EVALUATION OF IRON AND ZINC LEVELS, MICROBIOLOGICAL LOAD AND ACCEPTABILITY OF CRACKERS, NOODLES AND COOKIES MODIFIED USING SELECTED UNDERUTILIZED CROPS

BY

HABWE FLORENCE OYIERA

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DECLARATION

I Habwe Florence Oyiera declare that this thesis is my own original work and has not been presented for a degree in any other University, and that all sources of information have been specifically acknowledged by list of references cited.

Signed:…………………...…..…......... **Date……..………………**
Habwe Florence Oyiera
PG/PHD/047/09

This thesis has been submitted for examination with our approval as University Supervisors.

………………………………………………. **Date……..……………..**
Prof. Mary K. Walingo.
Vice Chancellor
Maasai Mara University
Kenya.

………………………………………….. **Date…………………...**
Prof. Isaac J. Jondiko
Chemistry Department
Faculty of Science
Maseno University
Kenya.

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DEDICATION

To my family I dedicate this achievement.

ABSTRACT

Dietary deficiencies of iron and zinc are high. Underutilized crops are rich in micronutrients but are cultivated at subsistence level due to high perishability and poor processing of products. These crops are potential sources of iron and zinc but there is no documentation that reveals if they can be processed into safe, acceptable and nutritious food products that can improve their exploitation. An informal experimental study design was used to evaluate preparation of safe, acceptable, and micronutrient rich food products (crackers, noodles and cookies) from cassava (*Manihot esculenta*), fingermillet (*Eleusine coracana*), simsim (*Sesamum orientale L.*), and slenderleaf (*Crotalaria ochroleuca* and *Crotalaria brevidens*). Iron recommended dietary allowance (RDA) was used to calculate selected crops quantities used to modify crackers, noodles and cookies. Iron and zinc levels in raw crops, processed crops, and modified food products were analyzed using Atomic Absorption Spectrophotometer (AAS). Product safety was assessed using total plate count, total coliform, *Escherichia coli*, *Staphylococcus aureus,* and moulds; and moisture content. Product acceptability was assessed using organoleptic tests. Paired-samples *t*-test was used to compare iron and zinc levels; microbiological load; and moisture content, between raw and processed crops. Contributions of the food products to iron and zinc percentage RDA for six population sub-groups were determined. Microbiological load levels in food products were compared with recommended maximum intake levels using one sample *t*-test. *Chi*-square analysis was performed to assess product acceptability. Selected underutilized crops are good sources of iron and zinc with iron levels ranging between 1.6-4mg/g in raw, and 1.5-3mg/g in processed crops. Zinc levels range between 0.9-2.8mg/g in raw and 0.8-2.7mg/g in processed crops. Acceptable quality crackers, noodles and cookies, from cassava, fingermillet, simsim and slenderleaf were prepared. Crackers, noodles and cookies recorded iron levels of 1.5mg/g, 1.6mg/g and 1.6mg/g with zinc levels of 1.2mg/g, 1.0mg/g and 1.5mg/g respectively. These products contribute 66%, 88% and 53%RDA for iron per serving of 8g, 10g and 6g respectively. They also contribute 64%, 66% and 60%RDA for zinc per serving respectively. Blanching increased moisture content of vegetables while grilling reduced moisture content of other selected crops and microbial load in all selected crops. Modified products recorded microbiological load levels within acceptable maximum consumption limits therefore safe for consumption. The products were highly accepted as over 50% of participants liked all modified products. The products contributed over 100%RDA to various population sub-groups aged between 6months to over 70years. This study brings fourth safe, acceptable and nutritious products prepared from underutilized crops. Promotion could lead to increased consumption and marketability of these products which could increase iron and zinc intakes thus reduce micronutrient deficiencies. Modified crackers, noodles and cookies should be promoted and marketed in order to increase consumption thus increase utilization of underutilized crops and also reduce micronutrient deficiencies in populations.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
AIVs	African Indigenous Vegetables
ANCP	Agriculture-Nutrition-Community-of-Practice
AOAC	Association of Official Analytical Chemist
ASF	Animal Source Foods
ATSDR	Agency for Toxic Substances and Disease Registry
BPW	Buffered Peptone Water
CIDA	Canadian International Development Agency
CFU	Colony Forming Units
DALYs	Disability Adjusted Life Years.
EOLSS	Encyclopedia of Life Support Systems
FAO	Food and Agriculture Organization of the United Nations
FNB	Food and Nutrition Board
FSANZ	Food Standard Australia New Zealand
GBD	Global Burden of Disease
GOK	Government of Kenya
HIV	Human Immunodeficiency Virus
HCN	Hydrocyanic acid
ICMSF	International Commission on Microbiological Specifications for Foods
ICRAF	International Center for Research in Agro forestry
IDA	Iron Deficiency Anaemia
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IOM	Institute of Medicine
ISO	International Organization for Standardization
IPGRI	International Plant Genetic Resources Institute
IUFoST	International Union of Food Science and Technology
KDHS	Kenya Demographic and Health Survey

KNBS	Kenya National Bureau of Statistics
KEMRI	Kenya Medical Research Institute.
KENRIK	Kenya Resource Center for Indigenous Knowledge
LACON	Locally Appropriate, Cost-Optimized, Nutritious Diet
MGREF	Microbiological Guidelines for Ready-to-eat Food
MND	Micronutrient Deficiency
MNM	Micronutrient Malnutrition
MoH	Ministry of Health
MPHS	Ministry of Public Health and Sanitation
MPN	Most Probable Number
MUG	4-Methyl-umbelliferyl-β-D-glucuronide
NAS	National Academy of Sciences
NHMRC	National Health and Medical Research Council
NIH	National Institutes of Health
NUS	Neglected and Underutilized Species
PDA	Potato Dextrose Agar
PEM	Protein Energy Malnutrition
PPM	Parts Per Million
RDA	Recommended Dietary Allowance
RNI	Recommended Nutrient Intake
DRI	Dietary Reference Intake
SCN	Sub-Committee on Nutrition
SSA	Sub-Saharan Africa
UL	Tolerable Upper Intake Levels
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children’s Fund
USFDA	United States Food and Drug-Administration
USNLM	US National Library of Medicine
VRBA	Violet Red Bile Agar
WHO	World Health Organization

DEFINITION OF TERMS

Adequate Intake	Is a recommended intake value based on estimates of nutrient intake by a group or groups of apparently healthy people that are assumed to be adequate.
Dietary Reference Intake	Is a system of nutrition recommendations from the Institute of Medicine (IOM) of the U.S. National Academy of Sciences. The DRI provides several different types of reference value.
Processing	Treatment of raw materials by cleaning, washing, grilling and/or roasting them in readiness for product preparation.
Recommended Dietary Allowance	Is the daily dietary intake level of a nutrient considered sufficient by the Food and Nutrition Board of the Institute of Medicine to meet the requirements of 97.5% of healthy individuals in each life-stage and sex group.
Tolerable Upper Intake Levels	Is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population. Unless otherwise specified, the UL represents total intake from food, water, and supplements
Underutilized crops	Are a range of plant species with under-exploited potential for contributing to food security and health (nutritional).
A serving	Amount of a single portion in volume and/or weight

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CHAPTER ONE: INTRODUCTION

1.1. Background

An estimated 842 million people, one eighth of the world population were suffering from chronic hunger between 2011 and 2013 (FAO, 2013). The supply of nutritionally adequate foods to the global population is still challenging (Gudrun, Katja, & Irmgard, 2013). Whereas protein-energy malnutrition (PEM) is the most lethal form of malnutrition, micronutrient deficiency (MND) is the most serious threat to health and development of populations worldwide, particularly pre-school children and pregnant women in low-income countries (WHO, 2004a).

Trace mineral deficiencies is a large health and nutrition problem affecting populations in both developed and developing countries (IOM, 2001). 'Hidden hunger' affects as many as 3 billion people globally while 38% of children under five in Sub-Saharan Africa are stunted due to chronic malnutrition (Anonymous, 2013; Mason & Garcia, 1993; R. M. Welch, Combs-Jr, & Duxbury, 1997; WHO, 1999). Malnutrition and diet-related diseases, leads to high social and economic costs at all income levels (FAO, 2013), and is most prevalent in Africa (UNICEF, 2004; WHO, 2002b) yet, Africa has plenty of underutilized crops rich in micronutrients important for good health (Oniang'o, Shiundu, Maundu, & John, 2005). Consumption of a broad range of plant species, in particular those currently identified as 'underutilized', can contribute to improved health and nutrition, livelihoods and household food security (Jaenicke & Höschle-Zeledon, 2006). Iron and zinc have become a matter of great interest concerning the nutritional value of diets (Luo & 2Xie, 2012). Incorporation of vegetables as a food source rich in micronutrients provides one strategy to sustainably improve the micronutrient status in the human body (Ali & Tsou, 1997). Although nutritious and important for good health, most crops regarded as 'underutilized' have not been exploited for ability to enhance supply of micronutrients. Exploitation of underutilized crops thorough product formulation could ensure year round availability, increase consumption and in the long run minimize micronutrient malnutrition. However the ability of the cooked or processed crops in Kenya to supply the micronutrients is not documented.

Iron deficiency is the most common and widespread nutritional disorder in the world, and is a public health problem in both industrialized and non-industrialized countries. The result of a long-term negative iron balance, in its more severe stages, iron deficiency causes anaemia (WHO & FAO, 2006). Anaemia affects 40% of the world's population which is more than 2 billion people (WHO & FAO, 2006), 50% of which is attributable to dietary iron (Fe) deficiency (Stoltzfus, 2003; WHO & FAO, 2006). This corresponds to 24.8% of the population with highest prevalence in preschool children 25.4%, school age children (47.4%) and pregnant women (41.8%) (de-Benoist, 2008; Fritschel, 2000). Iron Deficiency Anaemia (IDA) ranks number 9 among 26 risk factors included in the Global Burden of Disease GBD 2000, accounts for 841,000 deaths and 35,057,000 disability-adjusted life years lost (Bothwell & MacPhail, 1992; Stoltzfus, 2003). Africa and parts of Asia bear 71% of the global mortality burden and 65% of the disability-adjusted life years lost due to Iron (Fe) Deficiency Anaemia (IDA) (Stoltzfus, 2003) with the highest proportion of individuals affected being in Africa (47.5–67.6%) (Benoist, McLean, Egli, & Cogswell, 2008). Micronutrient malnutrition remains a major problem facing Kenya's population. The problem is worsened by the HIV/AIDS pandemic (Hongo, 2003). IDA has widespread and serious economic and health consequences in the Sub-Saharan African populations (FAO, 2003). In Kenya, 60% of the population is iron deficient with 56% rates among women, 46% among men and 89% in children under 6 years (FAO, 2005; GOK & UNICEF, 2002; Hongo, 2003). Anaemia prevalence is as high as 73% in the Lake Basin region, it stands at 91.3% in preschool children, 72.9% in women of child bearing age and 42.7% in adult men (GOK & UNICEF, 2002). WHO (2001) rates of >40% as severe, between 20%-39% moderate, while, between 5%-19% indicates mild prevalence of anaemia. The rates in Kenya and particularly the Lake Basin region are above 40%, indicating that it borders on being a severe public health problem. This indicates an urgent need for action to reduce the exceedingly high IDA prevalence rate levels.

An estimated 20% of the world's population is at risk for zinc (Zn) deficiency (WHO & FAO, 2006; Wuehler, Peerson, & Brown, 2005). In Sub-Saharan Africa Zn deficiency risk stands at 34.6% (Wuehler et al., 2005). Zinc deficiency is widespread in developing countries, but is under-recognized due to lack of sensitive biomarkers of zinc status (FAO/WHO/IAEA, 1996; Wood 2000). Zinc deficiency is widespread in areas where diets lack diversity (Kennedy, Nantel, & Shetty, 2003) and has been implicated as a contributing factor to stunting in approximately one third of children in low-income countries (de-Romana, Salazar, & Hambidge, 2005). In Kenya, it is a public health problem as about 50% of children under 6 years and 50% of women are affected (GOK & UNICEF, 2002). It is important to examine zinc in the diet (Caulfield & Black, 2004) but its concentration in food varies depending partly on processing and cooking methods besides other factors (IOM, 2001). This calls for consideration of assessment of food preparation methods and food combinations with implications to zinc because cooking varies zinc concentration in food (Hongo, 2003; K. M. Walingo, 2009). Besides other factors, cooking varies zinc concentration in food (IOM, 2001). However, the effect of cooking methods like blanching and grilling on zinc levels in selected underutilized crops is not documented.

In addressing food security, agricultural policies have focused on increasing productivity, but have paid less attention to the nutritional value of food systems. These policies often overlook the health benefits of a diverse diet based on a variety of nutritious foods such as neglected and underutilized species (NUS) which could have much to offer in this respect and could be used more widely to diversity diet (Anonymous, 2013; Padulosi, Thompson, & Rudebjer, 2013). Underutilized crops are cheap, readily available and culturally acceptable. However it is not documented whether underutilized crops commonly available in the Lake Victoria Basin can supply adequate iron and zinc after processing and cooking to overcome their deficiencies.

A lack of resources for producing and purchasing quality foods can sometimes present a barrier to achieving dietary diversity, especially in the case of poorer populations (WHO & FAO, 2006). NUS present tremendous opportunities for fighting poverty, hunger and malnutrition. Their value in traditional foods and cultures can empower indigenous communities particularly women (Padulosi et al., 2013), therefore the time for action on NUS is now. Some of the proposed actions include effective food processing technologies to prolong shelf-life (Gudrun et al., 2013). This indicates that despite availability and affordability of NUS very little has been done to utilize them as an opportunity to fight poverty, hunger and malnutrition. An effort to exploit the potential of underutilized food crops in Kenya through preparation of crackers, noodles and cookies is not documented.

The neglected and underutilized crops contain micronutrients needed for good health (Abukutsa-Onyango, 2003; Grivetti & Ogle, 2000; Oniang'o et al., 2005); however, perishability and poor processing are among major constraints facing their production in developing countries (Abukutsa-Onyango, 2007; Mnzava, 1997; Schippers, 2000). Few studies have been undertaken to address perishability and there is need to encourage research that examines the relative contribution of underutilized crops to local diets and nutrition (Vinceti et al., 2013). Termites, roots and tubers, leafy vegetables, mushrooms and wild fruits are current contenders forming the basis for an approach to improve dietary diversity because they are traditional, culturally-acceptable and nutritious (Vinceti et al., 2013). Improved dietary diversity, diet modification and appropriate traditional food processing technologies on micronutrient rich crops are among the long term strategies that could help eradicate or minimize micronutrient malnutrition (Abukutsa-Onyango, 2003; Pasricha, Drakesmith, Black, Hipgrave, & Biggs, 2013; K. M. Walingo, 2009).

Snack foods like noodles, cookies and cracker are widely adapted for everyday use widely consumed throughout the world and their global consumption is second only to bread; it is a fast growing sector of the pasta industry. Their storage has been facilitated by the introduction of technological innovations that enhance quality and adaptation to meet up with consumer demands. This is because they are convenient, easy to cook, low cost and have relatively long shelf-life (Onyema, Ekpunobi, Edowube, Odinma, & Sokwaibe, 2014). Wheat flour which is usually used to make these products is not only low in fibre and protein content but also poor in essential amino acid; lysine, and minerals. Flour of hard wheat (*Tritium aestivuml*) is the main primary ingredient (Fu, 2008). Therefore exploitation of the feed value potential of underutilized food products to process crackers, noodles and cookies could increase acceptability and reduce perishability thus increase marketability and consumption and in the long run minimize micronutrient malnutrition of public health concern like iron and zinc. Efforts to process food products from combinations of cassava with fingermillet, simsim or slenderleaf in Kenya are not documented.

Cassava, *Manihot esculenta* (Crantz) is an important staple food and a major source of dietary energy for over 500 million people in the world (Chijindu & Boateng, 2008). In Africa, it is mostly used for human consumption and commercially for the production of animal feed and starch-based products (IITA, 2000). The extreme perishability of cassava roots stimulated the development of a range of processing techniques even by the earliest American and Indian cultivators of the crop more than 4,000 years ago (McFarlane, 1982). Processing is therefore indispensable to facilitate preservation, improve palatability and product quality. Production of cassava chips is the simplest way of obtaining a product which can be stored and reduce losses (Chijindu & Boateng, 2008). Cassava is a major source of carbohydrates, contains very little protein and is relatively rich in calcium and ascorbic acid (Doku, 1969). Besides there being efforts to process cassava to improve palatability and quality, there is limited evidence of efforts to improve the nutritive value of cassava which could be achieved by combination with other food crops during processing; targeting particularly micronutrients of major public health concern (iron and zinc). Therefore attempts should be made to combine cassava with other nutrient rich underutilized crops to improve nutritive value and at the same time use cassava as a base ingredient by using its starch for binding properties in the prepared product.

Millet is used in various cultures in many diverse ways but its potential vastly untapped (Lawler, 2009). Efforts should therefore be made to exploit the potential of processing fingermillet into food products. Simsim seeds are exceptionally rich in iron and zinc (Nakai, Harada, & Nakahara, 2003). On the other hand, cultivation of slenderleaf in Kenya has always been done at subsistence level and their potential as commercial commodities not been exploited, partly due to perishability and poor processing strategies (Abukutsa-Onyango, 2003; Grivetti & Ogle, 2000; Oniang'o et al., 2005). Despite the documented benefits of these NUS in addressing deficiency, they are highly perishable. Apart from drying, it is not documented if these NUS can be processed into nutritious food products with reduced perishability.

Food processing technologies, particularly at household level, are challenging and often not applicable to traditional crops (Gudrun et al., 2013), yet indigenous knowledge on food preservation processes which needs to be mapped is being lost (Habwe, 2008; Jaenicke & Höschle-Zeledon, 2006). There is limited information on safety of processed foods (IPIGRI, 2006). Poor processing can increase the risk of producing unsafe and unhealthy food (Gudrun et al., 2013). This is so because, harmful microbes may enter the manufacturing process and reach the end product through raw materials, air in the manufacturing area, chemicals employed, process surfaces, or factory personnel (Wirtanen & Salo, 2007). This indicates that there is a high probability of food being contaminated during processing. However, possible microbiological contamination of processed crops and food products prepared using underutilized crops has not been documented.

