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DIETARY RISK ASSESSMENT DUE TO BISPHENOL A (BPA) IN FANTE KENKEY

BY

FRANCISCA AKABOKALIE AGALIK

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FRANCISCA AKABOKALIE AGALIK

(BSc. Catering and Hospitality Education)

A thesis submitted to the **Department of Food Science and Technology**, Kwame Nkrumah University of Science and Technology, Kumasi in partial fulfillment of the requirements for the award of

MASTER OF SCIENCE IN FOOD QUALITY MANAGEMENT

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Francisca Akabokalie Agalik ………………………… …………………...
(PG 7046716)
Student Name and ID Signature Date

Certified by:

Dr Mrs. G. M Ankar-Brewoo …………………………. …………………..
(Supervisor) Signature Date

Certified by:

Dr. Mrs. Faustina Dufie Wireko-Manu ……………………… …………………...
(Head of Department) Signature Date

ABSTRACT

The relative inexpensiveness of plastics has contributed to its ubiquity. Plastics are used as packaging materials for several food products. Inherent in these plastics is Bisphenol A, a chemical with estrogen-mimicking properties. The continuous use of plastic films as a primary packaging material for Fante kenkey is a worry, as Bisphenol A may leach from the plastic films into the Fante kenkey. This study set out to determine the risks associated within the consumption of Fante kenkey wrapped in plastic films. A dietary questionnaire was used to collect information on the consumption of Fante kenkey in the study area. Fante kenkey samples were homogenised and Bisphenol A extracted using acetonitrile as part of a QuEChERS method. Extracts were then analyzed using a Cecil-Adept Binary Pump HPLC (High Performance Liquid Chromatography) coupled with a Shimadzu fluorescence detector. Bisphenol A was detected in 54% of the samples analyzed, with a range from 5.5×10^{-8} mg/g to 3.155×10^{-6} mg/g. The Palisade @Risk software was used to run a Monte Carlo simulation at 1000,000 iterations to obtain the risks. Chronic daily intake of Bisphenol A among consumers had a mean, median and mode of 6.278×10^{-7}, 2.453×10^{-7} and 1.022×10^{-7} respectively. The Hazard quotients presented in the study were all below 1, indicating no significant risk associated with the consumption of Fante kenkey containing Bisphenol A. Margin of exposure values were also above 10,000 indicating a low public health concern. Though the population under study is at no significant risks, producers of Fante kenkey must be encouraged to desist from the use of plastic films as a packaging material.

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ABBREVIATIONS

AT	Averaging Time
BMDL	Benchmark Dose Lower Bound
BPA	Bisphenol A
BW	Body Weight
CD	Compact Disk
CDI	Chronic Daily Intake
CR:	Contact Rate
DVD	Digital Video Disk
ED	Exposure Duration
EF	Exposure Frequency
HQ	Hazard Quotient
MoE	Margin Of Exposure
PVC	Polyvinyl Chloride

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

As indicated by Russian chemist Aleksandr Dianin, Bisphenol was discovered in 1891. It has been utilized since the 1950s to solidify polycarbonate plastic and make epoxy pitch, which is contained in the covering of sustenance and refreshment containers (Rogers, 2013). Bisphenol A (BPA) is a member of the diphenyl methane derivatives; it is an exhausting crystalline solid that is soluble in natural solvents, however inadequately soluble in water (Niu ,2015) and commercially utilized in 1957.

BPA is used to manufacture plastics and epoxy gums. BPA-based plastic is clear and extreme and is made into an assortment of regular customer merchandise, for example, infant and water bottles, food storage containers, power fittings, and vehicle spare parts. In Ghana, plastics are used in the packaging of food including Fante kenkey, porridge, banku, rice etc. According to Pivnenko *et al*. (2015), epoxy tars including BPA are utilized as lining and coatings within numerous food and beverage cans. In 2015, a 4 million tons' value of BPA synthetic were produced for assembling polycarbonate plastics (French Constitutional Council, 2015) which was used in the manufacturing of games gear, restorative and dental contraptions, compact discs, family unit hardware, eyeglass focal points, foundry castings, and the coating of water funnels.

Fante kenkey or 'Dorkuno' is a staple Ghanaian local dish which is similar to sourdough dumpling. It is packaged in transparent plastic film and plantain leaves. Fante kenkey is usually served with stew, soup or pepper sauce and fried fish. The Fante kenkey is normally prepared at a boiling temperature of 65°C (125°F). This high temperature is likely to enhance migration of Bisphenol A from the transparent plastic film. Moreover, BPA displays estrogen impersonating, hormone-like properties that increase concern over its presence in food containers and Fante kenkey. Many government institutions have investigated the safety of BPA since 2008; which made a few avoid the use of polycarbonate items (CERHR, 2007).

In Ghana, a study conducted by Mensah (2013) showed that Fante kenkey wrapped in polyethylene films preceding cooking exposes the kenkey to possible contamination with Bisphenol A (BPA) and Phthalates. The author added that these chemicals leach from the polyethylene into the Fante kenkey as polyethylene was not intended for boiling temperature. Similarly, in Ghana, Ayiku (2013) reported that though the pellets utilized for the manufacture of the polyethylene films are food grade, these polyethylene films are meant for packaging of food under normal room temperature only and not for cooking. He further indicated that massive education on the risk of cooking food wrapped in polyethylene films and the need to utilize plantain leaves only in packaging the kenkey was ongoing among kenkey processors and sellers.

The US Government in 2006 supported an evaluation of scientific literature on BPA. At the end of the survey, according to Vom Saal *et al.* (2007), which was conducted by thirty-eight specialists in fields (Bisphenol A) concluded that, BPA at concentrations found in the human body is related with organic changes in prostate, breast, testis, mammary glands, body size, brain structure and chemistry. Vogel (2009) also came out with similar findings in the behavior of laboratory animals. The results further expressed that the normal BPA levels in humans were higher than those that cause damage to various creatures in research centers. Ghana government however has no known sponsored studies in BPA.

1.2 Problem Statement and Justification

The consumption of Fante kenkey is increasing in recent years. In the preparation of this meal the sourdough dumpling is wrapped in plastic flexible films before final packaging with the plantain leaves. The packaged par boiled dough is then boiled for about 2 hours to produce kenkey. This condition of boiling is likely to cause the leaching of BPA from plastics into the kenkey. There is enough data in literature which support the leaching of bisphenol a into packaged food products. However little data exist for the levels of BPA in the prepared fante kenkey. Hence the exposure levels and associated risk have not been quantified as this data will assist in the regulation of plastic film packaged fante kenkey by the right authorities concern. There is therefore the need to assess the levels of BPA in fante kenkey and consequently the risks associated with its consumption by consumers.

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1.3 Main Objective

The general objective is to determine the toxicological safety limit of BPA in plastic film packaged fante kenkey.

Specifically, the study sought to:

1. Determine the levels of Bisphenol A in plastic film packaged fante kenkey.
2. Assess the dietary exposure and risk due to Bisphenol A in plastic film packaged fante kenkey.

CHAPTER TWO

LITERATURE REVIEW

2.1. Bisphenol A (BPA)

Bisphenol A (BPA) is a monomer and found in epoxy resins regularly utilized as a part of can linings and hard polycarbonate plastics, for example, infant bottles, water bottles, food storage containers, power fittings, and vehicle body primers. It is generally found in the environment since it gives a defensive obstruction amongst food and metal in cans, and furthermore gives shape and solidness (affect protection) to plastics.

$HO\text{-}C_6H_4\text{-}C(CH_3)_2\text{-}C_6H_4\text{-}OH$ is the chemical formula of Bisphenol A. Bisphenol A was first synthesized as an artificial estrogen. Bisphenol A has turned out to be prominent in $BMDL_{10}$, LD_{50}; as a result of its capacity to form cross-links with different chemicals (Chemical fact sheet, 2012). Alonso-Magdalena *et al.* (2006) stated that, the properties of Bisphenol A empower it to be utilized as a raw material for products such as, polymers and epoxy tars. These products are used for the manufacture of food and beverage containers and sealants in dental products. These are altogether made possible because of the properties of the chemical. Production of Bisphenol A stands tall among different chemicals, in light of its wide utilization. In 2003, in excess of 6.4 billion pounds of BPA were produced around the world. Its annual growth rate has been evaluated between 6 to 10 % according to Vom Saal *et al*. (2005).

Humans being get exposed to this synthetic or chemical due to the mobilization. However, in most developed countries, it is used to formulate polycarbonate plastics and also to line jars or cans (Calafat *et al*., 2005). When foods with very high or very low pH or foods at high temperature come into contact with plastic material, it often leads to leaching of Bisphenol A from the plastic material into the food matrix (Vom Saal *et al.*, 2005). The functions of endocrine system can also be disrupted by BPA. (Vom Saal *et al.*, 1998). Studies carried out by Vom Saal *et al.* (2005) involving the use of laboratory animals as test subjects encountered even similar problems when the doses of Bisphenol A presented to the animals were low. From the study, the results indicated that the presence of BPA in the human body is a requisite for disaster and they can change the balance in the human body. The study however, added on to existing knowledge of presence of BPA in human body.

