on the size of operations, the costs incurred in transportation of the produce vary among the producers and vendors. The assessment of cost incurred by vendors in transporting *kenkey* to vending site is shown in Table 3.11.

| Table 3.11: Cost of transporting types of white *kenkey* to vending location |
|---------------------------------------------------|----------------|----------------|---------|----------|--------|
| White *kenkey* (*Nsio*)                          | GH¢2-4 | 4 | 5 | 20 | 51     |
| Sweet *kenkey*                                   | 5      | 1 | 0 | 14 | 20     |
| Total                                            | 30     | 5 | 2 | 34 | 71     |

White *kenkey* (*nsiho*) vendors (35%) used GH¢ 2-4 on transportation of produce to vending sites per batch. Only two (2%) paid more than GH¢ 5 (Table 3.11). The majority of sweet *kenkey* vendors did not incur transportation costs because they handled relatively small quantities of product that is easily conveyed on the head as they walk to the vending sites. They were in the other category.
3.7.8 White kenkey sales

The selling price of white kenkey varied among processors, probably because of variation in sizes. The unit price of average sized non-sweetened white kenkey ranged from GHC 0.20 to GHC 0.50. (Figure 3.12). However, majority of vendors confirmed selling it for GHC 0.30. The sweetened white kenkey was generally sold at higher costs of GH¢1.00.

![Figure 3.12: Cost of different types of white kenkey](image)

Most of vendors sold between 50-100 balls of nsiho kenkey, while a smaller number of vendors sold above 170 balls daily (Table 3.12). Sweet kenkey vendors sold between 100-170 balls daily.
Table 3.12 Daily sale of white kenkey by vendors

<table>
<thead>
<tr>
<th>Type of kenkey</th>
<th>50-100 balls</th>
<th>110-160 balls</th>
<th>Above 170 balls</th>
</tr>
</thead>
<tbody>
<tr>
<td>White kenkey (Nsiho)</td>
<td>29</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Sweet kenkey</td>
<td>15</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
<td><strong>16</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

The breakdown of income generated by white kenkey vendors is shown in Table 3.13.

Most white kenkey vendors generated GH¢20-40 daily. Some vendors however generated above GH¢100 for both white kenkey (nsiho) and sweet kenkey.

Table 3.13 Daily income generated by white kenkey vendors

<table>
<thead>
<tr>
<th>Type of kenkey</th>
<th>GH¢20-40</th>
<th>GH¢50-100</th>
<th>&gt;GH¢100</th>
<th>other</th>
</tr>
</thead>
<tbody>
<tr>
<td>White kenkey (nsiho)</td>
<td>36</td>
<td>6</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Sweet kenkey</td>
<td>12</td>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>48</strong></td>
<td><strong>13</strong></td>
<td><strong>3</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

3.7.9 Shelf-life of white kenkey from vendors’ perspective

The shelf life of sweet and non-sweetened white kenkey was different, from the vendors’ experience (Figure 3.13). The white non-sweetened kenkey generally had longer shelf stability than the sweetened white kenkey. Majority of the vendors indicated that white kenkey would keep for 3-5 days, while sweet kenkey would not keep longer than 2 days.
3.8. Survey of consumers of white *kenkey*

3.8.1 Demographics of consumers

Consumers of non-sweetened and sweetened white *kenkey* were interviewed in the three districts of Asuogyaman, Manya Krobo and Fanteakwa (Table 3.14).

Table 3.14 Breakdown of consumers in districts and towns of the Eastern region

<table>
<thead>
<tr>
<th>Districts</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asuogyaman</td>
<td>85</td>
<td>63.0</td>
</tr>
<tr>
<td>South Senchi</td>
<td>15</td>
<td>11.1</td>
</tr>
<tr>
<td>Atimpoku</td>
<td>32</td>
<td>23.7</td>
</tr>
<tr>
<td>Anum</td>
<td>38</td>
<td>28.1</td>
</tr>
<tr>
<td>Manya Krobo</td>
<td>15</td>
<td>11.1</td>
</tr>
<tr>
<td>Somanya</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Kpong</td>
<td>13</td>
<td>9.6</td>
</tr>
<tr>
<td>Fantekwa</td>
<td>35</td>
<td>25.9</td>
</tr>
<tr>
<td>Osino</td>
<td>35</td>
<td>25.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>135</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
The consumers in the first two districts were mainly for the non-sweetened white kenkey whiles those from the Fanteakwa district were for the sweetened white kenkey. This was because Osino in the Fanteakwa District was the only community where sweetened white kenkey was produced.

3.8.2 Socio-cultural characteristics of white kenkey consumers

One hundred and thirty-five (135) consumers made up of sixty (60) males and seventy-five (75) females took part in the survey (Table 3.15a).

Table 3.15a Demographic and sociocultural characteristics of white kenkey (nsiho) consumers (n=135)

<table>
<thead>
<tr>
<th>Demographic variable</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>44.4</td>
</tr>
<tr>
<td>Female</td>
<td>55.6</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
<tr>
<td>Marital status</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>Married</td>
<td>44.40</td>
</tr>
<tr>
<td>Single</td>
<td>53.30</td>
</tr>
<tr>
<td>Divorced</td>
<td>1.50</td>
</tr>
<tr>
<td>Widowed</td>
<td>0.70</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
<tr>
<td>Ethnic group</td>
<td></td>
</tr>
<tr>
<td>Ewe</td>
<td>32.6</td>
</tr>
<tr>
<td>Twi</td>
<td>44.4</td>
</tr>
<tr>
<td>Krobo</td>
<td>9.6</td>
</tr>
<tr>
<td>Ga</td>
<td>2.2</td>
</tr>
<tr>
<td>Fante</td>
<td>1.5</td>
</tr>
<tr>
<td>Others</td>
<td>9.6</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
<tr>
<td>Age range</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>&lt;20</td>
<td>13.3</td>
</tr>
<tr>
<td>20-29</td>
<td>31.9</td>
</tr>
<tr>
<td>30-39</td>
<td>17.8</td>
</tr>
<tr>
<td>40-49</td>
<td>19.3</td>
</tr>
<tr>
<td>&gt;50</td>
<td>17.8</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
<tr>
<td>Educational level</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Nil</td>
<td>8.1</td>
</tr>
<tr>
<td>Non-formal</td>
<td>3.7</td>
</tr>
<tr>
<td>Primary</td>
<td>13.3</td>
</tr>
<tr>
<td>Middle</td>
<td>11.9</td>
</tr>
<tr>
<td>JHS</td>
<td>31.1</td>
</tr>
<tr>
<td>Secondary</td>
<td>11.1</td>
</tr>
<tr>
<td>SHS</td>
<td>14.1</td>
</tr>
<tr>
<td>Tertiary</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Female consumers dominated for non-sweetened and sweetened white *kenkey*. The gender distribution of 44.4% males and 55.6% females reflects the male to female ratio of Ghana population according to the last population census (www.ghanadistricts.com/regions, 2006). The gender disparity in the purchase of white *kenkey* could be attributed to the fact that females cater and plan menu for the home. This is in contrast to results by Umoh and Odoba, (1999), who found that majority of street foods consumers in West Africa were male. White *kenkey* (sweetened or non-sweetened) is a convenient food and is widely patronized by singles (particularly females). The reason for this could be attributed to the ready to eat nature and affordability of white *kenkey*.

Ewe consumers preferred non-sweetened white *kenkey* (*nsiho*) whereas Twi speaking consumers prefered sweetened white *kenkey*. This was because white *kenkey* (*nsiho*) is produced in Eastern region of Ghana which bordered the Volta region, where there are a lot of Ewe inhabitants who like the *kenkey*. The consumers interviewed were mainly young and about a third were in 20-29 age groups (Table 3.15a). This was because this age group are dominantly single and they find purchasing *kenkey* very convenient. Mensah *et al.*, (2002), established that consumers of street foods like *kenkey* included people who had acquired various educational levels.
In this study, consumers with Junior High School (JHS) level of education formed a third of consumers. Two fifth of consumers had an average household size of 6-9. Half each of consumers were dependent and head of households (Table 3.15b).

Table 3.15b Consumers’ household size and role in household

<table>
<thead>
<tr>
<th>Household size</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;3</td>
<td>8.1</td>
</tr>
<tr>
<td>3-5</td>
<td>38.5</td>
</tr>
<tr>
<td>6-9</td>
<td>40</td>
</tr>
<tr>
<td>10-13</td>
<td>9.6</td>
</tr>
<tr>
<td>&gt;14</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Role in Household</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>49.6</td>
</tr>
<tr>
<td>Dependent</td>
<td>50.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

3.8.3 Reasons for white kenkey consumption.

Majority of consumers (45.90%) favour white kenkey because of its convenience (ready-to-eat) (Figure 3.14).
Figure 3.14: Reasons for white kenkey consumption

Only a fraction patronized white kenkey because it was perceived to be inexpensive. Non-sweetened white kenkey is a convenient ready to eat food, and it is usually eaten with or without sauce. Most consumers eat sweetened white kenkey without an accompaniment and others eat it with roasted peanuts.

3.8.4 Modes of consumption of white kenkey

The consumption modes of the sweetened and non-sweetened white kenkey were different (Table 3.16).

Table 3.16: Types of kenkey consumed, type of fish and methods of preparation and sauces used

<table>
<thead>
<tr>
<th>Type of kenkey bought</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White kenkey (Nsiho)</td>
<td>74.1</td>
</tr>
<tr>
<td>Sweet kenkey</td>
<td>25.9</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of fish</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrimps</td>
<td>2.2</td>
</tr>
<tr>
<td>Small Tilapia</td>
<td>54.8</td>
</tr>
<tr>
<td>Small herrings</td>
<td>6.7</td>
</tr>
<tr>
<td>Red fish</td>
<td>2.2</td>
</tr>
<tr>
<td>Others</td>
<td>17.8</td>
</tr>
<tr>
<td>Not applicable</td>
<td>16.3</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

**Preparation of fish**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fried</td>
<td>77.0</td>
</tr>
<tr>
<td>Grilled</td>
<td>3.7</td>
</tr>
<tr>
<td>others</td>
<td>.7</td>
</tr>
<tr>
<td>not applicable</td>
<td>18.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

**Type of sauce**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh pepper</td>
<td>65.9</td>
</tr>
<tr>
<td>Black pepper</td>
<td>6.7</td>
</tr>
<tr>
<td>Tomato sauce</td>
<td>3.7</td>
</tr>
<tr>
<td>okro</td>
<td>.7</td>
</tr>
<tr>
<td>Soup</td>
<td>3.7</td>
</tr>
<tr>
<td>Others</td>
<td>19.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

About three-fourth of the total number of respondents indicated that they consumed white *kenkey* (non-sweetened), whereas 25.9% consumed sweetened white *kenkey*. This was probably because the survey for white *kenkey* (*nshio*) was conducted in five towns in two districts whereas for the sweet white *kenkey*, only one town in the only one district (Fanteakwa) best known in all of Ghana for sweet white *kenkey* was considered.

More than half of the number of consumers indicated that they eat white *kenkey* with small tilapia (*Oreochromis niloticus*), but very few (2.2%) also eat it with red fish (*Sebastes Marinus*). Consumers mostly eat sweet white *kenkey* alone or with roasted peanuts. Those who ate white *kenkey* with fish, most of them (more than two-thirds of consumers) indicated that they preferred the fish fried than grilled or other methods of processing (Table 3.16). Alongside with fried fish, many respondents (66%) eat non-sweetened white *kenkey* with fresh pepper sauce, just as for Ga- *kenkey* as observed by
Halm et al. (2004). The pepper sauce is usually a blend of onions, tomatoes, pepper, and salt, which is freshly prepared and a hot pepper sauce (*shito*) is included.

### 3.8.5 Consumption patterns of white *kenkey*

Consumers of white *kenkey* generally eat it on very regular basis. Two fifth of the number of respondents indicated that they consumed white *kenkey* 2-3 days in a week (Table 3.17).

<table>
<thead>
<tr>
<th>Consumption rates</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;7</td>
<td>8.9</td>
</tr>
<tr>
<td>6-7</td>
<td>8.1</td>
</tr>
<tr>
<td>4-5</td>
<td>20.0</td>
</tr>
<tr>
<td>2-3</td>
<td>38.5</td>
</tr>
<tr>
<td>once</td>
<td>20.0</td>
</tr>
<tr>
<td>rarely</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

The results also indicated that one fifth of the total number of respondents consumed white *kenkey* 4-5 times a week.

Consumers of white *kenkey* frequently consume it as a breakfast or lunch item, and seldom for dinner. Fifty-three (53%) respondents consumed *kenkey* for lunch whilst (44%) ate *kenkey* as breakfast (Figure 3.15).
Survey results revealed that as much as 64.4% consumers buy white *kenkey* from hawkers. Consumers who buy white *kenkey* from street vendors place and other sources constituted 17.8% (Table 3.18).

<table>
<thead>
<tr>
<th>Places bought</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawker</td>
<td>64.4</td>
</tr>
<tr>
<td>Street vendor</td>
<td>17.8</td>
</tr>
<tr>
<td>Others</td>
<td>17.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Places eaten</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>At home</td>
<td>74.1</td>
</tr>
<tr>
<td>Street vendors place</td>
<td>14.1</td>
</tr>
<tr>
<td>Others</td>
<td>11.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

This is in line with what was observed by Halm *et al.*, (2004) that the lengthy and laborious process of making *kenkey* leads to most consumers purchasing *kenkey* from a commercial *kenkey* producer rather than cooking it at home. The survey results indicated that most consumers bought both types of *kenkey* from hawkers and consumed in their homes. More than half of consumers eat *kenkey* at home. Only a small fraction of 11.9% eat the *kenkey* from other sources (Table 3.18).
### 3.8.6 Quality attributes desired by white kenkey consumers

The quality characteristics of white kenkey are very important to consumers. In increasing order of priority, consumers of non-sweetened white kenkey indicated their important quality preferences as crumbliness, taste and softness of product. On the other hand, sweetened white kenkey consumers preferred softness and taste. The attribute of taste is important in sweet kenkey because of the sweetness impacted as a result of sugar addition. Consumers (36%) like white kenkey because of its taste (Figure 3.16). Only a small fraction of consumers (7.40%) looked out for appearance and other characteristics in good quality white kenkey.

![Preferred quality characteristics of white kenkey](image)

**Figure 3.16: Preferred quality characteristics of white kenkey**

Quality attributes of white kenkey as assessed by consumers (Figure 3.17). As much as twenty-four (24%) consumers indicated softness as best quality attribute for non-sweetened white kenkey.
In order of preference for quality attribute of non-sweetened white *kenkey*, consumers indicated softness > crumbliness > taste > appearance. The consumers pointed out that taste was the best quality attribute they looked for in sweetened white *kenkey*. Consumers denoted taste > crumbliness > softness as the order of quality attributes preferred for sweetened white *kenkey*.

### 3.9 Conclusion

The two main types of white *kenkey* are the non-sweetened and sweetened types. The base raw material for white *kenkey* (non-sweetened or sweetened) is maize dough obtained after milling of soaked dehulled maize. Depending on the location, the process of white *kenkey* may or may not include a further fermentation step. The process of white *kenkey* -making is lengthy and laborious, and consequently it is more often purchased from a commercial *kenkey* producer or vendor and consumed at home. The producers are generally older women with little or no formal education, and they usually do not have written records of process controls and product throughputs.
Production of white kenkey is done on a small scale, artisanal level, usually based in households. Inspite of their cottage nature, production of white kenkey is a profitable means of employment for producers and vendors. However, unlike Ga- and Fante-kenkey, the enterprise of white kenkey (nsiho) processing has remained at the level of “ethnic food”, restricted to very few communities.

White kenkey is very popular among its consumers, who cut across all socio economic groups, and most of them eat it as frequently as 2-3 times in a week, usually for breakfast or lunch. Among the kenkey types, non-sweetened white kenkey is far more patronized than sweetened kenkey. The two kenkey types are eaten differently. The non-sweetened white kenkey is frequently eaten with fish and pepper sauce whiles the sweetened white kenkey is eaten with or without an accompaniment. For consumers of white kenkey, crumbliness and taste are important quality attributes. In particular crumbliness and softness are important to consumers of non-sweetened white kenkey (nsiho) and taste and softness for sweetened kenkey. The shelf life of non-sweetened white kenkey may be as long as five days, while that of sweetened kenkey is only about two days. Spoilage is characterized by moldiness or a sharp fermented smell.

The enterprise of kenkey-making is lucrative because the product is very popular among its consumers. It is important to systematically study and understand the white kenkey production process with the view to optimizing the process and product characteristics. The optimized process and product characteristics could provide scale-up criteria for the industrialization of white kenkey production.
CHAPTER 4

OBJECTIVE 2: To determine the sensory profile and consumer acceptability of different fermented maize products.

4.0 Introduction

Kenkey is the principal and most popular product prepared from fermented maize dough in Ghana. It is a stiff gruel or dumpling, usually packaged in maize husks, plantain leaves, or other broad leaves (depending on the type of kenkey). There are different types of kenkey based mainly on the procedure used in preparation and packaging. A third type of kenkey made using dehulled maize is white kenkey (Akporhi or Nsiho) produced mainly in the Central, Western and Eastern regions of Ghana.

Differences exist in the organoleptic properties for the different types of kenkey (Sefa-Dedeh, 1993; Amoa-Awua et al., 2007) due to the differences in processing procedures and packaging material. Some of the quality attributes of kenkey have directly been linked to processing parameters such as steeping of the maize grains and dough fermentation. Extended periods of maize dough fermentation have been associated with the development of undesirable flavours and high acidity (Halm et al., 2004). Bediako-Amoa (1973) observed that the best Ga-kenkey was obtained from 48-hour fermented dough and that further fermentation adversely affected consumer acceptance. In determining the quality characteristics of kenkey as possible primary scale up variables for the industrialization of its production, consumers considered texture as a critical sensory attribute (Halm et al., 2004). Other sensory attributes of Ga-kenkey that are important to consumers were taste (sourness), colour and smell (Amponsah, 2010, Dzigbor, 2012 and Owusu-Brafi, 2014).
Current trends in urbanization, and the increasing popularity of *kenkey* among consumers, require larger scale production with consistent quality. Upgrading production from the artisanal to industrial level will require consumer input on critical quality attributes that influence product acceptability. Furthermore, even though *kenkey* is very popular among Ghanaian consumers, it remains an ethnic food with little or no international appeal. Widening of its international appeal will greatly improve the chances of success for production at the industrial level. This study was necessary to make a choice between white *kenkey* and other fermented maize products using drivers of quantitative descriptive analysis and consumer studies. The objective of this study was to determine the sensory characteristics of the major *kenkey* types and other fermented maize in Ghana. The study also determined the consumer acceptance of *kenkey* and other fermented maize products that influence acceptability.

4.1. Materials and Methods

4.1.1 Fermented maize dough products used for sensory analysis

Five different types of *kenkey* namely Fante *kenkey*, Ga-kenkey, non-sweetened white *kenkey* produced at Atimpoku, non-sweetened white *kenkey* produced at Senchi and sweet white *kenkey* produced at Osino. Two other fermented cereal products apart from *kenkey*, used in the study were *banku* and *kafa*, obtained from vendors in the Accra and Tema metropolis. *Banku* flours were also purchased from CSIR- Food Research Institute and Neat Foods Company. These were reconstituted and cooked into *banku* and labeled FRI *banku* and Neat *banku* respectively.

The types of fermented maize products used in the study are listed as follows:

- Fante *kenkey*
- Ga *kenkey*
• White kenkey (Atimpoku)
• White kenkey (Senchi)
• Sweet white kenkey (Osino)
• Normal banku (prepared from maize and cassava doughs)
• Kafa (Agidi)
• Food Research Institute (FRI) instant banku
• Neat banku (From Neat Foods Company).

Description of samples can be found in Appendix 4

4.1.2 Sample preparation

*Ga kenkey, Fante kenkey, non-sweetened white kenkey* (Atimpoku and Senchi), sweetened kenkey and traditionally processed (normal) banku were obtained from commercial vendors whilst the two instant banku samples, from FRI and Neat Company were prepared from dehydrated flours following the manufacturer’s instructions on the package. The samples were cut into 2 g cubes and served to panelists in disposable plastic plates.

4.2 Methods

4.2.1 Quantitative Descriptive Analysis of fermented maize products

4.2.1.1 Training of sensory panel

A trained panel of 16 members was used to assess the samples. The panel was made up of students and staff from the Ghana Atomic Energy Commission and staff of the CSIR-Food Research Institute. Training involved a two-day group discussion to develop terms for the description of the appearance, texture, taste and aroma of the kenkey and banku samples. The panel was also trained to quantify the intensity of sensory attributes using line scales. Table 4.1 shows the fourteen sensory attributes generated during the group discussions and their definitions.
The sensory descriptors for appearance, texture, taste and aroma agreed on during the group discussions were used to evaluate the kenkey and banku samples.

Table 4.1: Sensory descriptors generated by panel members for appearance, texture, taste and aroma of kenkey types and other maize dough products

<table>
<thead>
<tr>
<th>Sensory attribute</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brownish colour</td>
<td>colour of brown</td>
</tr>
<tr>
<td>Creamy colour</td>
<td>colour similar to cream</td>
</tr>
<tr>
<td>Whitish colour</td>
<td>colour that is similar to white</td>
</tr>
<tr>
<td>Maize odour</td>
<td>odour characteristic of maize kernel</td>
</tr>
<tr>
<td>Fruity odour</td>
<td>odour similar to that of ripe fruit</td>
</tr>
<tr>
<td>Burnt odour</td>
<td>odour of wood smoke</td>
</tr>
<tr>
<td>Fermented odour</td>
<td>odour characteristic of fermented maize dough</td>
</tr>
<tr>
<td>Hard texture</td>
<td>texture that is the opposite to soft</td>
</tr>
<tr>
<td>Sticky texture</td>
<td>texture that clings to the fingers and tongue</td>
</tr>
<tr>
<td>Rough texture</td>
<td>texture that is coarse and uneven</td>
</tr>
<tr>
<td>Sour taste</td>
<td>taste that is acidic and sharp</td>
</tr>
<tr>
<td>Sweet taste</td>
<td>tastes sweet as in sugar</td>
</tr>
<tr>
<td>Salty taste</td>
<td>tastes of table salt (sodium chloride)</td>
</tr>
<tr>
<td>Strong taste</td>
<td>opposite of bland taste or tasteless</td>
</tr>
</tbody>
</table>

4.2.1.2 Sensory Evaluation

Kenkey samples were scored by a trained sensory panel using a modified version of quantitative descriptive analysis (QDA) since standards were not provided (Tomlins et al. 2012; Meilgaard et al., 2007). Each sample was coded with a three-digit random number and presented to panelists in a randomized order. There were a total of nine samples and each panelist evaluated four samples per session over four different sessions. Each panelist was provided with a plastic plate containing four samples (5 g
each) and a cup of water at room temperature for rinsing the mouth in-between sample
tasting. Evaluations were done on a 100 mm line-marking scale anchored at the low
end with ‘not’ and at the high end with ‘very’ (Appendix 5), under ambient
temperature (30-35°C) and controlled white lighting. Panelists were instructed to
evaluate the samples in the order indicated on the evaluation sheets provided.

4.3 Consumer Testing

The consumer testing was conducted to determine consumer preference and/or
acceptance of products. Based on the outcome from cluster analysis of the sensory
data, six samples were chosen for consumer testing. These included non-sweetened
white kenkey (Atimpoku), sweetened white kenkey, Ga and Fante kenkey, normal
banku and kafa. The ballot sheet is found in (Appendix 6a). Consumers were given
information sheets on the objective of the work and also asked to sign consent forms
(Appendix 6b). A total of two hundred consumers including 110 Ghanaians and 90
internationals (from Europe, USA, Canada and some Asian countries) participated in
the study. The Ghanaian consumers were randomly selected from the Accra, Legon
and Tema areas of the Greater Accra Region of Ghana. The international consumers
were selected from Multinational organizations such as United Nations Development
Program (UNDP) and Foreign students from the International Student Hostel at the
University of Ghana, Legon.

Criteria for recruitment included the following: (1) age of at least 18 years (2) having
no aversion/allergy to maize products and (3) availability for the test. Consumers were
presented with coded samples following the Randomized Block design for six samples
as described by Cochran and Cox (1957). Consumers were served a 2 g slice of each
of the coded samples. All samples were presented at the same time. The test was
carried out at the Basement Canteen of University of Ghana, Legon and at Adenta Community.

Consumers rated the taste, odour and overall acceptability of the samples using a 7-point hedonic scale (Meilgaard et al., 2006; Stone and Sidel, 2004). 1. Dislike very much, 2. Dislike moderately, 3. Dislike slightly, 4. Neither like nor dislike, 5. Like slightly, 6. Like moderately and 7. Like very much. Demographic information of the consumers were also collected as well as questions about the type of kenkey they preferred, their preference for kenkey or banku, the frequency and reason for eating kenkey, and where they normally obtain the kenkey.

4.3.1 Consent of participants
Consent was sought from sensory panelists and from adult consumers participating in this study. Enumerators informed participants about the study and explained that their participation was entirely voluntary, and that the responses would be strictly confidential and anonymous. (Appendix 6b)

4.3.2 Statistical analysis
Analysis of variance was carried out using SPSS v. 16.0 (SPSS Inc. Chicago, IL 60606-6412) whilst cluster analysis (Agglomeration method) and Principal Component Analysis were carried out using XLSTAT (V. 5.2, Addinsoft) version 2012, Addinsoft, Paris, France.
4.4 Results and discussions

4.4.1 Sensory profile of kenkey and other fermented maize dough products.

The mean scores for the sensory attributes of the nine fermented maize dough products in the study are presented in Table 4.2a and 4.2b. There were significant differences (p<0.05) in the sensory attributes among the product types. Overall the mean sensory scores revealed that the dehulled maize dough samples had a milder taste than the whole maize dough products (Ga and Fante-kenkey, and the Banku samples). They also had a whiter colour but were not perceived to have a smoother texture despite the removal of the chaff and endosperm.

Principal component analyses (PCA) was used to relate the different types of fermented maize dough products with their sensory attributes (Figure 4.1). Nine samples were grouped into five classes based on the principal component analyses.

![Figure 4.1](http://ugspace.ug.edu.gh)

Figure 4.1. Principal Component Analysis (PCA) bi-plot showing the relationship between kenkey and other traditional fermented maize products, and the sensory attributes used to describe their appearance, texture, taste and aroma.
All three Banku products, (ie FRI Banku, Normal Banku and Neat Banku) formed one group as the PCA did not show differences in their sensory characteristics. Their main sensory characteristics were creamy colour and sticky texture (Figure 4.1). Banku is usually prepared from a mixture of maize and cassava dough. Cassava dough has a lighter colour and higher starch content than maize and that could account for the creamy colour and sticky texture of Banku in comparison to the whole maize products (Ga and Fante kenkey).

Fante-kenkey and Ga kenkey were classed separately based on their sensory attributes. The main difference between the two products is duration of fermentation, addition of salt to the stiff porridge (aflata) during Ga-kenkey production, different aflata to uncooked dough ratio, and type of leaves used for packaging. The taste of Fante-kenkey was described as sour, salty and burnt, with a fermented and raw maize odour and brownish colour. The same sensory characteristics were attributed to Ga-kenkey but the intensity of each attribute was significantly less. The more intense sensory characteristics of Fante-kenkey could be due to a more pronounced fermentation and additional sensory notes from dried banana or plantain leaves rather than the maize husks used to wrap the product before cooking. Fante kenkey was adjudged to have a saltier taste, which was unexpected, because it is usually Ga kenkey that is salted during processing and not Fante kenkey. Even though some processors add salt to Fante kenkey, it is most likely that consumers may have judged sourness as saltiness.

Products processed from dehulled maize kernels formed the fourth group on the bi-plot (Figure 4.1). Non-sweetened white kenkey samples (Atimpoku and South Senchi) occupied almost the same spot on the bi-plot and clustered with sweetened kenkey. Sweet kenkey is essentially white kenkey to which sugar is added during
processing. Sweet *kenkey* has a markedly sweet taste and is easily distinguishable from white *kenkey* based on sweetness and packing material. This group was described as having whitish colour, sweet taste, fruity odour, and slightly hard texture. These characteristics could be attributed to the decortication of the maize resulting in the loss of the hulls and some part of the germ. Fruity odour is often associated with yeasts and all the samples analyzed had been fermented by lactic acid bacteria and yeasts (Halm et al. 1993). Amoa-Awua *et al.*, 1997; Hayford *et al.* 1999).