Moisture is also of great importance for the safe storage of cereals and their products regarding microorganisms (Nasir, Butt, Anjum, Sharif, & Minhas, 2003). Higher moisture content favors mould growth and lowest moisture content gives maximum resistance against fungal growth. Moisture content of flour is very important regarding its shelf life, lower the flour moisture, the better its storage stability. The flour having 9% and 10% moisture content is suitable for storage stability and longer shelf life of flour (Nasir et al., 2003). The moisture content of selected underutilized crops after processing and product preparation has not been documented

Kenya has witnessed a decline in utilization and consumption of underutilized crops partly due to the long period needed to handle and prepare them; and dislike of their tastes and appearance (Abukutsa-Onyango, 2007; Waudo, Kimeywe, Mbithe, & Maundu, 2007). Products made with cereal flours are a staple food in many communities and are therefore of global importance in international nutrition (Cauvain, 2004; Frontela, Ros, & Martínez, 2011). One of the recommendations to help improve and increase utilization and consumption of NUS is the need to improve processing (ANCP, 2013). Reduced consumption of NUS which are largely nutritious despite the high prevalence of micronutrient malnutrition is dislike of their tastes and appearances among other attributes. It is not known if processing the readily available but underutilized foods can increase acceptability and enhance consumption of these NUS.

Previous work focused on preparation of African Indigenous Vegetable (AIV) recipes (Habwe, 2008). There is lack of documented effort to process food crops into food product with extended shelf life. Furthermore, the contribution of the food products towards recommended dietary intakes of iron and zinc for various population age groups is not documented.

Due to increased allergies to wheat in the United States of America, preparation of food products from cassava were invented by Silmak, (1990). These inventions proposed the use of cassava alone to prepare crackers, noodles and cookies but these products have traditionally been processed using wheat flour. These are products common in the markets and well accepted by consumers and there are existing standardized recipes for product preparation like those by Crocker (1969). However, combinations of cassava with nutrient micronutrient rich underutilized crops to process similar food products have not been documented.

1.2. Statement of the Problem

Micronutrient deficiencies are most prevalent in Africa and remain a major problem facing Kenya's poor and needy population, whose impact is worsened by HIV/AIDS pandemic and malaria particularly in Western region. Iron and zinc deficiency rates are severe and this poses severe consequences whose impact could translate into poor economic development and would set a vicious cycle effect that will take many generations to correct if left unchecked. Yet there are plenty of underutilized crops rich in micronutrients important for good health whose potential has not been exploited. Effect of processing and cooking on iron and zinc in these crops is also not documented.

Individuals at most risk of not meeting their dietary reference intakes are infants, young children and women of reproductive age, especially pregnant and lactating women who have higher requirements for specific nutrients than adult men. However, the contribution of cookies, noodles and crackers processed from underutilized crops toward recommended dietary intakes for specific population sub-groups is unknown.

Food contamination is a major issue concerning food preparation and processing for human consumption. This is because harmful microbes may enter the manufacturing process and reach the end product through raw materials, food handlers, or food handling environment and cause food borne illnesses. Microbiological load of the most common microbes after crop processing is unknown and it is vital in order to ascertain product safety for human consumption.

Underutilized food crops have been neglected by agronomic researchers and policy makers. Despite these, diets continuously change due to changing culture; loss of local knowledge; more time needed to handle and prepare the underutilized species. However, increased perishability; poor processing; and dislikes of tastes and appearances have led to neglect and reduced consumption of the NUS. This calls for the need of appropriate food processing and preparation technologies which could reduce perishability and increase acceptability and thus increase consumption of the underutilized crops.

1.3. General Objective

To prepare safe, acceptable, and micronutrient rich crackers, noodles and cookies from underutilized crops comprising cassava, finger millet, simsim and slenderleaf.

1.4. Specific Objectives

1.4.1. To determine iron and zinc levels in raw and processed underutilized crops comprising cassava roots, fingermillet grains, simsim seeds, and slenderleaf vegetables.

1.4.2. To prepare modified crackers, noodles and cookies using selected underutilized food crops and evaluate their iron and zinc levels.

1.4.3. To determine the contribution of the modified crackers, noodles, and cookies to iron and zinc recommended dietary allowance intakes of different population sub-groups.

1.4.4. To determine microbiological load and moisture content in the modified crackers, noodles and cookies.

1.4.5. To assess acceptability of the modified crackers, noodles & cookies through sensory evaluation.

1.5. Research Hypothesis

1.5.1. Iron and zinc levels in selected food crops reduce after processing vegetables.

1.5.2. Crackers, noodles and cookies can be modified using cassava roots, fingermillet grains, simsim seeds, and slenderleaf vegetables; and they are rich in iron and zinc.

1.5.3. Modified crackers, noodles and cookies can contribute 100%RDA of iron and zinc to different population sub-groups.

1.5.4. Modified crackers, noodles and cookies contain microbiological load levels and moisture content levels within recommended maximum limits of such products.

1.5.5. Modified crackers, noodles and cookies are highly acceptable among men, women, boys and girls.

1.6. Justification of the Study

Availability of formulated food products from readily available underutilized crops could reduce their perishability hence improve their marketability. Food product processing could also increase acceptability of the NUS and in the long rung increase consumption of these crops. Increased consumption could eventually translate to increased intake of micronutrients of public health concern and thus eliminate or minimize micronutrient malnutrition in the long run. Improved marketability of NUS could promote large scale production of these crops and large scale food processing. As a result, the economic status of the indigenous population at national and household levels could improve.

Since iron and zinc content of crops vary depending on their location, condition, and processing which they are exposed to, analysis of iron and zinc content of both raw and processed food crops could provide information on their levels and effect of processing on the same. This information is vital in determining adequate intake quantities of the food products for iron and zinc. The information is vital for vulnerable populations who cannot afford fortified foods or cannot access pharmaceutical micronutrient supplementation. This research could inform the policy makers in improving food policies through integration of the role of underutilized food crops in the elimination of micronutrient malnutrition.

Information on microbiological load of the prepared food products is vital in ensuring that the populations consume products free from food borne illnesses thus safe for human consumption. Information on contribution of modified food products to dietary reference intakes for Fe and Zn is paramount in the effort towards control and/or elimination of micronutrient malnutrition.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

Over three billion people are afflicted with micronutrient malnutrition and the numbers are increasing (Anonymous, 2013). Major malnutrition problems are found in developing countries especially in Africa (FAO, 1996), yet Africa has plenty of underutilized food crop rich in micronutrients important for good health (Oniang'o et al., 2005) which can supply the required micronutrients. However research has concentrated on nutrient content of raw crops with little attention to nutrient content of processed or cooked crops (Maundu, 1997).

2.2. Micronutrient Malnutrition

Malnutrition in Kenya remains a major public health problem. Micronutrients are essential vitamins and minerals needed in very small amounts and supplied by a variety of foods in the diet (FAO, 2003). Vitamins and minerals are essential for physical and mental development, immune system functioning, various metabolic processes, preventing specific disease conditions and promoting growth (FAO, 2002, 2003). Micronutrient malnutrition refers to vitamin and mineral nutritional deficiency diseases that result from diets which lack adequate amounts of essential vitamins and minerals (FAO, 1996). One of the objectives of The Nutrition Action Plan 2012-2017 is to reduce the prevalence of micronutrient deficiencies in the Kenyan population (MPHS, 2013). Micronutrient deficiencies usually occur when the habitual diet lacks diversity or are overly dependent on a single staple food (FAO/WHO, 2002). Integration of food rich in micronutrients into the diet is a sustainable way to improve micronutrient status in human body (Ali & Tsou, 1997) by ensuring that commonly consumed foods are nutritious (ICRAF, 2004). Therefore increasing overall intake by increasing consumption of food sources of micronutrients through food products could contribute to increased micronutrient intake and thus minimize micronutrient deficiencies.

Dietary micronutrient deficiencies (MNDs) are widespread risks due to inadequate intakes for minerals including iron and zinc (Joya et al., 2014). These deficiencies are likely to be widespread in global terms (Black et al., 2008; Bouis, Hotz, McClafferty, Meenakshi, & Pfeiffer, 2011; Broadley & White, 2010).

2.2.1. Iron

Iron deficiency causes 30%–50% of anemia (WHO, 2007). Iron deficiency is the most common anaemia worldwide as 1.6 billion people are anaemic (McLean, Cogswell, Egli, Wojdyla, & de-Benoist, 2009) and several hundred million people manifest iron deficiency anaemia (Miller, 2013). Therefore, the health burden of iron deficiency may be extrapolated from the global prevalence of anemia but it is not distributed evenly throughout the world, as there is a fivefold increase in underdeveloped geographies (Miller, 2013). In these regions, 40%–50% of the population remains anaemic at all ages with the exception of nonelderly men (McLean et al., 2009). This corresponds to 24.8% of the population with highest prevalence in preschool children 25.4%, school age children (47.4%) and pregnant women (41.8%) (de-Benoist, 2008; Fritschel, 2000). Iron Deficiency Anaemia (IDA) ranks number 9 among 26 risk factors included in the Global Burden of Disease (GBD) 2000, accounting for 841,000 deaths and 35,057,000 disability-adjusted life years lost (Bothwell & MacPhail, 1992; Stoltzfus, 2003). Iron deficiency anaemia is considered a micronutrient deficiency of public health significance due to its widespread and serious economic and health consequences in the sub-Saharan African population (FAO, 2003).

Africa and parts of Asia bear 71% of the global mortality burden and 65% of the disability-adjusted life years lost due to iron (Fe) deficiency anaemia (IDA) (Stoltzfus, 2003). The highest proportion of individuals affected are in Africa (47.5–67.6%) (Benoist et al., 2008), with 14% prevalence in East African region (Joy et al., 2014). In Kenya, 60% of the population is iron deficient with 56% rates among women, 46% among men and 89% in children under 6 years (FAO, 2005; GOK & UNICEF, 2002; Hongo, 2003). Anaemia prevalence is as high as 73% in the Lake Basin region, standings at 91.3% in preschool children, 72.9% in women of child bearing age and 42.7% in adult men (GOK & UNICEF, 2002). Anaemia prevalence rates >40% indicate severe, >20% moderate, while >5% indicate mild prevalence of anaemia (WHO, 2001). The rates in Kenya and particularly the Lake Basin region are above 40%, indicating the severity of prevalence of anaemia. This indicates an urgent need for action to help reduce the high IDA prevalence rate levels to mild or normal rates less than 5%.

IDA during pregnancy can result in serious consequences to both mother and baby. Maternal anaemia may also lead to foetal growth retardation, low-birth weight infants and increased rates of early neonatal mortality (WHO, 2002a). Anaemia affects cognitive performance, behavior and physical growth of infants and children of preschool and school age (WHO, 2001). IDA in adults diminishes their stamina and work capacity by 10-15 percent, and provokes losses in gross domestic product of up to 1.5% thus exerting a high economic burden on society (FAO, 2003). However, Africa is endowed with iron rich underutilized crops which have not been exploited to increase iron rich sources. There is lack of information on the processing of NUS to increase their consumption and utilization to help contribute to iron intake that could prevent IDA.

The Recommended Nutrient Intake (RNI) is the daily dietary intake level that is sufficient to meet the nutrient requirement of almost all (97–98%) healthy individuals in a particular age, gender and physiological status group (WHO, 2004a). The recommended daily intakes for Fe are: man (16mg), woman (18mg), pregnant woman (20mg), lactating woman (20mg), children one to six years (11mg), children six to eleven years (14mg), and children eleven to eighteen years (19mg); the RDA for men and premenopausal women is 8 and 18 mg/day, respectively while RDA for pregnant women is 27 mg/day (IOM, 2001). Food products that could supply the recommended nutrient intake (RNI) to various groups from a combination of selected underutilized crops have not been documented. There is lack of information on the contribution level of food products from underutilized crops to RDA of various population groups.

Iron absorption is enhanced when consumed with ascorbic acid, present in fruits and vegetables (FAO, 2003; ICRAF, 2004). In every 100g fresh weight edible portions of raw African indigenous vegetables (AIVs), there is certain amount of iron present as shown by the following examples: vegetable cowpea (39mg), African night shades (12mg), vegetable amaranth (10mg), jute mallow (7.7mg), slender leaf (4.0mg) and pumpkin leaves (2.1mg) (Abukutsa-Onyango, 2003). The potential of slenderleaf has not been exploited (Abukutsa-Onyango, 2007). Iron levels in food product from a combination of slenderleaf with other crops merit examination in a bid to expand availability of micronutrient rich food products. However, food products processed from slenderleaf have not been documented.

2.2.2. Zinc

An estimated 20% of the world's population is at risk for zinc (Zn) deficiency (WHO & FAO, 2006; Wuehler et al., 2005). Zinc deficiency is widespread in developing countries, but is under-recognized due to lack of sensitive biomarkers of zinc status (FAO/WHO/IAEA, 1996; Wood 2000). Zinc deficiency is also widespread in areas where diets lack diversity (Kennedy et al., 2003) and it has been implicated as a contributing factor to stunting in approximately one third of children in low-income countries (de-Romana et al., 2005). In Africa, the mean estimated risk of zinc deficiency is 40% and is greatest in the East African region at 75% (Joy et al., 2014). In Kenya, zinc deficiency is a public health problem as about 50% of children under 6 years and 50% of women were affected (GOK & UNICEF, 2002). Little effort has been made to increase zinc intake through consumption of cheap and easily available underutilized food crops to help address zinc deficiency.

Zinc is required for the catalytic activity of approximately 100 enzymes (IOM, 2001) and plays a role in immune function, protein synthesis, wound healing, DNA synthesis and cell division (IOM, 2001). Zinc supports normal growth and development during pregnancy, childhood, and adolescence (Maret & Sandstead, 2006) and is vital for proper sense of taste and smell (Prasad, Beck, Grabowski, Kaplan, & Mathog, 1997). Zinc deficiency is associated with decreased immune function, poor growth, increased susceptibility to and severity of infections, adverse outcomes of pregnancy, and neurobehavioral abnormalities (Bhuta, Bird, & Black, 2000; Brown, Peerson, Rivera, & Allen, 2002; Fraker & King, 2004). A daily intake of zinc is required to maintain a steady body state because the body has no specialized zinc storage system (Rink & Gabriel, 2000). Although elimination of its deficiency improves health status considerably, zinc has received little (Gudrun et al., 2013). There is lack of documented information on the contribution of underutilized food crops to recommended dietary allowance for zinc.

In many low income countries, staple diets are predominantly plant based and the intake of rich sources of readily available dietary zinc such as red meat, poultry and fish, is often low because of economic, cultural, or religious constraints (Gibson, 2012). A wide variety of whole grains and plant-based foods are a good source of zinc (IOM, 2001). It's concentrations in foods vary depending on various factors including food processing methods, and cooking (IOM, 2001). This calls for consideration of the assessment of appropriate traditional food processing and preparation technologies that can reduce nutrient loss (K. M. Walingo, 2009). Given that the world is changing in terms of food choices, there is need to incorporate traditional food processing technologies with modern food processing technologies to process underutilized food crops in order to enhance utilization. It is not documented whether modern food processing technologies can increase utilization and consumption of underutilized food crops and their impact on nutrient levels, particularly iron and zinc.

It is important to examine zinc in the diet (Caulfield & Black, 2004) but its concentrations in food varies depending partly on processing and cooking (IOM, 2001). This calls for consideration of assessment of food preparation methods and food combinations with implications to zinc (Hongo, 2003; K. M. Walingo, 2009). However, there is lack of documented information on effect of food combinations and processing on zinc levels in underutilized crops.

2.2.3. Iron and Zinc Bioavailability

There are 2 types of dietary iron: non-heme iron present in both plant foods and animal tissues, and heme iron from hemoglobin and myoglobin in animal source foods (Zimmermann, Chaouki, & Hurrell, 2005). In many developing countries, cereal and legume based diets contain low amounts of bioavailable iron, which may increase the risk of iron deficiency (Zimmermann et al., 2005). Chemical forms of iron with high bioavailability include ferrous sulfate and ferrous fumarate, whereas those with low or variable bioavailability include reduced elemental iron and ferric Pyrophosphate (R. F. Hurrell, 1985; Patrick, 1985). The sulfate salt of zinc is more bioavailable than its oxide form (Lowe, Wiseman, & Cole, 1994; Wedekind & Baker, 1990). In many developing countries, monotonous cereal and legume based diets contain low amounts of bioavailable iron (Zimmermann et al., 2005). Low iron bioavailability is thought to play a central role in the etiology of iron deficiency anaemia in developing countries (WHO, 2001), however, little direct scientific evidence supports this claim (Zimmermann et al., 2005). Ascorbic acid is the only main absorption enhancer in vegetarian diets, and iron absorption from vegetarian and vegan meals can be best optimized by the inclusion of ascorbic acid containing vegetables (Hallberg & Rossander, 1982). Cooking, industrial processing, and storage degrade ascorbic acid and remove its enhancing effect on iron absorption (Teucher, Olivares, & Cori, 2004). However, cooking or food processing is inevitable and iron status of individuals mainly influences the absorption of non-heme iron (Miret, Simpson, & McKie, 2003). This study assumed 100% iron bioavailability from modified products. However, bioavailability of iron in crackers, noodles and cookies prepared from cassava, fingermillet, simsim and slenderleaf is not documented.

Humans absorb zinc more efficiently when dietary zinc is low and it partly reflects the immediate effect of the amount ingested rather than long-term adaptation to changed zinc intake (D. Y. Lee, Prasad, Hydrick-Adair, Brewer, & Johnson, 1993; Sandstrom, Arvidsson, Cederblad, & Bjorn-Rasmussen, 1980). As more zinc is ingested, absorptive efficiency decreases considerably, but the absolute amount absorbed increases (Hunt, 2015). Several dietary factors many influence human zinc absorption (Lonnerdal, 2000). Zinc bioavailability from plant sources such as legumes, whole grains, nuts and seeds is less because these sources have high phytic acid (Harland & Oberleas, 1987). Although phytic acid in unrefined foods reduces fractional zinc absorption, the higher zinc content of these foods may make them preferable to more refined foods (Hunt, 2015). This study assumed 100% zinc bioavailability from modified products. However, bioavailability of zinc in crackers, noodles and cookies prepared from cassava, fingermillet, simsim and slenderleaf is not documented.

2.3. Underutilized Crops

Terms such as 'underutilized', 'neglected', 'orphan', 'minor', 'promising' and 'niche' are often used interchangeably to characterize the range of plant species with under-exploited potential for contributing to food security, health (nutritional/medicinal), income generation, and environmental services (Jaenicke & Höschle-Zeledon, 2006). There are more than 45,000 species of plants in Sub-Saharan Africa of which more than 1,000 can be consumed and are the mainstay of traditional African diets (MacCalla, 1994). These plants are inexpensive, easily accessible and provide millions of African consumers with minerals needed to maintain health (Abukutsa-Onyango, 2003; Abukutsa-Onyango, Tushaboomwe, Onyango, & Macha, 2005; FAO, 2003; ICRAF, 2004; MacCalla, 1994). Indigenous diets from underutilized crops can help alleviate nutrient deficiencies by increasing nutrient supplies (Engle & Altoveras, 2006; ICRAF, 2004). Although there is clear evidence that underutilized crops are a good source of some micronutrients, most of the existing data is based on values in raw foods (Maundu, 1997) with very little effort to explore the nutritive value of cooked crops (Habwe, 2008). Given that processing may alter the micronutrient content of food, micronutrient levels in final food products, rather than raw foods provide a better estimate of amounts that will be consumed by the population. More emphasis is on the nutritive value of raw crops but effect of cooking and processing on the nutrients is not well documented.

