EVALUATION AND DESIGN OF A STEAM COOKING PROCESS FOR GA-*KENKEY* PRODUCTION

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DECLARATION

I declare that this work was conducted by me under supervision in the Department of Nutrition and Food Science, University of Ghana.

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ABSTRACT

Kenkey is a traditional fermented corn meal product that is native to the coastal regions of Ghana. The traditional method of cooking Ga-*kenkey* takes a lot of time and features a high degree of variability in the sensory attributes of the *kenkey* balls. A major source of variability is due to the way the Ga-*kenkey* balls are arranged in the cooking pot in relation to the amount of water used in cooking. The objective of this study was to develop a cooking process that would reduce the cooking time for Ga-*kenkey*, as well as assure consistent product quality irrespective of location in the cooking pot. The study was in three parts: (a) a survey of Ga-*kenkey* processors to get insights on their processing techniques, challenges as well as best practices (b) The second part of the study involved the determination of cooking times, heat transfer profiles in the three layers of Ga-*kenkey* in the cooking pot, determination of quality attributes of Ga-*kenkey* that consumers rate, optimization of steaming process for Ga-*kenkey* production. (c) The third part of the study involved the design of a steam cooker for Ga-*kenkey* to assure uniform product quality irrespective of location in the cooking pot. The results showed that 98% of the respondents were females with a majority of them aged between 31-40 years. Most of the *kenkey* processors (66%) indicated that *kenkey* requires about 3 hours to cook. The most used technique by the *kenkey* processors (62%) was touching the *kenkey* ball to determine the degree of cook whiles increasing the intensity of the fire was the technique most used by processors (80%) in ensuring that the Ga-*kenkey* cooks fast. Difference in variability among the *kenkey* layers were observed for moisture, colour, texture, firmness and heat penetration. The bottom layers of *kenkey* had the highest values for moisture (66.4$\pm$0.7), lightness (58.37$\pm$0.10), degree of gelatinization (50.4$\pm$0.1) and rate of heat penetration but the least values for hardness (3.066$\pm$0.515) as well as the other texture parameters. Ga-*kenkey* from the bottom had the most acceptable preference score (1.73). Steam cooking of

Ga-*kenkey* was affected by the steam cooking time and the presence or absence of corn husk in the steaming cage. The steam cooked Ga-*kenkey* reached its highest values for moisture (65.4±0.2) and degree of gelatinization (85.9±0.4) after 15 minutes of steam cooking. Ga-*kenkey* with corn husk in the steaming cage showed a lower rate of heat penetration compared to Ga-*kenkeys* without corn husk in the steaming cage. Ga-*kenkey* steam cooked for 5 minutes with husk had the most preferred sensory score (3.20). It is concluded that variability exists at the different layers of Ga-*kenkey* within the same cooking. Ga-*kenkey* from the bottom layer of the cooking pot is most preferred by consumers. Steam cooking with husk gives a better steam cooked Ga-*kenkey*. A stainless steel with thickness of 0.055 cm is required for designing a pressure cooker of volume 437,000cm^3 for cooking 200 balls of *kenkey* at a pressure of 40 Kpa.

DEDICATION

This research work is dedicated to my late father Mr. Kojo Owusu-Brafi and my fiancée Matilda Ama Dziedzorm Agbe.

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CHAPTER 1

INTRODUCTION

1.0 Background

Kenkey is a traditional fermented corn meal product that is native to the coastal regions of Ghana including the capital, Accra (Asante *et al*., 2011).The key ingredient used in *kenkey* production is maize. There are two main types of *kenkey*: the Ga and Fante *kenkey* both of which have historical and cultural ties to the Ga and Fante ethnic groups respectively. The two types also differ in the processing method used in their production (Kordylas, 1990). Processing of Ga-*kenkey* involves cleaning the maize, soaking the maize in water for 48 hours, milling the maize and making the meal into dough, fermenting the dough for a minimum period of 24 hours, dividing the fermented dough into two parts and cooking one part, mixing the cooked part with the uncooked part into *aflata*, molding the *aflata* into balls, wrapping the balls in corn husk and boiling (for extended periods of time) to obtain Ga-*kenkey* (Halm *et al*., 1996). The entire Ga-*kenkey* making process takes a minimum of 72 hours and some of the unit operations are both labor intensive and time consuming.

Furthermore, the traditional Ga-*kenkey* production process is still very much artisanal. The unit operations are not standardized and vary considerably among processors and from batch to batch for the same processor. This introduces substantial variability in product quality attributes (physical and sensory) between and within production batches. Amponsah (2010) suggested that the arrangement of Ga-*kenkey* balls in the cooking pot in relation to the amount of water used in cooking introduced layers of *kenkey* in the cooking pot. Three layers of Ga-*kenkey* balls were identified in the cooking pot as follows: the bottom layer directly in contact with the cooking water, the middle layer above the bottom layer, and not in contact with the cooking water, and the top layer above the middle layer. The variation in the location of the *kenkey* balls in relation to the cooking water introduced variability in heat transfer mode to cook the product by either direct contact with boiling water (in the bottom layers) or steam (in the top layers).

Consumers normally have expectations for specific defining product quality attributes. It is important that those attributes are met in the product, regardless of where and when it is obtained or consumed. This is not necessarily true of *kenkey* because of the non-standardized production methods. Consequently, for most consumers of Ga-*kenkey*, no two meals are exactly the same experience because of the inherent variability in quality attributes. Furthermore, the time and labour required for *kenkey* processing is a disincentive for consumers to cook their own meal, and prefer to obtain it from the local commercial Ga-*kenkey* processor. It is important that food, including Ga-*kenkey*, should be obtained within the shortest possible time for food security assurance, and also for it to be made at home by consumers at their convenience. An efficient cooking process that will assure consistent product quality and require less time and labour is very necessary to sustain consumer interest and demand for Ga-*kenkey*.

Some work has been done to reduce the time involved in making Ga-*kenkey* and to optimize the Ga-*kenkey* production process (Amponsah, 2010, Dzigbor, 2012). Work has also been directed towards reducing the fermentation time by speeding the fermentation process (Nout *et al.*, 1996). The cooking time of *kenkey* can be reduced using steam cooking as an option since according to NAGAO (1996), steam cooking shortens the cooking time of foods. However the right amount of steam and exposure time to the steam is important to obtain Ga-*kenkey* of acceptable quality attributes.

1.1 Justification

Ga-*kenkey* is so popular that it has almost become a national staple. However, its production methods are still very much cottage and the Ga-*kenkey* product features significant variation from producer to producer, and even from the same producer. In fact, Ga-*kenkey* produced on the same day and in the same pot from the same batch of dough can differ significantly in texture. This clearly indicates that the cooking process itself introduces variability in terms of texture to the consumer. This variability will come from both the cooking time, and the position of the product within the cooking pot. The consumer therefore does not get the same texture for *kenkey* either when they buy from the same *kenkey* maker or a different *kenkey* maker.

Ga-*kenkey* production is tedious and takes a long time, and as such people find it difficult to prepare the Ga-*kenkey* on their own. A cooking method which helps reduce the tedium associated with the traditional cooking method and time of cooking Ga-*kenkey* and at the same time tastes like Ga-*kenkey* cooked the traditional way is very important in assuring consistent product quality and sustain consumer confidence.

1.2 Objective

The objective of this study was to improve the cooking process of Ga-*kenkey* by reducing the cooking time, as well as assure consistent product quality irrespective of location in the cooking pot.

1.3 Specific objectives

- To assess the cooking time of Ga-*kenkey* using different Ga-*kenkey* makers.
- To asses variability in Ga-*kenkey* cooked in the same cooking pot.
- To determine consumer preference for Ga-*kenkey* in relation to their position in the cooking pot.

- To design and optimize a steam cooking technique to produce Ga-*kenkey* that would yield a product that is comparable in consumer acceptance to Ga-*kenkey* produced using the traditional cooking method.
- To determine how the cooking time of Ga-*kenkey* could be reduced using steam cooking techniques.
- To design a steam cooker for cooking *kenkey*.

CHAPTER 2

LITERATURE REVIEW

2.1 Processing of *kenkey*

Kenkey or Komi is a fermented maize meal staple in Ghana, and it is eaten by almost all ethnic groups in Ghana and other West African countries. *Kenkey* is also eaten in many parts of the world including Europe and the United States by Ghanaians residents there. There are many types of *kenkey*, and they vary depending on the ethnic origins and packaging material and style. The most common types of *kenkey* are the Ga and Fante *kenkey* which is from the Gas and Fantes respectively. While the Ga-*kenkey* is usually molded spherically and wrapped in corn sheaths, the Fante-*kenkey* is molded cylindrically and wrapped in Plantain leaves. There are other different types of *kenkey* in Ghana and these include the ewe *kenkey* (Muller, 1970). Apart from shape and wrapping differences, the different kinds of *kenkey* vary based on whether salt is added or not, the fermentation time of the dough and whether the maize was dehusked or not. There are other types of *kenkey* in Ghana (Muller, 1970). The minor types of *kenkey* include: *Nsihu, Dokon pa,* and *Ntaw* and Ga-*kenkey*. For all *kenkey* types, the processing is usually done by individuals or with help from family and friends, along traditional production process routines. Training in *kenkey* processing is by apprenticeship, and the tradition is passed down from one person as they help and observe in the process (Muller, 1970).

The main raw material used in making *kenkey* is maize. During *kenkey* processing whole maize is steeped for 1 to 2 days at room temperature, milled and made into dough (Nche *et al.*, 1994, Amponsah, 2010, Dzigbor, 2012).The dough is allowed to undergo spontaneous fermentation at room temperature for a period of days depending on the kind of *kenkey* being processed. After fermentation, the dough is divided into two parts and one part of the fermented dough is mixed with water to obtain a thin slurry. The slurry is cooked (with or without salt addition depending on the type of *kenkey*) into a thick and sticky paste, called *aflata*. The *aflata* is thoroughly mixed with the uncooked portion of the dough. Cooking of a portion of the dough serves as a binding agent as well as moisturizer (Sefa-Dedeh and Plange, 1989) when it is mixed with the raw dough.

After mixing, it is molded, wrapped in corn husks or plantain leaves and cooked to give *kenkey*. Cooking is normally done in aluminum pots and the main fuel used for cooking is firewood. Amongst all the different types of *kenkey* , the one that is most patronized by consumers is the Ga-*kenkey* and this is evident by the number of people seen to be engaged in the production as well as in the sales at different parts of Accra and other towns within the country.

2.1.1 Ga-kenkey

Ga-*kenkey* is a very popular food in the Ga communities, and has also found appeal among so many other ethnic groups that it has almost become a national staple in Ghana. Its preparation takes a minimum of 6 days from the soaking of the maize through fermentation of the dough to the cooking of the *kenkey* (Nche *et al.*, 1994). What makes Ga-*kenkey* processing different from the other *kenkey* types is the addition of salt during cooking of the *aflata* and the use of corn husks as wrapping material (Nche *et al.*, 1994). Critical to the quality of Ga-*kenkey* is its texture. This is affected by the raw material, the *aflata*lization process and the cooking time. Good Ga-*kenkey* is neither too sticky nor crumbly (Sefa-Dedeh and Plange, 1989).

Dough with a high starch gelatinisation index and a high set-back viscosity, on cooling, is required to give an *aflata* of adequate binding and moisturising capacity (Sefa-Dedeh and

Plange, 1989). The *aflata* serves as a binding agent and moisturizer when it is subsequently mixed with the uncooked dough (Nche*et al.*,1996). This is very important in determining the desired textural characteristics of cooked Ga-*kenkey*, which is a cohesive mass of coarse particulate matter cemented by the *aflata* (Sefa-Dedeh and Plange, 1989). The choice of ingredients, the pretreatment of maize and dough for *aflata* production and the cooking time are, therefore, crucial to the achievement of these properties. The women *kenkey* producers prefer maize with a high swelling index (Sefa-Dedeh and Plange, 1989).

Ga-*kenkey* processing and sale is usually done on small scale as a business. Some consumers however prefer their own home cooked *kenkey*, though this is not a common practice since the processing is tedious and time consuming. It takes considerable time between 4-6 days, and a great deal of drudgery for the entire *kenkey* production process Ga-*kenkey* production therefore needs to be encouraged through the provision of an optimized alternative way of processing which involves less time and are less energy input. This could either be done by reducing the time involved in processing or designing equipment to be used for some of the processing. There is tremendous variability in the physical and textural properties of Ga-*kenkey* from the same processor and across different processor as a result of different processing techniques. The variability may arise from the steeping process, fermentation process, *aflata* preparation, mixing process and the cooking of the *kenkey* (Amponsah, 2010, Dzigbor, 2012). Options for developing an industrial scale processing of *kenkey* depend largely on identifying the causes of (textural, physical, sensory) quality variability in the *kenkey* ball and minimizing them.

2.2 Cooking of Ga-*kenkey*

The cooking of Ga-*kenkey* involves a number of steps and also involves some changes in the fermented maize. There are two cooking processes which are: the cooking of part of the dough to form a paste called *aflata* after which the *aflata* is mixed with raw dough and wrapped in corn husk and the second cooking is done to get Ga-*kenkey*. There are also changes which occur during the cooking process. There is usually an increase in water uptake and changes in the nature of the starch granules of the dough used making the kenkey.

2.2.1 Cooking Process of Ga-*kenkey*

The cooking of Ga-*kenkey* is a complex process and it is in two stages. The first stage involves the *aflata* making in which a portion of the fermented dough is slurried and cooked into a thick paste (Sefa-Dedeh and Plange, 1989). The cooked paste is mixed with the uncooked fermented dough to form a gelatinous paste that is molded into balls and wrapped in corn husks for further cooking. It has been suggested that this unit operation is critical for the unique texture development of Ga-*kenkey* as cooking of a portion of the dough serves as a binding agent as well as moisturizer (Sefa-Dedeh and Plange, 1989) when it is mixed with the raw dough.

The second cooking stage in Ga-*kenkey* processing involves intensely boiling the *kenkey* balls in a closed pot for a prolonged period of time, lasting up to 3 hours (Amoa-Awua *et al.*, 2007). The drastic cooking process essentially sterilizes the product and reduces aflatoxins content in infected maize by about 80% for B_1 and G_1; 35% for B_2 and G_2 (Kpodo *et al.*, 1996), given the acidic nature of the environment. Indeed the drastic cooking step is considered by Amoa-Awua *et al.*, (2007) to be a critical control point, or a kill step in designing an HACCP plan for a Ga-*kenkey* manufacturing plant.

2.2.2 Changes during cooking of Ga-*kenkey*

Gelatinization and absorption of moisture of the starch granules of the maize used in making Ga-*kenkey* are the major changes that are seen in Ga-*kenkey* during the cooking process. These changes are seen both at the *aflata* making stages and the *kenkey* cooking stages. The cooking process for Ga-*kenkey* allows uptake of water by the starch granules of the maize used for making the *kenkey* thus causing it swell. The change in heat penetration during cooking together with the swelling causes gelatinization of the starch granules of the maize which is the main ingredient. These result in textural and colour changes in the *kenkey* from the beginning of cooking to the end of cooking.

2.2.2.1 Gelatinization

Gelatinization can be described as a sequence of changes in starch granules upon heating: starch granules first absorb large amounts of water, then swell to many times their original size at a specific temperature that is peculiar of the starch source, and finally leach their starch components. Depending chiefly on the starch/water ratio but also on a number of processing parameters such as temperature, heating rate, strain history, etc. a viscous solution or a gel is formed. Many aspects of starch gelatinization have been extensively studied in the past since it is a phenomenon encountered in many food processes and these include: baking, production of cereals and soups (Sakonidoua *et al*., 2003).

The extent of gelatinization achieved by High Pressure (HP) treatment and the rheological properties of the pressurized starch suspensions such as: normal maize, waxy maize, high-amylose maize VII, tapioca, and rice are highly dependent on the starch type, water content and the processing conditions used, such as pressure levels, temperature ranges, and treatment time (Hibi *et al*., 1993; Katopo *et al*., 2002).

The extent of gelatinization of a food starch is believed to be dependent on the properties of the food. The condition under which food is made to gelatinize can affect the texture of the food. Since foods gelatinize on the application of heat the kind of heat source can have an effect on the rate of gelatinization of the food. Gelatinization measurements can be used in predicting how a particular food may behave under the same conditions under which another food with the same properties was processed.

Tan *et al*. (2009) investigated the effect of pressure/heat combination on the gelatinization and rheological properties of japonica rice in comparison with thermal treatment at atmospheric pressure and realized that pressure/heat-induced starch gelatinization was highly dependent on the pressure and temperature and can help in the improvement of the taste and texture of related products made by rice starch (Tan *et al*., 2009).

Ji *et al.* (2004) determined if subpopulations of maize starch granules with different gelatinization temperature ranges have physical and chemical properties that are different from those of other subpopulations their results indicate that subpopulations with different physical and chemical properties occur in waxy maize starch and granules that are more resistant to gelatinization may be slightly more crystalline and this can be seen by the fact that they become less highly substituted upon hydroxypropylation.

The gelatinization properties of rice starch at different water concentrations by differential scanning calorimetry at constant heating rate have been observed and observations made were that water content influenced both gelatinization enthalpy and activation energy (Ea), while heating rate influenced the temperature (Spigno and De Faveri, 2004).

In an investigation by Turhan and Gunasekaran (2002) to analyze the gelatinization kinetics of wheat starches commercially used in the production of instantized cereals it was found out that the rate of the gelatinization increased with increasing cooking temperature as expected and at the same conditions, the rate of the in vitro gelatinization was higher than that of the in situ gelatinization for both hard and soft wheat starches.

The amount of moisture of the food absorbs as well as the amount of heat penetration in the food during cooking of the food can affect the degree of gelatinization of the food. This work however seeks to access the degree of gelatinization of starch in Ga-*kenkey* from different layers within the cooking pot during cooking and to assess the contribution of moisture absorbed during cooking and the temperature profile during cooking on the gelatinization rate of *Ga-kenkey*. Gelatinization however because it reflect the change in the structure of the starch granules of a starchy food would consequently have an effect on the texture and appearance of the food and in this instance since gelatinization is being assessed with respect to the cooking time of *kenkey* it is expected the it would have an effect on the texture of the *kenkey*.

2.2.2.2 Moisture changes during cooking

Water in foods is measured as moisture content of food. According to Slade and Levine (1991) water in foods is regarded as the universal plasticizer. This property of water depends on the nature of the starch in the food as well as the amount of moisture in the food (Lai and Padua 1998). This effect of water in the food contributes to the texture of the food. This means that it serves as a softener or makes less brittle a food material. Thus knowledge of the amount of moisture in a food like Ga-*kenkey* which is composed of starch is very important especially in an optimization process. Water can however serve as both a plasticizer and an antiplasticizer depending on the physical property measured (Chang *et al.* 2000).

2.2.2.2.1 Water as a Plasticizer

The plasticizing effect of water can be observed in different properties of the food. Water as a plasticer can cause a desirable texture in some foods. The plasticizing role of water is supported by its properties: low molecular weight, low density, high dielectric constant, high ability of forming H-bonds and low *Tg*. The plasticizing effect is most efficient at relatively small amount of adsorbed water, which is not available as a solvent. High mobility of water molecules usually results in water losses either by evaporation or by extraction. According to Ta-Te-Lin and Pitt (1986) the yield strain increases in hundreds % in apples and this trend is typical for materials with moisture content higher than 10% w.b. at the beginning of a sorption isotherm. The materials with moisture content below 10% w.b. can be classified as brittle and increasing water content reduces the probability of the brittle fracture. In wet conditions, the moisture content in cells increases causing the increase of the turgor pressure and then also modulus of elasticity (Ta-Te-Lin and Pitt, 1986).

These can be seen in the mechanical, physical as well as the thermal properties of the food. According to Chang *et al.* (2000), the effects of moisture causes a reduction in glass transition temperature (Tg), tensile modulus, linear expansion, and water vapour permeability in starch films. Chang *et al.* (2000) observed a general decrease in the modulus of elasticity which is an index for "stiffness" for both native and cross-linked tapioca starch films with increasing moisture content. Where an antiplasticizating effect were observed in the starch films, further hydration of starch films beyond the "antiplasticization range" of moisture content, water appeared to exerted a plasticizing effect thereby reducing the tensile strength.

Increasing moisture content has also been observed to lower the glass transition temperature (*T*g) an effect generally perceived to arise from plasticization of the amorphous regions of partially crystalline polymeric systems (Slade *et al*., 1989).

Cooke *et al*. (1996) also observed that the enthalpy change associated with melting of the crystalline phase increases with increasing moisture and attributed it to the enthalpic association of water molecules with the helix structure of the polysaccharide. A relaxation test carried out by Cuq *et al.* (2003) on spaghetti also showed that moist spaghetti are characterized by nearly constant high values of apparent relaxation coefficient and they also behaved as a visco-plastic material. It has also been observed that in absence or at low concentrations of moisture as plasticizer, high-temperature compression molded wheat gluten powder upon cooling vitrifies into a rigid material (Jansens *et al*., 2013).

2.2.2.2.2 Water as an Antiplasticizer

Water can also act as an antiplasticizer thus reducing the plastic nature of the food. Thus causing stiffness in some foods and making the texture undesirable. This can also be seen in the mechanical, physical and the thermal properties of the food. Antiplasticization by water results in maxima in tensile strength, strain-at-break, and toughness (Chang *et al.* 2000). Chang *et al.* (2000) observed maximum values for strain and toughness at 6% to 8% moisture for native and cross-linked tapioca starch films. However, the tensile strength of cross-linked starch films is generally higher than that of the native starch films at the same moisture contents. Mechanical antiplasticizing effect of water has been observed to occur up to a moisture content of about 17% in extruded starch bars (Nicholls *et al.*, 1995).