Table 4.2(a) Means and standard deviation for sensory attributes used in evaluating *kenkey* samples by a trained panel

<table>
<thead>
<tr>
<th>Attribute/Sample</th>
<th>Ga <em>kenkey</em></th>
<th>Fante <em>kenkey</em></th>
<th>White <em>kenkey</em> (Atimpoku)</th>
<th>White <em>kenkey</em> (Senchi)</th>
<th>Sweet <em>kenkey</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>creamy</td>
<td>55.6±36.8b</td>
<td>54.6±34.6b</td>
<td>11.7±14.4a</td>
<td>21.6±22.2a</td>
<td>11.6±15.9a</td>
</tr>
<tr>
<td>brownish</td>
<td>68.2±36.6c</td>
<td>69.3±31.1c</td>
<td>3.8±4.6a</td>
<td>7.0±6.3a</td>
<td>5.4±6.5a</td>
</tr>
<tr>
<td>whitish</td>
<td>7.1±7.3a</td>
<td>3.8±4.6a</td>
<td>90.6±25.4d</td>
<td>84.2±20.2d</td>
<td>89.0±23.6d</td>
</tr>
<tr>
<td>maize</td>
<td>87.5±33.2c</td>
<td>51.4±33.2ab</td>
<td>43.2±29.6ab</td>
<td>45.7±28.8ab</td>
<td>39.3±27.7ab</td>
</tr>
<tr>
<td>fruity</td>
<td>14.9±17.4a</td>
<td>21.5±29.7a</td>
<td>68.3±32.4b</td>
<td>67.6±29.3b</td>
<td>65.7±34.5b</td>
</tr>
<tr>
<td>burnt</td>
<td>46.7±31.6c</td>
<td>51.6±37.5c</td>
<td>11.8±20.2a</td>
<td>9.1±13.5a</td>
<td>9.4±27.4a</td>
</tr>
<tr>
<td>fermented</td>
<td>66.1±32.9c</td>
<td>53.9±36.2c</td>
<td>15.3±18.9a</td>
<td>18.9±21.2a</td>
<td>9.7±13.5a</td>
</tr>
</tbody>
</table>
Table 4.2(a) Means and standard deviation for sensory attributes used in evaluating *kenkey* samples by a trained panel

<table>
<thead>
<tr>
<th>Attribute/ Sample</th>
<th>Ga <em>kenkey</em></th>
<th>Fante <em>kenkey</em></th>
<th>White <em>kenkey</em> (Atimpoku)</th>
<th>White <em>kenkey</em> (Senchi)</th>
<th>Sweet <em>kenkey</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>hard</td>
<td>8.5±21.4c</td>
<td>54.4±25.3c</td>
<td>55.1±28.6c</td>
<td>62.0±26.2c</td>
<td>67.6±25.3d</td>
</tr>
<tr>
<td>sticky</td>
<td>58.1±35.1c</td>
<td>61.1±26.1c</td>
<td>19.7±20.9a</td>
<td>23.0±21.4a</td>
<td>21.1±23.0a</td>
</tr>
<tr>
<td>smooth</td>
<td>29.8±21.1a</td>
<td>34.4±26.8a</td>
<td>70.5±24.5b</td>
<td>70.1±22.8b</td>
<td>66.3±30.3c</td>
</tr>
<tr>
<td>Sour</td>
<td>71.2±28.4c</td>
<td>57.3±25.7d</td>
<td>15.3±21.0b</td>
<td>15.3±15.6a</td>
<td>10.3±15.7a</td>
</tr>
<tr>
<td>Sweet</td>
<td>16.6±20.7a</td>
<td>19.5±22.7a</td>
<td>52.2±31.5b</td>
<td>53.3±31.1b</td>
<td>87.2±25.2c</td>
</tr>
<tr>
<td>Salty</td>
<td>54.0±30.3d</td>
<td>21.5±21.0b</td>
<td>35.7±29.6c</td>
<td>38.4±33.0c</td>
<td>8.5±16.2a</td>
</tr>
<tr>
<td>Strong</td>
<td>56.8±32.2c</td>
<td>51.7±29.2bc</td>
<td>20.5±23.9b</td>
<td>26.8±23.7ab</td>
<td>24.4±24.6a</td>
</tr>
</tbody>
</table>
Table 4.2(b) Means and standard deviation for sensory attributes used in evaluating other maize products by a trained panel

<table>
<thead>
<tr>
<th>Attribute/ Sample</th>
<th>Normal banku</th>
<th>Neat banku</th>
<th>FRI banku</th>
<th>Kafa</th>
</tr>
</thead>
<tbody>
<tr>
<td>creamy</td>
<td>54.9±32.3b</td>
<td>55.6±35.7b</td>
<td>49.9±32.4b</td>
<td>60.9±36.8b</td>
</tr>
<tr>
<td>brownish</td>
<td>37.1±27.6c</td>
<td>48.3±34.0cd</td>
<td>55.4±31.9d</td>
<td>33.1±38.4b</td>
</tr>
<tr>
<td>whitish</td>
<td>32.5±22.3c</td>
<td>19.1±22.5b</td>
<td>13.9±14.2ab</td>
<td>38.7±23.8c</td>
</tr>
<tr>
<td>maize</td>
<td>54.7±26.0ab</td>
<td>55.5±30.9ab</td>
<td>61.8±26.1b</td>
<td>32.5±27.6a</td>
</tr>
<tr>
<td>fruity</td>
<td>14.8±16.9a</td>
<td>14.6±21.7a</td>
<td>13.4±16.3a</td>
<td>24.8±29.2a</td>
</tr>
<tr>
<td>burnt</td>
<td>39.3±27.4bc</td>
<td>34.9±27.8bc</td>
<td>50.0±29.6c</td>
<td>15.0±27.4a</td>
</tr>
<tr>
<td>fermented</td>
<td>59.4±32.6c</td>
<td>55.0±34.5c</td>
<td>57.7±29.1c</td>
<td>32.6±32.6b</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute/ Sample</th>
<th>Normal banku</th>
<th>Neat banku</th>
<th>FRI banku</th>
<th>Kafa</th>
</tr>
</thead>
<tbody>
<tr>
<td>hard</td>
<td>21.7±18b</td>
<td>30.2±21b</td>
<td>22.6±19b</td>
<td>9.2±9.1a</td>
</tr>
<tr>
<td>sticky</td>
<td>75.2±29.4d</td>
<td>68.1±22.4cd</td>
<td>74.9±22.7d</td>
<td>41.1±27.3b</td>
</tr>
<tr>
<td>smooth</td>
<td>42.4±27.7a</td>
<td>60.9±24.9a</td>
<td>40.1±23.0a</td>
<td>77.7±30.3b</td>
</tr>
<tr>
<td>Sour</td>
<td>67.0±28.1de</td>
<td>44.5±24.8c</td>
<td>44.5±24.8c</td>
<td>34.0±28.0b</td>
</tr>
<tr>
<td>Sweet</td>
<td>18.0±19.5a</td>
<td>21.8±25.9a</td>
<td>16.5±15.8a</td>
<td>47.9±141.3b</td>
</tr>
<tr>
<td>Salty</td>
<td>48.7±29.8cd</td>
<td>37.1±26.4c</td>
<td>52.4±27.2d</td>
<td>11.6±17.1ab</td>
</tr>
<tr>
<td>Strong</td>
<td>53.8±32.9c</td>
<td>41.8±29.2abc</td>
<td>45.7±31.6abc</td>
<td>67.4±141.1c</td>
</tr>
</tbody>
</table>

University of Ghana http://ugspace.ug.edu.gh
The absence of fruity odour in the Banku, Ga and Fante kenkey samples (Table 4.2a and 4.2b) may be due to masking by other odour notes associated with the endosperm and hulls. Kafa belonged to an entirely separate group and was described as having a much smoother texture than the rest. To produce kafa, whole maize kernels are steeped, milled, reconstituted into slurry and sieved to remove the chaff and other particles before it is fermented. This would account for its smoother texture. It was closer in sensory characteristics to the dehulled maize products on the PCA bi-plot.

4.4.2 Consumer testing

Agglomerate Hierarchical Clustering (Ward’s method), was used to group the nine products. The Ward’s method was able to separate sweet kenkey from the white kenkey samples, and thus gave six groups as follows; (i) Ga-kenkey, (ii) Fante-kenkey, (iii) Non-sweetened white kenkey (Atimpoku and Senchi), (iv) normal Banku, FRI Banku and Neat Banku, (v) Sweetened kenkey, and (vi) Kafa. Based on this clustering, the six samples selected for consumer testing were taken from each of the 6 groups as follows: Ga kenkey, Fante kenkey, normal banku, non-sweetened white kenkey (Atimpoku), sweet kenkey and Kafa. Acceptability of the six samples was evaluated using a seven-point hedonic scale (Appendix 6a). The accompanying questionnaire was administered where necessary in the local dialects to those consumers who were illiterate. The mean scores for acceptability of the six products by 110 Ghanaian and 90 international consumers are presented in table 4.3.
Table 4.3. Mean acceptability score for kenkey and other maize products tested

<table>
<thead>
<tr>
<th>Sample</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kafa</td>
<td>4.2 ±1.96&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fante kenkey</td>
<td>4.3 ± 2.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Normal banku</td>
<td>4.7 ± 1.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ga kenkey</td>
<td>5.0 ± 1.66&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>White kenkey (Atimpoku)</td>
<td>5.2 ± 1.64&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sweetened kenkey</td>
<td>5.3 ± 1.88&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Samples with the same superscript letters are not significantly different (p<0.05). Overall acceptability was measured on a 7-point Hedonic scale by 200 consumers.

All six products were acceptable to the consumers, since none of them was scored below 4 (neither like nor dislike) on the 7-point hedonic scale. There were no significant differences in overall acceptability at (p>0.05) between Kafa, Fante kenkey and Banku. Sweet and non-sweetened white kenkey was the most liked by the Ghanaian consumers, and was followed by Ga-kenkey, while the international consumers’ preference was most for sweet white kenkey and white kenkey (nsiho). From the table, it was observed that consumers preferred products which were prepared using salt or sugar than those without any additive.

4.4.3 Consumption patterns of fermented maize dough products.

4.4.3.1 Clustering of consumers by product groups.

The results of the consumer survey were also evaluated in order to identify the drivers and potential markets for kenkey. Three clusters of consumers emerged. The first cluster, “the All likers” consisted of consumers who liked all the products and was made up of 34% of all the consumers interviewed (Figure 4.2a).
The other clusters were the ‘banku likers, 36% and ‘white likers’ 30% of all consumers. Banku, Ga-kenkey, white kenkey and sweet white kenkey were acceptable to banku likers, and white kenkey, sweet white kenkey and Ga-kenkey to white likers.

4.4.3.2 Gender and Nationality

Figure 4.2b shows the distribution of consumers in the three food clusters according to gender. The male consumers were predominantly in the “All likers” cluster, suggesting they accepted all types of fermented maize dough products. On the other hand, female consumers were more selective in their preference for fermented maize products and were largely in the “banku” and “white likers” cluster.
The consumption patterns were also decomposed into Ghanaian and international components, and the results are presented in Figure 4.2c.
The Ghanaian consumers were largely non-selective, and clustered into the “All likers” group. This is probably because they are more familiar with fermented maize dough products, as their traditional staples, and consequently accepted most of them. The international consumers, were however, more discriminatory in their choice for the products, and consequently did not cluster in the “All likers” group. Their preferences for fermented maize dough products were predominantly for the “white likers” and “banku” clusters (Figure 4.2c). Thus the international consumers liked sweet white kenkey and white kenkey best which represent the products made from dehulled or polished maize.

4.4.3.3 Frequency of kenkey consumption

Kenkey is a very popular food among Ghanaian consumers. About 12% of the Ghanaian consumers eat kenkey more than once a day, 16% once a day, and close to 40% a few times a week (Figure 4.3a).
For international consumers, the appeal and taste for kenkey probably needs to be acquired. Most of the internationals (about 40%) rarely eat kenkey, 25%, about once a week whilst about 5% had never eaten kenkey. This must be understood from the point of view that almost all the internationals interviewed were foreign students who had been in Ghana for less then 2 months.

Figure 4.3b illustrates the frequency of consumption of kenkey by nationality. It showed that 60% of the all likers eat kenkey more than once in a day, whilst most of the banku likers rarely eat kenkey which is surprising since they are similar products in some aspects. Banku is home prepared whilst kenkey is ready to eat street-vended food.

![Figure 4.3b. Frequency of consumption of kenkey by consumers who like all six fermented maize products](image)

4.5 Effect of demographic characteristics of consumers on kenkey consumption

None of the socio-economic factors evaluated (which are level of education, ethnicity, nationality, age, gender, occupation, residential status in Ghana and marital status of the consumers) significantly influenced (p>0.05) the acceptability of any of the products. The main reasons given by Ghanaian consumers for eating kenkey is its convenience and also
that it gives energy (Figure 4.4). The other reason given by international consumers was its affordability.

Most of the Ghanaian consumers obtained *kenkey* from street hawkers or at home. *Kenkey* served at home is usually purchased from a vendor, because the process is laborious and time consuming. Similarly, *kenkey* obtained at the workplace will come from a vendor and in a restaurant from a supplier. However, *kenkey* eaten in a chopbar would have been prepared in the chopbar.

![Graph (a)](image)

![Graph (b)](image)
4.6 Implications for developing kenkey suited to International and the local market

Cluster analysis approach has been commonly used in consumer acceptance in order to determine which groups of people would prefer which type of product. This approach is very useful in the marketing approach because it helps target specific consumers with the type of product they like. The liking can be dependent upon many factors (socio-economic background; food customs) and knowing the consumers would help predict the product that they are more likely to adopt when launching a new product on the market.
Three clusters of product ‘likers’ or consumers emerged with different sensory characteristics.

For the European market and also part of the Ghanaian market, considerations will be based on the preferences of the “white likers” cluster to which most of the internationals belonged. Sensory attributes which will be emphasized in optimizing kenkey for this market are whitish colour, fruity odour, smooth and non-sticky texture, a less sour product without a pronounced fermented odour, and bland taste. Important processing factors which will be explored to achieve these will include dehulling/polishing of maize kernels, reduced steeping and fermentation period (to reduce the period of production).

4.7 Conclusions

Based on sensory characteristics of the fermented maize products, consumption patterns were clustered into three groups: consumers who accepted all types of fermented maize products, those who accepted the banku category and those who preferred the white (dehulled) maize category of products. While most Ghanaian consumers are comfortable with all the products, female Ghanaian consumers tended to be more selective for the banku and white products category. The same category of products was preferred by the international consumers. Their preferences were driven by color, taste, flavor and texture of the products.

This study has provided information on the sensory characteristics of the main types of kenkey and other competing fermented maize products consumed in Ghana. The results will help to provide a basis for understanding the acceptability of these products by Ghanaian and international consumers and provide directions that the product could be adapted to suite international and Ghanaian markets and help it succeed as a marketable product.
CHAPTER 5

Objective 3: To evaluate the physico-chemical, rheological and microstructural characteristics of non-sweetened and sweetened white kenkey.

5.0 Introduction

*Ga* and Fante-kenkey are the most popular and most consumed types of kenkey in Ghana. There are other less popular types, including white kenkey, that have remained as ethnic foods, and their distribution and consumption are largely limited to the localities with which they are associated. The white kenkey types consist of the non-sweetened (*nsiho*) and the sweetened white kenkey. Non-sweetened white kenkey (*nsiho*) and sweet kenkey are prepared with dough obtained from dehulled maize grains. Their preparation involves all the stages of *Ga* and *Fante kenkey* preparation with slight modifications. In the processing of the white kenkey types, the grains are dehulled, steeped in water for 48 hours and then milled mechanically into a smooth meal (Ijabadeniyi and Omoya, 2006).

During a survey on the production practices of white kenkey in some selected communities, two different procedures were observed for further processing after production of the smooth meal. In one procedure, the smooth meal is pre-cooked into a thick gelatinous paste (*aflata*). The *aflata* is moulded into balls and wrapped in clean maize husks. The balls are packed into a pot containing small amount of water lined with sticks and maize husk and steamed to cook. In another processing procedure, the smooth meal is kneaded into stiff dough and fermented spontaneously for 12 hours. After fermentation, two-third portion of the dough is pre-cooked into ohu (*aflata*). The hot ohu is mixed with the remaining one-third uncooked dough as done for Ga and Fante kenkey.
The mixture is moulded into balls and packaged with clean maize husks. The balls are packed into perforated pan and placed over a pot of boiling water and steamed to cook. In the case of sweet white kenkey, the meal obtained is divided into two; a portion is precooked into (thick gelatinous paste) aflata. The smooth meal is made into slurry and mixed with the aflata and sweetened with sugar. The paste obtained is packaged with aworum leaves (M. cuspidata) and steamed to obtain sweetened white kenkey.

The effects of steeping as a critical unit operation on the physicochemical and textural properties of kenkey have been well established. Amponsah, (2010) studied the effects of steeping and reuse of steep water in steeping new batches of maize for Ga kenkey production. Physicochemical properties such as steep water pH, titratable acidity (TTA), soluble solids content were determined. Other causes of kenkey quality variability were identified by the determination of degree of mixing in the aflata process, temperature profile of kenkey during cooking and scanning electron microscopy (Amponsah, 2010).

Physiochemical changes (pH, titratable acidity and nutritional analysis) of kenkey during fermentation of maize using single and combined starter cultures was investigated (Fadahunsi et al., 2012). The pH decreased during 72 h fermentation for treatments. Nche et al., (1996) studied the effects of water uptake during soaking of whole or dry-milled maize. The extent of starch damage, dough pH, fermentation time on pasting and set-back viscosities of aflata dough used for kenkey production were determined.

Preliminary studies on the acceptability of the different types of kenkey indicated that while the preference for Fante and white kenkey was not very different for Ghanaian consumers, international consumers liked white kenkey but not Fante kenkey. Their preferences were driven by sensory attributes of color, taste, flavor and texture of the products. It is important to understand the underlying physicochemical characteristics of
the white kenkey types that influence the sensory and quality characteristics. This will facilitate efforts at optimizing the process and quality characteristics of the products in the direction that will enhance their acceptability to both local and international consumers. The objective of this study was to evaluate the physicochemical, rheological and microstructural characteristics of non-sweetened and sweetened white kenkey.

5.1 Materials and Methods

5.1.1 Materials

Two different types of white kenkey were obtained from five processors in 3 different towns in the Eastern Region for laboratory analysis. Five samples each of Anum, Atimopoku and sweet white kenkey were obtained. Sweet white kenkey was obtained from processors in the Osino township in the Fanteakwa district for analysis. Nsiho or non-sweetened white kenkey were obtained from Anum and Atimpoku in the Asuogyaman district for analysis. The nsiho samples from Anum were clearly distinguishable from those from Atimpoku because there was a major difference in the production procedures employed in the two towns. At Atimpoku the only fermentation process was when the dehulled maize grains was steeped in water, whilst at Anum the dehulled maize grains were not only steeped in water (to initiate fermentation) but the smooth meal obtained after milling the steeped grains was kneaded into dough and further fermented for 12 h. In the sweet kenkey also, the dehulled maize grains was only fermented by steeping in water. The production procedures employed are shown in Figure 5.1.
Figure 5.1. Flow diagram for the production of nsiho (Atimpoku procedure), nsiho (Anum procedure) and sweet white kenkey (Osino procedure)
5.2. Sampling procedure

Five(5) samples each were obtained from five different producers from Atimpoku, Anum and Osino communities. The samples were packed in plastic bags and coded. Each sample was clearly labelled with the date, time, sale point and name of producer. Kenkey samples were collected aseptically into sterile bags and placed in an ice chest to avoid contamination and to keep samples in the state at which they were bought. Samples were immediately transported to the Food Processing laboratory of CSIR-Food Research Institute for analysis. The five samples from each location were mixed thoroughly and random samples were taken for the analysis.

5.3 Analytical Methods

5.3.1 Moisture content

Air oven method was employed. Approximately 5 grams of well-mixed sample was placed into a moisture dish that had previously been dried, cooled in a dessicator and weighed. The dish was covered with the lid and weighed. The sample was put in an air oven at 104 ± 1ºC while the lid was put under the dish. The sample was heated for 60 min counting from when the oven regained the temperature of 104 ± 1ºC after introducing the samples. The dish was covered with its lid and the sample was placed in a dessicator to cool to room temperature. The moisture content was determined as percent loss in moisture (AACC Method 44-15A, 2000).

5.3.2 pH determination

The pH was measured using a pH meter (Research pH meter, 3330, Jenway, UK) equipped with a glass electrode (Orion 9102, Orion Research, and Boston, MA, USA),
after calibration using standard buffer solutions (Merck) at pH 4.0 and 7.0 at ambient temperature (AACC method 02-52, 2000).

### 5.3.3 Titratable acidity

Titratable acidity was determined potentiometrically through neutralization by sodium hydroxide (0.1N) of the total acids in the sample until complete stuff in pH (measured at pH 8.5) and maintained for 10 mins using an automatic titrator.

Ten grams of sample was dispersed into 20 ml of distilled water and homogenized for 2 min. The electrode of the pH meter was placed into the sample solution and the pH was read after 1 min. 70 ml of distilled water was added to the sample solution and freshly prepared 0.1N sodium hydroxide was added whiles agitating to continue neutralization until a pH of 8.5 was reached. After 5 min, the pH was adjusted to 8.5 and the final amount of sodium hydroxide used was read. The results were expressed as follows:

\[
% \text{lactic acid} = \frac{V \times 900 \times N}{M \times ms}
\]

- **V** = volume of titrant (ml)
- **N** = normality of soda
- **M** = mass of sample (g)
- **Ms** = Dry matter (% dry basis)

(AACC method 02-52, 2000).

### 5.3.4 Chemical Analysis

#### 5.3.4.1 Proximate analysis

Samples were analyzed for moisture, protein (6.25 X N), ash, and fat according to the AACC Method.
5.3.4.2 Protein content

The Kjedahl method (modified AACC Method 46-12, American Association of Cereal Chemist, 2000) was used for protein content analyses. Sample (0.5 g) was weighed accurately into a digestion tube. One Kjeltab (Thompson & Capper, Cheshire, UK), a 5 g tablet consisting of 100 parts K₂SO₄, 6 parts CuSO₄·5H₂O and parts selenium was added. To that, 20 ml of concentrated H₂SO₄ was added. Samples were digested for approximately 1.5 h using a Buchi 430 Digestor 9 (Buchi, Flavil, Switzerland). Distillation of ammonia, reaction with boric acid and titration with standard HCl (0.1M) was done with a Buchi 322 Distillation unit (Buch, Flavil, Switzerland). The crude protein content was calculated using the following equation:

\[
\% \text{ Protein} = \frac{(\text{ml standard NaOH} \times \text{M of NaOH}) \times 1.4007 \times \text{factor}}{\text{Weight of sample}}
\]

The conversion factor used for calculating protein content was 6.25.

5.3.4.3 Ash

AACC Method 08-01(American Association of Cereal Chemists, 2000) was used to determine the ash content of the white kenkey samples. Approximately 4 grams of sample was weighed accurately into a silica ashing crucible which had previously been ignited, cooled in a dessicator and weighed. The samples were incinerated in a muffle furnace until a light grey ash was obtained, cooled in a dessicator and weighed. Ash was calculated as follows:

\[
\% \text{ Ash} = \frac{(\text{weight of crucible + ash}) - \text{weight of an empty crucible} \times 100}{\text{Weight of sample}}
\]
5.3.4.4 Crude Fat

The crude fat content of the white *kenkey* samples were determined by the modification of AACC Method 30-25 (American Association of Cereal Chemists, 2000). Approximately 20 g of well-mixed sample was weighed accurately into a thimble. A piece of fat-free absorbent cotton wool was placed on top to prevent escape of sample from the thimble and distribute solvent as it dropped on the sample. The sample was extracted with petroleum ether which was put into a flask previously dried in an oven, cooled in dessicator and weighed. The extraction was done for 5 h in a Soxhlet extractor and maintained at condensation rate of 5-6 drops per second. The solvent was evaporated on water bath in a fume cupboard. The flask with fat was then dried completely in an oven at 105°C for approximately 1 h. The flask was then cooled in a dessicator and weighed. The crude fat content was calculated as follows:

% Crude fat= (weight of flask+ fat) - (weight of flask) x100/ weight of sample

5.4. Mineral elements

The dry ashing method was used in the present study for Atomic absorption spectroscopy analysis (AOAC, 2005). All glasswares were washed with 1% nitric acid followed by demineralised water. 3 g of *kenkey* sample was weighed into platinum crucibles. The crucible and the test portion were placed in the muffle furnace at a temperature 550°C for 8 hours. The crucible with ash was put in desiccator to cool. 5 mL of nitric acid of mass fraction not less than 65 %, having a density of approximately $\rho (\text{HNO}_3) = 1400 \text{ mg/mL}$ was added, and the resultant solution heated on hot plate until the ash dissolved. 10 mL of 0.1 mol.L$^{-1}$ nitric acid was added and filtered into 50 ml volumetric flask. The resultant solution was top up to the mark with 0.1 mol.L$^{-1}$ nitric acid. Blank solution was treated the same way as the sample. The absorbance was read
using Buck Scientific 210VGP Flame Atomic Absorption Spectrophotometer (Buck Scientific, Inc. East Norwalk, USA). Cathode lamps used were Cu (wavelength 324.8 nm, lamp current 1.5 mA), Fe (wavelength 248.3 nm, lamp current 7.0 mA), Mn (wavelength 279.5 nm, lamp current 3.0 mA), and Zn (wavelength 213.9 nm, lamp current 2.0 mA). Air/Acetylene gas was used for all the analysis. The metal content of the samples were derived from calibration curves made up of minimum of three standards.

5.5 Amino acid and vitamin analysis

The amino acids content was determined using AOAC method 982.30 (1990).

5.6 Determination of Glucose and Lactic acid

Glucose and Lactic acids were determined using High Performance Liquid Chromatography (HPLC 360 Auto sampler (Shimadzu LC-9A), as described by Mestres and Rouau, (1997).

5.6.1 Sample preparation

One gram of sample was weighed with a screw-capped tube and 3 ml of 0.5 M H₂SO₄ was added. The content was homogenized using a Rotator, SB2, Stuart (Bibby Scientific Ltd, Staffordshire, UK) for an hour. The mixture was centrifuged (Centrifuge 1207, VWR International LLC, West Chester, United States) at 7.2 ×1000 g for 5 min. The supernatant was filtered into an HPLC sample vial through a 0.45-µm RC filter (Minisart, R.C 15 17762, Sartorius AG, 37070, Germany). Separation of organic acids was achieved with an Aminex HPX-87H HPLC column (Bio-Rad Labs., Richmond, Calif., USA) held at 45°C, using 9 mM H₂SO₄ as a mobile phase at a flow rate of 0.4
mL/min. UV detector (Series 200, Perkin Elmer) response was monitored by Turbochrom software (Perkin Elmer).

5.6.2 Determination of Organic Acids

Organic acids were identified and quantified by comparison of their retention times with the following standard acids: -lactic acid, acetic acid, maltose, glucose, fructose. The analysis was externally calibrated using mixed standard solutions in de-ionized water, prepared for the samples.

5.6.3 Sugar Determinations

Concentrations of glucose, fructose, and maltose were monitored using a refractive index detector (Perkin Elmer) in series with the UV detector and calibrated using standard sugar solutions (Sigma).

5.7 Colour Determination

The colour of the white kenkey samples were measured using a Minolta Chromameter CR310-Japan colorimeter model D25-PC2 (Hunter of employees of the National Institute of Aglaboratories, Reston, VA) after calibration using a white tile (L=97.51, a=5.45, b=-3.50) according to AACC Method 14-22.01, 2000). Colour was expressed in terms of lightness (L) and colour difference. E was calculated as  

\[ E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \]

(\Delta L is change in L value (standard L- recorded L), \Delta a is change in a value standard a- recorded a, \Delta b is change in b value (standard b- recorded b) , where lightness (L) = (+), green (a) = (-); yellow (b) = (+), blue (b) =(-) colour value. Analysis was conducted five times per sample and the mean calculated.
5.8 Stress Relaxation analysis of white kenkey

Freshly prepared non-sweetened white kenkey (Anum), non-sweetened white kenkey (Atimpoku) and sweet white kenkey were purchased and kept at room temperature for two hours. The samples were mixed and samples were taken from the whole using cylindrical stainless steel moulds of diameter 4 cm and height 2 cm, cylindrical shapes were cut out from the kenkey samples. The samples were covered with cling film to prevent dehydration.

The stress relaxation tests were performed by TA-XT2 Texture Analyzer (Stable Microsystems, Surrey, England) equipped with 25 kg load cell. A penetrometer probe of 6 mm diameter was used. The test samples were compressed 5mm of its original height with a cross head speed of 0.3mm/s. The constant compressive strain was applied to the sample for 80s and compressing the samples for 80 seconds. All tests were performed in ten replicates.

5.9 Scanning Electron Microscopy (SEM)

5.9.1 Samples for Scanning Electron Micrography

Samples which were analyzed by scanning electron microscopy were non-sweetened white kenkey (nsiho) and its intermediary products obtained from processors in Anum and Atimpoku. Sweet kenkey was purchased from vendors in Osino.

5.9.2 Granule morphology

The morphology and structure of starch granules were characterized by scanning electron micrography as described by Naguleswaran et al. (2011). Samples were prepared by sprinkling them on double-sided adhesive tape attached to a circular specimen stub, and
coated with gold using a Balzers SCD 004 sputtering coater. Samples were viewed using an Environmental Scanning Electron Microscope (Quanta 200F, Fei, Philips, Holland) at an accelerating voltage of 20 KV, working distance of 11.3 mm, pressure 0.45 Torr, resolution- 800µm, large field detector and secondary 200 µm were used.

5.9.3 Study design and analyses
Two different types of white kenkey (sweetened and non-sweetened) were obtained from 3 different towns (Anum, Atimpoku and Osino) in the Eastern Region. Two types of non-sweetened white kenkey (nsiho) were obtained from processors at Anum and Atimpoku, while sweet white kenkey was obtained from processors in the Osino township in the Fanteakwa district. The different samples were each analysed for physicochemical, proximate, textural, and microstructural characteristics. The data generated from the various analyses were used to determine the differences in the characteristics of the kenkey types.

5.9.4 Statistical Analysis
The differences in the physicochemical properties data were analysed using ANOVA.

5.10 Results and Discussion
5.10.1 Moisture
Table 5.1 shows the results of the physicochemical analysis of dehulled maize grains, intermediary products and white kenkey obtained from Atimpoku and Anum as well as sweet kenkey from Osino. The moisture content of the maize grains ranged from 11-12%, to prevent mould growth during maize storage. The moisture content of the kernels should not exceed 12% (Souci et al, 2001). The results show that the maize
grains had been adequately dried before storage to prevent mould growth and possible subsequent aflatoxin contamination.

<table>
<thead>
<tr>
<th>Kenkey types</th>
<th>Moisture (g/100 g)</th>
<th>pH</th>
<th>Titratable Acidity (% lactic acid dry matter basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atimpoku white non sweetened kenkey</td>
<td>Dehulled maize grains</td>
<td>11 ± 0.24</td>
<td>ND</td>
</tr>
<tr>
<td>Steeped grains</td>
<td>32 ± 0.32</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Dehulled maize dough</td>
<td>53 ± 0.26</td>
<td>3.89 ± 0.02</td>
<td>ND</td>
</tr>
<tr>
<td>Precooked dough (aflata) white kenkey</td>
<td>77 ± 0.06</td>
<td>4.0</td>
<td>0.85 ± 0.02</td>
</tr>
<tr>
<td>Fermented dehulled maize dough</td>
<td>52 ± 0.12b</td>
<td>3.06 ± 0.006</td>
<td>0.63 ± 0.06</td>
</tr>
<tr>
<td>Precooked dough (aflata) + Raw dough</td>
<td>76 ± 0.72</td>
<td>3.48 ± 0.012</td>
<td>0.48 ± 0.09</td>
</tr>
<tr>
<td>Sweet white kenkey</td>
<td>Dehulled maize grains</td>
<td>12 ± 0.17</td>
<td>ND</td>
</tr>
<tr>
<td>Milled dough</td>
<td>53 ± 0.16b</td>
<td>3.75 ± 0.05b</td>
<td>1.19 ± 0.04</td>
</tr>
<tr>
<td>Precooked dough (aflata)</td>
<td>87 ± 0.11c</td>
<td>4.24 ± 0.02b</td>
<td>0.56 ± 0.24</td>
</tr>
<tr>
<td>Precooked dough (aflata) + Raw dough</td>
<td>76 ± 0.63c</td>
<td>3.95 ± 0.02b</td>
<td>0.64 ± 0.04</td>
</tr>
</tbody>
</table>

Table 5.1: Physicochemical properties of intermediates and kenkey samples during processing of dehulled maize into traditional white kenkey types.
The mean moisture content of the steeped maize grains for both Atimpoku and Anum were between 31 and 32%. All the production sites from which the steeped grains were collected had steeped the maize grains for 48 hours, leading to massive water uptake. When the grains from the production sites of Atimpoku and Osino were milled into smooth meal, and made into dough, they were not subjected to any further fermentation, and the moisture content of the dough was 53%. On the other hand, at Anum, the steeped grains after milling and making dough, was subjected to a fermentation period. The moisture content of the dough after 12 hours of fermentation was 52%.

In the production of non-sweetened white kenkey at Atimpoku, fermentation was only restricted to steeping of the dehulled grains, the dough was precooked into aflata, packaged in maize husks and steamed to obtain the final product. The moisture content of the milled grain/ meal increased from 53% to 77% in the precooked dough (aflata) because of the gelatinization process undergone by the maize starches. There was no significant difference ($p \geq 0.05$) between the moisture content of the aflata (77%) and that of the steamed final product (76%). Similarly, the moisture content of the aflata obtained in the production of non-sweetened white kenkey at Anum was 76%, even though the process had a further 12 hour fermentation time, unlike that of the non-sweetened white kenkey process at Atimpoku. While the moisture content of the aflata from both processes was not significantly different, the moisture content of the non-sweetened white kenkey from Anum (70%) was significantly lower ($p \leq 0.05$) than that

<table>
<thead>
<tr>
<th>Sweet white kenkey</th>
<th>$77 \pm 0.26^\circ$</th>
<th>$4.37 \pm 0.52^\circ$</th>
<th>$0.45 \pm 0.05$</th>
</tr>
</thead>
</table>

Five samples of kenkey were analysed per sample, ND- not determined
from Atimpoku (76%). The differences in moisture content between non-sweetened white kenkey from two different locations could be due to differences in the processing methods (ie use of partially-fermented dough versus fermented dough) or due to difference composition in the maize cultivars used in the processing.

The moisture content of aflata for sweet white kenkey (87%) obtained from Osino was significantly higher than those of all the other products. Upon mixing with raw dough the moisture content dropped to 76% and did not change much even when it was steamed to obtain the final sweet white kenkey, the final moisture content of the sweet kenkey produced after steaming was 77%.

5.10.2 pH and titratable acidity

Analysis of the intermediary and final products obtained from the production sites for pH and titratable acidity was limited to products obtained after milling of the steeped dehulled maize grains. In the Atimpoku samples, the mean pH of the milled grains/meal was 3.89. This pH value increased to 4.0 in the precooked samples (aflata) and could be attributed to the addition of water to the fermented meal during pre-cooking. In the final non-sweetened white kenkey produced after packing and steaming, the pH value obtained was 4.2. The slight rise in pH could be attributed to escape or leaching out of organic acids during steaming. In the Anum samples the pH after dough fermentation was 3.06. This dough fermentation caused a significant reduction in pH, 3.06 compared to 3.89 in the Atimpoku samples which were not subjected to dough fermentation. During precooking into aflata, the pH also increased to 3.48 due to the addition of water and loss of volatile acids. By adding raw uncooked dough to the aflata before packaging and
steaming, the mean pH reduced to 3.23 probably due to the lower pH of the uncooked fermented dough fraction.