2.2. Characteristics of Bisphenol A

Bisphenol A is produced by a chemical reaction between phenol and acetone and is catalyzed by an acid. Bisphenol A has the chemical formula $C_{15}H_{16}O_2$ and atomic mass number of 228.29 g/mole (Niu, 2015).

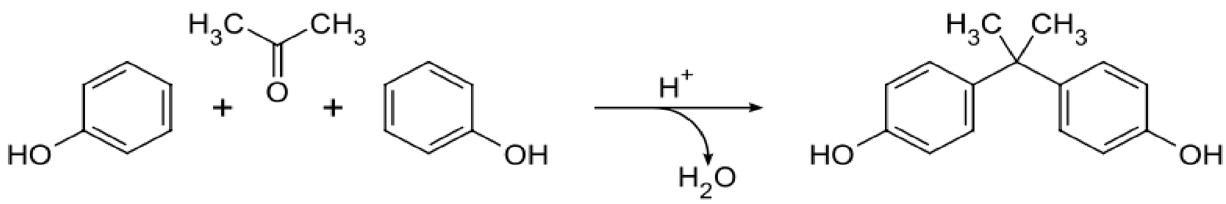

Figure 2.1: Production of Bisphenol A

It has a European Chemical Substances Information System (EINECS) number of 80-05-7 and EC No 201-245-8. It's IUPAC name is 4,4'-Dihydroxy-2,2-diphenylpropane, otherwise known as 2,2-bis(4-Hydroxyphenyl) propane or 4-[2-(4-Hydroxyphenyl) propan-2-yl] phenol. Bisphenol A is additionally referred to in different sectors as Bis (4-hydroxyphenyl) dimethyl methane,4,4′-Dihydroxydiphenyl propane and Diphenylolpropane.

Bisphenol A have been portrayed by Lewis (2001) and O'Neil (2006) as a white solid, which are available in crystalline form, or as flakes. In the presence of dilute acetic acid, they solidify as crystals whiles they show up as needles within the sight of water (Lide and Milne, 1994). They are known to produce mild phenolic odour during normal room temperature (O'Neil, 2006). Bisphenol A melts inside a temperature range of 150– 158 °C, likewise bubbles within a temperature range of 360– 398 °C at 101.33 kPa (IUCLID, 2000; Cousins *et al*., 2002).

The thickness (density) of BPA is 1.195 kg/dm3 at 25 °C (IUCLID, 2000; Lewis, 2001), and has a vapor pressure of 5.3 x 10−6 Pa at 25 °C (Cousins *et al*., 2002). Hansch *et al*. (1995) stated that BPA is a moderately hydrophobic compound and has an octanol–water partition coefficient (log *P*ow) of 3.32 and the two-hydroxyl groups make it somewhat polar. According to (Lide and Milne, 1994; O'Neil, 2006; Lide, 2004), BPA is dissolvable in various compounds and these include: acetic acid, aqueous alkaline solution, alcohol, acetone, benzene and diethyl ether.

In water, its solvency is 120–300 mg/L at 25 °C and additionally has a pKa value of between 9.59 and 11.30 (Cousins *et al*., 2002). The pKa value influences BPA to stay in its non – ionized shape in fluid media and even possible in pH values below 7. The BPA molecule has a fairly solid fluorophore and it can be identified by its fluorescence. Stephen (2000) also stated that its chromophore is relatively weak, and the sensitivity of ultraviolet (UV) identification is much lower than that of fluorescence identification. BPA does not persist or hold in the environment, despite the fact that it is genuinely stable in its solid form. A report by Cousins *et al*. (2002) indicated that the dominant loss process for BPA in river, water and soil is aerobic biodegradation, with a degradation half-life of approximately 4.5 days. The photo-oxidation half-life for BPA in atmosphere is around four hours with its loss process due to the rapid reaction with hydroxyl radicals (Cousins *et al*., 2002).

2.3. Uses of Bisphenol A

Since 1957, Bisphenol A-based plastics have been in business primarily in making plastics, and products (Bisphenol A Global Industry Group, 2002). According to U. S. Health day News Reporter (Gardner, 2009), at the very least 3.6 million tones (8 billion pounds) of BPA are utilized by manufactures yearly. It is the most widely recognized type of polycarbonate plastic and a key monomer in epoxy tars production (Replogle, 2009). Under biphasic conditions, Bisphenol A and phosgene respond to give polycarbonate and the hydrochloric corrosive is searched with watery base:

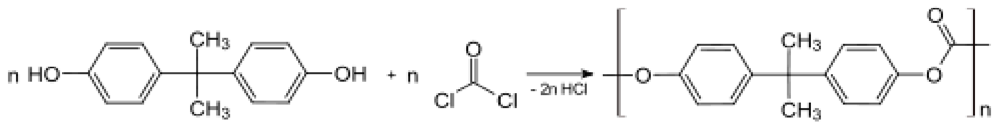

Figure 2.2: Production of polycarbonate

In place of phosgene, diphenyl carbonate may be utilized. Phenol is discarded as opposed to hydrochloric acid. This transesterification procedure avoids the poisonous quality and treatment of phosgene (Wittcoff *et al.,* 2004).

Apart from food related issues, a study by Fiege *et al*. (2000) showed that child and water bottles, sports hardware, restorative and dental devices, dental fillings sealants, CDs and DVDs, family unit gadgets, eyeglass focal points, foundry castings, and the coating of water funnels are normal items produced using polycarbonate plastic, which is clear and relatively shatterproof.

BPA is likewise utilized as part of the synthesis of polysulfones and polyether ketones, as an antioxidant in few plasticizers, and as a polymerization inhibitor in PVC. Erickson (2009) likewise expressed that epoxy gums containing Bisphenol A are utilized as coatings inside all food and beverage cans, however, in Japan, according to Bryne (2008), epoxy coating is mostly replaced by PET film due to BPA health concerns. Bisphenol A is like wise an antecedent to the resistant tetrabromobisphenol A, and was used as a fungicide(PANNA, 2011).

According to Raloff (2009), in a number of thermal paper applications such as point of sale receipts, airline tickets, event and cinema tickets, labels, BPA is a preferred color developer used in carbonless copy paper. At the point when utilized as a part of thermal paper, BPA is available as "free" (i.e., discrete, non-polymerized) BPA, which is probably going to be more available for exposure than BPA polymerized into a resin or plastic (U.S. EPA, 2010). After taking care of, BPA in thermal paper can be transferred to skin, and there is some worry that residues on hands could be ingested through coincidental hand-to-mouth contact. (Zalko *et al*., 2011).

Moreover, a few investigations recommend that dermal assimilation may contribute some fraction to the general human exposure (Biedermann, Tschudin *et al*., 2010; Zalko, Jacq ues *et al*. 2011). The utilization of BPA in paper may likewise add to the presence of BPA in the stream of recycled paper and in landfills according to European data (JRC-IHCP 2010).

In spite of the fact that there are no estimates for the measure of BPA utilized as a part of thermal paper in the United States, in Western Europe, the volume of BPA reported to be utilized as a part of thermal paper in 2005/2006 was 1,890 tons for every year, while total production was estimated at 1,150,000 tons for each year (JRC-IHCP, 2010), which accounts for roughly 0.2% of the annual use of BPA. Studies by Pivnenko *et al*. (2015) reported that in paper recycling, potential spreading and accumulation of BPA suggest its essence for decades' in paper recycling loop even after a hypothetical ban. Epoxy resin could conceivably contain BPA, and is utilized to tie gutta percha in some root channel systems (Marciano *et al*., 2011).

2.4. Identification in plastics

For recycling purposes, a Plastic identification code is used for splitting plastic packaging into seven broad classes. In the United State of America, as of 2014 there were no BPA labeling requirements for plastics. "In general, plastics that are marked with Resin Identification Codes 1, 2, 3, 4, 5, and 6 are probably not going to contain BPA. A few, however not all plastics that are marked with the Resin Identification Code 7 might be made with BPA (NIHS, 2010). According to Biello (2008) type 7 plastics, such as polycarbonate (sometimes related to the letters of "PC" near the recycling symbol) and epoxy resins, are produced using Bisphenol A monomer. Type 3 (PVC) may contain Bisphenol A as an antioxidant in "flexible PVC" softened by plasticizers, however not rigid PVC like pipe, windows, and siding (Fiege *et al*., 2000).

2.5. Human Exposure to BPA

Diet, including ingestion of contaminated food and water is the major exposure route to BPA (Cichna-Markl, Methods, 2012). Bisphenol A is leached from the lining of food and beverage cans or jars where it is utilized as an ingredient in the plastic used to protect the food from direct contact with the can (EWG, 2007). Moreover, it is particularly likely to leach or filter from plastics when they are cleaned with harsh detergents or when they contain acidic or high-temperature liquids. BPA is utilized to form epoxy resin coating of water pipes; in older buildings, such resin coatings are used to avoid replacement of deteriorating pipes.