2.2.2.2.3 Changes in heat penetration during cooking of Ga-*kenkey*

Changes in heat penetration could occur during cooking of the Ga-*kenkey* balls. Such changes can occur in the same ball of Ga-*kenkey* or Ga-*kenkey* at different layers within the same cooking pot. These changes may occur as result of the arrangement of the Ga-*kenkey* balls in relation to the cooking water and the heat source for cooking the *kenkey* balls. Changes in heat can be assessed by monitoring the temperature as cooking of the Ga-*kenkey* is done.

2.2.2.2.3 Textural changes

Textural changes are observed in Ga-*kenkey*. After the *kenkey* have been cooked and this is due to the extent of gelatinization of the starch granules of the maize used in making the *kenkey*. Depending on the temperature of the *kenkey*, differences in texture can also be observed. Texture thus plays a very important role in foods. Texture affects the preference of a particular food. It also serves as indices for determining product quality.

Texture is affected by the structural composition of the food, the way in which the foods are processed as well as the extent of processing. The kind of ingredients used in making a particular food also has an influence on the texture of the food. An idea of the texture of a particular food can therefore help in assessing the product quality, consumer acceptance of the product and the extent to which the food has been processed. This information about texture can also help in optimizing a product to suit consumer preference.

Texture has been defined by Bourne (2002) as the group of physical characteristics that arise from the structural elements of the food, are sensed by the feeling of touch, are related to the deformation, disintegration, and flow of the food under a force and are measured objectively by functions of mass, time and distances. Very similarly to Bourne's definition, the International Organization for Standardization has defined texture as "all the mechanical, geometrical and surface attributes of a product perceptible by means of mechanical, tactile and, where appropriate, visual and auditory receptors" (ISO,1994).

Nisha *et al*. (2006) determined the kinetic parameters for texture development in three different food model systems (cubes, whole green gram and red gram splits) over different temperature ranges, the kinetics of texture development for different cooking methods and the possibility of developing a mathematical model relating the calculated kinetic data of texture development at isothermal conditions to the non-isothermal conditions using the time temperature profiles of different cooking methods. They observed that the texture development followed first order kinetics in potato cubes, whole green gram and red gram splits.

Studies to explore the effect of different ratios of rice to black gram dhal and fermentation time on the texture of *idli*, analyzing the instrumental texture profile (TPA) parameters as a function of raw material composition and fermentation time and to find the optimum levels to maximize the desirable textural properties of *idli* using RSM have also been conducted (Durgadeviand Shetty, 2012). The results obtained showed that RSM based TPA for *idli* was found to be an effective tool to predict the relationship between the rice to black gram dhal ratio and fermentation time on the textural properties namely hardness, adhesiveness, springiness, cohesiveness, chewiness and resilience (Durgadevi and Shetty, 2012).

Renard *et al.* (2006) examined relationship between food structure and sensory perception and found out that that neutral exopolysaccharide contributes to the viscosity but not to the elasticity.

An alternative approaches to enhance taste perception by structural modifications of the food matrix has also been researched by Stieger and he found out that modulation of the serum release in food gels appears to be a powerful textural tool to enhance sweetness and this can be exploited to optimize the development of products with reduced salt and sugar content while maintaining taste intensity (Stieger, 2011).

Research on whether the feel of the package in a consumer's hand influences the perceived texture of the food has also shown that texture of the container influenced participants' ratings of certain texture attributes (Piqueras-Fiszman and Spence,2012).

Forde *et al*. (2013) assessed ad libitum intake of meals with equivalent components that varied in texture and taste intensity and observed that food texture may be used to produce slower eating rates that result in a reduced overall energy intake within a realistic hot lunchtime meal.

Floury *et al*. (2009) worked on developing a manufacturing process, and then characterized the structural and textural properties of a range of lipoproteic model matrices with different dry matter, fat and salt contents at different pH values and found out that the structural arrangement of the network determines the textural characteristics of a product and is strongly affected by composition factors such as the dry matter and the fat/dry matter ratio, which determine the droplet size and distribution (Floury *et al*., 2009).

Luschera *et al*. (2005) examined the impact on plant tissue storage of potato at subzero temperatures without ice formation, compared to pressure shift freezing and freezing to different solid states at pressures up to 400 MPa (Luschera *et al*. 2005).

Studies on the relationship between food structure and texture perception have shown that relation of food structure to texture perception is not straightforward and its study is complicated by the dynamic nature of texture perception and by the presence of large individual differences in oral processes (Wilkinsony *et al*., 2000).

Works on how to relate the distribution of sensory responses to well defined and measurable mechanical properties like stiffness, toughness, elasticity and brittleness reveals that textural differences are frequently accompanied by other organoleptic differences in flavour and colour (Peleg, 2006).

Thermal degradation kinetics of litchi texture loss during heating shows that the thermal firmness degradation curve of litchi has a short term shoulder-like increase at the initial heating stage, and then a decrease after which it remains in a tail-like non-zero equilibrium stage during prolonged heating (Yu *et al*., 2001).

Thussu and Datta (2011) compared the texture development during moisture removal processes and the effect of oven temperature and sample size and found that the framework of texture (Young's Modulus) prediction is applicable moisture removal processes and therefore can be used to predict texture. Herremans *et al*., (2013) characterized the texture, microstructural and optical properties of aerated sugar gels by a series of destructive and non-destructive techniques, and explored the (micro) structure property relationships of these gels. They observed changes in the microstructure of sugar foams from different mixing times in relation to the texture properties.

Fongaro and Kvaal (2013) evaluated the ability of different image texture analysis methods to describe the surface aspect of an Italian peculiar pasta (*Pizzoccheri*), as well as its changes associated with cooking and observed that through a direct comparison of these surface texture indices of the samples it is possible to establish which one has a rough or smooth surface and so to obtain a characterization of the aspects of the samples and this can predicted pasta cooking quality due to the correlations with the physical parameters.

Meyer *et al*., (2011) tried to find out how inulin can be used to mimic the features of fat for mouth feel and creaminess, and how these effects may be related to changes in rheology of the food system will be described for liquid, semi-solid and solid dairy products and concluded that the effect of inulin on rheological behaviour and on texture in different dairy products clearly and not surprisingly not only depends on the concentration but also on the degree of polymerisation of the inulin.

Grygorczyk *et al.* (2013) examined the role of texture in consumer liking of commercial yogurts found in the Canadian market and it was revealed that yogurt texture was an important factor affecting consumer liking.

Studies where a controlled experimental design and a range of texture characterization techniques were used to illustrate the effect of fat addition, at different levels of total solids, on the formation of structure in acid milk gels made from reconstituted skim milk have shown that there are differences in the microstructure of acid milk gels, caused by differences in the solids-non-fat contents and this influences the perception of the textural attributes of these products and an image analysis could be done and used to model these changes in perception (Pereira *et al*.,2006).

Benedini *et al.* (2012) investigated the sensory and texture characteristics of Parma hams as affected by changes in their salt content in a 20-25% range and they found out that changes in salt concentration over the range of 4-5.5% as per cent edible meat can considerably impact a variety of texture as well as odour and taste characteristics that are key to product acceptance.

On comparing the efficacy of selected pretreatments such as calcium infusion, heat, and pressure pretreatment and their combinations on the textural characteristics of carrot processed by PATP and thermal processing Rastogi *et al.*(2008) found out that the carrot texture after PATP and thermal processing was strongly influenced by the nature and intensity of pretreatment conditions with the individual pretreatments at their appropriate levels resulting in a maximum hardness enhancement of 2.4-fold.

Ruiz-Ramı´rez *et al.* (2005) in a study to describe the profiles of aw, water content and texture in crusted dry-cured loin versus non-crusted dry-cured loin observed that crusted loins were characterized by a higher hardness and chewiness and lower cohesiveness at the surface (3-mm thick) than non-crusted loins and whiles the springiness dry-cured loin showed low relationships with X and aw, hardness and chewiness, fitted with a non-linear model, were better described by X than by aw.

Engelena *et al*. (2003) examined the effect of oral and product temperature on the perception of texture and flavor attributes and was concluded from the study that product and oral temperature influence the perception of certain flavour and texture attributes in semi-solids, with a larger effect on custard desserts than on mayonnaise.

In this work the influence of both the traditional cooking method for *kenkey* as well as that of the steam cooking techniques that would be employed on the texture of *kenkey* would be assessed to determine the impact they have on the *kenkey*. And also to determine if any of the steam cooking techniques that would be employed could match the texture of *kenkey* obtained from the traditional cooking method with an acceptable texture. Rheology of food can both be assessed by Texture profile analysis and Stress relaxation test.

2.2.2.2.3.1 Texture Profile

Texture profile analysis (TPA) is an objective test commonly used for texture assessment of foods. Texture profile parameters include: hardness, chewiness, cohesiveness, gumminess, and springiness.

• Hardness describes a product which displays substantial resistance to deformation or the "first bite" that would be perceived by human sensory analysis (Bourne, 2002). Human subject sensory studies often refer to products on a scale of soft-firm-hard (Szczesniak, 1963).

• Chewiness can be described as the textural property manifested by a low resistance to breakdown on mastication (Jowitt, 1974). Chewiness can be explained with a human sensory analysis on a scale of tender-chewy- tough.

• Cohesiveness has been defined as the strength of the internal bonds making up the product (Szczesniak, 1963).

• Gumminess, the energy required to disintegrate a semisolid food to a state ready for swallowing, and it is related to the primary parameters of hardness and cohesiveness (Szczesniak, 1963). On a subjective scale, cohesiveness can be described as mealy pasty gummy.

• Springiness was determined as the force in which the sample returns to its original size after compression (Munoz, 1986) or the elasticity of the product. All attributes contribute to the overall acceptance and desirability of the food product. These attributes can also be an excellent measure for studying the strength of the gelatinized starch matrix form during after the *kenkey* have been cooked.

Caine *et al.* (2003) compared the texture profile analysis test to Warner-Bratzler shear which is commonly used to measure tenderness of whole muscle cuts of meat. They believed it to be an obvious substitute. However, Caine *et al.* (2003) concluded that texture profile analysis was a superior test in explaining the variations found using a human sensory panel.

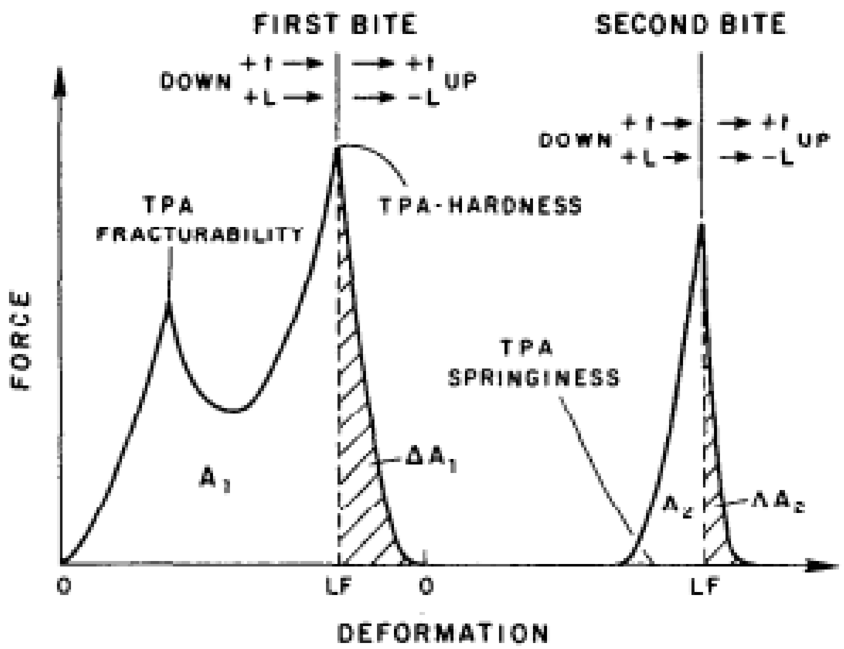

Figure 1: Texture profile analysis curves showing texture parameters (Peleg, 1978).

The texture profile of food is important in assessing the effect of processing conditions on the food sample. Texture profile can also indicate the nature of and quality of a particular food. Measurements from texture profile could serve as an index which can be used for optimizing a food product. The nature of a food however contributes to the overall texture profile of the food.

Durgadevi and Shetty (2012) explored the effect of different ratios of rice to black gram dhal and fermentation time on the texture of *idli*, analyzing the instrumental texture profile (TPA) parameters as a function of raw material composition and fermentation time and to find the optimum levels to maximize the desirable textural properties of *idli* using Response Surface Method (RSM). They observed that RSM based TPA for *idli* was an effective tool to predict the relationship between the rice to black gram dhal ratio and fermentation time on the textural properties namely hardness, adhesiveness, springiness, cohesiveness, chewiness and resilience.

Herrero *et al*. (2008) applied tensile tests to cooked meat sausages to determine their tensile parameters (breaking strength and energy to fracture) and related the results to TPA parameters, folding test score and physico-chemical characteristics, in order to provide a complete characterization of the cooked meat sausages and observed that breaking strength (BS) and the energy to fracture (EF) by tensile test can be used together with the TPA, to determine textural properties of cooked meat sausages as well as providing information which permits grouping of cooked meat sausages into three different textural profiles.

Herrero *et al*. (2007) also applied tensile tests to dry fermented sausages to determine their breaking strength, relating the results obtained to that of compression textural parameters (TPA) and physico-chemical characteristics, in order to provide a complete characterization of the dry fermented sausages. They found out that the determination of breaking strength by tensile test can be used together with the TPA to determine textural properties of dry fermented sausages and thus TPA parameters could be used to construct regression models to predict breaking strength.

Evaluation of the effects of commercial liquid smoke flavourings on the texture of pork loin and bacon using Texture Profile analysis (TPA) analysis, and to determine whether texture qualities change with storage time indicates that the commercial smoke flavourings causes changes to the texture of meat products and the commercial smoke flavourings changes more accentuated in bacon than in loin (Martinez *et al*., 2004).

Caine *et al.* (2003) correlate Texture Profile analysis (TPA) parameters obtained using a star-shaped compression probe and Warner-Bratzler shear (WBS) with trained-panel ratings of the sensory characteristics of cooked rib steaks and observed that both TPA and WBS negatively correlated with trained panel sensory characteristics however, TPA explained more of the variation in subjective sensory tenderness of the rib steaks than WBS.

Evaluation of the effect of the addition of passion fruit peel powder (PFPP) on the fermentation kinetics and texture parameters, post-acidification and bacteria counts of probiotic yoghurts four weeks of cold storage by do Espírito *et al*. (2012) showed that the PFPP increased firmness, consistency and cohesiveness of all skim yoghurts pointing out the suitability of the use of passion fruit by-product in the formulation of both skim and whole probiotic yoghurts.

Rahman and Al-Farsi, (2005) measured instrumental TPA attributes of date flesh as a function of moisture content by two-cycle compression. They observed that hardness, chewiness, and resilience increased exponentially with the decrease of moisture content, whereas adhesiveness, cohesiveness and springiness increased exponentially with the decrease of moisture content concluded that elastic nature (hardness, adhesiveness, and chewiness) and plastic nature (cohesiveness, resilience and springiness) can explain the instrumental TPA attributes of dried dates.

Verification of the effects of refrigeration, freezing and replacement of milk fat by inulin and whey protein concentrate (WPC) on the texture profile and sensory features of synbiotic guava mousses containing the probiotic strain, Lactobacillus acidophilus La-5, and the prebiotic fibre oligofructose have shown that replacement of milk fat by the simultaneous addition of inulin and WPC in refrigerated and frozen mousses caused changes in the product texture, particularly increased firmness and adhesiveness, and decreased cohesiveness (Buriti *et al.*, 2010). To obtain a texture profile similar to the traditional product, the simultaneous addition of inulin and WPC is advisable only for the partial replacement of milk fat in refrigerated and frozen mousses (Buriti *et al*., 2010).

2.2.2.2.3.2 Stress Relaxation Test

Stress relaxation test are important in determining the rheology of foods which consequently can affect the overall texture of the food. Determining the stress relaxation behaviour is important. It helps in predicting the behaviour of foods and can also serve as quality indices to examine the quality of a particular food. Stress relaxation behaviour can also be used in predicting the effect of a process on a particular food. The stress relaxation behaviour could however be affected by the nature of the food, the constituent of the food and processing condition applied to the food.

Bellido and Hatcher (2009) have investigated a new procedure for describing and discriminating the stress relaxation behaviour of soft solid foods using yellow alkaline noodles (YAN) as a model system and have found out that yellow alkaline noodles made from Canada Western Red Spring (CWRS) and Canada Western Amber Durum (CWAD) wheat flour had more elastic-like behaviour than noodles made from Canada Western Hard White Spring (CWHWS). While the procedure proved to be useful in discerning the mechanical behavior of yellow alkaline noodles, it may also be applicable to other soft solid food systems.

Bhattacharya *et al*., 2006 studied the rheology of corn flour doughs employing stress relaxation and two-cycle compression tests performed at different moisture and gum Arabic contents of the dough and the results were correlated with sensory measurements. It was observed that Corn doughs were sensitive to moisture contents which were reflected by the values of the relaxation constants (K1 and K2).

The effects of thermal treatment on the viscoelastic properties of moth bean flour dough at different moisture contents, by employing the technique of stress relaxation at low- and high-strains, using a suitable model to explain the stress decay curve, and to relate the instrumental and sensory attributes of the dough and fried products were determined by Bhattacharya (2010) and it was found out that heat treatment of the flour imparts an enhanced viscoelastic solid behaviour and induces cohesive characteristics. It can result in improving the post-extrusion or post-flattening shape retention in relation to the development of products with better acceptable attributes.

Herrero and Careche, (2005) developed a stress relaxation test for frozen stored Cape hake and related it with sensory relaxation parameters could be used as markers for evaluating textural quality of frozen Cape hake, replacing sensory assessment.

Evaluation of the effect of two cooking methods (steaming and boiling), different cooking times and storage temperature on the stress-relaxation characteristics of cassava dough reconstituted from cooked cassava flour as well as finding the best model to describe the experimental stress-relaxation data using the Maxwell and Peleg models was examined by Rodrı´guez-Sandoval *et al.* (2006) and they realize that the dough's rheological attributes depend on the cooking method and the storage temperature and that both the Maxwell and Peleg models estimated the stress-relaxation behaviour of reconstituted cassava dough successfully, but the two-element Maxwell model with a residual spring in parallel was the best in predicting experimental data.

Hassan *et al.*, (2005) worked on obtaining data to describe the stress relaxation characteristic of eight Saudi date cultivars at their khalal (balah) and rutab stages of maturity, investigated the effect of maturity stage on stress relaxation properties, and tried to find the best model to describe the obtained stress relaxation data using three popular stress relaxation models, namely the generalized Maxwell, Nussinovitch, and Peleg. They observed that the Maxwell model was the best in predicting experimental data; however the Nussinovitch and Peleg models were valid as well for quantifying relaxation behaviour of the eight Saudi date cultivars tested.

Determination of the effect of high molecular weight-glutenin subunits (HMW-GS) and low molecular weight-glutenin subunits and (LMW-GS) on the modulus of elasticity, stress relaxation and quality related to SDS-sedimentation volume and mixing data and the stress relaxation behaviour of wheat kernels when subjected to strain have shown that HMW- and LMW-GS appeared to be predominant factors that affect the relaxation stress constants and relaxation times of the wheat kernel (Hernández *et al*., 2012).

A.R.P *et al*. (2013) investigated the effects of moisture content, conditioning temperature and compression loads on mechanical properties, stress relaxation behavior and the cohesiveness of distillers dried grains with solubles (DDGS) bulk solids. They observed that moisture content, temperature and compressive load highly influences the bridging between DDGS particles and subsequently the caking and flowability of DDGS bulk solids thus maintaining uniform moisture content of product during production and adopting effective and quicker cooling methods after drying could reduce the caking tendency of DDGS during transportation and storage (A.R.P *et al*., 2013).

Stress relaxation behaviour of frozen sucrose solutions in the presence ofxanthan gum, gelatin and guar gum has been investigated by Sahagian and Goff using a thermomechanical analyzer and their findings suggested that the mechanical spectrum, in terms of the decay of internal stress is strongly dependent on temperature and rate of freezing thus at temperatures where food stability is critical, stabilizer action may evolve from modification of the kinetics and specifically, the rheological and viscoelastic response of the systems at sub-zero temperatures (Sahagian and Goff, 1995).

This work however seeks to examine the effect of the different layers created in the cooking pot during the traditional Ga-*kenkey* as a result of the way the cooking is done on the texture of Ga-*kenkey* by assessing the texture profile and stress relaxation behavior of Ga-*kenkey* and on steamed Ga-*kenkey* at different steam cooking times.

2.2.2.2.4 Colour changes

Changes in colour of the dough used in making the Ga-*kenkey* is observed during both the preparation of the *aflata* and cooking of the Ga-*kenkey*. The changes in colour could be attributed to the rate of gelatinization of the starch granules of the maize used in making the *kenkey*. The composition of food can contribute greatly to its colour. Colour has a great influence on the acceptance of food by consumers. It can also be used as index for determining food quality. Processing has an effect on the colour of foods. The type of processing method used by processors, the mode of application of the processing method and the types ingredients used during processing can influence the colour of foods. Colour thus can be used to determine the effect of a processing method or can be used as a means of predicting the effect of processing as well as the preference of a product by a consumer.