As was with the Atimpoku samples, the pH of the white kenkey increased during steaming due to leaching out of organic acids. The final pH obtained was 4.2. In the sweet kenkey sample from Osino, a relatively higher increase in pH was recorded between the milled meal, 3.75 and the pre-cooked dough, 4.24. The results of the moisture content had already shown that a higher volume of water was added to the dough during the precooking of sweet kenkey compared to the non-sweetened white kenkey. The higher volume of water used would account for the higher pH rise.

Addition of fresh uncooked dough to the pre-cooked sweet dough resulted in a reduction in pH from 4.2 to 3.95, a trend which had also been observed in the Anum non-sweetened white kenkey process. As had been observed for the non-sweetened white kenkey samples from Anum and Atimpoku, steaming of the final product also resulted in an increase in pH from 3.95 to 4.15 in this case also due to leaching out of organic acids during steaming.

The results of the analysis of titratable acidity were in agreement with the results of the pH determination. In every unit operation where a reduction in pH was observed a corresponding increase in percentage titratable acidity was recorded and vice versa (Table 5.1). In all samples from all production sites in the production of the different type of white kenkey a decrease in titratable acidity was observed corresponding to an increase in pH during the pre-cooking of fermented dough due to addition of water.
In the Anum white *kenkey*, the mean titratable acidity decreased from 0.93% to 0.48% during precooking, in the Osino sweet *kenkey* from 1.19% to 0.56% during the same unit operation. Addition of uncooked fermented dough to precooked dough resulted in an increase in titratable acidity from 0.48% to 0.67% in Anum white *kenkey* and from 0.56% to 0.64% in Osino sweet *kenkey*. Decrease in titratable acidity was recorded in all samples during steaming; from 0.85% to 0.40% in Atimpoku non-sweetened white *kenkey*, 0.67% to 0.50% in Anum non-sweetened white *kenkey* and 0.64% to 0.55% in Osino sweet *kenkey*. All these were due to loss of organic acids by leaching and volatilization during steaming.

5.10.3 Chemical composition of white *kenkey*

Mean chemical composition of three types of white *kenkey* from Atimpoku, Anum, and *Osino* communities is shown in Table 5.2. Iron content ranged from 14-22 mg/kg dry matter basis. *Atimpoku* and *Anum* white *kenkey* recorded 22 mg/kg and 14 mg/kg iron content respectively.

Table 5.2: Mean chemical composition of three types of white *kenkey* (*nsiho*)

<table>
<thead>
<tr>
<th></th>
<th>Iron (mg/kg)</th>
<th>Ash (g/100 g)</th>
<th>Fat (g/100 g)</th>
<th>Protein (g/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anum white <em>kenkey</em></td>
<td>14 ± 0.53a</td>
<td>0.59 ±0.02a</td>
<td>0.15 ± 0.01a</td>
<td>2.84 ± 0.04a</td>
</tr>
<tr>
<td>Atimpoku white</td>
<td>22 ± 1.16b</td>
<td>0.58 ±0.03a</td>
<td>0.09 ± 0.01a</td>
<td>2.45 ±0.12b</td>
</tr>
<tr>
<td><em>kenkey</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet white <em>kenkey</em></td>
<td>19 ± 0.14c</td>
<td>0.11 ±0.05b</td>
<td>0.19 ±0.03b</td>
<td>1.61 ± 0.06c</td>
</tr>
</tbody>
</table>

Mean of duplicate determination. Same superscript letters in a column are not significantly different at \( p \leq 0.05 \)
The iron content is not affected by fermentation unless some salts are added to the product during fermentation or by leaching when the liquid portion is separated from the fermented food. Sometimes, when fermentation is carried out in metal containers, some minerals are solubilised by the fermented product, which may cause an increase in mineral content (Sahlin, 1999). Highly significant differences (p ≤0.05) existed in ash, protein and moisture content of different white kenkey.

Ash content varied from 0.11-0.59 g/100 g. Anum kenkey recorded the highest ash content and Atimpoku kenkey the least. Fat content of sweet white kenkey was 0.19 g/100 g and Atimpoku white kenkey was 0.09 g/100 g. According to Obiri- Danso et al., (1997), ash content of whole grain kenkey varied from 0.5-1.9 g/100 g. Except for sweet kenkey which gave low ash value, other kenkey type’s ash content corresponded with literature range (Obiri- Danso et al., 1997).

The mean protein content of non-sweetened white kenkey samples collected from production sites at Atimpoku was 2.45 g/100 g and from Anum was 2.84 g/100 g. The mean protein content of sweet kenkey collected from production sites at Osino was 1.61 g/100 g. When compared to the protein content of maize kernel of 8-10 g/100 g, the protein content of white kenkey samples was very low. Two reasons will account for this difference. The values reported for the white kenkey samples in the present work are expressed on wet weight basis (as is) and the moisture contents of white kenkey samples are high (ie more than 70% for Atimpoku white kenkey, 76% for Anum white kenkey and 77.5% for Osino sweet kenkey). Since the moisture content of suitably dried maize should be more than 12%, one would expect the protein content of kenkey produced from such maize to be about 50% of the value stated for the maize. Indeed the protein content
of kenkey produced from whole kernels has been reported to be 5.06 g/100 g for Fante kenkey and 5.36 g/100 g for Ga kenkey (Adinsi et al., 2013) on wet weight basis.

The second factor which will account for the low level of protein in the white kenkey samples is due to the use of dehulled maize grains in producing these types of kenkey, which is not rich in protein. The maize kernel consists of an endosperm, a germ and a seed coat. The endosperm constitutes about 80% of the mature kernel dry weight and the germ or embryo and the seed coat or pericarp about 10% of the weight each. In dehulling, the seed coat and the germ are removed and discarded. The endosperm contains mainly starch (87.6% by weight), but contains also about 8% protein. The germ contains mainly fat and protein with fat accounting for about 33.2% and protein about 8% of its dry weight. The seed coat contains mainly fibre (86.7 %, Table 2.1). Thus by discarding part of the germ and the seed coat about 26.7 % of the total protein in the maize kernel is lost. This loss of protein by dehulling and degemring the grains accounts for the lower protein content of kenkey made from dehulled maize grains.

Table 5.3 shows the amino acid profile of the white kenkey types.

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Atimpoku white kenkey</th>
<th>Anum white kenkey</th>
<th>Sweet white kenkey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leucine</td>
<td>1.37</td>
<td>1.02</td>
<td>0.81</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.43</td>
<td>0.31</td>
<td>0.26</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.19</td>
<td>0.19</td>
<td>0.10</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.16</td>
<td>0.19</td>
<td>0.15</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.33</td>
<td>0.26</td>
<td>0.19</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>0.45</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.26</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>Serine</td>
<td>0.21</td>
<td>1.80</td>
<td>0.13</td>
</tr>
<tr>
<td>Glutamique acid</td>
<td>2.03</td>
<td>1.70</td>
<td>1.30</td>
</tr>
<tr>
<td>Glycine</td>
<td>0.24</td>
<td>0.25</td>
<td>0.16</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.91</td>
<td>0.73</td>
<td>0.56</td>
</tr>
</tbody>
</table>
Tyrosine  0.37  0.33  0.41
Gaba  0.00  0.01  0.01
Histidine  0.30  0.28  0.21
Ornitine  0.02  0.00  0.00
Arginine  0.22  0.21  0.14
Proline  1.46  1.16  0.94

In collecting the white *kenkey* samples, it was not possible to ascertain the variety of maize which had been used to produce the white *kenkey*. The amino acid profiles however showed that differences in the mean values for non-sweetened white *kenkey* produced in Atimpoku and Anum and sweet *kenkey* produced at Osino were marginal. The amino acids which were recorded in the lowest concentrations (ie less than 0.2 g/100 g) in all three samples of white *kenkey* were lysine, methionine, Gaba and Ornitine. According to Adinsi *et al.*, (2013), lysine level for Ga and Fante *kenkey* is 0.27 g/100g db.

The levels of some of the most important vitamins assessed for *kenkey* are shown in Table 5.4.

<table>
<thead>
<tr>
<th></th>
<th>Atimpoku White <em>kenkey</em></th>
<th>Anum <em>kenkey</em></th>
<th>Sweet <em>kenkey</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin B1</td>
<td>17</td>
<td>47</td>
<td>36</td>
</tr>
<tr>
<td>Vitamin B3</td>
<td>138</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B6</td>
<td>30</td>
<td></td>
<td>123</td>
</tr>
<tr>
<td>Vitamin B8</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin E</td>
<td>405</td>
<td>404</td>
<td></td>
</tr>
</tbody>
</table>

Anum white *kenkey* recorded high vitamin B1 levels compared to the others. This could be because it is the only type of white *kenkey* for which the dough is further fermented.
during the process. Cereal dough fermentation is known to bring about increased level of vitamins especially vitamin B groups (Adams, 1990). According to Paredes-López and Harry, (1988) and Adams,(1990) the quantity as well as quality of the food proteins as expressed by biological value, and often the content of water soluble vitamins is generally increased. White kenkey value is for example ten folds lower for vitamin B1 than Ga kenkey. This is due to degerming and dehulling during the production of white kenkey, which eliminates a large part of the vitamins which is mainly located in the germ and aleurone layer.

5.10.4 Glucose and lactic acids

The mean values of the concentration of glucose of Atimpoku non-sweetened white kenkey, Anum non-sweetened white kenkey and Osino sweet kenkey were 2 mg/g, 6 mg/g and 28 mg/g respectively, all expressed on dry matter basis. The very high concentration of glucose in the sweet kenkey was due to the addition of table sugar (sucrose) to the dough during mixing of precooked dough (aflata) with the raw dough. The sucrose is hydrolysed to glucose and fructose. With respect to the non-sweetened white kenkey samples, Atimpoku white kenkey recorded a lower level of glucose because it had been fermented for a shorter period than the Anum kenkey. In addition to steeping, Anum processors ferment the dough obtained after milling whilst Atimpoku processors do not. This may have caused a more extended conversion of glucose in the Anum samples than in the Atimpoku samples though the results of lactic acid concentration did not support this. The mean concentration of lactic acid in white kenkey samples for both areas was 2 mg/g and 0.6 mg/g for the sweet kenkey from Osino.
5.10.5 Colour of white Kenkey

All three types of white kenkey were whitish in colour as shown in Table 5.5. This could be attributed to the dehulling of the maize grains which removes the yellowish fibrous seed coat and also the slightly yellowish germ.

<table>
<thead>
<tr>
<th>Sample</th>
<th>L</th>
<th>a</th>
<th>b</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atimpoku white kenkey</td>
<td>82 ± 1.13a</td>
<td>0.02 ± 1.82a</td>
<td>6.71 ± 2.04a</td>
<td>17</td>
</tr>
<tr>
<td>Anum white kenkey</td>
<td>82 ± 0.64a</td>
<td>-0.93 ± 0.38b</td>
<td>6.74 ± 1.78a</td>
<td>16</td>
</tr>
<tr>
<td>Sweet white kenkey</td>
<td>78 ± 2.41b</td>
<td>-0.72 ± 1.24c</td>
<td>8.67 ± 1.24b</td>
<td>21</td>
</tr>
</tbody>
</table>

Values are means of five determinations. Same letters superscripts in a column are not significantly different at p ≤0.05

The results show that the non-sweetened white kenkey samples from Atimpoku and Anum both of which had an L-value of 82 were whiter than the sweet kenkey. All the three types of kenkey had been produced from dehulled maize grains. However, whilst the Atimpoku and Anum white kenkey had been wrapped/packaged and steamed in the brownish yellowish dried maize husks, the sweet kenkey had been wrapped and steamed in fresh greenish M. cuspidata leaves called aworum in the local dialect. Sweet kenkey recorded the highest negative a value. Steaming in the green leaves impacted slightly darker colour to the white kenkey than steaming in the dried maize husks.

The E values which record the difference between the deviations in whiteness of a product compared to a standard white colour confirmed that the sweet kenkey with the higher E value was less white than the non-sweetened white kenkey samples. Studies by Nago et al., (1998), indicated that Beninese ogi had a high luminosity L and a low E (total colour difference with standard white tile).
5.10.6 Stress Relaxation of traditional white kenkey

Texture can be related to the deformation, disintegration and flow of food when a force is applied (Bourne, 2002). Kenkey has rheological properties that are partly viscous and partly elastic. When a force is applied to such viscoelastic material, it does not instantaneously take up its new dimensions as purely elastic material (would) it takes some finite time. In addition, when the force is removed the material does not return instantaneously to its non-deformed state, and may even remain permanently deformed (Steffe, 1996). Transient (eg stress relaxation) and dynamic measurements (creep compliance, dynamic mechanical analysis) are used to characterize the viscoelastic properties of such foods, using simple shear, simple compression or bulk compression tests. In stress relaxation a constant strain is applied and the change in the stress with time is measured.

Stress relaxation parameters were summarized into firmness and elasticity values (or viscous and elastic components) and are given in Table 5.6.

Table 5.6: Textural parameters of traditional white kenkey samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Firmness (g)</th>
<th>Elasticity (g.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anum white kenkey</td>
<td>182.30 ± 24.65a</td>
<td>12.90 ± 2.35a</td>
</tr>
<tr>
<td>Atimpoku white kenkey</td>
<td>157.42 ± 33.93b</td>
<td>10.98 ± 0.92b</td>
</tr>
<tr>
<td>Sweet white kenkey</td>
<td>124.27 ± 7.58c</td>
<td>3.95 ± 1.38c</td>
</tr>
</tbody>
</table>

Values are means of ten determination ± standard deviation. Means with different superscript letters within a column are significantly different at p ≤ 0.05

There were differences in the texture measurements between the non-sweetened white kenkey samples produced by the Atimpoku method and those produced by the Anum method. There was significant variation (p<0.05) in the values recorded for firmness and
elasticity between the two samples sites (Table 5.6). This was because one involved a procedure which is often described as aflatalization where aflata (gelatinized dough) is mixed with the raw dough (Anum) whilst the other (Atimpoku) did not. Mixing of aflata with raw dough is an elaborate procedure which is used in the production of Ga and Fante kenkey. It involves precooking part of fermented maize dough into aflata which is then mixed with the remaining uncooked fermented dough before packaging and cooking.

The aflatalization process has been reported by several authors to result in the characteristic texture of kenkey which is related to its elasticity (Halm et al., 2004, Sefa-Dedeh, 1993, Nche et al., 1996). The Anum white kenkey process involved aflatalization whilst the Atimpoku process did not. The measured textural characteristics were significantly different. The mean value for firmness was 182.30 g and 157.42 g for Anum and Atimpoku kenkey respectively. Results indicated that firmness increased with raw dough addition. The mean value for the elasticity of Anum samples was 12.90 g.s and that of the Atimpoku samples 10.98 g.s.

The value for firmness and elasticity for sweet kenkey were significantly different (p<0.05) from the values for Anum and Atimpoku non-sweetened white kenkey samples. The value for each of these parameters was much lower in sweet kenkey than the values recorded for the non-sweetened white kenkey samples. Incidentally, production of Osino sweet kenkey also involves aflatalization yet it was much less stickier than even the Atimpoku non-sweetened white kenkey which did not include an aflatalization process. The reason for the lower textural values could be attributed to the effect of adding substantial amount of water and table sugar to sweet kenkey during processing. The sugar acts as a humectant and absorbs more water which makes the product very soft. Sugar
influences the gelatinization temperature during gelatinization as a result the peak viscosity of the sweet kenkey is lowered. This makes the sweet kenkey have a flowing behavior.

5.10.7 Microstructure of maize during processing into white kenkey

Scanning electron microscopy (SEM) is commonly used to evaluate and characterize the internal structure of food materials. Many authors have used SEM to describe starch granule morphology and the structural arrangement of the endosperm and to analyze the effect of certain treatments on starch granules (Fannon et al., 1992; McDonough et al., 1997; Raeker et al., 1998; Sarpistein and Kohler 1999; Lauro et al., 2000; McPherson and Jane, 2000; Perera et al., 2001; Naito et al., 2004; Wilson and Betchel 2004). The typical maize (Zea mays L.) kernel is made up of three main structural parts: pericarp, germ, and endosperm (Wolf et al., 1952).

Dehulling removes the pericarp and germ from endosperm (Lin et al., 2002), which is composed of two zones. The hard or vitreous starch zone and the soft or floury starch zone (Hoseney 1998). The properties of the starch granules in the two zones of endosperm are quite different (Cagampang and Kirleis 1985) and the anatomical proportions determine the functionality and end use of the type of maize. The microstructural features of dehulled maize flour are shown in Figures 5.2 A and B. The figures show that the maize starches are smooth and round granules clustered together. In dehulled maize grain the hull and germ are removed and it consists mainly of the endosperm. The endosperm makes up about 80% of the total weight of the kernel and consists largely of smooth starch granules held together by a protein matrix (Figure 5.2 C).
5.2 A: Dehulled, steeped maize flour (magnifications: 400x)

5.2B: Dehulled steeped maize flour (magnifications: 800x)
5.10.7.1 Effect of processing treatments on microstructure

5.10.7.1.1 Fermentation

In the production of white kenkey two different procedures were observed. In one instance at Atimpoku area, the dehulled maize, after steeping was milled into a smooth meal which was made into a slurry and cooked into a thick viscous aflata. In another procedure, at Anum area the smooth meal was made into a dough and left to undergo spontaneous fermentation for about 12 hours. Thereafter, a portion of the dough was slurried in water and cooked to obtain a viscous starch paste, called aflata. The aflata was then thoroughly mixed with the non-cooked portion, and then molded into balls, wrapped in maize husks and then steam cooked to obtain white kenkey (nsiho). Figures 5.3A and B show the microstructure of the fermented maize dough at different magnifications. Fermentation for 12 hours showed very little influence on the starch granules in the dough as they were still intact, smooth spherical granules.
Figure 5.3A: 12-hour fermented maize dough (magnifications: 1500x)

Figure 5.3B: 12-hour fermented maize dough (magnifications: 3000x)
**5.10.7.1.2: Effect of pre-cooking on microstructure**

It has been well established that native, raw starch has very little interaction with cold water. In heating a suspension of starch in water, the interaction of starch with the water is minimal as the temperature increases until a critical temperature known as the gelatinization or pasting temperature is reached. At that temperature, the starch granules swell rapidly and absorb several times its volume of water. Thus, in cooking starchy pastes, this phenomenon occurs, in which the starch granules absorb water, and the amylose molecules leach out of the starch granules as they swell.

Figures 5.4A and B show that in the dough that was fermented, there was extensive transformation of the starch granules in the cooked dough, with very few starch granules remaining intact. On the other hand, even though cooking of the partially-fermented dough also showed modification of the starch granules, their transformation was not as extensive (Figure 5.5A, B and C) as was observed in the cooked fermented maize dough. The cooked partially fermented maize dough still had non-gelatinized starches, that remained intact and granular. The difference between the microstructure of the fermented cooked dehulled maize dough and the partially fermented cooked dough could be that fermentation, even for 12 hours substantially loosened the structure of the starch granules such that they were more easily transformed by heat during cooking.

Another reason could be that the processors of the fermented maize dough method probably employed a more severe cooking method than the processors of the partially-fermented procedure. It was also observed that apart from having more visible intact starch granules, the cooked partially fermented dough also had larger air cells and voids than the cooked fermented dough.
Figure 5.4 A&B: Micrographs of cooked fermented maize dough (*aflata*) for Anum white *kenkey* at (A) low magnification and (B) High magnification, showing extensive starch transformation.
Figure 5.5A &B: Micrographs of cooked partially-fermented maize dough (*aflata*) for Atimpoku white *kenkey*, showing some intact starch granules that were not transformed during cooking of the *aflata*. 
5.10.7.1.3 Microstructure of mixture of cooked and non-cooked maize dough

One of the critical unit operations for many types of kenkey is that a portion of the dough is slurried in water and cooked to form a viscous paste called aflata. While still hot, it is thoroughly mixed with the non cooked dough to form a thick gelatinous paste which is molded, wrapped in maize sheaths and then steam cooked to obtain the final product. It has been suggested that mixing the cooked dough with the non-cooked portion is critical for the unique texture of the types of kenkey for which it is employed.

Figures 5.6A & B show the microstructure of the mixtures of cooked and non-cooked maize dough, obtained from commercial white kenkey processors. Compared to the micrographs of the cooked fermented dough (aflata), the microstructure of the mixed dough shows several intact starch granules imbeded in a mass of gelatinized starch paste. The microstructure shown in the figures confirm the suggestion by other researchers that
Figure 5.6 A&B: Microstructure of mixture of aflata and non-cooked maize dough for Anum white kenkey at low (A) and high (B) magnifications. They show intact starch granules that largely originate from raw dough, imbeded in the cooked starch paste.

The cooked maize dough (aflata) serves as a binding agent when it is subsequently mixed with the non-cooked dough (Sefa-Dedeh and Plange, 1989, Nche et al., 1996). The aflata holds the non-cooked dough together and allows for easy shaping and wrapping (Nout et al., 1996).

5.10.7.1.4 Microstructure of kenkey types

Figures 5.7, 5.8 and 5.9 show the microstructure of the three white kenkey types:
Figure 5.7: Microstructure of non-sweetened white kenkey (nsiho) from (A) Anum and (B) Atimpoku.

Anum (which goes through a fermentation stage and a mixed aflata–raw dough intermediate) Atimpoku white kenkey that is made from fully cooked aflata without mixing with raw dough, and the sweetened white kenkey that is made from a mixed aflata with raw dough in equal proportions. White kenkey from Anum is processed by fermenting dehulled maize dough, cooking a portion of it into aflata and mixing with the rest of the non-cooked dough. When molded and steam cooked to obtain white kenkey, it shows a porous microstructure with relatively small air cells, and thin cell walls (Figure
5.7A). The microstructure of Anum white kenkey is probably influenced by the fermentation stage of the dough. Fermentation for 12 hours probably loosened the starch structure and heat treatment probably completely transforming the starches into paste. Consequently, there were no visible starch granules in the micrograph of the Anum white kenkey.

On the other hand, the micrograph of white kenkey from Atimpoku showed relatively large cells, with thicker walls (Figure 5.7 B). This type of white kenkey was processed without fermenting the dough, and the cooked maize dough (aflata) was also not mixed with raw maize dough. Consequently the microstructure of the kenkey made using this process seemed to be firmer than the kenkey produced using the fermentation and mixing procedure.

5.10.7.1 Microstructure of Sweetened white kenkey

Sweetened white kenkey is made by cooking non fermented maize dough into aflata, mixing with raw dough, molding and wrapping the aflata in broad leaves and then steam cooking to obtain the final product. Sugar is usually added to the maize dough before steaming, in order to sweeten the final product. The microstructure of sweetened white kenkey (from Osino) showed long and narrow (or collapsed) air cells with thinner walls reflecting the softer and relatively fluid nature of the cooked starch paste (Figure 5.8).
Figure 5.8: Microstructure of sweetened white kenkey, showing cooked paste with elongated and collapsed cells due to a relatively soft paste. There were no visible starch granules.

There were no visible starch granules, indicating that they were completely transformed into a cooked paste. The presence of sugar during cooking of the starch is known to influence the gelatinization process and has implications on the microstructure and viscosity of the paste. The sugar being a humectant competes for water and consequently the starch granules may not swell as much as they should (Bean and Osman, 1959).

The sugar decreased the viscosity and the strength of the cooled paste (Bean and Osman, 1959). Table 5.6 in section 5.9.6 showed that the firmness of the sweetened kenkey was the lowest among the three types of kenkey, as it recorded a firmness value of 124.27 g which was significantly lower than that recorded for the non-sweetened white kenkey types.
5.11 Conclusion

The white kenkey types are all prepared using steeped dehulled maize. As a result, they had a relatively high lightness value in color, and the proximate compositions showed them to be lower in protein, fat, ash and iron content as compared to non dehulled maize. The white kenkey types are high moisture and relatively low acid foods, that might not store for long times at ambient conditions as they may easily be susceptible to mold spoilage. White kenkey types that were processed using a fermentation step showed higher vitamins B1 content, but the amino acid profile was not different than those that did not go through fermentation.

The sweetened white kenkey were weaker in textural hardness, and not as sticky and adhesive as the non-sweetened white kenkey types. Fermentation tended to increase the stickiness and adhesiveness of non-sweetened white kenkey. The microstructural studies showed that the white kenkey types were basically pastes of completely gelatinized starches. Both the textural and microstructural characteristics were influenced by the precooking (aflata) method, mixing of raw dough with aflata, and the addition of sugar as a sweetener.
CHAPTER 6

OBJECTIVE 4: To evaluate the effect of unit operations in the production of white kenkey (nsiho) and determine the drivers for consumer acceptability.

6.0 Introduction

Kenkey is a popular Ghanaian staple that is produced using fermented maize dough as the main ingredient. During the traditional kenkey production, (Muller and Nyarko-Mensah, 1972, Nche et al, 1994) whole maize is soaked for 1–2 days at ambient temperature (25–30 °C), milled and made into a dough (moisture content approx. 500 g/kg dry matter), which is then allowed to ferment spontaneously at ambient temperature for several days. In the further processing of kenkey, part of the fermented dough is slurried in water and cooked into a thick and sticky paste, called aflata. Critical to the quality of Ga-kenkey is its texture. The ratio of aflata mixed with uncooked fermented maize dough influences the texture and sensory acceptability of kenkey. In a sensory evaluation of the texture of kenkey, Bediako-Amoa (1976) observed that the highest score was obtained for kenkey prepared from a mixture of equal proportions of aflata and the uncooked dough. Good Ga-kenkey is neither too sticky nor crumbly (Sefa-Dedeh and Plange, 1989).

The process of kenkey-making is lengthy and laborious and is based on traditional technologies. Consequently, inspite of its popularity kenkey is mostly purchased from artisanal commercial processors, rather than in the home kitchen. Several studies have been carried out to upgrade and mechanize some of the unit operations involved in the production of kenkey in order to make the process less tedious, faster and of more consistent and predictable product quality. It has been shown that some aspects of the kenkey process can be upgraded by shortening the fermentation period using an
accelerated fermentation process (Nche et al., 1994) or reducing physical labour by using pre-cooked dehydrated kenkey mixes (Nche et al., 1996; Nout et al., 1996). Nout et al., (1996), concluded that the traditional 4-6 days required for the kenkey manufacturing procedure can be shortened to 24 hours by a combination of reducing steeping time of maize by using pre-cracked maize kernels, using starter dough in a dough-aflata mixture, and by cooking in sausage casings (Nout et al., 1996). Nche et al., (1994) and Bediako-Amoa and Austin, (1976), attempted to reduce process time, by omitting the maize steeping step and substituting it with a lactic starter-fermentation of a suspension of dry-milled flour. An accelerated procedure for industrial production of kenkey flour was developed by inoculating dry-milled maize flour with dough containing an enrichment of lactic acid bacteria (Nche et al. 1994). This was done to accomplish fermentation and obtain the required level of acidification within 24 hr of incubation at 30°C.

The production process of white kenkey is in several ways similar to the traditional Ga and Fante kenkey, except that dehulled maize is used instead of whole maize. Furthermore the maize dough fermentation is limited and does not extend beyond 12 hours. In some cases, the white kenkey production process may or may not include mixing of cooked dough with non cooked dough as a unit operation. The objectives of this study were to evaluate the unit operations of the white kenkey (nsiho) process and to determine their effects on physicochemical characteristics, texture and consumer acceptance of white kenkey (nsiho).
6.1 Materials and methods

Two types of white kenkey are commonly recognized in Ghana, namely, the partially fermented type in which steeping is the only means of fermentation (from Atimpoku) and the further fermented type (from Anum), where there is fermentation of dough apart from steeping stage. Apart from the fermentation operation that distinguishes between the two types of kenkey, another critical unit operation that sets them apart is the mixing of raw non-cooked dough with hot, cooked aflata, for the further fermented white kenkey type (obtainable from Anum). In this study, the unit operations of both types were evaluated using a factorial experimental design approach. For the further fermented white kenkey type (Anum) in which raw and cooked dough are mixed as a unit operation, the effects of the proportion of aflata to raw dough on the textural characteristics and consumer acceptability were also evaluated. The desired level of lactic acid and sucrose desired in the partially fermented kenkey type (Atimpoku) was evaluated using consumer acceptability test.

6.1.1 White kenkey production (traditional method)

One hundred kilograms (100kg) of clean, sound maize (abileehi) was obtained from the open market and dehulled using an Engelberg mill (Engelberg Ltd., Doncaster, U.K.). Two kilogram (2kg) each of the dehulled maize grains were washed thoroughly and steeped in clean water at room temperature (30 °C) for three time periods (12, 30 and 48 hours). At the end of each steeping period the dehulled maize grains were drained, washed, and milled using a mini disc attrition mill (Disc Attrition Mill, Rajan Universal, and Chennai, India). The dehulled maize meal obtained was divided into two portions. One portion was made into slurry by adding water in a ratio of 1:1. The slurry was cooked into a thick paste and moulded into balls of about 300 g each. The balls were
wrapped in maize husks and steamed to obtain the partially-fermented type (Atimpoku) white kenkey using a steam cooker (Philips HD9120, Philips Viva collection, Dampfgarer, the Netherlands).

Sufficient water was mixed with the other portion of the dehulled maize meal and kneaded into dough of about 40-45% moisture content. The maize dough was divided into two portions and allowed to ferment spontaneously for 12 and 24 hours respectively. At the end of the fermentation period about 70% of the weight of the dough was cooked into aflata, and while still hot it was mixed with the rest of the non-cooked dough to form a thick gelatinous paste. The thick paste was moulded into balls, wrapped with maize husks and steamed into further fermented white kenkey (as commonly found in Anum).

The flow chart for the procedures described is shown in Figure 6.1. The experiment was carried out in triplicate and samples analyzed included steeped grains, the maize meal from steeped grains, fermented dough and white kenkey. The indices that were monitored to determine the effects of treatments (steeping and fermentation time) on the process and product characteristics included grain moisture content after steeping, water absorption rate of grains, dough pH and titratable acidity, glucose and lactic acid of dough and kenkey, texture and consumer acceptability of white kenkey.
Figure 6.1: Flow diagram for white kenkey experimental treatments
6.1.2 Analytical Methods

6.1.2.1 Determination of moisture content

Moisture content of the products were determined using the air-oven method at 105°C as described in the AACC Method 44-15, (2000). The moisture content was determined as loss in moisture using the following equation:

\[
\% \text{ Moisture} = \frac{A}{B} \times 100
\]

In which \(A\) = loss in sample weight in grams, \(B\) = original weight of sample.

6.1.2.2 Determination of pH

The pH was measured directly using a pH meter (Research pH meter, 3330, Jenway, UK) equipped with a glass electrode (Orion 9102, Orion Research, and Boston, MA, USA), after calibration using standard buffer solutions (Merck) at pH 4.0 and 7.0 at ambient temperature. The pH was determined for dough and kenkey samples. The sample was blended with an equal volume of distilled water in a stomacher (AACC method 02-52, 2000).

6.1.2.3 Titratable acidity

Ten grams (10g) of sample was dispersed into 20 ml of distilled water and homogenized for 2 min using a magnetic agitator. The electrode of the pH meter was placed into the sample solution and the pH was read after 1 min. 70 ml of distilled water was added to the sample solution and freshly prepared 0.1N sodium hydroxide was added whiles agitating to continue neutralization until a pH of 8.5 was reached. After 5 min, the pH was adjusted to 8.5 and the final amount of sodium hydroxide used was read (AACC method 02-52, 2000).