Supply of nutritionally adequate foods to the global population is still challenging (Gudrun et al., 2013). Kenya has diverse agro-ecological zones which contribute to a wide diversity of indigenous neglected and underutilized species (Termote et al., 2013). This broad and excellent variety of NUS, coupled with high rates of malnutrition (KNBS & ICF-Macro, 2010), makes Kenya an ideal location to study the role of local foods in meeting nutritional adequacy (Termote et al., 2013). However, the importance of NUS also known as minor or orphan crops such as millets and leafy vegetables is often overlooked (Anonymous, 2013), little is known about their nutritional value and safety (Termote et al., 2013). Nutritional value and safety of NUS such as cassava, fingermillet, simsim and slenderleaf particularly after processing and product preparation is not documented.

2.3.1. Cassava (*Manihot esculenta* Cranzt)

Cassava is a perennial crop native to tropical America (Olsen & Schaal, 2001) from which about 700 million poor people in Africa, Asia and Latin America obtain more than 500 calories per day

(FAO, 2006, 2007). The third largest carbohydrate food source within the tropical regions, after rice and corn is cassava (Ceballos, Iglesias, Perez, & Dixon, 2004). It is vital for both food security, income generation and is a staple food of importance to over 500 million people in Africa (Barratt et al., 2006; FAO, 2004; Montagnac, Christopher, & Tanumi, 2009). Africa is the largest producer of cassava accounting for 53% of world production (Teka, Emire, Haki, & Gezmu, 2013). Cassava is grown in areas where mineral and vitamin deficiencies are widespread especially Africa (Montagnac et al., 2009). In areas of unreliable rainfall, cassava is a strategic famine reserve crop and is grown by poor farmers mostly women (IITA, 2000). Cassava has advantage over other crops due to its outstanding ecological adaptation, high resistance to plant diseases, high tolerance to drought and poor soils, low labor requirement, ease of cultivation and high yields (El-Sharkawy, 2003; Richardson, 2013; Teka et al., 2013). These advantages makes cassava a suitable vehicle for availing micronutrients to the poor vulnerable populations by combining with other nutrient rich crops to process quality and acceptable food products. There is no documented information on food product processing using combinations of cassava with other nutritious crops in Kenya.

Often cassava is considered an inferior food because the storage root is low in protein, essential minerals and vitamins (Enidiok, Attah, & Otuechere, 2008; Oboh & Elusiyan, 2007). Other major drawbacks result from rapid tuber postharvest perishability (Enidiok et al., 2008). Processing is therefore indispensable to facilitate preservation, improve palatability and product quality (Chijindu & Boateng, 2008). Efforts to process cassava into food products with reduced perishability in Kenya is not been documented.

Since cassava roots are grossly deficient in proteins, fat, some minerals especially iron and zinc (Igbabul, Adole, & Sule, 2013), continued consumption can lead to malnutrition (Richardson, 2013) thus creating potentiality of cassava being a dysfunctional food (Teka et al., 2013); yet over 200 million people depend on it as a daily source of energy. Improving the nutritional value of cassava could alleviate some aspects of hidden hunger, that is, subclinical nutrient deficiencies without overt clinical signs of malnutrition (Montagnac et al., 2009). Cassava is an abundant crop that defies the odds in drought seasons; it has drawbacks which can be overcome by appropriate processing to reduce perishability. Although cassava is deficient in the nutrients, it is high in starch (Igbabul et al., 2013), this starch content makes it attractive for use as a base ingredient in food product processing. This enables it to supply energy but also enables creative use of nutrient dense but less acceptable underutilized crops through combinations to process nutritious and acceptable food products which have not been documented.

2.3.2. Fingermillet (*Eleusine coracana* L.)

Millet is the world's seventh most important cereal grain. Roughly 95% of the world's growing millet area is in the developing countries, mainly in Africa and Asia (Léder, 2004). It is still a major staple food source for millions of poor people in Africa and Asia, especially in hot, dry areas (Adekunle, 2012; Amadou, Gounga, & Le, 2013). Like many other cereals, millet has high carbohydrate energy content and provides nutrients including iron and zinc among others, making it a useful component of nutritional balance in foods (Amadou et al., 2013; Devi, Vijayabharathi, Sathyabama, Malleshi, & Priyadarisini, 2014; Lawler, 2009). Food nutrient values have largely focused on raw crops; information on nutrient value of fingermillet after processing is not documented. Furthermore it is not documented whether products processed from fingermillet can contribute adequate iron and zinc recommended dietary allowance for various population sub-groups.

Fingermillet is the fourth most widely cultivated species in order of worldwide millet production and is produced entirely for food for millions of people in Asia and Africa (Léder, 2004; Mirza & Kumar, 2013). The plant is cultivated in a wide geographical zone ranging from the Middle East and into tropical Asia, from Senegal, Niger and northern Nigeria in West Africa and across southern and eastern Africa. Fingermillet is also known as African millet and black millet. Its varieties are well adapted to hot, humid and tropical conditions, and can survive water shortage (Adekunle, 2012; Léder, 2004). Despite these advantages, fingermillet has been neglected and there has been an impression that it is a "poor person's crop" or "famine food". As a result there is no documented information on any effort to process fingermillet into non-perishable products.

Fingermillet grows on a variety of soils and it is widely recognized that soil and climate can impact the nutrient composition of millet (Glew, Chuang, Roberts, & Glew, 2008). The crop has high nutritional quality (Mirza & Kumar, 2013) as it is a good source of minerals such as iron and zinc (Glew et al., 2008; Léder, 2004; Mathanghi & Sudha, 2012; Mirza & Kumar, 2013; Singh & Raghuvanshi, 2012). Being the rich in iron, iron deficiency can be addressed by introducing fingermillet in our daily diet (Singh & Raghuvanshi, 2012). More consumption of fingermillet would be beneficial to vulnerable populations living in communities where iron-deficiency anaemia is common (Vander-Jagt, Brock, El-Nafaty, Crossey, & Glew, 2007) like Western Kenya. Finger millet is also a good source of zinc, a trace element required for a healthy immune system (Hirano, Murakami, Fukuda, Yamasaki, & Suzuki, 2008), important for populations with high HIV prevalence like in Western Kenya. Simple traditional food processing methods that minimize nutrient loss can increase mineral availability (Makokha, Oniang'o, Njoroge, & Kamar, 2002). However, information of effect of processing on nutrient levels of underutilized food crops and their food products in not documented.

Fingermillet is easy to digest and is one of the least allergic and most digestible grains (Singh & Raghuvanshi, 2012). Despite the grain being an ancient food, research on millet and its food value is in its infancy, its potential vastly untapped (Singh & Raghuvanshi, 2012). Information on the processing of fingermillet into value added products in Kenya is not document. Exploitation of fingermillet for preparation of ready-to-use or ready- to- cook products could increase the consumption of millets among non-millet consumers and thereby counter nutritional security (Verma & Patel, 2013). Information on ready-to-cook or ready-to-eat food products prepared from a combination of fingermillet with cassava in Kenya has not been documented.

2.3.3. Simsim (*Sesamum indicum* L.)

Sesame is one of the oldest cultivated plants in the world (Hsu, Chu, & Liu, 2012). Its major producers are India, Sudan, China and Burma which produce 60% of its total world production (Abou-Gharbia, Shehata, & Shahidi, 2000). Sesame is a versatile crop that can be grown in dry arid regions, and has unique attributes that can fit most cropping systems and tolerate hot growing conditions, drought, disease, and insects (Langham, Riney, Smith, & Wiemers, 2008). Sesame seeds play an important role in human nutrition where they are used for the production of oil, paste and in food formulations (Abou-Gharbia et al., 2000; Abu-Jdayil, Al-Malah, & Asoud, 2002). The seed is an important source of oil (44–58%), protein (18–25%), carbohydrate

(13.5%) and ash (5%) (Kahyaoglu & Kaya, 2006; Shyu & Hwang, 2002). Simsim seeds are rich in minerals like iron and zinc which play vital roles in the body (Phillips, Ruggio, & Ashraf-Khorassani, 2005). The seeds also provide enough recommended daily levels of, minerals (Nakai et al., 2003). Simsim seeds therefore are good for increasing nutrient content of diets or food products thus help contribute to increase consumption of these nutrients, however, such potential should be assessed. The possibility of combining nutrient dense simsim with nutrient deficient cassava to process food products in Kenya has not been documented.

2.3.4. Slenderleaf sp. (*Crotalaria ochroleuca* and *Crotalaria brevidens*)

Green leafy vegetables (GLV) are relatively inexpensive, quick to cook, and rich in several nutrients essential for human health. They contribute appreciable amounts of minerals such as iron (Gupta, Lakshmi, & Prakash, 2006) to the diet. Besides being sources of micronutrients important for good health, African indigenous vegetables are important for dietary diversification (Oniang'o et al., 2005). Of all the traded vegetables, over 70% in rural markets and 10% in urban markets in western Kenya are indigenous (Abukutsa-Onyango, 2002; Schippers, 2000). However, AIVs have largely been neglected and stigmatized partly due to inadequate awareness of their value and processing (Abukutsa-Onyango, 2010b). There is lack of information and knowledge on processing and preparation alongside their nutrient contents after cooking.

Africa is the center of diversity of the two African slenderleaf species used as vegetables *Crotalaria ochroleuca* and *Crotalaria brevidens.* The former has a mild taste while the latter has a bitter taste which is attributed to the presence of secondary metabolites like alkaloids, oxalates and other phenol compounds responsible for the bitterness, toxic and medicinal attributes

(Abukutsa-Onyango, 2007; Schippers, 2000). *Crotalaria ochroleuca* has bright green leaves, and grows to a height of 250cm. It has pale yellow or cream flowers, the seeds are normally light yellow, and the pods are wider in diameter and big (Abukutsa-Onyango, 2007; Schippers, 2000). On the other hand, *Crotalaria brevidens* has bluish green leaves, grows to a height of 210 cm and has bright yellow flowers. Its seed is light brown in colour and normally contains anthocyanin, while the pods are small and narrow in shape (Abukutsa-Onyango, 2003, 2007). The main distinguishing features of the two species are the taste and pod size, but they are commonly called slenderleaf (Schippers, 2000).

Slenderleaf has been grown and consumed in West and East Africa for a long time and has been used in Kenya as a cooked vegetable (Abukutsa-Onyango, 2007). It contributes 100% of the daily dietary requirement for vitamin A, vitamin C, iron, calcium, copper and 40% of proteins when 100g of the fresh weight are consumed (Abukutsa-Onyango, 2003, 2007; Habwe, Walingo, Abukutsa-Onyango, & Oluoch, 2009). Slenderleaf is among the top ten priority AIVs with health improvement and wealth creation potential in Kenya (Abukutsa-Onyango, 2007) and Western region (Abukutsa-Onyango, Kavagi, Amoke, & Habwe, 2010). Cultivation of slenderleaf in Kenya has always been done at a subsistence level and their potential as commercial commodities has not been exploited despite its advantages (Abukutsa-Onyango, 2003). This has been attributed to perishability and poor processing strategies (Abukutsa-Onyango, 2007; Schippers, 2000). It has not been recorded that slenderleaf leaves have been used in preparation of food products with extended shelf life.

2.4. Food Processing

Reasons for processing food include preservation for use in times of shortage, increase of shelf life, removal of toxins, removal of anti-nutrients which improve digestibility and availability of minerals, and improvement of palatability, and fortification (Hotz & Gibson, 2007; Michaelsen et al., 2008). Food preparatory practices have changed over time. In East Africa, boiling and roasting were the principal cooking techniques from 1930s to 1960s. These were superior to current practices favouring frying and deep-frying (Raschke et al., 2007). Besides the shift towards frying instead of boiling vegetables and other crops in urban areas, there seem to be no distinctive urban recipes. However, boiling crops in unspecified amounts of water or wet heating may contribute to nutrient loss (Abukutsa-Onyango et al., 2005). However, information on effect of processing on nutrient levels in slenderleaf and its products has not been documented.

People tend to stick to food habits; thus, preparation techniques acquired in early childhood have long-lasting influence even if people move from villages to towns (Sodjinou, Agueh, Fayomi, & Delisle, 2009). Contrary to the above assertions, methods of food processing have been developed over the centuries and are adopted to make the final product more attractive in flavour, appearance, taste and consistency. Besides these aspects of consumer preferences, several of the methods aim at making the food safe and wholesome and increase its shelf life (Singh & Raghuvanshi, 2012). The common household practices of processing foods include milling, germinating or sprouting, malting, fermentation and cooking. Each of these processes modifies the nutritive value of the food (Singh & Raghuvanshi, 2012). The shelf-life of minimally processed products is increased by pre-processing factors (crop varieties, pre-harvest factors, harvesting, maturity), processing factors (pre-cooling, trimming, washing, cleaning, disinfection, cutting, peeling, handling, dipping, drying, packaging) and distribution conditions (Shewfelt, 1987). Information on effects of processing on nutrient levels in slenderleaf has not been documented. It is also not documented whether product processing from a combination of slenderleaf and cassava could result in products with adequate iron and zinc levels.

2.4.1. Cassava Processing

Cassava is not only used as human food, but it's products are also popular in international trade in different forms like flour, dried chips, pellets and starch, thus contributing to the economy of exporting countries like Nigeria, Malawi and Ghana (Eke, Achinewhu, Sanni, Barimalaa, & Dixon, 2007; Emmanuel, Clement, Agnes, Chiwona-Karltun, & Drinah, 2012; Mweta, Labuschange, Koen, Benesi, & Saka, 2008). Except for cassava crisp in Nigeria, there is no commercial processing of cassava for human consumption while products such as deep-fried and sun dried cassava are produced at a very small scale in Kenya (Karuri, Mbugua, Karugia, Wanda, & Jagwe, 2001). Traditional cassava utilization in Kenya is limited to roasting and boiling of fresh roots for consumption (Karuri et al., 2001). To improve bioavailability of nutrients, cassava and its products should pass through different effective processing methods (Teka et al., 2013). Although cassava is widely used by most communities in Kenya, it has not been exploited to process food products. Fortunately some researchers like Slimak, (1990) came up with patented innovations in processing food products from cassava. This therefore indicates that cassava has a potential of being used in product preparation, however, there is need to assess the nutrient levels and acceptability of food products prepared from a combination of cassava with other nutritious underutilized crops.

Traditional cassava preservation methods include: removing the leaves two weeks before harvest which lengthens the shelf life to two weeks, dipping the roots in paraffin or a wax, or storing them in plastic bags, which reduces the incidence of vascular streaking and extends the shelf life to three or four weeks; and packing the roots in moist mulch to extend shelf life (Onwueme, 1978). Although cassava offers the advantage of a flexible harvesting time, allowing farmers to keep the roots in the ground until needed (Iglesias, Mayer, Ch´avez, & Calle, 1997), fresh cassava has a very short shelf life once removed from the stem making it urgent to get it to the market. Alternatively, immediate processing is required (Karuri et al., 2001). There is no documented information on whether processing cassava into food products through value addition by combining with NUS can reduce it's perishability and improve its nutrition quality.

2.4.2. Fingermillet Processing

Millet being a staple food and consumed at household levels, it's processing must be considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs (Belton & Taylor, 2002; Hamad, 2012). Due to an emerging need for the world to feed its growing population, it is important to explore plants like millets which are grown in poor countries and consumed by low income households (Obiana, 2003). Millet has been used in many diverse ways including making bread, baby food, and porridge. The porridge is prepared when five measures of boiling water for two measures of millet flour are added with sugar or salt then cooked covered using low flame for 30–35 minutes (Lu et al., 2009). Millet has also been used as a stuffing ingredient for cabbage rolls in some countries and soup commonly used by nursing mothers to aid in milk production and healing from childbirth (Lawler, 2009). Basic preparation of millet consists of washing and toasting while moving the millet until one notes a characteristic scent (Lu et al., 2009). Millet treatment procedures include fermentation, roasting (dry or wet), parboiling, and drying among others. However, traditional art of food preparation is not standardized and routine procedures have been passed on to women through generations (Léder, 2004). Nutritional quality of millets demands for examination of their nutritional characteristics and development of value added products (Amadou et al., 2013). Apart from baking bread and other products mentioned above, food products from a combination of fingermillet with cassava have not been exploited, & their nutritional quality is not documented.

Fingermillet on the other hand were gently roasted after sprouting and drying, ground then sieved. The flour was eaten as gruel, either sweetened or salted, and was popular as weaning food in India (Achaya, 2009). In India, fingermillet is processed by milling, malting, fermentation, popping, and decortications to produce noodles, vermicelli, pasta, Indian sweet (halwa) mixes, papads, soups, and bakery products (Shobana et al., 2013). In Northern and Western Africa a steamed, granulated product called *couscous*, made from cereal flours including fingermillet is highly popular. In Uganda, Tanzania and Kenya, a stiff porridge is prepared from cereal mixture of fingermillet and it is commonly called *ugali* (Amadou, Gbadamosi, & Guo-Wei, 2011; Léder, 2004). However, apart from composite flours for porridge, there are no other common food products processed from a combination of cassava with fingermillet in Kenya.

Composite flours made by using fingermillet can be used for preparation of various nutrient dense recipes which can be effectively used for supplementary feeding programs (Singh & Raghuvanshi, 2012). Being a staple food and consumed at household level, processing is considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs (Hamad, 2012; Obilana & Manyasa, 2002). The emerging principal uses of millets as an industrial raw material include production of biscuits and confectionery, beverages, weaning foods and beer (Anukam & Reid, 2009; Laminu, Modu, & Numan, 2011). Future trends should focus on the millet consumption in the developed countries that could help its industrial revolution (Amadou et al., 2013). However influence of diversity through processing of fingermillet in combination with other crops into food products through improvement of traditional processing methods on acceptability and nutritional quality remains unexploited.

2.4.3. Simsim Processing

Fried sesame seed with sugar is used as a soup ingredient, the paste of roasted simsim seed is used in bakeries, while the dehulled and defatted sesame can be used in food products as a protein and tryptophan/methionine supplement (Albo, 2001; Eleazar, Salvador, Alicia, & Guillerrmo, 2003). Consequently simsim meals are carefully prepared for human consumption (Gandhi & Srivastava, 2007). Simsim (*Sesamum indicum*) is consumed as a seed in Western Kenya and it was considered to be very nutritious (Kinyuru et al., 2012). However, the use of simsim value addition of food products by combining it with underutilized crops in Kenya has not been documented.