Gimeno *et al*. (2001) evaluated the effect of calcium ascorbate at different concentrations as a partial substitute of NaCl in dry fermented sausages on the desiccation and acidification process, colour and texture development as well as hygienic safety. They observed that colour gave rise to some significant differences especially with the highest amount of calcium ascorbate. Murat and Onur (2000) studied the effect of process variables on the color attributes of hazelnuts during roasting and the development of internal browning during hazelnut roasting and the observed that that roasting temperature is the main factor, affecting development of colour during roasting of hazelnuts.

Cruz-Romero *et al.* (2008), studied the effects of high pressure treatment on the proximal composition, volatile compounds, colour and fatty acids of oysters and found out that the volatile component profile of fresh oysters were affected by high pressure treatment thus affecting the colour and flavour. Bhattacharya also tried to generate data on the changes in the colour measurements (in the Hunter system) during parboiling of rice at different pressures and processing times. He observed that pressure and time of steaming have a marked effect on Hunter colour parameters of rice and suggested the use of a relatively low pressure for obtaining light coloured parboiled rice (Bhattacharya, 1996).

Christopoulos and Tsantiliafter investigating changes in antioxidants (TP,TAC) and colour, as well as, the relationships among these antioxidants and colour attributes found that the differences in colour among cultivars was as a result of genetic factors such as antioxidants (Christopoulos and Tsantili, 2011).

Goncalves *et al.* (2007) also investigated the evolution of colour in sweet cherries during postharvest storage at different temperatures, the relationship between colour attributes and anthocyanins content in cherries, and unravel any potential differences in colour attributes and anthocyanin colour relationships among four different cherry cultivars and found out that chromatic functions of chroma and hue correlate closely with the evolution of colour and anthocyanins levels during storage of sweet cherries and indicate that colour measurements can be used to monitor pigment evolution and anthocyanin contents of cherries and vice versa. Bozkurt and Bayram (2006) evaluated the sensory, colour and textural attributes of sucuk made without additives during the ripening period, and to compare the results of sensory and instrumental methods and observed that physical characteristics, colour and texture, are the main factors that affect selection of food.

Mele´ndez-Martı´nez *et al*. (2009) assessed the effect of externally added ascorbic acid on the typical changes in individual carotenoids and colour observed during the shelf-life of orange juice changes in the carotenoids led to colour differences that can be discerned visually.

Bayram *et al*., (2004) studied the soaking of soybean to produce soy-bulgur as a new type of food product by measuring the changes in the properties of soybean kernel such as weight, volume, density, moisture content and colour (L, a, b and YI-values) and observed that the L (lightness) and b (yellowness) values of soybean colour increased during the soaking in contrast to a (redness) and yellowness index values.

Cavaa *et al*. (2005) investigated the effect of using different irradiation doses on the instrumental colour, lipid oxidation and hexanal generation of vacuum slices of dry-cured Iberian hams from free-range reared pigs and intensively reared pigs and concluded that differences in composition characteristics of raw material could play an important role in the irradiation-induced changes on colour and lipid oxidation of vacuum-packaged dry-cured ham slices.

Zhang *et al*. (2004) also studied the development of a method, which permits the application of radio frequency heating to a comminuted cased meat products and which could be easily integrated with current methods for meat pasteurisation by assessing quality attributes such as texture and colour of the radio frequency heated products and compared to products pasteurised by conventional methods. They observed that radio frequency cooked comminuted cased meat products had less colour development than their steam cooked ones.

Studies have been done to develop a method for precisely measuring the colour of extruded food product using a charge coupled device (CCD) spectrophotometer and to correlate the colour of the final product with that measured in-line (Valadez-Blanco *et al.*, 2007). It was found out that feed forward network with three hidden neurons provided an acceptable correlation between the in-line and off-line colour measurements (Valadez-Blanco *et al.*, 2007).

Research on the effect of strain and harvest date on fruit colour, quality parameters, volatile emissions and consumer acceptability during the ripening process has also be conducted by Iglesias *et al*. (2012) and observations made were that a there was a high correlation between consumer acceptability and some of the volatile compounds emitted, in addition to fruit that exhibit bigger hue angles on the exposed side with lower red colour.

The effect of pressurization and cold storage of strawberry purée on colour, anthocyanins, ascorbic acid and pectin methylesterase has been investigated and it was observed that colour of strawberry purée showed significant differences between the different temperatures assayed at the different pressures assayed (Bodelón*et al*., 2012).

PennisiForell *et al*. (2010) studied the effect of two emulsifiers and natural antioxidants on the oxidative stability, colour, and fatty acid profile of low-fat meat burgers enriched in unsaturated fatty acids and phytosterols which had been frozen and subsequently cooked.

Wang *et al.* (2013) found out that the better green colour could be retained in HHP-treated samples than thermal-treated ones during storage and this was more obvious with the increase of pressure level after evaluating comprehensively related properties affecting colour quality of high hydrostatic pressure processed spinach puree during storage.

The effect of freeze drying and air drying at different temperatures on the colour and texture of pumpkin and green pepper has been investigated and it was found out that air drying at 30 °C produced very small changes in colour whereas the air drying at70 °C originated more intense colour changes (Guinéa and Barrocab, 2012).

Studies on the kinetics of browning during deep-fat frying of blanched and unblanched potato chips by using the dynamic method and to find a relationship between browning development and acrylamide formation proved a linear correlation between acrylamide content of potato chips and their colour represented by the redness component a* in the range of the temperatures studied (Pedreschi *et al*., 2005).

Wadhwani and McMahon (2012), assessed how the translucent appearance (colour) of low-fat Cheddar cheese affects consumer acceptability and if increasing cheese opacity alters flavour perception and concluded colour significantly affected the overall liking of low-fat versions of Cheddar cheese.

Studies on the influence of the heating medium used for grilling on browning colour formation in fish, using two different heat transfer systems and convective heating by Matsuda *et al*. (2013) showed that the composition of the grilling environment could affect colour development in the heat different heat transfer systems.

2.2.3 Heat Penetration

Temperature measurements are very important in processes that involve the application of heat. Temperature measurements in such process can provide information about the efficiency of the process. Temperature measurement in foods can be assessed using temperature changes as well as the heat penetrations and temperature profile. Temperature profiles measurements provide heat penetration with time on application of heat when heat is applied to food product. Temperature profile measurements are important in food processing which involve the application of heat because it can inform whether the heating process was effective or not.

These measurements can be used to predict the behavior of certain foods when heat is applied to them. Information taken from the temperature profile can be used in an optimization process to optimize the amount of heat needed to heat food thus avoiding wasting the source of heat. The temperature profile can however be affected by the nature of the food as well as the processing condition.

Heat measurements have been exploited in a number of processes. Rosset *et al.* (2004) evaluated the chill chain in school catering, by monitoring time temperature profiles and integrating these field data in a simplified quantitative risk assessment approach and observed the coincidence of extended storage duration which was due to weekends and temperature abuse and suggested this could lead to a significant microbial development.

Investigations on the use of peroxidase as Time-temperature indicator (TTI) to monitor thermal processes, to develop a computer vision based method and to determine the intrinsic time-temperature profile of food particles treated by microwave heating have shown that in microwave heating, heating time and location significantly affected temperature change. The interaction of heating time and location significantly affected the temperature change (Deng *et al*., 2003).

Chen *et al*. (2008) developed a numeric model to couple electromagnetic (EM) and thermal field calculations in packaged foods moving in pressurized915 MHz microwave (MW) cavities with circulating water at above 120^{o}C whiles employing a commercial EM package with a customized heat transfer sub-model to solve EM field and thermal field equations. Their results indicated that inside an inhomogeneous food package, the dielectric properties could be deliberately altered so as to redirect surplus microwave to the area with less initial energy, which resulted in more uniform heating (Chen *et al*., 2008).

Scheerlinck *et al*. (2008) applied the methodology of dynamic optimal experimental design to estimate the thermal conductivity and the volumetric heat capacity of conduction heated foods simultaneously. Their findings showed that the methodology guarantees an optimal regime for simultaneous parameter estimation. Pulse heating with two peaks one at the beginning and one at the end of the experiment was an optimal heating profile and the optimal measurement position was located at some distance from, and close to the heating probe.

Yang and Gunasekaran (2004) investigated the temperature distribution (TD) in 2% agar gel sample cylinders heated by continuous and pulsed microwave energy, predicted the sample TD by solving the Lambert's Lawand Maxwell's equations of microwave power absorbed by the samples and compared the measured and predicted TD in the sample under continuous and pulsed microwave heating. Their results showed that the measured temperature distributions and the corresponding predictions using both models indicate better temperature uniformity in the agar gel cylinders under pulsed microwave heating, though the total process time is longer, than under continuous microwave heating (Yang and Gunasekaran, 2004).

Farag *et al*. (2012) worked on developing and validating a mathematical model to predict temperature profiles within a wood cube subjected to microwave heating (MWH) taking into account the effect of heat induction in a wooden cube of known dielectric and physical properties upon irradiation by 2.45 GHzmicrowaves at 2.3 KW nominal power and heat transfer due to free convection or perfect insulator (FC or PI) at the surface of the cube. They observed that MWH leads to non-uniform distribution of temperature which is strongly affected by penetration depth (Dp) and surface heat loss and that homogenous mixing of materials which are strong microwave to heat converters leads to maintaining the shape of the temperature profile while exhibiting a significant increase in temperature compared to the virgin material exposed to the same power and heating time (Farag *et al*., 2012).

This work however seeks to evaluate the heat penetration during the traditional cooking and the use of different steam cooking techniques in Ga-*kenkey* cooking by exploring the temperature profile of the Ga-*kenkey* during cooking and to use the results in optimize the steam cooking process for Ga-*kenkey* cooking.

2.3 Reduction of time involved in making Ga-kenkey

Considering the time involved in making Ga-*kenkey*, it is imperative to develop processing technique that cut down on the time and effort required in the making of Ga-*kenkey*. A number of researchers have reported work done to improve on the processing of Ga-*kenkey* by reducing the time and energy needed in its processing. Nche *et al.* (1996) have shown that some parts of the *kenkey* process can be upgraded by shortening the fermentation period using an accelerated fermentation process or by reducing physical labour using pre-cooked dehydrated *kenkey* mixes (Nche *et al.*, 1996). They created a process where fermentation takes place after the dumpling has been made and filled into a casing material, instead of fermentation prior to dumpling making.

In addition, several stages have been optimized (i.e. soaking period, amount of *aflata* used, fermentation period and cooking time). This would finally result in a 24 hour process with reduced energy requirement, yielding a ready-to-eat product.

Nche *et al.* (1994) in their attempt to reduce processing time for Ga-*kenkey*, omitted the soaking stage and substituted it with a lactic starter-fermentation of a suspension of dry-milled flour (Nche *et al.*, 1994). According to Bediako-Amoa and Austin (1976), household-scale *kenkey* making could be made less tedious by supplying a mix containing dehydrated fermented flour and dehydrated, pre-gelatinised *aflata*. It has, however, been reported that significant starch damage occured in a dough of very low pasting and set-back viscosities (Adeyemi and Beckley, 1986). Soaking of maize, on the other hand, is known to facilitate smooth milling (Akingbala *et al*., 1987). Soaked maize kernels were first coarsely milled crucial to the production of dough with high moisture using a 12 tooth rotor and a 4 mm screen. However not much research works have been done to focus on the reduction of the cooking time which usually takes between 2 to 3 hours so as to cut down the processing time. Steam cooking can be used as a means of reducing the cooking time involved in cooking Ga-*kenkey*.

2.3.1 Steam cooking

Steam cooking or steaming is among the healthiest cooking techniques and is an energy efficient heating operation in the food processing industry (Huang *et al.*, 2013). Its application can be seen in a wide range of foods from cereals, tubers to vegetables. For various processing of food, steam can be used for precooking (Lopez, 1987; Rahman, 1999), pre-gelatinization of wheat grains (Miller, 1988), disinfestations against fruit flies (Lurie, 1998), and microbial decontamination (Hoke *et al.,* 2002).

Steaming rate or the effect of steaming can be affected by the nature of the food i.e. whether it is solid or liquid as well as the composition i.e. what material the food is made up of. Gates *et al*. (2008) worked on developing a laboratory scale steaming process and used it to characterize the effect of steaming on the mechanical behaviour of unkilned and kilned oat groats. The results they obtained suggested that mild steam treatment yields softer oat groats, whereas cold or over-treated groats tend to be harder.

The development of surface and interior colour during wheat grain steaming have been evaluated by Horrobin *et al.* (2003) They showed that browning reactions occur when wheat grains are cooked by direct contact with saturated steam at elevated pressure and possible relationship between the colour development and moisture uptake during the cooking process.

Huang *et al*.(2013) have observed that foods steamed in rice cooker are heated quickly by condensation heat transfer on the food's surface with the heat transfer inside foods being heated is highly dependent on their structure.

Evaluation of the influence of steaming treatments on the stability and distribution of lutein and tocols in seed fractions, inactivation of a-amylase, heat damage, as measured by furosine content and bread making and gelatinisation properties of einkorn whole meal flour have shown that steaming treatments have a sharp influence on most chemical and technological characteristics of the whole meal flours (Hidalgo *et al*., 2008).

Fang and Chinnan developed a kinetics model for cowpea starch gelatinization, integrated the kinetics model with the heat and mass transfer model and predicted and experimentally validated starch gelatinization in an intact seed during steaming. Their findings revealed that factors that determine the extent of starch gelatinization are the diffusion of water and time during steaming of cowpea seed (Fang and Chinnan, 2004).

Effects of hydrothermal treatment on the pasting, thermal and hydration properties of rice flour prepared from three Indica varieties of milled rice, which contained 1.2%, 17.9% and 28.8% amylose were studied by Lai (2001) and his studies showed that pasting and hydration properties of hydrothermally-treated rice are markedly dependent on the rice variety. Under limited moisture content rice undergoes physical modification resulting in the delay of glass transition (Tg).The degree of gelatinization is higher in waxy rice than in non-waxy rice when subjected to the same hydrothermal conditions. The modifications of starch granules or the degrees of re-association of starch molecules of rice are reflected by the changes of their hydration properties before and after hydrothermal treatment (Lai, 2001).

Iwuoha (2004) investigated the physicochemical properties of flour as functions of yam tuber variety (YTV), tuber steaming time (TST), and flour particle size (FPS) and observed the test variables have significant effects on the physicochemical qualities of yam flour. There is inferential evidence that YTV, TST and FPS may be used by yam tuber processors, as strategic working tools, to manipulate/control the physicochemical properties of the resultant flours.

Stapley *et al*. (1999) tried modelling the steaming of whole wheat grains and observed that the most favourable conditions for steaming are those in which heat can be easily conducted away from the grains (e.g. by contact with the walls of the metal cooker, rather than by contact with other grains only).

This research work seeks however to exploit the use of steam cooking in reducing the time involved in cooking *kenkey* by generating steam from a source and feeding it into a vessel where *kenkey* would be cooked and expecting that the time for cooking the *kenkey* would be reduced. Steaming however is believed to affect the gelatinization of food and consequently would influence the texture of a particular food as well as the colour of the gelatinized food.

2.4 Optimization

For an efficient process to be achieved, optimization is very important. Models are normally used in an optimization process. Two common model development approaches are the rigorous and the empirical ones. The *rigorous* modeling aims at developing a physically sound process model, which becomes expensive and time consuming if knowledge about the physical phenomena taking place in the process is lacking. However, an *empirical* process model is directly identified from existing plant measurement data avoiding laboratory experiments which is seen in a rigorous modeling (Marquardt and Kahrs, 2007).

According to Bulsari (1995) the application of neural networks as empirical models has become popular in engineering. This is due to their ability to accurately describe nonlinear and multi-dimensional interrelationships among process variables, provided that adequate measurement data is available (Cybenko, 1989). However, a major drawback of empirical models is that the prediction is valid only inside the data domain that is sufficiently covered by measurement data and this restricts the application of empirical process models in certain engineering tasks. The number of required data points for model identification may also be very large, in particular if the process is controlled by a large number of independent variables (Marquardt and Kahrs, 2007). The option of choosing between a rigorous model and an empirical process model therefore depends on the time available to the researcher and the expected validity of the results is always available.

Optimization has been used in several processes and products to obtain an efficient process, product or both. Optimization when used can help to reduce waste in a process and also ensure efficient use of resources and energy. However the ease of optimization would depend on the kind of process and if it is a product the nature of the product would play a key role in the optimization process.

Van Den Hout *et al*. (2008) looked at the optimizing feed quality of soybean during steaming by performing model simulations and their findings showed that the steaming process can be optimized better on initial moisture content of the soybeans than on steam temperature using Trypsin inhibitors Activity (TIA) and nitrogen solubility index (NSI) as quality parameters (Van Den Hout *et al*., 2008).

Bon *et al*. (2010) studied the optimization feasibility of the milk pasteurization process using a general process simulator (ProSimPlus) and observed that generated simulation flow sheet and the objective functions can be modified according to the interest of the user and offers the user the potential to analyze the process and study different parameters of interest thereby making it possible to optimize the process operation depending on different operating variables such as refrigeration water temperature, milk temperature and milk mass flow rate or to optimize the process design depending on different design parameters such as the heat exchanger size or assess modifications in the plant.

Li and Lou (2008) performed studies on the basis of stochastic programing **(**SP) methodology, to deal with uncertain parameters, and integrating multi-objective optimization (MOO) deterministic algorithms to identify the optimal chemical process design from a number of alternatives for the purpose of profit maximization and environmental impact minimization using Pareto frontier and concluded that consideration of uncertainty may generate more reliable results, and avoid or minimize the potential risks.

Asenjo *et al*. (2000) used a developed multiproduct batch protein plant to explore alternative optimization strategies and to study the role of process variables in the simultaneous optimization of both the process variables and the structure of the plant and observed that the process performance models are able to predict a consistent set of size and time factors as a function of process variables and that for feasible designs that include the size and time constraints that correspond to the plant structure, the process variables accommodate the size and time factors to reduce idle times and equipment under occupancy.

Rao and Pawar, (2010) optimized process parameters of multi-pass milling operations considering minimization of total production time by maximization of production rate subjected to the constraints of arbor strength, arbor deflection and cutting power while considering process parameters such as: feed per tooth, cutting speed and depth of cut with their upper and lower bound values. Three non-traditional optimization algorithms (artificial bee colony (ABC), particle swarm optimization (PSO) and simulated annealing (SA)) were applied to obtain the optimum process parameter values for various selected cutting strategies. They concluded that ABC, PSO and SA algorithms can be easily modified to suit optimization of process parameters of other machining processes such as grinding, turning and drilling Rao and Pawar, (2010).

Chen (2004) determined the potential of fermentor temperature as a tool in the optimization of perfusion cultures, and demonstrated that reduced fermentor temperature results in increased cellular productivity of prourokinase (pro-UK) in a porous microcarrier perfusion culture of an rCHO cell line. Their findings demonstrated that temperature shift offers the prospect of enhancing the productivity of pro-UK by a recombinant CHO cell line in high-density perfusion culture suggesting that culture temperature can serve as a process optimization variable for protein production in animal cell culture.

A new hybrid numerical approach, using Weighted Sum of Squared Objective Functions (WSSOF) for multiresponses optimization of carbon dioxide oxidative coupling of methane (CO_2 OCM) aimed at obtaining an optimal process parameters and catalyst compositions with high catalytic performances has been developed by Istadi where the hybrid numerical approach combined the single-response modeling and optimization using Response Surface Methodology (RSM) and WSSOF technique of multi-responses optimization process and observed that the results of the multi-response optimization could be used to facilitate in recommending suitable operating conditions and catalyst compositions for the CO_2 OCM process (Istadi ,2005).

Cook *et al*. (2000) in a study proposed the combination of a neural network (NN) and a genetic algorithm (GA) to develop a modeling and analysis tool to be used to investigate the relationships between various process and product parameters in a manufacturing process. Conclusions drawn from their study was that NN-GA tool could be used by plant personnel to study and evaluate the relationships between process parameters and final product characteristics, as well as to provide operators with information that will allow them to make required process adjustments in real time.

This work assessed how different steam cooking times in combination with the use of corn husk as an insulator in a steam cooker can be used to optimize the cooking of *kenkey* so as to shorten the time involved in cooking the *kenkey* as well as obtaining a *kenkey* with a uniform characteristic in terms of texture and colour regardless of where in the cooking vessel it is found.

CHAPTER 3

3.0 METHODOLOGY

3.1 Summary

The study was in three parts: (a) a survey of Ga-*kenkey* processors to get insights on their processing techniques, challenges as well as best practices (b) The second part of the study involved the determination of cooking times, heat transfer profiles in the three layers of Ga-*kenkey* in the cooking pot i.e. the bottom layer, middle layer and top layer, determination of quality attributes of Ga-*kenkey* that consumers rate, optimization of steaming process for Ga-*kenkey* production. (c) The third part of the study involved the design of a steam cooker for Ga-*kenkey* to assure uniform product quality irrespective of location in the cooking pot.

3.2 Sampling procedure used for survey of Ga-*kenkey* makers

A pre-tested semi structured questionnaire was administered to a total of 50 *Ga-kenkey* makers within Accra to find out if they used any techniques to shorten the cooking times of Ga-*kenkey*, and to ensure that the Ga-*kenkey* is well cooked. The questionnaire captured some biodata (sex, age and educational level), the amount of maize they used in making a batch of *Ga-kenkey*, the amount of Ga-*kenkey* they produced in a day and if they were willing to accept a different packaging material other than the corn husk for wrapping *Ga-kenkey* if it is introduced. The questionnaire is attached in Appendix 1.

