THE ROLE OF FERMENTED MAIZE-BASED PRODUCTS ON NUTRITION STATUS AND MORBIDITY OF CHILDREN 6-59 MONTHS OLD IN WESTERN KENYA

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DEPARTEMENT OF FOOD SCIENCE, NUTRITION AND TECHNOLOGY

2017

DECLARATION

I hereby declare that the dissertation is my original work and has not been presented for the award of a degree in any other University.

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DEDICATION

To

My husband, Mugangayi, my children Ligavo, Asenwa and Lihavi (Junior), my sister Malesi wa Mudome, my father Adavachi Wa Malenya and my mother Lihavi (Senior). In hope that it will ensure not only to them, but also all sons and daughters a surer, better and safer fermented maize products consumption/supply.

UNIVERSITY OF NAIROBI

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ABBREVIATIONS

AATF	African Agricultural Technology Foundation
AEZ	Agro-ecological Zone.
ANOVA	Analysis of Variance
CO_2	Carbon dioxide
DDS	Dietary Diversity Score
ENA	Emergency Nutrition assessment
FAO	Food and Agriculture Organization
FMP	Fermented Maize Products
GFP	Good Farming Practices
GMP	Good Manufacturing Practices
GOK	Government of Kenya
H/A	Height-for- age
H/W	Height-for-weight
HH	Household
KARLRO	Kenya Agricultural and Livestock Research Organisation
KCSE	Kenya Certificate of Secondary Education
KEBS	Kenya Bureau of Standards
MUAC	Mid-Upper Arm Circumference
ORS	Oral Rehydration Solution
RA	Research Assistants
SDG	Sustainable Development Goals
SPSS	Statistical Package for Social Science
UN	United Nations
UNICEF	United Nations Children's Fund
W/A	Weight-for-age
WEMA	Water Efficient Maize for Africa
WFP	World Food Program
WHO	World Health Organization

OPERATIONAL DEFINITIONS

Acute malnutrition: A condition of the body brought about by short term inadequacy of diet and diseases, determined by comparing anthropometric indices with reference data and cut offs.

Anthropometry: is a scientific study of the measurement of the human body and involves physical measurement of the body, such as height and weight, head circumference or skinfold.

Bioavailability: This is the degree to which food nutrients are available for absorption and utilization in the body.

Complementary food: is defined as the food when breast milk is no longer enough to meet the nutritional needs of the infant hence any nutrient- containing foods or liquids are added to the diet of the child.

Demography: Characteristic of the community including family size, education levels, age and sex distribution in the household.

Dietary Diversity Score is a measure of the number of food groups consumed over a reference period usually 24 hours.

Fermentation: Is a metabolic process that converts sugars to acids, gases or alcohol or broadly referred to as the bulk growth of microorganism on a growth medium, often with the goal of producing a specific chemical product.

Household: People living together and eating from the same pot at the time of study (FSAU, 2005)

Livelihood: Comprises of the capabilities, assets (including both material and social resource) and activities required for a means of living (Chambers and Conway, 1992)

Malnutrition: It is an imbalance between the supply of energy and protein, and the body's demand for them to ensure optimal growth and function. It is currently the most widespread serious health problem of children in the world being the moderate or severe form (FAO/WHO, 1998).

Maize: A crop belonging to the grass- family scientifically known as *Zea mays;* it is one of the most cultivated cereals and its staple food.

Nutrition knowledge: Awareness or familiarity of nutrition information and skills gained through nutrition education and counseling on good nutrition and dietary management of medical condition offered by health workers.

Nutrition status: A measurement of the extent to which an individual's physiological needs for nutrients are being met.

Socio-Economic factors: Income level and education level.

Stunted: Height-for-age below -2 Z-score or below 80% of median height for-age for reference population (WHO, 2006)

Supplement: Something intended to provide nutrients that may otherwise not be consumed in sufficient qualitie**s**

Underweight: Weight-for- age below -2 Z-score or below 80% of median weight for reference population (WHO, 2006).

Wasted: Weight-for-Height below -2 Z-score or below 80% of median weight for height for reference population (WHO, 2006).

Weaning: is the process of introducing semi-solid or solid foods to the breast or formula-fed child to meet extra nutritional needs for rapid growth and development. It is influenced by socioeconomic status, cultural and religious beliefs and practices.

Weaning period - transition from breast-feeding to complete reliance on other foods

ABSTRACT

Introduction: Most of the rural communities in Kenya heavily depend on maize based products as a weaning diet for children less than five years. Fermented maize based foods constitute a substantial part of the diet in many African countries yet information on their consumption, quality and influence on nutrition status and morbidity of children under five years remain limited in Kenya. The current study sought to determine and document the role of fermented maize based products to nutrition status and morbidity of children 6- 59 months old in Homa Bay and Kakamega Counties.

*Methodology:*A structured questionnaire was used to collect socio- economic data, anthropometric measurements and 24- hour food recall in 120 households. Samples were collected from two localities in Homabay and Kakamega Counties and analyzed in the laboratory for contaminants (*Staphylococcus aureas*, coliforms and aflatoxin) and nutritive value (phytates, proteins, crude fibre, zinc, and iron). The samples collected included maize flour, soaked maize flour, cooked fermented porridge porridge fermented roasted (*Mkarango*) product and beverage (*busaa*).

Results: The mean weight of the children was 14.5 kilograms, while mean height and age were 90.9 centimetres and 32 months respectively. Child nutrition status was above average, those who were severely underweight, stunted and wasted were 6.7%, 21% and 9.2%, respectively. There was a high mean individual dietary diversity of 6.5 for Kakamega County and Homa Bay. Of the children accessed 50% had been sick two weeks prior to the study. Sources of water for household use were varied: 5.8% had tap water and 5.0% from boreholes, 46.7% from rivers, 22.5% from springs, 13.3% from protected wells and 6.7% from unprotected wells. 55% of the population used chemical for water treatment and 33.3% did not dispose-off child feaces hygienically. The mean phytates content ranged from 3040- 3480mg/100gm in soaked flour and maize flour. The mean iron content was 1.26/100gm to 5.4mg/100gm in *mkarango* and fermented cooked porridge which had significant difference at $p< 0.05$. Zinc content in the maize products ranged between 2.17mg/100gm in maize flour to 4.9 mg/100gm in *busaa*. The contents of crude protein ranged 2.9% -14.4% in fermented porridge and *busaa*. The mean crude fibre content ranged from 2.8- 3.5% in fermented cooked *uji* and flour. The mean *Staphylococcus aureus* load on the products ranged from 3.4- 5.5 log cfu/g in *mkarango* and unfermented

Conclusion: Most household consume fermented porridges as family food but few use it as complementary food. Untreated water from unprotected flowing rivers and springs is used in preparation fermented maize products. The nutrient quality of fermented maize product is better than the unfermented ones. Most of the consumed fermented maize products that are handled unhygienically hence heavily contaminated.

Recommendation: Maize is a major food staple in Kenya, mostly utilized as a weaning diet in form of unfermented thin porridge. For fermented maize products to be accepted as weaning diet for the under five years, a strong campaign to inform care givers on the on benefits of fermentation is a need.

CHAPTER ONE: INTRODUCTION

1.1 Background

Freedom from hunger is the most fundamental human right that can be obtained if an individual is food secure. Globally, nearly 1.02 billion people are food insecure and one third of pre-school children in developing countries are malnourished (FAO, 2009). Hunger and poverty are two sides of the same coin. Those who are poor are generally hungry and those who are hungry are poor. For households to have access to enough food for healthy life is an important component of their poverty (Hoddinott and Yohannnes, 2002). Households become food secure when their livelihood system (i.e. capabilities, assets and activities required for a means of living) change or fail to adapt to the challenges and shocks from the external environment (Kruger *et al*., 2008).

Maize is grown in different agro-ecological zones in Kenya as a staple food and has high calorific value but deficient in some essential nutrient like amino acid- lysine (Nyoro *et al*., 2007). Maize is of paramount importance because it constitutes the major ingredient of the most common dishes: thick porridge (*ugali*), boiled mixture of maize and beans (*githeri or nyoyo or makhayo* in some Kenyan communities), boiled mixture of shelled maize kernel and beans (*muthokoi*) and thin porridge (*uji*) (De Groote *et al*., 2010)

Maize is a staple food and source of carbohydrates to a large proportion of people in Kenya. It is a commodity that has undergone structural reforms. As a food commodity maize provides a large proportion of caloric needs to majority of consumers in urban or rural areas (Nyoro *et al*, 2007). A large proportion of maize production comes from small scale producers although most of them retain part of produce for consumption. About 3.5milllion small scale farmers are involved in maize production, producing 75% of the total maize crop (Economic Survey, 2001).

Fermentation of foods such as maize is one of the oldest methods of food preparation and preservation (Katongole, 2008). Fermented foods constitute a substantial part of the diet in many African countries and are considered an important means of preserving and introducing variety into the diet, which often consists of staple food such as milk, cassava, fish and cereals (Belton and Taylor, 2004). Fermented foods have a role in social functions such as marriage, naming, rainmaking and funeral ceremonies, where they are served as inebriating drinks and weaning foods (Hounhouigan, 1994). In addition, fermentation provides a natural way to reduce the volume of material to be transported, to destroy undesirable components, to enhance the nutritive value and appearance of the food, reduce energy required for cooking and to make safer products (Hounhouigan, 1994).

Fermentation is a chemical anaerobic process where conversion of various carbohydrates to carbon dioxide (CO_2) and alcohol or when cells yeast metabolizes sugar to get these products (FAO, 1995). Fermentation is a technique that has been employed for generations to preserve maize and other products for consumption at a later date and improve food security (FAO and WHO, 1995). Fermentation can salvage food waste which otherwise would not be usable as food by changing the consistency of the product and making it digestible. Fermentation is cheap because it does not require sophisticated equipment, always carried out spontaneously (FAO and WHO, 1995). Consumption of maize to provide sufficient nutrients is difficult due to dietary bulk of the food (Roba, 2005). The most common method of lowering dietary bulk in maize is by germination of maize whereby amylolytic enzymes are elaborated (Roba, 2005). During fermentation these enzymes hydrolyse the starch which is the main causes of bulkiness in the maize (Afoakwa *et al*., 2007). Fermentation and malting of maize have been used to enhance the overall nutritional quality and also allows for preparation of low dietary bulk maize foods (Afoakwa *et al*., 2007).

In addition, the probiotic effects and the reduced levels of pathogenic bacteria observed in fermented foods and beverages are especially important when it comes to developing countries where fermented foods have been reported to reduce the severity, duration and morbidity of diarrhea (Mensah *et al*., 1990). The high dependence on maize as a staple in Kenya (WEMA,KARI and AAFT, 2010) coupled with the low nutritive value of the commodity has led to the investigation of simple traditional methods in improvement of the chemical and functional qualities of maize- based foods (Afoakwa, 1996).

1.2 Problem Statement

Maize is the most important and widely consumed cereal in Kenya and a staple food crop for 96 percent of Kenya's population with 125 kg per capita consumption and provides 40 percent of the calories (WEMA, KARI and AAFT, 2010). Yields per hectares and production volumes still remain well below the projected consumption level of 36.0 million bags in 2009 thus necessitates imports to cover deficits (Economic Review of Agriculture, 2010). Sorghum, maize and millet beverages possess similar features which involve the lactic acid bacteria fermentation which plays a key role in safety acceptability of the products. They are popularly consumed by adults because of the social, religious, therapeutic values and to some extent used for weaning children under five years old (Nwachukwu *et al*., 2010). However, the extent of fermented maize based products use by children under five and their contributing to nutritional status is not yet established. On the other hand, the contribution of fermented maize based products to morbidity is not known, given that modes of preparation and handling are mainly traditional that may lead to contamination.

The current project sought to establish and document the role of fermented maize-based products on nutritional status and morbidity of children 6-59 months old in Homa bay and Kakamega counties.

1.3 Justification of the Study

Fermented maize-based products have probiotic effects, reduced level of pathogenic bacteria and high acceptability (Katongole, 2008), by encouraging their utilization will help the Ministry of Health to reduce severity, duration and morbidity of diarrhea which stands at 58%(KDHS, 2014) in Kenya. The promotion of utilizing fermented maize products as a complementary food may contribute to the achievement of three of the Sustainable Development Goals (SDGs): to eradicate extreme poverty and hunger, reduce child mortality and finally to combat HIV/AIDS, malaria and other diseases. KFSSG (2008) reported that 1.38 million Kenyans are highly food insecure especially in rural areas and the impact is most observed in children less than five years who are nutritionally vulnerable. By utilization of fermentation of maize-based products as a technique for preservation would benefit Kenya as a country to be food secure at household levels like *mkarango* can be kept for long after preparation, hence can increase food security also salvage that which could be lost through spoilage. In Kenya, about 11% of children below five years are underweight, 4% are wasted, and 26% are stunted (KDHS, 2014). The contribution of fermented maize based products that may help to fight against micronutrient and protein- energy malnutrition need to be established.

Maize plays an important role in income generation, employment creation and food security (Nyoro *et al.*, 2007). Despite Kenya being highly dependent on maize as a staple food, most communities in Kenya have not exploited fermented maize products in feeding their under five children, there is the avoidance of fermented maize foods but they prefer consumption of packed foods such as popcorn, canned foods like sweet corn, beverages like thin unfermented porridge and boxed dinners like thick porridge. Therefore, the need to document the existing information on the extent to which fermented maize based products are utilized to feed children 6- 59 months in Western Kenyan.

1.4 Purpose of the Study

The purpose of the study is to provide data that can be used to create awareness on the importance of fermented maize products as an adult and complementary food and thus its utilization. Further, the study results will be able to contribute to policy and nutritional interventions hence help in the fight towards reducing micronutrient and macronutrient deficiencies.

1.4 Aim of the Study

To generate and document information on the utilization of fermented maize products as complementary food and importance attached to it in diet and nutrition security in Kenya.

1.6 Objectives

1.6.1 Main objective

To determine the role of fermented maize based products on nutrition status and morbidity of children 6- 59 months old in Homa Bay and Kakamega Counties.

1.6.2 Specific objectives

1. To asses current information on socio- demographic characteristics, dietary diversity and utilization of fermented maize-based products by caregivers and children 6-59 months in Homa Bay and Kakamega Counties of Kenya.

2. To determine nutritive and microbial quality of fermented maize based products commonly consumed in Homa Bay and Kakamega Counties of Kenya.

3. To determine nutrition status and morbidity of children 6-59 months in Homa Bay and Kakamega Counties of Kenya.

1.7 Research Questions

1. Which fermented maize based products are available at household level, to what extent are they used as complementary foods and under what household conditions, for children 6- 59 months in Homa Bay and Kakamega Counties?

2. What are the nutrition properties, microbial contaminants and aflatoxin levels in fermented maize products utilized at household levels in Homa Bay and Kakamega Counties?

3. What is the nutritional status of children 6- 59 months in Homa Bay and Kakamega Counties?

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CHAPTER TWO: LITERATURE REVIEW

2.1 History of Maize Production in Kenya

Maize, scientific name *Zea mays,* also known as corn belongs to the *Gramineae* family (grass-family). Maize arrived in East Africa from Central America during the 16th century. The first variety was mostly of Carribean origin, flint in texture and variety of colors (De Grootes *et al*., 2012). At the beginning of the 20th century European settler farmers started large scale maize grain production in East and Southern Africa, using many white dent varieties (WEMA, AATF and KARI, 2010). Self- sufficiency in maize production was achieved during the 1970's when production was high and the surplus was exported. Nationally maize is a staple which is relied on as a primary source of nutrition. All that is produced is consumed and none is exported presently in Kenya.

2.1.1 Nature of complimentary foods in Kenya

The period of complementary feeding, is defined as the time when breast milk is no longer enough to meet the nutritional needs of the infant hence any nutrient- containing foods or liquids are added to the diet of the child. It's introduced from six to 18- 24 months of age to meet the evolving needs of the growing child (Hotz and Gibson, 2001). This period is the time, also known as 'critical window'; malnutrition starts in many infants which contribute to significantly high prevalence of malnutrition (Anigo *et al*., 2010). An insult to this critical and vulnerable time in the growth and development, (including insufficient quantities and inadequate quality of complementary foods, poor child feeding practices and high rates of infection) is irreversible (Hotz and Gibson, 2001). In Kenya, the principal food given to children 6- 12months of age is a cereal-based porridge which is supplemented with fruits (banana or papaya) and vegetables (pumpkins, potatoes or amarantha leaves) or milk (Hoffman *et al*., Panel paper). Mothers home-make or purchase cereal blends of unfermented maize flour that is made from staple foods which are bulky foods low in nutrient density and low energy (Anigo *et al*., 2010).

2.2 Role played by maize in human diet

Maize is a staple crop, source of food and nutritional security for many people (FAO, 1995). It is significantly diversified through commercially manufactured baby food and other products like whole corn, corn flour, corn starch, corn gluten, corn syrup, corn meal, corn oil, popcorn, cornflakes, etc (Ajao *et al*., 2010). Maize is an appetizer which helps to clean the colon and dextrose produced is used for medical purposes (Ajao *et al*., 2010). Yellow maize provides antioxidants (vitamin A) that neutralize the effects of harmful free- radicals that cause disease like cancer (De Grootes *et al.,* 2012). Maize provides vitamins E but lacks the lower B vitamins that characterize sorghum or wheat. Maize is rich in carbohydrates that is derived from its abundant starch provide high levels of energy-calories. Maize is low in usable protein and its leucine blocks the human body's absorption of niacin, a vitamin whose absence causes protein deficieny (McCann, 2005; Shiferaw *et al.,* 2011). This has led to the development of 'Quality Protein Maize' QPM with enhanced nutritional value especially high levels of lysine and tryptophan in the endosperm (Shiferaw *et al*., 2011). It has dietary fibre which prevents constipation, colorectal cancer and facilitates the removal of toxic substances also accelerates the passage of feaces through the intestines. Maize is low in cholesterol and fat content. Finally maize lowers LDL cholesterol and guard against cardiac diseases, diabetes and hypertension (Shiferaw *et al.*, 2011).