In the working environment, while dealing and manufacturing products which contain BPA, inward breath and dermal exposures are the most probable courses (TSAI, WENTIEN, 2006). There are numerous uses of BPA for which related potential exposures have not been completely evaluated including advanced media, electrical and electronic equipment, cars, sports safety equipment, electrical laminates for printed circuit sheets, composites, paints, and glues.

Notwithstanding being available in numerous products that individuals use on a daily basis, BPA can bioaccumulate, particularly in water bodies. In one study, it was seen that in spite of the fact that BPA is biodegradable, it is as yet recognized after wastewater treatment in numerous concentration of roughly 1 ug/L. This investigation likewise looks at different pathways where BPA could possibly bioaccumulate and discovered low direct potential in microorganisms, green growth, invertebrates, and fish in the earth recommending that some environmental exposures more less likely (TSAI, WEN-TIEN, 2006).

According to Calafat *et al*. (2005) the Centers for Disease Control and Prevention (CDC) in 1998-1994 discovered Bisphenol A in the urine of 95% from adults sampled and in 93% of children and adults tested in 20032004 (Calafat *et al*.,2008). The USEPA Reference Dose for BPA is 50 µg/kg/day which is not enforceable however, is the recommended or suggested safe level of exposure.

The Consumer Reports magazine in November 2009 published an analysis of BPA content in some canned foods and beverages, where in particular cases the content of a single can of food could exceed the FDA "Cumulative Exposure Daily Intake" limit (Consumer Report, 2009).

A report by World Health Organization (2009) in Canada showed that the majority of canned soft drinks tested in their study had low, but measurable levels of Bisphenol A. Also, Schecter *et al*. (2010) conducted a study in the University of Texas School of Public Health about human exposure to BPA using samples of fresh and canned foods. The results indicated that, out of 105 samples of fresh and canned foods, BPA was in 63 of the foods, including fresh turkey sold in plastic packaging and canned infant formula.

Food Packaging and Bisphenol A and Bis (2-Ethyhexyl) Phthalate Exposure were also conducted by Ruthann and Rudel (2011) in the United State of America using a dietary intervention. The researcher chose 20 respondents in view of their self-detailed use of canned and packaged foods to study BPA. From the study, respondents ate their usual diets, followed by three days of consuming foods that were not canned or packaged. The findings of the study indicated that evidence of BPA in respondents' urine decreased by half to 70% during the period of eating fresh foods; and, also, respondents' reports of their food practices suggested that consumption of canned foods and beverages and restaurant meals were the most likely sources of exposure to BPA in their usual diets. However, the researcher indicated that, even beyond these 20 respondents, BPA exposure in the country is widespread, with detectable levels in urine tests in excess of an expected 90% of the U.S. populace. Also, consumption of soda, school lunches, and meals prepared outside the house were statistically significantly associated with higher urinary BPA according to the study conducted in U.S. (Lankind and Naiman, 2010) .

Studies carried by Paul (2011) at the Harvard School of Public Health showed that consumers were exposed to BPA when used in the lining of food cans for food absorption. The researcher further indicated that when respondents ate the canned soup foods, they experienced more than a 1,000 percent increase in their urinary concentrations of BPA, compared to when they dined on fresh soup. Also, Carwile (2009) found that drinking from polycarbonate bottles expanded urinary Bisphenol A levels by 66%, from 1.2 ug/g creatinine to 2 ug/g creatinine and Ahearn (2008) suggested that individuals wishing to lower their exposure to Bisphenol A should avoid canned food and polycarbonate plastic containers unless the packaging indicates the plastic is Bisphenol A-free, and, also avoid microwaving food in plastic containers, placing plastics in the dishwasher, or using harsh detergents.

Exposure can likewise happen through air and through skin absorption, besides diet (Lang *et al.*, 2008). Free BPA is found in high fixation in thermal paper and carbonless duplicate paper, which would be relied upon to be more accessible for exposure than BPA bound into resin or plastic (Fukazawa *et al*., 2001). Babu *et al*. (2015) stated that notable uses of thermal papers include receipts, event and cinema tickets, labels, and airline tickets. A study reviewed by Biedermann *et al*. (2010) in Switzerland about thermal printing papers exposure to human showed that 11 of 13 thermal printing papers contained 8 – 17 g/kg Bisphenol A (BPA).

The researcher also stated that, upon dry finger contact with a thermal paper receipt is around 1 ug BPA (0.2 – 6 ug) was then transferred to the forefinger and the middle finger, and for wet or oil fingers roughly 10 times more was transferred. Extraction of BPA from the fingers was conceivable up to 2 hours after exposure. Furthermore, it has been exhibited by Liao and Kannan (2011) that thermal receipts set in contact with paper cash in a wallet for 24 hours cause a dramatic increase in the concentration of BPA in paper currency, making paper money a secondary source of exposure. Pivnenko *et al*. (2015) stated that BPA in the majority of the waste paper sampled (newspapers, magazines, office paper, and so on), showed a direct effect of contamination through paper recycling and free BPA can readily be transferred to skin, and deposit on the hands. Bodily intake through dermal retention (99% of which originates from taking care of receipts) has been appeared to the general population to be 0.219ng/kg bw/day. Occupationally exposed persons absorb higher amounts at 16.3 ng/kg bw/day, whereas aggregate intake food/beverage/environment) for adults is estimated at 0.36–0.43 ug/kg bw/day whilst estimated intake for occupationally exposed adults is 0.043–100 ug/kg bw/day.

A study by Koch (2011) found that Americans of all age groups had twice as much BPA in their bodies as Canadians; the explanations behind the dissimilarity were unknown, as there was no proof to recommend higher measures of BPA in U.S. foods. The consumer products available in the U.S. containing BPA were BPA-free in Canada. As indicated by another researcher, differences in the studies might have been the parameter or the methodology. Differences in sampling, in the logical techniques utilized and in the sensitivity of the measures could be the reason (Vandenberg, 2011).

Lakind *et al.* (2015) compared data from the National Health and Nutrition Examination Surveys (NHANES) from four eras in the vicinity of 2003 and 2012. The urinary BPA data showed that the median daily intake for the general populace is around 25 ng/kg/day and beneath current health based rules. Added to that, the daily intake of BPA in the United States has decreased significantly compared to the intakes estimates in 2003–2004.

However, according the researcher public attention and government action could decrease the exposure of BPA in food fairly. These investigations did exclude kids under age six. Age of exposure is a critical factor in determining the degree to which endocrine disrupting by the chemical affect the developing fetuse or newborn children has not the same adult (Diamanti- Kandarakis, 2009).

2.6. Health Effect

The largest exposure humans have to BPA is by mouth from such sources as food packaging, the epoxy lining of metal food and beverage cans, and plastic bottles. In 2012, the United States' Food and Drug Administration (FDA) banned the use of BPA in baby bottles (Mirmira, 2014); however, a spokesperson for the Environmental Working Group said, "If the agency truly wants to prevent people from being exposed to this toxic chemical associated with a variety of serious and chronic conditions it should ban its use in cans of infant formula, food and beverages" (FDA, 2012). The Natural Resources Defense Council called the move insufficient, saying the FDA expected to forbid or ban BPA from all food packaging. The FDA maintains that the organization continues to support the reduction of BPA for use in products that hold food (Mirmira, 2014).

The Environmental Protection Agency (EPA) likewise holds the position that BPA is not a health concern. In 2011, the main researcher of the United Kingdom's Food Standards Agency Andrew Wadge commented on dietary exposure of adult humans to BPA in 2011 US survey (Teeguarden *et al.*,2011) saying, "This proves other autonomous studies and adds to the proof that BPA is rapidly absorbed, detoxified, and disposed from people, thusly is not a health concern"(Andrew, 2011).

The ongoing laboratory research in 2015 gave reason for worry about the potential dangers of endocrine-disrupting chemicals including BPA in the environment, and that based on the prudent rule these substances should keep on being surveyed and firmly regulated (Gore *et al.*,2015). A report in 2016 said that the potential damages caused by BPA were a topic of scientific debate and that further examination was a need on account because of the relationship between BPA exposure and adverse human health effects including reproductive and developmental effects and metabolic disease.

The US Government in 2006 also supported an evaluation of the scientific literature on BPA. At the end of the survey, according to Vom Saal *et al.* (2007), the group that made up of thirty-eight experts in fields involved with Bisphenol A meeting at Chapel Hill, North Carolina, issued the Chapel Hill Consensus Statement which stated that, "BPA at concentrations found in the human body is related with organic changes in the prostate, breast, testis, mammary glands, body size, brain structure and chemistry, and behavior of laboratory animals." (Vogel, 2009).

2.6.1 Metabolic disease

2.6.2 Obesity

According to Bhandari *et al*. (2013) many animal studies have investigated the relationship between endocrine disrupting chemicals (including BPA) and obesity. In any case, the connection between Bisphenol A exposure and obesity in humans is vague (Oppeneer and Robien, 2015). Proposed mechanisms for BPA exposure to increase the risk of obesity include BPA-induced thyroid dysfunction, activation of the PPAR-gamma receptor, and disruption of neural circuits that regulate feeding behavior (Rezy *et al*.,2014) . In the past, BPA has been viewed as a feeble mimicker of estrogen but now it is proven to be a powerful mimicker (Alonso-Magdalena *et al.*,2012).When it ties to estrogen receptors it triggers elective estrogenic effects that start outside of the nucleus. This distinctive way prompted by BPA has been appeared to adjust glucose and lipid digestion in animal studies (Alonso-Magdalena *et al*., 2010). There are diverse impacts of BPA exposure amid various stages of development. During adulthood, BPA exposure adjusts insulin sensitivity and insulin discharge without influencing weight (Alonso-Magdalena *et al*., 2011).