2.4.4. Slenderleaf Processing

There are different ways in which African Indigenous Vegetables (AIVs) are consumed as side dishes, processed into soups, sauces or pastes included with the main course (Oomen & Grubben, 1978). These vegetables are usually either boiled or fried and eaten along with stiff porridge made from cereals. However, mashing the vegetables with maize or with starchy tubers is also widespread in Kenya. Cooking the vegetable with flour made from cereals or dried tubers is also possible (Maundu, 1997; Vorster, Jansen-van, Van-Zujl, & Sonja, 2007). Preparation of food products with extended shelf-life from AIVs and NUS in Kenya remains unexploited.

The high convenience and nutritional value originating from mild or minimal processing and preservation treatments present many advantages for consumers and food services (Wiley, 1994). Blanching extends the keeping time of vegetables for several months in the freezer. It involves immersing them in fast-boiling water or steaming them for a specified amount of time, depending on the size and type of vegetable and then plunging them into ice-cold water before draining and packing (Helpwithcooking.com, 2001-2008). Vegetable blanching impedes enzyme action during storage time thus reducing their deterioration. It also improves and enhances flavor of vegetables upon cooking (Helpwithcooking.com, 2001-2008). Heat treatments are rarely used for stabilizing minimally processed vegetables due to their negative effects on flavor, texture, and fresh-like quality (Ahmed, Mirza, & Arreola, 1991). However, development of suitable heat treatments associated with a low negative impact could be of great interest in producing minimally processed vegetables with a longer shelf life which could be used both as semi-manufactured and final products (Pittia, Nicoli, Comi, & Massini, 1999). Retention of the original texture of vegetables can be obtained by the application of low temperature blanching treatments due to the activation of pectin methylesterase followed by cross-linking with cations (C. Y. Lee, Bourne, & Van, 1999). Effect of processing on acceptability of NUS with regards to Organoleptic attributes remains underexploited.

2.5. Consumption of NUS

Consumption of underutilized crops in Sub-Saharan African (SSA) countries is low compared to countries in Asia and Latin America (Ruel, Minot, & Smith, 2004). Low consumption among women, children and youth in the urban and Peri-urban populations of Lake Victoria region is due to lack of knowledge on preparation and cooking coupled with dislike of their tastes (Waudo et al., 2007). Value addition along the value chain could help acceptability of NUS (Abukutsa-Onyango, 2010b). However, assessment of whether value addition of NUS through combinations of underutilized crops to formulate food products could increase acceptability is unexploited.

Strategic contribution of NUS to address food and nutrition insecurity became more broadly recognized only recently. Maximizing the nutrient output of farming systems for a culturally acceptable and nutritious diet has unfortunately never been an objective of agriculture. Only maximum production with minimum costs has been the focus (Welch, 2008). Fortunately this trend is changing as AIVs are becoming the vegetable of choice where consumption has been minimal. This is due to availability of these vegetables to the lower end of the market consumers whose majority are the poor (Shiundu & Oniang'o, 2007). However, these crops are highly perishable thus scarce during off-season. Efforts to processed food products with increased shelf-life from these crops in Kenya remain a gray area due to lack of documented information.

In South Africa, wild traditional vegetables are moving from the wild into home gardens, thereby becoming cash crops (Rendsburg, Vorster, & Ntombela, 2007) and in a way popular to most consumers (van-den-Heever & du-Plooy, 2007). In Kenya, farmers have started to reduce the cultivated land under other crops to expand production of AIVs and marketing of traditional vegetables (Virchow, Oluoch, & Kimathi, 2007). A range of organizations are now backing efforts to enhance the conservation and use of NUS, but further investments are needed to mainstream these species in food and agricultural systems (Anonymous, 2013; Termote et al., 2013). In addition to improving agricultural systems in order to close the nutrition gap, effective food processing technologies to prolong shelf-life are required (Gudrun et al., 2013). The use of NUS to process food products with extended shelf-life could ensure availability on market shelf even during off-season thereby increase consumption (Habwe et al., 2009).

In Kenya most vegetables were consumed after boiling, cereals were traditionally prepared into porridges, while seeds and legumes were pounded. Flours are commonly used to prepare porridge, as example millet is the basic weaning porridge. The preference for millet is attributed to its dark color which is attributed to a rich nutritional value. However, traditionally one food is prepared alone with minimal food combinations in Western Kenya (Kinyuru et al., 2012). Preparation of food products with extended shelf life like crackers, noodles and cookies from a combination of underutilized/traditional food crops in Kenya has not been documented.

2.5. Snack Foods

Snack foods are the most enjoyable food products consumed all over the world (Pichetnawin, 2004). “Snack foods” refer to a wide range of food products consumed as light meals or a partial replacement for a regular meal which are convenient because they are quick and easy to eat (Barbara, 2011). Snack foods do not only apply to newer products such as potato crisps, but also includes traditional food items (Barbara, 2011). However, snack foods frequently receive criticism due to their high levels of salt, sugar, and fat, and are nutritionally damaging when eaten regularly in place of a traditional food (FAO, 2010). These foods, however, can be nutritious when made from fruits, pulses, or cereals which yield more nutrient dense products and their consumption does not lead to health problems (FAO, 2010). There are a number of traditional and newer snack foods products from African indigenous vegetables (M. K. Walingo & Habwe, 2011). Most foods are functional and plants are sources of functional foods (IFICF, 2007). Early snack products such as crackers, noodles and cookies are made from wheat flour, however, other base ingredients like rice, corn, potato, and tapioca were continuously added to the list of the upcoming and important raw materials (Pichetnawin, 2004). There is no documented information indicating whether preparation of snack products from a combination of cassava with simsim, fingermillet & slenderleaf could lead to acceptable nutritious products that could contribute to iron and zinc intake of various population sub-groups.

2.5.1. Cassava Products Processing Procedures According to Inventions by Silmak (1990)

The following cassava food product processing procedures were inventions in the United States of America by Slimak, (1990). However, these inventions propose the use of cassava alone to prepare food products, but combinations of cassava with nutrient micronutrient rich underutilized crops to process food products have not been documented.

2.5.1.1. Cassava Crackers

In any suitable machine for mixing heavy dough, combine 572g cassava flour, 340g water, 3.25g salt, 75g oil, and 23.6g baking powder. By any conventional means, including but not limited to molding, rolling, cutting, extruding, and the like, shape into desired shapes. Coat with a very thin film of oil, sprinkling with salt. Heat to 350^{o}F for 20 minutes. Cook by any conventional or the art, including baking, frying e.t.c. Alternatively, omit oil, or oil and salt, increasing water by 30 grams. Alternatively, use binders, flours, sweeteners, extenders, flavours, seasonings, fillers and other ingredients common to the art to produce a hyperallergenic cracker (Slimak, 1990).

2.5.1.2. Cassava Noodles

Using conventional equipment for kneading thick dough, combine 572g cassava flour and 340g boiling water. Knead well until dough is well mixed and forms soft doughy clumps. Extrude to various shapes of macaroni, fettuccine, spaghetti, lasagna and the like. Cut to desired lengths, dry by any conventional means, preferably air drying on trays, conveyors or the like. Alternatively a small amount of flour and water, preferably 20g cassava flour and 120g water maybe cooked to a thick paste and added to the above mixture.

When cooking, immerse noodles in boiling water for 2-10 minutes depending on the width of noodles. Any other cooking techniques of the art may also be used. Noodles will change from off-white opaque to light brown as the starch granules gelatinize. Noodles may be used in any type pasta dish soups, stews, pasta and sauce dishes, and the like (Slimak, 1990).

2.5.1.3. Cassava Cookies

Combine and mix well by the conventional art: 375.5g cassava flour, 226.5g water, 6.5g salt; 100g oil, 8g cassava baking powder. Form into cookie shapes by the conventional art. Bake at 350 ^{o}F on ungreased surface for 8-10 minutes, or until a light golden brown on the underside. Alternatively, add toppings as desired to the unbaked or baked dough. Any desired fruit, nut, flavours, seasonings of the conventional art may also be used. When a liquid sweetener or honey is used, the following ingredients are combined as described above: 357.5g cassava flour, 226.5g water, 6.5g salt, 50g honey, 50g oil, 8g cassava baking powder (Slimak, 1990).

Although Silmak, (1990) invented the use of cassava alone to prepare crackers, noodles and cookies, these products have traditionally been processed using wheat flour. These are products common in the markets and well accepted by consumers and there are existing standardized recipes for product preparation like those by Crocker (1969). However, standard recipes for preparing similar products using underutilized food crops have not been documented.

2.5.2. Original Recipes According to (Crocker, 1969)

2.5.2.1. Crackers

Ingredients

50g	Cassava flour
50g	Simsim flour
10g	Sugar
10g	Margarine
14mls	Water
1g	Baking powder

Preparation

The oven was preheated to 175°C while a large baking sheet was greased. The flours were then whisked together the flours. Margarine was then beaten together with sugar until light. The flour was then stirred in the flour mixture. Water was slowly poured in and stirred until dough was formed. On a well floured board, the dough was rolled to between ⅛ and ¼ inch thick. A knife was used to cut the dough into desired shapes, baked in the preheated oven for 10 minutes, then removed from oven (Crocker, 1969).

2.5.2.2. Noodles

<u>Ingredients</u>

50g	Cassava flour
60g	Fingermillet flour
1tsp	Salt
2	Eggs
10mls	Water

<u>Preparation</u>

All dry ingredients were mixed in a bowl and a well made in the centre. Water was added little by little while mixing thoroughly after each addition. Water was added enough to form dough into a very light paste. It underwent kneading for about 10 minutes till smooth and elastic. The dough was then rolled into ¼ inch thin rectangle and cut cross wise into ⅛ inch strips for narrow noodles and ¼ inch strips for wide noodles. The strips were shaken out and placed on a clean dry towel to dry for about 2hrs (Crocker, 1969).

2.5.2.3. Cookies

<u>Ingredients</u>

50g	Cassava flour
15g	C. ochroleuca powder
12g	C. brevidens powder
22g	Margarine
12g	Sugar
1 ¼ tbp	Salt
50mls	Water

Preparation

The oven was heated to 175°C, the flour, sugar and other dry ingredients were mixed thoroughly then margarine rubbed in to incorporate air. Mixing was continued as water was added till soft then pressed evenly onto bottom of a greased square pan. This was baked for 10 minutes at 175°C. Cookies were then removed from oven and left to cool (Crocker, 1969).

2.5.3. Characteristics of Standard Products

The characteristics bellow were adapted from ―Judge's Guide for Foods and Nutrition Exhibits, Kansas State University, July 2001 (Judging-Baked-Foods, 2001).

Shortened Cakes (Crackers)

These are cakes that contain butter, margarine or vegetable shortening and may be called creamed cakes or butter cakes.

Appearance: Rounded top, free of cracks, uniform, characteristic color throughout crust and crumb, thin crust, high volume.

Texture: Soft, velvety crumb, even grain, small, thin-walled air cells, free of tunnels, moist, smooth mouth feel, not sticky, light – but not crumbly.

Tenderness: Handles easily, yet breaks apart without difficulty, seems to "melt in your mouth," offers no resistance when bitten.

Flavour: Delicate, sweet flavour, well blended.

The characteristics of crackers modified from a combination of cassava and simsim have not been documented.

Rolled Biscuits (Noodles)

Small quick breads that use baking soda or baking powder as leavener, and should have flat tops and straight sides.

Appearance: Cylindrical, pale golden brown top crust, even height, creamy white crumb with no brown or yellow flecks, evenly contoured, straight sides and flat, fairly smooth top, uniform size, free of excess flour.

Texture: Small uniform gas holes, thin cell walls, crumb peels off in sheets, flakes or layers.

Tenderness: Crisp, tender outer crust, offer little resistance to bite, light and moist.

Flavour: Bland, mild, no bitterness or rancidity

The characteristics of noodles modified from a combination of cassava and fingermillet have not been documented.

Cookies

A cookie can be any of various hand-held, flour-based sweet cakes — either crisp or soft. They are generally classified as drop, bar, molded (hand formed), pressed, refrigerator or rolled.

Appearance: Uniform shape, even contour, uniform color, ingredients evenly mixed.

Texture: Characteristic of type – soft or crisp.

Tenderness: Breaks apart easily when chewed, not crumbly or hard.

Flavour: Pleasing, well blended, not eggy.

The characteristics of cookies modified from a combination of cassava and slenderleaf have not been documented.

2.6. Recommended Dietary Allowance for Iron and Zinc

Recommended Dietary Allowance (RDA) is the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97-98 percent) healthy individuals in a particular age, gender and physiological status group (IOM, 2001; WHO, 2004b). RDA for most nutrients is set at 2 standard deviations higher than the average amount required by a population group to meet the requirements of almost every person in the group (WHO & FAO, 2006). Increasing dietary diversity entails increasing both quantity and range of micronutrient-rich foods consumed. It is the preferred way of improving nutrition of a population because it has the potential to improve intake of many food constituents (WHO & FAO, 2006). This requires improved access to, availability and consumption of different types of micronutrient-rich foods in adequate quantities, especially among those who are at risk for, or vulnerable to micronutrient malnutrition (WHO & FAO, 2006). However, lack of resources for producing and purchasing higher quality foods is a barrier to achieving dietary diversity poorer populations (WHO & FAO, 2006). It is therefore paramount to help poorer communities identify traditional and wild micronutrient-rich foods as a simple means of satisfying micronutrient needs (Ruel, 2001). There is lack of information on whether underutilized food crops could be processed into food products like crackers, noodles and cookies that could contribute to iron and zinc dietary reference intakes of the general population.

2.6.1. RDA for Iron and Zinc Intakes for Various Population Sub-groups

Table.2.1. Iron and Zinc RDA for Various Population Sub-groups

Life Stage Group	**RDA**	
	Fe (mg/day)	**Zn (mg/day)**
Infants		
6-12 mo	11	3
Children		
1-3 y	7	3
4-8 y	10	5
Males		
9-13 y	8	8
14-18 y	11	11
19-30 y	8	11
31-50 y	8	11
51-70 y	8	11
>70 y	8	11
Females		
9-13 y	8	8
14-18 y	15	9
19-30 y	18	8
31-50 y	18	8
51-70 y	8	8
>70 y	8	8
Pregnancy		
14-18 y	27	12
19-30 y	27	11
31-50 y	27	11
Lactation		
14-18 y	10	13
19-30 y	9	12
31-50 y	9	12

Note: RDA is the average daily dietary intake level; sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a group.

Source (IOM, 2001)

2.7. Food Contamination

Harmful microbes may enter the manufacturing process and reach the end product through raw materials, air in the manufacturing area, chemicals employed, process surfaces, or factory personnel (Wirtanen & Salo, 2005). The most efficient means for limiting the growth of microbes are good production hygiene, the sensible running of the process line, and the well-designed use of cleaning and decontamination processes (Wirtanen & Salo, 2007). Common food borne pathogens such as *Bacillus cereus, Staphylococcus aureus, L. monocytogenes, Mycobacterium paratuberculosis, Clostridium perfringens, Escherichia coli* O157:H7, *Salmonella* Typhimurium, *Campylobacter jejuni,* and *Yersinia enterocolitica* have readily been found to produce biofilms on surfaces (Wirtanen & Salo, 2005). There is lack of information on the microbes that are bound to contaminate underutilized food crops after processing and modified food products.

Total coliforms includes thermo tolerant coliforms and bacteria of fecal origin, as well as some bacteria that may be isolated from environmental sources. Thus presence of total coliforms may indicate fecal contamination because it might be caused by entry of soil or organic matter or by human handling (Bartram & Pedley, 1996). In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermo tolerant coliforms (Bartram & Pedley, 1996). Given that food preparation entails human handling and heat treatment, it is important to assess the coliform levels in processed crops and modified products. However, total coliform levels in processed crops and in modified food products have not been documented.

Total plate count on the other hand provides a general indication of the microbiological quality of a food. However, it does not differentiate between the natural micro flora of a food, spoilage microorganisms, organisms added to fermented foods or pathogenic microorganisms. Depending on the product, a high total plate count may indicate that the product may have been prepared unhygienically or stored inappropriately. Therefore when assessing total plate count results, the processing and/or ingredients present in the foods needs to be considered (FSANZ, 2009). Information on Total plate count levels in raw and processed underutilized crops together with levels in modified crackers, noodles and cookies is not available.

Many microbes from faeces are pathogenic in animals and humans; therefore the presence of the intestinal bacterium *Escherichia coli* in foods indicates a potential hygiene hazard (Wirtanen & Salo, 2005). However, most strains of *E. coli* are harmless but a few strains with well-characterized traits are known to be associated with pathogenicity as they can be opportunistic pathogens that cause infections in immune compromised hosts (Wirtanen & Salo, 2007). There are also pathogenic strains of *E. coli* that when ingested, cause gastrointestinal illness in healthy humans (Ewing, 1986). *E. coli* is a definitive proof of fecal contamination because it is abundant in human and animal faeces and not usually found in other niches (Bartram & Pedley, 1996; Ewing, 1986). As a result, it is often unnecessary to undertake further testing to confirm the specific presence of *E. coli* (Bartram & Pedley, 1996). *E. coli* has been isolated from a large number of foods including vegetables and can cause outbreaks of diarrhea (Wirtanen & Salo, 2005). Their presence in ready-to-eat foods (fully cooked or those containing raw fruits or vegetables) can be an indication of poor hygiene and sanitation or inadequate heat treatment (FSANZ, 2009). *E. coli* is usually an indicator of fecal contamination therefore analysis for both blanched and unblanched products are recommended (FSANZ, 2009). Although blanching may diminish the level of contamination, recontamination can occur during subsequent handling (ICMSF, 1986). Processing of food products from underutilized crops will employ handling at various stages yet information on its effect on *E. coli* levels in processed crops and modified crackers, noodles and cookies is not documented.

Staphylococcus aureus always originates from food handlers or from utensils previously contaminated by humans (Wirtanen & Salo, 2005). Contamination sources are mainly hair, skin, mucous membrane, etc. Contamination can be through hands or fingers during food processing (Wirtanen & Salo, 2005). Contamination of food can occur as a result of poor hygienic practices in any part of the food chain (Wirtanen & Salo, 2005). Manufacturers have therefore become increasingly conscious of customer demands relating to concerns of food safety (Wirtanen & Salo, 2007). *S. aureus*, besides causing colour defects, is harmful to the end products (Wirtanen & Salo, 2007). Extensive food handling may result in increased levels and increased food safety risk (ICMSF, 1986). Processing of food products from underutilized crops will involve food handling, use of utensils and equipment. However, there is lack of information on the effect of processing and handling on *S. aureus* levels in processed crops and prepared food products.