The results were expressed as follows;
% lactic acid = V X 900 X N/ (M x ms)

V = volume of titrant (ml)
N = normality of soda
M = mass of sample (g)
Ms = Dry matter (% dry basis)

6.1.2.4 Wet particle size distribution

Fifty grams (50 g) of dehulled maize dough obtained from (2 h, 8h, 16h, 24h, 30 h and 48 h) steeped dehulled maize grains at 35°C were sieved using sieve shaker (Meinzer 11 sieve shaker, 0610-03, UK). The sieves were stacked coarsest to finest mesh. Mesh size of sieves were 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and <0.125 mm. Sample was placed on the top sieve and washed down manually using distilled water. The sieve stack was gradually disassembled; each sieve was washed with water until no more solid material passed through the sieve. The contents of each sieve were quantitatively washed off into a container. The water was evaporated in an oven at 105°C for 12-24 hours in Grant Oven (GmbH+ co. KG, Germany) and the dried residue cooled in a desiccator and weighed. Dry matter of the sample was determined as follows:

Dry material (g) = wet material (50g) × Dry matter content (% wet basis)/100

The percentage of overs was calculated for each sieve as:

Overs (%) = 100 × (W2 - W1)/Dry material

Where W2, is the weight of container plus dried overs and W1, is the weight of the empty container.
The residue in the collector was calculated as follows: Where $W_2$, is the weight of container plus dried overs and $W_1$, is the weight of the empty container (AACC method 55-30.01, 2000).

\[
\text{Collector} (\%) = 100 - \sum_{\text{Sieve} 1}^{\text{Sieve} n} \text{Overs} (\%)
\]

6.1.2.5 Rates of water uptake and leaching of solids during steeping.

Dehulled maize grains (250 g) were soaked in 350 ml of distilled water at 35ºC for 2h, 8h, 16h, 24h, 30h and 48h. Samples of maize steep water (1.5 ml) were collected in 4 replicates into vials at the end of each steeping time and stored at -20ºC until analysis. The moisture content of the grains at each steeping time was determined. Proteins and sugars were determined in the steep water.

6.1.2.6 Protein determination in steep water using Bradford Reagent

Protein solution (Bovine Serum Albumin (BSA) containing 10 to 100 microgram protein was made up to a volume of 0.1 ml and was pipetted into 12 x 100 mm test tubes. The volume in the test tube was adjusted to 0.1 ml with appropriate buffer. Five milliliters of protein reagent was added to the test tube and the contents mixed either by inversion or vortexing. The absorbance at 595 nm was measured after 2min using T80+ UV/VIS spectrophotometer (PG Instruments Ltd, UK) and before 1 hr in 3 ml cuvettes against a reagent blank prepared from 0.1 ml of the appropriate buffer and 5 ml of protein reagent. The weight of protein was plotted against the corresponding absorbance resulting in a standard curve used to determine the protein in unknown samples.
Protein solution containing 1 to 10 µg protein was made up to a volume of 0.1 ml and was pipetted into 12 x 100 mm test tubes. The volume of the test tubes was adjusted to 0.1 ml with the appropriate buffer. One milliliter of protein reagent was added to the test tube and the contents mixed as in the standard method. Absorbance at 595 nm was measured as in the standard method except in 1 ml cuvettes against a reagent blank prepared from 0.1 ml of the appropriate buffer and 1 ml of protein reagent. Standard curves were prepared and used as in the standard method. Protein concentrations in the extracted samples were determined from the standard curve and results expressed in mg/ml (Kruger, 2002).

6.1.2.7 Determination of organic acids and sugars by HPLC

Glucose and Lactic acids were determined using High Performance Liquid Chromatography (HPLC 360 Auto sampler (Shimadzu LC-9A), as described by Mestres and Rouau, (1997).

One gram of sample was weighed with a screw-capped tube and 3 ml of 0.5 M H₂SO₄ was added. This content was homogenized using a Rotator, SB2, Stuart (Bibby Scientific Ltd, Staffordshire, UK) for an hour. The mixture was centrifuged (Centrifuge 1207, VWR International LLC, West Chester, United States) at 7.2 ×1000 g for 5 min. The supernatant was filtered into an HPLC sample vial through a 0.45-µm RC filter (Minisart, R.C 15 17762, Sartorius AG, 37070, Germany). Separation of organic acids was achieved with an Aminex HPX-87H HPLC column (Bio-Rad Labs., Richmond, Calif., USA) held at 45°C, using 9 mM H₂SO₄ as a mobile phase at a flow rate of 0.4 mL/min. UV detector (Series 200, Perkin Elmer) response was monitored by Turbochrom software (Perkin Elmer).
Organic acids were identified and quantified by comparison of their retention times with the following standard acids: -lactic acid, acetic acid, maltose, glucose, fructose, (Sigma). The analysis was externally calibrated using mixed standard solutions in de-ionized water, prepared for the samples. Concentrations of glucose, fructose, and maltose were monitored using a refractive index detector (Perkin Elmer) in series with the UV detector and calibrated using standard sugar solutions (Sigma).

6.1.2.8 Texture measurements

For determination of texture using the TA-XT2 Texture Analyzer, 50 g of paste obtained from maize meal or fermented dough to be cooked into white kenkey was packed into 10 different 28cm diameter cylindrical silicon moulds and steamed for 30 min into white kenkey using a steam cooker, (Philips HD9120 steam cooker, Philips Viva collection, Dampfgarer, the Netherlands). The sample was then covered with cling film to prevent dehydration and cooled for one hour. The top portion of the kenkey was cut and sample turned upside down.

Texture was measured using a penetrometer probe of 6 mm diameter at two points per sample using a TA-XT2 Texture Analyzer (Stable Microsystems, Surrey, England) equipped with 25kg load cell. A compression and withdrawal test was performed using the following conditions: pre-test speed 2mm/s, trigger force of 5g, test speed 1 mm/s, 20% strain, holding time of 10sec, post- test speed of 1 mm/s (Fizman and Damasio, 2000).
6.1.2.9 Colour Determination

The colour of maize dough and white kenkey samples were measured using a colorimeter (Minolta Chromameter, CR310-Japan Colorimeter D25-PC2, National Institute of Aglaboratories, Reston, VA) which was calibrated with a white tile (L=97.51, a=5.45, b=-3.50) according to (AACC method 14-22.01, 2000).

The colour was expressed in terms of lightness (L) and colour difference (ΔE). (ΔE) was calculated as \((\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}\) where \(L\) = lightness; \(a (+) = \text{red} \ a (-) = \text{green}\); \(b (+) = \text{yellow} \ b (-) = \text{blue}\) colour value. The colour of each sample was measured five times, and the mean calculated.

6.2 Effects of aflata to raw dough ratio on texture and consumer acceptance of white kenkey

6.2.1 Kenkey Preparation (Experimental)

Maize grain (1.5 kg) was washed thoroughly and steeped in water (1:2) w/v for 30 h. Grains were washed after steeping and milled using mini disc attrition mill (Disc Attrition Mill, Rajan Universal, and Chennai, India). Water was added to meal in 1:2 w/w. Kneaded dough obtained was fermented for 12 hours at ambient temperature (25-30°C). Fermented dehulled maize dough (800 g) was mixed with 400 g water, and 8 g of salt was added to the slurry. It was cooked for 10 min to obtain a pre-cooked, thick gelatinous paste traditionally called aflata. The aflata was mixed with raw dehulled maize dough in four levels (or proportions) of % aflata:% raw dough: 100:0, 66:34, 50:50, and 33 :67 (w/w). 100% aflata: 0% dehulled maize dough is used for Atimpoku process, 66% aflata:33% dehulled dough is used for Anum process, 50% aflata: 50% dehulled dough is used for sweet kenkey and Ga kenkey process and 33% aflata: 66%
dehulled dough is used by Fante kenkey process. The mixtures were moulded into 28 cm diameter cylindrical silicon moulds and steamed for 15 min, 30 min and 45 min using Philips steam cooker HD9120, (Philips Viva collection Dampfgarer, Netherlands).

Samples were left to cool for an hour after steaming and covered with cling film to prevent dehydration. The top portion of the kenkey was cut and the sample turned upside down. Texture was measured using a penetrometer probe of 6 mm diameter at two points per sample using a TA-XT2 Texture Analyzer (Stable Microsystems, Surrey, England) equipped with 25 kg load cell. A compression and withdrawal test was performed using the following conditions: pre-test speed 2mm/s, trigger force of 5g, test speed 1 mm/s, 20% strain, holding time of 10sec, post- test speed of 1 mm/s (Fizman and Damasio, 2000). Hardness value was measured as the peak force of the product and stickiness was evaluated by the area of the negative curve during compression. Texture data for each treatment was taken in ten replicates.

6.2.2 Consumer acceptability of white kenkey

White kenkey samples were prepared using 4 different levels of aflato (100% , 66% ,50% and 33% aflato), and 2 steaming times of 15 min and 45 min respectively to obtain a total of 8 samples for consumer analyses. Consumers (95) consisting of 37 females and 58 males, with 20-59 age range were used for the study. The consumers were selected according to criteria of familiarity with the product. The consumer tests were carried out in the Sensory Science Laboratory of the CSIR-Food Research Institute and the Research Laboratory of the Department of Nutrition and Food Science at the University of Ghana, Legon.
The samples were evaluated on a nine-point hedonic scale (1- dislike extremely, 5- neither like nor dislike and 9- like extremely) as suggested by Tomlins et al., (2005), Meilgaard et al., (1988), based on the attributes of taste, texture and overall acceptability. To avoid any changes in the sensory properties of white kenkey during the session, all samples were not cooked at once, but one at a time, so that each of them experienced the same time–temperature history prior to consumer assessment. All the eight white kenkey samples were presented randomly on white plates labelled with three random digits codes. The samples were presented simultaneously to each consumer. Consumers were offered mineral water to rinse their mouths between samples.

6.3 Determination of the optimal levels for the ratio of sugar and acid in white kenkey

Dehulled maize grains (3000 g) were steeped in 5000 ml of water for 48 h at 30°C and milled in a Disc Attrition Mill, (Rajan Universal, and Chennai, India). Different concentration of table salt and food grade lactic acid (Kosher, 85% FCC- W261106-1KG-K, Spain) were added to the maize meal and cooked into stiff porridge(aflata) based on the runs shown in Table 6.1.

Table 6.1: Full factorial plan used in spiking experiment which involved two factors and two levels with a central points based on (%) dry basis

<table>
<thead>
<tr>
<th>Runs</th>
<th>Samples</th>
<th>Lactic acid levels (%)</th>
<th>Sucrose levels (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1LA0.5S</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>1LA5S</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>3centre</td>
<td>0.6LA2.75S</td>
<td>0.60</td>
<td>2.75</td>
</tr>
<tr>
<td>4</td>
<td>0.2LA0.5S</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>5</td>
<td>0.2LA5S</td>
<td>0.20</td>
<td>5.00</td>
</tr>
<tr>
<td>6</td>
<td>0.6LA2.75S</td>
<td>0.60</td>
<td>2.75</td>
</tr>
</tbody>
</table>

LA-Lactic acid, S- Sucrose
The levels were based on HPLC determination of organic acids. Table sugar was used instead of glucose because their sweetness levels were comparable. The aflata obtained was molded and packaged into maize husk and steamed for 30 mins into white kenkey (nsiho).

6.3.1 Consumer acceptability of spiked white kenkey
Consumer acceptance test of spiked white kenkey samples were carried out using 75 consumers recruited from CSIR-Food Research Institute. All consumers selected were age between 18 and 65 years, had no known food allergies and consumed kenkey at least twice in a week. Each of the consumers was served with 4g slice each of six samples of spiked white kenkey coded with 3-digit random numbers. The samples were evaluated for taste, odour and overall acceptability using a 9-point hedonic scale, ranging from 1 (dislike extremely) to 9 (like extremely). Consumers were served with water and cream crackers to rinse their mouth between samples to minimize any residual effect (Meilgaard et al., 2006).

6.3.2 Ethical clearance and consumer consent
This research was assessed and approved by the CSIR (Council for Scientific and Industrial Research - Institutional Review Board. Consent was sought from consumers participating in this study and they were told that their participation was entirely voluntary and that they could withdraw from the panel at any time.
6.4 Statistical analysis

XLSTAT (V. 5.2) 2012, (Addinsoft, Paris, France and Minitab 14, Minitab Inc, Brandon Court, United Kingdom) were used for statistical analysis in this study. Methods applied were analysis of variance (ANOVA), multivariate analysis using Principal Component Analysis (PCA) based on the correlation matrix to determine which white kenkey samples contributed most to drawing distinctions within the data sets. Cluster analysis (agglomerative hierarchical cluster, Euclidean distance and Ward’s method) were used.

The data were analyzed using Mintab Release 14 statistical software (Minitab Inc, Brandon Court, United Kingdom). Analysis of variance (ANOVA, alpha=0.05) and Duncan multiple range test were performed to determine significant differences between means.

6.5 Results and Discussions.

6.5.1: Effects of steeping and fermentation times on steep water, grain and dough characteristics

6.5.2 Rate of water uptake by dehulled grains during steeping.

Steeping is an important unit operation that prepares grains for further processing and the hydration rates vary for different cereal grains. Consequently water hydration data in the form of water content versus steeping time have been fitted and interpreted by different mathematical models based on diffusion theories. Becker, (1960) performed a quantitative analysis of water uptake by wheat grain employing a simplified solution of Fick’s diffusion equation, and Turhan et al.,(2002) applied Peleg’s model to study water absorption in chickpea during soaking. Figure 6.2 shows the hydration rate of dehulled maize grains at room temperature (35°C). It is observed that the hydration rate was faster
before 5 hours of steeping but thereafter the level of moisture decreased. Plateau is formed by the 8-10 hour of steeping because the grains were highly hydrated at that time.

Figure 6.2 Hydration rate of steeping dehulled maize grains at 35°C

6.5.3 Metabolites release during steeping of dehulled maize grains.

Water soluble protein diffusion rate into the steep water during steeping of dehulled maize grains at 35 °C is shown in Figure 6.3.
Figure 6.3: Changes in the protein content of steep water during steeping of dehulled maize grains at 35 °C

The graph shows that protein content of the steep water remained fairly constant for the first 10 hours of steeping of the dehulled maize grains, but thereafter there was a rapid increase in protein content in the steep water with increasing steeping time. The protein content of the steep water after 48 hours of steeping almost doubled to 1.97 mg/ml as compared to 1 mg/ml for 4 and 8 hours of steeping. The increased protein content is due to microbial proliferation.

Simple carbohydrates and organic acids obtained from the steep water at different steeping times at 35°C are given in Table 6.2. While there was depletion of simple sugars
Table 6.2: Profile of simple sugars (mg/ml), organic acids (mg/ml) and ethanol (mg/ml) in the steep water of dehulled maize grains at 35°C

<table>
<thead>
<tr>
<th>Steeping time (h)</th>
<th>Maltotriose (mg/ml)</th>
<th>Maltose (mg/ml)</th>
<th>Glucose (mg/ml)</th>
<th>Fructose (mg/ml)</th>
<th>Lactic acid (mg/ml)</th>
<th>Acetic acid (mg/ml)</th>
<th>Ethanol (mg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.06</td>
<td>0.06</td>
<td>0.61 ± 0.06</td>
<td>0.21</td>
<td>-</td>
<td>0.11 ± 4x10^{-3}</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>0.79</td>
<td>1.22 ± 0.04</td>
<td>0.30 ± 6x10^{-3}</td>
<td>0.06</td>
<td>0.11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>0.19</td>
<td>0.84 ± 0.38</td>
<td>0.41 ± 4.0x10^{-2}</td>
<td>0.88 ± 0.28</td>
<td>0.15 ± 4.75x10^{-2}</td>
<td>0.47 ± 0.18</td>
</tr>
<tr>
<td>16</td>
<td>-</td>
<td>0.16</td>
<td>2.60 ± 1.82</td>
<td>0.72 ± 0.14</td>
<td>0.96 ± 0.76</td>
<td>0.20 ± 9.9x10^{-2}</td>
<td>0.67</td>
</tr>
<tr>
<td>24</td>
<td>-</td>
<td>-</td>
<td>0.17 ± 0.12</td>
<td>0.35 ± 0.18</td>
<td>1.85 ± 0.06</td>
<td>0.26 ± 1.6x10^{-2}</td>
<td>0.97 ± 6.7x10^{-2}</td>
</tr>
<tr>
<td>30</td>
<td>-</td>
<td>-</td>
<td>0.08</td>
<td>0.15 ± 8.6x10^{-3}</td>
<td>2.09 ± 0.26</td>
<td>0.28 ± 8.6x10^{-3}</td>
<td>1.08 ± 1.6x10^{-2}</td>
</tr>
<tr>
<td>48</td>
<td>-</td>
<td>-</td>
<td>0.11 ± 0.01</td>
<td>0.15 ± 1.2x10^{-2}</td>
<td>2.74 ± 0.25</td>
<td>0.33</td>
<td>1.08 ± 8.6x10^{-4}</td>
</tr>
</tbody>
</table>

Values are means of two determinations ± standard deviation.

(maltotriose, maltose and glucose) with steeping time, there was an accumulation of organic acids (lactic and acetic) and ethanol. (Table 6.2) This suggests that there was some microbial (fermentation) activity in the steep water, converting the simple sugars into organic acids (lactic and acetic) and alcohol.

6.5.4 Particle size distribution of dehulled dough obtained from steeping kinetics at 35°C

Particle size distribution of maize dough from different steeping times at 35°C is illustrated in Figure 6.4.
Results showed that as steeping times increased, the dough became finer (Figure 6.4). Greater percentage of dough was finer than 0.125 mm. The same trend for particle size analysis was observed for 2, 4, 8 hour grains compared to >10 hour steeped grains. This is because the optimal stage of water absorption is between 2-8 hours. Moisture diffuses through the endosperm and germ about eight times faster than the pericarp (Tolaba et al., 1990). According to May, (1987), the kernel absorbs approximately 3.5 gallons/bushels and reaches a maximum moisture content of approximately 45% in the first 8 to 10 hours of steeping.

Nche et al., (1996), detected water uptake by coarsely dry-milled maize (grits) reached 0.63 mL/g dry matter in 1 h, compared with 0.50 mL/g in 3 days for whole grain. High endogenous activity of proteases and carbohydrases were recorded in both grits and whole maize when soaked at 4 °C or 25°C.
6.5.5 Physicochemical properties of dehulled steeped maize grains and maize meal

The physicochemical properties of dehulled maize grains and maize meal obtained from steeping grains for 12 h, 30 h and 48 h is shown in Table 6.3.

Table 6.3: Effect of steeping times on physicochemical properties of steeped grains and maize meal

<table>
<thead>
<tr>
<th>Dehulled grains</th>
<th>Moisture (g/100g)</th>
<th>pH</th>
<th>Titratable acidity(%) lactic acid equivalent dry basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>12h steeping</td>
<td>34.72 ±1.18^a</td>
<td>4.63 ± 0.39^a</td>
<td>0.10 ±0.02^a</td>
</tr>
<tr>
<td>30h steeping</td>
<td>40.49 ±2.46^b</td>
<td>4.19 ±0.41^b</td>
<td>0.18 ±0.04^b</td>
</tr>
<tr>
<td>48h steeping</td>
<td>38.49 ±1.68^b</td>
<td>3.65 ±0.04^c</td>
<td>0.24 ±0.02^c</td>
</tr>
<tr>
<td>Maize meal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12h steeping</td>
<td>33.27 ±1.70^a</td>
<td>4.97 ±0.16^a</td>
<td>0.19 ±0.03^a</td>
</tr>
<tr>
<td>30h steeping</td>
<td>36.44 ±4.50^b</td>
<td>4.13 ±0.29^b</td>
<td>0.25 ±0.06^b</td>
</tr>
<tr>
<td>48h steeping</td>
<td>33.83 ±1.29^a</td>
<td>3.58 ±0.03^b</td>
<td>0.31 ±0.02^b</td>
</tr>
</tbody>
</table>

Values are means of triplicate determinations ± standard deviation, same superscript letters in a column are not significantly different at p≤0.05

Moisture content of steeped dehulled grains ranged from 35- 40 g/100 g. The 12 h steeped grain recorded significantly lower moisture because the grains had relatively less time to imbibe more water during steeping. The moisture of grains steeped from 30 h and 48 h were not significantly different (p<0.05). Microbial fermentation of sugars is thought to start during steeping of grains (Michodjëhoun-Mestres et al., 2005) with a resultant production of organic acids (mainly lactic acid) and a concomitant decrease in pH of the medium. The pH values decreased from 4.6 for 12 h steeped grains to 3.7 for
48 h steeped grains. pH values decreased as steeping times increased. The general reduction in pH during steeping is indicative of presence and activity of lactic acid bacteria and their production of acid during spontaneous steeping (Table 6.3).

Titratable acidity values ranged from 0.10% lactic acid equivalent for 12 h steeped grains to 0.24% lactic acid equivalent for 48 h steeped grains. Titratable acidity significantly increased as steeping duration increased from 12 h to 48 h (Table 6.3). According to Teniola and Odunfa, (2001), while pH decreased with steeping time, titratable acidity increased steadily. They found no significant variation (p<0.05) in pH and titratable acidity beyond 48 h steeping time.

### 6.5.6 Physicochemical properties of fermented dehulled maize dough

Moisture content of maize meal was 33-36%. Moisture content of 12 h fermented dough ranged from 55-57g/100 g (Table 6.4).

<table>
<thead>
<tr>
<th>Steeping time (hours)</th>
<th>Dough fermentation (hours)</th>
<th>Moisture (g/100 g)</th>
<th>pH</th>
<th>Titratable acidity (% lactic acid equivalent dry basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>12</td>
<td>55.28 ± 0.44a</td>
<td>4.89 ± 0.05</td>
<td>0.24 ± 0.01a</td>
</tr>
<tr>
<td>30</td>
<td>55.27 ± 2.04b</td>
<td>3.49 ± 0.09</td>
<td>0.64 ± 0.03b</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>57.47 ± 2.35c</td>
<td>3.54 ± 0.14</td>
<td>0.61 ± 0.14c</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>55.77 ± 1.31a</td>
<td>3.64 ± 0.32</td>
<td>0.62 ± 0.08a</td>
</tr>
<tr>
<td>30</td>
<td>55.27 ± 1.37b</td>
<td>3.57 ± 0.15</td>
<td>0.78 ± 0.02b</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>56.95 ± 0.42c</td>
<td>3.50 ± 0.04</td>
<td>0.74 ± 0.02c</td>
<td></td>
</tr>
</tbody>
</table>

Values are means of triplicate determinations ± standard deviation, same letters in a column are not significantly different at p ≤0.05
The 12 h fermented maize dough made from 48 h steeped grains recorded the highest moisture of 57 g/100 g. The moisture values of 24 h fermented dough from 12 h, 30 h and 48 h steeped grains were not significantly (p<0.05) different and ranged from 55-57g/100 g. Results from studies by Hounhouigan et al., (1993a) on mawe (maize product), observed increase in moisture content during fermentation. This was attributed to the combined effects of dry matter depletion (by release of carbon dioxide) and production of water during aerobic and anaerobic catabolism by yeasts and hetero-fermentative lactic acid bacteria.

pH of 4.9 was recorded for the 12 h fermented dough made from 12 h steeped grains (Table 6.4). When the grains were steeped for a longer period (48 hours) and fermented for 12 hours the pH of the dough was lower than 4.9 (Table 6.4). Variation in pH of the dough was expected because there is activity of lactic acid bacteria and their hydrolysis of glucose to produce organic acid, which decreased pH. Therefore 48 h steeping of maize brought about significant decreases in pH values. Lowering of pH suggests the presence of organic acids like lactic acid (Adebolu et al., 2007).

Titratable acidity values varied from 0.24 to 0.64 % lactic acid equivalent (Table 6.4) for both 12 h fermented dough obtained from 12 h and 30 h steeped grains. Significant variation (p ≤0.05) existed for titratable acidity of 12 h fermented dough obtained from 12 h, 30 h and 48 h steeping respectively. Similar pH and titratable acidity trends of steeped grains showed that while pH decreased with steeping time, titratable acidity increased steadily (Ingbian and Agwu, 2010). There was no significant variation (p ≥0.05) in TTA value for 24 h fermented dough produced from 30 h and 48 h steeped grains treatments. No significant difference existed at p ≥0.05 for 12 h and 24 h fermented dough.
6.5.7 Colour measurement of maize meal

The colour values of the fresh maize meal from 12, 30 and 48 h steeped grains are shown in Table 6.5.

Table 6.5: Effect of steeping times on colour of maize meal

<table>
<thead>
<tr>
<th>Maize meal</th>
<th>L</th>
<th>ΔE</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 hours steeping</td>
<td>89 ± 0.86(^a)</td>
<td>10 ± 0.81</td>
</tr>
<tr>
<td>30 hours steeping</td>
<td>88 ± 0.54(^a)</td>
<td>11 ± 0.47</td>
</tr>
<tr>
<td>48 hours steeping</td>
<td>87 ± 0.29(^b)</td>
<td>12 ± 2.40</td>
</tr>
</tbody>
</table>

Means are values of five determinations, same letters in a column are not significantly different at \(p \leq 0.05\)

The maize meal obtained from 12 hour steeped dehulled maize meal recorded L value of 89 and the maize meal from 48 h steeped dehulled maize recorded L value of 87. The colorimetric L value of a sample is a measure of its whiteness, and it is represented on a scale of 0-100, where 0 is the L value of black and 100 is the score for white. Dehulled maize meal obtained from 12 h steeping was significantly whiter (ie had a higher L value) than the others.

Longer steeping times of the maize before milling produced meals that were slightly darker (ie had lower L values) as shown in Table 6.5. \(\Delta E\) value is a calculated value of the total color difference (Good, 2004) but does not give information about how colors differ. The larger the \(\Delta E\) value, the larger the color difference. Maize meal obtained from 48 h steeped dehulled maize recorded high \(\Delta E\), which implied it had the largest colour difference and was less white.
6.5.8 Colour measurement of fermented maize dough

The colour values of fermented maize dough made from 12, 30 and 48 h steeped grains is given in Table 6.6.

Table 6.6: Effect of steeping times and dough fermentation duration on colour of fermented maize dough

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fermentation</th>
<th>Colour parameter</th>
<th>Steeping time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 h</td>
</tr>
<tr>
<td>Fermented dough</td>
<td>12 h</td>
<td>L</td>
<td>85 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>24 h</td>
<td>L</td>
<td>86 ± 1.19&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fermented dough</td>
<td>12 h</td>
<td>E</td>
<td>13 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>24 h</td>
<td>E</td>
<td>12 ± 1.18&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are mean of five determination ± standard deviation, L- Whiteness, ΔE- Delta

High L value was recorded for both 12 h and 24 h fermented dough produced from 30 h steeping. However, low L value was recorded for both 12 h and 24 h fermented dough processed from 48 h steeping, which confirms the observation that longer steeping times of dehulled maize resulted in maize meal that had reduced whiteness.

L value of 12 h fermented dough produced from 12, 30 and 48 h steeped grains ranged from 85-87 (Table 6.6). 12 h fermented dough processed from 12 h steeped grains recorded the largest colour difference because of its high ΔE value. There was however no significant variation (p<0.05) in colour of dough from 30 h and 48 h steeped grains.

Hounhouigan et al., (1993a) in their work on Mawe (dehulled maize product) found that L-values increased with increasing fermentation time and ΔE values decreased correspondingly. They found that whiteness of the product became more intense when fermentation is increased. On the other hand, studies by Li Cui et al., (2012), observed
that after fermentation, whole maize flour had a darker colour (lower L-value). Similar results obtained by Cuevas-Rodriguez et al. (2004), found that fermentation of quality protein maize (QPM) tended to yield a slightly darker colour and suggested it may be attributed to the influence of mycelia colour and the drying step.

6.5.9 Glucose and lactic acid of dehulled maize dough

Changes in glucose and lactic acid of dehulled maize dough are described in Table 6.7. Glucose levels varied from 3.35-16.75%.

Table 6.7: Glucose (% dry basis) and lactic acid (% db) of dehulled maize dough.

<table>
<thead>
<tr>
<th>Steeping time (h)</th>
<th>Fermentation time (h)</th>
<th>Glucose</th>
<th>Lactic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>0.85 ± 0.06</td>
<td>0.01 ± 0.001</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>2.76 ± 0.35</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>2.96 ± 0.68</td>
<td>0.32 ± 0.02</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>2.45 ± 0.55</td>
<td>0.11</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
<td>3.76 ± 0.07</td>
<td>0.22</td>
</tr>
<tr>
<td>30</td>
<td>24</td>
<td>3.91 ± 0.12</td>
<td>0.22 ± 0.08</td>
</tr>
<tr>
<td>48</td>
<td>0</td>
<td>1.21</td>
<td>0.14</td>
</tr>
<tr>
<td>48</td>
<td>12</td>
<td>1.41 ± 0.48</td>
<td>0.08</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>1.65</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Values are means of two determinations ± standard deviation.

Glucose levels increased with increase in fermentation time. High glucose levels were recorded in the 24 h fermented dough produced from 12 h, 30 h and 48 h steeped grains. The reason for this trend is that hydrolysis of carbohydrates to sugar occurs during steeping and fermentation. During fermentation, the amounts of fermentable sugars first
increased then decreased as shown in table 6.7. The transient increase in glucose inspite of an increasing population of micro-organisms is probably the result of amylolytic activities producing larger amounts of sugars than the micro-organisms require for their metabolism (Michodjehoun- Mestres et al., 2005). Amylolytic activities of lactic acid bacteria have been reported in fermenting cereals (Odunfa and Adeyele, 1987, Umefa and Faulks, 1988, Agati et al., 1998).

Lactic acid levels in dough ranged from 0.01-0.32 %. Lactic acid levels increased with fermentation time. This confirms previous studies related to involvement of microorganisms in the fermentation of cereal products (Kheterpaul and Chauchan, 1990: Hounhouigan et al., 1983). Melaku and Faulks (1988) also indicated that numbers of LAB increased during the first stages of the natural fermentation with a slight reduction in number during the later stages of fermentation. Lactic acid bacteria convert glucose into lactic acid through the homo-fermentative pathway (Hofvendahl and Hagerda, 2000). Lactic acid is the main organic acid produced during white kenkey fermentation. Results showed a slight decrease in lactic acid content at the later stages of fermentation. The decrease could be attributed to the utilization of lactic acid by yeast (Muyanja et al., 2003) and also because of depletion of nutrients available in dough (Nwachukwu et al., 2010).

**6.5.10 Effect of steeping time and dough fermentation on physicochemical properties of white kenkey**

Data on moisture content, pH and titratable acidity (TTA) of white kenkey are given in table 6.8.
Table 6.8 Effect of steeping times and dough fermentation duration on moisture content, pH and Titratable acidity (TTA) of white kenkey

<table>
<thead>
<tr>
<th>Steeping time (hours)</th>
<th>Dough Fermentation (h)</th>
<th>Moisture (g/100 g)</th>
<th>pH</th>
<th>Titratable acidity (% lactic acid equivalent dry basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>79 ± 3.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.59 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.27 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>30</td>
<td>75 ± 2.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.91 ± 0.28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.28 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>76 ± 2.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.43 ± 0.13&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.29 ± 0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>77 ± 0.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.33 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.28 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>30</td>
<td>75 ± 1.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.94 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.29 ± 0.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>79 ± 3.51&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.99 ± 0.88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.40 ± 0.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>78 ± 2.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.40 ± 0.56&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.60 ± 0.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>30</td>
<td>77 ± 1.77&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.01 ± 0.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.54 ± 0.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>81 ± 1.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.02 ± 0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.50 ± 0.17&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Values are means of three determinations± standard deviation. Same letters in a column are not significantly different at p ≤ 0.05

White kenkey prepared from partially-fermented meal obtained from 12 h steeped grains recorded 79 g/100 g moisture, while that obtained from 30 h steeped grains gave a moisture content of 75 g/100 g. There was no significant variation (p ≥ 0.05) between the moisture content of kenkey obtained from grains steeped for 30 hours and those obtained from grains steeped for 48 hours. Moisture of white kenkey produced from 12 h fermented dough also ranged from 75 to 79 g/100 g. White kenkey produced from 24 h fermented dough obtained from 48 h steeped grains recorded high moisture of 81g/100g. Thus, long steeping times (48 hours) for dehulled maize and long fermentation time (24 hours) will yield kenkey of very high moisture content.
pH of 5.59 was recorded for white *kenkey* processed from 12 h steeped, partially fermented meal. When the *kenkey* was prepared using partially-fermented dough obtained from dehulled maize that had been steeped for 30 hours, the pH significantly dropped to 4.91. It further dropped to 4.43 when it was made using maize that had been steeped for 48 hours (Table 6.8). There were no significant differences (p ≤0.05) in the pH of *kenkey* made from 30 h and 48 h steeped dehulled grains. pH values for white *kenkey* produced from 12 h fermented dough decreased as the steeping times increased. Clearly steeping of dehulled maize grains influences the pH of *kenkey*. Changes observed in pH are similar to findings reported by other researchers who have studied other fermented foods (Sulma *et al.*, 1991; Choi *et al.*, 1994; Dziedzoave *et al.*, 1996). Nche *et al.* (1994) reported a decrease in pH in *kenkey* to be associated with an increase in Lactic acid Bacteria numbers with simultaneous production of organic acids.