2.6.3 Thyroid function

Zoller (2007) stated in his work that Bisphenol-A has been appeared to tie to thyroid hormone receptor and maybe affects its functions. Boas (2009) review that environmental chemicals and thyroid function raised worries about BPA impacts on triiodothyronine and inferred that "available proof proposes that overseeing organizations need to control the use of thyroid-disrupting chemicals, especially as such uses relate exposures of pregnant women, neonates and little kids to the operators. Also, some researches stated that B PA altered long-term potentiation in the hippocampus and even nanomolar (10^{-9} mol) dosage could incite critical consequences on memory processes. In 2009, a study conducted by Kashiwagi *et al*. (2009) reviewed summarized BPA unfriendly consequences for thyroid hormone activity and also raises worries about a BPA impact on the anteroventral periventricular nucleus.

2.6.4 Disruption of the Dopaminergic system

A study conducted by Jones and Miller (2008) on review of human participants' concluded that BPA emulates estrogenic movement and influences different dopaminergic processes to improve mesolimbic dopamine action bringing about hyperactivity, attention deficits, and a heightened sensitivity to drugs of abuse.

2.6.5 Cancer

As indicated by the WHO's INFOSAN, carcinogenicity studies directed under the US National Toxicology Program, have demonstrated increases in leukemia and testicular interstitial cell tumors in male rats. Be that as it may, as indicated by the note "these investigations have not been considered as convincing proof regarding a potential cancer risk because of the doubtful statistical significance of the suspicious differences in incidences from controls" (WHO, 2009). A review by Soto and Sonnenschein (2010) showed that Bisphenol A may promote cancer risk. No less than one study recommended that Bisphenol A suppresses DNA methylation (Bagchi and Debasis,2010), which is associated with epigenetic changes (Dolinoy *et al*., 2007). Evidence from animal models is accumulating that perinatal exposure of BPA alters breast development and increases breast cancer risk. In numerous studies, higher susceptibility to breast cancer has been found in rodents and primates exposing to BPA. However, the relationship between BPA and consequent improvement of breast cancer in people is unclear (Rochester *et al*., 2013).

2.6.6 Infertility

As of 2013, the proof to help a connection between BPA exposure and male infertility is weak however limited confirmation does support a relationship with lower sperm quality (Rochester *et al*., 2013). According to Rochester *et al*. (2013), there is speculative proof to help BPA exposure has negative effects on human fertility. However, barely any studies have researched whether intermittent miscarriage is related with BPA levels. Exposure to BPA does not give off an impression of being connected with higher rates of endometrial hyperplasia, yet has been related with increased self-reporting of decreased male sexual function but few investigations have been conducted about this relationship (Rochester *et al*., 2013)

2.6.7 Asthma

Studies carried out by Midoro-Horiuti *et al.* (2010) discovered a connection between BPA exposure and asthma; a recent report on mice has presumed that perinatal exposure to 10 µg/ml of BPA in drinking water increases allergic sensitization and bronchial irritation and responsiveness in an animal model of asthma. An investigation published in JAMA pediatrics has revealed that prenatal exposure to BPA is additionally connected to bring down lung capacity in some young children. This research had 398 mother-newborn child pairs and looked at their urine samples to recognize concentrations of BPA. The result showed that every 10-fold increase in BPA was attached to a 55% increase in the chances of wheezing and the higher concentration of BPA during pregnancy were connected to decrease lung capacity in children under four years old yet the connection disappeared at age 5. Also, at the University of Maryland School of Medicine, an Associate professor of pediatrics said, "Exposure during pregnancy, not after, seems, by all accounts to be the critical time for BPA, perhaps on the ground that it is influencing important pathways that help the lung develop (Oaklander, 2014).

Researchers at the Columbia Center for Children's Environmental Health in 2013 likewise found a connection between the compound and an increased risk for asthma. They revealed that children with larger amounts of BPA at ages 3, 5 and 7 had increased chances of developing asthma when they were between the ages of 5 and 12. They however stated that the children in this study had about the same concentration of BPA exposure as the average U.S child. Furthermore, an instructor at Columbia University Medical Center stated that they saw an increased risk of asthma at fairly routine, low doses of BPA (Donohue, 2013). Another researcher who studies environmental chemicals and children's health reported that while the investigation does not demonstrate that BPA causes asthma or wheezing, it is an important study since we don't know a clue about a considerable measure at the present time about how BPA affects immune response and asthma. They measured BPA at different ages, measured asthma and wheeze at multiple points, and still found consistent associations (Harley, 2013).

2.7 Production and Packaging of Fante kenkey

In Africa, over the years, fermentation has been utilized as a food processing and preservation method or technique. According to Steinkraus (1996) porridges, alcoholic and nonalcoholic beverages, bread, fermented fish and dairy products are from fermentation processes. In Ghana, Nigeria and Ethiopia, specific fermented foods include kenkey, nsiho, fomfom, banku, momoni' and koko. Kenkey is a sour tasting cooked solid dumpling of elastic consistency produced from fermented maize dough shaped into balls or cylindrical forms and wrapped in maize husks or plantain leaves. It has a moisture content of between 62 to 68 %, a pH of 3.7 and a time span of usability (shelf life) of around 3 to 4 days. There are two primary kinds of kenkey, Fanti kenkey locally referred to as Dokono and the Ga kenkey known as Komi. The materials for packaging or bundling the balls of kenkey and the addition of salt to Ga kenkey make the main differences. Ga kenkey has a shorter shelf life than Fanti kenkey and this is because Fanti kenkey is wrapped in several layers of plantain leaves, which gives it a longer shelf life than the Ga kenkey.

Kenkey is a staple for the vast majority of the peoples' groups in the coastal areas of Ghana, principally the Gas, Fantis and Ewes. The type of kenkey produced depends on the ethnic affiliation. In Ghana, the bulk of the maize produced is consumed in the form of fermented products by Ghanaians in the Ashanti, Central and Western Regions of

Ghana as Fanti kenkey whilst those from in and around Accra produce the Ga kenkey. In any case, as a result of urbanization and movement of individuals or people from one place to the other, kenkey has assumed an important place in the diets of most workers henceforth it can be found in all the urban centres in Ghana as a ready-to-eat street food. The traditional method of kenkey production has prior been depicted by different researchers including Christian (1966,1970), Whitby (1968), Dovlo (1970), NyarkoMensah and Muller (1972), Plahar and Leung (1982), Sefa-Dedeh and Plange (1989),

Halm *et al.*(1993, 1996 and 2004). It includes the following processes as outlined in Figure 1 below: cleaning; steeping; milling and doughing; dough fermentation; *aflata* preparation; mixing of *aflata* and raw dough; moulding and packaging and cooking into kenkey.

Table 1: BPA Concentration Standards In Foods From Other Countries

Country	Food	Concentration (ng/g)		Reference (Source)
		Range	Mean	
New Zealand	Beetroot[c]	22.0 – 24.0	23.0	Thomson and Grounds, 2005
	Sauces[c]	11.0 – 21.0	15.33	
	Meat[c]	29.0 – 98.0	63.5	
	Fish[c]	<20.0 – 109.0	23.0	
Japan	Cookies[p]	1.0 – 14.0	5.5	Sajiki *et al.*, 2007
	Tuna bread[p]	nd – 8.0	4.67	
	Corn[c]	3.0 – 20.0	9.33	
USA	Spaghetti and meatballs[p]	2.74 – 4.31	3.67	Schecter *et al.*, 2010

	Cinnamon Apple sauce[p]		<0.20	
Belgium	Beverages[c]	<0.02 – 8.1	1.01	Greens *et al.*, 2010
Canada	Fish[c]	9.0 – 534.0	137.0	Cao *et al.*, 2010
	Soup[c]	4.1 – 189.0	78.66	
	Vegetables[c]	4.3 – 92.0	20.0	
Portugal	Seafood[c]	nd – 62	21.17	Cunha *et al.*, 2017
Greece	Softdrinks[p]	nd – 10.2	2.55	Tzatzarakis *et al.*, 2016
Poland	Seafood[c]	32.8 – 37.0	–	Konieczna *et al.*, 2018
	Corn[c]	50.9 – 145.4	–	