3.2.1 Sampling of Ga-*kenkey* processors

Sampling was done using convenient sampling within communities in Accra where *Ga-kenkey* production is believed to be dominant. The inclusion criteria used was that a respondent should be a commercial *Ga-kenkey* processor. In instances where the communities had a cluster of *Ga-kenkey* houses, only one respondent was interviewed.

3.3 Impact of product location within the cooking vessel on properties of *kenkey*.

In all experiments, where necessary, we collaborated with one very popular commercial Ga-*kenkey* processor located at the South Gate of the campus of the University of Ghana.

3.3.1 Temperature profile of Ga-*kenkey* from different layers within the cooking vessel

During cooking of the *kenkey*, the cold point temperature of the *kenkey* balls was monitored using K type thermocouples connected to Cole Parmer 2-channel temperature Data Logger. The temperature of the *kenkey* balls at the three layers in the cooking pot (Top, Middle, and Bottom) were monitored from the start of the cooking till the end. Temperature measurements were taken on five different days when the *kenkey* was cooked by the processor, and used to generate temperature profiles of the *kenkey* balls in relation to the cook water in the vessel during the traditional cooking of Ga-*kenkey*

3.3.2. Moisture content determination of Ga-*kenkey* from different layers within the cooking pot

Three Ga-*kenkey* balls each from the three different layers (the bottom layer, middle layer and top layer) within the cooking pot were sampled after they had been cooked from a commercial Ga-*kenkey* processor. The Ga-*kenkey* from each layer in the cooking pot was cut into thin slices of 2 mm. The moisture content of the *kenkey* was determined according to the AOAC method no. 934.06 (AOAC, 2000) using the vacuum oven at 70 ^{o}C and 25 in Hg. All moisture measurements were done in triplicates.

3.3.3. Texture Profile Analysis of Ga-*kenkey* from different layers within the cooking vessel

Three Ga-*kenkey* balls each from the three different layers (the bottom layer, middle layer and top layer) within the cooking pot were sampled after they had been cooked. The samples were cooled to room temperature and cut into cylindrical shapes using a cork borer. Each cylinder was then cut into a standard shape measuring 10 mm in diameter and 10 mm in height. The cylinders were analyzed using texture profile analysis as described by Bourne (1978). Samples were compressed to 50% of their original height by a Texture Analyzer (Sable Micro Systems Model TA. XT2, Texture Technologies Corp., Scarsdale, NT) equipped with a cylindrical probe of diameter 3.5 mm. Settings for the Texture Analyzer were: test speed: 1.2 mm/s, rupture test distance: 4 mm, distance: 5 mm (50%), force: 100g, time: 5 seconds, load cell: 5 kg, trigger: auto – 5g. Texture parameters hardness, springiness, cohesiveness, gumminess, and chewiness were obtained from Texture Analyzer.

3.3.4. Stress Relaxation analysis of traditional Ga-*kenkey* from different layers within the cooking vessel

Three Ga-*kenkey* balls each from the three different layers (the bottom layer, middle layer and top layer) within the cooking pot were sampled after they had been cooked by the commercial Ga-*kenkey* processor. The samples were cut into cylindrical shapes using a cork borer. Each cylinder was then cut into a standard shape measuring 10 mm in diameter and 10 mm in height. The stress relaxation tests were performed by Texture Analyzer (Sable Micro Systems Model TA. XT2, Texture Technologies Corp., Scarsdale, NT) equipped with a cylindrical probe of diameter 3.5 mm using a load cell of 10 N. The test samples were compressed 5 mm of its original height with a crosshead speed of 0.3 mm/s. This constant compressive strain was applied to the sample for 80 s and compressing the sample for 80 seconds. All tests were performed in 5 replicates.

3.4 Experiments on steam cooking

3.4.1 Steam cooking of Ga-*kenkey*

Molded, wrapped but uncooked Ga-*kenkey* balls were obtained from the commercial Ga-*kenkey* processor. The samples were steam cooked in a retort at a steam temperature of 120 ^{o}C and pressure of 40 KPa which were measured by a pressure gauge and thermometer on the retort respectively using a 4 x 2 factorial design where 4 different steaming times (5min, 7.5 min, 10min, 12.5 min and 15 min) and 2 mesh cages pre-lined with or without corn husks as shown in Plate 1 in Appendix 11.

3.4.2. Temperature Profile of Steam Cooked Ga-*kenkey*

During steam cooking of the *kenkey* balls in the retort (120 ^{o}C at 40 KPa pressure), the cold point temperatures were monitored using K type thermocouples connected to a 2-channel Cole Parmer temperature Data Logger. The cold point temperature of the *kenkey* balls was monitored at 4 different steaming times (5min, 7.5 min, 10min, 12.5 min and 15 min). During the steaming process the *kenkey* balls were arranged in a rectangular mesh cage (prelined with or without corn husks. Temperature measurements were used to generate temperature profiles for cooking of Ga-*kenkey* at the different steaming times.

3.4.3. Moisture Content Determination of Steam Cooked Ga-*kenkey*

Ga-*kenkey* balls were steam cooked in a retort at a steam temperature of 120 ^{o}C and pressure of 40 KPa using different steaming times (5min, 7.5 min, 10min, 12.5 min and 15 min). The Ga-*kenkey* balls were all kept in a rectangular mesh cage (cage having corn husk and cage not having corn husk). Ga-*kenkey* balls were sampled at the different steaming times in the different mesh cages. The samples of Ga-*kenkey* were cut into thin slices of 2 mm and the moisture content determined according to the AOAC method no. 934.06 (AOAC, 2000). All moisture measurements were done in triplicates.

3.4.4 Texture Profile Analysis of Steam cooked Ga-*kenkey*

Two steam cooked Ga-*kenkey* balls were sampled at the different steaming times and the different mesh cages. The samples were cut into cylindrical shapes using a cork borer. Each cylinder was then cut into a standard shape measuring 10 mm in diameter and 10 mm in height. The cylinders were analyzed using texture profile analysis as described by Bourne (1978). Samples were compressed to 50% of their original height by a Texture Analyzer (Sable Micro Systems Model TA. XT2, Texture Technologies Corp., Scarsdale, NT). Settings for the Texture Analyzer were: test speed: 1.2 mm/s, rupture test distance: 4 mm, distance: 5 mm (50%), force: 100g, time: 5 seconds, load cell: 5 kg, trigger: auto – 5g. Texture parameters hardness, springiness, cohesiveness, gumminess, and chewiness were obtained from Texture Analyzer

3.4.5 Stress Relaxation Analysis of Steam cooked Ga-*kenkey*

Two steam cooked Ga-*kenkey* balls were sampled at the different steaming times and the different mesh cages. The Ga-*kenkey* samples were cut into cylindrical shapes using a cork borer. Each cylinder was then cut into a standard shape measuring 10 mm in diameter and 10 mm in height. The stress relaxation tests were performed using a Texture Analyzer (Sable Micro Systems Model TA. XT2, Texture Technologies Corp., Scarsdale, NT) equipped with a cylindrical probe of diameter 3.5 mm using a load cell of 10 N. The test samples were compressed 5 mm of its original height with a crosshead speed of 0.3 mm/s. This constant compressive strain was applied to the sample for 80 s and compressing the sample for 80 seconds. All tests were performed in 5 replicates.

3.5 Colour determination of cooked Ga-*kenkey*

The colour of Ga-*kenkey* balls from each of the three different layers (the bottom layer, middle layer and top layer) within the cooking pot as well as from the steam cooked samples at the different times (5min, 7.5 min, 10min, 12.5 min and 15 min) with or without corn husk were measured using the CIE L*a*b* colour system using a Minolta L*a*b* Chroma Meter. The Hunter L*a*b* readings were calibrated against a standard white tile. Colour coordinates were recorded as: L* = lightness (0 = black, 100 = white), a* (-a* = greenness, +a* = redness), b* (-b* = blueness, +b* = yellowness).

3.6 Degree of gelatinization

Standards representing 0, 25, 75 and 100% gelatinization of starch were prepared from dried milled gelatinized corn flour. Gelatinization of the corn starch was done by adding 100 mls of water to 200g of corn flour. The flour was then cooked to obtain a paste. The paste obtained was cooked in a retort at 120 ^{o}C at 40Pa for 10 minutes. The paste was then dried in an air oven at 60 ^{o}C overnight. The dried paste was then milled using a hammer mill into flour. A standard graph was then drawn using absorbance values from the amylose/iodine blue value according to Birch and Priestley (1973). Ga-*kenkey* from the different layers of the pot (bottom, middle and top) as well as the Ga-*kenkey* which were steam cooked at the different times (5min, 7.5 min, 10min, 12.5 min and 15 min) with or without corn husk inside the cage where the *kenkey* balls were kept during cooking were oven dried at 60 ^{o}C overnight and milled into flour using a hammer mill. The degree of gelatinization of the Ga-*kenkey* samples were then determined according to the method described by Birch and Priestley (1973).

3.7 Sensory evaluation of Ga-*kenkey*

A consumer preference sensory test was done on Ga-*kenkey* from the different layers (the bottom layer, middle layer and top layer) in the cooking pot using 50 untrained panelists to determine the layer(s) that were most preferred by consumers using a seven point hedonic scale sensory ballot sheet shown in Appendix 4.

Another consumer preference test was conducted on all the steamed samples (5min, 7.5 min, 10min, 12.5 min and 15 min) to determine the steam cooking time that produced the *kenkey* with comparable acceptability as the most preferred layer from the traditional process. A sensory panelist of 50 would be used for this test using a seven point hedonic scale sensory ballot sheet shown in Appendix 5.

3.8 Statistical analyses

SPSS software version 16 was used to analyze data collected on survey. Correlations and cross tabulations were done to determine associations between the amounts of Ga-*kenkey* cooked, Ga-*kenkey* techniques used in cooking and the cooking time. ANOVA was also done to determine if differences existed between means of treatments *for* Ga-*kenkey.*

Statgraphic plus 3.0 was used to analyze data obtained from the temperature profile, colour, TPA, stress relaxation, degree of gelatinization, moisture content and sensory analysis. ANOVA was done to determine if differences existed among them (the temperature profile, TPA, moisture content and sensory analysis).The Friedman rank test was used to analyze the sensory data for acceptability.

CHAPTER 4

4.0 RESULTS AND DISCUSSIONS

4.1 Survey on Ga-*kenkey* Processors in Accra

4.1.1 Biodata of Ga-*kenkey* Processors

Results from the survey indicated that majority of the people involved in making Ga-*kenkey* within Accra are adult females with minimal level of formal education. 98% of the respondents were females with a majority of them being within the ages of 31-40 years as shown in Table 1. A few of them however were within ages less than 30 years and above 50 years. Only 10% of all processors (i.e. 5 out of 50 respondents were above age 50, indicating that the *kenkey* processing business was dominated by people in their active and productive years of life, probably because it involves a great deal of physical activity. Most of the Ga-*kenkey* makers had some form of formal education (88%) with the highest level of education being tertiary. A few however had no formal education at all. Most of the Ga-*kenkey* makers (64%) who had formal education were educated up to either the primary level or JHS level (Table 1).

Table 1: Biological data of Ga-*kenkey* processors.

Biodata	Frequency	Percent (%)
Sex (n=50)		
Male	1	2
Female	49	98
Age (n=50)		
15-20	3	6
21-30	9	18
31-41	20	40
41-50	13	26
Above 50	5	10
Educational level (n=50)		
No formal education	11	22
Primary	16	32
JHS	16	32
SHS	5	10
Tertiary	2	4

4.1.2. Processing of Ga-*kenkey*

4.1.2.1. Scale of operations

Most of the Ga-*kenkey* processors purchased maize in bags. The amount of maize used for preparing a batch of corn dough for *kenkey* processing differed among the processors. The amount of maize used for making a batch of Ga-*kenkey* ranged from less than a bag (48%), 1 bag (44%) to more than 2 bags (2%) of maize (Figure 2). Thus most processors operate on small scale, and do not require more than a bag of maize (92%) per batch of operation. Consequently the quantity of Ga-*kenkey* produced by each processor per day ranged from less than 100 balls to 1000 balls with 200 balls being the modal quantity produced by most (28, or 56%) processors (Figure 3). The survey showed that it took between 2 to 4 hours for the processors to cook a batch of Ga-*kenkey*. While most of the processors (66%) indicated that their *kenkey* cooked over a period of 3 hours, a few (10%) said it took about 2 hours for them to cook a batch of Ga-*kenkey* (Figure 4) Amoa-Awuah (2007) and Kpodo (1996) indicated that it required 3 hours to cook a batch of *kenkey*.

In spite of the prolonged cooking time required per batch of *kenkey*, processors still frequently make it on daily basis. The survey showed that Ga-*kenkey* was made throughout the week with varying frequency among processors (Figure 5). Most of the processors (44%) made *kenkey* 6 days in the week, while others make it less than 5 days in a week (Figure 5). It may be concluded that the scale of operations of the typical Ga-*kenkey* processor is small, but has a rapid turnover rate since they manufacture *kenkey* almost on daily basis. The high frequency of small scale manufacture, inspite of the drudgery associated with the process suggests that the product is very popular among consumers, who do not process it themselves at home, but rely on its daily availability from the local processor.

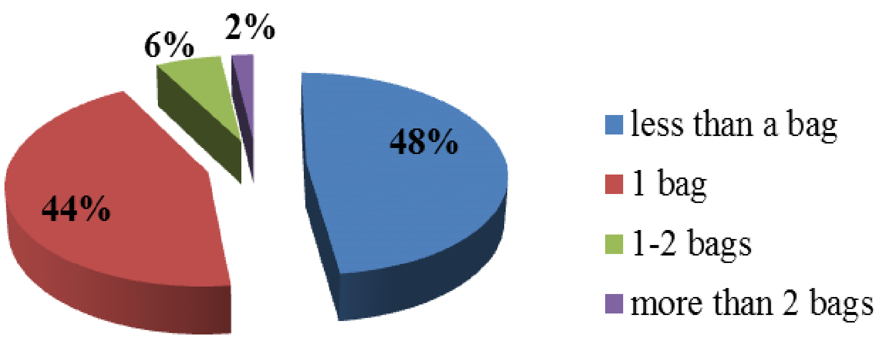

Figure 2: Amount of maize used in making a batch of Ga-*kenkey* by Ga-*kenkey* processors.

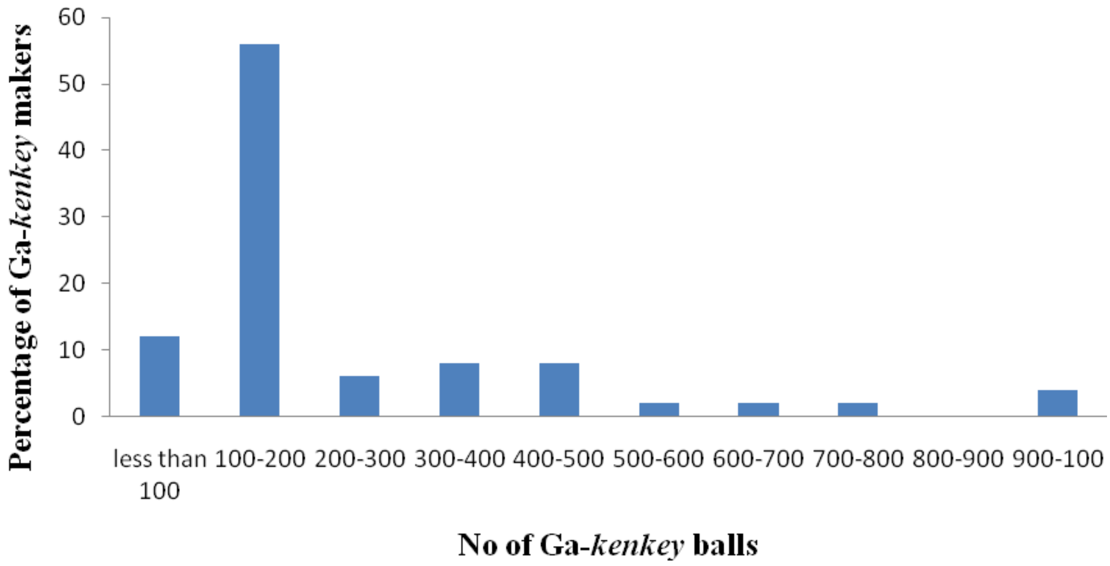

Figure 3: Number of Ga-*kenkey* balls produced in a day by the processors

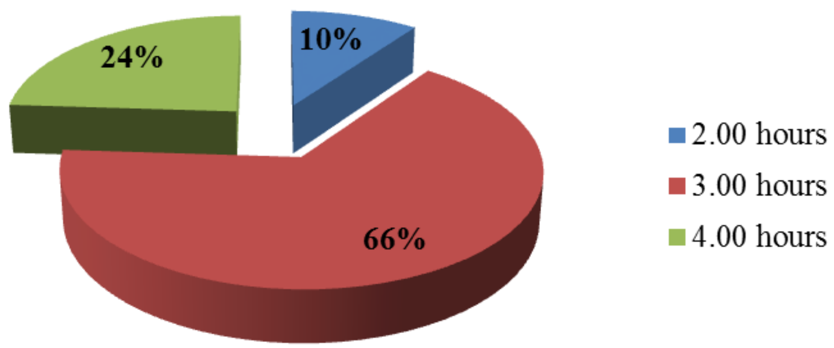

Figure 4: Hours taken by processors to cook a batch of Ga-*kenkey*.

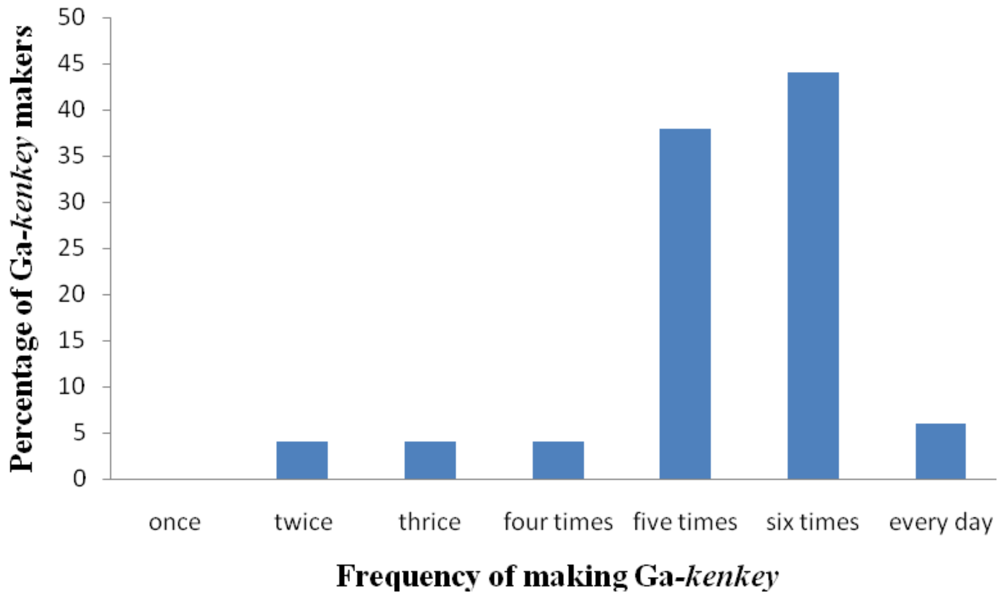

Figure 5: Frequency at which processors in Accra cook Ga-*kenkey* within a week.

4.1.2.2 Processing Techniques employed by kenkey processors.

Considering the tedium and time involved in processing the *kenkey*, several techniques are employed by processors to ensure that the *kenkey* is well cooked before it is taken off the fire. Results of the survey showed that these techniques exploited sensory characteristics such as the colour, of the *kenkey*, smell of the *kenkey* during cooking, and the texture of the cooked *kenkey*. Whiles some used only one of these sensory characteristics others used a combination of any two of them. The most used technique by the processors was touching (62%) the *kenkey* ball to determine its softness, and hence the degree of cook (Table 2).

In order to ensure that the Ga-*kenkey* was cooked satisfactorily within the expected time frame, most of the processors (94%) also employed additional techniques during the *kenkey* cooking process. Amongst these techniques (Table 3) the addition of water once during cooking of the Ga-*kenkey* is the most used (40%) *kenkey* cooking technique. In order to accelerate the *kenkey* cooking process, most *kenkey* processors (86%) adopt some techniques which include: adding water, increasing the intensity of the fire and increasing the thickness of plastic covering used to cover the *kenkey* during cooking. Increasing the intensity of the fire stands out as the technique used by majority of the processors (80%) in ensuring that the Ga-*kenkey* cooks fast (Table 4).

There was strong correlation between some bio-data of producers and the processing methods and techniques used by the *kenkey* processors (Table 5). It was observed that the age of the *kenkey* processors correlated positively with the length of time the *kenkey* processor had been involved in making the *kenkey* as well as the time taken for them to cook the *kenkey* implying that age influences the time taken in cooking the *kenkey*. Their education level correlated negatively with how they knew their *kenkey* was cooked, while it correlated positively with the amount of maize they used for a batch of *kenkey* (Table 5). The techniques used to ensure satisfactory cooking of kenkey correlated positively with the length of time taken by the processors to cook *kenkey* and how they knew the *kenkey* was well cooked before they took it off the fire (Table 5). There was a positive correlation between the techniques used to accelerate the *kenkey* cooking process and the number of balls of Ga-*kenkey* cooked in a day (Table 5). The results show that age and education influence the processing of Ga-*kenkey*. Ga-*kenkey* processors use a number of techniques in the cooking process to ensure that their *kenkey* cooks well and faster. The techniques used have an influence on the cooking time of their *kenkey*.