The large and diverse group of microscopic food borne molds includes several hundred species. Their ability to attack many foods is due in large part to their relatively versatile environmental requirements like free oxygen, acid/alkaline from pH 2 to above pH 9, and broad temperature range (10-35°C), with a few species capable of growth below or above this range (Tournas, Stack, Mislivec, Koch, & Bandler, 2001). Moisture requirements of food borne molds are relatively low at a water activity (a_w) of 0.85 or less, (Tournas et al., 2001). Molds cause various degrees of deterioration and decomposition of foods and can invade and grow on any type of food at any time. They invade crops such as grains, nuts, beans, and fruits in fields before harvesting and during storage. They also grow on processed foods and food mixtures leading to the production of abnormal flavors and odors (Tournas et al., 2001). A food may appear mold-free but upon mycological examination, it is found to be contaminated (Tournas et al., 2001). Several food borne molds may be hazardous to human health because of their ability to produce toxic metabolites known as mycotoxins which are stable compounds that are not destroyed during food processing or home cooking. Although the generating organisms may not survive food preparation, preformed toxin may still be present. Certain food borne molds may also elicit allergic reactions or cause infections (Tournas et al., 2001). There is lack of documented information on mold levels in processed crops and modified crackers, noodles and cookies.

Grains harvested when in good condition and rapidly dried to a water activity level preventing microbial growth, and then stored under conditions such that the excessive ingress or movement of water is avoided, have virtually no microbiological risks. However, in practice, these conditions are not always met and mould growth may result (ICMSF, 1986). Many of the field and storage fungi found on grains and in flours derived from them are capable of producing mycotoxins in incorrectly dried or stored cereal products (ICMSF, 1986). Because underutilized crops were procured from open air market with unknown previous storage conditions, information of levels of molds in raw, processed crops and modified crackers, noodles and cookies is therefore paramount.

2.7.1. Moisture Content in Relation to Microbiological Contamination

Moisture is of great importance for the safe storage of cereals and their products regarding microorganisms (Nasir et al., 2003). The amount of agricultural waste is estimated to be about 30-35%, part of which is due to lack of relevant industries. One of the most important methods for food maintenance is drying or the dehydration process. In addition to the conservational effect on the product, drying reduces its weight and volume significantly (Abasi, Mousavi, Mohebi, & Kiani, 2009). Producing dried products is still common with traditional methods of food preservation but problems concerned with these methods involve long drying time and chance of microbial contamination due to moisture, which leads to decomposition of food products (Bondaruk, Błaszczak, & Markowski, 2007; Lewicki, 2006). However, temperature, nature of rehydration process, and type of nutrition impact the amount of moisture (Abdel-Kaber, 1994; Mayor & Sereho, 2004; Ruiz-López & García-Alvarado, 2007).

Water is a requirement for growth and metabolism of microbes which occur in food products; it occurs in food systems in both the free and bound states, free water supports microbiological growth (Labuza, 1979). The higher the moisture content of a food sample, the lower its shelf life because of its high susceptibility to bacterial attack (Onyema et al., 2014). Dried foods are capable of increasing in their shelf life if the environment is dry and remained constant and this result in the loss of moisture into the atmosphere (Ebabhamiegbebho, Igene, & Evivie, 2011). However, there is no documented information on the moisture content of crackers, noodles and cookies prepared from a combination of cassava with either simsim, fingermillet, or slenderleaf.

2.8. Sensory Analysis of Food Acceptability

Humans have used their senses to evaluate food for several thousands of years as so many phytotoxins and bacterial metabolites are bitter, sour or rancid (Clark, Drek, Drake, Bodyflelt, & Costello, 2009). For today's consumers, the primary consideration for selecting and eating a food commodity is the product's palatability or eating quality, and other quality parameters, such as nutrition and wholesomeness are secondary (Lawless & Heymann, 1998; Meiselman & Macfie, 1996). Individuals can often tell by sight, smell, taste and even touch, whether or not a given food item is good or bad, safe or toxic (Clark et al., 2009) . Human sensory evaluation is most critical in advancing and assuring higher quality products for consumers (Bodyfeld, Drake, & Rankin, 2008) whose goal is to understand the perceptual characteristics of the product (Clark et al., 2009). Humans possess and utilize five primary senses for perceiving stimuli: sight, hearing, touch, taste and smell while eyes are used to determine appearance and color, the nose for smell, the tongue for taste, skin for touch and the ear for any possible sound effect (Bodyfeld et al., 2008). Potential food buyers taste and evaluate a portion or a sample of product that represent the entire product (Clark et al., 2009). Food and beverage industry players should ensure that the quality of food is appealing and appetizing or more specifically that the eating quality attributes of; aroma, taste, aftertaste, tactual properties and appearance is acceptable to the consumer so that they crave for more (Singh-Ackbarali & Maharaj, 2014), in order to increase utilization through increased consumption. This is because food quality is that "which the consumer likes best" and the grades of quality are understood more by the degree of desirable attributes and absence of undesirable characteristics which are primarily detected by the consumer's sensory organs (Singh-Ackbarali & Maharaj, 2014). Part of the reason for underutilization of the nutritious crops is dislike of their tastes and appearance, therefore processing of food products from these crops and subjecting them to sensory evaluation is important. However, there is no documented information on the acceptability of crackers, noodles and cookies prepared using underutilized crops.

Sensory evaluation is a scientific discipline used to evoke, measure, analyze and interpret responses to products as perceived through the senses of sight, smell, touch, taste and hearing (Sidel & Stone, 1993). Sensory analysis uses human panelists sensory perception related to thresholds of determination of attributes and the variance in individual sensory response experimental design to measure the sensory characteristics and acceptability of food products (Singh-Ackbarali & Maharaj, 2014). Appearance serves as a primary deciding factor in purchasing decision and is composed of a number of characteristics including color, size and shape, surface texture, clarity and carbonation level (Zhao, Zhang, Hoon, Chandrashekar, & Erlenback, 2003). The appearance aspects of food are first noticed because they can be perceived quickly and non-invasively; followed by ortho-nasal perception of food odor or aroma (Wilkinson, Dijksterhuis, & Minekus, 2000). Colour is an important sensory attribute of any food because of its influence on acceptability, because the eye accepts the food before the mouth (Ubbor & Akobundu, 2009). Odor or aroma is attributable to the detection of the volatile compounds released from the food (Bodyfeld et al., 2008). The sense of smell is more defined than taste because an individual requires a relatively high concentration of tastant in order to perceive a taste solution (Young & Trask, 2002). Upon food ingestion, retro-nasal (in-nose) perception of the aroma continues, as well as food’s consistency and texture, taste, aroma and sound (Clark et al., 2009). The main reason of processing food products from a combination of underutilized crops is to increase their utilization besides increasing nutrient levels. However, acceptability of food products prepared from underutilized food crops is not documented.

Upon food ingestion the sensors in the mouth detect food texture and consistency. Components of texture include mechanical properties of hardness, cohesiveness, adhesiveness, denseness and chewiness; geometrical properties (smooth, gritty, grainy, chalky and lumpy); and moisture properties (juicy, oily or greasy) (Wilkinson et al., 2000). Flavor on the other hand is the impression perceived via the chemical senses from a product in the mouth and includes aromatics released from the food product once in the mouth, it is also the taste sensations (sweet, sour, salty, bitter and umami) released from a soluble substance in the mouth together with chemical feel factors in the mouth (astringency, cooling, metallic, “spicy heat”) (Zhao et al., 2003). Flavor is the sum of sensory impressions or sensations perceived when a food is in the mouth (Clark et al., 2009). Since there is no one instrument that can replicate or replace the human psychological and emotional response, the sensory evaluation component of any food study is essential and the importance of good experimental design cannot be overemphasized in sensory experiments (Lawless & Klein, 1989; Meiselman, Mastroianni, Buller, & Edwards, 1999). Information on sensory analysis of crackers, noodles and cookies prepared from underutilized crops to determine their acceptability is not documented.

2. 8.1. Sensory Analysis Methods

There are many types of sensory analysis methods, the most popular being difference tests, descriptive analysis and consumer acceptance testing (Lawless & Heymann, 1998). Difference tests include the triangle test, where the panel member attempts to detect which one of three samples is different from the other two, and duo-trio tests, where the panel member selects which one of two samples is different from the identified standard. Difference tests estimate the magnitude of sensory differences between samples, but one limitation of these tests is that the nature of the differences is not defined. It is usually a common practice to use a combination of difference tests and descriptive sensory analysis for problem-solving. Descriptive sensory analysis uses several techniques that seek to discriminate between a ranges of products based on their sensory characteristics and also to determine a quantitative description of the sensory differences that can be identified, not just the defects. No judgment of “good” or “bad” is made as in traditional quality judging methods because this is not the purpose of the evaluation. Here the panel is a powerful instrument that identifies and quantifies a product’s sensory properties (Singh-Ackbarali & Maharaj, 2014). Sensory profiling is as simple as having several assessors rating samples for a number of identified sensory attributes. For example, sweetness may be rated on a five-point scale, with a rating of one indicating not sweet and a rating of five meaning very sweet. External standards such as solutions of varying concentrations of sugar may help to define attributes and standardize the scale for each assessor. Developing and refining a vocabulary, or sensory lexicon, is an essential part of sensory profile work and is done in an objective manner. A flavour lexicon is a set of word descriptors that describe a product’s flavour. The panel generates its own list to describe the products, while a lexicon provides possible terms with references and definitions for clarification (Diary-Industry-Technical-Review, 2005). Descriptive sensory analysis of crackers, noodles and cookies prepared from underutilized crops has not been tested.

Consumer acceptance, preference, and hedonic (degree of liking) tests are used to determine the degree of consumer acceptance for a product. It is also considered to be consumer test hence it should be conducted using untrained consumer panels. Although panelists can be asked to indicate their degree of liking, preference or acceptance of a product directly, hedonic tests are often used to measure preference or acceptance indirectly. Category scales, ranking tests and the paired-comparison test can all be used to assess product acceptance. Acceptance of a food product usually indicates actual use of the product as either for purchase or/and eating (Singh-Ackbarali & Maharaj, 2014). Since product flavour quality drives consumer acceptance and demand, the ability to measure sensory attributes characteristic of products is necessary for production of products that meet consumer expectations. Information on whether crackers, noodles and cookies prepared from underutilized crops are acceptable has not been documented.

2.9. Gaps in Knowledge

Most researchers have concentrated on increasing crop production with very little effort to explore the nutritive value of cooked crops. Therefore nutritional value of underutilized food crops after cooking/processing is not documented.

Given that value addition along the value chain could help raise the status of AIVs (Abukutsa-Onyango, 2010a), there is lack of documented information on preparation of food products with extended shelf-life from underutilized crops. Efforts to use NUS in processing food products with extended shelf-life in Kenya have not been documented. Furthermore there is lack of documented information on preparation of food products using cassava as a base ingredient.

It is not documented whether food product preparation by combining micronutrient deficient cassava with micronutrient rich fingermillet, simsim or slenderleaf can result in products rich in iron and zinc. There is also lack of documented information on whether processed products can provide adequate recommended dietary intakes of iron and zinc for various population groups.

Food processing techniques that can reduce perishability ensure safety, increase acceptability and at the same time increase nutrient value of underutilized food crops have not been documented. Information on levels of microorganisms that could contaminate food from environment and human handling during processing products from underutilized crops is also not documented. It has not documented whether preparation of food products from a combination of cassava with other underutilized crops like slenderleaf, fingermillet and simsim can increase acceptability.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

This was an informal experimental study where food products (cookies, crackers and noodles) were prepared from selected underutilized crops. The raw crops and the food products were analyzed for iron and zinc levels; microbiological (total viable count, total coliform count, *E. coli*, *staphylococcus aureas*, and moulds) levels; moisture content; and food product acceptability (appearance, smell, taste, texture, and general acceptability) using Organoleptic tests. The crops bought from the open air market and used in this study were: finger millet (*Eleusine coracana*), groundnuts (*Arachis hypogaea*), simsim (*Sesamum orientale* L.), cassava (*Manihot esculenta*), and Slenderleaf *sp.* (*Crotalaria ochroleuca* and *Crotalaria brevidens*).

3.2. Materials and Methods

All the reagents, chemicals and standards used in this work were from Aldrich supplied by Kobia Limited Nairobi. The methods used in this work for the various determinations of the samples are standard methods and all chemicals used for the study were of analytical grade.

3.2.1. Source of the Selected Underutilized Crops

Selected underutilized food crops comprising of cassava roots, simsim seeds, fingermillet grains and slenderleaf vegetables were procured at Luanda market located at 34°36’ East and 0° North at an altitude of about 1530 meters above sea level. Same amount (500g) of each crop was procured from three different sellers at different locations of the market and mixed. The procured samples were cleaned and made free from dirt and foreign matter. This was followed by washing using distilled and deionized water after which processing was carried out for analysis and product modification. Processing of raw material involved the following activities; fresh vegetable leaves were separated from roots, washed under running double glass-distilled and deionized water. Vegetables were then blanched, drained completely and dried under shade (procedure described in section 3.2.4.4). All samples were then labeled as **A** (raw sample) and **B** (processed sample) (Appendix I). Processed samples were used to prepare food products 6, 7, and 8 (Appendix I) representing noodles, cookies and crackers respectively.

3.2.2. Sample Preparation for Elemental Analysis

Raw and processed samples comprising cassava, fingermillet, simsim and slenderleaf were dried at 105^0C in an oven for 24 hours before being crushed into powder using pestle and mortar. Dried and ground samples were then stored in clean and dried 100ml polypropylene bottles for further processing. Digestion of food samples were carried out as follows: Food samples of 0.1g were put in a beaker and 10ml of tri-acid mixture (concentrated HNO_3, $HClO_4$ and H_2SO_4) in the ratio 3:1:1 was added. The mixture was heated on a hot plate at 105^oC until white fumes were observed. The digested samples were then filtered using a Watmann filter paper No. 42 into a 50 mL volumetric flask and topped up to the mark with distilled water and two drops of HNO_3 added for preservation. Digested samples were transferred into plastic bottles for analysis using the Atomic Absorption Spectrophotometer (AAS) (Varian AA240) (Lindsay & Norvell, 1978).

3.2.3. AAS Determination of Iron and Zinc

Standards of each element (1000 parts per million) was prepared as follows: A zinc stock solution (1000ppm Zn^{2+}) was prepared by dissolving 4.697g of $Zn(NO_3)_2.6H_2O$ and made up to the mark in a 1000mL volumetric flask with distilled water. Working standards were prepared from it through serial dilution. Iron stock solution (1000ppm Fe^{2+}) was prepared by dissolving 5.054g of $Fe(NO_3)_2.7H_2O$ in distilled water and made up to the mark in 1000mL volumetric flask. Different standards were made from it through serial dilution. The spectrophotometer (Varian AA240) was operated under standard conditions using wavelength specified for each element (iron 248.3nm and zinc 213.9nm). The standard solution was aspirated into the AAS machine after placing the element light in place to generate light specific to the element. The machine then generated a standard curve of absorption against concentration. Sample filtrate was then aspirated into the machine which in turn gave the sample's (solution) absorption. The standard curve was used to obtain the sample's concentration by dropping a line to the x-axis (concentration) from the y-axis (absorption data) (AOAC, 2000). This was carried out three times and the average results obtained (Appendix II; Appendix III).

3.2.4. Crop Processing for Product Modification

Crop processing and product preparation were carried out at Maseno University Nutrition Department Foods Laboratory at 65% humidity and 23^{o}C.

3.2.4.1. Cassava (Manihot esculenta)

Dry cassava was procured and cleaned by picking dirt by hand then part of it taken for elemental analysis of raw dried samples. The remaining cassava was processed by washing under running double glass-distilled and deionized water to remove dirt then further dried in the open air under the sun. Dried cassava was milled into powder and sieved by a 0.5mm size sieve, then left in the open to release the toxic cyanide which is known to be volatile for product processing.

3.2.4.2. Fingermillet (Eleusine coracana)

Fingermillet was cleaned by removing dirt by hand then part of it taken for elemental analysis of the raw dried samples. For the processed samples, the remaining fingermillet was processed by washing under running double glass-distilled and deionized water to remove dirt then further dried in the open air under the sun. Dried fingermillet was further processed by grilling in the oven to initiate cooking and to produce a characteristic scent. The dried and partially cooked millet was then milled into flour and sieved by a 0.5mm size sieve ready for elemental analysis and product preparation.

3.2.4.3. Simsim (Sesamum orientale **L.***)*

Simsim was cleaned by removing dirt and foreign particles by hand then part of it taken for elemental analysis of the raw dried samples. For the processed samples, the remaining simsim was washed under running double glass-distilled and deionized water to remove dirt then further dried in the open air under the sun. Dried simism was processed further by grilling till golden brown to improve colour and flavour. This was followed by grinding then sieving by a 0.5mm size sieve in readiness for Fe and Zn analysis and product processing.

3.2.4.4. Slenderleaf sp. (Crotalaria ochroleuca and Crotalaria brevidens)

Slenderleaf was destalked and part of it dried under shade in readiness for elemental analysis. The remaining vegetables were washed under running double glass-distilled and deionized water to remove surface soil contamination. Vegetables were rinsed three times using deionized water to remove all the dirt. Each vegetable was processed separately (*ochroleuca* and *brevidens*). After washing, life processes were stopped by immediately blanching as specified below. The blanched vegetables were then dried under shade and ground using mortar and pestle and sieved by a 0.5mm size sieve.

The following procedure was followed in blanching the vegetables:

1. A large pan half-full of double glass-distilled water was brought to rapid boiling.
2. Clean raw vegetables were put in a wire basket and gently lowered in the boiling water.
3. Once the water began to boil again, vegetables were left in for two minutes.
4. Vegetable basket was removed from the boiling water and plunged into ice-cold water for two minutes to stop the cooking process (over-blanching results into loss of nutrients, flavor and texture).
5. The blanched vegetables were drained and dried under shade until completely dry.

3.2.5. Food Products Processing Procedures

Modified products' recipes of crackers, noodles and cookies adopted the use of cassava to prepare them according to inventions by Silmak, (1990). However, preparation procedures were according to recipes by Crocker, (1969). However, the ingredients were weighed after calculating the expected nutrient value of the end product to meet the recommended daily allowance for iron intake of 18mg/day of an adult female. This is also the highest level among healthy individuals. RDA for iron was selected for this calculation as opposed to zinc because according to literature, IDA poses higher public health concern in Kenya with prevalence rates of 56% among women and 89% in children under 6 years. These rates are even higher in the Lake Basin region at 72% in women and 91% in pre-school children. On the other hand, zinc deficiency prevalence rate in Kenya is at 50% in preschool children as well as in women. Cassava was used as a base ingredient in all recipes because the starch in cassava was expected to contribute to the binding properties of the processed food products. As a result cassava was assumed to contribute to the RDA for iron (18mg) in the ratio of 1:1 with any of the other selected crops in each food product. This was because cassava was used as a binding agent due to its binding properties of starch; and cassava was also used as a base ingredient.