Foot notes: p: plastic-wrapped; c: canned

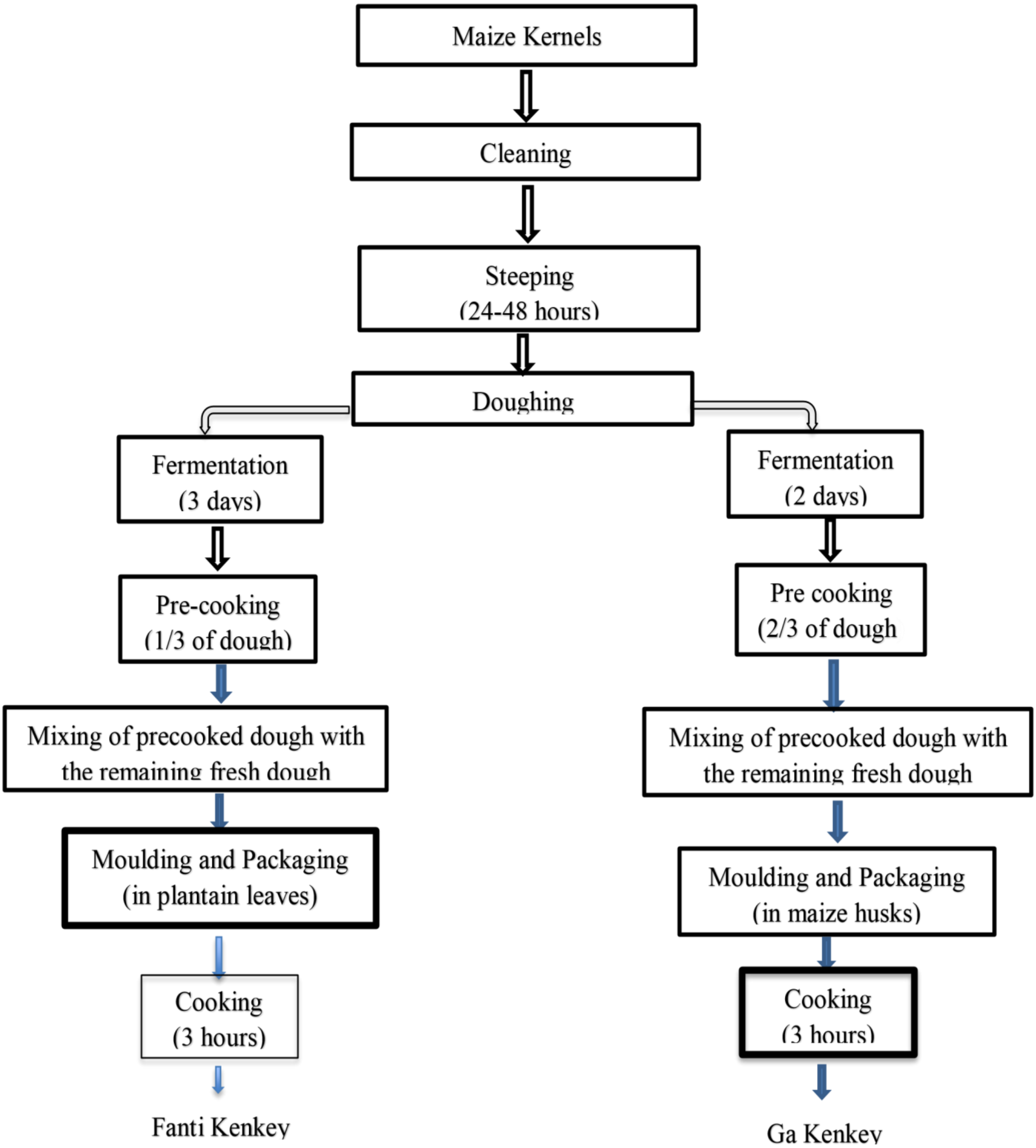

Figure 1: Process flow diagram for kenkey production in Ghana.
Source:(Halm *et al*., 1996).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Source of Foods

Fante kenkey were collected from kenkey manufacturers at Yamoransa in the central region, Dako Jum (Dokonu Jum), Susanso and Offinso in the Ashanti region of Ghana.

3.1.2 Chemicals

Acetonitrile was obtained from Prolabo VWR International (Paris-France). $MgSO_{4,}$ NaCl and Bisphenol A standards were obtained from Sigma Aldrich, Germany

3.2 Methods

3.2.1 Study area

The study area included Central and Ashanti regions of Ghana. The study communities were Yamoransa in the central region of Ghana, which is about 4 hour drive away from the Ashanti region. Offinso is between 45 minutes to an hour drive from Kumasi. Dakojom (*Dokono Dwuom*) is 15 to 30 minutes' drive away from KNUST and Susanso is 5mintes drive away from Tech junction. These areas were chosen for the study because the areas are noted for producing more and better Fante kenkey.

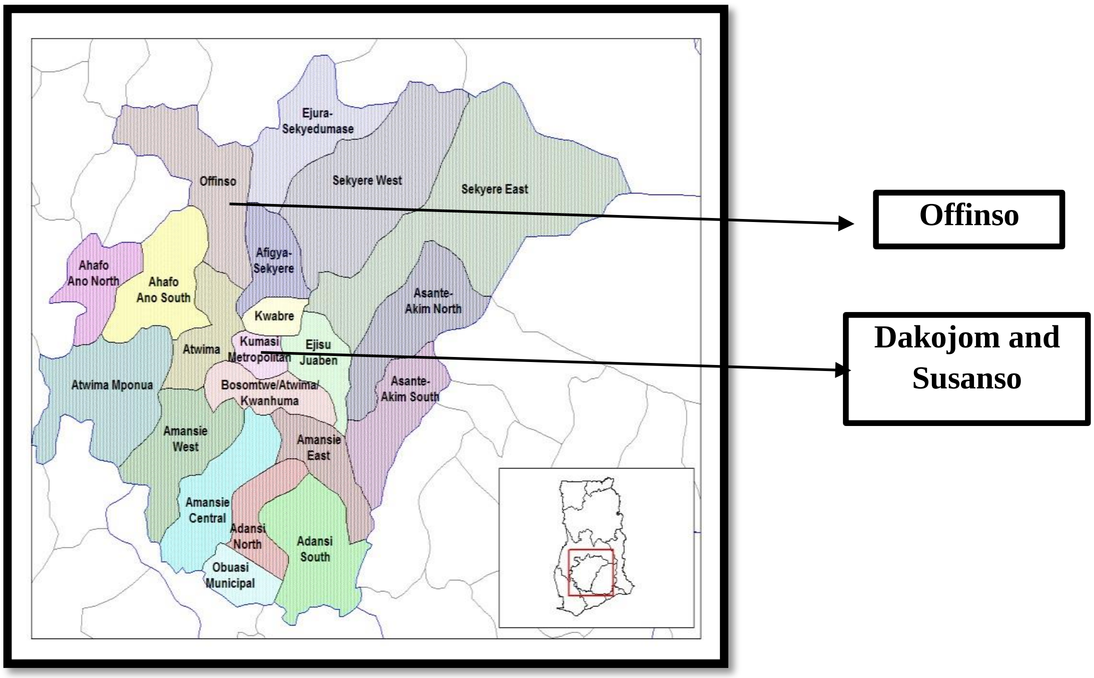

Figure 2.3: Map of Ashanti Region

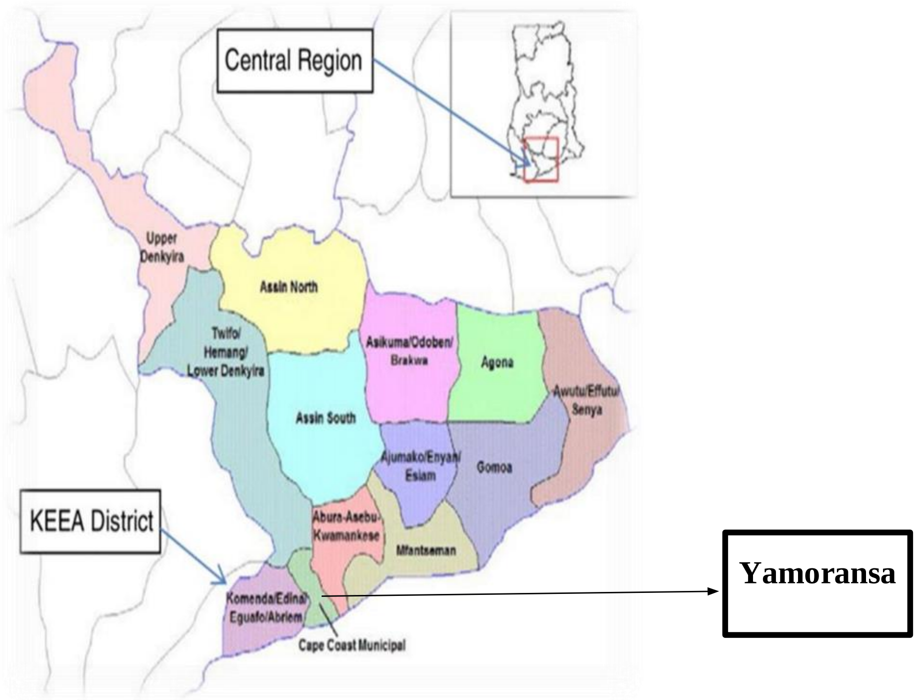

Figure 2.4: Map of Central Region

3.2.2 Study Population and selection

A total of 52 samples with and without plastic film wrappings were randomly selected from the study period, which was between May and October 2017. Of the 52 samples, 34 food samples had plastic film wrapping and 18 samples without plastic film.