Table 2: Processing techniques used by processors to ensure that the *kenkey* is well cooked before it is removed from fire.

Techniques used to assess if Ga-*kenkey* is well cooked (n=50)	Frequency	Percent (%)
Look at the colour change from white to cream	1	2
Smell it to see if it has the aroma of cooked *kenkey*	2	4
Smell it to see if it has the aroma cooked *kenkey* and break a ball of *kenkey* to see whether it is gummy or sticky	1	2
Touch a ball to see how soft it is	31	62
Touch a ball to see how soft it is and smell it to see if it has the aroma cooked *kenkey*	7	14
Touch a ball to see how soft it is and hit it and listen to the sound it makes	2	4
Touch a ball to see how soft it is and look at the thickness of the cooking water	1	2
Touch a ball to see how soft it is and look to see if the cooking water is finished	1	2
Touch a ball to see how soft it is and the colour change from white to cream	1	2
Touch to see how soft and sticky it is	2	4
The plastic covering sinks and also touch a ball to see how soft it is	1	2

Table 3: Processing techniques used by processors to ensure that the Ga-*kenkey* is well cooked during heating

Use of techniques in cooking Ga-*kenkey* well	**Frequency**	**Percent (%)**
Add water and increase the intensity of the fire	1	2.0
Add warm water once in a while	1	2.0
Add water once in a while and increase the thickness of the plastic covering	1	2.0
Add water once in a while	20	40.0
Add water once in a while and keep it on fire for a longer time	2	4.0
Add water once in a while and reduce the intensity of the fire	1	2.0
Increase the intensity of the fire	3	6.0
Increase the thickness of the plastic covering	1	2.0
Increase the thickness of the plastic covering, allow the water to boil before adding the *kenkey* balls and add water once a while during cooking	1	2.0
Keep *kenkey* on fire for a longer time	4	8.0
Reduce the intensity of the fire	2	4.0

Table 4: Processing techniques used by processors to ensure that their Ga-*kenkey* cooks fast.

	Frequency	Percent (%)
Use of techniques in cooking Ga-*kenkey* faster		
Yes	43	86
No	7	14
Techniques used to ensure that *kenkey* cook faster		
Increase the intensity of the fire	40	80
Increase the thickness of the plastic covering	2	4
Increase the amount of water added	1	2

Table 5: Relationship between biodata, processing methods and techniques used by Ga-*kenkey* processors

		Period involved making Ga-keneky	Hours Taken To Cook *Kenkey*	How *kenkey* is known to be cooked	Amont of Maize used to prepare a batch of *kenkey*.	Balls of Ga-*kenkey* made in a day	Number of days in the week Ga-*kenkey* is made	Knowledge of alternative wrapping material	Willingness to try other alternative wrapping material
Sex (n=50)	Pearson Correlation	0.058	0.035	0.095	0.080	0.100	-0.084	-0.048	-0.168
	Sig. (1-tailed)	0.0344	0.404	0.257	0.291	0.244	0.280	0.371	0.122
Age (n=50)	Pearson Correlation	0.419**	0.235*	-0.013	-0.095	-0.064	-0.158	-.043	0.024
	Sig. (1-tailed)	0.001	0.050	0.466	0.255	0.329	0.137	0.383	0.435
Educational level (n=50)	Pearson Correlation	-0.127	-0.129	-0.249*	0.266*	-0.093	-0.087	0.012	0.064
	Sig. (1-tailed)	0.189	0.186	0.040	0.031	0.261	0.273	0.467	0.330
Techniques do you used to ensure *kenkey* cooks well (n=50)	Pearson Correlation	-0.012	0.309*	0.282*	0.025	0.190	-0.031	0.134	0.124
	Sig. (1-tailed)	0.466	0.015	0.024	0.431	0.093	0.415	0.176	0.195
Techniques used to ensure *kenkey* cooks faster (N=50)	Pearson Correlation	-0.222	0.336**	0.054	0.039	0.342**	-0.186	0.187	0.053
	Sig. (1-tailed)	0.061	0.008	0.355	0.395	0.007	0.098	0.097	0.356

**. Correlation is significant at the 0.01 level (1-tailed).

* Correlation is significant at the 0.05 level (1-tailed)

4.1.3 Knowledge and attitudes towards the use of alternative wrapping for Ga-*kenkey*

Most of the *kenkey* processors (90%) had no knowledge of any other form of wrapping for Ga-*kenkey* other than the use of corn husk. However the few who knew (10%) about other forms of wrapping only knew plantain leaves as the only form of alternative wrapping for Ga-*kenkey*. Majority of the *kenkey* processors (58%) however were willing to try alternative forms of wrapping for Ga-*kenkey*. Those who were not willing (42%) gave reasons such as lack of expertise in using the alternative, feeling the Ga-*kenkey* would not cook well, and fear the alternative wrapper would adversely affect *kenkey* quality. Of the reasons given, concern the taste of the *kenkey* would be compromised was the reason mostly given (57%) for preferring the old wrapping (corn husk). This indicates that although most *kenkey* processors interviewed were willing to try alternative wrapping for Ga-*kenkey* an alternative wrapping if introduced should satisfy the concerns raised. Also a lot of education would have to be done on any alternative wrapping, to help bridge the knowledge gap relating to the use of any alternative wrapper.

Table 6: Knowledge and attitudes towards the use of alternative wrapping for Ga-kenkey by processors.

	Frequency	Percent (%)
Knowledge of alternative wrapping for Ga-*kenkey* (n=50)		
Has knowledge of alternative wrapping for Ga-*kenkey*	5	10
Has no knowledge of alternative wrapping for Ga-*kenkey*	45	90
Alternative wrapping for Ga-*kenkey* known (n=5)		
Plantain leaves	5	100
Attitude towards the use of alternative wrapping material (n=50)		
Willing to try other alternative wrapping material	29	58
Not willing to try other alternative wrapping material	21	42
Reasons for unwillingness to try other alternative wrapping material (n=21)		
Used to and prefer the old way	12	57
Don't think it would provide an acceptable Ga-*kenkey*	1	5
Don't think it would taste like Ga-*kenkey*	5	24
Feel it would not cook it well	2	10
Would not know how to use it	1	5

4.2 Variability in properties of Ga-*kenkey* cooked in the same cooking pot

Observation of the arrangement of Ga-*kenkey* within the cooking pot by different processors *kenkey* showed that three different layers or sections could be identified in the cooking pot with respect to the cooking water. The first layer is the bottom layer where the Ga-*kenkey* is fully submerged in the cooking water and then there is a top layer which has no contact with the cooking water. In between these two clear regions, there is a middle or transition layer, where the *kenkey* sits in the cooking water (but is not submerged) for at least part of the cooking process as shown in Plate 2 in Appendix 12.

Results obtained from tests for moisture, colour, Temperature Profile Analysis (TPA), stress relaxation and degree of gelatinization conducted on *kenkey* from each of these three regions (top, middle and bottom) showed significant differences in *kenkey* in the different *kenkey* layers. As can be seen from the results shown in Table 7, the differences were most significant between *kenkey* from the top and bottom layers, and this demonstrates that the position of the *kenkey* ball in the cooking vessel is a major source of variability in the properties of the *kenkey* product.

4.2.1 Moisture variability in cooked Ga-*kenkey* from the same cooking pot

Moisture was observed to be high (66.4$\pm$0.7) in the bottom *kenkey* followed by the middle *kenkey* (62.7$\pm$0.7) with the top *kenkey* having the least amount of moisture (61.9$\pm$0.4) as shown in Table 7. While *kenkey* obtained from the bottom clearly had higher moisture than that from the top layer, there were no significant differences in moisture content of *kenkey* obtained from the bottom and the middle layers. This indicates that there is a variation in moisture absorption by the *kenkey* at the different layers of the cooking pot due to the difference in level of contact with the cooking water during cooking of the *kenkey*. The differences in moisture can have an impact on the texture of the *kenkey* at the different layers of *kenkey* in the pot since the amount of moisture affects the plasticity of food this influencing the texture perception by consumers.

4.2.2 Colour variability in cooked Ga-*kenkey* from the same cooking pot

Colour measurements were taken as L*, a*, b* with L*.indicating level of lightness, a* indicating level of redness and b* indicating level of yellowness. Results show that there were significant difference for the L*, a* and b* values among *kenkey* from the different layers in the cooking pot. Ga-*kenkey* from the bottom layer showed the highest L* value (58.37$\pm$0.10) with Ga-*kenkey* from the top layer showing the lowest (56.26$\pm$0.03) (Table 7). The values for colour readings for L* indicates that the *kenkey* at the bottom is lighter in colour compared to the middle and top *kenkey* and this could be due to the high moisture content or the loss of more soluble solids into the cooking water compared to the middle and the top *kenkey* since the bottom *kenkey* is submerged in the cooking water. The bottom *kenkey* also recorded high reading for a* values for colour (0.09$\pm$0.02) with the middle *kenkey* recording the least for the a* values for colour (-0.03$\pm$0.0). The a* values for colour also suggest that the Ga-*kenkey* had little or no redness since very little values were recorded for all the Ga-*kenkey* from the different layers. The b* values for colour were however high for the middle *kenkey* (15.15$\pm$0.18) compared to the values for the top *kenkey* (14.07$\pm$0.03) and bottom *kenkey* (14.93$\pm$0.02) as shown in Table 7. The b* values for colour suggested that Ga-*kenkey* from the middle layer was more yellowish compared to the top and bottom *kenkey*. The results indicate that there are variability in colour for Ga-*kenkey* from the different layers within the same cooking pot.

4.2.3 Texture Profile variability in cooked Ga-*kenkey* from the same cooking pot

Texture profile analysis is the measurement and classification of the mechanical properties of a product often a food product, as they relate to its sensory properties detected by humans. Texture profile analysis of food necessary to know if the textural characteristics of a product would be within the known acceptable range by consumers before the product is sent to the market to ensure that products succeed in the marketplace.

All the Texture profile parameters assessed were seen to be significantly different for the Ga-*kenkey* taken from the different layers of the cooking pot (top, middle and bottom) as shown in Table 7.

4. 2.3.1 Variability in the Hardness of Ga-*kenkey*

Hardness is the force required to compress a substance between molar teeth or between tongue and palate (Civille and Szczesniak, 1973). Hardness measurements in Ga-*kenkey* tell how soft the Ga-*kenkey* is. Ga-*kenkey* from the bottom layer of the cooking pot had the least hardness (3.066$\pm$0.515)N/cm^2 while *kenkey* obtained from the top layer of the cooking pot had the most hardness value (12.116$\pm$9.614)N/cm^2 (Table 7). None of the Ga-*kenkey* from the different layers of the cooking pot was seen to be similar. This suggests that the softness of Ga-*kenkey* increases from the top layer to the bottom layer and that the different layers created within the cooking pot during cooking of Ga-*kenkey* create variability in the hardness of Ga-*kenkey*.

4.2.3.2 Variability in Fracturability of Ga-*kenkey*

Fracturability is the force under which a sample crumbles, cracks, or shatters. This is usually influenced by the hardness and cohesiveness of the sample (Civille and Szczesniak, 1973). Ga-*kenkey* is expected to be soft and thus a good Ga-*kenkey* is not expected to have high fracturability (i.e. will not easily shatter or crumble when subjected to force). The fracturability of Ga-*kenkey* from the bottom layer of the cooking pot was the least (0.217$\pm$0.130)N/cm^2 with Ga-*kenkey* from the middle layer of the cooking pot having the most fracturability value (1.137$\pm$0.536)N/cm^2 (Table 7). Ga-*kenkey* from the bottom and top layers of the cooking pot had similar fracturability compared to Ga-*kenkey* from the middle layer. This suggests that there is variability in the fracturability of Ga-*kenkey* balls from the different layers within the same cooking pot.

4. 2.3.3 Variability in Adhesiveness of Ga-*kenkey*

Adhesiveness is the force required to remove the material that adheres to the mouth generally the palate during the normal eating process or a surface (Civille and Szczesniak, 1973). Adhesiveness in Ga-*kenkey* tells how sticky the Ga-*kenkey* is. Some level of adhesiveness is accepted by consumers in Ga-*kenkey*. The adhesiveness of Ga-*kenkey* from the top layer of the cooking pot was the least (-0.142$\pm$0.162)Nxs with Ga-*kenkey* from the bottom layer of the cooking pot having the most adhesiveness value (-1.491$\pm$0.791)Nxs (Table 7). There was significant variation in the adhesiveness of the Ga-*kenkey* from the different layers of the cooking pot, and this suggests that the position of the *kenkey* in the cooking pot during cooking of Ga-*kenkey* creates variability in the adhesiveness of Ga-*kenkey*.

4. 2.3.4 Variability in Springiness of Ga-*kenkey*

Springiness refers to the degree to which a product returns to its original shape once it has been compressed between the teeth (Civille and Szczesniak, 1973). Most people who eat Ga-*kenkey* hardly chew it or chew very little of it before swallowing. Low springiness is therefore desirable for a good Ga-*kenkey*. The springiness of Ga-*kenkey* from the middle layer of the cooking pot was the least (0.33$\pm$0.055)cm with Ga-*kenkey* from the top layer of the cooking pot having the most springiness (0.586$\pm$0.059)cm (Table 7). The springiness of Ga-*kenkey* from the bottom and middle layers were not significantly different. This suggests that the different layers created within the cooking pot during cooking of Ga-*kenkey* create no variability in the springiness of Ga-*kenkey* the bottom and middle layers compared to Ga-*kenkey* from the top layers.

4. 2.3.5 Variability in Cohesiveness of Ga-*kenkey*

Cohesiveness refers to the degree to which a substance is compressed between the teeth before it breaks (Civille and Szczesniak, 1973). Since Ga-*kenkey* is hardly chewed, a good Ga-*kenkey* is expected to be less cohesive. The Ga-*kenkey* from the middle layer of the cooking pot had the least cohesiveness (0.331$\pm$0.131) with Ga-*kenkey* from the top layer of the cooking pot having the most cohesiveness (0.692$\pm$0.057) (Table 7). None of the Ga-*kenkey* balls from the different layers of the cooking pot were similar in cohesiveness. This suggests that the different layers created within the cooking pot during cooking of Ga-*kenkey* create variability in the cohesiveness of Ga-*kenkey*.

4.2.3.6 Variability in Gumminess of Ga-*kenkey*

Gumminess refers to the denseness that persists throughout mastication or the energy required to disintegrate a semi-solid food to a state ready for swallowing (Civille and Szczesniak, 1973). Since Ga-*kenkey* is hardly chewed before swallowing, *Ga-kenkey* with low gummines is usually preferred by *Ga-kenkey* consumers. The gumminess of Ga-*kenkey* from the bottom layer of the cooking pot was the least (1.353$\pm$0.344)N/cm^2 with Ga-*kenkey* from the top layer of the cooking pot being the most gummy (8.36$\pm$0.88)N/cm^2 (Table 7). There were significant differences in gumminess of Ga-*kenkey*s from the three different layers of the cooking pot. This suggests that the different layers created within the cooking pot during cooking of Ga-*kenkey* create variability in the gummines of Ga-*kenkey*.

4. 2.3.7 Variability in Chewiness of Ga-*kenkey*

Chewiness refers to the length of time required to masticate a sample at a constant rate of force application to reduce it to a consistency suitable for swallowing (Civille and Szczesniak, 1973). Ga-*kenkey* with minimal chewiness is more desirable. The chewiness of Ga-*kenkey* from the bottom layer of the cooking pot was the least (0.53±0.230)N/cm with Ga-*kenkey* from the top layer having a significantly higher chewiness value 4.903±0.747)N/cm (Table 7).

4. 2.3.8 Variability in Resilience of Ga-*kenkey*

Resilience is a measurement of how the sample recovers from deformation. Consumers expect a low resilience in Ga-*kenkey* since they expect to chew the *kenkey* for a very short time before they swallow (Civille and Szczesniak, 1973). The resilience of Ga-*kenkey* from the middle layer of the cooking pot was the least (0.205±0.161) with Ga-*kenkey* from the top layer of the cooking pot having a significantly higher resilience value (1.141±0.193) (Table 7). This suggests that the different layers created within the cooking pot during cooking of Ga-*kenkey* create variability in the resilience of Ga-*kenkey*.

4. 2.3.9 Variability of Modulus of Deformation of Ga-*kenkey*

Modulus of deformation refers to the ratio of the initial stress applied to a sample to the corresponding strain observed in the sample (Civille and Szczesniak, 1973). Ga-*kenkey* because it is more preferred for it to be soft and less chewable by consumers requires that less stress during chewing is exerted, thus a low stress to strain ratio is more desirable. The modulus of deformation of Ga-*kenkey* from the bottom layer of the cooking pot was the least (0.15±0.07) with Ga-*kenkey* from the middle layer of the cooking pot having the highest modulus of deformation value (0.73±0.35). The modulus of deformation of Ga-*kenkey* was significantly different across the different layers created within the cooking pot (Table 7).

4.2.4 Variability in Viscoleastic properties in cooked Ga-*kenkey* from the same cooking pot

Most food materials such as *kenkey* have 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 a 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 it may even remain permanently deformed (Steffe, 2001). Transient (e.g. 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. Figure 6 is a typical stress relaxation curve for *kenkey*.

Stress relaxation parameters were summarized into firmness and elasticity values (or viscous and elastic components). There was a significant difference for both the firmness and elasticity values for Ga-*kenkey* from the different layers within the pot. Ga-*kenkey* from the bottom layer recoded the lowest firmness value (0.162±0.029) with Ga-*kenkey* from the top layer recording the highest value for firmness as shown in Table 7. In other words *kenkey* obtained from the bottom layers had more viscous character than *kenkey* obtained from the top layers. Firmness of the Ga-*kenkey* form the middle was similar to Ga-*kenkey* from the bottom layer whiles the firmness of Ga-*kenkey* from the top layer was very different. Elasticity among the Ga-*kenkey* was also seen to be low (24.507±5.194) in Ga-*kenkey* from the middle layer with Ga-*kenkey* from the top layer having the highest elasticity value (32.789±4.982) as seen in Table 7. In other words, Ga-*kenkey* from the top layers had more elastic character than that obtained from the bottom layers. The elasticity of Ga-*kenkey* from the middle layer was not different from that of Ga-*kenkey* from the bottom layer. The results indicate that the position of Ga-*kenkey* within the cooking pot affects both its firmness and elasticity. The data showed that the viscous components of *kenkey* from the bottom and middle layers were not significantly different, and that the elastic component of the top layer was significantly higher than those of both the middle and bottom layers.

4.2.5 Variability in the Degree of gelatinization in cooked Ga-*kenkey* from the same cooking pot

The degree of starch gelatinization was a measure of the extent to which the starches were transformed (or cooked) during the *kenkey* cooking process. The degree of gelatinization was significantly different among *kenkey* obtained from the different layers within the cooking pot. Products obtained from the top layer had the least degree of gelatinization (38.7$\pm$0.1) followed by *kenkey* from the middle layer. Ga-*kenkey* obtained from the bottom layer showed the highest degree of gelatinization (50.4$\pm$0.1) as shown in Table 7. This suggests that Ga-*kenkey* from the bottom layer of the cooking pot is more gelatinized compared to the middle and top *kenkey*. Differences in the degree of gelatinization at the different layers within the same cooking pot could be due to the differences in the contact of the Ga-*kenkey* at the different layers with the heat source thus affecting the rate of heat penetration at the different layers as seen in their temperature profile in Figure 7. The Figure shows that *kenkey* at the bottom layer was exposed to higher temperatures for longer time than that at the top layer.

Table 7: Variability in cooked Ga-*kenkey* at different layers of cooking pot.