2.3 Nutritional value of maize

There are important differences in the chemical composition of the main parts of the maize kernel as shown in Table 2.1.The seed-coat or pericarp is characterized by a high crude fibre content of about 87 percent, which is constituted mainly of hemicellulose (67 percent), cellulose (23 percent) and lignin (0.1 percent) (Burge and Duensing, 1989). On the other hand, the endosperm contains a high level of starch (87.6 percent) and protein levels of about 8 percent. Crude fat content in the endosperm is relatively low. Finally, the germ is characterized by a high crude fat content, averaging about 33 percent. The germ also contains a relatively high level of protein (18.4 percent) and minerals (Burge and Duensing, 1989; Gwirtz *et al*., 2014).

Table 2.1: Proximate Chemical Composition of Maize Kernels (%)

Chemical Component	**Pericarp**	**Endosperm**	**Germ**
Protein	3.7	8.0	18.4
Ether Extract	1.0	0.8	33.2
Crude Fibre	86.7	2.7	8.8
Ash	0.8	0.3	10.5
Starch	7.3	87.6	8.3
Sugar	0.34	0.62	10.8

Source: Gwirtz *et al*., (2014).

2.3.1 Crude Proteins in Fermented Maize Products

The word protein is of Greek derivation and means "of first importance." Proteins are the basic material of every body cell. Protein is priority in infant diet because by the age of four years, body protein content reaches the adult level of about 18% of body weight (Roth, 2011). An adequate supply of protein in the daily diet is essential for normal growth and development and for the maintenance of health. Proteins build and repair body tissue, play major roles in regulating various body functions, and provide energy if there is insufficient carbohydrate and fat in the diet (Roth, 2011). In maize, after starch the next largest chemical component of the kernel is proteins which range from about 8 to 11 percent of the kernel weight. Most of it is found in the endosperm. Nutrional quality of maize as a food is determined by the amino acid make- up of its proteins (FAO, 1992).

2.3.2 Crude Fibre in Fermented Maize Products

Dietary fibre consists of remnants of the plants cells resisitant to digestion by the alimentary enzymes of man, whose components are hemicellulose, cellulose, lignin, oligosaccharides, pectins, gums and waxes (Rodriguez *et al.*, 2006). The effect of dietary fibre on food compotents digestibility in human had a negative influence on the digestion and assimilation of proteins especially when the ingested fibre was less purified (Rodriguez *et al.*, 2006).The fibre polysaccharides affect the absorption of lipids as they can be strong inhibitors of pancreatic lipase that are involved the lipid metabolism hence decease in levels of total cholesterol and low density lipoproteins in plasma, which is associated to a greater dilution and excretion of bile acids (Rodriguez *et al.*, 2006). Dietary fibre also influence the bioavailability of carbohydrates in the intestines which has been confirmed in diabetic patients whose levels of glucose in blood decreased by having diets rich in fibre. Dietary fibre plays a significant role in the prevention of diseases such as cardiovascular disease (CVD), colon and breast cancer. Diets which are rich in fibre contain cereals, fruits and vegetables which have a positive health effect. (Norhaizan *et al*., 2009).

2.3.3 Phytates in Fermented Maize Products

Phytates (inositol hexakisphosphate) is a phosphorous containing compound that binds with minerals and inhibits their absorption (Norhaizan *et al.,* 2009). In its structure phytates has high density of negatively charged phosphate groups which form stable complexes with mineral ions causing non-availability for intestinal absorption (Walter *et al*., 2004). Cereals like maize are good sources of carbohydrates, proteins, B vitamins, minerals and dietary fibre (Roba, 2009). However, cereals also provide anti- nutritional factors, such as inhibitors and chelating agents which interfere with gastrointestinal tract reducing their bioacessibility and bioavailability (Sokrab *et al.*, 2012). The principal chelating agents in cereals are dietary fibre and phytates (Roba, 2009). The presence of phytates in human diet has a negative effect on mineral uptake. Minerals of concern include zinc, iron, calcium, magnesium, manganese and copper (Konietzny and Greiner, 2003). Minerals are involved in activation of intracellular and extracellular enzymes, in regulation of critical pH level in the body fluids necessary for control of metabolic reactions and osmotic balance between the cell and the environment. Reductions of such anti-nutritional factors by processing methods such as gamma irradiation, dehulling, soaking, sprouting, cooking, malting and fermentation have been documented (Sokrab *et al*., 2012).

2.3.4 Zinc in Fermented Maize Products

Zinc is a trace mineral that is essential for all forms of life, including plants, animals and organisms. Zinc deficiency is estimated by WHO (year) to be one of the ten biggest factors that contribute up to burden of disease in developing countries. In children, zinc deficiency contribute up to 15% of diarrhea deaths, 10% of malaria deaths and & 6% of pneumonia deaths. Zinc has other symptoms like growth retardation, hypogonadism, delayed sexual maturation, skin lesions, impaired wound healing, and loss of taste, behavioral disturbances, night blindness and immune deficiency (Reed, 1980).

2.3.5 Iron in Fermented Maize Products

Iron is the fourth most abundant element on earth, but iron deficiency in human is one of the most widespread nutritional problems in the world (USAID, 2010). Is the most common and widespread nutritional disorder in the world about 40% of the world's population (.i.e. more than 2billion individuals) are thought to suffer from anaemia (WHO and FAO, 2006). The main prevalence among specific population are estimated to be pregnant women, infants and children aged 1-2 years 50%, preschool-aged children 25%, adolescents 30-55% and non-pregnant women 35% (WHO, 2006). Iron deficiency refers to depleted body iron stores with regard to degree of depletion or to the presence of anemia. Iron-deficiency anemia refers to several depletion of iron stores that result in low hemoglobin concentration (Rolfes *et al*., 2012). The hemoglobin synthesis decreases resulting into red blood cells that are pale (hypochromic) and small – microcytic (Rolfes *et al*., 2012). Inadequate iron, energy metabolism in the cells falters hence fatigue, weaknesses, headache, apathy and poor resistance to cold temperatures. Iron deficiency causes substantial reduction in productivity (physical work capacity), this effect is evident when the haemoglobin concentration falls below 100g/l (Viteri, 1974). Behaviour and conjucture function - iron deficiency anaemia in young children is associated with impaired psychomotor performance as well as changes in behavior. There is decrease in responsiveness and activity with increased body tension, fearfulness and tendancy to fatigue in association with iron deficiency anaemia (Bowman *et al.*, 2001)

2.4 Lactic acid fermentation of maize based products and implication on nutritive value and safety

2.4.1 Maize as Fermentation Substrate

In Africa, cereal grains such as maize, sorghum and millet are common substrates for producing a wide variety of fermented products. Cereal grains consist of an embryo (germ) and an endosperm is found as granules of nutrients (amino acids, sugars, lipids, minerals, vitamins and enzymes). The husk mainly comprised cellulose, pentosan, pectin and minerals (Katongole, 2008). The grains are malted, milled and fermented to produce thin gruels and alcoholic beverages known by various names in different parts of Africa (Katongole, 2008). Fermentation is one of the oldest and most economical methods of processing and preserving foods. A fermented food is one or more of its constituents acted upon by microorganisms to produce a considerably altered final product acceptable to human use (Adegoke *et al*, 2010). Fermentation processes are enabled by technological factors controlling the activity of lactic acid bacteria and yeasts (Hammes *et al*, 2005). The variation of the ecological parameters acting on the microbial association such as the nature of the substrate (cereal), temperature size of inoculum and length of propagation intervals, leads in each case to a characteristic species association (Adegoke *et al*, 2010). Fermented foods provide varieties in the diet, increase water soluble vitamins, improve organoleptic properties and digestibility (Adegoke *et al*, 2010). Cereals like maize are deficient in lysine but rich in cysteine and methionine. Legumes, on the other hand, are rich in lysine but deficient in sulphur- containing amino acids thus by combining, cereals with legumes, the overall protein quality is improved (Katongole, 2008). A wide variety of substrates are fermented but the products of great relevance in young children feeding are produced by the lactic fermentation of cereals e.g. maize, millet and sorghum (Mensah, 1990; Nwachukwu *et al*., 2010) as shown in Table 2.2.

Table 2.2: Fermented Maize Products from Africa

	Food	**Substrate**	**Cooked type**	**Food Consumption**
Ghana	Kenkey	Maize	dumpling	Adults
	Koko or akasa	Maize	porridge	All ages
Nigeria	Ogi	Maize	porridge	All ages
Ethiopia	Njera	Maize	pancake	All ages
Kenya, Uganda, Tanganyika	Uji	Maize, sorghum and millet	porridge	All ages
Uganda	Obusera	Maize	porridge	All ages
South Africa	Mahewu	Maize	beverage	Adults

Sources: Soro-Yao et al., (2014)

Maize grown in subsistence agriculture continues to be used as a basic food crop (FAO, 1992). Maize is planted for its grains that are used for making flour or eaten as a vegetable either boiled or roasted (Obire *et al.*, 2015). Maize can also be prepared in form of *uji* (porridge) which is a sour cereal gruel from East Africa and the basic cereal used for uji is maize, but mixtures of maize and sorghum or millet in proportion of 4:1 are also used (Mbugua, 1984; Katongele, 2008). The information above does not give elaborate on the extent to which these fermented products are utilized in complementary feeding.

2.4.2 Lactic Acid Fermentation of Maize

Fermentation is a common traditional household technology in many parts of the world and is defined as a desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes (FAO,1995; Afoakwa, 2007). Spontaneous lactic acid fermentation is widely applied in the processing of cereals for the preparation of a wide variety of dishes in Africa (Afoakwa *et al*., 2007). Fermentation is purposely carried out to enhance properties such as taste, aroma, shelf-life, texture, nutritional value and as well reduce their anti- nutritional factors (Afoakwa *et al*., 2007). It is the chemical breakdown of a substance by bacteria, yeasts, and/or other microorganisms typically involving effervescence, an alcohol or an acid and the giving off of heat (FAO, 1995; Afoakwa *et al*., 2007).

2.4.3 Types of Fermentation

Fermented foods are produced worldwide using various manufacturing techniques, raw materials and microorganisms. However, there are only four main fermentation processes namely, alcoholic, lactic acid, acetic acid and alkali fermentation (Soni and Sandhu, 1990; Katongole, 2008). Alcoholic fermentation results in production of ethanol, and yeasts are the predominant organisms (eg wines and beers). Lactic acid fermentation (eg fermented milks and cereal) is mainly carried out by lactic acid bacteria (McKay and Baldwin, 1990; Katongole, 2008). A second group of bacteria of importance in food fermentations are acetic acid producers from the Aceto-bacter species. *Aceto-bacter* converts alcohol to acetic acid in the presence of excess oxygen (McKay and Baldwin, 1990; Katongole, 2008). Alkali fermentation often takes place during the fermentation of fish and seeds, popularly known as condiment (McKay and Baldwin, 1990; Katongole, 2008).

2.4.4 Benefits of Lactic Fermentation

The benefits of fermentation may include improvement in palatability and acceptability by developing improved flavours and textures; preservation through formation of acidulants, alcohol, and antibacterial compounds; enrichment of nutritive content by microbial synthesis of essential nutrients and improving digestibility of protein and carbohydrates; removal of anti-nutrients, natural toxicants and mycotoxins; and decreased cooking times. The content and quality of maize proteins may be improved by fermentation (Wang and Fields, 1978; Cahvan *et al*. 1988). Natural fermentation of maize increases relative nutritive value and available lysine (Hamad and Fields, 1979). Bacterial fermentations involving proteolytic activity are expected to increase the biological availability of essential amino acids more so than yeast fermentations which mainly degrade carbohydrates (Chaven and Kadam 1989; Muyanja *et al*., 2002). Starch and fiber tend to decrease during fermentation of maize (El-Tinay *et al*. 1979). Although it would not be expected that fermentation would alter the mineral content of the product, the hydrolysis of chelating agents such as phytic acid during fermentation, improves the bioavailability of minerals (Roba, 2009). Changes in the vitamin content of maize with fermentation vary according to the fermentation process, and the raw material used in the fermentation. Bacteria and yeast assist many of our natural processes and they are replete with B group vitamins generally show an increase on fermentation (Peggy, 2012). Reddy and Pierson (1994) reviewed the effect of fermentation on anti-nutritional and toxic components in plant foods. Fermentation of corn meal and soybean-corn meal blends lowers flatus producing carbohydrates, trypsin inhibitor and phytates (Katongole, 2008). However, fermentation of maize with fungi, such as *Rhizopus oligosporus*, has been reported to release bound trypsin inhibitor, thus increasing its activity (Wang *et al*., 1972). Fungal and lactic acid fermentations have also been reported to reduce aflatoxin B_1, sometimes by opening of the lactone ring which results in complete detoxification (Nout, 1994). Another benefit of fermentation is that frequently the product does not require cooking or the heating time required for preparation is greatly reduced (Steinkraus, 1994). Friendly bacteria in the gut help to stimulate peristalysis (feacal elimination), staving off constipation. Also they keep pathogens from gaining territory in the human gut, i.e. they help keep us from getting sick (Peggy, 2012).

2.4.5 Hazards in Maize Products

Mycotoxins are natural, secondary metabolites produced by fungi on agricultural commodities in the field and during storage under wide range of climatic conditions (Krska *et al*., 2008). Optimal conditions for the growth of these fungi and toxin production in contaminated foodstuffs are high humidity and temperature of, both of which are common in tropical countries (Katongole, 2009). Enough maize is stored for consumption throughout the year, which allows for contamination by fungi and hence aflatoxin production (Katongole, 2009). Several hundred different mycotoxins e.g. aflatoxins and ochratoxins (produced by Aspergillus sp.), fumonisins, trichothecenes and zearalenone (produced by Fusarium sp.), patulin (produced by Penicillium sp.) and ergot alkanoids (produced in the sclertia of Claviceps sp.) (Krska *et al*., 2008). These compounds cause adverse health effects such as kidney and liver damage, mutagenic and tetratogenic effects, birth defects, cancers and death (Rahmani *et al*., 2009). In Kenya incidence where more than 125 deaths occurred in 2004 were attributed to aflatoxin contamination (Kang'ethe, 2011). Most of the mycotoxins are heat stable and not destroyed by cooking (Adegoke *et al.*, 2010). Low- level, chronic exposure is carcinogenic and has been linked to growth retardation in children ((Hoffmann *et al*., 2013). According to a study by

(William *et al*., 2004), mycotoxin exposure contributes to more than 40% off global disease burden. While fermented foods, the mainstay of many developing countries, have long been perceived as safe for consumption, a number of researchers have investigated the fate of many prevalent food borne bacterial pathogens during the production of such foods (Farnworth, 2003). Lactic fermented foods provide protection against foodborne illnesses, and children consuming lactic fermented products on a regular basis, a commonly used weaning food in Tanzania with a final pH< 4 show a significantly lower number of diarrhoeal episodes than non-users (Lorri and Svanberg, 1994). It is of paramount importance that these fermented products be prepared under good sanitary and hygienic conditions. In developing countries, most food borne illness is of a bacterial nature (Adegoke *et al*., 2010). This is due to poverty, low level of education, poor sanitation and hygiene practices, poor methods of food preservation and keeping unavailability of potable drinking water and absence or scarcity of health facilities (Nigatu and Gashe, 1994). Sources of food contamination are numerous like soils, polluted water, flies and pests, domestic animals, unclean utensils and pots, dirty hands and a polluted environment caused by lack of sanitation, domestic animal dropping, dust and dirt (Motarjemi, *et al*., 1993). The extent of food borne – diarrheal disease in young children is associated with practices of food preparation, handling and storage as well as feeding methods (Adegoke *et al*., 2010).

2.5 Nutritional Status of children Using Maize- based complementary food

Maize meal porridge was an integral part of the infants' diet as is generally the case of South African infants (Faber, 2005). Not only is maize meal a bulky food of low nutrient density but is also high in phytates which is an inhibitor of 'iron and zinc' absorption. Several food items, especially energy- rich foods such as margarine have been added to porridge (Faber *et al*., 2007).The addition of micronutrient- rich foods to porridge could be more appropriate, as 23% of the infants were overweight for length(z-score >2SD) and the complementary diet was inadequate for most of the micronutrients (Faber, 2005). While <1% of the infants were severe underweight for length, 16% stunting and 6% wasting (Faber *et al*., 2007).

2.6 Potential impact for use of lactic acid fermented maize products as complementary food on children nutritional status

2.6.1 Malnutrition Among Children 5-59 months old

Malnutrition generally refers various forms, including acute and chronic under nutrition, micronutrient deficiencies, as well as overweight and obesity (Republic of Kenya, 2012). Over 150 million children under the age of five years globally do not receive the nutrition they require to fully develop mentally and physically (Fischer *et al*., 2002; WFP/UNICEF, 2006). Ten million children under the age of five die every year from preventive and curative illness (UNICEF, 2009). It is estimated that malnutrition contributes to over 50% of these deaths through diseases like acute respiratory diseases, diarrheal diseases, measles and malaria where malnutrition plays an underlying factor (Black *et al*., 2008). The Kenya Demographic and Heath Survey (2014) indicate in Table 1, that malnutrition remains a major public health problem Kenya.