The TTA of white *kenkey* increased as the steeping time of the maize grains from which they were made increased. The increase in TTA could be ascribed to production of lactic acid and associated metabolites during steeping of the dehulled maize, as a result of microbial fermentation. White *kenkey* produced from 24 h fermented dough processed from 30 h and 48 h steep grains recorded same TTA value of 0.54 % lactic acid dry basis equivalent.

6.5.11 Colour measurement of white *kenkey*

The colour values of white *kenkey* made from 12, 30 and 48 h steeped grains is given in table 6.9.
Table 6.9: Effect of steeping and dough fermentation time on the colour of white *kenkey*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fermentation time</th>
<th>Colour parameter</th>
<th>Steeping time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 h</td>
<td>30 h</td>
<td>48 h</td>
</tr>
<tr>
<td>White <em>kenkey</em></td>
<td>0 h</td>
<td>L</td>
<td>80 ± 0.86&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>12 h</td>
<td>L</td>
<td>81 ± 0.26&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>24 h</td>
<td>L</td>
<td>83 ± 0.22&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>White <em>kenkey</em></td>
<td>0 h</td>
<td>E</td>
<td>18 ± 0.94</td>
</tr>
<tr>
<td></td>
<td>12 h</td>
<td>E</td>
<td>18 ± 0.13</td>
</tr>
<tr>
<td></td>
<td>24 h</td>
<td>E</td>
<td>16 ± 0.32</td>
</tr>
</tbody>
</table>

Values are means of five determination ± standard deviation

White *kenkey* produced from partially-fermented meal recorded L value of 78 for 48 h steeping and 80 for 30 h steeped grains (Table 6.9). High E values were recorded by *kenkey* samples produced from 48 h steeped grains. This indicated that it had the largest colour difference and were less white. It could be deduced that longer steeping reduced the whiteness (L) of the samples as observed earlier for the fresh meal.

Fermentation times increased the L value of the *kenkey* but increased steeping times reduced it (Table 6.9). Hounhouigan *et al.*, (1993) in their work on *Mawe* found that L-values increased with increasing fermentation time and E values decreased correspondingly. They found that whiteness of the product became more intense when the duration of fermentation was increased. White *kenkey* produced from 12 h fermented dough using 12 h steeped maize gave the largest colour difference (E value) as shown in Table 6.9. Comparable L values were recorded for white *kenkey* produced from 12 h fermented and 24 h fermented dough.
6.5.12 Glucose and Lactic acid content of white kenkey

Glucose and lactic acid levels for white *kenkey* prepared from dehulled maize that was steeped for 12, 30 and 48 h and fermented for 0, 12 and 24 hours are presented in Table 6.10.

Table 6.10: Glucose and lactic acid levels of white *kenkey*

<table>
<thead>
<tr>
<th>Steeping time(h)</th>
<th>Fermentation time(h)</th>
<th>Glucose(mg/g)</th>
<th>Lactic acid (% dry matter basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>3 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>6 ± 0.42&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.02</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>16&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.82</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>7 ± 0.91&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.25</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
<td>19 ± 0.42&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>24</td>
<td>26 ± 0.35&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.48</td>
</tr>
<tr>
<td>48</td>
<td>0</td>
<td>7 ± 0.46&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.83</td>
</tr>
<tr>
<td>48</td>
<td>12</td>
<td>11 ± 0.21&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0.95</td>
</tr>
<tr>
<td>48</td>
<td>24</td>
<td>7 ± 0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.89</td>
</tr>
</tbody>
</table>

Values are means of duplicate determination ± standard deviation

The glucose values of white *kenkey* ranged from 3 mg/g for *kenkey* produced from 12 h steeped grains to 26 mg/g for *kenkey* produced from 30 h steeped grains and fermented for 24 h. The glucose levels increased with fermentation times for all steeping times. This was expected because during fermentation, carbohydrates are hydrolyzed to glucose by amylolytic activities of lactic acid bacteria (Bayizit et al., 2010).

However, the glucose level of *kenkey* produced from 24 h fermented dough obtained from 48 h steeped grains was minimal. Organic acids are produced during metabolism of fermentable sugars (Bayizit et al., 2010). Erbas et al., (2006), stated that production of
organic acids in fermented cereals is attributed mainly to presence of homo- and hetero-fermentative lactic acid bacteria. It was observed that the level of lactic acid in the kenkey increased as fermentation time of the dough used increased. Lactic acid levels in kenkey varied from 0.83-3.48 mg/g (% dry matter basis) (Table 6.10).

6.5.13 Effects of steeping of maize and dough fermentation on the texture of white Kenkey

The effects of steeping and fermentation on the hardness and stickiness of white kenkey is illustrated in Figure 6.5 a and 6.5 b.

Figure 6.5a: Effect of steeping and fermentation duration on hardness of white kenkey
Hardness is an important textural property of kenkey. It is the force necessary to attain a given deformation. Kenkey produced using 30 h steeped maize for all fermentation times generally recorded high hardness values (Figure 6.5a). Stickiness is the force of adhesion that results when two surfaces are contacted with each other under the curve. Kenkey prepared from 12 h fermented dough obtained from 12 h steeped grain recorded maximum stickiness of 27.89 g.s, whereas that from 24 h fermented dough obtained from 12 h steeping recorded low stickiness value of 15.37 g.s. It therefore appears that if dehulled maize is steeped for 12 hours, milled and made into dough, the stickiness of the kenkey will depend on the length of fermentation time. While relatively short fermentation time led to kenkey with high stickiness, prolonged fermentation of 24 hours reduced the stickiness of kenkey.
On the other hand, extended steeping time of the dehulled maize grains also yielded kenkey with low stickiness even when the fermentation time of the dough was relatively short. For example, kenkey processed from 12 h fermented dough made from 30 h steeped grains recorded stickiness value of 15.98g.s. The one factor that is common to both extended steeping and fermentation time is microbial fermentation which leads to breakdown and depletion of simple sugars. Stickiness is a function of starch gelatinization, and the presence of sugars has been reported to influence starch gelatinization (Saalia et al., 2012). Highly significant differences existed at p ≤0.05 between stickiness of white kenkey. Anova results indicated significant variation in hardness at p ≤0.05.

6.5.14 Principal component analysis (PCA)

In this study, PCA was used to objectively interpret, compare and ascertain the relationship between the physicochemical and biochemical properties of white kenkey samples from different treatments. It also helped to evaluate the most important physicochemical variables (pH glucose, TTA, lactic acid and hardness. PCA of physicochemical and biochemical indices (Figure 6.6) obtained for white kenkey resulted in a two-factor solution accounting for 80.02% of total variance, of which 56.26% was explained by the first (F1) and 23.75% by the second components.
Figure 6.6 Biplot of effect of steeping and fermentation variables on physicochemical and biochemical properties of white kenkey

White kenkey samples from fresh meal (S12FO, S30FO and S48FO) were found in the left part of the quadrant, while further fermented kenkey were mostly in the right side of the PCA. PCA showed that fermentation times increased along the F1 axis thus increasing acidity and steeping times increased along the F2 axis, improving the texture of kenkey. As fermentation time increased, glucose, lactic acid, TTA and L value increased but reduced pH which is found in the left quadrant. As fermentation time increased, the whiteness of kenkey increased but reduced with increased steeping time.

It was observed that as steeping time increased, hardness of kenkey improved whereas stickiness reduced (Figure 6.6). The particle size of the kenkey becomes finer with increased steeping times. Results indicated that when pH of samples increased, L value and TTA decreased. Fermentation influenced the measured physicochemical and biochemical indices.
6.5.15 Effects of aflato ratio and steaming time on white *kenkey* textural characteristics

Figure 6.7 illustrates a typical force (kg) - time (sec.) curve for compression test of white *kenkey* (*nsiho*).

![Graph showing force vs. time for kenkey compression test]

**Figure 6.7:** A typical force (kg) - time (sec.) curve for compression test of white *kenkey*

Maximum force of first compression test indicates hardness of the sample.

Negative area under the curve indicates the stickiness of the sample.
Hardness value was recorded as the peak force of the first compression of the product. Stickiness was evaluated as the area of the negative curve obtained after a probe was brought into contact with the dough (Dhaliwal et al., 1988), (Mossmam et al., 1983). Anova revealed that aflata proportion and steaming time had a significant effect (p<0.05) on both hardness and stickiness of white kenkey. The interaction of aflata and steaming times was also significant at a minor level, implying that the effect of the proportion of aflata on the textural characteristics of kenkey were dependent on the steaming duration used in making the kenkey.

Figure 6.8, illustrates that hardness increased with decreased aflata proportion and increased raw dough amount.

![Bar graph showing the effect of steaming duration and proportion of precooked dough(aflata) to raw dehulled maize dough on instrumental hardness of white kenkey.](image-url)

**Figure 6.8:** Effect of steaming duration and proportion of precooked dough(aflata) to raw dehulled maize dough on instrumental hardness of white kenkey
Hardness value for 30 and 45 min steaming were not significantly (p<0.05) different. It can be observed in Figure 6.9, that stickiness increased with the proportion of raw dough.

![Figure 6.9: Effect of steaming time and proportion of precooked dough (aflata) to raw dehulled maize dough on instrumental stickiness of white kenkey](image)

There were significant effects (p<0.05) of aflata proportion and steaming time on the texture of white kenkey. The interaction of aflata and steaming times was also significant, implying that the effects of the proportion of aflata on the textural characteristics of kenkey were dependent on the steaming duration used in preparing the kenkey. Hardness and stickiness values increased with increased steaming times for all aflata proportions used for kenkey preparation. The hardness and stickiness values increased when aflata proportions were less than 50%. When the steaming time was more than 15 minutes, the hardness and stickiness values increased.
6.5.16 Consumer acceptability of white kenkey

Table 6.11 presents mean values of taste, texture and overall acceptability of the different white kenkey samples. Mean values of the taste evaluation varied between 4.5 and 6.5 on a 9-point hedonic scale. Kenkey produced from 100% aflata and 66% aflata, steamed for 45 minutes presented highest mean value (Table 6.11).

Table 6.11: Mean values for consumer liking of taste, texture and overall acceptability of white kenkey

<table>
<thead>
<tr>
<th>Steaming time (mins)</th>
<th>Samples (proportion of aflata)</th>
<th>Taste</th>
<th>Texture</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>100%</td>
<td>5.43 ± 2.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.86 ± 2.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.75 ± 2.13&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>5.26 ± 2.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.08 ± 2.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.55 ± 1.97&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>5.17 ± 1.90&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6 ± 1.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.67 ± 1.74&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>33%</td>
<td>4.55 ± 2.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.91 ± 2.17&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.87 ± 2.01&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>45</td>
<td>100%</td>
<td>6.51 ± 1.63&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6.58 ± 1.69&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.68 ± 1.45&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>6.32 ± 1.75&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.83 ± 1.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.22 ± 1.80&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>5.80 ± 1.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.89 ± 2.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.26 ± 2.07&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>33%</td>
<td>5.48 ± 2.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.52 ± 2.11&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5 ± 2.05&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Mean values in the same column followed by same superscript letters do not differ (p>0.05). 95 consumers

Consumers who preferred 100% aflata and 66% aflata, steamed for 45 minutes liked Atimpoku and Anum non-sweetened white kenkey process respectively. White kenkey prepared from 33% aflata and steamed for 15 min. recorded the lowest mean taste value of 4.55. In general, kenkey steamed for 15 min. recorded lower scores.

Consumers were segmented into three clusters based on the mean taste and textural scores (Figure 6.10a and 6.10b).
C1= High steaming level likers, C2= High aflata level likers, C3= all likers

Figure 6.10a: Consumer clustered according to taste scores

Figure 6.10b: Consumer clustered according to textural scores
It was observed that consumers in cluster 1 preferred highly steamed *kenkey* and cluster 2 consumers liked white *kenkey* with high *aflata* levels. Generally, consumers in cluster 1 were particular about the texture and taste of the white *kenkey* whilst the cluster 2 consumers wanted *kenkey* with high textural properties, the taste did not matter to them. Results showed that *aflata* levels have more impact on texture than taste. Consumers in cluster 3(C3) liked all samples. At 6% level, there was a gender difference between cluster 3 and other clusters. Males were dominant in cluster 3 and they liked all types of *kenkey*.

The correlation between consumer clusters and texture and taste attributes are shown in Table 6.12. It is indicated that whereas cluster 1 consumers were particular about texture and taste (r=0.96) of white *kenkey*, Cluster 2 consumers were more sensitive to texture (r=0.99). High correlation existed between hardness and instrumental stickiness

<table>
<thead>
<tr>
<th>Consumer cluster</th>
<th>Taste</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>C2</td>
<td>0.76</td>
<td>0.99</td>
</tr>
<tr>
<td>C3</td>
<td>0.78</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Comparing texture measurement with consumer cluster, it can be deduced that consumers in cluster one liked white *kenkey* with high *aflata* levels and long steaming duration. Consumers in this cluster likeliness were for low hardness and high stickiness white *kenkey*. There was high correlation between texture measurement and preference of cluster 2 consumers. They desire white *kenkey* with low hardness and low stickiness.

In a sensory evaluation of texture of Ga *kenkey*, panelists scored high for *kenkey* prepared from 50% *aflata* (Bediako-Amoa and Austin, 1976). Main sensory attributes consumers
require in similar product *amala* are stickiness, firmness and smoothness. Stickiness and firmness were highly correlated (Akissoe *et al.*, 2006).

### 6.5.17 Sensory preference for white kenkey based on the levels of lactic acid and sucrose

The results of consumer preference for white *kenkey* based on spiking with different levels of lactic acid and table sugar are presented in Table 6.13.

Table 6.13: Mean consumer acceptance scores for white *kenkey* spiked with lactic acid and sucrose levels

<table>
<thead>
<tr>
<th>Samples</th>
<th>Taste</th>
<th>Aroma</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1LA0.5S</td>
<td>3.59 ± 2.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.75 ± 2.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.79 ± 2.19&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1LA5S</td>
<td>4.97 ± 2.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.79 ± 1.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.28 ± 2.18&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.6LA2.75S</td>
<td>5.93 ± 2.13&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.40 ± 1.51&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.33 ± 1.67&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.2LA0.5S</td>
<td>7.08 ± 1.62&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6.68 ± 1.65&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6.99 ± 1.65&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.2LA5S</td>
<td>7.60 ± 1.48&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6.84 ± 1.61&lt;sup&gt;e&lt;/sup&gt;</td>
<td>7.33 ± 1.56&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.6LA2.75S</td>
<td>5.92 ± 1.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.25 ± 1.48&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.83 ± 1.84&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Different letters in a column are significantly different at p<0.05. 1LA0.5S- 1% lactic acid: 0.5% sucrose, 1LA5S- 1% lactic acid: 5% sucrose, 0.6LA2.75S- 0.6% lactic acid: 2.75% sucrose, 0.2LA0.5S- 0.2% lactic acid: 0.5% sucrose, 0.2LA5S- 0.2% lactic acid: 5% sucrose and 0.6LA2.75S- 0.6% lactic acid: 2.75% sucrose. 75 consumers.

Based on the taste attribute, the preference for white *kenkey* was for the two samples with the least amount of lactic acid ie 0.2%. Interestingly, these two samples also contained the highest and lowest levels of sugar 0.5 and 5%. This suggests that the level of acidity in white *kenkey* is more critical to its taste than the level of sweetness. However of these samples containing only 0.2% lactic acid, the one containing 5% sugar was liked very much (7.60) and the one 0.5% sugar liked moderately (7.08) based on taste. Consumers preference was for white *kenkey* with low level of lactic acid, thus minimal fermentation (Atimpoku procedure).
The two samples which contained the highest levels of lactic acid (1%) were also the least liked with regards to taste. Of these the one containing the higher level of sugar, 5%, was preferred (4.97) to the one containing less sugar, 0.5% (3.59). The results of the test show that all the scores for the different attributes in the different sample were almost all significantly different (p<0.05) from each other. The same order of preference or ranking for the taste was also recorded for the aroma of the samples and this could probably be due to the aroma of the lactic acid as well. This same order ranking was also recorded for the acceptability of the samples. Thus the preference for the samples was first for the kenkey containing 0.2% lactic acid with 5% sugar, followed by 0.2% lactic acid with 0.5% sugar, then 0.6% lactic with 5% sugar, next 1% lactic acid with 5% sugar and lastly 1% lactic acid with 0.5% sugar. The best level of lactic acid and sugar in kenkey based on factorial plan design is 0.2% lactic acid with 5% sugar and the least 1% lactic acid with 0.2% sugar based on human sensory preference.

6.6 Conclusion

The steeping process initiated spontaneous microbial fermentation activity as manifested by indices such as decreases in pH and increase in titratable acidity of the steep water and the maize meal obtained from milling the steeped grain. The characteristics of dough from different steeping and fermentation times suggest that steeping may be complimentary to dough fermentation rate. Steeping of grains for short time periods and fermenting the dough obtained from it may be equivalent to steeping for longer time and fermenting for shorter time periods. The steeping time influenced glucose content. While steeping increased glucose level, fermentation of the dough reduced it by converting it to lactic acid as manifested by increased levels of the acid in the dough and kenkey.
The physical characteristic of dough and *kenkey* were also influenced by the steeping time of grains and fermentation of the dough. The color of white *kenkey* darkened as the grain steeping time increased, and steeping produced maize meal with very fine particle size distribution. Steeping of grains and fermentation of the dough influenced the textural characteristics of *kenkey* made from it. Maximum hardness and stickiness of *kenkey* were obtained when maize was steeped for 12 hours and fermented for 12 hours. Longer fermentation time reduced hardness and stickiness.

In the processing of *kenkey*, the ratio of *aflata* and raw maize dough influenced the textural characteristics of the product. High *aflata* ratios produced softer textured *kenkey*, while increasing the ratio of raw dough in the *aflata* mix increased the stickiness and hardness of *kenkey*. Consumers preferred *kenkey* that was made using high *aflata* ratios and steamed for longer time periods. Consumers preferred white *kenkey* that had about 0.2% level of lactic acid. The preference for sucrose in white *kenkey* among consumers was wide and ranged between 0.5% and 5%.
CHAPTER 7

OBJECTIVE 5: To optimize the white kenkey production process using Response Surface Methodology

7.0 Introduction

White kenkey (nsiho) is one of several types of kenkey. It is produced after dehulling maize grains, and steeping them in water for about 48 hours before further processing. Apart from the dehulling step, the production of white kenkey also undergoes all the other unit operations for Ga and Fante kenkey, except that the maize dough is not fermented for long periods. Just as for the many kenkey types, the processing of white kenkey is prolonged and tedious, and it is based on traditional technologies that have very little quality assurance mechanisms (Amoa Awua et al., 2007).

Consequently there are frequently wide variations in the quality characteristics of white kenkey among producers, and within batches from the same producer (Amponsah, 2010). Current trends in urbanization, and the increasing popularity of kenkey among consumers, require industrial scale production with consistent and predictable quality. Critical to achieving these is a clear understanding and determination of simple process parameters in the unit operations that affect the quality of kenkey. Several studies have reported efforts to upgrade and mechanize some of the unit operations involved in the production of kenkey in order to make the process less tedious, faster and have more consistent quality output (Nche et al., 1996; Nche et al., 1994, Nout et al., 1996).

Optimization techniques are frequently employed to determine process conditions that yield optimum product or process output. A popular optimization technique is response
surface modeling, which is a type of statistical modelling that employs full or fractional factorial designs to identify combinations of experimental variables that lead to an optimum (Gacula and Singh 1984). Response surface methodology (RSM) has been applied in many cases of food product development with the aim of either optimizing the product quality based on ingredient formulations or the production process (Amonsou et al., 2010). Nath and Chattopadhyay (2007) used response surface methodology to optimize process variables with respect to textural properties of potato-soy snack.

There are several types of response surface designs, and the choice of design is influenced by the shape of the experimental region. In most cases, the region is determined by the ranges of the independent variables (or factors). If it is desired that the predictions be independent of direction from center of the experimental region -then the region is spherical and the design of choice is box-behnken (Box and Behnken, 1960, Montgomery, 2001). Thus, box-behnken designs are a class of rotatable or nearly rotatable second-order designs based on three-level incomplete factorial designs, and they are frequently used for response surface modeling. Box-behnken designs exclude the corners (Figure 7.1), where all independent variables are simultaneously at the maximum levels, and they therefore permit a wider range of individual ranges and they allow efficient estimation of the first- and second-order coefficients.

In the evaluation of the kenkey process, several unit operations have been noted to influence the quality characteristics of the final product. Key among them are steeping time of maize, fermentation time of the maize dough, and the ratio and homogeneity of mixing aflata with non-cooked maize dough, among several other variables. The objective of this work was to optimize the processing parameters of steeping time,
fermentation time and steeping temperature on the physicochemical properties of white *kenkey* using response surface methodology.

![Figure 7.1: Experimental region of Box-Behnken Design for 3 factors (k=3), showing that there are no experimental points at the vertices of the cube.](image)

**7.1 Materials and methods**

**7.1.1 Raw materials**

The local variety of maize (*ableehi*) was purchased from the local market in Accra, Ghana, and dehulled using an Engelberg mill (Engelberg Ltd., Doncaster, U.K.).

**7.1.2 Design of study.**

The Box Behnken design (Box and Behnken, 1960; Montgomery, 2001) was used to determine the combinations of process variables of steeping time, fermentation times and steeping temperature that provided the optimum quality characteristics for sensory acceptability and physicochemical properties of white *kenkey*. The factors and their levels used in the study are shown in Table 7.1.
Table 7.1 Variables and their levels used in the Box-Behnken design

<table>
<thead>
<tr>
<th>Variables</th>
<th>Symbols</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coded</td>
<td>0</td>
</tr>
<tr>
<td>Steeping times (hours)</td>
<td>X₁</td>
<td>12</td>
</tr>
<tr>
<td>Fermentation times (hours)</td>
<td>X₂</td>
<td>0</td>
</tr>
<tr>
<td>Steeping temperature (ºC)</td>
<td>X₃</td>
<td>25</td>
</tr>
</tbody>
</table>

The number of experimental runs (N) in a Box–Behnken design is satisfied by N = k² + k + C₀, where (k) is the number of factors and C₀ is the number of replications at the center point (Aslan and Cebeci, 2006). Alternatively, N for Box-Behnken designs could also be determined using the relationship N=2k (k−1) +C₀, (where k is number of factors and C₀ is the number of center points) while that for a central composite design may be determined by N=2k +2k +C₀ (Ferreira et al., 2007).

Thus, for the three factor Box-Behnken design used in this work a total of 15 experimental runs were used (Table 7.2). In determining the design matrix (factor combinations per experimental unit) for the Box-Behnken design, the level of one of the factors was fixed at the center point while combinations of all levels of the other factors were applied (Myers and Montgomery 2002). As shown in Table 7.2, the level of factor X₃ (i.e. steeping temperature) was fixed and then, the combinations of all levels of the factors X₁ and X₂ were applied and subsequently, the same procedures were performed for the factors X₂ and X₁, respectively. The last rows of the design matrix (Table 7.2) contain the three replicate center points. The data obtained from running the experiments was fitted into the following second order polynomial model as suggested by Montgomery, (2001):

\[ y = b₀ + b₁x₁ + b₂x₂ + b₃x₃ + b₁₁x₁² + b₂₂x₂² + b₃₃x₃² + b₁₂x₁x₂ + b₁₃x₁x₃ + \ldots \]
Where \( y \) is the response, \( b_0 \) model constant; \( x_1, x_2 \) and \( x_3 \) independent variables; \( b_1, b_2 \) and \( b_3 \) are linear coefficients; \( b_{12}, b_{13} \) and \( b_{23} \) are cross product coefficients and \( b_{11}, b_{22} \) and \( b_{33} \) are the quadratic coefficients (Montgomery, 2001).

**Table 7.2:** Box-Behnken Design matrix of variables (k=3) for optimization of the *kenkey* process

<table>
<thead>
<tr>
<th>Run number</th>
<th>( X_1 )</th>
<th>( X_2 )</th>
<th>( X_3 )</th>
<th>Steeping time (hours)</th>
<th>Fermentation time (hours)</th>
<th>Steeping temperature (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>2.</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>48</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>3.</td>
<td>-1</td>
<td>1</td>
<td>0</td>
<td>12</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>4.</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>48</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>5.</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
<td>12</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>6.</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>48</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>7.</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>12</td>
<td>45</td>
</tr>
<tr>
<td>8.</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>48</td>
<td>12</td>
<td>45</td>
</tr>
<tr>
<td>9.</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>30</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>10.</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>30</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>11.</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>30</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>12.</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>30</td>
<td>24</td>
<td>45</td>
</tr>
<tr>
<td>13.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>14.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>15.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>12</td>
<td>35</td>
</tr>
</tbody>
</table>

### 7.2 White *kenkey* (*nsiho*) preparation.

Two kilograms (2 kg) each of dehulled maize grains was washed with water, steeped in water at room temperature (ca 30°C) and in water baths (Grant, UK) set at 35 °C and 45°C respectively for stipulated steeping times according to the experimental design (Table 7.1 and 7.2). The steeped grains were washed again and milled using a mini disc attrition mill (Disc Attrition Mill, Rajan Universal, and Chennai, India). For treatment which had 0 h fermentation, the fresh meal was made into slurry and cooked into white...
kenkey. The slurry was prepared by adding water in a ratio of 1:1 to the fresh meal. The mixture was cooked into a thick paste.

Fifty (50 g) each of paste was packed into 28 cm diameter cylindrical silicon containers and steamed for 30 minutes to obtain white kenkey (Atimpoku type) using Philips HD9120 steam cooker (Philips Viva collection, Dampfgarer, the Netherlands). The other portion of the fresh meal was kneaded into dough after adding sufficient water to make a ratio of 1:2 (w/v) and allowed to ferment spontaneously for specified times as shown in Table 7.2. After the dough fermentation, 200 g of fermented dough was slurried with water and cooked as described above. The cooked dough was mixed with 100 g of uncooked fermented dough into a thick viscous paste. Fifty grams (50 g) each of the paste was packed into silicon moulds and steamed for 45 minutes to obtain white kenkey (Anum type) using Philips HD9120 steam cooker, (Philips Viva collection, Dampfgarer, the Netherlands). Moisture, pH, titratable acidity, glucose and lactic acid were determined for dough samples and white kenkey. The hardness and stickiness of the white kenkey was determined.

7.3 Physicochemical properties

7.3.1 Determination of moisture content

Moisture content of the products were determined using the air-oven method at 105°C as described in the (AACC Method 44-15A, 2000). The moisture content was determined as loss in moisture using the following equation:

\[ \% \text{ Moisture} = \frac{A}{B} \times 100 \]

In which A= loss in sample weight in grams, B= original weight of sample
7.3.2 Determination of pH

The pH was measured directly using a pH meter (Research pH meter, 3330, Jenway, UK) equipped with a glass electrode (Orion 9102, Orion Research, and Boston, MA, USA), after calibration using standard buffer solutions (Merck) at pH 4.0 and 7.0 at ambient temperature. The pH was determined for dough and kenkey samples. The sample was blended with an equal volume of distilled water in a stomacher (AACC method 02-52, 2000).

7.3.3 Titratable acidity

Ten grams of sample was dispersed into 20 ml of distilled water and homogenized for 2 min using a magnetic agitator. The electrode of the pH meter was placed into the sample solution and the pH was read after 1 min. Distilled water (70 ml) was added to the sample solution and freshly prepared 0.1N sodium hydroxide was added whiles agitating to continue neutralization until a pH of 8.5 was reached. After 5 min, the pH was adjusted to 8.5 and the final amount of sodium hydroxide used was read (AACC method 02-52, 2000). The results were expressed as follows:

\[
\% \text{ lactic acid} = \frac{V \times 900 \times N}{M \times ms}
\]

\(V\)= volume of titrant (ml)
\(N\)= normality of sodium hydroxide
\(M\)= mass of sample (g)
\(Ms\)= Dry matter (% dry basis)

7.3.4 Determination of organic acids and sugars by High Performance Liquid Chromatography

Glucose and Lactic acids were determined using High Performance Liquid Chromatography (HPLC 360 Auto sampler (Shimadzu LC-9A), as described by Mestres and Rouau, (1997).
Sample preparation

One gram of sample was weighed with a screw-capped tube and 3 ml of 0.5 M H₂SO₄ was added. This content was homogenized using a Rotator, SB2, Stuart (Bibby Scientific Ltd, Staffordshire, UK) for an hour. The mixture was centrifuged (Centrifuge 1207, VWR International LLC, West Chester, United States) at 7.2 ×1000 g for 5 min. The supernatant was filtered into an HPLC sample vial through a 0.45-µm RC filter (Minisart, R.C 15 17762, Sartorius AG, 37070, Germany). Separation of organic acids was achieved with an Aminex HPX-87H HPLC column (Bio-Rad Labs., Richmond, Calif., USA) held at 45°C, using 9 mM H₂SO₄ as a mobile phase at a flow rate of 0.4 mL/min. UV detector (Series 200, Perkin Elmer) response was monitored by Turbochrom software (Perkin Elmer).

Determination of Organic Acids

Organic acids were identified and quantified by comparison of their retention times with the following standard acids: -lactic acid, acetic acid, maltose, glucose, fructose, (Sigma). The analysis was externally calibrated using mixed standard solutions in de-ionized water, prepared for the samples.

Sugar Determinations

Concentrations of glucose, fructose, and maltose were monitored using a refractive index detector (Perkin Elmer) in series with the UV detector and calibrated using standard sugar solutions (Sigma).

7.3.5 Colour Determination

The colour of maize dough and white kenkey samples were measured using a colorimeter (Minolta Chromameter, CR310-Japan Colorimeter D25-PC2, National
Institute of Ag laboratories, Reston, VA) which was calibrated with a white tile (L=97.51, a=5.45, b=-3.50) according to (AACC Method 14-22.01, 2000). The colour which was expressed in terms of lightness (L) and colour difference (ΔE) was calculated as $(ΔL^2 + Δa^2 + Δb^2)^{1/2}$ where $L =$ lightness; $a (+) =$ red a (-) = green; $b (+) =$ yellow, $b(-) =$ blue colour value. The colour of each sample was measured five times per sample. The means were calculated.

7.3.6 Texture measurements

For determination of texture using the TA-XT2 Texture Analyzer, 50 g of paste obtained from maize meal or fermented dough to be cooked into white kenkey was packed into 10 different 28 cm diameter cylindrical silicon moulds and steamed for 30 min into white kenkey using a steam cooker, (Philips HD9120 steam cooker (Philips Viva collection, Dampfgarer, the Netherlands). The sample was then covered with cling film to prevent dehydration and cooled for one hour. The top portion of the kenkey was cut and sample turned upside down.