	SAMPLE			
	Top *kenkey*	**Middle *kenkey***	**Bottom *kenkey***	**p-value**
Moisture	61.9± 0.4[a]	62.7±0.7[a]	66.4±0.7[b]	0.0003
Colour				
L*	56.26±0.03[a]	57.46±0.34[b]	58.37±0.10[c]	0.0000
a*	-0.03±0.02[a]	-0.03±0.00[b]	0.09±0.02[c]	0.0002
b*	14.07±0.03[a]	15.15±0.18[c]	14.93±0.02[b]	0.0000
TPA				
Hardness (N/cm^2)	12.116±9.614[c]	8.474±1.268[b]	3.066±0.515[a]	0.0000
Fracturability (N/cm^2)	0.273±0.398[a]	1.137±0.536[b]	0.217±0.130[a]	0.0000
Adhesiveness (Nxs)	-0.142±0.162[c]	-0.892±0.55[b]	-1.491±0.791[a]	0.0000
Springiness (cm)	0.586±0.059[b]	0.33±0.055[a]	0.398±0.155[a]	0.0000
Cohesiveness (ratio)	0.692±0.057[c]	0.331±0.131[a]	0.449±0.120[b]	0.0000
Gumminess (N/cm^2)	8.36±0.88[c]	2.755±1.055[b]	1.353±0.344[a]	0.0000
Chewiness (N/cm)	4.903±0.747[b]	0.914±0.361[a]	0.53±0.230[a]	0.0000
Resilience	1.141±0.193[c]	0.205±0.161[a]	0.593±0.156[b]	0.0000
Modulus of Deform	0.2±0.26[a]	0.73±0.35[b]	0.15±0.07[a]	0.0000
Stress Relaxation				
Firmness	0.265±0.077[b]	0.183±0.033[a]	0.162±0.029[a]	0.0005
Elasticity	32.789±4.982[b]	24.507±5.194[a]	24.578±6.447[a]	0.0048
Degree of Gelatinization	38.7±0.1 [a]	41.4±0.1[b]	50.4±0.1[c]	0.0000

*Different letters (a, b, c) in the same column or row for each parameter indicate significant differences between means ($p \geq 0.05$

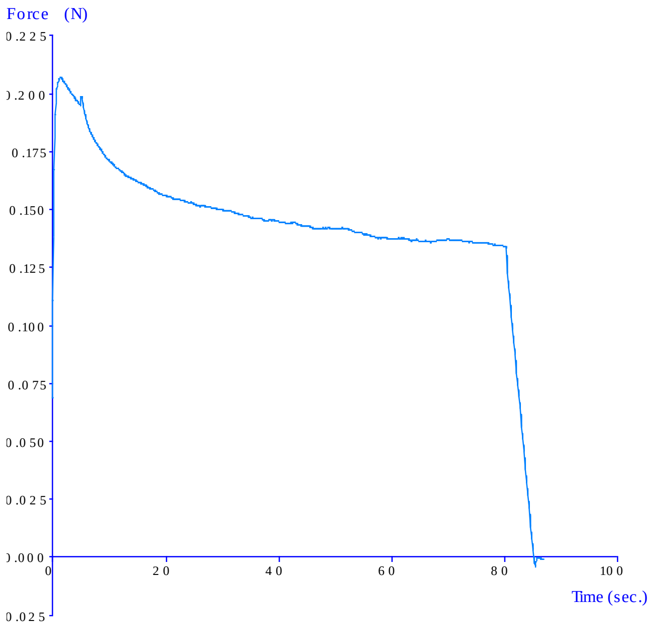

Figure 6: A typical stress-relaxation curve for *kenkey*

4.2.6 The temperature profile variability in cooked Ga-*kenkey* from the same cooking pot

The temperature profile for the Ga-*kenkey* at the different layers within the cooking pot (Figure 7) shows a great deal of variability in the time required for the cold point of the *kenkey* to get to the boiling water temperature (100^{o}C) in the cooking vessel. The rate of heat penetration during cooking was faster for the *kenkey* at the bottom layer, followed by the *kenkey* at the middle with the *kenkey* at the top layer having the slowest heat penetration as shown in Figure 7. Due to the arrangement of the *kenkey* in the pot, the bottom layer which was directly in contact with the cooking water heated up faster, whereas the top *kenkey* depend on steam from the cooking water to heat it.

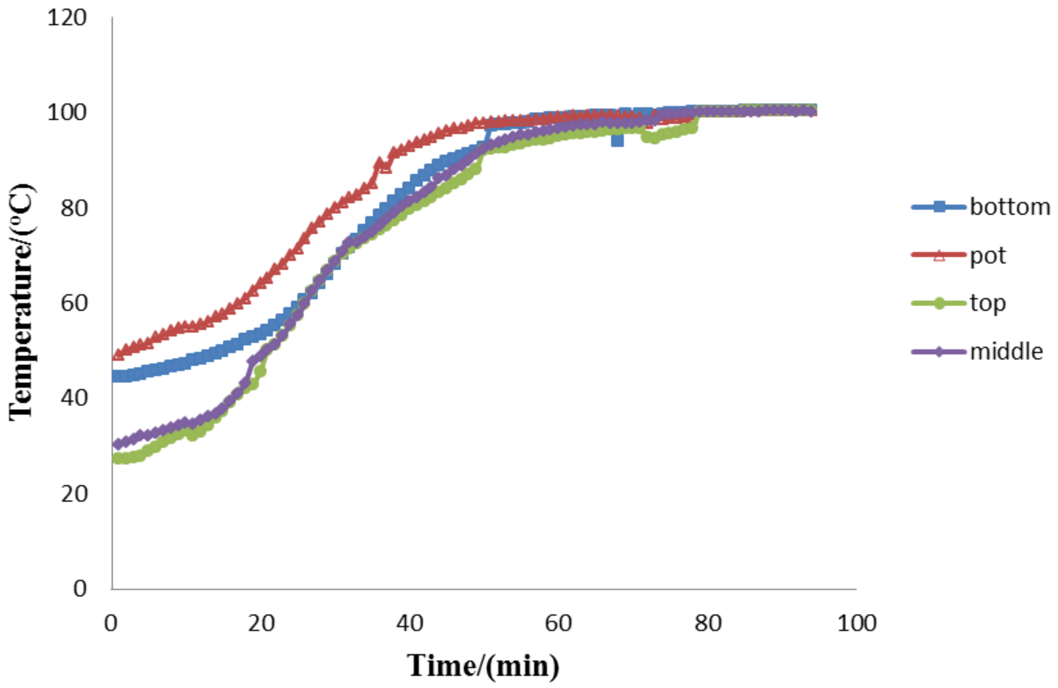

Figure 7: Temperature profile of Ga-*kenkey* at different layers cooked within the same cooking pot.

4.3 Sensory preference for Ga-*kenkey* from the same cooking pot

Sensory preference tests of Ga-*kenkey* obtained from the three layers within the cooking pot indicates that for all the sensory attributes (colour, taste, texture and overall acceptance), *kenkey* from the bottom layer was most preferred. The mean scores for overall acceptance score from the Friedman's test (Table 8) shows also that *kenkey* from the bottom layer is most preferred (1.73) followed by *kenkey* from the top layer (2.11) with the middle layer *kenkey* being the least preferred (2.16). There was a significant difference in consumer preference for texture and overall acceptance between *kenkey* obtained from the three layers whereas no significant difference were observed for colour and taste from the three layers (Table 8). This indicated that for all the sensory attributes texture and the overall acceptance of the Ga-*kenkey* from the same cooking pot was influenced by the different layers within the pot. It also indicates that texture is an important sensory attribute for consumer assessment of *kenkey* quality and acceptability as it had an influence on the overall acceptance of the product from the different layers within the same cooking pot. Ga-*kenkey* from the bottom layer is most preferred by consumers of Ga-*kenkey*

Table 8: Friedman sensory ranking for preference of cooked Ga-*kenkey* from different layers within the cooking pot.

	SAMPLE			
Sensory Parameters	**Top *kenkey***	**Middle *kenkey***	**Bottom *kenkey***	**p-value**
Color	2.03	2.07	1.90	0.663
Taste	2.05	2.19	1.76	0.584
Texture	2.26	2.07	1.67	0.007
Overall acceptance	2.11	2.16	1.73	0.046

* ($p \geq 0.05$)

4.4 Steam cooking of Ga-*kenkey*

The objectives of the experiments on Steam Cooking were firstly to investigate the effect of key parameters on product quality, and determine the optimum parameters to select to obtain the most acceptable *kenkey* product.

Results showed that the steam cooking time (5 min, 7.5 min, 10 min 12.5 min and 15 min) had a significant impact on the moisture, colour, and degree of gelatinization of the starch granules of the *kenkey* produced as well as on other physical and structural properties as indicated by Texture Profile Analysis (TPA) and stress relaxation test Tables 9 and 10. The results also showed that the cooking conditions (presence of corn husk, absence of corn husk) also significantly impacted the physical and chemical properties of the product.

The cooking process itself was monitored by means of Temperature Profile Analysis and results showed that the heat penetration was impacted by the duration of cooking as well as by the presence or absence of the corn husk Figure 7.

4.4.1 Moisture of steam cooked Ga-*kenkey*

There were significant differences in the moisture content of the steamed cooked Ga *kenkey* for the different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and steaming conditions (presence of corn husk, absence of corn husk). Steam cooking *kenkey* for 15 min with corn husk or without corn husks had the highest moisture values of (65.4 ± 0.2). The lowest moisture *kenkey* (63.6 ± 0.2) was obtained when the steaming was done for 5 minutes with corn husks in the cage (Table 9). Moisture values were seen not to be different for the steamed Ga-*kenkey* with or without corn husk in the steaming vessel. Differences in moisture were however seen at the different steam cooking times. This indicates that the presence of or absence of corn husk within the steaming vessel during cooking does not affect the moisture absorbed by the steamed Ga-*kenkey* but rather the steaming time influences the rate of absorption of moisture during the steam cooking.

4.4.2 Colour of steam cooked Ga-*kenkey*

The L* value for colour which indicates lightness was significantly different for the different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk). The lowest L* value for colour was recorded for steaming condition (10 min with corn husk) (49.64 ± 0.06) whiles the highest L* value for colour was recorded for steaming condition (7.5 min without corn husk). The L* values for colour of all the steamed cooked Ga-*kenkey* at a particular steaming time was different for the different steaming condition (presence of corn husk, absence of corn husk). The results for the L* values for colour indicates that both the steaming time and the steaming conditions affect the lightness of the steam cooked Ga-*kenkey*. However steaming at (12.5 min with corn husk) and steaming condition (5 min without corn husk) will provide Ga-*kenkey* of the same lightness.

The b* value for colour which indicates yellowness appeared to be significantly different for the different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk). The steaming condition (10 min with corn husk) recorded the lowest b value for colour (8.75$\pm$ 0.07) whiles the highest b* value for colour was observed for steaming condition (5 min with corn husk) (14.07$\pm$0.03) as shown in Table 9. The b* values for colour was seen to be different for the different steam cooking times. The b* values for colour of all the steamed cooked Ga-*kenkey* at a particular steaming time was also different for the different steaming condition (presence of corn husk, absence of corn husk) as was for the L* values for colour as shown in Table 9. The results for the b* values for colour indicates that both the steaming time and the steaming conditions affect the yellowness of the steam cooked Ga-*kenkey*.

4.4.3 Degree of Gelatinization of steam cooked Ga-*kenkey*

The degree of gelatinization was significantly different for the different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk). Steaming for 5 min with corn husks showed the lowest degree of gelatinization whiles the highest degree of gelatinization was obtained by steaming for 15 min with corn husk as shown in Table 9. The degree of gelatinization was different for all the steamed cooked Ga-*kenkey* at the different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk). The degree of gelatinization for all the steamed cooked Ga-*kenkey* at a particular steaming time was different for the different steaming condition (presence of corn husk, absence of corn husk). Steam cooking with the presence of corn husks in the cage generally had higher degree of gelatinization for all the steam cooking times (Table 9). The results suggest that both steaming time and steaming conditions affects the degree of gelatinization of the steamed cooked Ga-*kenkey*. Steam cooking with husk increases the rate of degree of gelatinization. The higher degree of gelatinization of steam cooked Ga-*kenkey* in the presence of husk, compared to that of steam cooked Ga-*kenkey* without husk could be due to the fact that in the steam cooked Ga-*kenkey* cooked without husk, the rate of heat penetration is faster compared to the steam cooked Ga-*kenkey* cooked with husk. This causes outer layer of the Ga-*kenkey* cooked without husk to gelatinize faster thus creating a barrier which then reduces the rate of heat penetration to the inner part of the *kenkey* and reducing the rate of gelatinization of the entire *kenkey* ball compared to Ga-*kenkey* steam cooked with husk

Table 9: Moisture, colour and degree of gelatinization of steamed cooked Ga-*kenkey* for different steam cooking times and steaming condition.

	SC	STEAMING TIME 5	7.5	10	12.5	15	p-value
Moisture	Husk	63.8 ± 0.2^{a}	64.8 ± 0.2^{b}	64.9 ± 0.2^{b}	65.0 ± 0.1^{bc}	65.4 ± 0.2^{d}	0.0000
	No Husk	63.6 ± 0.2^{a}	64.8 ± 0.1^{b}	$65.0 \pm 0.0b^{c}$	65.2 ± 0.1^{cd}	65.4 ± 0.1^{d}	
Colour							
L*	Husk	56.26 ± 0.03^{f}	60.46 ± 0.07^{d}	51.95 ± 0.06^{b}	57.18 ± 0.09^{g}	52.15 ± 0.14^{c}	0.0000
	No Husk	57.28 ± 0.07^{g}	54.29 ± 0.03^{i}	49.64 ± 0.06^{a}	55.47 ± 0.07^{e}	58.64 ± 0.1^{h}	
a*	Husk	-0.03 ± 0.02^{a}	1.09 ± 0.02^{f}	0.94 ± 0.05^{d}	1.07 ± 0.02^{ef}	0.78 ± 0.02^{c}	0.0000
	No Husk	0.98 ± 0.03^{d}	0.81 ± 0.03^{c}	0.67 ± 0.04^{b}	1.03 ± 0.04^{e}	1.39 ± 0.0^{g}	
b*	Husk	14.07 ± 0.03^{h}	10.50 ± 0.10^{f}	8.75 ± 0.07^{a}	9.52 ± 0.08^{c}	10.49 ± 0.03^{f}	0.0000
	No Husk	10.18 ± 0.05^{e}	9.35 ± 0.13^{b}	9.48 ± 0.07^{c}	10.02 ± 0.07^{d}	11.57 ± 0.1^{g}	
Degree of Gelatinization	Husk	51.3 ± 0.1^{a}	62.83 ± 0.06^{d}	70.8 ± 0.2^{f}	79.6 ± 0.1^{h}	88.1 ± 0.1^{j}	0.0000
	No Husk	59.2 ± 2.3^{b}	61.53 ± 0.15^{c}	69.0 ± 0.2^{e}	78.1 ± 0.2^{g}	85.9 ± 0.4^{i}	

* SC= Steaming condition

*Different letters (a, b, c) in the same column or row for each parameter indicate significant differences between means ($p \geq 0.05$)

4.4.4 Texture Profile Analysis of steam cooked Ga-*kenkey*

Texture Profile Analysis (TPA) showed that all the TPA parameters assessed for the steam cooked Ga-*kenkey* was significantly different with steaming time.

4.4.4.1 Hardness of steam cooked Ga-*kenkey*

Hardness was lowest (0.983±0.607)N/cm^{2}for 15 minutes steam cooked Ga-*kenkey* with corn husk whiles 10 minutes steam cooked Ga-*kenkey* with corn husk had the highest hardness value (18.161±2.398)N/cm^2 as shown in Table 10. Hardness for the steam cooked Ga-*kenkey* was similar at the same steam cooking times for the different steam cooking conditions (with or without corn husk) except for the steam cooking times 5 minutes and 75.5 minutes as shown in Table 10. This indicates that there was no effect of the different steam cooking conditions (with or without corn husk) on the steam cooked Ga-*kenkey*. Steaming at 15 minutes with corn husk produced steam cooked Ga-*kenkey* with the softest texture.

4.4.4.2 Fracturability of steam cooked Ga-*kenkey*

Fracturability of the steam cooked *kenkey* was significantly different for all the steam cooked Ga-*kenkey*s. Steam cooked Ga-*kenkey* (15 minutes with corn husk) had the lowest fracturability (0.006±0.013)N/cm^2 with steam cooked Ga-*kenkey* (10 minutes with corn husk) having the highest fracturability (2.825±0.758)N/cm^2 shown in Table 10. The fracturabilty of the steam cooked Ga-*kenkey* at the same steaming times for the different steam cooking conditions (with or without corn husk) were generally different except for Ga-*kenkey* steam cooked at 12.5 minutes and 15 minutes as shown in Table 10. The results indicate that the presence or absence of corn husk during the steam cooking process affects steam cooked Ga-*kenkey* at the steam cooking.

4.4.4.3 Adhesiveness of steam cooked Ga-*kenkey*

Adhesiveness of steam cooked Ga-*kenkey* was observed to be significantly different. Steam cooked Ga-*kenkey* (15 minutes with corn husk) had the least adhesiveness (-0.033±0.022)Nxs with steam cooked Ga-*kenkey* (7.5 minutes without corn husk) having the highest value for adhesiveness (-0.563±0.247)Nxs as shown in Table 10. The adhesiveness for the steam cooked Ga-*kenkey*s at the same steam cooking times was different for the different steaming conditions (with or without corn husk) as seen in Table 10. This suggests that the presence of corn husk during the steaming process affects the adhesiveness of steam cooked Ga-*kenkey*.

4.4.4.4 Springiness of steam cooked Ga-*kenkey*

The springiness of all steam cooked Ga-*kenkey* was significantly different from each other. Steam cooked Ga-*kenkey* (12.5 minutes with corn husk) had the least adhesiveness (0.146±0.046)cm with steam cooked Ga-*kenkey* (10 minutes without corn husk) having the highest value for springiness (0.656±0.066)cm as seen in Table 10. The springiness of the steam cooked Ga-*kenkey* at the same steam cooking times were seen to be different for all the different steaming conditions (with or without corn husk) (Table 10). This suggests that the springiness of the steam cooked Ga-*kenkey*s are affected by the presence of corn husk during the steam cooking process.

4.4.4.5 Cohesiveness of steam cooked Ga-*kenkey*

The cohesiveness of the steam cooked Ga-*kenkey*s were also significantly different with steam cooked Ga-*kenkey* (7.5 minutes with corn husk) being the least cohesive (0.337±0.070) whiles steam cooked Ga-*kenkey* (12.5 minutes without corn husk) had the highest cohesiveness (0.849±0.036) as seen in Table 10. Cohesiveness for all the steam cooked Ga-*kenkey*at the same steam cooking times was different for the different steaming conditions (with or without corn husk) except for steam cooking times (7.5 and 10) minutes (Table 10). This implies that the cohesiveness of the steam cooked Ga-*kenkeys* were affected by the presence of corn husk.

4.4.4.6 Gumminess of steam cooked Ga-*kenkey*

Gumminess of the steam cooked Ga-*kenkey* was significantly different for the steam cooking times and conditions. Steam cooked Ga-*kenkey* for 12.5 minutes with corn husk was observed to have the least gumminess $(0.438 \pm 0.203) N/cm^2$ whiles steam cooked Ga-*kenkey* for 7.5 minutes without corn husk had the highest gumminess $(4.522 \pm 2.493) N/cm^2$ as seen in Table 10. All the steam cooked Ga-*kenkey*s at the same steam cooking times had different gumminess for all the different steaming conditions (with or without corn husk) except for steam cooking times 10 and 15 minutes where the was some similarity in the gumminess of the steam cooked Ga-*kenkey*s as seen in Table 10. The results suggest that gumminess of steam cooked Ga-*kenkey* is affected by the presence of corn husk.

4.4.4.7 Chewiness of steam cooked Ga-*kenkey*

Chewiness of the steam cooked Ga-*kenkey* was observed to be significant for the different cooking times and conditions. The chewiness of steam cooked Ga-*kenkey* for 12.5 minutes with corn husk was observed to be the least (0.067 ± 0.044)N/cm whiles steam cooked Ga-*kenkey* for 10 minutes without corn husk had the highest chewiness (5.113 ± 1.213)N/cm as seen in Table 10. All the steam cooked Ga-*kenkey*s at the same steam cooking times had different chewiness for all the different steaming conditions (with or without corn husk) except for steam cooking times (10 ,12.5 and 15) minutes (Table 10). The results suggest that chewiness of steam cooked Ga-*kenkey* is affected by the presence of corn husk.

4.4.4.8 Resilience of steam cooked Ga-*kenkey*

The resilience of the steam cooked Ga-*kenkey* was also seen as significant for the different steam cooking times and conditions. The resilience of steam cooked Ga-*kenkey* for 7.5 minutes with corn husk was observed to be the least (0.149$\pm$0.055) whiles steam cooked Ga-*kenkey* for 12.5 minutes with corn husk had the highest resilience (3.594$\pm$1.943) as seen in Table 10. All the steam cooked Ga-*kenkey*s at the same steam cooking times was seen to have similar resilience for all the different steaming conditions (with or without corn husk in Table 10. The results suggest that resilience of steam cooked Ga-*kenkey* is not affected by the presence of corn husk during steam cooking.

4.4.4.9 Modulus of Deformation of steam cooked Ga-*kenkey*

The modulus of deformation of the steam cooked Ga-*kenkey* appeared to be significant for the different steam cooking times and conditions. The steam cooked Ga-*kenkey* for 12.5 minutes with corn husk was observed to have the least modulus of deformation (0.03$\pm$0.03) whiles steam cooked Ga-*kenkey* for 10 minutes with corn husk had the highest modulus of deformation (1.84$\pm$0.51) as seen in Table 10. All the steam cooked Ga-*kenkey* at the same steam cooking times was observed to have similar modulus of deformation for all the different steaming conditions as seen in table 10. The results observed suggest that modulus of deformation of steam cooked Ga-*kenkey* is not affected by the presence of corn husk during steam cooking.

Table 10: Texture Profile Analysis (TPA) of steamed cooked Ga-kenkey at different steam cooking times and steaming condition.