Table 2.3 Malnutrition in Kenya, Homa Bay and Kakamega Counties

	Stunted%	Wasted%	Underweight%
Kenya	28	4	11
Homa Bay County	18.7	2.3	5.4
Kakamega County	28.7	1.8	10.1

Source: KDHS (2014)

Malnutrition is a common condition associated with high mortality and morbidity hence requires specialized treatment and prevention interventions (Briend *et al*., 2006). Kenya experiences total chronic undernourishment of 43% (sum of underweight, wasting and stunting). Over nutrition occurs when energy intake exceeds that energy expenditure and results in excess body fat accumulation (Bowman *et al*., 2001). Under nutrition occurs when energy intake is less than total energy expenditure over a considerable period of time, resulting in clinically significant weight loss. In children, underweight is classified using the weight-for-height index and the height-for-age index (Bowman *et al*., 2001). Like other cereals, the nutritive value of maize is low due to deficiency in essential amino acids (lysine and tryptophan) and the presence of anti-nutrient factors such phytates, tannins and polyphenols (Awad *et al*., 2012). Malnutrition is a major health problem in developing countries and contributes to infants' mortality, poor physical and intellectual development of infants as well as lowered resistance to disease and consequently stifles development. Protein- energy malnutrition generally occurs during the crucial transitional phase when children are weaned from liquid to semi- solid or fully adult foods (Amankwah *et al*., 2009).

2.6.2 Effects of Malnutrition on Children 6- 59 months In Homa Bay and Kakamega Counties

Kenya is highly dependent on maize as a staple food and when reported that 1.38 million Kenyans are highly food insecure especially the greatest impact is observed in children who are the most nutritionally vulnerable group of the population (KFSSG, 2008). Kenya Demographics Health Survey (2014) showed that about 11% of children below five years are underweight, 4% are wasted and 26% are stunted. Cereal-based tradition complementary foods e.g. maize commonly fed to infants are inadequate to meet daily nutrients and energy requirements, while infant formula foods are too expensive for mothers of low socio-economic status (Oyarekua, 2013).

Malnutrition slows down economic growth and perpetuates poverty through low productivity, poor cognitive function and deficits in schooling, health care cost and may result in morbidity and mostly mortality (UNICEF, 2006). The children who survive do so with greatly reduced capacity to lead productive lives (UNICEF, 2006). Malnutrition in this context takes three forms (1) failure to grow linearly resulting in stunting (2) loss of the tissues of the body resulting in wasting and (3) accumulation of fluid resulting in kwashiorkor (also called nutrition oedema or hunger oedema) (USAID, 2009).

2.7 Gaps in Knowledge

Although a lot has been documented from mostly West African countries that most of FMPs are consumed by all ages and that fermented maize product have a positive impact on healthy living. In the Homa Bay and Kakamega counties, the extent to which fermented maize products are utilized as complementary food for children 6- 59months has little documentation. Little information exist on the nutrient quality, safety and quality of FMPs found at household level. Assumptions that the entire population has knowledge on and utilize fermented maize products to wean children 5- 59 months.

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CHAPTER THREE

SOCIO-DEMOGRAPHIC CHARACTERISTICS, DIETARY DIVERISTY AND UTILIZATION OF FERMENTED MAIZE BASED PRODUCTS IN HOMA BAY AND KAKAMEGA COUNTIES OF KENYA

3.1 Abstract

Introduction: Fermented foods constitute a substantial part of the diet in many African countries and are considered an important means of preserving and introducing variety into diet. Information on nutrition status of less than five years and nutrient quality of fermented maize based products is limited in Kenya.

Objective: The objective of the current study was to establish the socio- demographic characteristics, dietary diversity score and utilization of fermented maize products by children 6-59 months old in Western Kenya.

Methodology: A structured questionnaire was used to collect socio- economic data, 24-hour recall and socio- demography for children 6- 59 mths old. Data was analyzed using Statistical package for Social Sciences (Version 20). Descriptive statistics were used to summarize the data while Pearson Chi square and correlation coefficient (R) were used to test for statistical association.

Results: A total of 120 caregivers had a gender ratio of 0.85: 0.15 female to male and that of the targeted children was 51.7: 48.3 for female: male. Only 15% of the caregivers had completed Secondary school and college training. There was a high mean dietary diversity score of 6.5 for Kakamega and Homa Bay counties. Of the children accessed 50% had been sick two weeks prior to the study.

*Conclusion:*The education level of most care givers is low hence there was limited information on the importance of fermented maize products. Fermented maize based products were consumed by most household (85%) in Western Region, mainly (70%) in form of thin porridge, *uji.* Fermented maize products are important carbohydrate foods and highly utilized for "family consumption" but used in small amounts by very few people as weaning food. *Recommendation:* Create awareness on utilization of fermented maize based products as complementary foods.

3.2 Introduction

Age, gender, household characteristics, dietary intake and health status are influenced by underlying factors such as food security, community infrastructure including sanitation, safe water, local market conditions, prices of related health outputs and available household resources (Fedorov and Sahn, 2005). Conventionally, nutrition problems are first and foremost equated with outright hunger, meaning insufficient consumption of dietary energy (FAO, 2010). Consumption of low energy foods leads to undernourishment which is directly felt by those suffering from hunger and is easily recognized because it causes wasting and stunting, a lack of micronutrient in people's diets has less directly perceptible but nevertheless potentially serious consequences for the health and wellbeing of the affected individuals. Micronutrients deficiencies can cause, lack of stamina, impaired physical and cognitive development, morbidity, blindness and causing increased susceptibility to infectious diseases- premature death.

Maize (*Zea mays*) belongs to the grass family called *Graminae*. The two varieties of maize grown in the study area were yellow maize found in Homa Bay and White maize in Kakamega counties. Traditionally, fermented maize products are achieved through spontaneous fermentation at ambient temperature. Fermented foods are consumed in every country of the world and there is growing evidence that fermented foods are good for health (Kunyanga et al., 2009). Fermentation provides a natural way to reduce the volume of the materials to be transported, destroy undesirable compounds, enhance the nutritive value and appearance of food, reduce the energy required for cooking and make a safer product (Katongele, 2008).

Most of the rural community in Kenya heavily depends on maize based products as a weaning diet for children less than five years which is a source of high calorific value but deficient in some essential nutrients like lysine, tryptophan, threonine and micronutrient. (Sokrab *et al*., 2015). The consequences of malnutrition extend beyond individuals and families to the entire communities and nations that include compromised immune function and cognitive.

3.3 Materials and Methods

3.3.1 Study Area

3.3.1.1 Kakamega Region in Western Kenya.

Kakamega County is found in the former Western Province. The County's largest town is Kakamega. The total population is 1 660 651 people with 398709 households and covers a total area of 3 244 square kilometers. The population density is 515 persons per kilometer with 57% of the population living below the poverty line (KNBS, 2009). The county comprises of twelve Sub-counties: Shinyalu, Ikolomani, Lurambi, Butere, Mumias West, Mumias East, Lugari, Khwisero, Malava, Likuyani, Navakholo and Matungu. Kakamega County has a mixture of both subsistence and cash crop farming, with sugar cane being the preferred medium to other large scale cash crops such as tea. The County has two sugar factories. There is also a significant tourism industry centering on Kakamega Forest.

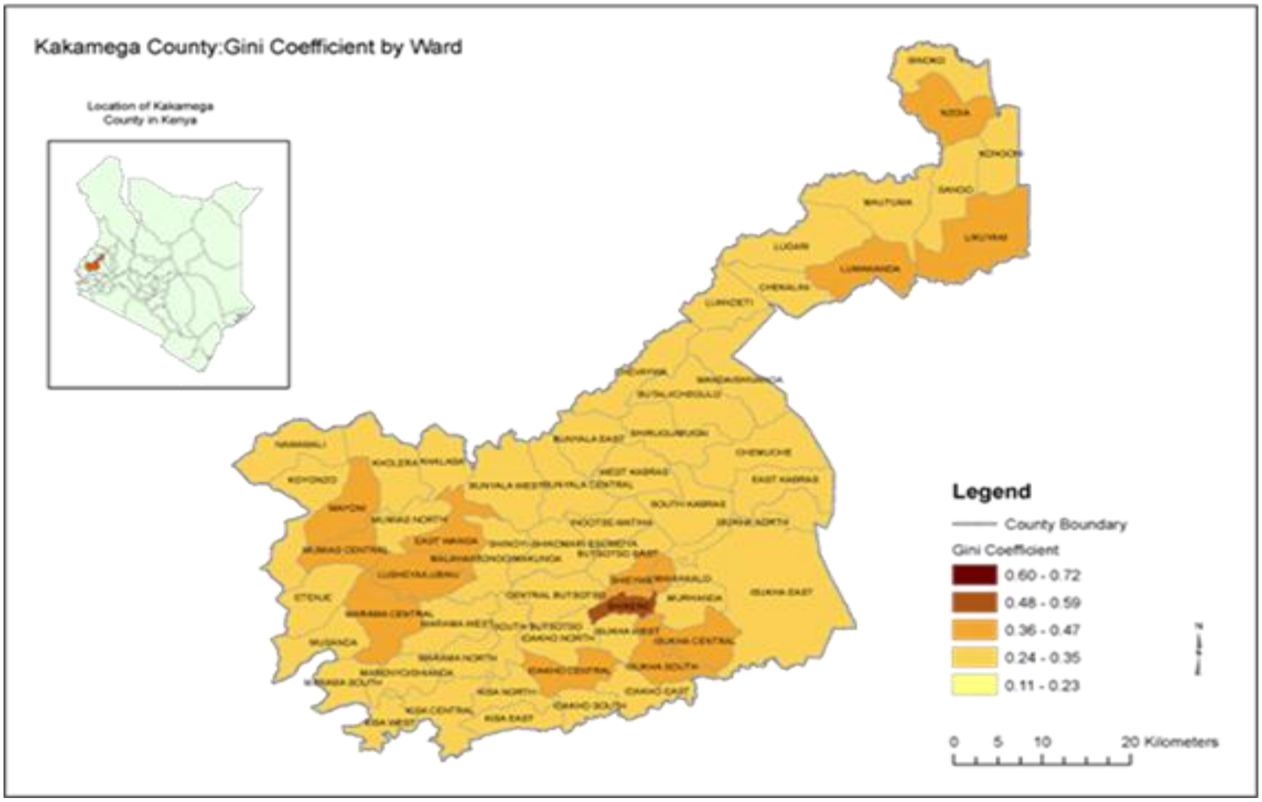

Figure 3.1 : Map of Kakamega County in Kenya. Source: Googlemap (2016)

3.3.1.2 Homa Bay County in Western Kenya

Homa Bay County is found in the former Nyanza Province. The County's largest town is Homa Bay. The total population of the County is 963 794 people with 206255 household and covers a total area of 3 183.3 square kilometers plus additional area of mass water 1227 square kilometer. The population density is 303 persons per kilometer with 43.7% of the population living below the poverty line (KNBS, 2009). The county comprises of nine Sub-Counties:

Mbita, Ndhiwa, Homa Bay, Rangwe, Karachuonyo, Kabondo, Kasipul and Suba. Fishing and agriculture are the main economic activities in Homa Bay County. Fish caught in the lake include Tilapia and Nile Perch, which is consumed locally, sold to other towns such as Kisumu and Nairobi and exported worldwide. Areas around Kasipul, Kabondo, Rangwe and Ndhiwa are very fertile; producing bounty harvests of cotton, maize, sugar cane, cassava, banana, pineapples, sorghum, millet, sunflower, sorghum, ground nuts and sweet potatoes. Sugar cane grown in the county is crushed at the Sony Sugar factory in Awendo and Sukari Industry. Tourism is also a major income-earner for Homa Bay, with tourist attraction sites such as Ruma National Park and Mfangano Island. These counties depend on maize as the main subsistence crop hence dependence on it as a staple including weaning children less than five years.

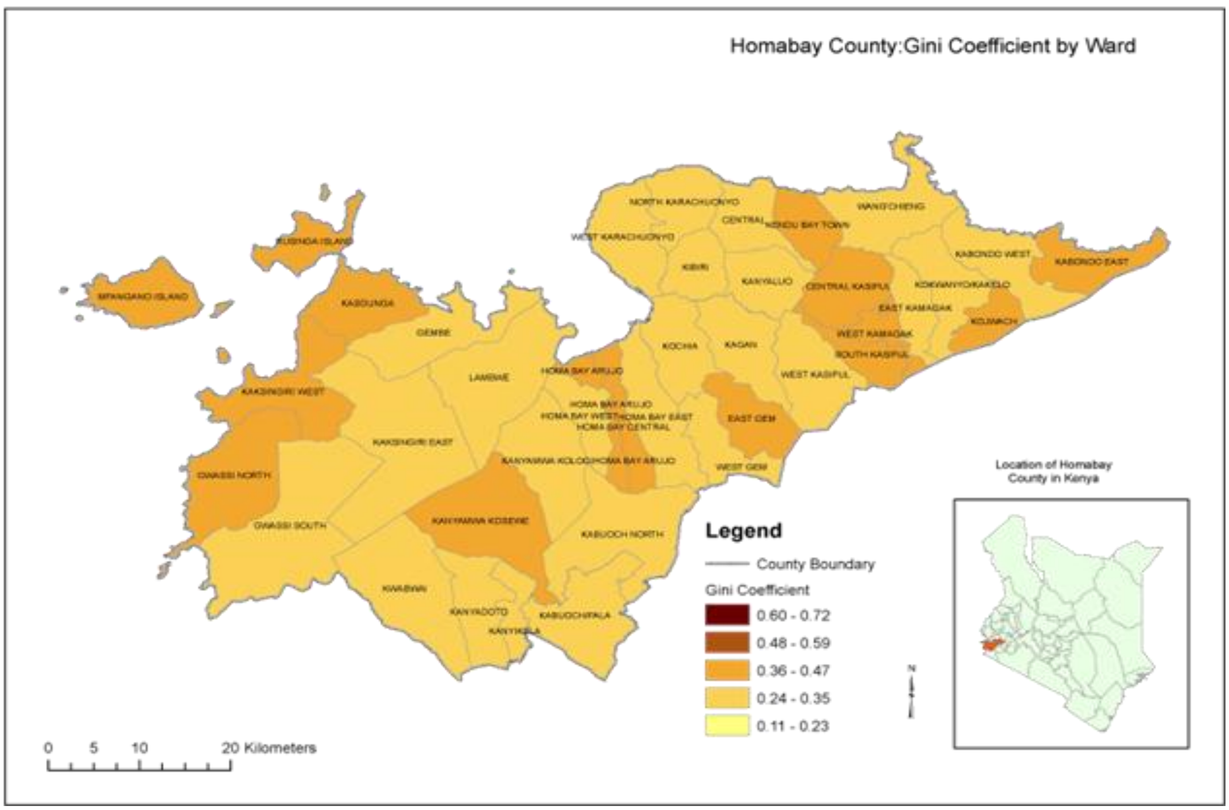

Figure 1.2: Map of Homa Bay County in Kenya. Source: Googlemap (2016)

3.3.2 Sampling of Households with Target Child

Sampling was done in Western Kenya which was represented by Homa Bay and Kakamega counties. These two counties are found in regions that rely heavily on maize consumption (Economic Review of Agriculture, 2015) but have some cultural variations that are likely to influence the nutritional outcomes.

Sub locations were identified in Homa Bay and Kakamega counties in Western region and were purposively selected as they are among the largest producers and consumers of maize and maize based products. One (1) sub-county (Ndhiwa and Shinyalu) was randomly selected from each of the two counties and two (2) major densely populated where maize fermented products are processed and utilized was purposively selected from each of the Sub-Counties.

Thirty (30) households with children of age 6-59 months were systematically selected from each sub-location after determining starting point randomly. The assessment of children was one (1) child per household (the oldest) because it was assumed that children in the same HH are subjected to similar conditions. In the study, 120 questionnaires (Appendix 1&11, Pg 92-102) were administered to caregivers in Murhanda Location in Kakamega and Kanyamwa Location in Homa Bay counties.

3.3.3 Data Analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS) version 20.0. Descriptive summary statistic such as frequencies, means, medians and standard deviation (sd) was used to describe the characteristics of the study population.

Pearson correlation coefficient was used to show relationship between continuous variables such as the age of child with nutrition status. Significance level was set at $p<0.05$ with confidence interval of 95%.

Chi-square tests were performed to establish the relationship between the socio- demographic, morbidity and dietary intake and the nutritional status of the children.

3.4 Results

3.4.1 Socio-demographic, socio economic characteristics and utilization of fermented maize products by the children 6-59months at household level

3.4.1.1 Socio demographic and socio economic characteristics

Table 3.1, shows the socio- demographic and socio-economic characteristics of the 120 caregivers and the targeted children. Most caregivers (39.1%) were married, 2.3% were widowed, while 5.8% were single parents and 0.3% was separated. Only 15 % of the caregivers were male. 42.5% indicated completion of primary education and 51.3% of the males were involved in income generation for their families where most of the caregivers (20%) were involved farming as source of income. More than half (51.7%) of the targeted children were female and 48.2% were male. The mean age of the index child was 32.1 months (sd= 15.3). The age 36- 47months (25.8%) had the highest population whereas 6- 11 months had the minimum population (7.5%). From the study , there were more girls (51.7%) than boys (48.3%). The ratio of boy: girl varied across the grouped age.