3.2.3 Study sampling and participation

Lists of Fante kenkey manufacturers were identified. Fifty-two (52) of them were selected randomly for the study. The selection criterions for the respondents were based on the number of years a seller has spent in selling the product. The minimum number of years was chosen to be five (5). Rationale for the study was explained to the manufacturers. With the assistance of the vendors, participants were selected to undertake the study after giving their consent.

3.2.4 Dietary and lifestyle questionnaires

A structured one-week dietary recalls questionnaire was prepared covering the demographics, exposure frequency and durations as shown in appendix 1 and administered to a total of three hundred respondents. The content of the questionnaire was initially explained to the respondent to obtain their consent. The same questionnaires were asked for breakfast, lunch and supper. The picture of Fante kenkey, which varied from (1/3, ½, 2/3, 1, 1.5, 2, 2.5, 3), were used to confirm the answering of questionnaire by respondent. The prices of "Fante kenkey" were GH₵ 50p, GH₵ 1.00, GH₵ 2.00 were purchased from Fante kenkey sellers. Pictures with the weight (g) of each was measured (80, 125, 160, 260, 365,495, 660, 835) and used as a standard weight for the study. The standard weights were used as a basis for the quantities of "Fante kenkey" consumed by the respondent per day. The respondents were required to indicate the number of times they consume 'Fante kenkey' per day. The questionnaire also required respondents' biodata to be taken. The questionnaire was pre- tested before the study.

3.2.5 Sampling, Sample Preparation and Storage

The Fante kenkey samples were obtained from Central and Ashanti regions of Ghana. 17 samples were obtained from Yamoransa in the central region .15 samples from Offinso, 10 from Dakojom (*Dokono Dwuom*) and 10 from susanso. These areas were chosen for the study because the areas are noted for producing more and better Fante kenkey. The samples were homogenized using a Crompton blender (cq Taura 500, India). Samples were then packaged into Ziploc bags and stored at -15 °C pending further analysis.

3.2.6 Extraction and Clean-up

This was done following a QuEChERS method as proposed by UCT (2013). A weight of 10 g of the homogenate was weighed into a 50 mL centrifuge tube and 10ml of acetonitrile added. The tube was then shaken vigorously for 10 min. Subsequently; 4 g of $MgSO_4$ and 1 g of NaCl were added to the tube and vortexed for 10 s. The tube was then shaken for 10 min and centrifuged at 4000 rpm for 5 min. The supernatant was then evaporated at 40 °C and reconstituted in 2 ml of mobile phase solution.

3.2.7 Instrumentation

A Cecil-Adept Binary Pump HPLC coupled with Shimadzu 10AxL fluorescence detector (Ex: 230 nm, Em: 316). A Phoenix C18, 5 µm, 3.9 x 150 mm column was used with its temperature maintained at 40 °C. A gradient elution was used with 10mM Potassium Phosphate (Mobile Phase A) and 100% Acetonitrile (Mobile Phase B) at the 5% B for 0 –

2 min, 35% B for 2.1 – 12.5 min, 70% B for 12.6 – 17 min and 5% B for 18.1 – 23 min.

A volume of 100 µL was injected for determination of Bisphenol A.

3.7 Data analysis

The data obtained from the food frequency questionnaire survey was entered into Microsoft Excel. Palisade @Risk software which was used to fit the distributions of the hazard concentration (C) average exposure concentration over the period (e.g., mg/L or mg/m^3) , contact rate (CR) Is the amount of contaminated medium contacted per unit time (L/day m/day), exposure frequency (EF) is a variable that describes how often exposure occurs , exposure duration (ED) is a variable that describes how long exposure occurs , body weight (BW) is the average body mass over the exposure period (kg), averaging time (AT) is the period over which the exposure is averaged (days) . The chronic daily intake (CDI), hazard quotient (HQ) and margin of exposure (MoE) were estimated using the USEPA recommended equations 1, 2 and 3.

CDI = chronic daily intake is the amount of chemical at the exchange boundary (L/day or m^3/day)

HQ = Hazard quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected.

MoE = Margin of exposure is use to estimate the risk of cancer

$$CDI = \frac{CXCRXEFXED}{BWXAT}$$ Equation 1

$$\text{Hazard Quotient (HQ)} = \frac{CDI}{RfD}$$ Equation 2

$$\text{Margin of Exposure (MoE)} = \frac{BMDL}{CDI}$$ Equation 3

Where BMDL is the Benchmark dose lower limit that corresponds to a specific change in an adverse response in unexposed subjects, and the lower 95% confidence limit. The results were expressed as means with standard deviations of the data acquired.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Socio-demographic characteristics of respondents in the Kumasi Metropolis

Majority (56%) of the respondents interviewed were males as shown in 4.1.
This appears that the study captured more males' consumers of Fante kenkey than their female correspondents. Consumers between the ages of 16 and 30 years were seen to consume the product more frequently.
They represented 40% of the total respondents. The youngest of the consumers were between the ages of 0 and 15 years.
The results show that most consumers of "Fante kenkey" within the study area were the youth.

In addition, Table 4.1 also indicated that among the 300 consumers interviewed, 170 were single, which represents 57%, 115 were married which represent 38%, 15 were divorced, which also represents 5%. Moreover, on the educational level of respondents (consumers), majority of the respondents had tertiary education with informal education being the least. Out of 300 consumers' interviewed, 85 of them had tertiary education, 84 had junior high school education, 65 respondents had secondary education, finally, informal education being the least with 21 respondents. This amounts to the fact that the study captured more educated consumers of Fante kenkey than their counterparts.

According to the data collected, Christianity is the dominant religious group in the study areas. Out of 300 consumers interviewed, 203 were Christians representing 68 %, 85 were Muslim representing 28 %, 5 were Traditionalist, representing 2 % and 7 were from other religious groups.

Table 4.1: Socio-demographic characteristics of respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	113	56
	Female	87	44
Age	0-15	35	12
	16-30	121	40
	31-45	106	35
	Above 46	38	13
Marital status	Married	115	38
	Single	170	57
	Divorced/ Separated	15	5
Education level	Informal	21	7
	Basic	45	15
	J.H.S	84	28
	S.H.S	65	22
	Tertiary	85	28
Religious Affiliation	Christian	203	68
	Muslim	85	28
	Traditional	5	2
	Others	7	2

Source: Field Survey, 2017

4.2 Factors of exposure

The chronic daily intake (CDI) was estimated from the concentration of the hazard (BPA), mass of food, exposure frequency, exposure duration and body weight. These variables and their statistical distributions have been presented in Table 4.2.

4.2.1 Mass of food consumed

The mean mass of Fante kenkey consumed by respondents were 507 g, with a range from 80 g to 2505 g. The modal consumed was 80 g; this translates to one-third of a ball of Fante kenkey as shown in the Appendix iii. The lowest 5 % (5^{th} percentile) of the study population consumed 260 g of Fante kenkey per day while the top 5 % (95^{th} percentile) consumed 1095 g. Siaw *et al.* (2018) who also worked in the Kumasi Metropolis reported

66 g to 1094 g as the range for the mass of some frequently consumed foods including Fante kenkey. The wide difference between the values reported could be due to the different foods involved in the study as well as people's preference for them.

4.2.2 Exposure Frequency (EF) and Exposure Duration (ED)

Fante kenkey was consumed on at least one day in a week, as indicated by the min value presented in Table 4.2. This gives a range of 52 days to 364 days per year, thus other consumers take Fante kenkey on virtually every day of the year. This frequency of consumption suggests that Fante kenkey is a staple food. Exposure duration ranged from 1 year to 70 years. Most respondents had been consuming Fante kenkey for 12 years as indicated by the mode. The 95th percentile consumers had consumed Fante kenkey for 44 years as compared to the 9 years of consumption by the 5th percentile consumers.

The table below is the replicate of fante kenkey from the various communities which is converted to central tendency metrics.

Table 4.2: Statistical parameters of Fante kenkey consumption in the Kumasi Metropolis

Variable	Statistical distribution	Central tendency metrics				Percentiles		
		Min*	Max*	Mean	Mode	5th	50^{th}	95^{th}
Hazard (BPA) ($\times10^{-6}$ mg/g)	Expon (7.63865×10^{-7}, -1.59138×10^{-8})	0	3.15	0.76	0	0	0.00615	2.52
Mass of food (g)	Pearson5 (6.3510, 3267.6, -104.87)	80	2505	507.12	80	260	495	1095
Exposure frequency (days)	Negbin (3, 0.024017)	52	364	121.91	104	52	104	364
Exposure duration (years)	Negbin (5,0.18330)	1	70	22.28	12	9	21	44
Body weight (kg)	Negbin (25,0.26767)	12	116	68.40	64	46	70	92

*Min – minimum; max - maximum 2w

4.2.3 Body weight

The body weight of consumers ranged from 12 kg to 116 kg, with 5^{th} and 95^{th} percentile values of 46 kg and 92 kg respectively. Similar findings have been reported by Opoku (2016) and Siaw *et al.* (2018) in studies conducted in the Kumasi Metropolis. Opoku (2016) reported a body weight range of 16 kg to 131 kg whereas Siaw *et al.* (2018) reported a range of 20 to 120 kg.