		STEAMING TIME					
TPA	**SC**	**5**	**7.5**	**10**	**12.5**	**15**	**p-value**
Hardness (N/cm^2)	Husk	5.021±1.754^{b}	6.213±2.393^{bc}	17.260±2.691^{e}	0.591±0.240^{a}	0.983±0.607^{a}	0.0000
	No Husk	7.901±1.499^{c}	10.736±4.732^{d}	18.161±2.398^{e}	2.371±1.621^{a}	2.007±1.341^{a}	
Fracturability (N/cm^2)	Husk	0.949±0.282^{a}	1.358±0.232^{cd}	2.825±0.758^{e}	0.003±0.008^{a}	0.006±0.013^{a}	0.0000
	No Husk	1.041±0.445^{bc}	1.637±0.473^{d}	2.659±0.647^{e}	0.005±0.016^{a}	0.009±0.022^{a}	
Adhesiveness (Nxs)	Husk	-0.398±0.156^{b}	-0.348±0.083^{bc}	-0.561±0.305^{a}	-0.023±0.027^{d}	-0.029±0.020^{d}	0.0000
	No Husk	-0.233±0.092^{c}	-0.563±0.247^{a}	-0.461±0.154^{ab}	-0.040±0.021^{d}	-0.033±0.022^{d}	
Springiness (cm)	Husk	0.399±0.084^{d}	0.410±0.118^{d}	0.617±0.067^{fg}	0.146±0.046^{a}	0.204±0.076^{ab}	0.0000
	No Husk	0.510±0.118^{e}	0.545±0.172^{ef}	0.656±0.066^{g}	0.250±0.086^{bc}	0.338±0.145^{cd}	

* SC= Steaming condition

*Different letters (a, b, c) in the same column or row for each parameter indicate significant differences between means ($p \geq 0.05$)

Table 10 continued: Texture Profile Analysis (TPA) of steamed cooked Ga-*kenkey* at different steam cooking times and steaming condition.

		STEAMING TIME					
TPA	**SC**	**5**	**7.5**	**10**	**12.5**	**15**	**p-value**
Cohesiveness (ratio)	Husk	0.351 ± 0.069^{ab}	0.337 ± 0.070^{a}	0.392 ± 0.057^{abc}	0.751 ± 0.200^{d}	0.838 ± 0.051^{e}	0.0000
	No Husk	0.439 ± 0.096^{c}	0.381 ± 0.085^{abc}	0.426 ± 0.068^{bc}	0.849 ± 0.036^{e}	0.808 ± 0.057^{de}	
Gumminess (N/cm^2)	Husk	2.059 ± 1.476^{c}	2.246 ± 1.301^{c}	6.745 ± 1.314^{e}	0.438 ± 0.203^{a}	0.814 ± 0.480^{ab}	0.0000
	No Husk	3.702 ± 1.563^{d}	4.522 ± 2.493^{d}	7.705 ± 1.329^{e}	1.997 ± 1.379^{bc}	1.602 ± 1.086^{abc}	
Chewiness (N/cm)	Husk	0.916 ± 0.966^{ab}	1.045 ± 0.912^{b}	4.222 ± 1.167^{d}	0.067 ± 0.044^{a}	0.194 ± 0.149^{ab}	0.0000
	No Husk	2.007 ± 1.134^{c}	2.775 ± 2.076^{c}	5.113 ± 1.213^{d}	0.562 ± 0.442^{ab}	0.600 ± 0.451^{ab}	
Resilience	Husk	0.161 ± 0.053^{a}	0.149 ± 0.055^{a}	0.174 ± 0.041^{a}	3.594 ± 1.943^{c}	2.863 ± 1.087^{bc}	0.0000
	No Husk	0.234 ± 0.074^{a}	0.168 ± 0.066^{a}	0.196 ± 0.046^{a}	2.875 ± 1.126^{bc}	2.211 ± 1.035^{b}	
Modulus of Deform	Husk	0.62 ± 0.20^{b}	0.88 ± 0.17^{cd}	1.84 ± 0.51^{e}	0.03 ± 0.03^{a}	0.02 ± 0.03^{a}	0.0000
	No Husk	0.67 ± 0.31^{bc}	1.05 ± 0.32^{d}	1.74 ± 0.44^{e}	0.03 ± 0.02^{a}	0.03 ± 0.02^{a}	

* SC= Steaming condition

*Different letters (a, b, c) in the same column or row for each parameter indicate significant differences between means ($p \geq 0.05$)

4.4.5 Viscoelastic properties of steam cooked Ga-*kenkey*

The firmness (or viscous component) of *kenkey* made by steaming for various times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk) was significantly different. Firmness was lowest for Ga-*kenkey* obtained by steaming for 5 minutes with corn husk, and highest in Ga-*kenkey* obtained by steaming for 7.5 minutes without corn husk as shown in Table 11. Similarities in firmness were observed for Ga-*kenkey* steam cooked for (10 minutes with corn husk, 10 minutes without corn husk, 12.5 minutes with corn husk and 12.5 minutes without corn husk) (Table 11). For the same steam cooking time, firmness values were similar for the steam cooked Ga-*kenkeys* steam cooked for (10 minutes with or without corn husk, 12.5 minutes with or without corn husk and 15 minutes with or without corn husk) (Table 11). Firmness was however different for the steam cooking times 5 minutes and 7.5 minutes at the different steaming conditions (with or without corn husk) as shown in Table 11. This showed that the presence or absence of corn husk during steaming affected the rheology of steam cooked Ga-*kenkeys.* The elasticity was also seen to be significantly different for all the steam cooked Ga-*kenkey*s. Elasticity values were seen to be lowest in steam cooked Ga-*kenkey* (5 min with corn husk) and highest in steam cooked Ga-*kenkey* (15 min without corn husk). Differences in elasticity for the steam cooked Ga-*kenkeys* were seen for steam cooking at (5 min with corn husk, 5 min without corn husk and 15 min without corn husk (Table 11). The results indicates that the presence or absence of corn husk also affects the elasticity of steam cooked Ga-*kenkey*.

Table 11: Stress relaxation test of steamed cooked Ga-*kenkey* at different steam cooking times and steaming condition.

		STEAMING TIME					
Stress Relaxation	**SC**	**5**	**7.5**	**10**	**12.5**	**15**	**p-value**
Firmness	Husk	0.278± 0.067[a]	0.996± 0.828[bc]	0.494± 0.186[ab]	0.600± 0.531[ab]	1.703± 1.388[de]	0.0000
	No Husk	1.222± 0.099[cd]	2.303± 0.496[e]	0.416± 0.131[ab]	0.603± 0.539[ab]	1.693± 1.088[de]	
Elasticity	Husk	44.062± 9.071[a]	52.600± 3.956[bcd]	50.208± 5.604[abc]	47.451± 9.282[abc]	52.131± 9.070[bcd]	0.0014
	No Husk	45.278± 0.807[b]	53.162± 2.600[cd]	48.194± 7.888[abc]	46.548± 9.937[ab]	57.143± 4.767[d]	

* SC= Steaming condition

*Different letters (a, b, c) in the same column or row for each parameter indicate significant differences between means ($p \geq 0.05$)

4.5 Temperature profile for steamed cooked Ga-*kenkey*

The temperature profile for the different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk) showed that the heat penetration for Ga-*kenkey* during steaming without corn hush was higher compared to that *kenkey* with corn hush for all the steam cooking times as shown in Figure 8. At the end of 5 minutes of steam cooking, the temperature of the Ga-*kenkey* without corn husk was seen to be 73.2 ^{o}C whiles that of Ga-*kenkey* with corn husk was 45.1 ^{o}C showing a temperature difference of 28.1 ^{o}C between the two steam cooking conditions. A temperature difference of 33.9 ^{o}C, 32.3 ^{o}C, 19.7 ^{o}C, 9.8 ^{o}C was also seen for the steam cooking times (7.5 min, 10 min 12.5 min and 15 min) respectively (Figure 8). The results indicate that the presence of corn husk affected the rate of heat penetration of the steam cooked Ga-*kenkey*s at the different steam cooking times.

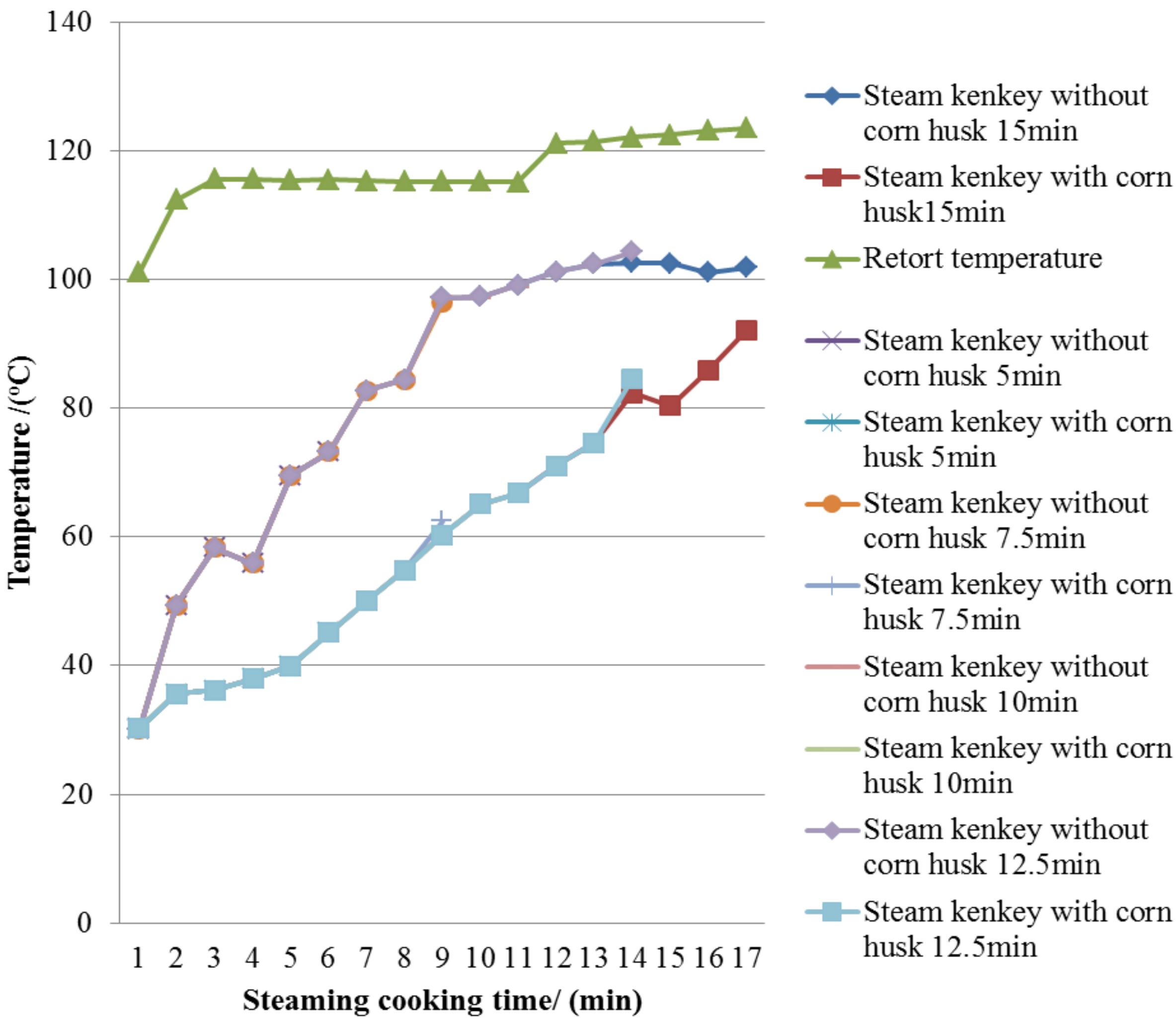

Figure 8: Temperature profile of Ga-*kenkey* steam cooked at different steam cooking times and steaming conditions (with or without corn husk).

4.6 Sensory preference for Ga-*kenkey* produced by cooking with live steam

The sensory scores for preference of steam cooked Ga-*kenkey* at different steam cooking times (5 min, 7.5 min, 10 min 12.5 min and 15 min) and conditions (presence of corn husk, absence of corn husk) compared to Ga-*kenkey* preferred most by Ga-*kenkey* consumers in terms of the layers in the cooking pot (Ga-*kenkey* from the bottom layer of the pot) showed that for steamed cooked Ga-*kenkey* with steaming condition (with corn husk) at the different steaming times compared to Ga-*kenkey* from the bottom layer of the cooking pot, there was no significant difference for preference of colour and taste of the steamed cooked Ga-*kenkey*s. A significant difference was however seen for texture and overall acceptance of the steam cooked Ga-*kenkey*s. All the steam cooked Ga-*kenkey*s (with corn husk) had the same level of preference for colour as that of the Ga-*kenkey* from the bottom layer as shown in Table 12. Sensory preference for taste for the steamed cooked Ga-*kenkey* was also the same as that of Ga-*kenkey* from the bottom layer of the cooking pot except for the steamed cooked Ga-*kenkey* at steam cooking time (7.5 min) with Ga-*kenkey* at steam cooking time (7.5 min) being the least preferred in terms of texture to the other steamed cooked Ga-*kenkey*s as can be seen in Table 12. Preference for texture for all the steamed cooked Ga-*kenkey* was seen to be different from that of Ga-*kenkey* from the bottom layer of the cooking pot. Ga-*kenkey* from the bottom layer of the cooking pot was the most preferred followed by Ga-*kenkey* steamed cooked at 15 min with corn husk with Ga-*kenkey* steamed cooked at 5 min with corn husk and Ga-*kenkey* steamed cooked at 12.5 min with corn husk having the least preference for texture as shown in table 12. There was however no difference in preference for texture for steam cooked Ga-*kenkey*s: 7.5 minutes with corn husk, 10 minutes with corn husk, 12.5 minutes with corn husk and 15 minutes with corn husk. The overall acceptance for the steam cooked Ga-*kenkey*s were also different from Ga-*kenkey* from the bottom layer of the cooking pot with Ga *kenkey* from the bottom layer of the cooking pot having the most overall acceptance level compared to the steam cooked Ga-*kenkey*s. Steam cooked Ga-*kenkey*s: 5 minutes with corn husk, 7.5 minutes with corn husk, 10 minutes with corn husk and 12.5 minutes with corn husk followed as next Ga-*kenkey* which had a better overall acceptance with them having the same overall acceptance score. Steam cooked Ga-*kenkey* (15 minutes with corn husk) had the least overall acceptance as shown in Table 12. The result indicates that the different steaming times affect only the texture preference and overall acceptance of steam cooked Ga-*kenkey* since significant difference were observed for only these sensory parameters accessed.

No significant difference of overall acceptance was observed for steamed cooked Ga-*kenkey* with steaming condition (without corn husk) compared with Ga-*kenkey* from the bottom layer of the cooking pot whiles significant differences were seen for colour, taste and texture of the steam cooked Ga-*kenkey*s. All the steam cooked Ga-*kenkey*s (without corn husk) had the same level of preference for colour as that of the Ga-*kenkey* from the bottom layer except for steam cooked Ga-*kenkey* (5 min without corn husk) as shown in Table 13. Sensory preference for taste for the steamed cooked Ga-*kenkey*s was different from that of Ga-*kenkey* from the bottom layer of the cooking pot except for the steamed cooked Ga-*kenkey* at steam cooking time (15 min without corn husk and 12.5 min without corn husk) with Ga-*kenkey* at steam cooking time (15 min without corn husk and 12.5 min without corn husk) having the same preference for taste as Ga-*kenkey* from the bottom layer of the cooking pot. Preference for texture of all the steam cooked at all the steam cooking time without husk was also different from that of the texture of Ga-*kenkey* from the bottom layer of the cooking pot. Ga-*kenkey* from the bottom layer of the cooking pot was preferred most by consumers followed by all the steam cooked Ga-*kenkey*s having the same preference level as shown in Table 13. The same trend was observed for preference for overall acceptance as observed for texture of the steam cooking time without husk compared with the Ga-*kenkey* from the bottom layer as can be seen in Table 13. Result indicates that no differences were observed for the preference of the steam cooked Ga-*kenkey* without corn husk at the different steam cooking times.

Comparing the steam cooked Ga-*kenkey* at the different steam cooking time and steaming condition (with or without husk) with Ga-*kenkey* from the bottom layer, steam Ga-*kenkey* at steaming time 5 minutes with husk has the most preference since it had the most preferred sensory score for texture and overall acceptance second to that Ga-*kenkey* from the bottom layer.

Table 12: Friedman sensory ranking for preference of steam cooked Ga-*kenkey* at different steaming time steaming condition (with corn hush in the steaming cage).

Sensory Parameters	SAMPLE						p-value
	BOTTOM	**5H**	**7.5H**	**10H**	**12.5H**	**15H**	
Colour	2.85	3.57	3.22	3.72	3.78	3.87	0.183
Taste	2.83	3.65	3.95	3.67	3.42	3.48	0.221
Texture	1.92	4.13	3.77	3.57	4.4	3.22	0.000
Overall acceptance	2.37	3.20	3.72	3.73	3.65	4.33	0.000

* BOTTOM= Ga-*kenkey* from the bottom layer of the cooking pot, 5H= Ga-*kenkey* steamed cooked at 5 min with corn husk, 7.5H= Ga-*kenkey* steamed cooked at 7.5 min with corn husk, 10 H= Ga-*kenkey* steamed cooked at 10 min with corn husk, 12.5H= Ga-*kenkey* steamed cooked at 12.5 min with corn husk, 15H= Ga-*kenkey* steamed cooked at 15 min with corn husk.

* ($p \geq 0.05$)

Table 13: Friedman sensory ranking for preference of steam cooked Ga-*kenkey* at different steaming time and steaming condition (without corn hush in the steaming cage).

Sensory Parameters	SAMPLE						p-value
	BOTTOM	**5NH**	**7.5NH**	**10NH**	**12.5NH**	**15NH**	
Colour	3.07	4.35	3.97	3.5	3.33	2.78	0.006
Taste	2.57	3.87	4.12	4.07	3.22	3.17	0.003
Texture	2.37	3.38	3.95	3.82	3.85	3.63	0.006
Overall acceptance	2.7	3.45	3.95	3.38	3.97	3.55	0.080

* BOTTOM= Ga-*kenkey* from the bottom layer of the cooking pot, 5NH= Ga-*kenkey* steamed cooked at 5 min without corn husk, 7.5NH= Ga-*kenkey* steamed cooked at 7.5 min without corn husk, 10 NH= Ga-*kenkey* steamed cooked at 10 min without corn husk, 12.5NH= Ga-*kenkey* steamed cooked at 12.5 min without corn husk, 15NH= Ga-*kenkey* steamed cooked at 15 min without corn husk.

* ($p \geq 0.05$)

CHAPTER 5

5.0 DESIGN OF STEAM COOKER FOR COOKING GA-*KENKEY*

5.1 Sizing of vessel

The total volume of the pressure cooker was calculated as follows. A ball of *kenkey* weighed 346g and had a volume 154 cm^3.

Therefore volume occupied by 200 balls of kenkey is $200 \times 154cm^3 = 30{,}800cm^3$.

Assuming that the free space in the cooker was half the volume occupied by the *kenkey*, the total volume of the cooker would be 46,200cm^3.

Below in Figure 9 is a sketch of the vessel. The vessel was conceived to be cylindrical in shape with spherical bottom.

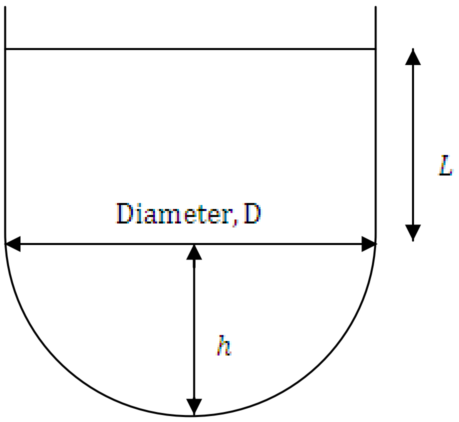

Figure 9: sketch of the steam cooking vessel for cooking Ga-*kenkey*.

$D = L + h$

Volume of hemisphere at the bottom $= \frac{3}{8}\pi r^2 h$ [1]

$$\text{Volume of the cylindrical shape} = \pi r^2 L \qquad [2]$$

$$\text{Volume of the vessel} = \frac{5}{32}\pi D^2 L + \frac{3}{32}\pi D^3 \qquad [3]$$

$$= \frac{5}{32}\pi D^2 L + \frac{3}{32}\pi D^3 = 46{,}200\ \text{cm}^3 = 0.0462\text{m}^3$$

$$\text{By trial and error, } D = 0.4\text{m and } L = 0.35\text{m}$$

$$h = D - L = 0.05\text{m}$$

5.2 Material of construction

Stainless steel (grade SS 316) was used for the construction of the steam cooker. It is one of the most hygienic surfaces for the preparation of foods and very easy to clean, as its unique surface has no pores or cracks to harbor dirt, or bacteria. It is very attractive and requires minimal care, since it will not easily rust and it takes little seasoning. It will not affect flavor, as it does not react with acidic foods during food preparation or cooking (Dzigbor, 2012).

5.3 Calculating the thickness of vessel wall

The vessel would be subjected to internal pressure of the steam and the weight of 200 balls of *kenkey*. The internal pressure acting on the long sides of the cylinder would give rise to circumferential stress in the wall of the cylinder. The ends of the cylinder would be closed; therefore the pressure acting on the ends is transmitted to the wall cylinder thus producing a longitudinal stress in the walls.

The circumferential stress acting in the walls of the cylinder is given by

$$\sigma_1 = \frac{Pr}{t}$$

The average tensile stress for stainless steel is 63.3MPa (Paul *et al.* 2004). From the calculation above, the diameter of the cooking vessel is 0.40m. The steam enters the cylinder at a pressure of 50psi. Therefore the thickness of the vessel wall to tolerate the pressure from the steam is calculated as follows:

$$\sigma_1 = \frac{\mathrm{Pr}}{\mathrm{t}} \qquad \text{(Case et al.,1999)}$$

$$63.3 \times 10^6\ \mathrm{N/m^2} = \frac{344.7 \times 10^3\ \mathrm{N/m^2} \times 0.20m}{t}$$

Therefore the thickness is 0.001m

The longitudinal stress acting on the walls of the cylinder is also given by

$$\sigma_2 = \frac{Pr}{2t} \qquad (\text{Case } et\ al.\text{ ,1999})$$

Apart from the pressure of the steam, the weight of the balls of the *kenkey* would also exert perpendicular force on the bottom end of the cylinder. This must be added to the steam pressure to calculate the thickness of the vessel wall.