Table 3.1: Socio- Demographic and Socio-Economic Characteristics of the Households in Homa Bay and Kakamega Counties

Characteristics	**County (N)**		**Percentage**
Marital Status	**Kakamega**	**Homa Bay**	
Single	2	1	2.5
Married	48	56	86.7
Separated	2	0	1.7
Divorced	2	1	2.5
Widowed	2	8	8.3
Caregiver's Gender			
Male	6	12	15.0
Female	54	46	85.0
Education Level of caregivers			
Completed College	2	1	2.5
Completed Secondary	6	9	12.5
Completed Primary	30	28	42.5
Dropped from Primary	12	23	29.2
Dropped from Secondary	10	3	10.8
Illiterate	2	1	2.5
Socio -Economics			
Salaried employees	2	1	2.5
Farmers	10	14	20.0
Casual Labourer	4	5	7.5
Self-employed/ business	4	4	6.6
Housewife	5	2	5.8
Unemployed	2	3	4.2
Child's Gender			
Male	27	31	48.3
Female	33	29	51.7
Child's Age			
6- 11mths	12	11	22.8
12- 23mths	18	13	23.5
24- 35mths	16	17	25.8
36- 47mths	8	10	20.2
48- 59mths	6	9	7.7

N - the number of respondents

3.4.2 Child Dietary Diversity in Homa Bay and Kakamega Counties

In Figure 3.3 dietary diversity score was analyzed out of twelve (cereals, milk, sugar and honey, oil and fats, meat, pulses / legumes, eggs, roots/tubers, vegetables, fruits, fish / seafood and miscellaneous) food groups which children had consumed 24-hours prior to the study. More children were fed cereals, oils/ fats and milk while animal products meat and eggs were least fed to children.

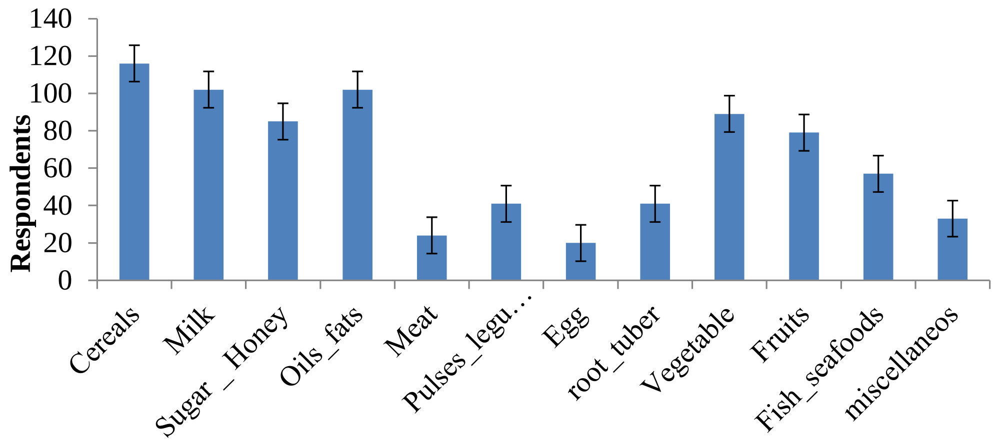

Figure 3.3: Child Diversity Score in Homa Bay and Kakamega Counties

3.4.2.1 General Child Dietary Diversity in Homa Bay and Kakamega Counties

7% of the children had a dietary diversity score of less than four (4) food groups and majority of the children had good diversity score of 4-7 and 8-12 food groups with 61% and 32% of the respondents, respectively. There was a negative signifant correlation between dietary diversity score and caregivers education level (r= -0.204, p= 0.025). As shown in Figure 3.4, mean dietary diversity score (DDS) of the children was 6.5 (sd= 1.8) for Kakamega County and 6.4

(sd= 1.7) for Homa Bay county. There was no significant difference (p= 0.877) in dietary diversity score per county.

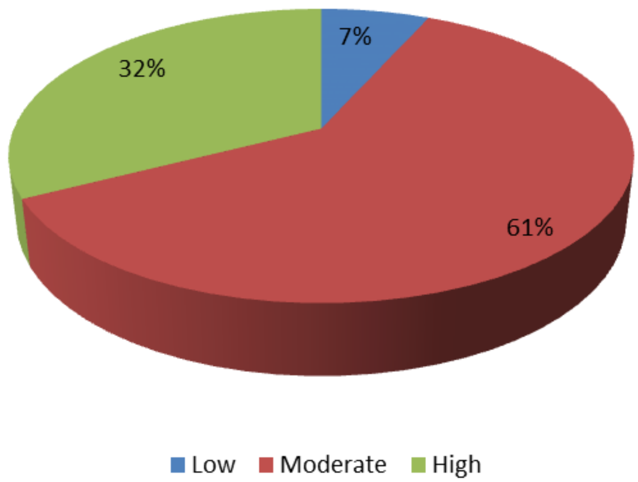

Figure 3.4: Child Dietary Diversity Score for Western Region

3.4.2.2 Dietary Diversity Score per Age Group in Homa Bay and Kakamega Counties

In Figure 3.5, there was a positive and no significant correlation between the dietary diversity score levels with height-for-age and weight-for-age, Pearson r= 0.423, 0.249 respectively ($p>0.05$). Whereas the weight-for-height had a negative and insignificant ($p>0.05$) correlation (Pearson r= -0.060) with dietary diversity. However, 3.3% of the children aged 6-17 months had a low or poor dietary diversity score and 18 to 41 months old had the highest dietary diversity score.

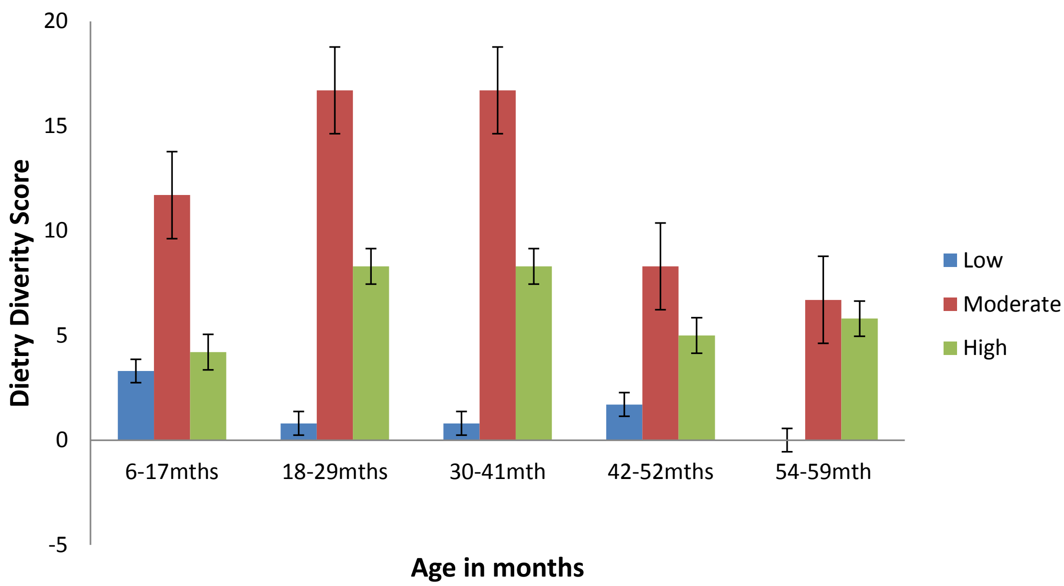

Figure 3.5: Dietary Diversity Score per Age Group in Homa Bay and Kakamega Counties

3.4.3 Availability and frequency of Consumption of fermented maize based products

3.4.3.1 Source and Preference of Fermented Maize Products to the Household

As shown in Figure 3.6, more than three quarters (82%) of the household consumed fermented maize products which were sourced from own production, only 4.0% sourced them from local open air market and 14.0% were neither producing nor purchasing. About 85% consumed fermented maize products as a food for the whole family.

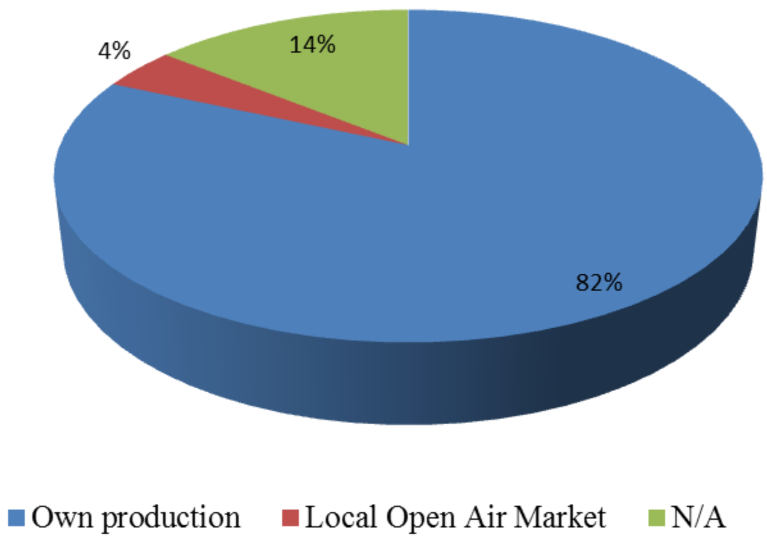

Figure 3.6: Sources of Fermented Maize Products in Homa Bay and Kakamega Counties

3.4.3.2 Preparation Methods of Child Fermented Maize Products in Homa Bay and Kakamega counties

As shown in Figure 3.7, at household level, fermented maize products for child consumption were prepared by use of warm water, mixed with flour and left to ferment for 12 hours (26.7%) whereas 20.8% used cold water, 4.2% made thick paste left for 4 days, roasted the fermented dough, sundried it, stored and soaked for long before feeding the children and almost half of the study population (48.3%) did not have a preparation method maybe showing that they did not feed fermented maize products to their children. There was a significant difference (p=0.013) between those who had a preparation method and those who did not for the children.

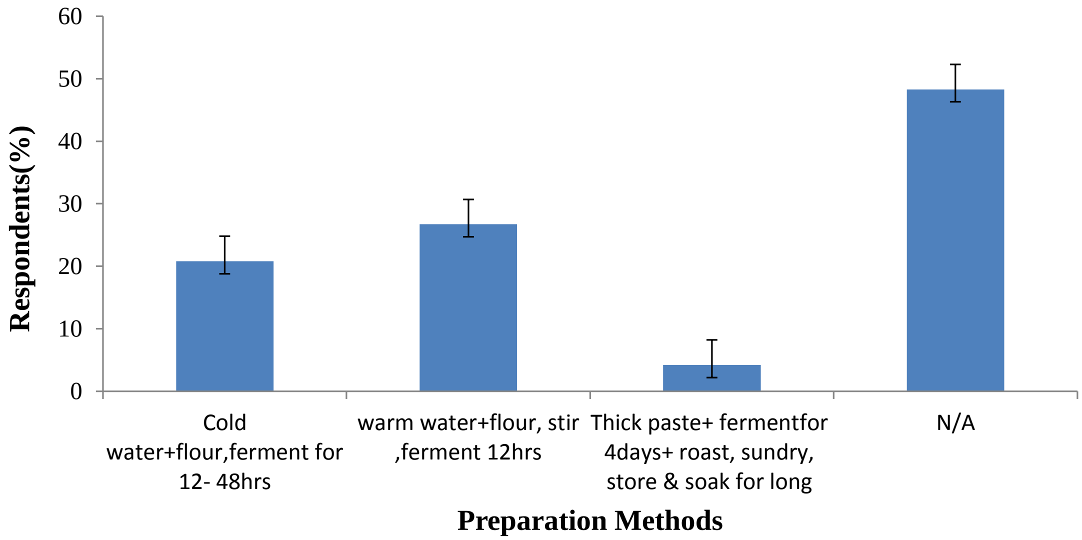

Figure 3.7: Preparation Methods of Fermented Products for Children

3.4.3.3 Most Preferred Fermented Maize Products Consumption in Homa Bay and Kakamega counties

The distribution of preference of fermented maize products per county as food for children is shown in Table 3.2, 70% of households preferred thin porridge, *uji*, while 10% preferred *mkarango*, 3.3% preferred busaa and more than half of household (53.4%) did not prefer fermented maize products as weaning food for their children. Preference was statistically significant (P<0.05) among the foods. In Homa Bay there was no variety of the products. Most households (43.3%) preferred *uji*. Both counties preferred *uji* because it was cheap, affordable and the fermented maize product that can be eaten without addition of sugar. From probing, Homa Bay has hard water which makes it easier and shorter time taken to cook fermented products like thin porridge as compared to unfermented.

Table 3.2: Most Preferred Fermented Maize Products Consumption per County

Fermented Maize Products	Kakamega(%)	Homa Bay (%)	Total
Uji	26.7	43.3	70
Busaa	3.3	0	3.3
Mkarango	10	0	10
Not Applicable	10	6.7	16.7

3.4.3.4 Consumed Fermented Maize Products at Household level

In Figure 3.8 more than half (70%) of the study population consumed *uji*, 14.0% consumed mkarango, 1.0% fed busaa to children and 15% did not consume any fermented products. Almost 85% of the households including those that did not ferment maize products, consumed them.

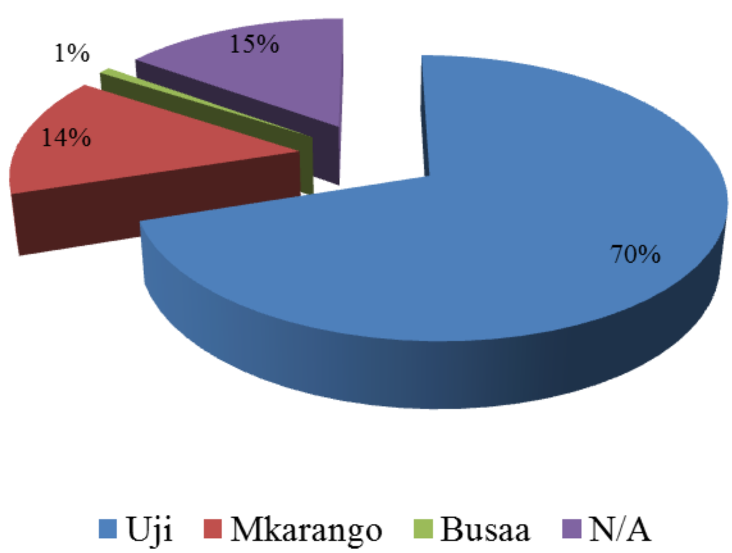

Figure 3.8: Consumed Fermented Maize Products in Homa Bay and Kakamega Counties

3.4.3.5 Frequency of Consumption of Fermented Maize Products in Homa Bay and Kakamega Counties.

As shown in Table 3.3, of the 120 caregivers, only 3.3% fed their children on FMPs more than once a day, a higher percentage 28.3 % (15% for Kakamega and 13.3% for Homa Bay counties) never used FMPs to wean their children.

Table 3.3: Frequency of Consumption of Fermented Maize Products per County.

	Kakamega	Homa Bay
>Once daily	3.3	0
Once daily	2.5	3.3
3- 6 times per week	6.7	10
1- 2 times per week	9.2	15
Once per month or less	13.3	8.3
Never	15	13.3

3.4.3.6 Frequency of Consumption of Protein Rich Food Compared to FMPs

As indicated in Table 3.4, milk / its products and fermented maize products were the most frequently consumed at 21.7% and 3.3% respectively of the households consuming more than once daily. Also meat and FMPs were the most frequently consumed at 25.8% and 24.2% respectively by the study population consuming at 1-2 times a week. Meat was most frequently consumed at 25.8% both 3- 6 times per week and 1-2 times per week. Eggs, chicken and FMPs had the highest percentage of never being fed to the children with 30.0%, 30.0% and 28.3%, respectively.

Table 3.4: Frequency of Consumption of Protein Rich Food compared to FMPs

	Eggs (%)	Fish (%)	Chicken (%)	Meat (%)	Milk (%)	Pulses (%)	FMPs (%)
>Once daily	0	1.7	1.7	1.7	21.7	0.8	3.3
Once daily	11.7	8.3	5.8	10.8	15.8	10.0	5.8
3- 6 times per week	23.3	20.0	16.7	25.8	17.5	24.2	16.7
1- 2 times per week	18.3	22.5	22.5	25.8	22.5	23.3	24.2
Once per month	16.7	20.8	23.3	14.2	10.0	19.2	21.7
Never	30.0	26.7	30.0	21.7	12.5	22.5	28.3

3.4.3.7 Frequency of Consumption of Fruits and Vegetable (Food Rich in Minerals & Vitamins) Compared to FMPs.

In Table 3.5, the dark green leafy vegetables were the most frequently consumed with 29.2% and 25.0% of children consuming once daily and 3- 6 times per week respectively. The pumpkins, spinach and the ripe papaya were not popular among the study children, had the highest 37.5%, 48.3% and 39.2% respectively for never feeding the study population. For more than once daily their consumption was 0% for all of them.

Table 3.5: Frequency of Consumption of Fruits and Vegetables (Food Rich in Minerals & Vitamins) compared to FMPs.