4.2.4 Concentration of Bisphenol A in Fante kenkey

Forty-eight samples of Fante kenkey were analyzed, out of which twenty-six (representing 54%) had varying levels of BPA. The concentration BPA varied from a minimum of 5.5×10^{-8} mg/g to a maximum of 3.155×10^{-6} mg/g. The mean and median concentration of BPA were found out to be 0.7639×10^{-6} mg/g and 0.00615×10^{-6} mg/g respectively; a 5th percentile value of 0 mg/g and a 95th percentile of 2.525×10^{-6} mg/g. In view of the toxic effects of BPA, it is a relief to note that BPA was not detected in 46% of the samples analyzed.

A study by Opoku (2016) on the risk associated with BPA in Hausa koko reported BPA Levels ranging from 0 mg/g to 3.8×10^{-5} mg/g with a mean of 3.5×10^{-7} mg/g. The findings from the present study are significantly higher, at a 95 % confidence interval, than the study by Opoku (2016). Though Hausa koko and Fante kenkey are both packaged in transparent plastic films, factors such as temperature, concentration of BPA in the plastic film, nature of the food and the duration of contact can influence the migration of BPA into the food (Vinas *et al.,* 2010). Significant differences exist between the production methods of Hausa koko and Fante kenkey. Hausa koko is a thin gruel made from milled fermented millet (Opoku, 2016) Whereas dough of the Fante kenkey is wrapped in a plastic film, further wrapped in dried plantain leaves and boiled for about 2 hours (personal communication), Hausa koko is only packaged into plastic films after it has been boiled (Opoku, 2016). The varying contact time and temperatures involved in production of these foods contribute to the differences in findings from the two studies.

The concentration of BPA in non-canned foods is usually low (Greens *et al.,* 2010), nonetheless, they may present a significant risk when consumed over a long period. A

Belgian study by Greens *et al*. (2010) reported BPA concentrations of 0.11 – 0.24 ng/g (1.1×10^{-7} – 2.4×10^{-7} mg/g) in some plastics packaged foods. These results are lower than that found in the present study on fante kenkey which also has plastic as the primary packaging material. The nature of the foods involved in these studies as well as the diffusivity of the different plastics could account for the difference in results. Another study by Schecter *et al.* (2010) found levels of BPA in some plastic-wrapped US foods to range from 0.20 to 4.31 ng/g (2.0×10^{-7} – 4.31×10^{-6} mg/g). Similar BPA levels of 0.1 to 8.7 µg/kg (1×10^{-7} – 8.7×10^{-6} mg/g) were also detected in 20 out of 37 Norwegian foods in a study by Sakhi *et al.* (2014). The concentrations of BPA in the current study are well below the EC's specific migratory limit of 0.6 mg/kg (6×10^{-4} mg/g) (EC, 2004). However, it remains clear from findings presented in this study that BPA migrates from plastics into foods.

4.3 Chronic Daily Intake of BPA through Fante kenkey

The chronic daily intake (CDI) is the lifetime average daily dose that a consumer can be exposed to (Gerba, 2009). The CDI is compared with the Reference dose (RfD) in determining whether or not a population is at risk (Gerba, 2009). When CDI values are far below the RfD, risk is negligible (Gerba, 2009). The chronic daily intakes of consumers are presented in Table 4.4. The mean and median exposure was 6.278×10^{-7} mg/kg bw/day and 2.453×10^{-7} mg/kg bw/day respectively. The lowest 5% (5^{th} percentile) of consumers had an exposure of 6.966×10^{-9} mg/kg bw/day while the top the 5% (95^{th} Percentile) 2.448×10^{-6} mg/kg bw/day. The level of exposure that was most likely to occur among consumers was 1.022×10^{-7} mg/kg bw/day. Daily intakes of BPA from this study is lower than that reported by Cao *et al.*, (2010). Cao and coworkers estimated the dietary intakes of BPA from composite food samples in Quebec, Canada. They reported intakes of 0.33 – 0.052 µg/kg bw/day across ages of 0 months to greater than 65 years for both males and females. The overall daily intake for all ages and sex groups was 0.075 µg/kg bw/day (7.5×10^{-5} mg/kg bw/day). The differences in population statistics and other factors of exposure contribute to this higher CDI than that of the current study. Also, whereas the study by Cao *et al.* (2010) used composite food samples, this study used a single food – Fante kenkey.

An EU study in 2003 estimated the daily intakes of Bisphenol A to be between 0.02 to 59 µg/kg bw/day (2×10^{-5} to 5.9×10^{-2} mg/kg bw/day). A 2009 US FDA study also pegged the daily intake among adults as ranging from 1×10^{-4} to 3×10^{-4} mg/kg bw/day. This level of exposure is much higher than results presented in the current study. Generally, low level intakes have been reported by researchers around the world **(**Thomson and Grounds, 2005; Greens *et al.*, 2010; Sakhi *et al.*, 2014). Kang *et al.* (2006) estimated an intake of less than 1 µg/kg bw/day using results from published studies. The range of exposure from the present study is lesser than the 5×10^{-6} mg/kg bw/day to 3.7×10^{-4} mg/kg bw/day given by Dekant and Völkel (2008) as a global range of BPA intake. Huang *et al.* (2017), who determined daily intakes of BPA using levels found in urine, also estimates that the global BPA intake is between 7.92×10^{-6} to 6.475×10^{-5} mg/kg bw/day. Ghana had an estimated BPA intake of 3.942×10^{-5} mg/kg bw/day.

Mean daily intakes of 3×10^{-6} mg/kg bw/day**,** 1.5×10^{-5} mg/kg bw/day and 4.26×10^{-6} mg/kg bw/day have been reported in New Zealand by Thomson and Grounds (2005), Greens *et al*. (2010) and Sakhi *et al.* (2014) respectively. These values are all higher than intakes of BPA from Fante kenkey as reported in this study.

Table 4.4: Chronic exposure of consumers to BPA

	Exposure (mg/kg bw/day)
Mean	6.278×10^{-7}
5th	6.966×10^{-9}
50^{th}	2.453×10^{-7}
95^{th}	2.448×10^{-6}
Mode	1.022×10^{-7}

The mean exposure from this study is lesser than the reference dose (RfD) of 0.05 mg/kg bw/day set by the US EPA (1988) as well the temporary tolerable daily intake of 0.004 mg/kg bw/day set by EFSA (EFSA, 2017). Based on this, it can be opined that consumers of Fante kenkey are not likely to have any adverse health effects resulting from the presence of BPA.

4.4 Risk Characterization

4.4.1 Hazard Quotient

The mean HQ value presented in this study was 1.25×10^{-5}. HQ values above 1 present a potential risk, though this risk cannot be predicted with certainty (NATA, 2014). The modal and median HQ were also very low; 2.04×10^{-8} and 4.9×10^{-6} respectively. The 5^{th} percentile group of consumers showed no significant risk due to an HQ value below 1. The same trend was also observed among 50^{th} and 95^{th} percentile groups. None of the groups of consumers in this study showed significant risks (HQ<1). This trend was expected due to the very low level of exposures that was observed among consumers.

The HQ associated with Hausa koko, another plastic-packaged food in Ghana was between 0 and 0.01 (Opoku, 2016). Though these HQ values are higher than that of the present study, there was no significant risk posed to consumers as in this study. Chen *et* *al.* (2016) estimated the 97.5th percentile hazard quotient of BPA intakes in Taiwan to be between 0.24 and 0.67. This HQ was calculated using the new EFSA t-TDI of 0.004 mg/kg bw/day. Though much higher values were obtained by their study than in the present study, they were all below the threshold of 1, thus posing no significant risks among consumers. Another study by Hartle *et al.* (2015) estimated the 95th percentile HQ of consumers between the ages of 5 to 14 years to be 0.01.

The low HQ levels from the present study and other studies (Sakhi *et al.*, 2014; Chen *et al.*, 2016) confirm EFSA's position that consumers of all age groups are at not health risk based on current levels of BPA intake (EFSA, 2015). EFSA (2015) reported that aggregated BPA exposure from both dietary and non-dietary sources are lower than the temporary tolerable daily intake of 0.004 mg/kg bw/day. Present levels of consumption pose no risk to consumers, but measures must be taken to ensure that this risk does not increase.