Texture was measured using a penetrometer probe of 6 mm diameter at two points per sample using a TA-XT2 Texture Analyzer (Stable Microsystems, Surrey, England) equipped with 25 kg load cell. A compression and withdrawal test was performed using the following conditions: pre-test speed 2 mm/s, trigger force of 5 g, test speed 1 mm/s, 20% strain, holding time of 10 sec, post-test speed of 1 mm/s (Fizman and Damasio, 2000). Hardness value was measured as the peak force of the product and stickiness was evaluated by the area of the negative curve during compression. Texture data for each treatment was taken in ten replicates.
7.4 Consumer acceptance of white *kenkey* (*nshiho*)

The 15 samples of *kenkey* obtained as described in the previous section were analysed for sensory acceptability. A balanced incomplete block design of 15 treatments (samples), $k = 5$ (No. of samples per judge), $r = 7$ (replicates), $b = 21$ (number of blocks/judge), $\lambda = 2$, $N=105$ described by Cochran and Cox (1957) and Montgomery (2001) was used. This design was used to allow each panelist to evaluate five samples at a time because an individual consumer would find it increasingly difficult to evaluate all 15 different products at one session.

Panelists ($n=21$) were randomly recruited from the CSIR-Food Research Institute. The consumers were equivalent to a power of 105 consumers. Criteria for recruitment were that panelists were regular consumers of *kenkey* and that they were very familiar with the characteristics of *kenkey*. The *kenkey* were presented to panelists in disposable plates coded with three-digit random numbers. Water and cream crackers were provided for panelists to rinse their mouths during the test to minimize any residual effect between samples. Panelists were asked to evaluate the samples based on the taste, texture, odour and overall acceptance using a 9-point hedonic scale ($9 = $like extremely, $5 = $neither dislike nor like, and $1 = $dislike extremely) as described by Peryam and Pilgrim, (1957) and Prinyawiwatkul *et al.*, (1997). The work and ballot sheets used in this study are shown in Appendix 8.

7.5. Data Analysis

The experimental data were analyzed using response surface regression techniques and the significance of regression coefficients was evaluated by F-test. The data obtained was
fitted to polynomial models and the model adequacies were checked in terms of lack of fit error, the values of $R^2$ and prediction error sum of squares (PRESS).

7.6 Results and Discussions

7.6.1 Moisture of maize dough

The moisture content of fermenting maize dough could influence the rate of fermentation (Akom-Quayson, 1992). The moisture content of the maize dough varied significantly with the process treatments of steeping time, steeping temperature and fermentation time. Dough made from dehulled maize that was steeped for short periods or fermented for long times were drier than those that were steeped for longer times and then fermented for very long times (Figure 7.2). Studies by Onyango et al. (2004) confirmed this findings that during fermentation the moisture content increase because of the loss of dry matter.

![Figure 7.2: Main effects plot for moisture of dehulled maize dough as a function of steeping time, fermentation time and steeping temperature](http://ugspace.ug.edu.gh)
7.6.2 Titratable acidity and pH of maize dough

Titratable acidity (TTA) of the maize dough ranged from 0.38 to 1.09 (% lactic acid dry matter basis), while the pH varied between 3.41 and 4.48 for all treatments. The pH and titratable acidity of maize dough were significantly influenced by the processing variables of steeping time, steeping temperature and fermentation time (Table 7.3). Increasing steeping time of the dehulled maize dough significantly increased the titratable acidity of the dough obtained from the milled steeped maize with a concomitant decrease in its pH. Steeping of grains has been associated with the initiation of lactic acid fermentation (Nche et al., 1996) which consequently increases TTA and decreases the pH as was observed. Increasing steeping temperature and fermentation time also significantly increased the total titratable acidity of the maize dough (Figures 7.3 and 7.4). The role of temperature in increasing TTA may be related to increased microbial (specifically lactic acid) activity, as suggested by Perez et al., (2003). On the other hand fermentation time of maize dough prolongs the time for more lactic acid to be formed through the microbial conversion of glucose with a resultant decrease in pH (Teniola and Odunfa 2001).

Table 7.3: ANOVA summary table showing mean square values

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>pH</th>
<th>Titratable acidity</th>
<th>Glucose</th>
<th>Lactic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steeping time</td>
<td>2</td>
<td>2.1174*</td>
<td>0.7695*</td>
<td>16.35</td>
<td>0.0599</td>
</tr>
<tr>
<td>Fermentation Time</td>
<td>2</td>
<td>0.0442</td>
<td>0.1377*</td>
<td>48.26*</td>
<td>0.3856</td>
</tr>
<tr>
<td>Steeping Temperature</td>
<td>2</td>
<td>0.0870</td>
<td>0.0177*</td>
<td>591.40*</td>
<td>1.1872*</td>
</tr>
</tbody>
</table>

*significant at p<0.05
7.6.3 Glucose concentration in maize dough

The glucose content in matured cereal grains is usually very low as it is tied up in more complex polysaccharides such as starch and cellulose. The glucose content of the maize dough ranged from 4.02 to 61.96 mg/g % dry matter basis. Glucose content decreased
with increased steeping times and steeping temperature (Figure 7.5). Generally, extended periods of fermentation also decreased the glucose levels in the maize dough (Figure 7.5). These results are in agreement with studies reported by Michodjèhoun-Mestres et al., (2005), which showed that during fermentation, fermentable sugars first increased, then decreased. The authors attributed the decrease in glucose concentration to the conversion to lactic acid by the increasing population of lactic acid bacteria. Anova results revealed that steeping times, fermentation times and steeping temperature significantly (p ≤0.05) affected glucose levels in the maize dough.

The decrease in glucose content with steeping time, fermentation and steeping temperature suggest that glucose was used as a substrate for fermentation. This is supported by Blandino et al, (2003) who indicated that organic acid like lactic acid are produced during cereal fermentation. The data for glucose concentration was fitted into second order polynomial model using response surface regression procedures. Figure 7.6 shows that increasing steeping time marginally decreased the glucose content of maize dough. When dehulled maize was steeped for long periods of time and fermented the rate of decrease in glucose content in the fermenting dough was far more rapid than dough obtained from maize that was not steeped for long periods. Fermentation of maize dough was consequently far more rapid as determined by the rate of glucose decrease when dehulled maize was steeped for some time, then milled into flour, made into dough and fermented.
Figure 7.5: Main effects plot for glucose of dehulled maize dough as a function of steeping time, fermentation time and steeping temperature.

Figure 7.6: Surface plots of glucose content of dehulled maize dough as a function of steeping time($X_1$) and fermentation time($X_2$)

Glucose = 122.530 - 0.219$X_1$ - 0.366$X_2$ - 5.326$X_3$ - 0.002$X_1^2$ - 0.019$X_2^2$ + 0.058$X_3^2$ - 0.003$X_1X_2$ + 0.009$X_1X_3$ + 0.022$X_2X_3$.

$R^2 = 79.5\%$

$X_1$- steeping time, $X_2$- fermentation time, $X_3$- steeping temperature
7.6.4 Organic acids concentration in fermenting dough

Lactic acid was the main organic acid observed in fermented maize dough. The lactic acid values varied between 1.18 mg/g to 4.88 mg/g dry matter basis depending on treatments (Appendix 12). Acetic acid was found in low amounts (0.2-0.85 mg/g) and there were also traces of ethanol (0.2-0.85 mg/g). The glucose and organic acids content of the dehulled maize dough (% dry matter basis) are shown in Appendix 12.

The main effects plot for lactic acid content of dehulled maize dough is shown in figure 7.7. As was observed that steeping time had marginal effect on glucose content (Figure 7.6), it also did not have significant effect on lactic acid content. Lactic acid content increased as fermentation time and steeping temperature increased. This could be due to increasing levels of lactic acid bacteria (LAB) with fermentation time as observed by many workers (Melaku and Faulks (1988), Blandino et al., 2003, Halm et al., 1993, Amoa-Awua et al., 2007. The data for lactic acid concentration was fitted into second order polynomial model using response surface regression procedures (Figure 7.8). Lactic acid content of dough increased rapidly as fermentation time increased at low steeping time. Highest lactic acid was obtained at low steeping and high fermentation time. Longer steeping time for dehulled maize and long fermentation time of dough showed a decrease in lactic acid concentration. The lowest lactic acid content was recorded at short steeping time and short fermentation time at which time glucose content was at its highest (Figure 7.6)
Figure 7.7: Main effects plot for lactic acid of dehulled maize dough as a function of steeping time, fermentation time and steeping temperature

Figure 7.8: Surface plots of lactic acid of dehulled maize dough as a function of steeping time($X_1$) and fermentation time($X_2$)

Lactic acid$= -1.46649-0.03831X_1+0.13299X_2+0.11833X_3+0.00037X_1^2+0.00056X_2^2-0.00081X_3^2-0.00041X_1X_2+0.00056X_1X_3-0.00333X_2X_3.

$R^2=51.7\%$

$X_1$- steeping time, $X_2$- fermentation time, $X_3$- steeping temperature
7.6.5 Physicochemical properties of white kenkey

The physicochemical properties of white kenkey were significantly influenced by the processing variables of steeping time, fermentation time and steeping temperature (Table 7.4). While some of the kenkey properties such as moisture and colour were not very sensitive to variations in the process variables, others such as pH of the kenkey varied significantly (p<0.05). It was therefore important to monitor how the effects of processing variables on the intermediate products (of maize dough) are carried into the final kenkey product.

7.6.5.1 Moisture content of kenkey

The texture of kenkey is a very critical quality characteristic, and it is partly influenced by the moisture content. The moisture content of the kenkey samples ranged from 72-78 % depending on the process treatments combinations of maize steeping time, steeping temperature and fermentation time. There were no significant variations (p<0.05) between the moisture content of the samples (Table 7.4). Thus, the differences observed between the maize dough samples under the different process conditions, did not transfer into the final product. This could be that the unit operation of aflatox cooking in the kenkey process and the subsequent steaming of the kenkey provided sufficient moistening effects to even out the process deficiencies.
Table 7.4: ANOVA summary table of the effects of process variables on *kenkey* physicochemical parameters (using mean square values)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Moisture</th>
<th>pH</th>
<th>Titratable acidity</th>
<th>Colour</th>
<th>Glucose</th>
<th>Lactic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steeping time</td>
<td>2</td>
<td>3.565</td>
<td>1.4499*</td>
<td>0.0102</td>
<td>3.565</td>
<td>0.848</td>
<td>0.0656</td>
</tr>
<tr>
<td>Fermentation Time</td>
<td>2</td>
<td>0.078</td>
<td>0.3144*</td>
<td>0.0381*</td>
<td>0.078</td>
<td>6.155</td>
<td>0.3496</td>
</tr>
<tr>
<td>Steeping Temperature</td>
<td>2</td>
<td>6.228</td>
<td>0.5368*</td>
<td>0.0189</td>
<td>6.228</td>
<td>39.771*</td>
<td>0.1565</td>
</tr>
</tbody>
</table>

*significant at p<0.05

7.6.5.2 *pH of white kenkey*

The pH values of the *kenkey* ranged from 3.73-5.11. All the process variables of steeping time, steeping temperature and fermentation time significantly (p<0.05) influenced the pH of the final *kenkey* product (Table 7.4). The pH decreased as the processes steeping and fermentation times increased (Figure 7.9). This was probably due to the breakdown of glucose and other simple sugars into organic acids, such as lactic acid, and the dissociation of which leads to decrease of the pH. Similar trends were observed by Lineback and Ingett (1982) and Owuama, (1998), who indicated that the biochemical changes that take place during steeping include rapid utilization of soluble carbohydrates.
Figure 7.9: Main effects plot for pH of white kenkey as a function of steeping time, fermentation time and steeping temperature.

The pH data of the kenkey was fitted to response surface regression model. The model was adequate, as it could explain 93.6% of the variations in the pH of kenkey based on the predictors of steeping time, steeping temperature and fermentation time. The response plot generated using the model (Figure 7.10) showed that as steeping times increased pH of the kenkey decreased (Figure 7.10) and it is consistent with observations by Owuama (1998).

Figure 7.10: Surface plots of pH of white kenkey as a function of steeping time ($X_1$) and fermentation time ($X_2$)
\[ pH = 4.16152 - 0.31225X_1 - 0.08458X_2 + 0.12150X_3 + 0.2248X_1^2 + 0.20316X_2^2 + 0.1888X_1X_2 - 0.10167X_1X_3 + 0.09300X_2X_3 \]
\[ R^2 = 93.6\% \]

\( X_1 \)- steeping time, \( X_2 \)- fermentation time, \( X_3 \)- steeping temperature

Analyses of the predictors showed that fermentation time had a stronger effect on the pH than the steeping time. The decrease in pH during steeping and fermentation was an indication of the presence and activity of microorganisms which hydrolyzed carbohydrates to organic acids (Teniola and Odunfa, 2001).

7.6.5.3 Titratable acidity of white kenkey

The titratable acidity (TTA) of the kenkey samples ranged from 0.47 to 0.87 % lactic acid dry matter basis. The process treatments of steeping time, steeping temperature and fermentation duration significantly influenced the titratable acidity (TTA) of kenkey \((p \leq 0.05)\). The effects of process variables of steeping time, fermentation time and steeping temperature are represented graphically in Figure 7.11. The figure shows that TTA increased with fermentation time but decreased with steeping time and steeping temperature.

![Figure 7.11: Main effects plot for titratable acidity of white kenkey as a function of steeping time, fermentation time and steeping temperature.](http://ugspace.ug.edu.gh)
The titratable acidity data for kenkey were modelled on the three process variables of steeping time, steeping temperature and fermentation time of the maize dough. The regression model showed to be a good fit and could explain almost 74% ($R^2=73.7$) of the variations in the TTA of kenkey. The model for TTA was used to generate a response surface plot (Figure 7.12a) in order to determine the trends of the variations of TTA with the process variables. The response plot (Figure 7.12a) showed that while steeping duration of maize had marginal effects on the TTA of the final product (kenkey), increasing fermentation time of the dough showed a rapid increase in the TTA of kenkey. Figure 7.12b shows a response plot of TTA as a function of steeping temperature and fermentation time. There was a significant interaction of the process variables, and the surface plot clearly demonstrates that the effect of one process variable on TTA depended on the level of the other process variable. For example, at low steeping temperatures, increasing fermentation time increased TTA of kenkey, while at high steeping temperatures, TTA of kenkey decreased with fermentation time, probably due to the loss of volatile acids (Teniola and Odunfa, 2001).

Figure: 7.12a: Surface plots of TTA of white kenkey as a function of steeping time ($X_1$) and fermentation time ($X_2$)
TTA=0.5925-0.02282X₁+0.04496X₂-0.037338X₃-
0.0266X₁²+0.0499X₂²+0.020193X₃²+0.008380X₁X₂+0.085429X₁X₃-0.088310X₂X₃

R²=73.7%  X₁- steeping time, X₂- fermentation time, X₃- steeping temperature

Figure 7.12b: Surface plots of TTA of white kenkey as a function of fermentation time (X₂) and steeping temperature (X₃)

7.6.5.4 Glucose content of white kenkey

The glucose content of the kenkey samples ranged between 0.5-5.75 mg/g, depending on the process treatments combinations. The glucose content in kenkey was significantly influenced only by the steeping temperature of the dehulled maize. The influence of the process treatments on the glucose content of kenkey is shown in figure 7.13. The figure shows that glucose content in kenkey was not influenced by steeping time. However, steeping dehulled maize at elevated temperature decreased the glucose content of kenkey. Since it was observed that increased steeping temperature decreased the titratable acidity in the kenkey, it may be surmised that steeping temperature probably reduced both the amylolytic and the fermentative capacities of the microorganisms. There was a direct
relationship between fermentation time and glucose content. Increased fermentation time resulted in increased glucose content.

![Graph showing the relationship between fermentation time and glucose content.](image)

**Figure 7.13**: Main effects plot for glucose of white *kenkey* as a function of steeping time, fermentation time and steeping temperature.

### 7.6.5.5 Lactic acid content of white kenkey

Lactic acid content in the *kenkey* ranged between 0.24 to 1.45 mg/g. The lactic acid content in *kenkey* as a function of process variables is shown in the main effects plot in figure 7.14. Lactic acid content increased as both steeping time and fermentation time increased. The high levels of lactic acid might be attributed to the predominance of Lactic acid Bacteria (LAB), which converts glucose to lactic acid (Blandino *et al.*, 2003).
7.6.5.6 **Colour**

Whiteness (L) value of white *kenkey* ranged from 77-82. The process treatments of steeping times, steeping temperature and fermentation duration significantly affected whiteness of white *kenkey*.

Figure 7.15 shows the main effects plot for colour (L) of white *kenkey*. The whiteness index (L-value) decreased as the steeping time of the dehulled maize increased (Figure 7.15). As fermentation time increased from 0-24 h, the whiteness index of *kenkey* increased. However, *kenkey* prepared with dough that was fermented beyond 24 hours showed decreased whiteness values. This was because of release of soluble solids. The effects of steeping temperature of dehulled maize on the whiteness index of *kenkey* was that as temperature increased the *kenkey* darkened probably due to oxidative or non-enzymatic reactions.
Figure 7.15: Main effects plot for whiteness (L) of white *kenkey* as a function of steeping time, fermentation time and steeping temperature.

7.7 Textural properties of white *kenkey*

7.7.1 Hardness

The hardness is an indicator of stability or design changes in texture (Civille, 2011). Hardness value is the force at maximum compression during first bite. It is also the measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Consumers of *kenkey* dislike very hard or too soft *kenkey*. They prefer crumbliness in quality *kenkey*.

The hardness of white *kenkey* ranged from 132.5 to 456.51 g. All the three processing treatments of steeping time, steeping temperature and fermentation time significantly influenced the hardness of *kenkey* (Table 7.5). The main effects plot for hardness of white *kenkey* is shown in figure 7.16. It was observed that as the steeping times of the dehulled maize grain increased, hardness of the white *kenkey* prepared from the dough decreased (figure 7.16). On the other hand, *kenkey* prepared from dough that was fermented for long periods recorded high hardness values, while *kenkey* prepared from 12 h fermented dough recorded low hardness values. The surface plot (Figure 7.17) indicated that high hardness value of *kenkey* was obtained when the grains were steeped...
for shorter times but the dough used for the kenkey was fermented for very long time durations. The loss in hardness with fermentation time could be ascribed to the weakening of the starch structure due to microbial activity. The least values for hardness of kenkey were obtained when the maize was steeped for long periods, and the maize dough also fermented for very long time.

Table 7.5 ANOVA summary table showing mean square values

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Hardness</th>
<th>Stickiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steeping time</td>
<td>2</td>
<td>49689*</td>
<td>1209*</td>
</tr>
<tr>
<td>Fermentation Time</td>
<td>2</td>
<td>30981*</td>
<td>1282.5*</td>
</tr>
<tr>
<td>Steeping Temperature</td>
<td>2</td>
<td>74229*</td>
<td>887.8*</td>
</tr>
</tbody>
</table>

*significant at p<0.05

Figure 7.16: Main effects plot for hardness of white kenkey as a function of steeping time, fermentation time and steeping temperature.
Figure 7.17: Surface plots of hardness of white kenkey as a function of fermentation time ($X_2$) and steeping temperature ($X_3$)

Hardness$=-407.349-1.703X_1+0.442X_2+40.411X_3-0.012X_1^2+0.237X_2^2+0.630X_3^2-0.305X_1X_2-0.077X_1X_3+0.125X_2X_3$  \[ R^2=51.2\% \]

$X_1$- steeping time, $X_2$- fermentation time, $X_3$- steeping temperature

7.7.2 Stickiness

Stickiness of dough involves quite different and variable factors. The contact of a dough with a surface causes a force of adhesion which may vary from flour to flour. If the dough is strong and elastic, the adhesive force is overcome, and the dough will separate from the surface (i.e., the dough is not sticky). If the dough is viscous, it will flow and not overcome the adhesive force (i.e., the dough is sticky) (Huang and Hoseney 1999). A food material is perceived as being sticky when the adhesive force is high and the cohesive force is low (Hoseney and Smewing 1999).

The measure of stickiness is the negative area under the curve (g.s), which is the ‘work of adhesion’, and the distance the sample is extended as the probe return, which is an indication of sample cohesion dough strength. These parameters conform to the parameters adhesive force, adhesiveness, and stringiness from a generalized texture.
profile analysis curve (Bourne 1978). Consumers of white kenkey desire mildly sticky kenkey and they use their fingers to assess this attribute.

Stickiness of white kenkey varied from 2.14-32 g.s. All the three processing treatments of steeping time, steeping temperature and fermentation time significantly influenced the stickiness of kenkey (Table 7.5). The effects of processing variables on the stickiness of kenkey is shown in the main effect plots (Figure 7.18). The graphs show that stickiness decreased with increased steeping and fermentation time. The highest stickiness value for kenkey was obtained at short steeping times and fermentation times (Figure 7.19).

Figure 7.18: Main effects plot for stickiness of white kenkey as a function of steeping time, fermentation time and steeping temperature.
Figure 7.19: Surface plots of stickiness of white kenkey as a function of fermentation time ($X_2$) and steeping temperature ($X_3$)

$$\text{Stickiness}=142.735-1.041X_1-1.878X_2-5.510X_3+0.005X_1^2+0.011X_2^2+0.070X_3^2+0.008X_1X_2+0.009X_1X_3+0.026X_2X_3$$

$X_1$- steeping time, $X_2$- fermentation time, $X_3$- steeping temperature

7.8. Effects of process treatments on consumer acceptability of white kenkey

Sensory properties are critical to consumer acceptability of every food product. For white kenkey, the most important sensory attributes are texture; taste, aroma and appearance. Results for the sensory evaluation of white kenkey are presented in Table 7.6.

The scores for texture ranged from 5.29 to 7.71 on a 9-point hedonic scale, and the scores for taste ranged from 6.29 to 7.57. Similarly the scores for aroma varied from 5.57 to 7.57 and acceptability ranged from 6.14 to 7.57 (Table 7.6). The score ranges of all the attributes suggest that consumer’s opinion for the kenkey sensory attributes ranged from like slightly to like very much. Inspite of the observed variations in the consumer
scores for sensory attributes, the process treatments (of steeping time, steeping temperature and fermentation time) did not have significant effects on the attributes of white kenkey (Table 7.7). The means plots (Figure 7.20) however showed that the score for texture of kenkey tended to increase with steeping time of maize, but decreased with steeping temperature of the maize as well as the fermentation time of the maize dough. Similarly the means plots showed that both steeping time and steeping temperature showed increases for overall acceptability of white kenkey, while fermentation time reduced it (Figure 7.21).

Table 7.6: Summary of the effects of process treatments on consumer response to critical sensory attributes of white kenkey

<table>
<thead>
<tr>
<th>Steeping time (hours)</th>
<th>Fermentation time (hours)</th>
<th>Steeping temperature (°C)</th>
<th>Taste</th>
<th>Aroma</th>
<th>Texture</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
<td>35</td>
<td>7.57±0.98</td>
<td>7.29±1.11</td>
<td>7.14±1.21</td>
<td>7.00±1.73</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>25</td>
<td>6.86±1.46</td>
<td>7.57±0.79</td>
<td>7.00±0.82</td>
<td>7.00±1.00</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>45</td>
<td>7.00±0.82</td>
<td>7.29±1.11</td>
<td>7.00±1.83</td>
<td>7.14±0.90</td>
</tr>
<tr>
<td>30</td>
<td>24</td>
<td>25</td>
<td>7.14±1.07</td>
<td>7.29±0.49</td>
<td>6.86±1.07</td>
<td>7.00±1.15</td>
</tr>
<tr>
<td>30</td>
<td>24</td>
<td>45</td>
<td>6.29±2.36</td>
<td>6.57±1.81</td>
<td>6.14±1.95</td>
<td>6.71±2.14</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
<td>35</td>
<td>7.00±0.82</td>
<td>7.00±0.82</td>
<td>6.43±1.81</td>
<td>6.57±1.40</td>
</tr>
</tbody>
</table>

Table 7.7: ANOVA summary table showing mean square values

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Taste</th>
<th>Texture</th>
<th>Odour</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steeping time</td>
<td>2</td>
<td>0.449</td>
<td>5.041</td>
<td>1.278</td>
<td>5.055</td>
</tr>
<tr>
<td>Fermentation Time</td>
<td>2</td>
<td>1.295</td>
<td>0.722</td>
<td>1.080</td>
<td>0.233</td>
</tr>
<tr>
<td>Steeping Temperature</td>
<td>2</td>
<td>1.242</td>
<td>0.180</td>
<td>3.085</td>
<td>0.231</td>
</tr>
</tbody>
</table>
7.8.1: Modelling of the sensory attributes of white kenkey on the process treatment variables.

The data for taste, aroma, texture and overall acceptability scores were fitted to response surface regression models (Table 7.8). Analysis of variance of the regression models
showed that the lack of fit, which measures the appropriateness of the selected model, was not significant for the sensory attributes of taste, texture and overall acceptability, indicating that the models were useful for predicting those responses, even though the r-squared values were low. The low coefficients of determination ($R^2$) of the responses indicate that a high proportion of variability could not be explained by the data. The models for the various sensory attributes were used to generate contour plots (Figures 7.22-7.29) to enable easy interpretation of the effects of the treatment variables.

Table 7.8: Regression parameters of the model

<table>
<thead>
<tr>
<th>Variables/factors</th>
<th>Estimated Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Taste</td>
</tr>
<tr>
<td>Constant</td>
<td>3.36</td>
</tr>
<tr>
<td>$X_1$</td>
<td>0.05</td>
</tr>
<tr>
<td>$X_2$</td>
<td>0.09</td>
</tr>
<tr>
<td>$X_3$</td>
<td>0.14</td>
</tr>
<tr>
<td>$X_1 X_2$</td>
<td>$-12 \times 10^{-4}$</td>
</tr>
<tr>
<td>$X_1 X_3$</td>
<td>$33 \times 10^{-5}$</td>
</tr>
<tr>
<td>$X_2 X_3$</td>
<td>$-417 \times 10^{-5}$</td>
</tr>
<tr>
<td>$X_1^2$</td>
<td>$-18 \times 10^{-5}$</td>
</tr>
<tr>
<td>$X_2^2$</td>
<td>$12 \times 10^{-5}$</td>
</tr>
<tr>
<td>$X_3^2$</td>
<td>$8 \times 10^{-5}$</td>
</tr>
<tr>
<td>$R^2$</td>
<td>5.9</td>
</tr>
</tbody>
</table>

$X_1$: Steeping time (hours), $X_2$: Steeping temperature (°C), $X_3$: Fermentation time (hours)
7.8.1.1 Taste

The contour plots show that as steeping time of dehulled maize increased the taste of the white kenkey obtained from partially fermented maize dough reduced marginally from 6.89 to 6.78 and the taste of kenkey obtained from fermented maize dough also marginally increased to 6.99 (Figure 7.22). The plots (Figure 7.23) also showed that increased steeping temperature and fermentation time of maize dough tended to negatively affect the taste of white kenkey. The effects of treatments on the taste of white kenkey as perceived by the consumers could be due to the amounts of organic acids and sugars produced under the conditions.

![Contour plots for the taste of white kenkey (nsiho) as a function of fermentation time and steeping time](image)

*Figure 7.22 Contour plots for the taste of white kenkey (nsiho) as a function of fermentation time and steeping time*
Figure 7.23: Contour plots for the taste of white kenkey (nsiho) as a function of steeping temperature and steeping time

7.8.1.2: Odour

The contour plots show that as steeping time of dehulled maize increased the odour of the white kenkey obtained from partially fermented maize dough reduced marginally from 7.28 to 6.32 and the odour of kenkey obtained from fermented maize dough reduced to 6.44 (Figure 7.24). The plots also showed that increased steeping temperature of maize dough tended to negatively affect the odour of white kenkey (Figure 7.25). The odour of white kenkey may originate from a number of factors including the accumulation of organic acids and alcohols during steeping and/or fermentation of the dough.
Figure 7.24 Contour plots for odour of white kenkey (nsiho) as a function of fermentation time and steeping time

Figure 7.25: Contour plots for odour of white kenkey(nsiho) as a function of steeping temperature and steeping time

7.8.1.3: Texture

In the consumption of kenkey (usually by hand), good white kenkey should have a smooth but stiff and crumbly texture. Figure 7.26 shows the contour plots for the effect of process variables on the texture attribute. The plots indicated that textural score of white
Kenkey improved from 6.4 to 7.1 when the steeping time of maize dough used in its preparation was increased. Texture of kenkey was enhanced when the fermentation time was increased. The plots also show that increased steeping temperature improved the texture of white kenkey (Figure 7.27). The effects of the process-variables on the textural characteristics could be on the depletion of soluble solids and sugars, and the modification of the starches during dough fermentation all add up to influence its functionality. Consequently the white kenkey behaves like starch gels.

![Contour plots for texture of white kenkey (nsiho) as a function of fermentation time and steeping time](image)

**Figure 7.26:** Contour plots for texture of white *kenkey* (*nsiho*) as a function of fermentation time and steeping time.
Figure 7.27 Contour plots for texture of white kenkey (nsiho) as a function of steeping temperature and steeping time

7.8.1.4: Overall Acceptability

The contour plots show that as steeping time of dehulled maize increased, the acceptability of the white kenkey obtained from partially fermented maize dough increased from 6.4 to 7.0 and the acceptability of kenkey obtained from fermented maize dough also marginally increased to 6.9 (figure 7.28). The plots also showed that increased steeping temperature positively affected the acceptability of white kenkey (figure 7.29).
Figure 7.28 Contour plots for acceptability of white kenkey (nsiho) as a function of fermentation time and steeping time

Figure 7.29 Contour plots for acceptability of white kenkey (nsiho) as a function of steeping temperature and steeping time
7.9 Selection of optimum conditions

The contour plots of all the sensory attributes for white *kenkey* were overlaid on same axis, using minitab (version 14, Minitab Inc. UK). The optimum region of the process treatment variables was where all the criteria of the sensory attributes were satisfied. The sensory criteria used were those based on the mean scores that suggested very acceptable sensory attributes which ranged from like moderately to like extremely. Consequently the constraints for the acceptable criteria for the sensory attributes ranged from scores of 7 (liked moderately) to 9 (liked extremely).

The overlaid contour plot for all the sensory attributes is illustrated in figure 7.30. From the plot, the process treatment combinations that provided optimum product sensory characteristics were steeping dehulled maize for 30-45 hours at 30-35°C and fermenting the dough for 12 hours (Figure 7.30). The location of the optimum region in the experimental space suggests that good quality white *kenkey* may be obtained when dehulled maize is steeped for a little over a day at ambient temperatures of 30-35°C and fermented for about half a day (12 hours).
7.10 Verification of optimized conditions

To verify that the predictive models obtained were adequate for determining consumer acceptability of white *kenkey*, two process treatment combinations were selected from within the optimum region and two from outside the region (Table 7.9). *Kenkey* made from the four treatments were subjected to sensory evaluation by the same panel of judges. Results from the verification study (Table 7.10) showed that the ratings for odour, texture, taste and acceptability compared well with the predicted ratings. The verification results indicated a good agreement between the observed and predicted ratings.
Table 7.9: Process treatment combinations for verification of optimum region

<table>
<thead>
<tr>
<th>Process treatment conditions</th>
<th>Steeping time (hr)</th>
<th>Steeping Temperature (°C)</th>
<th>Fermentation Time (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>25</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>T2</td>
<td>20</td>
<td>45</td>
<td>12</td>
</tr>
<tr>
<td>T3</td>
<td>30</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>T4</td>
<td>45</td>
<td>35</td>
<td>12</td>
</tr>
</tbody>
</table>

T1 and T2 are treatment conditions outside optimum region, T3 and T4 are pre-treatment conditions within optimum region.

Table 7.10. Predicted and validated ratings for sensory attributes in the optimum region

<table>
<thead>
<tr>
<th>Samples</th>
<th>Taste</th>
<th>Odour</th>
<th>Texture</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Observed</td>
<td>Predicted</td>
<td>Observed</td>
</tr>
<tr>
<td>T1</td>
<td>6.47</td>
<td>6.97</td>
<td>7.10</td>
<td>5.70</td>
</tr>
<tr>
<td>T2</td>
<td>6.85</td>
<td>7.12</td>
<td>7.00</td>
<td>5.62</td>
</tr>
<tr>
<td>T3</td>
<td>6.90</td>
<td>7.00</td>
<td>7.15</td>
<td>6.92</td>
</tr>
<tr>
<td>T4</td>
<td>7.01</td>
<td>7.37</td>
<td>6.70</td>
<td>6.65</td>
</tr>
</tbody>
</table>

Treatments T1 and T2 were outside of the optimum process region and T3 and T4 were within the optimum process region of steeping time, steeping temperature and fermentation time.