	Dark leafy green vegetables (%)	Pumpkin (%)	Spinach (%)	Ripe papaya (%)	FMPs (%)
>Once daily	13.3	0	0	0	3.3
Once daily	29.2	9.2	10.0	11.7	5.8
3-6 times per week	25.0	18.3	11.7	8.3	16.7
1- 2 times per week	19.2	23.3	19.2	22.5	24.2
Once per month or less	4.2	11.7	10.8	18.3	21.7
Never	9.2	37.5	48.3	39.2	28.3

3.4.3.8 Consumption of fermented maize products and socio- demography

In Table 3.6 shows that there was no significant association at ($p < 0.05$) between education level of the caregiver, age of the child, gender of the child and individual dietary diversity score with the consumption of fermented maize products . The gender of caregivers had statistical ($p<0.05$) association with the consumption of fermented maize products.

Table 3.6 Consumption of fermented Maize based Products and association with Socio-demography

Factors	Consumption of fermented maize products		
Education level of caregiver	**Yes %**	**No %**	**P- value**
No education	2.9	0	
Primary	74.5	55.6	0.118
Secondary	19.5	44.4	
Post –Secondary	2.9	0	
Age of the child			
6- 11months	18.6	22.2	
12- 23months	26.5	22.2	
24- 35months	28.4	22.2	0.879
36- 47 months	13.7	22.2	
48- 59 months	12.7	11.1	
Gender of the Child			
Male	48	50	0.878
Female	52	50	
IDDS			
Low	5.6	11.1	
Moderate	59.8	66.7	0.488
High	34.3	22.2	
Gender of Caregiver			
Male	11.8	33.3	0.018*
Female	88.2	66.7	

*Indicate Statistical significance at $p \leq 0.05$

3.4.3.9 Household Water Sources

As shown in Figure 17, there were several sources of water for household use, 5.8% had tap water and 5.0% from boreholes, 46.7% from rivers, 22.5% from springs, 13.3% from protected wells and 6.7% from unprotected wells. Majority (90.8%) of the study population obtained their water outside their compounds and the mean time taken to and from the watering point is 32.5 minutes (sd= 22.4).There was a significant difference (P= 0.01) in the time taken to and from the watering point in Kakamega and Homa Bay counties being highest in Homa Bay County.

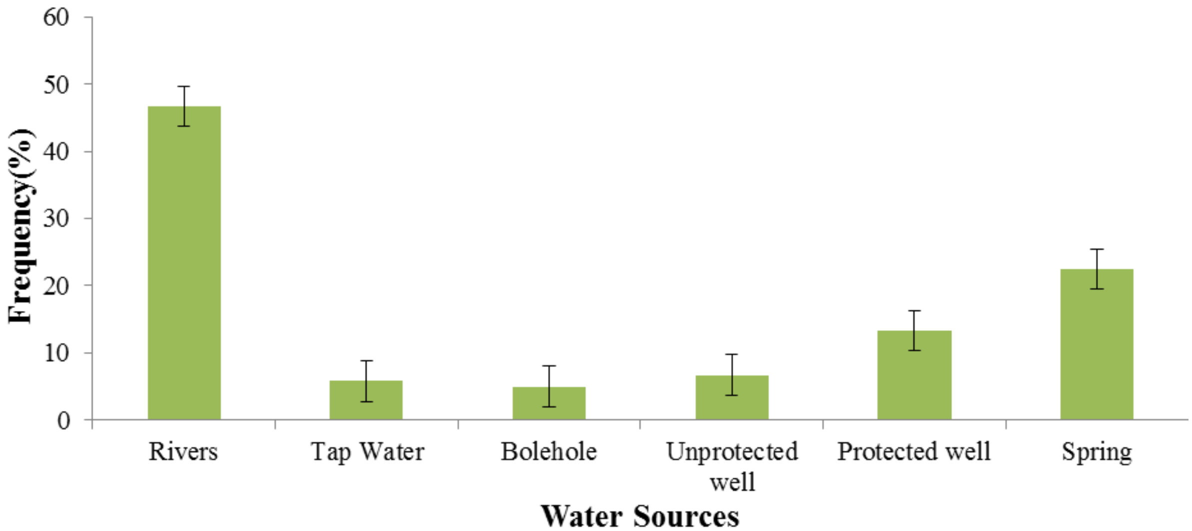

Figure 3.9: Main Water Sources in Homa Bay and Kakamega Counties

3.4.3.10 Water Treatment Methods in Homa Bay and Kakamega Counties

The Figure 13, shows methods of water treatment of drinking water at household level with 55% use of chemicals, 11.7% used filters, only 5% boiled and 27.5% did nothing. There was a significant difference (p= 0.018) in water treatment in the two counties.

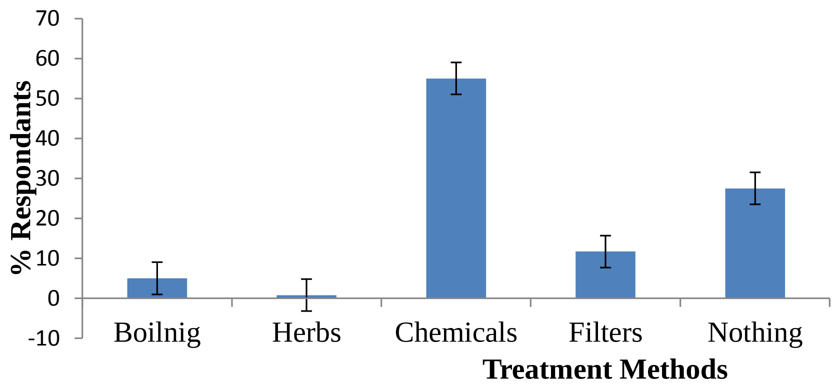

Figure 3.10: Water Treatment Methods

3.5 Discussion

3.5.1 Socio- Demographic Characteristics of the study population

The higher number of female than male caretakers is attributed to the fact that traditionally, most women are home makers who attend to the family farms. Men on the other hand fend for their families in either formal employment or casual labour. This result is in agreement with study carried in Busia (Nungo,2015) and KDHS (2014).

Majority of the target population was aged between 6- 59 months was a portion that is greatly dependent on the parents. The age- sex composition where female slightly out-numbered the male which are similar to the country findings (CBS, 2004). The mean household size in the study was 5 (five) which did not differ significantly ($p>0.05$) between the counties. This was slightly higher than the Kenyan National average household size 4.6 (KDHS, 2014). Large household sizes put pressure on limited resources that meet the health and nutritional requirements (CBS, 2004), however, from the study area they preferred large families because the elder children helped to take care of their siblings as both the parents help each other to fend.

Education level of the study population was generally low, with majority not completing primary school. In Homa Bay county , the drop-out in primary was very high while Kakamega county had higher secondary school drop- out. Most drop-outs got married immediately that's why in the study there were equal numbers of households per county but the population for Homa Bay was higher than Kakamega. This primary school drop-out at the age of 15-19 years and that prevalence of early child-bearing was highest in Homa Bay region was in greement with KDHS (2014) report. Also due to lack of information as a result of low education levels, the use of contraceptives in Kakamega was 60.3% which was higher than Homa Bay county at 45% (KDHS, 2014). Caregivers with higher education levels had better nourished children than those mothers with lower education, suggesting that most of them were better aware and more informed of nutritional needs of the household members and were very careful on what they fed their children. This is in line with what Mwadime (2000), Mbithe (2002) and Kiige(2004) reported in ANP literature.

3.5.1.1 Socio-Economic Activities

Majority of the study population 51.3% were male who were involved in economic activities because the male in these two counties are traditionally believed to be the sole- bread winners.

Their percentage in activities like salaried employment, farming, business/ self- employment and casual labour was high than the female counterparts who do more of the reproductive duties like homemaking and attending to family farms. Majority of the study popuation 20.1% practised farming because the climate is conduicive for crop production like maize, sugar cane ,tea, etc. and livestock poduction . Majority did not make fermented maize products for income generation but for own consumption.

3.5.2 Child Dietary Diversity

This is the measure of the number of food groups consumed over a reference period, usually 24 hours. Generally, there were twelve (12) food groups that the body needs to have every day that should be consumed at different proportions. Child diversity score (6.5) in the region of study was generally acceptable or appropriate, with majority of the children consuming food from more than half of the food groups per day. This may indicate that the children had both balance of nutrient consumption and the households were food secure. The levels of malnutrition among the children was very mild form. Majority of the children were normal for the three indicators of malnutrition measured. The age 6- 17months old had the lowest dietary diversity score because weaning starts at this time and most children are reluctant to eat weaning foods. At 18-41 months old had the highest dietary diversity score because children are active and do not breast feed a lot and have access to snacks frequently.

3.5.3 Food Frequency Consumption Patterns

The consumptoin of fermented maize products shows that thin porridge(uji) was most commonly consumed product at almost three quarters of the study population while utilization of other products mkarango and busaa were not popular especially in Homa Bay county. In

Kakamega county all products were utilized (mkarango 10% and busaa 3.3%). This showed that fermented maize products were highly acceptable for " family consumption" and has the potential to increase household weaning food fermented products, half of them never or fed once per month or less. 82.2% reflected that there was no difference in children fed on fermented and unfermented. 62% did not have a special method for child preparation of thin porridge though it was most consumed. This could be due to beliefs, taboos, cultures, the caregiver's perception ("if I don't take that porridge….") and level of education.

3.5.4 Availability of fermented Maize Products

Approximately 85% of the household members studied consumed fermented maize products. This shows that fermented maize products are highly accepted food in the region and it has a great potential of increasing household food security. Majority of the population prefer their own production and few source from the local open air market.

3.6 Conclusion

Kakamega and Homa Bay counties are not very different in demography and socio- economic characteristics but the education levels of most care givers is low hence there is little or no nutritional knowledge on the importance of fermented maize products.

Child diversity score in the region of study is generally acceptable or appropriate, with majority of the children consuming food from more than half of the food groups per day.

Fermented maize products are consumed by most household in Western Region, mainly in form of thin porridge, *uji.* Fermented maize products are important carbohydrate food and highly utilized for "family consumption" but used in small amounts by very few people as weaning food (though having the potential).

3.7 Recommendation

To improve nutritional knowledge, create awareness, improve practices and increase child consumption levels of fermented maize products requires capacity building (educate) of all stake holders: Ministry of Agriculture (Front line extension staff), Ministry of Health (Community Health Workers), Ministry of Education (Teachers) , Administration (Chiefs and Assistant Chiefs) and other service providers to incorporate utilization, nutritional and safety of fermented maize products considerations and messages into their routine work.

Future research efforts should be made to fabricate a simple, small, safe, acceptable, operational production machine to produce good quantity and quality of any fermented maize products at household level.

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CHAPTER FOUR

4.0 NUTRITIONAL AND MICROBIAL QUALITY OF FERMENTED MAIZE BASED PRODUCTS CONSUMED IN HOMA BAY AND KAKAMEGA COUNTIES OF KENYA

4.1 Abstract

Introduction: Malnutrition can be due to poor macronutrient intake referred to as Protein-Energy Malnutrition (PEM). Deficiency in minerals can be due to the presence of anti- nutrients e.g. phytates which lead to zinc and iron unbioavailabity in the human gut for absorption.

Objective: The objective of the study was to determine the levels of phytates, crude proteins, crude fibre, zinc, iron, *Staphylococcus aureus,* coliforms and aflatoxin in fermented and unfermented maize based products from different households from Homa Bay and Kakamega Counties**.**

Methodology: The nutritive value and microbial analyses were done using standard methods. *Results:*The mean phytates content ranged from 3040mg/100g to 3355mg/100g for *mkarango* (dried fermented maize flour) and maize flour products, respectively. The mean iron content was high in *busaa* at 3.94- 4.8 mg/100g in unfermented flour and busaa products. Zinc content in the maize products ranged between 2.17- 6.9 mg/100g in maize flour and fermented *uji*. The contents of crude protein ranged 2.9% -8.56% for fermented *uji* and soaked flour. The mean crude fibre content was high in flour at 3.35% and lowest in soaked flour at 2.76%. . The range of *Staphylococcus aureus,* coliforms and total aflatoxin load were 3.4 to 5.5 log cfu/g in *mkarango* and unfermented porridge, 3.13 to 5.54 log cfu/gm in unfermented porridge and *busaa* and 2.26- 8.18 ppb in flours and *busaa*, respectively.

Conclusion: The presence of *Staphylococcus aureus* and Coliforms in all the products shows unhygienic standards, excessive handling and the use of dirty untreated water. The fermented maize products from Homa Bay County had better nutrition qualities than those from Kakamega County.

Recommendation: Capacity building (training) of the caregivers on hygienic: Good Farming Practices, good child feeding practices, nutritive value of fermented maize products, hygienic preparation methods and handling.

4.2 Introduction

Maize (*Zea mays*) is the most important and widely consumed cereal in. It is the staple food crop for 96 percent of Kenya's population and provides 40 percent of the calorie requirements but also proteins (WEMA, AAFT and KARI, 2010). Phytates (inositol hexakisphosphate) is a phosphorous containing compound that binds with minerals and inhibits mineral absorption. In the structure of phytates, there is high density of negatively charged phosphate groups which form stable complexes with mineral ions causing non-availability for intestinal absorption (Walter *et al*., 2004). Phytates are generally found in foods high in fibre especially the wheat bran, whole grains and legumes (Norhaizan *et al*., 2009). Iron is the most abundant element on earth, but iron deficiency in human is one of the world widespread nutritional problems in the world (USAID, 2010). Iron deficiency anemia refers to severe depletion of iron stores those results in low haemoglobin concentration (Rolfes *et al*., 2012). Without adequate iron, energy metabolism in the cells falters hence fatigue, weaknesses, headache, apathy and poor resistance to cold temperatures (Rolfes *et al.*, 2012). Iron deficiency anaemia in young children is associated with impaired psychomotor performance as well as changes in behavior. There is decrease in responsiveness and activity with increased body tension, fearfulness and tendancy to fatigue in association with Iron deficiency anaemia (Bowman *et al*., 2001).

Zinc is a trace mineral that is essential for all forms of life, including plants, animals and organisms. The likelihood of deficiency in human is considered remote because of the ubiquitous nature of zinc in food supply. It is needed for activity of nearly 100 enzymes and those enzymes that use a metal ion as a cofactor are called metallo-enzymes (Katongole, 2008). Zinc is a stabilizer by helping certain protein to fold by attaching to the amino acids. The fold proteins have fingerlike projections that increase their structural stability and are used in the retinal (vitamin A) as receptors in the eye and also vitamin D receptors (Rodri`guez *et al*., 2006).

Dietary fibre plays a significant role in the prevention of diseases such as cardiovascular disease (CVD), colon and breast cancer. Diets which are rich in fibre contain cereals, fruits and vegetables which have a positive health effect. (Norhaizan *et al*., 2009). Crude protein content varies from about 8 to11 percent of kernel weight. The nutritional quality of maize as a food is determined by the amino acid make-up of its crude proteins. (FAO, 1992). Crude fibre is the residue that remains (cellulose, hemicellulose and lignin) after extraction of plant tissues with dilute acid or basic solutions (Rodriguez *et al*., 2006). In nutrition it's known as dietary fibre which consists of remnants of plant cells resistant to hydrolysis (digestion) (Rodriguez *et al*., 2006).

Staphylococcus aureus has long long been recognized as one of the most important bacteria that cause disease in humans. Although most Staphylococcus infections are not serious, *S. aureus* can cause serious infections such as blood stream infections, pneumonia, or bone and joint infections (Minnesota Department of Health, 2010).They are found colonizing the human body causing skin andsoft tissue infections (abscesses,furnuncles and cellulitis). They are spread via contaminated hands (Minnesota Department of Health, 2010). Mycotoxins are secondary metabolites of microscopic fungi which are not indispensible to the fungi's life but show toxic effects on human beings, animals, plants and micro-organisms.It is produced by the moulds *Aspergillus flavus* and *Aspergillus parasiticus* (Government of India, 2012). The KEBS standards on maize flour specification set acceptable microbiological limits to be met that is: aflatoxin maximum limit of 10ppb, *Staphylococcus aureus* limits 2 log cfu/g and coliforms should be absent from the foods (KEBS, 2014). The objective of the study was to analyse level of crude protein, crude fibre, zinc, iron, phytates and the level of contamination of fermented maize products that are available to children 6-59months old (consumers) so as to access their quality and safety.

4.3 Materials and Methods

4.3.1 Sampling of Fermented Maize Products

The fermented maize products and unfermented maize flour were randomly collected from the households where data was collected. In Homa Bay County the villages were Abaranono and Ogege found in Sub-locations Komungu and Goyo both of Ndhiwa Sub County. In Kakamega County the villages were Munyanda, Shiswa, Buyonga, Mukulusu and Itumbu found in Sublocations Shiswa and Mukulusu both of Shinyalu Sub County. The sampling of the household was purposive and the number of samples collected was according to availability, thus ensuring exhaustive sampling from the sample population of 120 households. Twenty-nine samples were collected from both counties *Busaa* (6), soaked fermenting flour (6), *Mkarango*

(Roasted) (5), fermented cooked porridge four (4) and unfermented cooked flour (4) and flour-four (4). On site the sample were labeled according to the date of collection, place and type of product. The samples were then packed in zip lock sample bags to prevent any further contamination during transport to Nairobi University Laboratories for analysis.

4.3.2 Analytic Methods

Analytical component involved determination of the levels of iron, zinc, crude fibre, crude proteins , phytates, total aflatoxins, *Staphylococcus aureas* and total coliforms from maize based products used in children food preparations. All data attained was subjected to analysis of variance (ANOVA) and the means separated by Duncan Multiple Range Test using Genstat 15th Edition, Significance level was set at $p \leq 0.05$.

4.3.2.1 Determination of Phytates

Phytates were determined by UV-VIS double beam scanning spectrophotometer (CE 4400; Cambridge England) according to procedures described by Pearson (1976).