The weight of 200 balls of kenkey is $346\mathrm{g} \times 200 = 69200\mathrm{g} = 69.2\mathrm{kg}$

Force exerted by the 200 balls of kenkey is $69.2\text{kg} \times 10\ \text{m/s}^2 = 692\text{N}$

The area of the hemispherical bottom end is given by $2\pi r^2 = 0.25\text{m}^2$

Therefore the pressure exerted by the balls of kenkey is given by

$$P = \frac{F}{A} = \frac{692\text{N}}{0.25\text{m}^2} = 2{,}768\ \text{N/m}^2$$

Total pressure is the sum of steam pressure and pressure exerted by the balls of *kenkey*

Total pressure $P = 344.7 \times 10^3\ \text{N/m}^2 + 2{,}768\ \text{N/m}^2 = 347{,}468\ \text{N/m}^2$

$$63.3 \times 10^6\ \text{N/m}^2 = \frac{347{,}468\ \text{N/m}^2 \times 0.20\text{m}}{2t}$$

This comes to 0.055cm or 0.55mm

Since the value of the wall thickness calculated from the circumferential stress is larger than that calculated from the longitudinal stress, the wall thickness is the larger value.

CHAPTER 6

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

Ga-*kenkey* processors use different cooking techniques to ensure that the *kenkey* cooks well and fast. Most processors operate on small scale but manufacture *kenkey* almost on daily basis. Majority of the processors cook the *kenkey* over a period of 3 hours. The most used technique by the processors to determine the degree of cook of *kenkey* and to ensure that the *kenkey* cooks fast is by touching the *kenkey* ball to determine its softness and increasing the intensity of the fire respectively. Age and education influence the processing of Ga-*kenkey*. Most of the *kenkey* processors know of corn husk as the only wrapping for kenkey with a few having knowledge of plantain leaves. Majority of the *kenkey* processors are willing to try alternative forms of wrapping for Ga-*kenkey* however a lot of education would have to be done on any alternative wrapping, to help bridge the knowledge gap relating to the use of any alternative wrapper

Variability in moisture, colour, Texture profile, heat penetration, stress relaxation and degree of gelatinization exist at the different *kenkey* layers within the same cooking pot. This is as a result of the arrangement of the Ga-*kenkey* with respect to the cooking water at the bottom of the pot. Moisture, softness, adhesiveness, degree of gelatinization and the rate of heat penetration of Ga-*kenkey* increases from the top layer to the bottom layer whiles chewiness, firmness and elasticity increases from the bottom layer to the top layer.

Ga-*kenkey* from the bottom layer of the cooking pot is most preferred by consumers largely due to its texture.

During steam cooking the heat penetration, the moisture absorbed, degree of gelatinization and steaming time affect the appearance and physical properties of the *kenkey* as well as the consumer preference of the *kenkey*. Hardness, adhesiveness and chewiness increase till 10 minutes of steam cooking and then decline over the steam cooking period. The presence of husk and the duration of steam cooking affect the hardness, adhesiveness, chewiness and rate of heat penetration of steam cooked Ga-*kenkey*

For steam cooked Ga-*kenkey*, steam cooking for 5 minutes with husk gives a steam cooked Ga-*kenkey* with a preference score for overall acceptance closer to Ga-*kenkey* obtained from the bottom thus steam cooking Ga-*kenkey* for 5 minutes with husk would give a steam cooked Ga-*kenkey* similar to Ga-*kenkey* obtained from the bottom layer of the pot.

A stainless steel vessel with a thickness of 0.055 cm is required for designing a pressure cooker of volume 437,000 cm^3 for cooking 200 balls of *kenkey* at a pressure of 40 Kpa.

6.2 Recommendation

It is recommended that further studies using different pressures as well as steam cooking times be conducted to determine their effects on the consumer acceptance of steam cooked Ga-*kenkey*. Confirmatory analysis should also be done to see the relationship between degree of gelatinization and consumer acceptability. Further work on degree of hydrolysis in the Ga-*kenkey* and leaching of starch from the Ga-*kenkey* during cooking as a result of the different layers created should be done. The keeping quality and shelf life of the steam cooked Ga-*kenkey* should also be investigated.

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APPENDICES

APPENDIX1: QUESTIONNAIRE TO DETERMINE THE AVERAGE COOKING TIME OF GA-*KENKEY* AND THE TECHNIQUES USED BY GA-*KENEKY* MAKERS TO HASTEN THE GA-*KENKEY* COOKING PROCESS.

DEPARTMENT OF FOOD SCIENCE AND FOOD SCIENCE, UNIVERSITY OF GHANA

Biodata

Age ……………

Sex

Male ☐ Female ☐

Educational level

No formal education ☐ Primary ☐ JHS ☐ SHS ☐ Tertiary ☐

How long have you been making Ga-*kenkey*?

Less than a year ☐ 1 year to 5 years ☐ more than 5 years ☐

How much maize do you use to prepare a batch of *kenkey*?

Less than half a bag ☐ 1 bag ☐ more than a bag ☐

How many balls of Ga-*kenkey* do you make in a day?

Less than 100 ☐ 100-200 ☐ 200-300 ☐ above 300 ☐

How many hours does it take you to cook your *kenkey*?

1hour ☐ 2 hours ☐ three hours ☐ four hours ☐

How many days in the week do you make Ga-*kenkey*?

One day ☐ two days ☐ three days ☐ four days ☐

five days ☐ six day ☐ every day ☐

How do you know your *kenkey* is cooked?

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Apart from corn sheaths, are there other alternative wrapping material?

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……………………………………………………………………………………
……………………………………………………………………………………

Would you be willing to try other alternative wrapping material?

Yes ☐ No ☐

If no, why not?

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Do you use any technique to ensure that your *kenkey* cook well?

Yes ☐ No ☐

If yes what techniques do you use?

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Do you use any techniques to ensure that your *kenkey* cook faster?

Yes ☐ No ☐

If yes what technique do you use?

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APPENDIX 2: WORK SHEET FOR PREFERENCE SENSORY ANALYSIS OF GA-*KENKEY* FROM THE DIFFERENT LAYERS WITHIN THE SAME COOKING POT

Sample code: A= Top layer *kenkey*, B= Middle layer *kenkey*, C= Bottom layer *kenkey*

Sample presentation

Panelist	Samples		
1	A	B	C
2	A	B	C
3	A	B	C
4	A	B	C
5	A	B	C
6	B	A	C
7	B	A	C
8	B	A	C
9	B	A	C
10	B	A	C
11	C	A	B
12	C	A	B
13	C	A	B
14	C	A	B
15	C	A	B
16	A	C	B
17	A	C	B
18	A	C	B
19	A	C	B
20	A	C	B
21	B	C	A
22	B	C	A
23	B	C	A
24	B	C	A
25	B	C	A
26	C	B	A

27	C	B	A
28	C	B	A
29	C	B	A
30	C	B	A
31	A	B	C
32	A	B	C
33	A	B	C
34	A	B	C
35	A	B	C
36	B	A	C
37	B	A	C
38	B	A	C
39	B	A	C
40	B	A	C
41	C	A	B
42	C	A	B
43	C	A	B
44	C	A	B
45	C	A	B
46	A	C	B
47	A	C	B
48	A	C	B
49	A	C	B
50	A	C	B

APPENDIX 3a: WORK SHEET FOR PREFERENCE SENSORY ANALYSIS OF STEAM COOKED GA-*KENKEY* WITH STEAMING CONDITION PRESENCE OF CORN HUSK

Sample code: A= Bottom layer *kenkey*, B= 5 Minutes steam cooked *kenkey* with husk, C= 7.5 Minutes steam cooked *kenkey* with husk, D= 10 Minutes steam cooked *kenkey* with husk, E= 12. 5 Minutes steam cooked *kenkey* with husk, F= 15 Minutes steam cooked *kenkey* with husk

Sample presentation

Panelist	**Samples**					
1	A	B	C	D	E	F
2	A	B	C	D	E	F
3	B	A	D	C	F	E
4	B	A	D	C	F	E
5	C	D	E	F	A	B
6	C	D	E	F	A	B
7	D	C	F	E	B	A
8	D	C	F	E	B	A
9	E	F	A	B	C	D
10	E	F	A	B	C	D
11	F	E	B	A	D	C
12	F	E	B	A	D	C
13	A	B	C	D	E	F
14	A	B	C	D	E	F
15	B	A	D	C	F	E
16	B	A	D	C	F	E
17	C	D	E	F	A	B
18	C	D	E	F	A	B

19	D	C	F	E	B	A
20	D	C	F	E	B	A
21	E	F	A	B	C	D
22	E	F	A	B	C	D
23	F	E	B	A	D	C
24	F	E	B	A	D	C
25	A	B	C	D	E	F
26	A	B	C	D	E	F
27	B	A	D	C	F	E
28	B	A	D	C	F	E
29	C	D	E	F	A	B
30	C	D	E	F	A	B

APPENDIX 3b: WORK SHEET FOR PREFERENCE SENSORY ANALYSIS OF STEAM COOKED GA-*KENKEY* WITH STEAMING CONDITION: ABSENCE OF CORN HUSK

Sample code: A= Bottom layer *kenkey*, B= 5 Minutes steam cooked *kenkey* without husk, C= 7.5 Minutes steam cooked *kenkey* without husk, D= 10 Minutes steam cooked *kenkey* without husk, E= 12. 5 Minutes steam cooked *kenkey* without husk, F= 15 Minutes steam cooked *kenkey* without husk

Sample presentation

Panelist	**Samples**					
1	A	B	C	D	E	F
2	A	B	C	D	E	F
3	B	A	D	C	F	E
4	B	A	D	C	F	E
5	C	D	E	F	A	B
6	C	D	E	F	A	B
7	D	C	F	E	B	A
8	D	C	F	E	B	A
9	E	F	A	B	C	D
10	E	F	A	B	C	D
11	F	E	B	A	D	C
12	F	E	B	A	D	C
13	A	B	C	D	E	F
14	A	B	C	D	E	F
15	B	A	D	C	F	E
16	B	A	D	C	F	E
17	C	D	E	F	A	B
18	C	D	E	F	A	B
19	D	C	F	E	B	A

20	D	C	F	E	B	A
21	E	F	A	B	C	D
22	E	F	A	B	C	D
23	F	E	B	A	D	C
24	F	E	B	A	D	C
25	A	B	C	D	E	F
26	A	B	C	D	E	F
27	B	A	D	C	F	E
28	B	A	D	C	F	E
29	C	D	E	F	A	B
30	C	D	E	F	A	B

APPENDIX 4: SENSORY ANALYSIS OF GA-*KENKEY* FROM THE DIFFERENT LAYERS WITHIN THE SAME COOKING POT.

DEPARTMENT OF NUTRITION AND FOOD SCIENCE, UNIVERSITY OF GHANA

You have been presented with three Ga-*kenkey* samples. Please indicate your level of preference for **colour, taste, texture and overall acceptance** for each sample using the hedonic scale below. Please rinse you mouth with water after tasting each sample or wipe your hands with tissue after touching each sample.

1 Like extremely **2 Like very much** **3 Like moderately**

4 Neither like nor dislike **5 Dislike** **6 Dislike moderately**

7 Dislike very much **8 Dislike extremely**

COLOUR

Please observe each sample and indicate your level of preference for the colour of each sample.

Code …………….. …………… ……………

Colour …………….. …………… ……………

TASTE

Please taste each sample and indicate your level of preference for the taste of each sample. Rinse your mouth with water and wait for 2 minutes before tasting the next sample.

Code …………….. …………… ……………

Taste …………….. …………… ……………

TEXTURE

Please press each sample between your fingers and indicate your level of preference for the texture of each sample. Wipe your hands with tissue before examining the next sample.

Code …………….. …………… ……………

Texture …………….. …………… ……………

OVERALL ACCEPTANCE

Code …………….. …………… ……………

Overall acceptance …………….. …………… ……………

Comments: :

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APPENDIX 5a: SENSORY ANALYSIS OF STEAM COOKED GA-*KENKEY* WITH STEAMING CONDITION: PRESENCE OF CORN HUSK

DEPARTMENT OF NUTRITION AND FOOD SCIENCE, UNIVERSITY OF GHANA

You have been presented with six Ga-*kenkey* samples. Please indicate your level of preference for **colour, taste, texture and overall acceptance** for each sample using the hedonic scale below. Please rinse you mouth with water after tasting each sample or wipe your hands with tissue after touching each sample.

1 Like extremely **2 Like very much** **3 Like moderately**

4 Neither like nor dislike **5 Dislike** **6 Dislike moderately**

7 Dislike very much **8 Dislike extremely**

COLOUR

Please observe each sample and indicate your level of preference for the colour of each sample.

Code	……..	……..	………	………	……….	……….
Colour	……..	……..	………	………	……….	……….

TASTE

Please taste each sample and indicate your level of preference for the taste of each sample. Rinse your mouth with water and wait for 2 minutes before tasting the next sample.

Code	……..	……..	………	………	……….	……….
Taste	……..	……..	………	………	……….	……….

TEXTURE

Please press each sample between your fingers and indicate your level of preference for the texture of each sample. Wipe your hands with tissue before examining the next sample.

Code …….. …….. ……… ……… ………. ……….

Texture …….. …….. ……… ……… ………. ……….

OVERALL ACCEPTANCE

Code …….. …….. ……… ……… ……….
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Overall acceptance …….. …….. ……… ……… ……….
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Comments: :
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APPENDIX 5b: SENSORY ANALYSIS OF STEAM COOKED GA-*KENKEY* WITH STEAMING CONDITION: ABSENCE OF CORN HUSK

DEPARTMENT OF NUTRITION AND FOOD SCIENCE, UNIVERSITY OF GHANA

You have been presented with six Ga-*kenkey* samples. Please indicate your level of preference for **colour, taste, texture and overall acceptance** for each sample using the hedonic scale below. Please rinse you mouth with water after tasting each sample or wipe your hands with tissue after touching each sample.

1 Like extremely **2 Like very much** **3 Like moderately**

4 Neither like nor dislike **5 Dislike** **6 Dislike moderately**

7 Dislike very much **8 Dislike extremely**

COLOUR

Please observe each sample and indicate your level of preference for the colour of each sample.

Code …….. …….. ……… ……… ………. ……….

Colour …….. …….. ……… ……… ………. ……….

TASTE

Please taste each sample and indicate your level of preference for the taste of each sample. Rinse your mouth with water and wait for 2 minutes before tasting the next sample.

Code …….. …….. ……… ……… ………. ……….

Taste …….. …….. ……… ……… ………. ……….

TEXTURE

Please press each sample between your fingers and indicate your level of preference for the texture of each sample. Wipe your hands with tissue before examining the next sample.

Code …….. …….. ……… ……… ………. ……….

Texture …….. …….. ……… ……… ………. ……….

OVERALL ACCEPTANCE

Code …….. …….. ……… ……… ………. ……….

Overall acceptance …….. …….. ……… ……… ………. ……….

Comments: :

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APPENDIX 6: STANDARD CURVE

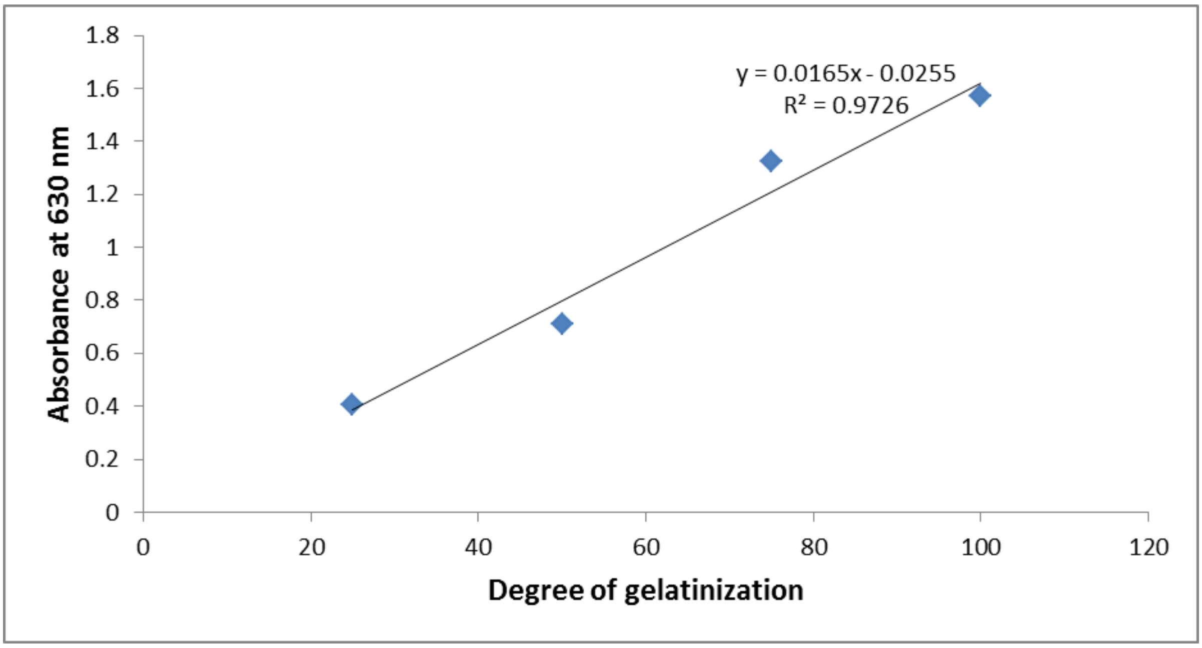


Figure 10: Standard curve of absorbance for different concentration of gelatinized starch at 630 nm

APPENDIX 7 Freidman's test Ranks for Ga-*kenkey* from the different layers (bottom, middle and top) within the same cooking pot

Ranks for colour	
	Mean Rank
Top	2.03
Middle	2.07
Bottom	1.9

APPENDIX 8a: Freidman's test Ranks for steam cooked Ga-*kenkey* with steaming condition (presence of husk)

Ranks for colour	
	Mean Rank
Bottom	2.85
5min	3.57
7.5min	3.22
10min	3.72
12.5min	3.78
15min	3.87

APPENDIX 8b: Freidman's test Ranks for steam cooked Ga-*kenkey* with steaming condition (absence of husk)

Ranks for colour	
	Mean Rank
Bottom	3.07
5min	4.35
7.5min	3.97
10min	3.5
12.5min	3.33
15min	2.78

APPENDIX 9: ANOVA TABLES

ANOVA Table for moisture by position in pot

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	33.6867	2	16.8433	41.19	0.0003
Within groups	2.45333	6	0.408889		
Total (Corr.)	36.14	8			

ANOVA Table for degree of gelatinization by position in pot

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	223.269	2	111.634	6698.07	0.0000
Within groups	0.1	6	0.0166667		
Total (Corr.)	223.369	8			

ANOVA Table for L value for colour by position in pot

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Between groups	6.70009	2	3.35004	80.44	0.0000
Within groups	0.249867	6	0.0416444		
Total (Corr.)	6.94996	8			
Between groups	39.8489	9	4.42765	9.41	0.0000
Within groups	41.8962	89	0.470744		
Total (Corr.)	81.7451	98			

APPENDIX 10: MULTIPLE RANGE TESTS TABLES

Multiple Range Tests for moisture by position in pot

Method: 95.0 percent LSD

position in pot	*Count*	*Mean*	*Homogeneous Groups*
1	3	61.9667	X
2	3	62.7333	X
3	3	66.4	X

* denotes a statistically significant difference.

Multiple Range Tests for Hardness by steam cooked Ga-*kenkey* sample

Method: 95.0 percent LSD

sample	*Count*	*Mean*	*Homogeneous Groups*
12.5MH	10	0.5908	X
15MH	10	0.9827	X
15MNH	10	2.007	X
12.5MNH	10	2.3705	X
5MH	10	5.0211	X
7.5MH	10	6.2131	XX
5MNH	10	7.901	X
7.5MNH	9	10.7364	X
10MH	10	17.2604	X
10MNH	10	18.1605	X

* denotes a statistically significant difference.

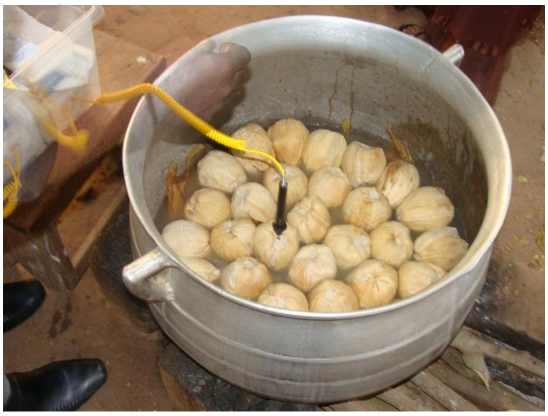
APPENDIX 11: STEAMING CONDITIONS USED IN STEAM COOKING

Steaming cooking with corn husk

Steaming cooking without corn husk

Plate 1: Steaming conditions used in steam cooking Ga-*kenkey*

APPENDIX 12: LAYERS OF GA-*KENKEY* IN THE SAME COOKING POT



Bottom layer

Middle layer

Top layer

Plate 2: Different layers of Ga-*kenkey* in the same cooking pot