7.11 Conclusion

The processing variables of maize steeping time, steeping temperature and dough fermentation time have significant influences on the physicochemical properties as well as the sensory attributes of white kenkey. The effects of the processing variables on the fermenting dough ultimately transfer into the final kenkey product. Long steeping and fermentation times increase the titratable acidity and lower the pH of the fermenting dough. Steeping at elevated temperatures also caused higher souring rates. Fermentation time has a stronger influence on the soaring indices of pH and TTA than steeping.
temperature. These trends showed both for the maize dough and the kenkey made from it.

Both steeping and fermentation decrease glucose content in the maize dough as well as in the kenkey, but fermentation increased lactic acid content in them. The lactic acid content is influenced largely by steeping temperature and the fermentation time of the dough. Depending on the process treatment combinations, consumers’ opinions of the kenkey range from like slightly to like very much. Increasing steeping time and temperature positively influenced the acceptability of white kenkey. The optimum process conditions for production of consumer acceptable white kenkey are steeping maize for 30-45 hours at temperatures of 30º-35ºC, and fermenting the dough for 12 hours. Kenkey obtained from these conditions consistently showed sensory characteristics which consumers desire.
CHAPTER 8

OBJECTIVE 6: To conduct sensory profiling and consumer acceptability studies of white kenkey from the optimized processing conditions.

8.0 Introduction

Two types of white kenkey (nsiho) are commonly recognized in Ghana, and they are the non-sweetened (Anum and Atimpoku) and sweetened (Osino) types. The basic raw material for white kenkey (sweetened or non-sweetened) is maize dough obtained after milling of steeped dehulled maize. The processing of white kenkey may or may not include a further fermentation step. For the partially fermented (Atimpoku) type steeping is the only step of fermentation whilst for the fermented (Anum) type, the dough is fermented for 12 h after obtaining a meal from steeped dehulled grains. Among the kenkey types, the non-sweetened white kenkey is far more patronized than sweetened white kenkey.

Some quality attributes of kenkey have been linked to processing parameters such as steeping of the maize grains and dough fermentation. Due to the differences in processing procedures and packaging material, it has been reported that differences exist in the organoleptic properties for the different types of kenkey (Sefa-Dedeh, 1993; Amoa-Awua et al., 2007).

Unlike Ga- and Fante- kenkey, the enterprise of white kenkey (nsiho) processing has remained at the level of “ethnic food”, restricted to very few ethnic communities (Atimpoku and Anum). Current trends in urbanization, and the increasing popularity of kenkey among consumers, require larger scale production with consistent quality. Upgrading production from the artisanal to industrial level will require consumer input
on critical quality attributes that influence product acceptability. Consumers have often been considered only capable of hedonic judgement (Meilgaard et al., 1999; Stone and Siedel, 1985), but in order to design food products that meet consumer sensory expectations, information about how consumers perceive the sensory characteristics of the product is invaluable (Guinard et al., 2001; ten Kleij and Musters, 2003). Descriptive sensory analysis with a trained panel enables scientists to measure the sensory reaction to stimuli resulting from the consumption of a product, providing a description of the qualitative and quantitative aspects of human perception, and allowing correlations to other parameters (Lawless and Heymann, 2010; Moussaoui and Varela, 2010; Murray et al., 2001; Stone and Sidel, 2004).

Descriptive analysis has always served as a link between product characteristics and consumer reaction. Sensory descriptive analysis requires as a first step the selection, training and maintenance of a panel of 8–20 assessors (Varela and Ares, 2012). The objective of this study was to determine the sensory profile and consumer acceptance of non-sweetened white kenkey prepared using the optimum process conditions of steeping time (30 and 45 h), steeping temperature (30°C and 35°C) and dough fermentation time of 12 h.

8.1 Materials and Methods

8.1.1 White kenkey preparation for Quantitative Descriptive sensory analysis (QDA)

White kenkey samples were prepared using four pre-determined treatments outside and within the optimum process parameters as shown in Table 8.1. Traditionally processed nsiho obtained from Anum was used as a control in the QDA.
### Table 8.1: Processing procedures used for dehulled maize dough preparation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Steeping time (hours)</th>
<th>Steeping temperature (°C)</th>
<th>Fermentation time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>25</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>T2</td>
<td>20</td>
<td>45</td>
<td>12</td>
</tr>
<tr>
<td>T3</td>
<td>30</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>T4</td>
<td>45</td>
<td>35</td>
<td>12</td>
</tr>
</tbody>
</table>

*Treatments T1 and T2 were outside of the optimum process region and T2 and T3 were within the optimum process region of steeping time, steeping temperature and fermentation time.

Fermented dehulled maize dough (800 g) were obtained using the four treatment conditions outlined in Table 8.1. The dough was mixed with 400 ml of water to obtain a slurry and 6g of table salt was added. Half a litre of water was brought to boil and the slurry poured into it whilst stirring continuously for 5 mins to form a thick paste. The paste was mixed thoroughly with 400 g of uncooked dehulled maize dough. Three hundred and fifty 350 g of the mixture was molded into a ball, wrapped with washed dried maize husk and steamed for 45min to produce white *kenkey*. Three (3) gram slices of the *white kenkey* were used for the sensory analysis.

### 8.2. Training of sensory panel

Eighteen (18) panelists from CSIR-Food Research Institute who had previous experience in descriptive sensory analysis of *kenkey* were selected for the study. Further training and group discussions were conducted for two (2) days for 6 hours each to generate descriptors for white *kenkey*. The panel was also trained to quantify the intensity of sensory attributes using line scales. All the panelists were over 18 years old, were regular consumers of white *kenkey*, had no known food allergy and had expressed the willingness to participate in the study. The training was carried out at the sensory University of Ghana http://ugspace.ug.edu.gh
laboratory of CSIR-Food Research Institute. The descriptors agreed on by the panel and their definitions are shown in Table 8.2.

Table 8.2: Generated sensory descriptors and their definition

<table>
<thead>
<tr>
<th>Descriptors</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aroma</strong></td>
<td></td>
</tr>
<tr>
<td>Boiled fresh maize</td>
<td>aroma characteristic of boiled fresh maize</td>
</tr>
<tr>
<td>Fermented maize dough</td>
<td>aroma characteristic of fermented maize dough</td>
</tr>
<tr>
<td>Smoky</td>
<td>aroma of wood smoke</td>
</tr>
<tr>
<td>Sweet</td>
<td>aroma that gives an impression of a sweet taste</td>
</tr>
<tr>
<td>Boiled dry maize</td>
<td>aroma characteristic of boiled dry maize as in cooked ‘maize grits’</td>
</tr>
<tr>
<td>Cooked rice</td>
<td>aroma characteristic of cooked non-aromatic rice</td>
</tr>
<tr>
<td>Maize porridge</td>
<td>aroma characteristic of cooked maize slurry</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td></td>
</tr>
<tr>
<td>Sticky</td>
<td>texture that clings to the fingers and tongue</td>
</tr>
<tr>
<td>Soft</td>
<td>Texture that is opposite to hard</td>
</tr>
<tr>
<td>Crumbly</td>
<td>Texture that easily breaks apart</td>
</tr>
<tr>
<td>Smooth</td>
<td>texture that is not coarse but even</td>
</tr>
<tr>
<td><strong>Taste</strong></td>
<td></td>
</tr>
<tr>
<td>Sweet</td>
<td>tastes sweet as in sugar</td>
</tr>
<tr>
<td>Salty</td>
<td>tastes of table salt (sodium chloride)</td>
</tr>
<tr>
<td>Sour</td>
<td>taste that is like vinegar (acetic acid)/ fermented taste</td>
</tr>
<tr>
<td>Milky</td>
<td>taste of milk or cream</td>
</tr>
<tr>
<td>Cooked rice</td>
<td>taste associated with cooked non-aromatic rice</td>
</tr>
<tr>
<td>Astringent</td>
<td>Dry mouth-feel (experience one has after eating unripe bananas)</td>
</tr>
<tr>
<td><strong>Colour</strong></td>
<td></td>
</tr>
<tr>
<td>Whitish colour</td>
<td>Colour that is similar to white</td>
</tr>
</tbody>
</table>

8.3 Test Protocol

Sensory analysis of the five white *kenkey* samples (ie the four treatments in Table 8.1 and a control sample obtained from traditional *kenkey* processors) was carried out by the
panelists in purposed booths at the sensory laboratory of Food Research Institute under controlled white fluorescent lights at ambient temperature. Each panelist was served with a 3 g slice of each of the five white *kenkey* samples. The samples were coded with 3 digit random numbers and served randomly to panelists on white paper plates. Each panelist evaluated all five samples per session over three different 20 min sessions. Each panelist was provided with biscuit and a cup of water at room temperature for rinsing the mouth in-between sample tasting. The samples were scored using a modified version of quantitative descriptive analysis (QDA) since standards were not provided (Meilgaard *et al*., 1988) (Tomlins *et al*., 2005).

Intensity ratings were scored on a 10 mm unstructured scale, anchored with the terms ‘not very’ at the low end and ‘very’ at the high end. There were three different sessions.

8.4 Physicochemical properties of optimized white *kenkey*

8.4.1 Determination of moisture content

Moisture content of the products was determined using the air-oven method at 105°C as described in the AACC Method 44-15A (American Association of Cereal chemists, 2000). The moisture content was determined in triplicate as loss in moisture.

8.4.2 Titratable acidity

Titratable acidity was determined according to AACC method 02-52, (2000). Ten grams of sample was dispersed into 20 ml of distilled water and homogenized for 2 min. The electrode of the pH meter was placed into the sample solution and the pH was read after 1 min. 70 ml of distilled water was added to the sample solution and freshly prepared 0.1N sodium hydroxide was added while agitating to continue neutralization until a pH
of 8.5 was reached. After 5 min, the pH was adjusted to 8.5 and the final amount of sodium hydroxide used was read. The results were expressed as follows;

\[
\% \text{ lactic acid} = \frac{V \times 900 \times N}{M \times ms}
\]

\(V=\) volume of titrant (ml)

\(N=\) normality of soda

\(M=\) mass of sample (g)

\(Ms=\) Dry matter (% dry basis)

### 8.4.3 Determination of Glucose and Lactic acid

Glucose and Lactic acids were determined using High Performance Liquid Chromatography (HPLC 360 Auto sampler (Shimadzu LC-9A), as described by Mestres and Rouau, (1997).

#### Sample preparation

One gram of sample was weighed with a screw-capped tube and 3 ml of 0.5 M H₂SO₄ was added. This content was homogenized using a Rotator, SB2, Stuart (Bibby Scientific Ltd, Staffordshire, UK) for an hour. The mixture was centrifuged (Centrifuge 1207, VWR International LLC, West Chester, United States) at 7.2 ×1000 g for 5 min. The supernatant was filtered into an HPLC sample vial through a 0.45-µm RC filter (Minisart, R.C 15 17762, Sartorius AG, 37070, Germany). Separation of organic acids was achieved with an Aminex HPX-87H HPLC column (Bio-Rad Labs., Richmond, Calif., USA) held at 45°C, using 9 mM H₂SO₄ as a mobile phase at a flow rate of 0.4 mL/min. UV detector (Series 200, Perkin Elmer) response was monitored by Turbochrom software (Perkin Elmer).

#### Determination of Organic Acids

Organic acids were identified and quantified by comparison of their retention times with the following standard acids: lactic acid, acetic acid, maltose, glucose, fructose, (Sigma).
The analysis was externally calibrated using mixed standard solutions in de-ionized water, prepared for the samples.

**Sugar Determinations**

Concentrations of glucose, fructose, and maltose were monitored using a refractive index detector (Perkin Elmer) in series with the UV detector and calibrated using standard sugar solutions (Sigma).

**8.4.4 Colour Determination**

The colour of the white *kenkey* samples was measured using a colorimeter (Minolta Chromameter, CR310-Japan Colorimeter D25-PC2, National Institute of Aglaboratories, Reston, VA) which was calibrated with a white tile (L=97.51, a=5.45, b=-3.50) according to (AACC Method 14-22.01, 2000). The colour was expressed in terms of L* a*, b* where L = lightness. Lightness range is from (0-100 scale). The colour of each sample was measured five times per sample. The mean was calculated.

**8.5 Consumer acceptance of optimized white *kenkey***

**8.5.1 Sample preparation**

Traditional Anum and Atimpoku white *kenkey (nsiho)* were obtained from processors in the Eastern region of Ghana. Two samples of optimized white *kenkey* were produced in the laboratory using dehulled maize dough which had been processed using processing variables from the optimum region.

The variables were as follows: Sample 1: 30 h steeping time, 30ºC temperature and 12 h fermentation time and Sample 2: 45 h steeping time, 35ºC temperature and 12 h fermentation time.
Consumer acceptance test was carried out using 65 consumers recruited from CSIR-Food Research Institute and Food Science and Technology students from Kwame Nkrumah University of Science and Technology. All selected participants regularly consumed kenkey at least twice in a week. Each participant evaluated all four (4) samples served as 3 g slices in a randomized order under white fluorescent light at the Sensory Laboratory of the CSIR-Food Research Institute. The samples were coded with 3-digit random numbers. A glass of water and cream crackers were provided to cleanse the palate between samples. Consumers were asked to provide their liking responses on a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely) for taste, texture, odour and overall acceptability.

8.6 Data Analysis

Graphical representation of the sensory profiles, obtained from the QDA, including aroma, taste and colour characteristics were provided as spider-web diagrams by plotting the mean values for the sensory descriptors. The differences between white kenkey means and each descriptor were calculated by analysis of variance (ANOVA) using Minitab 14, Minitab Inc, Brandon Court, United Kingdom). The results were evaluated at 95% confidence level (Mead, 1988). Principal Component Analysis were carried out using XLSTAT (V. 5.2, Addinsoft) version 2012, Addinsoft, Paris, France.

Analysis of variance (ANOVA, alpha=0.05) and Duncan Multiple range test were performed to determine significant differences between means of treatments for the consumer acceptance tests (Minitab 14, Minitab Inc, Brandon Court, United Kingdom).
8.7 Results and Discussion

8.7.1 Physicochemical properties for optimized white kenkey samples

The results of the physicochemical analysis of the different products T1, T2, T3, T4 and traditionally processed white kenkey (control) are shown in Table 8.3. Moisture content of the samples varied from 75.05 - 78.05% among all white kenkey samples. There were no significant (p<0.05) variations in moisture contents of T1, T2, T3, T4 and the control. The titratable acidity (TTA) values for the samples ranged from 0.11% to 0.24%. White kenkey T3 and T4 had TTA value of 0.13 and 0.14% respectively and they were significantly (p<0.05) different from T1 and T2 white kenkey and control (Table 8.3).

The lactic acid content of white kenkey samples T1, T2, T3 and T4 and the control were also significantly different. The control sample recorded the highest lactic acid content (Table 8.3). Acetic acid, maltose and fructose were not determined. Glucose content of white kenkey samples ranged from 3.85-6.00%. There were significant (p<0.05) variation in the glucose content of T3, T4 and T1, T2 white kenkey and the control sample. White kenkey T3, T4 recorded glucose content of 3.85-4.01%, which was significantly lower than T1 and T2 white kenkey (Table 8.3). The control recorded higher glucose content of 6%. The reason for this is that the longer the steeping time, the more glucose is formed.

L value measures the lightness or whiteness of samples. It ranges from (0-100). The L value of the samples ranged from 79.0 to 82.4. There were no significant differences (p<0.05) between white kenkey samples T1, T2, T3 and T4.
Table 8.3: Physicochemical and biochemical properties for four white kenkey samples and control

<table>
<thead>
<tr>
<th>Kenkey Samples</th>
<th>Moisture (%)</th>
<th>Titratable acidity (% lactic acid dry matter basis)</th>
<th>Lactic acid (%)</th>
<th>Glucose (%)</th>
<th>L-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>75.05 ± 0.22a</td>
<td>0.15 ± 0.01a</td>
<td>0.24±7x10^{-3}a</td>
<td>4.73±0.02a</td>
<td>79.0 ± 0.14a</td>
</tr>
<tr>
<td>T2</td>
<td>78.05 ± 0.19b</td>
<td>0.11 ± 0.01b</td>
<td>0.29±0.04b</td>
<td>4.65±0.11b</td>
<td>79.6 ± 0.11b</td>
</tr>
<tr>
<td>T3</td>
<td>76.55 ± 0.32c</td>
<td>0.14 ± 0.02a</td>
<td>0.17±7.1x10^{-3}c</td>
<td>4.01±0.55b</td>
<td>79.6 ± 0.19b</td>
</tr>
<tr>
<td>T4</td>
<td>77.77 ± 0.94b</td>
<td>0.13 ± 0.01a</td>
<td>0.14d</td>
<td>3.85±0.06b</td>
<td>80.3 ± 0.18c</td>
</tr>
<tr>
<td>Control</td>
<td>77.00 ± 0.04b</td>
<td>0.24±0.01c</td>
<td>0.65c</td>
<td>6c</td>
<td>82.43±0.76d</td>
</tr>
</tbody>
</table>

The same letter in a column means that there are no significant difference at p<0.05. Treatments T1 and T2 were outside of the optimum process region and T3 and T4 were within the optimum process region of steeping time, steeping temperature and fermentation time. Control: Traditional Anum nsiho

8.7.2 Quantitative Descriptive Analysis (QDA) of optimized and traditional white kenkey

The sensory scores for the various descriptors of the products made from outside and within the optimum region of processing variables and traditionally processed white kenkey are shown in Table 8.4. There were significant differences (p<0.05) in the sensory attributes among the product types. The descriptor that had consistently high intensity scores in all the five samples was whitish colour. All the samples scored between 7.5 and 8.5 for whitish colour on the scale of 0-10 cm. Thus all the samples had white colour, and there was not much difference in the intensity of whitish colour between the five samples. The whitish colour of the samples is due to the removal of the germ and the yellowish hull during decortication and degerming of the maize grains.

There was not much variation in the intensity of four other descriptors among the five different samples including the control. The descriptors boiled fresh maize aroma (3-5),
sweet aroma (3-4), maize porridge aroma (3-4), cooked rice taste (3-4) and astringent mouthfeel (2-3) had low intensity scores (Table 8.4).

Table 8.4 Means intensity rating for attributes used for describing white *kenkey* (*nsiho*) by trained panel (*n* = 18).

<table>
<thead>
<tr>
<th>Descriptors</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiled fresh maize aroma</td>
<td>4 ± 0.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4 ± 0.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4 ± 1.46&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3 ± 0.91&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fermented maize dough aroma</td>
<td>7 ± 0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5 ± 0.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6 ± 2.17&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7 ± 0.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 ± 0.68&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Smoky aroma</td>
<td>1 ± 0.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2 ± 0.51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.59 ± 0.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1 ± 0.55&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.39&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sweet aroma</td>
<td>3 ± 0.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 ± 0.77&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.96 ± 0.07&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 1.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5 ± 0.98&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Boiled dry maize aroma</td>
<td>3 ± 0.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 0.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.92 ± 0.80&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.09&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3 ± 0.18&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooked rice aroma</td>
<td>1 ± 0.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 0.43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3 ± 0.65&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2 ± 0.17&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3 ± 0.22&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maize porridge aroma</td>
<td>3 ± 1.56&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 ± 0.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4 ± 0.55&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4 ± 0.72&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3 ± 0.46&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sticky texture</td>
<td>5 ± 0.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7 ± 1.19&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5 ± 0.66&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5 ± 1.40&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4 ± 1.47&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Soft texture</td>
<td>4 ± 0.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6 ± 2.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3 ± 0.32&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7 ± 0.66&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5 ± 1.84&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crumbly texture</td>
<td>5 ± 0.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 0.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5 ± 0.44&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.85&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5 ± 1.36&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Smooth texture</td>
<td>4 ± 0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 ± 1.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2 ± 0.35&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6 ± 0.53&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6 ± 1.83&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sweet texture</td>
<td>4 ± 0.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 1.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4 ± 0.70&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4 ± 0.35&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5 ± 0.54&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Milky texture</td>
<td>4 ± 0.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 0.51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2 ± 0.29&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3 ± 0.58&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sour taste</td>
<td>5 ± 0.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 0.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3 ± 0.32&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.17&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4 ± 0.20&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Salty taste</td>
<td>4 ± 0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 ± 0.25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3 ± 0.39&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.53&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6 ± 0.60&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooked rice taste</td>
<td>3 ± 0.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 ± 0.36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3 ± 0.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.27&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3 ± 0.70&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Astringent mouthfeel</td>
<td>3 ± 1.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2 ± 1.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3 ± 0.30&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3 ± 0.98&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2 ± 0.33&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Whitish colour</td>
<td>8 ± 0.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8 ± 0.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8 ± 0.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9 ± 0.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8 ± 0.09&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Treatments T1 and T2 were outside of the optimum process region and T3 and T4 were within the optimum process region of steeping time, steeping temperature and fermentation time. Same superscripts letters in a row are not significantly different at p ≤ 0.05.
The intensity scores for the descriptors were used to generate a spider web (Figures 8.1) in order to compare the different products from within and outside the optimum region of the processing variables as well as the control. The scores for white kenkey (T3 and T4) and the control showed statistically significant difference (p<0.05) in intensity scores for fermented maize dough aroma, maize porridge aroma, boiled fresh maize aroma, cooked rice aroma, sour taste and salty taste (Figure 8.1). The intensity scores for fermented maize dough aroma (6-7), maize porridge aroma (3-4), boiled maize aroma (4), cooked rice aroma (3) were generally high for T3, T4 white kenkey compared to control sample. However, the scores for salty taste (5), sour taste (3) and cooked rice taste (4) were higher for the control sample than for T3, T4 white kenkey (Figure 8.1).

The intensities of salty taste, sweet taste, smooth texture, sweet aroma and smoky aroma were low in all samples except the control. With regard to salty taste, the reduced intensity in the optimized products could be attributed to using less salt than the traditional processors add to precooked dough (aflata). With smoky aroma, this was detected in the traditional product because the traditional processors use firewood both for cooking aflata and also steaming the product. The laboratory samples were however cooked on an electric stove during aflata preparation whilst an electric steamer was used for steaming hence the low scores for smoky aroma. The scores for smoky attributes could probably be attributed to burning of the dough during aflata preparation.
8.7.3 Principal Component analysis

Principal component analyses (PCA) was used to relate the white kenkey produced using the optimum processing conditions and the traditional non-sweetened Anum white kenkey (control) with their sensory attributes (Figure 8.2). Principal Components (PC) 1 and 2 together explained 63.7% of the variation in the samples but PC1 explained a bit more (32.6%) of the variation than PC2 (31.1%). T3 and T4 white kenkey had positive values on the PC1 axis for fermented maize dough aroma, maize porridge aroma, boiled dry maize aroma, sticky texture, soft texture and whitish colour. This is an indication that the panel perceived these two kenkey samples to have higher intensities of those characteristics (Figure 8.2). Component two separated T3 and T4 mainly by aroma.
Samples T3 and T4 were produced using the optimum process treatment conditions of 30-45 h steeping, 30-35°C temperature, 12 h fermentation. Fermented maize dough aroma was inversely correlated with cooked rice, sweet, and smoky aroma; as well as cooked rice taste and smooth texture. The latter attributes were related to the control sample. T4 and the control samples were related as far as PC1 axis is concerned. This was because the processing variables of steeping times were partly related: 45 h and 48 h steeping times respectively with 12 h fermentation. The results implied that the optimized kenkey was of high quality. They have positive values (high intensities) of all but fermented maize dough and boiled dry maize aromas; sour, milky and sweet tastes, and crumbly texture. The softer the texture of a kenkey sample, as in T4, the less crumbly it was. As expected, cooked rice taste and aroma are closely related and these were associated with the control sample.
Figure 8.2. Principal Component Analysis (PCA) bi-plot showing the relationship between white kenkey obtained from optimum region and non-sweetened traditional Anum white kenkey and the sensory attributes used to describe their appearance, texture, taste and aroma.

8.7.4 Consumer acceptance of optimized white kenkey

Consumer acceptability scores for some attributes of the optimized white kenkey (T3 and T4) as well as traditionally processed white kenkey obtained from Anum and Atimpoku.
are shown in Table 8.5. Acceptability of taste scores for the kenkey samples varied from 6.12-6.55 (Table 8.5). Aroma scores ranged from 6.61 for traditionally processed Atimpoku white kenkey to 7.14 for T3. The texture scores for all samples were between 5.97-6.64 (Table 8.5) on a 9-point hedonic scale. Overall acceptability scores ranged from 6.71 for T4 to 6.91 for the traditionally processed Anum white kenkey.

The mean scores for acceptability of taste, texture and overall acceptability were not significantly different (p ≤0.05) for T3 and T4 as well as traditionally processed white kenkey. There were significant (p ≤0.05) variations in the aroma of traditionally processed white kenkey as compared to the optimized white kenkey (T3 and T4). Results indicated that all kenkey samples were liked moderately by the consumers with regards to taste, texture and overall acceptability attributes except for differences in the aroma scores between traditional kenkey and (T3 and T4) kenkey. The control samples were comparable with the optimized kenkey. The optimized kenkey is a high quality product with high potential. Its production process has been standardized: 30-45 h, steeping temperature 30-35°C and 12 h fermentation. The white kenkey production time has been reduced.

The traditional and optimized kenkey products recorded moisture content of 77% with high textural score of 6-7. This inferred that the texture of the samples were slightly and moderately liked by consumers. Traditional Anum nsiho and T3 white kenkey gave high taste scores, which is reflected in the high glucose values of 6 and 4.01% and lactic acid values of 0.14 and 0.65% respectively (Table 8.3).
Table 8.5: Mean sensory attributes scores for traditionally processed white kenkey and white kenkey produced from within the optimum region

<table>
<thead>
<tr>
<th>Samples</th>
<th>Taste</th>
<th>Aroma</th>
<th>Texture</th>
<th>Overall Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Anum kenkey</td>
<td>6.53 ± 1.79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.76 ± 1.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.64 ± 1.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.91 ± 1.71&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Traditional Atimpoku kenkey</td>
<td>6.26 ± 1.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.61 ± 1.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.79 ± 1.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.79 ± 1.29&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>6.55 ± 1.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.14 ± 1.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.97 ± 1.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.86 ± 1.42&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>6.12 ± 2.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.67 ± 2.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.03 ± 2.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.71 ± 2.18&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means with the same superscript letters in a row are not significantly different (P < 0.05). T3 and T4 were within the optimum process region of steeping time, steeping temperature and fermentation time. 65 consumers.

8.7.5 Relationship between Physicochemical tests, QDA and consumer acceptability of white kenkey

Optimized white kenkey T3 gave an acidity value 0.14% which was closely associated with its high intensity for fermented maize dough aroma in QDA studies. This was validated by high taste and aroma scores of 6.55 and 7.14 for consumer test (Table 8.5).

There was high preference for sweet taste for T3 white kenkey, which is closely linked to its high glucose level of 4.01% and its hedonic score of 6.55 (Table 8.5).

Moisture content of T4 optimized kenkey was 77.77% which is linked to the panel high preference for sticky and soft texture and hedonic texture score of 6. High intensity score for whitish colour for optimized white kenkey according to QDA is linked to high whiteness value in the physicochemical test. Both the physicochemical test, descriptive panel and consumers test agreed that Anum white kenkey (control) recorded high values...
for acidity and lactic acid which closely relates to positive values for sour taste attribute and consumer taste score of like moderately (7).

The panel perceived high intensity for smooth texture for the control and this was associated with its high texture score of 6.64 and its moisture content of 77%.

8.8 Conclusion

By using sensory descriptive analysis, the sensory attributes of white kenkey produced using varying processing procedures were obtained for the first time. The results show that all of these descriptors are appropriate for differentiating sensory qualities among samples and could be used for basic research and product development for white kenkey (nsiho). The intensity scores for fermented maize dough aroma, maize porridge aroma, boiled fresh maize aroma, boiled dry maize aroma, crumbly texture, soft texture and sticky texture were generally high for kenkey obtained from optimum region compared to those of the control sample. Salty taste, sour taste and cooked rice taste, cooked rice aroma, sweet aroma were positive for traditional Anum nsiho.

Crumbly texture, soft texture, fermented maize dough aroma, boiled dry maize aroma, maize porridge aroma scored high intensity sensory properties for optimized white kenkey. The dominant sensory properties for the traditional white kenkey were smoky aroma, sweet aroma, sweet taste, salty taste. The sensory properties scores of sour taste, smooth texture, soft texture and boiled fresh maize aroma were comparable for optimized white kenkey and traditionally prepared white kenkey.

None of the samples scored less than 5 (neither like nor dislike), therefore, all two products including the traditionally processed kenkey were acceptable to consumers.
The linkage between the physiochemical, QDA and consumer test results has given an understanding of the relationship between descriptors and the consumer acceptability of white kenkey.

The traditional Anum kenkey was comparable to optimized kenkey sample which was produced by using 30h steeping time, 30ºC temperature and 12h fermentation.

The white kenkey samples processed using within the optimum region of process variables compared favourably with the traditionally processed white kenkey. The white kenkey samples of higher quality potential has been identified. The process for production of white kenkey has been standardized, saving production time.
CHAPTER 9

9.0 Summary and Conclusions

Kenkey is a popular fermented maize dough staple in Ghana, of which there are several types. The Ga and Fante kenkey types are the most popular while the white kenkey types are less popular. This is because production of the white kenkey types is largely restricted to specific ethnic groups and have remained as “ethnic food”. Two white kenkey types were identified in this study: the non-sweetened white kenkey (locally called nsiho) and the sweetened white kenkey.

Like all kenkey types, the production of white kenkey is a lengthy and laborious process and as a result, it is more often purchased from a commercial kenkey producer. Consequently its production serves as an important income commercial activity for the producers. The production processes are done at small scale, artisanal levels, usually based in households. The producers are largely elderly women usually without much formal education and consequently do not have written records of process controls and product throughputs.

Upgrading production from the artisanal to industrial level entails improvements in process controls to ensure products of consistent quality. This requires understanding of critical process factors on which to model final product sensory and quality attributes. The physico chemical properties and sensory attributes of white kenkey are influenced by processing variables such as maize steeping time, steeping temperature and dough fermentation time.

The steeping of maize grains initiates spontaneous microbial fermentation activity as manifested by increased titratable acidity of the maize meal. Steeping also increased the
glucose level while fermentation of the dough converted it to lactic acid. The characteristics of dough from different steeping and fermentation times suggest that steeping may compliment dough fermentation rate. The effects of the processing variables on the fermenting dough eventually transferred into the kenkey product.

White kenkey is a high moisture, low acid food (pH=4.2), that do not store for long at ambient conditions as they are easily susceptible to mold spoilage. The shelf life of non-sweetened white kenkey may be as long as five days, while that of sweetened kenkey is only about two days.

Steeping of grains and fermentation of the dough influence the textural characteristics of white kenkey. Textural and microstructural characteristics of white kenkey are also influenced by the precooking (aflata) method, mixing of raw dough with aflata, and the addition of sugar as a sweetener. Sweetened white kenkey is softer, and not as sticky and adhesive as the non-sweetened white kenkey types. Fermentation increases the stickiness of non-sweetened white kenkey, probably because of hydrolysis of fermentable sugars to glucose.

High aflata ratios produced softer textured kenkey, while increasing the ratio of raw dough in the aflata mix increased the stickiness and hardness of kenkey. Consumers preferred kenkey that was made using high aflata ratios and steamed for longer time periods. Crumbliness and softness are important quality attributes to consumers of non-sweetened white kenkey (nsiho) and taste and softness for sweetened kenkey. The acceptability of white kenkey was positively influenced by increased steeping time and temperature.
The optimum processing conditions for production of consumer acceptable white *kenkey* are steeping maize for 30-45 hours at temperatures of 30°-35°C, and fermenting the dough for 12 hours. White *kenkey* products prepared using the optimum processing variables and the traditionally processed white *kenkey* were acceptable to consumers.