4.3.2.2 Determination of Crude Proteins

Crude proteins were determined by the micro-Kjeldahl (AACC, 2000) method number 46-10.

4.3.2.3 Determination of Crude fibre

Crude fibre was determined according to AOAC (2000) method number 7.054.

4.3.2.4 Determination of Zinc and Iron

The minerals, zinc and iron were determined by Atomic Absorption Spectrophotometer according to AOAC (1997) Official Method 944.02.

4.3.2.5 Microbial Determination

Total coliforms and *Staphylococcus aureus* content was determined as per the laboratory methods and procedures described by Harrigan and McCance (1976). Plate count technique was used whereby a known amount of the product or its dilution was mixed with a culture medium in a petri dish and after incubation; the numbers of grown colonies were counted.

4.3.2.5.1 Preparation of Dilutions

The samples were diluted so as to count the number of microbes that grow after incubation. In fermented maize products, the first dilution was made by homogenizing 25 grams in 225 ml of diluents to obtain a 10^{-1} homogenate from which further dilutions were made where 1ml of the homogenate was mixed with 9ml of diluents to form a 10^{-2} homogenate up until the required dilutions were achieved.

4.3.2.5.2 Enumeration of Staphylococcus aureus

Baird Parker Agar (BPA) selective media was used to grow and enumerate *Staphylococcus aureus.* About 3 ml of Potassium tellurite (3%) was added 1 litre of BPA and about 25 ml egg York was also added of the medium. The BPA was poured into the sterile plates and left standing for 15 minutes to solidify. Dilutions of the FMPs were prepared and 0.5mls of each dilution range 10^{-1} to 10^{-3} were pipette into duplicate plates and spread well. The plates were incubated at 35^{0}C for 24- 48 hours. The plates that had colonies that was:

a) Convex, shiny black with or without narrow grey-white margins, surrounded by a clear zone extending into the opaque medium

b) Convex, shiny black with or without narrow grey-white margins.

Further confirmation tests for *Staphylococcus aureus* was carried out. One colony was selected and inoculated on plates of DNAse agar by streaking. The plates were incubated at 35^0C for 48 hours. The DNAse plates were flooded with 1 N HCl after the incubation period. Plates that showed clear zones on an opaque background indicating DNA decomposition confirmed *Staphylococcus aureus.* The average counts of confirmed *Staphylococus aureus* were reported in logarithmic form ($\log_{10}$ cfu/g).

4.3.2.5.3 Total Coliform

Violet Red Bile Agar (VRBA) was used to enumerate total conforms. Dilutions of the FMPs were prepared and 1 ml of each dilution (10^{-1} to 10^{-3}) was pipetted into duplicate in sterile petri dishes. The VRBA was poured into the plates and mixed well (swerved clockwise and anticlockwise). The plates were incubated at 35^0C for 24- 36 hours. Typical coliforms colonies were indicated by red background.

4.3.2.5.4 Determination of Aflatoxin Level

Aflatoxin was determined by ELISA method according to technique adopted by Manjula *et al*. (2009). About 20 gm of sample was extracted using 100 ml of 70% methanol. The samples were filtered through Whatman filter paper and 15 ml of the extract collected. The filtrate was tested using the Helica Total Aflatoxin Enzyme- Linked Immuno-assay (ELISA) kit. The limit of detection was 1 ppb. The samples were run in duplicates.

4.4 Results

4.4.1 Level of Phytates, Crude proteins, Crude Fibre, Zinc and Iron In Fermented Maize based Products from Homa Bay and Kakamega Counties, Kenya

Table 4.1 shows the chemical profiles for phytates, crude proteins, crude fibre, iron and zinc as per product.

Table 4.1: Levels of Phytates, Crude Proteins, Crude Fibre, Zinc and Iron in Fermented Maize Products in Homa Bay and Kakamega Counties of Kenya

Treatment	Crude Proteins (%)	Phytates (mg/100g)	Crude Fibre (%)	Iron(mg/100g)	Zinc(mg/100g)
Flour	5.94 ± 3.17^{abc}	3482 ± 951^{a}	3.52 ± 1.63^{ab}	3.79 ± 2.3^{ab}	2.17 ± 0.77^{a}
Fermented cooked	2.90 ± 3.10^{a}	3168 ± 951^{a}	2.84 ± 0.25^{a}	5.39 ± 2.16^{b}	4.37 ± 5.14^{a}
Soaked Flour	9.54 ± 0.47^{c}	3048 ± 951^{a}	2.90 ± 0.24^{a}	3.78 ± 2.30^{ab}	2.7 ± 0.93^{a}
Roasted	8.12 ± 0.38^{bc}	3093 ± 951^{a}	3.40 ± 0.32^{ab}	1.26 ± 2.30^{a}	2.92 ± 0.91^{a}
Busaa	14.6 ± 1.60^{d}	3131 ± 951^{a}	3.14 ± 0.24^{ab}	3.03 ± 2.30^{ab}	4.92 ± 4.09^{a}
Unfermented Cooked	5.59 ± 3.16^{ab}	3230 ± 951^{a}	3.34 ± 0.53^{ab}	2.74 ± 2.30^{ab}	2.21 ± 1.33^{a}
L.S.D.	3.47	865	2.84	3.11	4.52

Values= Means± standard deviation; Means in the same column with different superscripts are significantly different ($P \leq 0.05$).L.S.D means least Significant Difference.

Most of the variation were not significantly different, only the protein content in fermented cooked porridge, soaked flours and *busaa* being 2.9 %, 9.54 % and 14.6 % respectively, were significantly different at ($p < 0.05$). The cooked fermented *uji* and the flour recorded the highest protein content levels, 6.7% and 9.8% from Homa Bay and Kakamega counties, respectively

The Cooked fermented uji and the soaked flour recorded the highest fibre content levels, 4.6% and 3.5% from Homa Bay and Kakamega Counties, respectively. Maize products from Homa Bay had high levels of fibre while those from Kakamega were rich in protein content levels. There was a significant difference ($p < 0.05$) between fermented cooked porridge with levels of 5.39 mg/100g and roasted (*mkarango*) that had 1.26 mg/100g of iron content. The soaked flour and the cooked unfermented porridge recording the highest iron content levels, 6.0 mg/100g and 2.3 mg/100g from Homa Bay and Kakamega Counties respectively.

There was no significant difference ($p \leq 0.05$) between the levels of zinc in all products under analysis. The cooked unfermented uji and the soaked flour recording the highest zinc content levels, 9.2mg/100g and 3.7 mg/100g from Homa Bay and Kakamega counties respectively. The soaked flour and the cooked unfermented porridge recording the highest phytates content levels, 2550mg/100g and 3410mg/100g from Homa Bay and Kakamega counties respectively. The products from Kakamega county had higher phytate levels than those from Homa Bay. There was on significant difference in variation in the phytate content in maize products per county.

4.4.2 Aflatoxins, Total coliforms and *Staphylococcus aureas* in Fermented Maize based Products in Homa Bay and Kakamega counties

The results in Table 4.2 shows total count of targeted contaminant loads for coliforms, *Staphylococcus aureas* and aflatoxins. Staphylococcal count of the maize products ranged 3.71-4.68 log_{10}cfu/g, total coliform count ranged 3.12 -6.45 log_{10}cfu/g and total aflatoxin ranged 2.26-8.18ppb. There was a statistical significant difference ($p<0.05$) in the coliform load between the other products compared with *busaa*. There was no significant difference ($p<0.05$)

in the products with regards to *Staphylococcus aureas* loading. There was a significant difference ($p < 0.05$) in coliform load among cooked un/fermented porridge with *busaa* and *mkarango.*

Table 4.2: Aflatoxins, Total coliforms and *Staphylococcus aureas* in Fermented Maize based Products in Homa Bay and Kakamega counties

Treatment	*S. aureas* (log_{10}cfu/g)	Coliforms(log_{10}cfu/g)	Aflatoxins(ppb)
Flours	4.68 ± 0.66^{a}	4.29 ± 1.22^{ab}	2.26 ± 0.99^{a}
Fermented Cooked	3.71 ± 0.66^{a}	3.20 ± 2.55^{a}	7.9 ± 0.99^{a}
Soaked Flour	4.68 ± 0.66^{a}	5.71 ± 1.40^{bc}	2.34 ± 0.99^{a}
Roasted	4.04 ± 0.66^{a}	$5.80\pm 0.93b^{c}$	6.78 ± 0.99^{a}
Busaa	$4.68+ 0.66^{a}$	$6.45+0.76^{c}$	8.18 ± 0.99^{a}
Unfermented Cooked	5.53 ± 0.66^{a}	3.12 ± 2.49^{a}	6.73 ± 0.99^{a}
L.S.D	1.98	1.96	10.52

Values= Means± standard deviation; Means in the same column with different superscripts are significantly different ($P\leq 0.05$). log_{10}cfu=colony forming unit for counting of microbes. L.S.D means Least Significant Difference.

Staphylococcus aureas count of the samples ranged 3.83 - 5.35 log_{10} cfu/g for flours, 3.63 to7.54 log $_{10}$cfu/g for soaked flour, 1to 5.28 g log $_{10}$cfu/g for fermented cooked (uji), 1 to 4.91 log $_{10}$cfu/g for Roasted (mkarango),1 to 5.42 log $_{10}$cfu/g for busaa and finally 3.57 to 7.48 log $_{10}$cfu/g for unfermented cooked porridge. The cooked fermented uji and the flour recording the highest Staphylococcus *aureus* content levels, 4.78 log $_{10}$cfu/g and 6.08 log $_{10}$cfu/g from Homa Bay and Kakamega counties respectively.

Total coliforms count of the samples ranged 3 to 5.45 log $_{10}$cfu/g for flours, 1 to 6.59 log $_{10}$cfu/g for soaked flour, 1 to 5.45 log $_{10}$cfu/g for fermented cooked (uji), 1 to 6.65 log log $_{10}$cfu/g for

Roasted (mkarango), 5.62 to 7.10 log $_{10}$cfu/g for busaa and finally 1 to 5.76 log cfu/g for unfermented cooked (uji). The Cooked fermented uji and the soaked flour recording the highest coliforms content levels, 4.4 cfu/g and 6.55cfu/g from Homa Bay and Kakamega Counties respectively.

As in Table 4.2, all the collected samples from both the counties showed detectable levels of total aflatoxin. The aflatoxin mean content ranged from 2.26± 0.99 ppb in the flours to 8.18± 0.99 ppb in roasted products. 21% of the samples had >20ppb which are above the acceptable limits set by the World Food Program (2011) and the KEBS (2014) at 20ppb and 10ppb respectively. Busaa had the highest significant content among other products. This may be an indication of poor post- harvest handling i.e. storage temperature and the humidity of the environment. The cooked unfermented porridge and the soaked flour recording the highest aflatoxin content levels, 11.3ppb and 11.2ppb from Homa Bay and Kakamega counties respectively.

4.5 Discussion

4.5.1 Level of Phytates, Proteins, Crude fibre, zinc and iron

From the findings of the current study, it was established that protein, zinc and iron contents levels in the unfermented maize products was low but higher in in fermented. Busaa had the highest protein and zinc content while fermented cooked porridge had high iron content. The high level of zinc content in *Busaa* may be attributed to addition of milled malted finger millet and for proteins content levels it attributed the fermentation process whereby the fermenting microbes themselves are additional protein (Sokrab *et al*., 2012) Fermentation provides an optimum pH condition for enzymatic degradation of phytates which is present in maize in form of complexes with polyvalent cations, such as iron, zinc, calcium, magnesium and proteins (Katongele, 2008). The decrease in fibre content is attributed to fermentation where modifications of the composition and structure of dietary fibre occurs. These changes are motivated by the enzymatic activity developed during the fermentative process and consists of solubilization of different cell wall polysaccharides. Main enzymes are amylase, proteinase, poli-galactutonase and cellulose that selectively degrade distinct cell wall polysaccharides and therefore provoke decrease of the fibre (Rodriguez *et al*., 2006). Across the counties, products from Homa Bay had good qualities e.g. lower phytates and high crude fibre, zinc and iron than those from Kakamega. It can be attributed to the maize variety because in Homa Bay they had yellow maize and in Kakamega had white maize. De Groote and Kimenju (2012) agreed with the yellow maize have better qualities but most rejected by many Kenyans.

The high levels of incidences of total coliforms and *Staphylococcus aureas is* attributed to the unhygienic behavior of the individual preparing it, the environment where they are prepared and where they are consumed (Omokaro and Amadi, 2015).This is also attributed to the use of contaminated water as most of the study population utilized water from passing rivers and unprotected springs (no piped water). It was also attributed to the amount of cooking fuel which led to poor preparation methods due to time required for cooking. This situation is in agreement with Katongele (2008) who reported that the common practices of fermenting, cooking and roasting leads to significant reduction in levels of *Staphylococcus aureus* and Coliforms but addition of dirty untreated water and germinated finger millet rises the levels again (Mbata *et al*., 2009).

The incidence of detectable quantities of aflatoxin in the present study may be attributed to the substrate (spoilt or rotten maize) which may have been good for aflatoxin biosynthesis (Gacheru, 2015). The substrate before preparation may have been stored under conditions that favour the growth moulds e.g. *Aspergilus flavus* at temperature 36-38^{0}C (production of aflatoxins at 25^{0}C), relative humidity >70% and moisture content of 15 % (FAO, 1978). Also the *Aspergilus flavus* may have been destroyed by processing like roasting or cooking but the mycotoxins will often remain in the final product because they are heat stable (Katongele, 2008). For example, Ugali and bread prepared from contaminated maize and wheat retained 85.5 and 82.4% aflatoxin B and G, respectively in Ugali while the bread retained 83.8 and 67.8% aflatoxin B and G, respectively (Adegoke *et al.*, 2010). The fermentation process may have involved a fungus essential for the process but also capable of producing mycotoxins and the final product may have been infected with toxigenic fungus with subsequent toxin formation (Katongele, 2008). Incidences of aflatoxins contamination has been reported in Nigeria (Adegoke *et al.*, 2010). The results of the current study reported levels that are below the acceptable limits of Kenyan standards (10ppb).

4.6 Conclusion

Fermented maize based products from Homa bay County have low crude protein and phytates levels but high crude fibre content, zinc and iron content but low phytates content whereas the products from Kakamega were the opposite.

The presence of *Staphylococcus aureus* and Coliforms in all the sampled products shows unhygienic standards, excessive handling before, during and after processing, also the use of dirty untreated water.

Although levels of aflatoxin are reported to be below the acceptable limits of Kenyan standards (10ppb), some individual products like *busaa* had high levels hence there are elevated risks of aflatoxicosis (is a major health concern to human beings) in the current and potential use of aflatoxin contaminated maize at rural village level.

4.7 Recommendation

Deliberate awareness should be made to promote yellow maize production and utilization as fermented food in order to benefit from it high nutritive value, to avoid over dependency on white maize. Capacity building (training) of the caregivers on Good Farming Practices, good child feeding practices and hygienic preparation methods and handling.

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CHAPTER FIVE

5.0 NUTRITIONAL STATUS AND MORBIDITY OF CHILDREN 6- 59 MONTHS IN HOMA BAY AND KAKAMEGA COUNTIES OF KENYA

5.1 Abstract

Malnutrition is not just a consequence of too little food but a combination of factors including frequent illness, poor food quality, poor feeding practices, inadequate health services and poor water and sanitation. The problem is that maize fermented products available at household level and they have not been exploited to wean children 6- 59 months old. The objective of the current study was to determine the nutritional status and morbidity of children 6- 59months. A structured questionnaire was used to collect anthropometric measures and morbidity for children 6- 59 months old. Data was analyzed using Statistical package for Social Sciences (Version 20). Descriptive statistics, Chi square and Pearson correlation coefficient (r) were used to test for statistical associations. The mean weight, height and age were 14.5 kilograms, 90.9 centimetres and 32 months, respectively. Those who were severely underweight, stunted and wasted were 6.7%, 21% and 9.2%, respectively. Of the children accessed 50% had been found to have been sick two weeks prior to the study. Only 5.8% of the population had tap water and the rest got water from river (46.7%), springs etc. which were not protected. Water treatment for drinking at household level: 55%, 11.7% 5% and 27.5% utilized chemicals, water filters, boiling and did nothing. The water used in preparation of fermented maize products untreated which may have associations that will bring challenges on the nutritional status and morbidity of the child.. The nutritional status of the children was average. There is need to capacity build the caregivers good feeding practices.

5.2 Introduction

Maize (*Zea mays*) also known as corn is a cereal grain that is a staple food widely grown and consumed in Kenya. Maize is the most widely cultivated food crop in Kenya (Economic Review of Agriculture Kenya, 2015). It is a versatile crop that grows on a range of agro-ecological zones (Obire *et al*., 2015). There are principally two types of maize (white and yellow variety) that are produced in Kakamega and Homa Bay counties, respectively. Malnutrition has adverse effects on the growth and development of children less than five years are most at risk because of the high nutrient requirements for growth and development (Mariara *et al*., 2009).