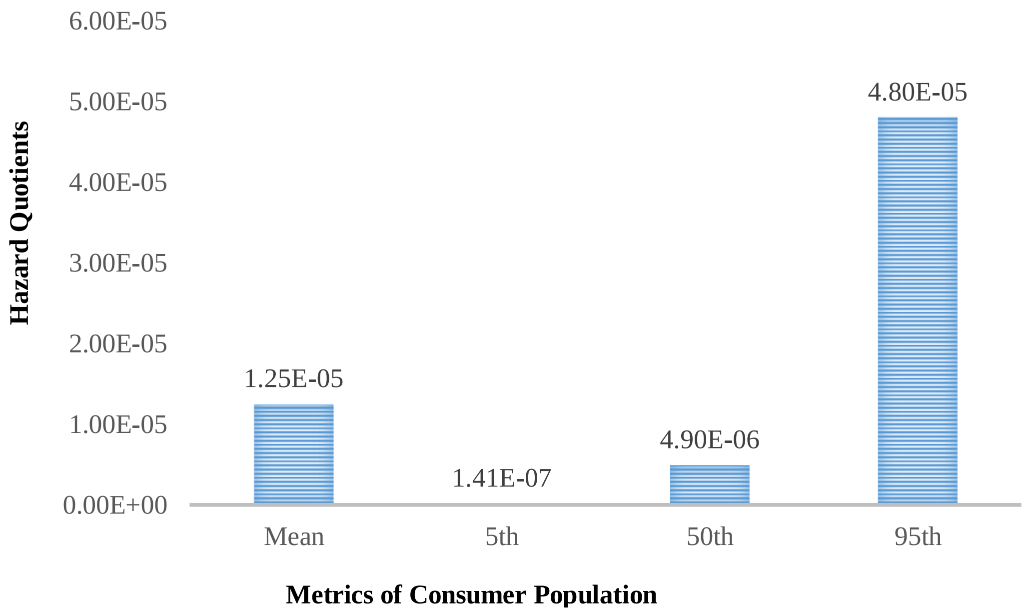

Figure 4.1 Hazard Quotient Due to BPA Intakes

4.4.2 Margin of Exposure (MoE)

The margin of exposure of a substance indicates the margin between its benchmark-dose lower bound (BMDL) and the actual exposure among consumers (EFSA, 2012). According to EFSA (2012), MoE values above 10,000 are of low public health concern. An MOE value of 10,000 means that exposure to the substance is 10,000 times lower than its BMDL.

The margin of exposure values for the 5th, 50th and 95th percentiles were 7,180,000, 204,000 and 20,400 respectively. On the other hand, mean MoE was 79,600. An MoE of 10,000 was obtained in a study by (CFSAN, 2014). CFSAN (2014) used a no-observedadverse-effect-level (NOAEL) of 5 mg/kg bw/day, which is much higher than the BMDL of 0.05 used in this study. Wikoff *et al.* (2015) also achieved MOE values higher than 800,000 in a US study. Results obtained in this study show that the 5th percentile population are not no risk at all, considering the very high MoE value of 7,180,000. The MoE for the 95th percentile population is not a cause for public health concern (>10,000), however, it is only slightly above the threshold of 10,000. The high MoE values corroborate the trend of low exposures and low HQ obtained in this study.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Bisphenol A was detected in 54% of the samples of Fante kenkey analysed. The detection of BPA in the Fante kenkey indicated migration from plastic film used in packaging,

The concentrations were low; ranging from a minimum of 5.5×10^{-8} mg/g to a maximum of 3.155×10^{-6} mg/g as compared to the recommended threshold i.e. 0.004mg/g. Chronic dietary exposures to Bisphenol A were low. A mean CDI of 6.278×10^{-7} mg/kg bw/day was obtained in this study, with 5th and 95th percentiles pegged at 6.966×10^{-9} mg/kg bw/day and 2.448×10^{-6} mg/kg bw/day respectively.

Bisphenol A presented no significant risk to the population under study. Mean, median, modal and all percentile HQ values were below 1. Current levels of exposure are also not a cause for public health concern in majority of the population because of the high MoE values. However, the 95th percentile group is only slightly above the threshold of 10,000.

5.2 Recommendation

Risk communication must be carried out to producers of fante kenkey, highlighting the dangers of the use of plastic films as a packaging material for fante kenkey.

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DIETARY QUESTIONNAIRE

QUESTIONS ABOUT WHAT YOU USUALLY EAT

INSTRUCTIONS:
Thus questionnaire is about your eating habits over the past 1 week. Give only 1 answer for each question

Please, mark like this:
◯ ◯ ◯ ◯

BIODATA

Gender		**Relations**		**Religion**		**Education**		**Work**		**Age (y)**				**Weight (kg)**					
M	◯	Sing	◯	Chris	◯	Info	◯	Stud	◯	0	◯	0	◯	0	◯	0	◯	0	◯
F	◯	Marr	◯	Musl	◯	Basic	◯	Trad	◯	1	◯	1	◯	1	◯	1	◯	1	◯
		Divo	◯	Tradi	◯	JHS	◯	CiSe	◯	2	◯	2	◯	2	◯	2	◯	2	◯
				Othe	◯	SHS	◯	PuSe	◯	3	◯	3	◯	3	◯	3	◯	3	◯
						Tert	◯	Other	◯	4	◯	4	◯	4	◯	4	◯	4	◯
										5	◯	5	◯	5	◯	5	◯	5	◯
										6	◯	6	◯	6	◯	6	◯	6	◯
										7	◯	7	◯	7	◯	7	◯	7	◯
										8	◯	8	◯	8	◯	8	◯	8	◯
										9	◯	9	◯	9	◯	9	◯	9	◯

BREAKFAST

Q1. Do you eat Fante kenkey for breakfast?

a. ◯ Yes
b. ◯ No

If no jump to question six.

Q2. How many balls of Fante kenkey do you eat for breakfast?

a. ◯ Half ball
b. ◯ One ball
c. ◯ One and half
d. ◯ Two balls
e. ◯ Two and half
f. ◯ Three balls

LUNCH

Q6. Do you eat Fante kenkey for lunch?

a. ◯ Yes
b. ◯ No

If no jump to question six.

Q7. How many slice of Fante kenkey do you eat for lunch?

a. ◯ Half ball
b. ◯ One ball
c. ◯ One and half
d. ◯ Two balls
e. ◯ Two and half
f. ◯ Three balls

Q3. How do you prefer Fante kenkey for breakfast?

a. ◯ mashed with sugar
b. ◯ Slices with shito
c. ◯ Slices with fresh grounded pepper
d. ◯ Slices with groundnut/ palmnut soup

Q8. What type of Fante kenkey do you prefer for lunch?

a. ◯ mashed with sugar
b. ◯ Slices with shito
c. ◯ Slices with fresh grounded pepper
d. ◯ Slices with groundnut/ palmnut soup

Q4. How many times do eat fante kenkey per day?

a. ◯ None
b. ◯ Once
c. ◯ Twice
d. ◯ Thrice
e. ◯ All times

Q9. How many times do eat fante kenkey for lunch per day?

a. ◯ None
b. ◯ Once
c. ◯ Twice
d. ◯ Thrice
e. ◯ Alltimes

Q5. How many times do you eat such breakfast per week?

a. ◯ None
b. ◯ Once
c. ◯ Twice
d. ◯ Thrice
e. ◯ All times

Q10.How many times do you eat such lunch per week?

a. ◯ None
b. ◯ Once
c. ◯ Twice
d. ◯ Thrice
e ◯ All

SUPPER

Q11. Do you eat Fante kenkey for supper?

a. ◯ Yes
b. ◯ No

Q12. How many balls of Fante kenkey do you eat for supper?

a. ◯ Half ball
b. ◯ One ball
c. ◯ One and half
d. ◯ Two balls
e. ◯ Two and half
f. ◯ Three balls

Q13. How do you prefer Fante kenkey for breakfast?

a. ◯ mashed with sugar
b. ◯ Slices with shito
c. ◯ Slices with grounded pepper
d. ◯ Slices with groundnut/ palmnut soup

Q14. How many times do you eat fantey kenkey per day

a. ◯ None
b. ◯ Once
c. ◯ Twice
d. ◯ Thrice
e. ◯ All times

Q15. How many times do you eat such breakfast per week?

a. ◯ None
b. ◯ Once
c. ◯ Twice

Q16. For how many years have you been eating Fante kenkey for breakfast, lunch and supper?

a. ◯ 0-5 years
b. ◯ 6-10 years
c. ◯ 11-15 years

d. ◯ Thrice
e. ◯ All times

d. ◯ 16-20 years
e ◯ 21 years and above

17. For each food shown on this page, indicate how much on average you would usually have eaten at a meal during the past week. When answering each question, think of the quantity you usually ate.

If you usually ate more than one, fill in the circle for the serving size.

⅓ of a ball (80g)

½ of a ball (125g)

⅔ of a ball (160g)

◯	◯	◯	◯	◯	◯	◯
Less than A	A	Between A and B	B	Between B and C	C	More than C

1 ball (260g)

1½ balls (365g)

2 balls (495g)

◯	◯	◯	◯	◯	◯	◯
Less than A	A	Between A and B	B	Between B and C	C	More than C

2½ balls (660g)

3 balls (835g)

◯	◯	◯	◯	◯
Less than A	A	Between A and B	B	More than B

Q18. How long have you been taken fante kenkey

Age (y)			
0	◯	0	◯
1	◯	1	◯
2	◯	2	◯
3	◯	3	◯
4	◯	4	◯
5	◯	5	◯
6	◯	6	◯
7	◯	7	◯
8	◯	8	◯
9	◯	9	◯