Highly scored sensory properties of optimized white *kenkey* were crumbly texture, soft texture, fermented maize dough aroma, boiled dry maize aroma, maize porridge aroma. The dominant sensory properties for the traditional white *kenkey* were smoky aroma, sweet aroma, sweet taste, salty taste. The sensory properties scores of sour taste, smooth texture, soft texture and boiled fresh maize aroma were comparable for optimized white *kenkey* and traditionally prepared white *kenkey*. The white *kenkey* samples processed within the optimum region of process variables compared favourably with the traditionally processed white *kenkey*. The white *kenkey* samples of higher quality potential has been identified. The process for production of white *kenkey* has been standardized, saving production time.

### 9.1 Recommendations

1. Aroma studies should be done for optimized white *kenkey*.

2. Shelf-life studies should be conducted on optimum white *kenkey* samples.

3. Women processors should be trained on the standardized method for production of white *kenkey*. This will help ensure the reproducibility and availability of consistent quality white *kenkey*.

4. Studies should be conducted to determine the sugar content of sweet white *kenkey*.
using different levels of sugar.

5. Fortification of optimized white *kenkey*.
CHAPTER 10

10.0 References


Annan, N.T. (2002). Aroma characteristics in Ghanaian maize dough fermentations. PhD thesis University of Ghana/ Royal Veterinary and Agricultural University, Denmark


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Appendices

APPENDIX 1

PRODUCTION

Processor Identification

<table>
<thead>
<tr>
<th>Background information</th>
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<tbody>
<tr>
<td>Name of the investigator/pollster</td>
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<tr>
<td>Questionnaire Number</td>
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<tr>
<td>Date of survey</td>
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<tr>
<td>Place of survey</td>
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<td></td>
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<tr>
<td>Language used during the survey</td>
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</tbody>
</table>

Person to be interviewed

<table>
<thead>
<tr>
<th>Surname and first name</th>
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<tbody>
<tr>
<td>Age</td>
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<tr>
<td>Gender</td>
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<tr>
<td>Ethnic /socio-cultural group</td>
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<tr>
<td>Educational level</td>
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<tr>
<td>Marital status</td>
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<tr>
<td>Number of persons in the household</td>
</tr>
<tr>
<td>Religion</td>
</tr>
<tr>
<td>Role in the household</td>
</tr>
</tbody>
</table>
1. Is there any particular reason why you produce *kenkey*?
   - Family trade
   - Profitable
   - Employment
   - others (specify)...........

2. How did you learn how to produce *kenkey*?
   - Family
   - training
   - Friends
   - others
   - (specify)...........

3. How many types of *kenkey* do you know?
   - Fanti
   - Ga
   - *Nsīho*
   - Asikyere dokono
   - Akporhie
   - others
   - specify...........

4. Which types of *kenkey* do you produce? ?
   - Fanti
   - Ga
   - *Nsīho*

5. Why do you produce these types?
   - Family trade
   - Profitable
   - Employment
   - Easy to prepare
   - other
   - (specify)...........

6. What quantity of *kenkey* do you produce per batch?

<table>
<thead>
<tr>
<th>Type of <em>kenkey</em></th>
<th>Quantity (specify the measuring unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
</tbody>
</table>

7. How many workers are involved?
   - 1-2 workers
   - 3-5 workers
   - Above 5 workers

8. Are you related to these workers? Yes No

9. Do you find *kenkey* making profitable? Yes No

10. Do you sell fried fish and sauce with the *kenkey*? Yes No

11. Where do you buy the maize and other raw materials?

<table>
<thead>
<tr>
<th>Raw materials and other</th>
<th>Source of raw material</th>
<th>Quantity of raw material</th>
<th>Cost (GHC)</th>
<th>Member of</th>
</tr>
</thead>
</table>


### Ingredients and Material Purchased

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Material</th>
<th>Purchased at a Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize husk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantain leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. What quantity of maize do you buy?
   - 50kg (Maxi bag) .......... 25kg (mini bag) ........... others specify ............

13. What is the price range for maize?
   - GH₵ 50-100
   - GH₵ 110-150

14. What type of maize do you prefer to use for the production of kenkey? Why?

<table>
<thead>
<tr>
<th>Local Name of the Maize</th>
<th>Most Important Quality Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

15. What quantity of maize do you process in a week?
   - 10-50kg
   - 50kg-100kg
   - Above 100kg

16. Do you store the maize after purchasing?
   - Yes [ ]
   - No [ ]

17. Where do you store the maize?
   - Store room [ ]
   - Container [ ]
   - Commercial mill [ ]
   - Market place [ ]
18. Why do you store the maize?

- Bulk purchase
- cost-effective
- Convenient
- Others (specify)

19. How long do you normally store the maize?

- 1-4 weeks
- 5-8 weeks
- 9-14 weeks

20. If you store one maxi bag of maize what proportion/quantity are you likely to lose through spoilage?

- After 2 months
- After 3 months
- After 4 months

21. What is the cost of transporting one maxi bag of maize?

- GHC 2.5 - 5
- GHC 6 - 10
- GHC > 10

22. How many times do you produce kenkey in a week?

- 1-3 times
- 4-6 times
- 7-10 times
- >10 times

23. Where do you produce the kenkey?

- At home
- Factory/location outside home
- Others (specify)

24. What procedure do you use to produce kenkey?

<table>
<thead>
<tr>
<th>Operations</th>
<th>Duration of the operation</th>
<th>Quantity of raw material used</th>
<th>Objective of the operation</th>
<th>Equipments used (Quantity and designation)</th>
<th>Labour (specify number and sex)</th>
<th>Products obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
25. For Intermediate and final products, indicate: the quality criteria used to appreciate the product and the quality problems met (fill the table).

<table>
<thead>
<tr>
<th>Products</th>
<th>How do you assess the quality of the product</th>
<th>What problems do you face with regards to the quality of the product.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steeped maize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fermented dough</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aflata</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
26. Does the fermentation time vary with:

a) the type of maize used? Yes [ ] No [ ] Specify

b) the soaking of the maize? Yes [ ] No [ ] Specify

c) A particular period of the year? Yes [ ] No [ ] Specify

27. How do you know when to stop steeping of the maize? How do you assess this?

Bite with teeth [ ] Experience [ ]

28. For how many days do you ferment the dough?

1 day [ ] 2 days [ ] 3 days [ ] others [ ] specify........

29. How do you determine that the dough is fermented enough and can be used to make kenkey?

Texture [ ] Taste [ ] Smell [ ] Colour Change [ ]

30. For how many days longer can you use the same dough to make kenkey?

3-4 days [ ] 5-7 days [ ] >7 days [ ]

31. In your opinion, which activities if not carried out well will affect the quality of kenkey produced?
32. Which of the activities in the processing of maize into *kenkey* are difficult to carry out with respect to the labour required?

<table>
<thead>
<tr>
<th>Activity</th>
<th>How does it affect quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making of mixture of dough for <em>Aflata</em></td>
<td></td>
</tr>
<tr>
<td>Aflata preparation</td>
<td></td>
</tr>
<tr>
<td>Mixing of <em>Aflata</em> with fresh dough</td>
<td></td>
</tr>
<tr>
<td>Molding of <em>kenkey</em></td>
<td></td>
</tr>
</tbody>
</table>

33. Does the selling price of *kenkey* vary during the year?

- [ ] Yes
- [ ] No

34. If yes what are the reasons which explain this variation of price?

- Cost of corn
- Cost of firewood
- Cost of Gas
- Cost of charcoal

35. Variation of raw material cost during the year

<table>
<thead>
<tr>
<th>Factor of variation</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
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</tbody>
</table>
36. How long can you keep *kenkey* and still eat it?

   1-3 days  □  4-6 days  □  7-14 days  □  others  □

37. What do you do if you want to keep/store the maize dough for a longer period?

38. What do you do with *kenkey* which you are unable to sell?

   Mash and add to *Aflata*  □  Reheat and sell  □ other  □
   specify................

Thank you for your collaboration.!!!!!!
Appendix 2

COMMERCIALISATION

Identification of wholesaler/retailers of *kenkey*

<table>
<thead>
<tr>
<th>Background information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the investigator/pollster</td>
</tr>
<tr>
<td>Questionnaire Number</td>
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<tr>
<td>Date of survey</td>
</tr>
<tr>
<td>Place of survey</td>
</tr>
<tr>
<td>- village/area:</td>
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<tr>
<td>- district</td>
</tr>
<tr>
<td>- region:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Language used during the survey</th>
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</table>

<table>
<thead>
<tr>
<th>Person to be interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surname and first name</td>
</tr>
<tr>
<td>Age</td>
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<tr>
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<td>Educational level</td>
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<td>Marital status</td>
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<td>Number of persons in the household</td>
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<td>Religion</td>
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<tr>
<td>Role in the household</td>
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</table>

<table>
<thead>
<tr>
<th>In which other category apart from selling are you engaged in?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of <em>kenkey</em></td>
</tr>
</tbody>
</table>
1. Which types of kenkey do you sell?
   Ga □ Fante □ Nsilo □ Other □ (specify)........................
2. How much is a ball of kenkey?
   20p □ 30p □ 40p □ 50p □ GHȻ1 □
3. Why do you sell this type of kenkey?
   Family trade □ Profitable □ Easy to prepare □ Other □ (specify)......
4. What are the quality characteristics you look out for in the kenkey that you are going to buy to sell?
   Aroma □ Softness □ Texture □ Taste □ Other □ (specify)...........
5. What is the cost of transporting the kenkey from the production site to the market?
   GHȻ2-4 □ GHȻ4-5 □ > GHȻ5 □
6. Which group of customers buy your kenkey?
   Lower group □ Middle group □ High income □ Office workers □
7. What quality characteristics do you think the customer looks out for in deciding to buy your kenkey?
   Softness □ Texture □ Aroma □ Appearance □
8. Do you think some of your customers will be prepared to pay more for the good quality of kenkey that you have described?
   Yes □ No □
9. What are the problems you encounter in your selling of kenkey?

<table>
<thead>
<tr>
<th>product</th>
<th>Problems of selling</th>
<th>Description of problems</th>
<th>Proposal for a solution</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>
10. How do you keep kenkey after cooking?

Leave in cooking pot    Arrange in polythene    Icechest    others (specify).................

11. How do you keep your cooked kenkey before selling?

Polythene    Basin    Ice- Chest    Other (specify).................

12. What do you do with kenkey that you are not able to sell the same day?

Mix with Aflata    Warm and sell the next day    Eat at home

13. For how long (days) can you keep the kenkey?

1-2 days    3-5 days    5-10 days    Above 10 days

14. What quantity of kenkey do you sell in a day? (Low production period and High production period)

50-100 balls    110-160 balls    Above 170 balls

15. How much do you generate from selling kenkey in a day?

GH C 20-40    GH C 50-100    > GH C 100
### Appendix 3

**Consumption**

#### Consumer Identification

<table>
<thead>
<tr>
<th>Background information</th>
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<tbody>
<tr>
<td>Name of the investigator/pollster</td>
</tr>
<tr>
<td>Questionnaire Number</td>
</tr>
<tr>
<td>Date of survey</td>
</tr>
</tbody>
</table>

#### Place of survey

- village/area: ..........................................................
- district: ..........................................................
- Region ..........................................................

#### Language used during the survey

**Person to be interviewed**

<table>
<thead>
<tr>
<th>Surname and first name</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Ethnic /socio-cultural group</td>
</tr>
<tr>
<td>Educational level</td>
</tr>
<tr>
<td>Nil</td>
</tr>
<tr>
<td>Marital status</td>
</tr>
<tr>
<td>Number of persons in the household</td>
</tr>
<tr>
<td>Religion</td>
</tr>
<tr>
<td>Role in the household</td>
</tr>
</tbody>
</table>

1. Why do you like eating kenkey?
2. Which type of kenkey do you often buy?

Ga kenkey  Fante kenkey  Nsilo  Others (specify)..............

3. Which type of fish do you eat the kenkey with?

Shrimps  Small Tilapia  Small herring  Red fish

4. How is the fish prepared?

Fried  Grilled  others (specify)..............

5. What are the sauces you eat kenkey with?

Fresh Pepper  black pepper (shito)  Tomato stew  
okro stew  soup  Other

6. How often do you eat kenkey?

more than 7 times,  6-7 times per week  4-5 times per week  2-3 times per week  Once a week  Rarely/ Never

7. At which time of the day do you eat kenkey?

Breakfast  Lunch  Dinner  Between meal  Special occasion

8. Where do you buy the kenkey from?

Hawker  other street vendor  Restaurant  others

9. Where do you eat the kenkey?

At home  At street Vendor’s place  Restaurants  Other places (specify)..................

10. What do you consider to be the quality of good kenkey?

Softness  Texture  Taste  Appearance

11. Will you be prepared to pay more for the good quality of kenkey that you have described above?

Yes  No

12. Do you see any variation in the size of kenkey during the year?

Yes  No

13. Is there any health benefits for eating kenkey?.........................................................................
Appendix 4

Description of fermented maize products

FRI Banku is dehydrated flour prepared from a combination of fermented whole maize dough mixed with fermented cassava dough in the ratio 2:1. Slurry of the flour is cooked with the addition of salt. The paste obtained is moulded into oval shapes. It is eaten with hot pepper sauces, stew or soups. The banku flour is produced by CSIR-Food Research Institute.

Neat Banku is dehydrated flour prepared from combination of fermented whole maize dough mixed with fermented cassava dough in the ratio 2:1. Slurry of the flour is cooked with the addition of salt. The paste obtained is moulded into oval shapes. It is eaten with either a hot sauce, stew or soup. This banku flour is produced by Neat Foods company limited. Normal Banku is a paste prepared from cooked fermented whole maize dough mixed with fermented cassava dough in the ratio 2:1. The paste is moulded into oval shapes. It is eaten with hot sauces, stew or soups.

Kafa is produced from whole maize. Slurry of milled maize which is sieved and fermented for 2 days. The sediment is poured into boiled water to pre-cook. The paste is moulded and packaged in green leaves. It has a moisture content of about 86%, pH 3.4, and shelf-life of about 2 to 3 days. Fante kenkey is non-salted cooked sour tasting stiff porridge with a pH of about 3.7, moisture level of between 52-55% and usually eaten with sauce and fish. During the production of the 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 plantain leaves, after which it is boiled for 6-7 hours. Fante kenkey has a shelf-life of about one week.
Ga *kenkey* is a cooked sour-tasting stiff porridge with a pH of about 3.7, moisture level of between 52-55% and usually eaten with sauce and fish. During the production of the *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 mixture is moulded into balls and wrapped in dried maize husk and boiled. *Ga kenkey* has a shelf-life of about 3 to 4 days.

White *kenkey* from Atimpoku (White Atim). White *kenkey* or *nsiho* is produced from dehulled or polished maize. The slurry of milled maize is precooked with addition of salt and moulded into balls. The balls are packaged in maize husk and steam-cooked for 1 hour. It has a moisture content of about 62-68%, pH 4, and shelf-life of about 3 to 4 days with no refrigeration. The sample was obtained from a town called Atimpoku.

White *kenkey* from South Senchi (White Senchi). This is the same as the white *kenkey* described above but the sample was obtained from a town called South Senchi.

Sweet *kenkey* is produced from dehulled or polished maize. The slurry of milled dehulled maize is precooked with addition of sugar and moulded into balls and packaged in *Awurom* leaf and steam-cooked for 45 min. It has a moisture content of about 77%, pH 4.3, and shelf-life of about 3 to 4 days with no refrigeration.
Appendix 5

Qualitative Descriptive Analysis (QDA) score sheet for *kenkey*

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>1st sample</th>
<th>2nd sample</th>
<th>3rd sample</th>
<th>4th Sample</th>
</tr>
</thead>
</table>

Please assess the samples in front of you. Rinse your mouth with water before tasting each sample.

**INCREASING INTENSITY**

<table>
<thead>
<tr>
<th>Brownish colour</th>
<th>not</th>
<th>very</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creamy colour</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>Whitish colour</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>Maize odour</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>Fruity odour</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>Burnt odour</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>Fermented odour</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>Texture</td>
<td>not</td>
<td>very</td>
</tr>
<tr>
<td>------------------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Hard texture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sticky texture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth texture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sour taste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet taste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salty taste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong taste</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(blunt)*
Appendix 6a

Acceptability
Questionnaire – Kenkey

Date (DD/MM): _____/_____/2011    Time: _______/______

<table>
<thead>
<tr>
<th>Place name</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Enumerator</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumer</th>
<th>First name: ___________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surname: _____________________________</td>
</tr>
</tbody>
</table>

Please could you follow the given order of presentation of the samples

Sample order:
1. ____________ 2. ____________ 3. ____________ 4. ____________ 5. ____________ 6. ____________

<table>
<thead>
<tr>
<th>Sample code</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Like very much</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Like moderately</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Like slightly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Neither like nor dislike</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Dislike slightly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Dislike moderately</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Dislike very much</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concerning the acceptability,
- Which sample did you like the most? ……………
Why?........................................

- Which sample did you like the least? ……………
Why?........................................

**INFORMATION ABOUT THE CONSUMER**

*Enumerator: If the respondent answers ‘don’t know’ to any question, please try and probe. If the answer still remains ‘don’t know’ please write “999”. For a ‘not applicable’ please write 991. Do not leave any question blank.*

| 1 | Age | [1] 18 -35  
[2] 36 -45  
[4] 56 -65  
[5] 66+ |
|---|-----|---|
| 2 | Gender | [1] Male  
[2] Female |
| 3 | Nationality |
| 4 | Ethnic Group (tick only one box) | [1] Fante  
[3] Other |
| 5 | Status in Ghana (tick only one box) | [1] Resident  
[2] Tourist |
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 6 | Marital status                                                           | [1] Married  
[2] Single  
[3] Other (please specify)          |
| 7 | Level of education (Highest achieved)                                    | [1] Primary  
[2] Secondary  
[4] Other (please specify)          |
| 8 | Occupation (tick only one box)                                           | [1] Professional  
[2] Skilled  
[3] Unskilled  
[4] Student  
[5] Unemployed  
[6] Other |
| 9 | Which type of *kenkey* do you eat the most often? (tick one box only)     | [1] Ga  
[2] Fante  
[4] Other (please specify)          
[5] Do not eat *Kenkey* (go to question 11) |
| 10| How do you eat *Kenkey*? (tick the most applicable box only)              | [1] in the solid form with a sauce  
[2] mashed with water |
| 11| Do you eat Banku?                                                        | [1] Yes  
[2] No (End of interview) |
| 12| If you eat Banku do you prefer it to *Kenkey*?                            | [1] prefer Banku to *Kenkey*  
[2] do not prefer Banku to *Kenkey* |
<table>
<thead>
<tr>
<th></th>
<th>(tick one box only)</th>
<th>(3) Like banku and kenkey equally</th>
</tr>
</thead>
</table>
| 13 | Why do you eat *Kenkey*? (tick one box only) | [1] Convenient  
[2] Affordable  
[3] Habit  
[4] Fills you up (heavy do)  
[5] Gives energy  
[6] Other (please specify) ……………….. |
| 14 | How often do you eat *Kenkey*? (tick one box only) | [1] more than once a day  
[2] once a day  
[2] A few times in a week  
[3] Once a week  
[4] Once a month  
[5] Rarely  
[6] Never |
| 15 | Where do you obtain *kenkey*? (tick one box only) | [1] At home  
[2] Street hawker  
[4] Chop bar  
[5] Restaurant  
[5] At work  
[6] Other (please specify) ……………….. |

Thank you for participating in this interview. Your results will help researchers produce improved foods.

University of Ghana http://ugspace.ug.edu.gh
Appendix 6b

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
CSIR-IRB CONSENT FORM TEMPLATE

Title: African Food Tradition Revisited by Research Project (AFTER)

Principal Investigator: Charlotte Oduro-Yeboah

Address: CSIR- Food Research Institute, P.O. Box M20, Accra, Ghana

General Information about Research: Things to indicate We, the team from Food Research Institute of the Council for Scientific and Industrial Research, are undertaking a study of the sensory and consumer preference for white *kenkey*. This study, undertaken through international collaboration in food technology research and development, is funded by the European Union under the title: African Food Tradition Revisited by Research. The information that you provide will contribute to a better understanding of the processing and preparation methods for white *kenkey* and will serve to improve the quality and safety of African traditional food products for consumers in Africa, in Europe and elsewhere. You are invited to participate in the study as your contribution is highly valued and can help introduce traditional foods of Africa to new consumers and new markets. The field teams will collect information related to the acceptance of white *kenkey* in terms of sensory attributes. If you wish to join the study, you will be asked to complete and sign the attached Consent Form agreeing on your participation.

Possible Risks and Discomforts

No risk or discomfort anticipated since the product is *kenkey* which has been prepared using varying processing treatment.

Possible Benefits

Availability of standardized *kenkey* at all times.

Alternatives to Participation

Not applicable

Confidentiality

The information you provide and which is collected through written notes will be used solely for scientific
purposes and will be treated as strictly confidential. Anonymity is guaranteed and individuals will not be identified in any publication or dissemination of the study findings. The rights of the indigenous knowledge and methods are protected and you are not waiving any legal claims or rights because of your participation.

**Compensation**

Lunch will be served to consumers to the tune of seven (7) Ghana cedis at the end of each study.

**Additional Cost**

Not applicable

**Staying in the Research**

Not applicable (It does not apply to this study)

**Voluntary Participation and Right to Leave the Research**

Your participation is voluntary and there is no penalty or loss of benefits that you may otherwise be entitled to if you do not wish to participate. You may refuse to answer any particular question and move to the next one, and you have the right to address any queries about the study now or at any point during your participation to the investigator or to the supervisor of the study as indicated in the Consent. While we hope you will participate you are under no obligation to do so. If you do choose to participate you are free to withdraw at any time and do not need to give a reason.

**Termination of Participation by the Researcher**

Not applicable

**Notification of Significant New Findings**

Significant new findings developed during the course of the research will be provided to the consumers.

**Contacts for Additional Information**

Charlotte Oduro-Yeboah(Mrs.)- 0266416122, Dr. Wisdom Amoa Awua- 0277487505

**Your rights as a Participant**
This research has been reviewed and approved by the Institutional Review Board and Institutional Animal Care and use Committee of Council for Scientific and Industrial Research (CSIR-IRB/IACUC). If you have any questions about your rights as a research participant you can contact the IRB/IACUC Office between the hours of 8am-5pm through the landline 0302777651 or email addresses: csirirb_iacuc@csir.org.gh or pselormey@gmail.com. You may also contact the chairman, Mr. Okyere Boateng through mobile number 0204362635 when necessary.
Appendix 6c

UNDERSTANDING OF DISCLOSED INFORMATION

To be completed by the participant

Title of Research: Description of sensory attributes of white Kenkey

Investigator's name:

Location:

1. Have you read the information sheet about this study (or: Was the information sheet read to you)? YES / NO

2. Do you understand what the study is about and the contribution expected from your participation? YES/NO

3. If you asked questions did you receive satisfactory answers? YES / NO

4. Do you understand that you are free to withdraw from this study at any time and without the need to give a reason? YES / NO

5. Do you agree to take part in this study? YES / NO.
Appendix 6d

VOLUNTEER AGREEMENT

The above document describing the benefits, risks and procedures for the research title 
(African Food Tradition revisited by Research project) has been read over and explained to me in (English) and 
I have perfectly understood the explanation. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree to participate as a volunteer.

______________________________  __________________________
Name                                                  Date
Signature or mark of volunteer

______________________________  __________________________
Name                                                  Date
Signature of Witness

______________________________  __________________________
Name                                                  Date
Signature of Person taking Consent
Appendix 7
Ballot sheet for consumer acceptance of white *kenkey (nsiho)* with different *aflata* proportion

Name: ------------------------------------------ Date---------------------

Sex------------------------------------------

Sample order:
1. ____________ 2. ____________ 3. ____________ 4. ____________ 5. ____________ 6. ____________
7. ---------------------- 8. ----------------------

<table>
<thead>
<tr>
<th>Scale/Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Like Extremely</td>
</tr>
<tr>
<td>8. Like Very much</td>
</tr>
<tr>
<td>7. Like Moderately</td>
</tr>
<tr>
<td>6. Like Slightly</td>
</tr>
<tr>
<td>5. Neither Like nor Dislike</td>
</tr>
<tr>
<td>4. Dislike Slightly</td>
</tr>
<tr>
<td>3. Dislike Moderately</td>
</tr>
<tr>
<td>2. Dislike Very much</td>
</tr>
<tr>
<td>1. Dislike Extremely</td>
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Attributes

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<table>
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<table>
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</tbody>
</table>

Any additional comments?

...........................................................................................................
Appendix 8

Ballot sheet for sensory evaluation of white *kenkey* prepared using Box Behnken design

Date:......................
Panellist Number:..........

Instructions:
You have been provided with five samples of white *kenkey*; please look at and taste the samples and indicate how much you like or dislike the sample using the scale below. Please clean your palates or rinse your mouth with water or cream crackers in between samples.

1 = Like extremely
2 = Like very much
3 = Like moderately
4 = Like slightly
5 = Neither like nor dislike
6 = Dislike slightly
7 = Dislike moderately
8 = Dislike very much
9 = Dislike extremely

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Sample codes</th>
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<tr>
<td>Taste</td>
<td></td>
</tr>
<tr>
<td>Smell</td>
<td></td>
</tr>
<tr>
<td>Texture</td>
<td></td>
</tr>
<tr>
<td>Overall acceptability</td>
<td></td>
</tr>
</tbody>
</table>

Comments.................................................................
........................................................................
........................................................................
........................................................................
Appendix 9: Ballot sheet for consumers’ validation of white kenkey (nsiho)

Name: --------------------------------------------------- Date---------------------

Sex--------------------------------------------- Age…………………………

Instructions:
You have been provided with four samples of white Kenkey; which you are to evaluate by indicating your degree of liking for each sample attribute of the sample. Please clean your palates or rinse your mouth with water or cream crackers in between samples.

<table>
<thead>
<tr>
<th>Scale/Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Like Extremely</td>
</tr>
<tr>
<td>8. Like Very much</td>
</tr>
<tr>
<td>7. Like Moderately</td>
</tr>
<tr>
<td>6. Like Slightly</td>
</tr>
<tr>
<td>5. Neither Like nor Dislike</td>
</tr>
<tr>
<td>4. Dislike Slightly</td>
</tr>
<tr>
<td>3. Dislike Moderately</td>
</tr>
<tr>
<td>2. Dislike Very much</td>
</tr>
<tr>
<td>1. Dislike Extremely</td>
</tr>
</tbody>
</table>

Attributes

<table>
<thead>
<tr>
<th>Taste</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Odour</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------</td>
</tr>
</tbody>
</table>

293
Appendix 10: Ballot sheet for Descriptive sensory analysis of white *kenkey*

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1st sample</th>
<th>2nd sample</th>
<th>3rd sample</th>
<th>4th Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5th Sample

Please assess the attributes of each of the five samples in the order as they appear on the sheet. Rinse your mouth with water before tasting each sample.

<table>
<thead>
<tr>
<th>Boiled fresh maize Aroma</th>
<th>Boiled dry maize Aroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>not</td>
<td>very</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooked rice Aroma</th>
<th>Maize porridge aroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>not</td>
<td>very</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sticky texture</th>
<th>Soft texture</th>
<th>Crumbly texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>not</td>
<td>very</td>
<td>very</td>
</tr>
</tbody>
</table>

INCREASING INTENSITY
| Smooth texture | not | very |
| Sweet taste    | not | very |
| Salty taste    | not | very |
| Sour taste     | not | very |
| Milky taste    |     |     |
| Cooked rice taste | not | very |
| Astrigent mouthfeel taste | not | very |
| White colour   |     |     |
Appendix 11: Ballot sheet for consumers ‘acceptance of optimal white *kenkey* and traditional white *kenkey*.

Name: ------------------------------------------- Date---------------------

Sex------------------------------------------ Age…………………………

Instructions:
You have been provided with five samples of white *Kenkey*; which you are to evaluate by indicating your degree of liking for each sample attribute of the sample. Please clean your palates or rinse your mouth with water or cream crackers in between samples.

<table>
<thead>
<tr>
<th>Scale/Interpretation</th>
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<tbody>
<tr>
<td>9. Like Extremely</td>
</tr>
<tr>
<td>8. Like Very much</td>
</tr>
<tr>
<td>7. Like Moderately</td>
</tr>
<tr>
<td>6. Like Slightly</td>
</tr>
<tr>
<td>5. Neither Like nor Dislike</td>
</tr>
<tr>
<td>4. Dislike Slightly</td>
</tr>
<tr>
<td>3. Dislike Moderately</td>
</tr>
<tr>
<td>2. Dislike Very much</td>
</tr>
<tr>
<td>1. Dislike Extremely</td>
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</table>

### Attributes

<table>
<thead>
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<th>Attributes</th>
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<tr>
<td>Taste</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Texture</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Odour</td>
<td>---</td>
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</table>
Overall acceptability

Any additional comments?

..........................................................
**Appendix 12:** Glucose and organic acid content of dehulled maize dough based on Box Behnken design (% dry matter basis)

<table>
<thead>
<tr>
<th>Run</th>
<th>Steeping time(h)</th>
<th>Fermentation time(h)</th>
<th>Steeping temperature(°C)</th>
<th>Glucose (mg/g)</th>
<th>Lactic acid (mg/g)</th>
<th>Acetic acid (mg/g)</th>
<th>Ethanol (mg/g)</th>
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<td>0.85</td>
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<tr>
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<td>12</td>
<td>45</td>
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<td>23.10</td>
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</table>
Appendix 13  Pictures illustrating unit operations for non-sweetened white *kenkey*

Whole grains

Dehulling machine

Dehulled grains

Steeped dehulled maize

Milling machine

Dehulled maize Meal (Atimpoku)
Fermenting dough (12h) - Anum

Slurry for aflata preparation

Preparation of aflata

Mixing of aflata and fresh dough (Anum)

Cooking of aflata

Maize husk
Washed husk for wrapping mixture

Mixture of *aflata* and fresh dough

Moulding of mixture

Moulding of *nsiho*

Balls of *nsiho* ready for steaming

Perforator for steaming (Anum)
Sticks lined cooking pot for steaming (Atimpoku)  
Nsího packed in cooking bowl-Anum

Nsího on fire at Anum  
Nsího on fire at Atimpoku

Steamed nsiho  
Prepared nsiho for hawking
Appendix 14  Pictures illustrating unit operations for sweetened white kenkey

Nsiho in plate  Preferred fish for consuming nsiho
Steeped dehulled maize  Dehulled maize dough
Slurry for precooking into aflata

Aflata preparation

Mixing of aflata with slurry of dough

Sugar addition to mixture

Mixture ready for packaging

Packaging of mixture into awurom leaves
Wrapping of mixture
Tying with sebre string

Steaming of sweet kenkey
Sweet kenkey in polythene lined basket

Sweet kenkey ready for hawking
Appendix 15  Pictures for sensory and consumer acceptance of *kenkey* types and other fermented maize products

Samples used for Sensory analysis  A panelist assessing samples

Samples used for consumer acceptance  A Caucasian consumer
Ghanaian consumers at Legon

Appendix 16 Pictures of experiments conducted in the Laboratory

Dehulled maize grains
Steeping of maize grains
Steeped grains ready for milling
Milling of steeped grains using mini Disc attrition mill
Intermediate moisture meal  Dehulled fermented dough (12h)

Precooking of dough (*aflata*)  Molding of *kenkey*

Steam cooking *kenkey*
Appendix 17  Sensory and consumer acceptance pictures

Samples for consumer acceptance of aflato proportions  A consumer assessing the optimal kenkey samples
A consumer rating the spiked white *kenkey*  
Rating of *kenkey* during validation test 

QDA training  
A trained panel assessing the *kenkey* samples