Most of the rural community in Kenya heavily depends on maize based products as a weaning diet for children less than five years which is a source of high calorific value but deficient in some essential nutrient like lysine, tryptophan, threonine and micronutrient (Katongole, 2008). The consequences of malnutrition extend beyond individuals and families to the entire communities and nations, which include: compromised immune function, cognitive development and performance, growth, reproductive and work capacity (FAO, 1992). Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue. The field of anthropometry encompasses a variety of human body measurements like weight, stature (standing height), recumbent length, skinfold thicknesses, circumferences (head, waist, limb, etc.), limb lengths, and breadths (shoulder, wrist, etc.). Several indexes and ratios can be derived from anthropometric measurements; perhaps the most well-known indicators like stunting, underweight and wasting values are calculated using measured height and weight values. These indices are used to screen for categories: severe (<-3 z-scores), moderate <-1 to ≥-3 z-scores) or normal (>-1 to <+1 z-scores). Global Acute Malnutrition(GAM) (<-2 z-scores) corresponded to moderately malnourished and severely malnourished cases in each of the three indices (HAZ, WHZ and WAZ)(WHO, 2005). Like other cereals maize is inadequate in nutrient content due to its deficiency in essential amino acids (lysine and tryptophans) and presence of anti-nutritional factors such as phytates, tannins and polyphenols (Sokrab *et al*., 2012). These may have associations that will bring challenges or positive impact on the nutritional status of the child. Majority of the people in developing countries (like Kenya) depend mainly on cereals grains due to limited income and high prices of food. The prices of for white maize are higher than for yellow maize (De Groote *et al*., 2012). Protein energy malnutrition is associated with poverty and poor nutrition knowledge, resulting in early weaning, delayed introduction of complementary foods, a low- protein diet and severe or frequent infections (Adeniyi *et al*., 2014).The weaning period is crucial stage of development, increasing metabolic demands, they require higher energy and quality proteins for maintenance and continued growth and mental development of the child. Poor quality of weaning foods and improper weaning practices predispose infants to malnutrition, growth retardation, infection, diseases and high mortality (Onofiok *et al*., 2005). The rationale for this investigation was find associations that may have influence on the nutritional status and morbidity of children 6- 59 month old in Homa Bay and Kakamega counties.

5.3 Materials and Methods

5.3.1 Sampling of Households with Targeted Child

Sampling was done according to section 3.3.2.

5.3.2 Data Analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS) version 20.0. Descriptive summary statistic such as frequencies, means, medians and standard deviation (sd) was used to describe the characteristics of the study population.

Nutritional status of the children was calculated using the Emergency Nutritional Assessment software (ENA for SMART). The indices of interest were weight for height (W/H), weight for age (W/A) and height for age (H/A). Data on dietary intake was analyzed using Nutri-Survey software and then exported to SPSS-for cross analysis with variable like nutrition status, morbidity and other practices.

Pearson correlation coefficient was used to show relationship between continuous variables such as the age of child with nutrition status. Significance level was set at $p<0.05$ with confidence interval of 95%.

5.3.3 Determination of Nutrition Status and Morbidity

In the current study, 120 questionnaires were administered to caregivers in Murhanda Location in Kakamega and Kanyamwa Location in Homa Bay counties.Salter scales were used to measure weight of children less than 5 years with the assistance of care giver who removed excess cloths from children and helped to harness the child. Weight was measured in duplicates to the nearest 0.1kg. Height board were used to measure height by the child standing up or laying straight (<2year) on it with their feet together knees straight and heels, buttocks and shoulder blade in contact with the vertical surface of height board. Measurement will be done to the nearest 0.1cm using a height/length board recommended by UNICEF (2009). MAUC of the children will be measured using MUAC tapes released by UNICEF in 2007. Morbidity was carried out through probing and observation.

5.4 Results

5.4.1 Anthropometry

5.4.1.1 Height for Age (Stunting)

The prevalence of stunting indicated by age based on Height-for-Age z-scores are as shown in Table 5.1. Children aged 42- 53 months (27.8%) had the highest prevalence of severe stunting. The study population indicated that 8.4% of the children were severely stunted,12.6% were moderately stunted while 79.0% of the children had normal height for age. The levels of stunting in the two counties had no statistically difference ($p = 0.842$). There was a negative but significant correlation between the child age in months with height-for-age, Pearson $r = -0.224$, at $p = 0.014$. Whereas a positive but significant correlation between stunting and individual dietary diversity score was noted, Pearson $r = 0.14$ at $p = 0.005$. There was a positive and significant correlation between the dietary diversity score levels with height-for-age, Pearson $r = 0.423$ at $p < 0.05$.

Table 5.1: Prevalence of Stunting by Age based on Height-for-Age z-score

Age in months	Severe stunting (<-3 z score) %	Moderate stunting (>= -3 and-2z score) %	Normal (>= -2 z score) %	Total (n)
6- 17	8.7	21.7	69.6	23
18- 29	0.0	9.7	90.3	31
30-41	9.1	6.1	84.8	33
42- 53	27.8	5.6	66.7	18
54- 59	6.7	26.7	66.7	15
Total	8.4	12.6	79.0	120

5.4.1.2 Weight for Age (Underweight)

There was no girl (0%) who had severe underweight compared to boys who had 3.4% (Table 5.2). Children aged 54-59 months had the highest prevalence of severe underweight (6.7%) while 6-17 months had the highest prevalence of moderate underweight. Among the study population, 1.7% were severely underweight, 5.0% were moderately underweight and 93.3% were normal. There was no statistical difference ($p= 0.324$) for Homa Bay and Kakamega counties. There was a negative but no significant correlation between the child age in months with underweight, Pearson $r= -0.087$, at $p= 0.343$. There was a positive and significant correlation between the dietary diversity score levels with weight-for-age, Pearson $r= 0.249$ at $p< 0.05$.

Table 5.2: Underweight Levels of Children per County

Nutritional Status	Kakamega %	Homa Bay %	Total %
Severe Underweight((< -3 z- scores)	1.7	0.0	1.7
Moderate underweight (< -2 to ≥-3 z-scores)	3.3	1.7	5.0
Normal ((≥-2 z-scores)	45	48.5	93.4

5.4.1.3 Weight-for-Height (Wasting)

The overall global acute malnutrition (GAM) prevalence was 9.2%. The mean Weight-for-Height z-score for the children was 1.06 (sd= 2.20). 12.9% of the children aged 18- 29 months indicated signs of severe wasting. About 2.5% were being moderately wasted while 90.8% of the children had normal weight-for -height . The severely wasted children all emanated from Kakamega County (5.9%), thus there was a statistical difference (p= 0.01) between the two counties. There was a negative but no significant correlation between wasting with consumption of FMPs Pearson r= -0.072, at p= 0.435. Whereas that of wasting with child age Pearson r= 0.074, wasting with caregivers age Pearson r= 0.137, wasting with caregiver education level Pearson r= 0.056 and wasting with dietary diversity score Pearson r= 0.5349 had a positive but no significant correlation at p> 0.05.

5.4.1.4 Mid-Upper Arm Circumference (MUAC)

In Table 5.3, only 0.8% of the children studied were severely malnourished, 4.2% were moderately malnourished while 97.2% were normal. No significant differences (p= 0.127) were noted between the counties. MUAC and child age in months had a positive but significant correlation, Pearson r= 0.192 at p= 0.036. The children aged 6- 17 months had 4.3% severe wasting, 0.0% were moderately wasting and 99.2% were normal. There were also no cases of oedema.

Table 5.3: Prevalence of Acute Malnutrition by Age based on MUAC cut off

Age in months	Severe wasting (< 115mm)	Moderate Wasting (>=115mm and < 125mm)	Normal(>=125mm) %	Total
6- 17	4.3	0.0	95.7	23
18- 29	0.0	0.0	100.0	31
30- 41	0.0	0.0	100.0	33
42- 53	0.0	0.0	100.0	18
54- 59	0.0	0.0	100.0	15
Total	0.8	0.0	99.2	120

5.4.1.5 Association between Nutritional Status and Socio- Demography

As shown in Table 5.4 most of the variable/factors were not significantly ($p>0.05$) associated with the nutritional indices with exception of wasting that was significantly ($p<0.05$) associated with the age of the study children.

5.4.1.6 Nutritional status and Consumption of Fermented Maize products

As shown in Table 5.5, stunting and individual dietary diversity score were statistically ($p=<0.05$) associated. There was, however, no significant association ($p> 0.05$) between consumption of fermented maize based products with underweight, stunting and wasting.

Table 5.4: Association between Nutritional Status and Socio- Demography

Factor	Wasting			Stunting			Underweight		
	Severe%	Moderate%	Normal %	Severe%	Moderate%	Normal %	Severe %	Moderate %	Normal %
Gender of Child									
1.Male	57.1	33.3	47.7	60	66.7	43.6	100	33.3	48.2
2.Female	42.9	66.7	52.3	40	33.3	56.4	0	66.7	51.8
p- value	0.7890			0.183			0.262		
Age of Child									
6- 11mths	0	100	18.2	20	33.3	1.7	0	33.3	18.8
12- 23mth	57.1	0	24.8	0	20	29.8	0	16.7	26.8
24- 35mth	28.6	0	28.4	30	13.3	29.9	0	33.3	27.7
36-47mth	0	0	15.6	40	6.7	12.8	50	16.7	14.3
48- 59mth	14.6	0	12.8	10	26.7	10.6	50	0	12.5
p- value	**0.023**			0.528			0.528		
Education of caregiver									
No education	0	0	2.8	0	6.7	2.1	70.20	0	2.7
Primary	71.4	66.7	72.5	90	73.3	70.2	50	50	73.2
Secondary	28.6	33.3	22.0	10	20	24.5	50	50	21.4
Post-Secondary	0	0	2.8	0	0	3.2	0	0	3.2
p- value	0.991			0.742			0.730		
Gender of Caregivers									
Male	14.3	33.3	14.7	30	6.7	14.9	0	0	16.1
Female	85.7	66.7	85.3	70	93.3	85.1	100	100	83.9
p- value	0.672			0.278			0.469		
Age of Caregiver									
15- 17	0	0	4.6	10	0	4.3	0	0	4.5
18- 35	100	66.7	67.9	70	73.3	69.1	100	100	67.9
36-44	0	33.3	13.8	0	13.3	14.9	0	0	14.3
>45	0	0	13.8	20	13.3	11.7	0	0	13.4
p- value	0.590			0.721			0.750		

* indicate Statistical significance at $p \leq 0.05$

Table 5.5 Nutritional status and Consumption of Fermented Maize products

	Wasting			Underweight			Stunting		
Factor	**Severe%**	**Moderate%**	**Normal %**	**Severe%**	**Moderate%**	**Normal %**	**Severe %**	**Moderate %**	**Normal %**
Consumption of FMPs									
Yes	71.4	66.7	87.2	50	66.7	85.7	70	86.7	87.2
No	28.6	33.3	12.8	50	33.3	14.3	30	13.3	12.8
p-value	0.326			0.372			0.332		
DDS									
Low	0	0	6.4	50	0	6.2	0	20	4.3
Moderate	28.6	66.7	63.3	50	66.7	60.7	100	33.3	61.7
High	71.4	33.3	30.3	0	33.3	33.0	0	46.7	34.0
p-value	0.253			0.147			0.05*		

* indicate Statistical significance at $p \leq 0.05$

5.4.2 Morbidity of children 6- 59months

5.4.2.1 Morbidity experience of the children

Of the children accessed, 50% had been found to have been sick two weeks prior to the study. In health-seeking behavior, 46.7% sought assistance from kiosks/ shops, 23.3% from public health facilities, 12.5% sought no assistance, 6.7% from private clinics/ Pharmacy, 5.8% from Community Health Workers.

Majority 29.4% of the children were reported not to have shown symptoms, 26.1% suffered from fever, 16.0% suffered bloody diarrhea, 6.7% from bloody diarrhea and stomach ache without diarrhea each and 7.6% had fever with chills.

5.4.2.2 Disease Association with Fermented Maize based Products.

In the symptoms associated with consumption of fermented maize product, there was a significant difference ($p < 0.05$) between those who associated and those who did not. About 64.2% reported that fermented maize products caused allergies and had something that caused children to diarrhoea.

5.4.2.3 Hygiene and Practices Sanitation

5.4.2.3.1 Hygiene Practises

Through observation and probing, it was confirmed that a significant proportion (66.7%) of children faeces was disposed of hygienically, 19.2% disposed it in nearby bushes, 7.5% buried it and 6.7% did not dispose, as shown in Figure 5.4. More than half of the caregiver (53.3%) washed their hands after using the toilet, 22.5% after attending to child who had defacated, 10% before feeding and 6.7% before preparing a meal. Of the caregivers interviewed, 63.3% of them washed hands with soap and water, 25.8% with water only, 5.8 with soap and ash and 3.3% with ash and water. There was no significant differnce ($p=0.082$) between the two counties when the methods of feaces disposal were compared.

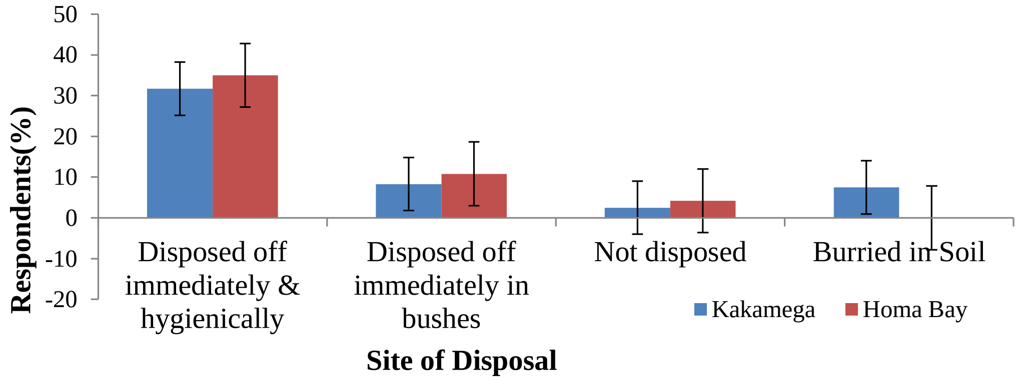

Figure 5.4: Disposal of Children Feaces per County

5.4.2.3.2Association between morbidity with nutritional status, water sources, dietary diversity score and consumption of fermented maize products

In Table 5.6 there was no significant difference (p> 0.05) between morbidity with indices of nutrition status, water source and dietary diversity score. Consumption of fermented maize products were completely not significant (p= 1) with morbidity. Meaning that fermented based maize products were least associated with ability to cause disease in children 6- 59 mths old.

Table 5.6: Association between morbidity with nutritional status, water sources, dietary diversity score and consumption of fermented maize products

Factors	Morbidity Yes (%)	No (%)	P- value
Wasting			
Severe	57.14	42.93	
Moderate	100	0	0.200
Normal	48.6	51.4	
Underweight			
Severe	0	100	0.095
Moderate	83.3	16.7	
Normal	49.1	50.9	
Stunting			
Severe	20	80	
Moderate	53.3	46.7	0.133
Normal	53.2	46.8	
Water Source			
Treated Water	71.4	28.8	0.243
Untreated Water	48.7	51.3	
Dietary Diversity Score			
Low	62.5	37.5	0.723
Moderate	47.9	52.1	
High	51.3	48.7	
Consumption of FMPs			
Yes	50	50	1
No	50	50	

5.5 Discussion

5.5.1 Nutritional status of children 6- 59 months

According to UNICEF conceptual framework, the causes of malnutrition are classified into underlying and immediate factors.The underlying factors are inadquate household food security, inadequate maternal and child care and insufficient health service while the immediate factors are inadquate food intake and illness (UNICEF, 2008) Among the dietary contribution factors, inadequate energy and nutrient density, high viscosity or undesirabe sensory properties of the diet have been highlighted (Bwibo and Neumann, 2003).

Stunting reflects chronic malnutrition and it is a result of failure to receive adquate nutrition over extended period or may also be caused by recurrent or chronic illness. The KDHS (2014) findings indicate that 26% of Kenyan children under five years were stunted of which 8% were severe. At the time of the survey, stunting was the highest in the indices of malnutrition but slightly lower than the prevalence at National level, at 21% of which 8.4% were severe. The children aged 42- 53 months had the highest prevalence of severe stunting because during this period most of them are left on their own starting school and when they require food which is not available at the point of need. Higher levels of stunting was found in Homa Bay County due to the early child bearing age leading to high depenency and low knowledge in nutrition. Therfore this high prevalence of stunting provided evidence that the study population suffer inadquate food availability, access and utilization persistently over the past years (Malkanthi *et al.*, 2007).

Wasting reflects acute malnutrition which is failure to receive inadquate nutrition in a period immediately before the survey e.g. result of recent and severe process that has produced a weight loss usually consequence of reduced food intake and disease or chronic inadequate food intake (ACC/SCN, 2000). The percentage of children who were wasting (9.2%) at the time the survey, which when compared to the National children in KDHS (2014) was higher (4% of which 1% were severely wasted). The wasting was higher in the study population because half the study children had been ill 2 weeks prior to the survey. Children aged 18- 29 months had the highest prevalence of wasting and during this period most of them are still being introduced to complementary feeding and are vulerable to diseases (KDHS, 2014).

Underweight reflects chronic or acute malnutrition or a combination of both. The of children who were underweight at the time of survey was 6.7% which was slightly more the half the percentage of Kenyan children who are underweght 11% (KDHS, 2014) . This difference was due to at the time of survey most household had just harvested maize therefore the families were food secure also public health facilities were available e.g. in Homa Bay County mobile clinic facility was reaching out to the community. In the current study, underweight could have been as a result of illnesses, considering that half of the study children were sick prior to the study. Children aged 54-59 had highest prevalence of underweight due the fact that they are energitic, actively invovled in school and food is required by the body to replenish in does not receive or inadquate. Findings from the study revealed that children aged 6- 17 months did not suffer from these vices because most them are still breastfeeding plus introduction of complementary feeding.