3.2.5.1. Calculation of the Weights Ratio of Selected Crops as Product Ingredients

Iron RDA was used as a base for calculating weights of cassava, fingermillet, simsim and slenderleaf used in product processing. The results on iron levels in these crops after processing were used to calculate their quantities to be used in product processing. Selected crops were assumed to contribute to Fe RDA (18mg) in the ratio of 1:1 between cassava and each of the other selected crops for each product. Apart from selected crops whose weight was calculated, other ingredients were also weighed according to recipes by Crocker (1969). Ingredients were as per the original recipes but wheat flour was replaced by selected crops.

Cassava-Simsim Crackers

In these crackers, wheat flour was replaced by cassava and simsim flours.

Weights Ratio Calculation:

Grilled cassava recorded iron levels of (1.8mg/g), while grilled simsim recorded (1.8mg/g).

Iron RDA = 18mg, the assumed contribution ratio between cassava and simsim was 1:1

Therefore contribution to iron RDA by cassava and simsim was, 9mg: 9mg

i) 1g of cassava = 1.8mg

Therefore? = 9mg

$\frac{9x1}{1.8}$ = **5g** of cassava

ii) 1g of simsim =1.8mg

Therefore?= 9mg

$\frac{9x1}{1.8}$ = **5g** of simsim

The ingredients comprised 50g of cassava and 50g of simsim after multiplying the above results by 10 to increase the quantity to enable product preparation.

Cassava-Fingermillet Noodles

In these noodles wheat flour was replaced by cassava and fingermillet flours.

Weights Ratio Calculation:

Elemental results indicated that iron content of grilled fingermillet was (1.5mg/g).

Iron RDA = 18mg, expected contribution ratio between cassava and fingermillet was 1:1

Therefore contribution of iron by cassava and fingermillet was, 9mg: 9mg

i) 1g of cassava = 1.8mg
  Therefore ? = 9mg
  $\frac{9x1}{1.8}$ = **5g** of cassava

ii) 1g of fingermillet =1.5mg
  Therefore ? = 9mg
  $\frac{9x1}{1.5}$ = **6g** of fingermillet

The ingredients comprised 50g of cassava and 60g of fingermillet after multiplying the above results by 10 to increase the quantity to enable product processing.

Cassava-Slenderleaf Cookies

In these cookies, wheat flour was replaced by cassava flour, *Crotalaria ochroleuca*, and *Crotalaria brevidens* powders.

Weights Ratio Calculation:

Elemental results indicated that iron content of grilled cassava was (1.8mg/g), blanched *Crotalaria ochroleuca* (2.9mg/g), while blanched *Crotalaria brevidens* was (3.9mg/g).

Therefore contribution of the three crops was assumed to be;

Cassava:	*Crotalaria ochroleuca*:	*Crotalaria brevidens*
9mg:	4.5mg:	4.5mg

i) 1g of cassava = 1.8mg

Therefore ? = 9mg

$\frac{9x1}{1.8}$ = **5g** of cassava

ii) 1g of *Crotalaria ochroleuca* =2.9mg

Therefore? = 4.5mg

$\frac{4.5x1}{2.9}$ = **1.5g** of mild slenderleaf

ii) 1g of *Crotalaria brevidens* = 3.9mg

Therefore ? = 4.5mg

$\frac{4.5x1}{3.9}$ = **1.2g** of bitter slenderleaf

The ingredients comprised 50g cassava, 15g *Crotalaria ochroleuca* and 12g *Crotalaria brevidens* after multiplying above results by 10 to increase quantity to enable product processing.

Standard procedures employed to process the crackers, noodles and cookies were adapted and modified by replacing wheat flour with the selected food crops while all other ingredients were similar to the original recipes described by Crocker (1969). The modified food products were allowed to cool then packaged in small transparent polythene and immediately transported for elemental, microbiological, and acceptability analysis.

3.2.6. Micronutrient Analysis of the Modified Crackers, Noodles and Cookies.

3.2.6.1. Sample Preparation for Elemental Analysis

Modified crackers, noodles and cookies were dried at 105^0C in an oven for 24 hours before being crushed into powder using pestle and mortar. Dried and ground samples were then stored in clean and dried 100ml polypropylene bottles for further processing. Digestion of food samples were carried out as follows: Food samples of 0.1g were put in a beaker and 10ml of tri-acid mixture (concentrated HNO_3, $HClO_4$ and H_2SO_4) in the ratio 3:1:1 was added. The mixture was heated on a hot plate at 105°C until white fumes were observed. The digested samples were then filtered using a Watmann filter paper No. 42 into a 50 mL volumetric flask and topped up to the mark with distilled water and two drops of HNO_3 added for preservation. Digested samples were transferred into plastic bottles ready for analysis using the Atomic Absorption Spectrophotometer (AAS) (Varian AA240) (Lindsay & Norvell, 1978).

3.2.6.2. AAS Determination of Iron and Zinc

Standards of each element (1000 parts per million) was prepared as follows: A zinc stock solution (1000ppm Zn^{2+}) was prepared by dissolving 4.697g of $Zn(NO_3)_2.6H_2O$ and made up to the mark in a 1000mL volumetric flask with distilled water. Working standards were prepared from it through serial dilution. Iron stock solution (1000ppm Fe^{2+}) was prepared by dissolving 5.054g of $Fe\ (NO_3)_2.7H_2O$ in distilled water and made up to the mark in 1000mL volumetric flask. Different standards were made from it through serial dilution. The spectrophotometer (Varian AA240) was operated under standard conditions using wavelength specified for each element (iron 248.3nm and zinc 213.9nm). The standard solution was aspirated into the AAS machine after placing the element light in place to generate light specific to the element. The machine then drew a standard curve of absorption against concentration. Sample filtrate was then aspirated into the machine which in turn gave the sample's (solution) absorption. The standard curve was used to obtain the sample's concentration by dropping a line to the x-axis (concentration) from the y-axis (absorption data) (AOAC, 2000). This was carried out three times and the average results obtained (Appendix II; Appendix III).

3.2.7. Contribution of the Food Products to Dietary Reference Intakes

Using the dietary reference intake levels (IOM, 2001), the results of the nutrient levels of the products were converted to percentages of those levels in order to determine their contribution to various population sub-groups.

Example:

If a product contains **4mg** of iron per serving and the reference value for a certain group is **8mg/day**, the product's contribution to that reference value was calculated as follows:

$$8\text{ mg} = 100\% \quad \text{Therefore} \quad 4\text{mg} = \frac{4\text{x}100}{8} = 50\%$$

Therefore the product's serving contributed 50% of the recommended reference value of iron.

This was applied to zinc and all other population sub-groups using the already recommended daily intakes here in.

3.2.8. Microbiological Analysis

Raw and processed crops together with modified crackers, noodles and cookies were analyzed for microbiological loads comprising of; total plate count (37^0C), total coliform count (37^0C), *E. coli* count, and *S. aureas* count (37^0C). The characteristics of bacteria investigated and their identification depended on the basic requirements of the individual organisms. Nutrients in form of culture medium were provided for their growth. These culture media were distributed in test tubes, or flasks which were then done into agar or slant cultures of plate cultures. Plate cultures were used for colonies counting in total plate count and total coliform units (AOAC, 1999).

3.2.8.1. Sample Preparation for Microbiological Analysis

A sample unit of 10 g was weighed aseptically into a stomacher-bag and 90ml of sterile buffered peptone water (BPW) added and mixed for 45 seconds. The food homogenate was shaken and mixed in the 1st tube was done and 1.0ml containing 9ml of sterile BPW pipetted into it. Mixing was done by aspirating at least 6 times with a pipette. Dilution weighing 1ml was transferred to the second tube containing 9ml of BPW and mixed. This was repeated using 3rd, 4th and 5th tubes (Andrews & Hammack, 1998).

3.2.8.2. Total Viable Count

The pour plate approach was utilized to determine total viable count. From each of the diluted homogenate in the 1st, 2nd, 3rd, 4th, and 5th tubes, 1.0ml of the homogenate was pipetted into a separate appropriately marked duplicate Petri-dish. A 15ml of sterile plate count agar (kept at about 45°C ± 1°C in water bath) was poured into each Petri dish, within 15 minutes of the original time of dilution. The sample and agar medium were mixed thoroughly and allowed to solidify. Petri dishes were inverted and incubated at 37°C ± 1°C for 72 hrs ± 3 hrs. Colonies on dishes containing 30-300 colonies were counted and results recorded per dilution counted, then the average value taken as per (ISO.4833., 2003).

3.2.8.3. Escherichia coli

A solid medium method was employed. Violet red bile agar (VRBA) was prepared and cooled to 48°C before use. The sample was prepared, homogenized and decimally diluted, in order to obtain and plate isolated colonies. Two 1mL aliquots of each dilution were transferred to

Petri dishes. Ten mL VRBA tempered to 48°C was poured into plates, swirled to mix, and let to solidify. This was then overlaid with 5 mL VRBA and let to solidify in order to prevent surface growth and spreading of colonies. Solidified plates were inverted and incubated for 18-24 h at 35°C (APHA, 1992). Plates were examined under magnifying lenses and with illumination. Purple-red colonies that were 0.5mm or larger in diameter and surrounded by a zone of precipitated bile acids were counted. Plates had 25-250 colonies. To confirm that the colonies were coliforms, at least 10 representative colonies were picked and transferred each to a tube of BGLB broth. The tubes were incubated at 35°C. This was examined at 24 and 48h for gas production. If gas-positive BGLB tube showed a pellicle, Gram stain was performed to ensure that gas production was not due to Gram-positive, lactose-fermenting bacilli. The number of coliforms per gram was determined by multiplying the number of suspect colonies by percent confirmed in BGLB by dilution factor. *E. coli* colonies were distinguished among the coliform colonies on VRBA by adding 100 μg of 4-methyl-umbelliferyl-β-D-glucuronide (MUG) per mL in the VRBA overlay. After incubation, a bluish fluorescence around colonies under long wave UV light was observed (Andrews & Hammack, 1998).

3.2.8.4. Staphylococcus aureus

Samples were ground and diluted. Media was then prepared. The sample was produced into the media, and incubation done at 37^{0}C for 24-48 hours. After plating, growth of colonies was observed on the selection media. Yellowish colonies indicated presence of pathogenic strains while whitish colonies indicated presence of Non-pathogenic strains (AOAC, 1999).

3.2.8.5. Molds

Pour plating was utilized. Each of the dilutions measuring 1.0ml, was aseptically pipetted into a separated appropriately labeled sterile Petri dish. Sterile potato dextrose agar measuring 15ml, kept at 45°C ± 1°C in a water bath to which 10% solution of sterile tartaric acid had been added to adjust pH to 3.5 ± 0.1 was added, mixed and allowed to solidify. Petri dishes were inverted and incubated at 25°C ± 1°C in the dark for 5 days and colonies counted then recorded (Milivec, 1977).

3.2.8.6. Moisture Content Determination

Moisture content determination was done by oven drying method and results reported on dry weight basis. About 5g of ground sample each from raw, processed crops and the food products was individually weighed in a moisture dish and was transferred into a hot air oven, then dried until a constant weight was obtained at a temperature not exceeding 239° F (115° C).

The moisture content of the sample was calculated using the following equation:

$$\%W = \frac{A - B}{B} \times 100$$

Where: %W = Percentage of moisture in the sample,
A = Weight of wet sample (grams), and
B = Weight of dry sample (grams)

The moisture content was recorded to the nearest tenth of one hundred percent (AOAC, 1999).

3.2.9. Sensory Analysis of Modified Crackers, Noodles and Cookies

Tests using sensory panels were conducted under controlled conditions using appropriate experimental designs, test methods and statistical analyses. The procedures for selecting and training sensory assessors and details on how to establish the basic taste acuity were according to The International Standardization Organization (ISO). A properly designed experimental area and appropriate experimental design, test method and statistical analysis were incorporated in the study (ISO.8586., 2012).

The modified crackers, noodles and cookies were evaluated by a panel of 76 judges. Disproportionate stratified random sampling was used to select 19 judges from each strata; age strata (<18yrs & >18yrs) and sex strata (men & women) totaling to 76 judges/panelists (38 females and 38 males). Before each test session panelists were given orientation about the procedure of sensory evaluation, their health status was also considered during selection to avoid those who are pregnant, suffering from colds, and with allergies that affect their sensitivity for the products. Each taster received a maximum of three foods in the session, rated each food as he/she finished it, and rinsed his/her mouth with clean water between samples in order to remove all traces of the previous sample. The sample food products were presented in identical containers with different codes, at the same time. The judges/panelists ranked the products on the basis of sensory visual appearance, taste, smell, texture and overall acceptability using a five point hedonic scale where numbers from 1 to 5 were assigned to the scale's five categories. High numbers reflected preference, 5 was assigned the "like extremely"; 4 "like"; 3 "neither like nor dislike"; 2 "dislike"; and 1 "dislike extremely". Score distributions were also used to calculate means and percentages (Abebe, Stoecker, Hinds, & Gates, 2006; Ojinnaka, Anyanwu, & Ihemeje, 2013; Singh-Ackbarali & Maharaj, 2014).

3.2.10. Measurement of Data

The assessment of the acceptability of the modified products was performed using a self reporting questionnaire known as acceptability assessment grading chart (Appendix.IV.). The questionnaire assessed the Organoleptic testes for each participant with emphasis on four major parameters on appearance, taste, smell and texture using a grading chart for each food product. Descriptive terms were used to enable tasters think in terms of the descriptive adjectives instead of numerical scores. The adjectives were; completely undesirable, undesirable, neither desirable nor undesirable, desirable, and very desirable. In addition, these adjectives were given numbers in series from 1-5 respectively (Appendix I). The overall grading of the four parameters was concluded as the general acceptability of the product by the participant. Both the adjectives and their subsequent numerical codes were entered in excel sheets in separate columns and later exported to SPSS for analysis. The food products were later termed as either unacceptable or acceptable per category if the participant either recorded codes 1, 2 or 3 (completely undesirable, undesirable or, neither desirable nor undesirable) for unacceptable or either code 4 or 5 (desirable or very desirable) for acceptable respectively. The differences in the proportions of the participants who accepted the appearance, taste, smell and texture as well as the general acceptability of each food products across the study groups (boys, girls, males and females) was analyzed using the Fishers' exact Chi-square test with critical significance levels set at $P \leq 0.05$.

3.2.11. Data Analysis

Differences in nutrient levels between raw and processed products were determined using paired samples T-test. Differences in microbiological load between raw and processed crops was also determined using paired samples T-test while load in food products were compared with recommended levels using one sample T-test. The differences in age across the study groups (girls, boys, male and females) was analyzed by Kruskal-Wallis test for comparing differences in continuous data. A post-hoc Dunn's correction for multiple comparisons was performed following a significant Kruskal-Wallis tests. However, Chi square test was used to analyze the acceptability of the crackers, noodles and cookies across the study groups. Acceptable attributes referred to the score values of 4 and 5 on the grading chart while 1, 2 and 3 were for unaccepted attributes. All analyses were performed using IBM® SPSS® software version 20.0.0 with critical significance levels set at $p \leq 0.05$.

3.2.11. Assumptions of the Study

1. The ration of crop contribution to Fe RDI was in the ratio of 1:1 between cassava as the base crop and each of the other selected crops.
2. The modified crackers, noodles and cookies had 100% bioavailability of Fe and Zn.
3. The Fe and Zn content of the modified crackers, noodles and cookies mainly emanate from the underutilized crops and not other ingredients in the recipes.

CHAPTER FOUR: RESULTS

4.1. Introduction

Results of the study have been presented as follows: Iron and zinc levels of raw and processed selected underutilized crops; modified crackers, noodles and cookies; iron and zinc levels in the modified crackers, noodles and cookies; product contribution to recommended dietary intakes; microbiological load and moisture content of selected food crops and modified food products; and acceptability of the modified food products.

4.2. Iron and Zinc Levels in Raw and Processed Selected Underutilized Crops

Table 4.1 summarizes the effects of food processing on iron and zinc. Data present mean micronutrient concentration of raw and processed crops. Data were based on dry weight.

Table.4.1. Mean Fe and Zn Levels in Raw and Processed Underutilized Crops

Sample	**IRON (mg/g)**				**ZINC (mg/g)**			
	Raw	**Processed**	***Mean difference***	**P-value**	**Raw**	**Processed**	***Mean difference***	**P-value**
C. brevidens	4.0	3.9	0.1	0.156	2.8	2.7	0.1	**0.040***
C. ochroleuca	3.2	2.9	0.3	**0.007****	2.2	2.0	0.2	**0.001****
Cassava	2.0	1.8	0.2	**0.003****	1.5	1.3	0.2	**0.027***
Finger millet	1.6	1.5	0.1	0.314	1.1	0.8	0.3	**0.015***
Simsim	1.8	1.8	0	0.878	0.9	0.9	0	0.255

The SD was negligible, ranging between 0.001 – 0.005 and are therefore not presented.
*-Significant, **-Highly significant; *C. brevidens*- bitter slenderleaf; *C. ochroleuca*- mild slenderleaf.

4.2.1. Iron Levels in Raw and Processed Underutilized Crops

There were highly significant reductions in iron levels in *C. ochroleuca* and cassava (P=0.007 and P=0.003 respectively), with insignificant reductions in iron levels in *C. brevidens*, fingermillet and simsim (P=0.156, P=0.314 and P=0.878 respectively) (Table.4.1.).

Among the selected indigenous food crops, raw bitter slenderleaf (*Crotalaria brevidens*) recorded the highest mean iron content followed by raw mild slenderleaf (*Crotalaria ochroleuca*) while raw fingermillet recorded the least mean iron content. The mean difference between the highest mean level and the lowest mean level was 2.4mg/g (Table.4.1.)

Processed *Crotalaria brevidens* recorded highest mean Fe content followed by C*rotalaria ochroleuca* while processed fingermillet recorded the least mean content. The mean difference between the highest mean level and the lowest mean level in the processed crops was similar to the mean difference in raw crops at 2.4mg/g (Table.4.1.).

Generally processing by either grilling or blanching reduced iron content in all the selected underutilized food crops except simsim, however, the reduction amounts differed from crop to crop. Mild slenderleaf recorded the highest reduction, followed by cassava, while simsim recorded no reductions in mean iron content after processing (Table.4.1.).

4.2.2. Zinc Levels in Raw and Processed Underutilized Crops

Processing significantly reduced zinc levels in *C. brevidens*, cassava and fingermillet (P=0.040, P=0.027 and P=0.015 respectively). Reduction in zinc level after processing *C. ochroleuca* was highly significant (P=0.001) (Table.4.1).