5.5.2 Morbidity of children 6- 59 months in Homa Bay and Kakamega counties

About half the children had been sick two weeks prior to the survey and slightly more than quarter suffered from fever which may have been caused by the cold rainy weather in the region at the time of study. Diarrhoea is among the listed major illness affecting children in Kenya and from the survey findings, only slightly two times (29%) less than that reported at National level of 58% were reported to suffer (KDHS, 2014). This happened because the Kenya Management of Diarrhorea in children under five recommended the use of zinc in Oral Rehydration Solution (ORS) (KDHS, 2014). The result from this study reveals that most caregivers are young mothers who are dependents on parents or parents in- law, they do not therefore take time to prevent their children from being exposed to dirty environment resulting in illness especially diarrhea (Kiige, 2004).

According to Sokrab *et al*. (2012),the protein content increased with fermentation which was so in observations made in this study where the unfermented had lower levels than the fermented. The explanation for the deviation may lie in the subsequent processes, like roasting and cooking where high temperature used could have denatured the proteins (Nungo, 2015). The reduction of phytates and crude fibre is in agreement with finding in Nigeria by Katongole (2008). This may be due to the soaking process and maize grain have some phytase which may have deactivated the mineral- binding phytic acid hence the increased contents of zinc and iron (Roba, 2009: AbdelRahaman *et al*.,2005). Microbial contamination increased due unhygienic personnel over-handling the products before, during and after preparation. Enyisi *et al*. (2015) reported that the amount of aflatoxin increased after fermentation which was also observed here.

5.5.3 Contribution of Fermented Maize based Products on Nutritional Status of children 6- 59 months in Homa Bay and Kakamega counties

Katongole reported improved protein quality, improved carbohydrate digestibility, probiotic effects, improved bioavailability of micronutrients and reduced cooking time in fermented foods which may reduce Protein-Energy Malnutrition (PEM) and ‘hidden hunger’ in children under five years.

5.5.4 Contribution of Consuming Fermented Maize based Products to Morbidity

Fermentation is a process that should be embraced by all households in the preparation of weaning meals for children less than five years because 64.2% reported that fermented maize products caused allergies and had something that caused children to diarrhoea. This has not agreed with Katongele (2008) who reported that the probiotic effects and the reduced level of pathogenic bacteria observed in fermented foods are especially important to developing countries where fermented foods have been reported to reduce the severity, duration and morbidity of diarrhea. According to KDHS (2014), 58% of the Kenyan children suffer from diarrhoea which can be halted by use of natural fermented maize based products which are rich in zinc instead of ORS with zinc which is expensive. According a study publish in the American Journal of Clinical Nutrition (2000), 'zinc- deficient persons experience increased susceptibility to variety of pathogens', so by weaning with fermented maize products may improve the immune function in under-fives. Anemia can be reduced because the infant and toddlers need more iron for their rapid growth.

5.6 Conclusion.

The levels of malnutrition among the children are of very mild form. Majority of the children are normal for the three indicators of malnutrition measured. The nutrition status in the study(stunting- 21%, underweight- 6.7%)were better than those in KDHS (2009)(26%,11% respectively) apart from wasting which was extremely high (study- 9.2% and Kenya- 4%) However, morbidity experience of children was quite high. The treatment-seeking behavior revealed that many bought drugs from local kiosks. Water used in the preparation of the weaning foods for children 6- 59months was untreated from unprotected spring and flowing rivers.

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CHAPTER SIX

General Conclusions and Recommendation

6.1 General Conclusions

The current study concludes that:

The education levels of most caregivers are low hence having little or no nutrition knowledge on the importance of fermented maize products. They have beliefs and some are ignorant that fermented products cannot be fed to weaning children. Fermented maize products are consumed by most household in Western Region, mainly in form of thin porridge, fermented maize products are highly utilized for "family consumption" but used in small amounts by very few people as weaning food (though having the potential).

Fermented maize based products from Homa Bay County (from yellow maize) have better nutritional characteristics than those from Kakamega County (from white maize). The fermented maize products at household and market levels are highly contaminated, indicating poor hygiene measures during preparation, storage and feeding process. Water used in the preparation of the weaning foods for children 6- 59months is largely untreated water from unprotected spring and flowing rivers.

The nutrition status of children was that majority of the children are normal for the three indicators of malnutrition measured. Stunting and underweight condition had reduced in percent whereas wasting had increased percent compared to KDHS (2009).

6.2 General Recommendation

It is recommended that:

To improve nutritional knowledge, create awareness, improve preparation/ feeding practices and increase child consumption levels of fermented maize products requires capacity building (educate) of all Stakeholders.

Future research efforts should be made to fabricate a simple, small, safe, acceptable, operational production machine to produce good quantity and quality of any fermented maize products at household level. Develop different FMPs inform of snacks or breakfast cereals.

The provision of safe clean water is the responsibility of the Government therefore the County governments of Kakamega and Homa Bay should intensify their efforts to provide safe pipe-borne water and proper sewage disposal in rural communities. Train care givers on home treatment methods.

Deliberate awareness should be made to promote yellow maize production and utilization by fermentation to reduce GAM levels in children 6-59 months old. The yellow maize should be packaged appropriately and availed to rural households and markets.

Create awareness on utilization of FMPs as another way to reduce global acute malnutrition (GAM) levels in children 6- 59 mths old.

Capacity building (training) of the caregivers on Good Farming Practices and good child feeding practices and for processors on Good Manufacturing Practices, will be in line with the need to prevent hazards in in food or reduce them to acceptable levels.

APPENDIX 1: CONSENT FORM

SURVEY ON THE ROLE OF FERMENTED MAIZE PRODUCTS ON THE NUTRITION STATUS OF CHILDREN 6-59 MONTHS

I am a student from the University of Nairobi pursuing a Master of Science degree in Applied Human Nutrition. I am involved in a study in which the main objective is to determine the role of fermented maize on the nutritional status of children 6-59 months

The information you provide will be useful in finding the utilization and nutrition status of children in the respective communities and will be used by leaders for future planning of development projects. The information you give will be confidential.

I encourage you to participate because your selection was random and I assure you that the information you provide will be treated with utmost confidentiality.

If it is okay with you, may I proceed to ask you some questions related to child feeding and maize fermentation processes?

Respondent agreed to be interviewed____________________________ 1= YES 2= NO

Signature of Interviewee____

Date____

APPENDIX 2: RESEARCH QUESTIONNAIRE

THE ROLE OF FERMENTED MAIZE PRODUCTS ON THE NUTRITION STATUS OF CHILDREN 6- 59 MONTHS

Household No.______ Interviewer Name: ________________Date of Interview ____/_____/2015

Village___________________ Sub/location ___________________

Location_________________

Sub/County___________________ County_______________________

1. IDENTIFICATION

1.1 Respondent's name ___________________________1.2 Sex ______________

1.4 Name of the Index child _________________________1.5DoB ___/ ___/ _____ 1.3 Age____

2.0 DEMOGRAGHIC CHARACTERISTICS

2.1 S/ No	2.2 Name	2.3 Relation ship to HH head -codes-	2.4 Sex M=1 F= 2	2.5 Age (years)	2.6 Marital status -codes-	2.7 Religion -codes-	2.8 Education -codes-	2.9 Occupation -codes-

RHHH	**MARITAL STATUS**	**RELIGION**	**EDUCATION**	**OCCUPATION**
1=HHH 2=Spouse or Wife 3=Son 4= Daughter 5= Grandson 6= G/daughter 7=relatives 8= parents 9= Housegirl 10= Gardener 11= In-law 12= grandfather	1= married 2= separated 3= widowed 4= single 5=divorced 6= not applicable	1=Christian 2= Muslim 3=Traditionalist 4= Others (Specify) 5=None	1= College 2= Completed secondary 3= Completed primary 4=Dropped from primary 5= Dropped from secondary 5= in primary 6= in secondary 7=Adult Education	1= salaried employee 2= farmer 3= self – employment/ business 4= casual laborer 5= student/ pupil 6= housewife 7=unemployed 8= N/A 9= others

13=grandmother			8= Illiterate 9= Preschool/ECDE 10=N/A	

3. HOUSEHOLD FERMENTED MAIZE CONSUMPTION PRACTISES

3.1 Does your household consume maize or any maize products?

3.1.1 If yes name the products of maize you often consume.____

3.1.2 Among the maize products do you consume any fermented maize products? Uji( ) Ugali( ) Mkarango( ) Busaa( ) any other(specify) ______________________

3.2 If yes, where do you normally obtain the fermented maize products from?

( ) Own production ( ) Local open air market( ) Local processors

( ) Other sources(Specify)

____

3.3 Which fermented maize products do you normally consume **(List in order of preference)**

( ) uji, ( ) ugali, ( ) busaa, ( ) mkarango, ( ) any other (specify)

____

3.3.1 What reasons are given for consuming the products?

1) cheap and affordable 2) Can be eaten without Sugar 3)Fermented uji cooks well when using hard water 4) Others

____

3.4 How do you normally prepare the fermented maize products that you consume at household levels?

1)Cold water + flour stir with the hand kept near fire or sun warm then leave for 12-24 hour. then cook thin porridge

2) Make a thick paste with cold water +flour the ferment for 4days. Roast on big pan with fire, soak the product in water, add sugar and milled germinated finger millet then filter and serve

3) Make a thick paste with cold water +flour the ferment for 4days. Roast on big pan with fire, sundry and store for future use. Soak in water before consumption add sugar to taste.

4)Any other

Preparation Method 1

____
____
____

Preparation Method 2

____
____
____

3.4.1. Do children under 5years have a special method of preparation? 1) Yes 2) No

3.4.2 If yes, which one?

1) Cold water + flour stir with the hand kept near fire or sun warm then leave for 12-24 hour then cook

2)Warm water +flour, stir, leave for 12hrs.

3) soak the snack for long time to soften

4) Any other

Preparation Method 3

____
____

3.5 Do you use any kinds of additives for flavouring? YES ( ) NO ( )

3.6 If yes, name them (***list in order of preference***) Sugar ( ) Salt ( ) Honey ( ) Blue band ( ) any other(specify)____
____

3.7 What kind of food and/or food supplements that is not of a plant or an animal origin) do you use in your processing? Yeast ( ) Bacteria ( ) any other(specify)

____

____

3.8 Which are the sources of food supplements? beans( ) milk ( )omena( )groundnuts( )soya( ) lemon( ) Avocado( ) germinated millet ( )

Anyother(specify____

____

3.9 What are the cultural values associated with each kind of traditional food as named in 3.3?

1) Provide energy 2) Used in cultural practice

3) Easily to prepare and consume 4) Makes stubborn children to sleep 5) Any other

MAIZE FERMENTED FOOD	**CULTURAL VALUE**
Uji	
Ugali	
Mkarango	
Busaa	
Any other(specify)	

3.10 What ingredients do you use for processing? What are their market prices?

1) Donot buy 2) Buy from neighbourhood at Ksh. 50/= 3) Buy from open market at ksh. 50/= and transportation charge 4) Any other

ITEMS	**QUANTITY**	**UNIT COST**	**TOTAL**
Labour			
Transport			
Maize			
Sugar			
Millet			
Any other (specify)			

3.11 Do you sell some of you maize fermented products? If yes, which ones? Uji () Ugali( ) Mkarango()busaa()

____

3.12 What constraint do you incur during fermented maize processing? Lack of ingredients ( ) Time( ) Lack of fuel( ) Water supply( ) any other (specify)____
____
_

4.0 MORBIDITY

4.1 In the last 2 weeks including today, has(name) been sick? ( ) YES ( ) NO

4.1.1 If yes, for how many days did (name) suffer the illness during the past 2wks?

1) None 2) < a week 3) 1 week 4) > a week 5)Any other

______________ days

4.2 Was the disease due to consumption of contaminated food (food- borne disease)?

Yes( ) No( )

4.3 Which diseases are prevalent due to food-borne and the diseases are associated to which fermented maize product? ____

FOOD-BORNE DISEASE	ASSOCIATED FERMENTED MAIZE PRODUCT
Diarrhoea	
Stomach ache	
Vomitting	
Any other (specify)	

4.4 When the child (name) was sick, where did you first seek assistance (tick code)?

Traditional Healer ( ) Community health worker ( ) Private clinic/ Pharmacy ( ) Shop/ kiosk ( )

Public Health facility ( ) Faith Based / Church owned facility ( ) Mobile Clinic ( ) Relative/Friend ( ) Herbs / Home remedy ( ) Prayer ( ) No Assistance sought. Why? _________ Others (specify) _______

4.5 Can you describe the main symptoms the child suffered from? (tick code)

Watery diarrhoea ( ) Bloody diarrhoea ( ) Fever ( ) Fever with chills ( ) Stomachs without diarrhoea ( )

4.6 According to your beliefs/ traditions what could be causing the disease?

____
____
__

4.7 Is there a difference between children fed on fermented maize products and the unfermented? 1)Yes 2) No

4.7.1 Explanation: 1) Fermented maize products make children have allergies

2) Fermented maize products make children more healthy 3) Any other

4.8 How is children's feaces disposed? (probe and OBSERVE) Disposed of immediately and hygienically ( ) Disposed of immediately in the nearby bushes( ) Not disposed(scattered in the compound) ( ) Buried ( ) Burn( ) Others(specify)____________________________

4.9On what occasion(s) do you wash your hands(record all applied)?

After using the toilet/defecating( ) After attending to a child who has defacated( )

Before feeding the child(including before breastfeeding ( ) before eating or preparing a meal ( ) After handling animals ( ) After changing sanitary pads ( ) When washing the face ( ) When bathing ( ) Others( )

4.9.1 Observe for presence of a hand washing facility next to the latrine/ in the compound?

Yes ( ) No ( )

4.9.2 How do you wash your hands? Soap and water( ) Ash and water ( ) soap and ash ( ) Only water ( ) No water or no soap or no ash ( ) Others(specify)( )

5.0: FOOD FREQUENCY QUESTIONNAIRE

For each food item below, kindly let me know the category that best describes the frequency with which your child usually eats that particular food item(*enumerator to indicate with a checklist)*							
Food Item	>Once daily	Once per day	3-6 times per week	Once or twice per week	Once per month or less	Never	Est. amts at every consumption time (mls)
Maize meal							
Irish potatoes							
Dark green leafy vegetables							
Sweet potatoes							
Pumpkin							
Spinach							
Ripe papaya							
Eggs							
Fish(liver intact)							
Chicken or other fowl							
Beef(sheep/goat meat)							
Milk and its products							
Beans							
Fermented Maize products							
Rice							
Cooked bananas							
Millet							
Sorghum							

6.0 INDIVIDUAL DIETARY DIVERSITY SCORE (index child 6-59 months old)

Kindly let me know the foods your child consumed in the past 24 hours

Before commencing the questionnaire, ask if the day before the interview was normal day ie no festivals, no feast, no fast; if YES proceed to other questions, if NO, continue. Include any snacks consumed	Did the child consume food from any of these food groups in the last 24hrs 1=YES 0= NO
1)Cereals & cereal product e.g. Maize, wheat, rice, sorghum, etc	
Milk & milk products e.g. Milk, cheese, mala, yoghurt, etc	
Sugar &honey eg sugar, honey, sweetened soda/ juices, sugarcane	
Oils & fats e.g. Oils, fats, margarine, butter	
Meat, poultry, offals e.g. Chicken, liver, kidney	
Pulses & legume e.g. Dried beans, peas, nuts, green grams, etc	
Eggs e.g. From chicken, ducks, guinea fowls, etc	
Roots & tuber s e.g. Irish potato, yams, cassava, sweet potato	
Vegetables e.g. Dark-green leafy vegetables	
10) Fruits e.g. Wild fruits, apple, oranges, ripe banana, etc	
11) Fish & Sea food e.g. Fresh and dried fish	
12) Miscellaneous e.g. spices, chocolates, sweets, beverages, etc	

7.0 ANTHROPOMETRY FOR INDEX CHILD 6-59 MONTHS

	Weight(to nearest 0.1kg)	**Height(**to the mearest 0.1 cm)	**MUAC(**to the nearest 0.1cm**)**
Test 1			
Test 2			
Average			

7.1Are there physical signs of protein energy malnutrition? **YES ( ) NO ( )**

If yes, check for the following symptoms and indicate with a tick the signs observed

Edema ( ) Dry/ peeling skin( ) Hair discoloration( ) Abdominal distention( ) Excessive loss of muscle and tissue( )Loss of appetite( ) Loose skin( )

8.0 HOUSEHOLD WATER SOURCES

8.1 What is your main current water source for HH use?

( ) River ( ) Lake ( ) Water tape ( ) Borehole ( ) Unprotected well ( ) Protected well ( )Public pan ( ) Tanker ( )Dam ( ) Springs ( )Roof catchment ( ) others(Specify).

____

8.2 Where is the source of water located? ( )within the compound ( )outside the compound

____

8.3 How much time does it take from house to source and back? Tape water ( ) 30mins( ) 1hr ( ) 2hrs ( ) >2hrs ( )

8.4 Do you do anything to the water before utilizing it?

( ) Boiling ( )Use of traditional herbs ( ) Use of chemicals ( ) Use of filters

( ) Nothing ( )any other (specify)

APPENDEX 3: TURNITIN ORIGINALITY REPORT

Turnitin Originality Report

THE ROLE OF FERMENTED MAIZE BASED PRODUCTS TO NUTRITION STATUS AND MORBIDITY OF CHILDREN 6-59 MONTHS OLD IN WESTERN KENYA by Winfred Mukhoyani Adavachi

From FOOD SAFETY (human nutrition)

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