Results indicate that, among the selected indigenous food crops, raw bitter slenderleaf (*Crotalaria brevidens*) recorded the highest mean zinc content of followed by raw mild slenderleaf (*Crotalaria ochroleuca*) while raw simsim recorded the least mean zinc content. Mean difference between the highest level and the lowest level was 1.9mg/g (Table.4.1.)

Similar to raw crops, processed *Crotalaria brevidens* recorded highest mean zinc content followed by C*rotalaria ochroleuca* while processed fingermillet recorded the least mean content. The mean difference between the highest mean level and the lowest mean level in the processed crops was similar to the mean difference in raw crops at 1.9mg/g (Table.4.1.).

Generally processing by either grilling or blanching reduced zinc content in all the selected underutilized food crops except simsim, however, the reduction amounts differed from crop to crop. Fingermillet recorded the highest reduction followed by cassava and mild slenderleaf, while simsim recorded no reductions in mean zinc content after processing (Table.4.1.).

4.3. Crackers, Noodles and Cookies Modified using Selected Underutilized Crops

Cassava was used as a base ingredient in the preparation of three food products because of presence of starch which was used as a binding agent. Cassava was mixed with one of the other selected crop for each product using preparation procedures described by Crocker (1969). Cassava was combined with slenderleaf, with fingermillet and with simsim to modify cookies, noodles, and crackers respectively. Below are modified products, recipes and characteristics.

4.3.1. Cassava-Simsim Crackers

Plate.4.1. Cassava-Simsim Crackers

Ingredients (15 servings)

50g	Cassava flour
50g	Simsim flour
10g	Sugar
10g	Margarine
14 ml	Water
1g	Baking powder

Net weight per serving = **8g**

Total net weight = **120g**

***Modification:** 100g wheat flour replaced by 50g cassava and 50g simsim flours

Preparation

The oven was preheated to 175^{o}C while a large baking sheet was greased. The flours were then whisked together the flours. Margarine was then beaten together with sugar until light; and the flour was then stirred in the mixed flours. Water was slowly poured in and stirred until dough was formed. On a well floured board, the dough was rolled to between ⅛ and ¼ inch thick. A knife was used to cut the dough into desired shapes, baked in the preheated oven for 10 minutes, then removed from oven (Crocker, 1969).

Characteristics

Golden brown in colour, dry but easy to break, soft and crunchy

4.3.2. Cassava-Fingermillet Noodles

Plate.4.2. Cassava-Fingermillet Noodles

Ingredients (10 servings)

50g	Cassava flour
60g	Fingermillet flour
1tsp	Salt
2	Eggs
10 ml	Water

Net weight per serving **= 10g**

Total net weight = **100g**

***Modification:** 100g wheat flour replaced by 50g cassava and 60g fingermillet flours.

Preparation

All dry ingredients were mixed in a bowl and a well made in the centre. Water was added a little at a time while mixing thoroughly after each addition form a soft dough. The dough was kneaded for about 10 minutes till smooth and elastic then rolled into ¼ inch thick rectangle and cut cross wise into ⅛ inch strips for narrow noodles and ¼ inch strips for wide noodles. The strips were shaken out and placed on a clean dry towel to dry for about 2hrs. When cooking, the raw dried noodles were immersed in boiling water for 10 minutes until they changed from light brown to dark brown as the starch granules gelatinized. Noodles may be used in pasta dish soups, stews, pasta and sauce dishes (Crocker, 1969).

<u>Characteristics</u>

Dark brown in colour, smooth to touch, dry but easy to break, soft after cooking

4.3.3. Cassava-Slenderleaf Cookies

Plate.4.3. Cassava-Slenderleaf Cookies

<u>Ingredients (16 servings)</u>

50g	Cassava flour
15g	C. *ochroleuca* powder
12g	*C. brevidens* powder
22g	Margarine
12g	Sugar
1 ¼ tbp	Salt
50 ml	Water

Net weight per serving = **6g**

Total net weight = **100g**

***Modification:** 75g wheat flour replaced by 50g cassava flour and 27g slenderleaf powder

<u>Preparation</u>

The oven was heated to 175°C, the flour, sugar and other dry ingredients were mixed thoroughly then margarine rubbed in to incorporate air. Mixing was continued as water was added till soft then pressed evenly onto bottom of a greased cookie sheet. This was baked for 10 minutes at 175°C. Cookies were then removed from oven and left to cool (Crocker, 1969).

<u>Characteristics</u>

Greenish in colour, dry but easy to break, soft.

4.4. Iron and Zinc Levels in the Modified Food Products

4.4.1. Iron Levels in the Modified Food Products

Table.4.2. Mean Iron Levels in the Modified Food Products

Products	**One serving size**	**Iron**		
		Concentration (mg/g)	**Total amount per serving (mg)**	**% RDA**
Crackers	8g	1.5	12	66
Noodles	10g	1.6	16	88
Cookies	6g	1.6	9.6	53

Among the prepared food products, cookies and noodles recorded the highest mean iron content while crackers recorded the least. There was a mean Fe content difference of 0.1mg/g between the highest level and the lowest level (Table 4.2.). One serving of cookies weighed 6g, while that of crackers weighed 8g, and that of noodles weighed 10g. As a result noodles recorded the highest amount of iron per serving followed by crackers while cookies recorded the least amount (Table 4.2.). Similarly, noodles recorded the highest iron percent RDA, followed by crackers, while cookies recorded the least %RDA for the age group of females aged ≥19 to ≤50 years which is the highest iron RDA among all population sub-groups. However, all the food products recorded more than 50% RDA per serving (Table 4.2).

4.4.2. Zinc Levels in the Modified Food Products

Table.4.3. Mean Zinc Levels in the Modified Food Products

Products	One serving size	ZINC		
		Concentration (mg/g)	Total amount per serving (mg)	% RDA
Crackers	8g	1.2	9.6	64
Noodles	10g	1.0	10	66
Cookies	6g	1.5	9	60

Cookies recorded the highest mean Zn content followed by crackers, while noodles recorded the least mean content. The difference between the highest mean Zn content and the least Zn content was 0.5mg/g (Table 4.3.). One serving of cookies weighed 6g that of crackers weighed 8g, while a serving of noodles weighed 10g. As a result, noodles recorded the highest mean Zn content per serving, followed by crackers, while cookies recorded the least mean Zn content (Table 4.3). Similarly, noodles recorded the highest %RDA for the age group of pregnant females aged 14 to 50 years which is the highest zinc RDA among all population sub-groups, followed by crackers, while cookies recorded the least %RDA. All products recorded 60%RDA and above per serving (Table 4.3).

4.5. Contribution of the Modified Food Products to Dietary Reference Intakes

4.5.1. Modified Products' Contribution to % Recommended Dietary Allowance for Iron.

Iron content of the modified products per serving were; Cookies (9.6mg/serving); Crackers (12mg/serving); and Noodles (16mg/serving).

Table.4.4. Product Contribution to Percentage Recommended Dietary Allowance for Iron.

Life Stage Group	*RDA Fe mg/d	% RDA/Serving		
	Set standards	Cookies	Crackers	Noodles
Infants				
6-12 months	**11**	87	109	145
Children				
1-3 years	**7**	137	171	229
4-8 years	**10**	96	120	160
Males				
9-13 years	**8**	120	150	200
14-18 years	**11**	87	109	145
19-30 years	**8**	120	150	200
31-50 years	**8**	120	150	200
51-70 years	**8**	120	150	200
>70 years	**8**	120	150	200
Females				
9-13 years	**8**	120	150	200
14-18 years	**15**	64	80	107
19-30 years	**18**	53	67	89
31-50 years	**18**	53	67	89
51-70 years	**8**	120	150	200
>70 years	**8**	120	150	200
Pregnancy				
14-18 years	**27**	36	44	59
19-30 years	**27**	36	44	59
31-50 years	**27**	36	44	59
Lactation				
14-18 years	**10**	96	120	160
19-30 years	**9**	107	133	178
31-50 years	**9**	107	133	178

*Source: (IOM, 2001) in bold (Table.2.1.)

Noodles contributed the highest percentage iron RDA for all the population sub-groups except pregnant women and women aged 19-50 years. This was followed by crackers which supplied over 100%RDA to various population sub-groups except for pregnant women and women aged 14-50 years old. Cookies contributed the least 100%RDA, some population sub-groups could receive 100% contribution except lactating women 14-18 years, pregnant women 14-50 years, females 14-50 years, males 14-18 years, children 4-8 years and infants 6-12 moths (Table.4.4).

4.5.2. Modified Products’ Contribution to Recommended Dietary Allowance for Zinc.

Zinc content of the modified products per serving were; Cookies (9mg/serving); Crackers (9.6mg/serving); and Noodles (10mg/serving).

Table.4.5. Product Contribution to Percentage Recommended Dietary Allowance for Zinc

Life Stage Group	*RDA Zn mg/d	% RDA/Serving		
	Set standards	Cookies	Crackers	Noodles
Infants				
6-12 months	**3**	300	320	333
Children				
1-3 years	**3**	300	320	333
4-8 years	**5**	180	192	200
Males				
9-13 years	**8**	113	120	125
14-18 years	**11**	82	87	91
19-30 years	**11**	82	87	91
31-50 years	**11**	82	87	91
51-70 years	**11**	82	87	91
>70 years	**11**	82	87	91
Females				
9-13 years	**8**	113	120	125
14-18 years	**9**	100	106	111
19-30 years	**8**	113	120	125
31-50 years	**8**	113	120	125
51-70 years	**8**	113	120	125
>70 years	**8**	113	120	125
Pregnancy				
14-18 years	**12**	75	80	83
19-30 years	**11**	82	87	91
31-50 years	**11**	82	87	91
Lactation				
14-18 years	**13**	69	74	77
19-30 years	**12**	75	80	83
31-50 years	**12**	75	80	83

*Source of reference values: (IOM, 2001) in bold

All the modified food products contribute over 100%RDA to all population sub-groups except lactation, pregnancy and males aged 14- >70 years, however the contribution to these groups from all the products were over 50%RDA (Table.4.5.).

4.6. Microbiological Load and Moisture Content in the Modified Food Products

4.6.1. Mean Microbiological Load in Raw and Processed Food Crops

Table.4.6. Mean Microbiological Load in Raw and Processed Underutilized Food Crops

Safety indicator	**Raw (n=5) Mean ±SD**	**Processed * (n=5) Mean ±SD**	***df (t)***	**P-*value***
Total Plate Count (37^0C) Cfu/gram	(1.49 ±1.98) x10^4	(0.7574 ±1.06) x10^4	4 (1.533)	0.200
Total Coliform Count MPN/g	21.20 ±24.45	16.40 ±16.15	4 (0.847)	0.445
S. aureas (37^0C) Cfu/g	5.40 ±5.13	1.60 ±1.14	4 (1.614)	0.182
Moulds Pda/g	(2.049 ±3.14) x10^6	(0.432 ±0.58) x10^6	4 (1.372)	0.242
E. coli	Absent	Absent	-	-

*Processing by either grilling or blanching where applicable according to the methodology here-in

Data presented are the microbiological levels in the selected crops both raw and processed. Generally raw and processed crops recorded high total plate count and mold levels above the recommended maximum consumption limits of <10^4Cfu/g and <10^5Pda/g respectively. However, total coliform count and *S. aureas* levels were within recommended maximum consumption limits of <100Mpn/g and <100Cfu/g respectively. Statistical analysis of data was conducted using the paired samples T-*test* to compare means between raw and processed crops. Results indicate that no *E. coli* was detected in the food samples. Generally, processing by either grilling or blanching reduced the microbial load in all the selected food crops. Mean total plate count (37^0C) reduced by 0.73 x 10^4Cfu/g at (P=0.200) after processing. Mean total coliform count reduced by 4.8Mpn/g at (P=0.445). *S. aureas* (37^0C) also reduced by 3.8Cfu/g at (P=0.182); moulds reduced by 1.617x10^6Pda/g at (P=0.242) after processing (Table.4.6).

4.6.2. Microbiological Load in Crops and Food Products Compared to Acceptable Levels

Table.4.7. Mean Microbiological Load in Crops & Food Products compared to Maximum Acceptable Levels

Products and Processed Crops	Total Plate Count (37^0C) Cfu/gram			Total Coliform Count Mpn/gram			*S. aureas* (37^0C) Cfu/gram			Moulds Pda/gram			*E.coli* Cfu/g
	Mean value*	RA cat.	Remark	*Mean value	RA cat.	Remark	Mean value*	RA cat.	Remark	Mean value*	RA cat.	Remark	
[a] *brevidens*	**7.3 x10^3**	$<10^4$	Good	**39**	<100	Satisfactory	**Nil**	$<10^2$	Good	**1.4x10^6**	$<10^5$	**Not Acceptable**	**Nil**
[a] *ochroleuca*	**3.2 x10^3**	$<10^4$	Good	**28**	<100	Satisfactory	**2**	$<10^2$	Good	**2.4x10^5**	$<10^5$	**Not Acceptable**	**Nil**
[b] **Cassava**	**2.6 x10^4**	$<10^4$	**Not Acceptable**	**7**	<100	Satisfactory	**1**	$<10^2$	Good	**5.1x10^5**	$<10^5$	**Not Acceptable**	**Nil**
[b] **Fingermillet**	**6.7 x10^2**	$<10^4$	Good	**3**	<100	Satisfactory	**2**	$<10^2$	Good	**Absent**	$<10^5$	Acceptable	**Nil**
[b] **Simsim**	**7.0 x10^2**	$<10^4$	Good	**5**	<100	Satisfactory	**3**	$<10^2$	Good	**9.2x10^3**	$<10^5$	Acceptable	**Nil**
Crackers	**2.8 x10^2**	$<10^4$	Good	**3**	<100	Satisfactory	**1**	$<10^2$	Good	**4.2 x10^3**	$<10^5$	Acceptable	**Nil**
Noodles	**3.8 x10^3**	$<10^4$	Good	**48**	<100	Satisfactory	**8**	$<10^2$	Good	**2.2 x10^3**	$<10^5$	Acceptable	**Nil**
Cookies	**5.4 x10^3**	$<10^4$	Good	**27**	<100	Satisfactory	**4**	$<10^2$	Good	**Nil**	$<10^5$	Acceptable	**Nil**

Data presented are mean for triplicate samples of microbiological indicators. Abbreviation: **Cat**- category; *- triplicate samples; [a]- blanched; [b]- grilled; **RA**- Recommended Maximum Allowance within the various foods.

Key

Plate Count: Good (>10^4Cfu/g); Acceptable (<10^5Cfu/g); Unsatisfactory (≥10^5Cfu/g).

Total Coliform: Satisfactory (<100Mpn/g); Cautionary (<1,000Mpn/g); Unsatisfactory (1,000 Mpn/g).

S. aureus: Satisfactory (<25Cfu/g); Good (<10^2Cfu/g); Acceptable ($10^2$to<10^3Cfu/g); Unsatisfactory (10^3 to <10^4Cfu/g); potentially hazardous (≥10^4Cfu/g).

E.coli: Good (<3Cfu/g); Acceptable (3 to <10^2Cfu/g); Satisfactory (3Mpn/g); Unsatisfactory (≥ 3Mpn/g).

Interpretation:

Good- Results are within expected microbiological levels for this type of product (lower range) and present no food safety concern.

Acceptable- Results are within expected microbiological levels for this type of product (upper range) and present no food safety concern.

Not acceptable/Unsatisfactory- Results are outside the expected microbiological levels for this type of product, present no food safety concern, but might indicate poor food handling practices.

Source: (MQGREF, 2009)

4.6.2.1. Total Plate Count (37^{o}C)

Grilled cassava recorded total plate count levels which are not acceptable according to the standards (<10^4Cfu/g) (MQGREF, 2009). Blanched *C. brevidens* recorded second highest, followed by blanched *C. ochroleuca*. Grilled simsim recorded the second least levels of total plate count while grilled fingermillet recorded least levels. However, all levels were within maximum acceptable levels of (<10^4Cfu/g) (MQGREF, 2009). Modified cookies recorded the highest levels among the three products, followed by noodles while crackers recorded the least level of total plate count, however, all the three products recorded levels within the safe range of (<10^4Cfu/g) (MQGREF, 2009) (Table.4.7.) thus safe for human consumption.

4.6.2.2. Total Coliform Count (MPN 37^{o}C)

Blanched *C. brevidens* recorded the highest total coliform count level, followed closely by blanched *C. ochroleuca* then grilled cassava recorded the third highest. On the other hand grilled simsim recorded the least level, and the second least was grilled fingermillet. However, all the processed crops recorded total coliform count levels below the recommended maximum allowance of (<100Mpn/g) (MQGREF, 2009). Noodles recorded the highest level of total coliform count, followed by cookies, while crackers recorded the least level of total coliform count. All levels recorded by modified crops were less than recommended maximum allowance of (<100Mpn/g) (MQGREF, 2009) (Table.4.7.) thus safe for human consumption.

4.6.2.3. Staphylococcus aureas (BPA 37^0C)

Grilled simsim recorded the highest level of *S. aureas* among the processed crops, fingermillet recorded the second least levels, while cassava recorded the least level. However, blanched *C. brevidens* was completely free of *S. aurea*. All the processed crops recorded levels within maximum recommended levels of ($<10^2$Cfu/g) (MQGREF, 2009). Results indicate minimal levels of *S. aureas* present in the modified food products. Crackers recorded the least level followed by cookies while noodles recorded the highest level of *S. aureas* among the products. However, the recorded levels were less than maximum recommended allowance of ($<10^2$Cfu/g) (MQGREF, 2009) (Table.4.7.) thus safe for human consumption.

4.6.2.4. Molds (PDA 35^oC)

Grilled cassava, blanched *C. brevidens,* and blanched *C. ochroleuca* recorded levels higher than recommended maximum allowance (10^5Pda/g) (MQGREF, 2009). However, grilled fingermillet recorded absence of molds while grilled simsim recorded acceptable levels. Cookies recorded absence of molds but noodles and crackers recorded levels below recommended maximum allowance of ($<10^5$Pda/g) (MQGREF, 2009) (Table.4.7.) thus safe for human consumption.

4.6.2.5. E. coli

Results indicate absence of *E. coli* in all the processed crops and modified food products (Table.4.7.) thus safe for human consumption.

4.6.3. Moisture Content in the Crops and Modified Food Products

4.6.3.1. Moisture Content in Raw and Processed Food Crops

Blanched vegetables recorded an increase in moisture content; however, grilling led to a reduction of moisture content of cassava, fingermillet and simsim (Fig.4.1.).

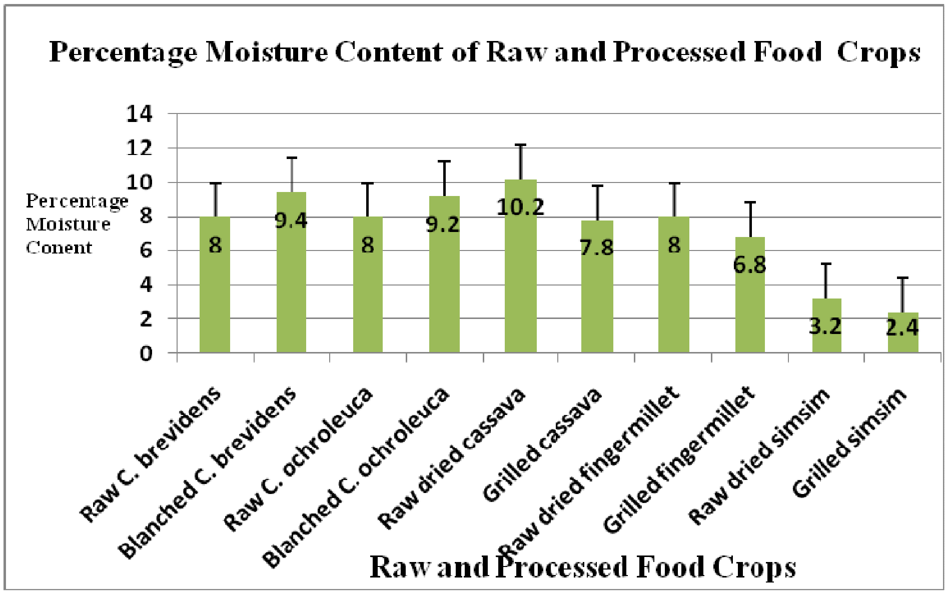

Fig.4.1. Effect of Processing on Moisture Content of Selected Crops

Among the raw crops, raw dried cassava recorded the highest moisture content, followed by *C. brevidens*, *C. ochroleuca* and fingermillet which recorded equal percentage moisture content while raw simsim recorded the least moisture content. Blanched *C. brevidens* recorded the highest moisture content, followed closely by blanched *C. ochroleuca*, grilled cassava recorded the third highest content, grilled fingermillet recorded the second least while grilled simsim recorded the least moisture content.

4.6.3.2. Moisture Content in the Modified Food Products

Noodles recorded the highest percentage moisture content among the three formulated products followed by cookies while crackers recorded the least percentage moisture content (Fig.4.2.).

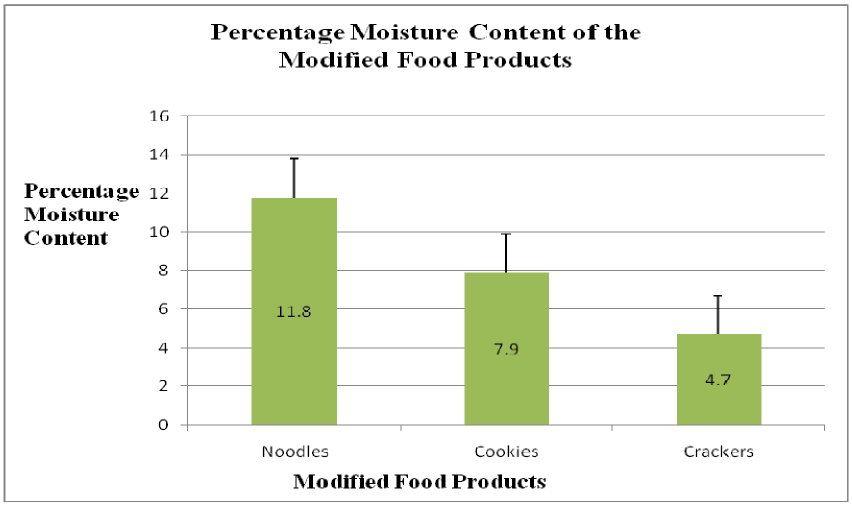

Fig.4.2. Percentage Moisture Content of Modified Food Products

4.7. Acceptability of the Modified Food Products through Sensory Evaluation

The modified crackers, noodles and cookies were subjected to sensory analysis to assess acceptability using organoleptic test. Products were regarded as acceptable if they had score values of 4 and 5 on the grading chart; on the other hand, 1, 2 and 3 scores were for unaccepted attributes therefore unacceptable products (Appendix. IV.).

4.7.1. Appearance Acceptability of the Modified Food Products

The appearance of crackers was most preferred by all the judges with no significant (P=0.538) differences in the liking of their appearance among judges. They were highly and equally liked by girls, women and boys, and least liked by men. Cookies followed closely in the liking of their appearance with no significant (P=0.909) differences among all the judges. However, they were highly liked by women and least liked by boys. Noodles appearance was the least liked among all the products with no significant (P=0.086) differences among the judges. However, the appearance of noodles was highly liked by girls and least liked by men (Table.4.8.).

Table 4.8: Modified Food Product Acceptability among Study Participants

Product Attribute	**CATEGORY**				***df* (χ^2)**	**P-value**
	Girls (n=19)	**Women (n=19)**	**Boys (n=19)**	**Men (n=19)**		
Cookie Acceptability, n (%)						
Appearance	14 (73.7)	15 (78.9)	13 (68.4)	14 (73.7)	3 (0.543)	0.909
Taste	16 (84.2)	12 (63.2)	16 (84.2)	14 (73.7)	3 (3.203)	0.361
Smell	12 (63.2)	12 (63.2)	17 (89.5)	15 (78.9)	3 (4.886)	0.180
Texture	15 (78.9)	16 (84.2)	15 (78.9)	17 (89.5)	3 (1.021)	0.796
Cracker Acceptability, n (%)						
Appearance	18 (94.7)	18 (94.7)	18 (94.7)	16 (84.2)	3 (2.171)	0.538
Taste	19 (100)	18 (94.7)	19 (100)	18 (94.7)	3 (2.054)	0.561
Smell	19 (100)	15 (78.9)	15 (78.9)	18 (94.7)	3 (6.428)	0.093
Texture	16 (84.2)	15 (78.9)	14 (73.7)	17 (89.5)	3 (1.751)	0.626
Noodle Acceptability, n (%)						
Appearance	15 (78.9)	14 (73.7)	12 (63.2)	8 (42.1)	3 (6.606)	0.086
Taste	6 (31.6)	4 (21.1)	8 (42.1)	10 (52.6)	3 (4.524)	0.210
Smell	10 (52.6)	7 (36.8)	6 (31.6)	14 (73.7)	3 (8.164)	**0.043**[*]
Texture	16 (84.2)	18 (94.7)	17 (89.5)	17 (89.5)	3 (1.118)	0.773
General Acceptability, n (%)						
Cookies	16 (84.2)	14 (73.7)	17 (89.5)	17 (89.5)	3 (2.375)	0.498
Crackers	19 (100)	19 100)	19 (100)	18 (94.7)	3 (3.040)	0.385
Noodles	15 (78.9)	11 (57.9)	15 (78.9)	18 (94.7)	3 (7.501)	0.058

[†]*% Acceptability* – calculated from a score of either 4 or 5 on a five- point hedonic scale, *****- Significant

4.7.2. Taste Acceptability of the Modified Food Products

The taste of crackers was the most liked with no significant difference among all the judges (P=0.561), however, they were most liked by girls and boys and least liked by women and men.

This was followed closely by cookies whose liking for taste was higher among boys and girls and least liked by women while men were the second least. There was no significant (P=0.361) difference in the liking of the taste of cookies among all judges. The taste of noodles was least liked by all the judges with no significant (P=0.210) difference among them. Men highly liked them followed by boys, then girls while women least liked the taste of noodles (Table.4.8.).

4.7.3. Smell Acceptability of the Modified Food Products

The smell of crackers was the most liked among all the judges. Girls were the highest, followed closely by men, then women and boys who equally least liked the smell. However, there was no significant (P=0.093) difference in the liking of smell of crackers among all judges. Acceptability of smell in cookies was second highest among all the products with no significant (P=0.180) difference among all the judges. However, boys recorded a higher percentage of liking followed closely by men while women and girls least liked the smell of cookies. The smell of noodles was the least liked among all the products with significant (P=0.043) differences in smell acceptability among all judges. Men highly liked the smell of noodles, followed by girls, then by women, while boys least liked the smell of noodles (Table.4.8.).

4.7.4. Texture Acceptability of the Modified Food Products

Despite noodles being the least liked in all the tested attributes, their texture was the most liked among all the products and among all the judges with no significant (P=0.773) differences among judges. The liking of the noodles texture was higher among women, followed by men and boys who liked the texture equally while girls least liked the texture of noodles. The texture of crackers was highly liked by men, followed by girls, then women and finally boys who least liked them. However, there was no significant (P=626) difference in the liking of the texture of crackers among all judges. Cookies on the other hand recorded highest texture liking among men, followed by boys and women who liked them equally, while girls least liked the texture of cookies. There were no significant (P=0.796) differences among all judges (Table.4.8.).

4.7.5. General Acceptability of the Modified Food Products

Generally, crackers were highly liked by 100% of girls, women and boys while over 94% of men generally liked crackers. However there was no significant (P=0.385) difference in the general liking of crackers by all judges. Cookies were generally liked by all judges and there were no significant (P=0.498) differences in general liking for cookies among all judges. Generally, men highly liked cookies compared to women. However, over 70% of all judges generally liked all the parameters for cookies (Table.4.8.). Noodles were highly liked among men and least liked among women. However, there were no significant (P=0.058) differences in acceptability among all judges. Generally all the three food products were highly liked by all judges (Table.4.8.).

CHAPTER FIVE: DISCUSSION

5.1. Introduction

Results of the study have been discussed as follows: iron and zinc levels of raw and processed selected underutilized crops; processing of food products from selected crops; iron & zinc levels in the food products; contribution of modified food products to dietary reference intakes; microbiological load and moisture content of crops and food products; and acceptability of the modified food products.

5.2. Iron and Zinc Levels in Raw and Processed Selected Underutilized Crops

5.2.1. Iron Levels in Raw and Processed Underutilized Crops

Raw and processed *C. brevidens* recorded higher iron content followed by raw *C. ochroleuca*, however, findings are within the reported ranges of between 0.08mg/g to 38mg/g (Grubben & Denton, 2004; Habwe, 2008; Maundu, Ngugi, & Kabuye, 1999; Sehmi, 1993). Raw cassava recorded iron levels higher than findings by other researchers whose levels ranged between 0.008mg/g and 0.147mg/g (English & Lewis, 1991; Grubben & Denton, 2004; Sehmi, 1993). Fingermillet recorded iron levels within reported ranges of 0.039mg/g to 17.1mg/g (Maundu et al., 1999; Sehmi, 1993; Shobana et al., 2013). Simsim on the other hand recorded levels within reported ranges of 0.018mg/g and 17.1mg/g (English & Lewis, 1991; Lukmwaji et al., 2008; Maundu et al., 1999; Sehmi, 1993). This indicates that selected underutilized crops are good sources of iron. Differences in iron contents in the selected crops could be due to differences in crop sources, and type; which results to differences in iron levels (Weinbeger & Msuya, 2004). Selected crops were procured from open air market and therefore the differences in iron levels witnessed in this study. Therefore nutrient levels recorded cannot be generalized for all underutilized crops as this is dependent on the geographical origin of the crop, and thus the richer the soils, the higher the iron levels of crops originating from those soils. Therefore more efforts should be geared towards enriching agricultural soils in order to harvest crops rich in iron.

Blanching reduced iron levels insignificantly (P=0.156) in *C. brevidens* and significantly (P=0.007) in *C. ochroleuca*. *C. brevidens* had a mean reduction of 0.1gm/g while *C. ochroleuca* had a mean reduction of 0.3mg/g. there should be no concern for these reductions as they appear to be negligible. The reductions in iron levels after processing could be due to leaching into the water used to blanch the vegetables, as it involves interaction of leaves with hot water which rupture the cell wall to release soluble nutrients (Kumar, Venkataraman, Jaya, & Krishnamurthy, 1978). Therefore soluble iron may have leached out in the blanching water while the differences in reduction may have been due to higher rate of leaching in the case of blanched *C. ochroleuca* than in the case of blanched *C. brevidens*. This indicates that processing could possibly have different effects on different crop species.

Highly significant (P=0.003) reduction in iron content in cassava after grilling concur with the fact that processing results into significant iron losses in cassava roots (Ebuehi, 2005). Although highly significant, the reduction was by 0.2mg/g which could have been lost during processing when cassava was washed and rinsed with deionized water to remove dust and dirt. However, processing has also been implicated in reduction of iron in plantain pulp (Ahenkora, Kyei, Marfo, & Banful, 1996). Processing reduced iron content in all the selected underutilized food crops but the reductions differed from crop to crop. The reduced levels could have come from environmental contamination or due to leaching as a result of washing crops in deionized water and blanching the vegetables. Mild slenderleaf and cassava recorded significant reductions in iron levels while bitter slenderleaf, fingermillet and simsim recorded insignificant reductions. However, (Achidi, Ajayi, Maziya-Dixon, & Bokanga, 2008) noted an increase in iron content in ground and cooked crops compared to the non-processed ones.

Although processing reduced iron levels in crops, the mean reduction differed from one crop to another. A study conducted by (Yang & Keding, 2009) also revealed that nutrient values of crops are affected differently by processing and cooking methods. This could also be due to the fact that for all types of food preparations employing heat, the time temperature relationship is important but the impact varies with the different cooking methods and product types (Adams & Erdwan, 1998). The potential contribution of plant foods to micronutrient status depends upon the retention of the nutrients after processing and cooking (Yang & Keding, 2009). Although there were significant ($P \leq 0.05$) reductions in iron levels after processing, the actual reductions were minimal ≥0.3mg/g. This therefore implies that effect of processing on iron levels differ from crop to crop and kind of processing employed.

All the selected underutilized crops both raw and processed recorded mean iron levels higher than levels reported in all purpose wheat flour 0.012mg/g-0.09mg/g which has traditionally been used in food product processing (Ardent, 2014; English & Lewis, 1991; Sehmi, 1993; Shobana et al., 2013). With the assumption of 100% iron bioavailability, all selected crops are better sources of iron than all purpose wheat flour which has traditionally been used in processing food products. If consumed, underutilized food crops could contribute to increased dietary iron intake and in the long run contribute to minimizing iron deficiencies in at risk populations. Cassava, fingermillet, simsim and slenderleaf should therefore be promoted in order to increase their consumption in order to increase dietary iron intake.

5.2.2. Zinc Levels in Raw and Processed Underutilized Crops

All the selected underutilized crops recorded presence of zinc, this concurs with the fact that grain and plant-based foods are good sources of zinc (IOM, 2001). Processed fingermillet recorded the least zinc levels among all the selected food crops, however, the recorded levels were within reported ranges (0.023mg/g- 17.1mg/g) (Maundu et al., 1999; Shobana et al., 2013). Cassava recorded minimal reduction in zinc level (0.2mg/g), finding which concur with (Abrams et al., 1992) who reported small reductions in zinc levels when cassava is processed. Average zinc level in cassava of is 1.4mg/g are almost similar to the levels 1.8mg/g reported by (Grubben & Denton, 2004). Simsim seeds recorded zinc levels within reported ranges of 0.05-8.1mg/g (English & Lewis, 1991; Lukmwaji et al., 2008; Maundu et al., 1999). Similar to iron levels in simsim there was no effect on zinc levels in simsim after processing. *C. brevidens* and *C. ochroleuca* recorded minimal reductions in zinc levels after processing at 0.1mg/g and 0.2mg/g respectively. These reductions may be due to the fact that blanching involves interaction of leaves with hot water which may rupture the cell wall (Kumar et al., 1978) and therefore soluble zinc may have leached out in the blanching water while the differences in reduction may have been due to higher rate of zinc leaching in *C. ochroleuca* than in *C. brevidens*.

This study reveals that blanching lead to significant ($P<0.05$) reductions in zinc content of slenderleaf vegetables; however the mean reductions were minimal. However, results by

(Adeniji & Tenkouano, 2008) indicated that blanching had no significant effect on zinc contents in different whole flour made from some plantain and banana hybrids pulp and peel mixture. This supports negligible losses of zinc in processing observed in this study. On the contrary, (Shashi & Salil, 1995) noted that blanching and cooking resulted in significant improvement in zinc levels because of increased extractability if zinc. Shashi and Salil, (1995) blanched spinach *(Spinach oleracia)* and amaranth *(Amaranthus tricolor)* leaves in distilled water. This was due to a significant ($P < 0.05$) increase in HCl-extractability of zinc in leaves blanched for 15 minutes.

Although zinc bioavailability and extractability was not assessed in this study, blanching resulted in significant ($P=0.04$) and ($P=0.01$) reductions in zinc levels in *Crotalaria brevidens* and *Crotalaria ochroleuca* respectively. Therefore effects of blanching on zinc levels of vegetables may be different from on vegetable/leaves to another. Generally processing lead to significant ($P \leq 0.04$) decrease in zinc levels in the processed crops, this concurs with (Achidi et al., 2008; Ahenkora et al., 1996) who reported small reduction of 0.63mg/100g in zinc levels when cassava leaves are ground and cooked. The reductions occurred at different levels except simsim which had reduction; this could be due to the fact that conditions of plants, food handling methods like processing and cooking affect their zinc content (IOM, 2001). Therefore zinc content of crops is determined by type of crop and processing method used.

All selected food crops recorded zinc levels higher than levels in all purpose wheat flour. Even the least zinc level (0.8mg/g) among the selected food crops is higher than that of all purpose wheat flour whose level ranges between 0.04mg/g to 0.7mg/g (Ardent, 2014; English & Lewis, 1991; Shobana et al., 2013). With the assumption of 100% zinc bioavailability, all selected crops are better sources of zinc than all purpose wheat flour which has traditionally been used in processing food products. If consumed, underutilized food crops could contribute to increased dietary zinc intake and in the long run contribute to minimizing zinc deficiencies in at risk populations. Cassava, fingermillet, simsim and slenderleaf should therefore be promoted in order to increase their consumption in order to increase dietary zinc intake.

5.3. Food Products Modified using Selected Underutilized Crops

5.3.1. Cassava-Slenderleaf Cookies

Although wheat flour has traditionally been used to prepare cookies, there has been increased need to use other indigenous crops in cookie preparation. African breadfruit was in the past used in combination with wheat flour to prepare cookies (Ojinnaka et al., 2013). Composite sorghum, (yellow Kaura variety)-maize (white flint variety)-wheat flour cookies have been formulated and found to be acceptable in Nigeria (Arogba, 1999). On the other hand (Slimak, 1990) invented the use of cassava alone to process cassava cookies. This study omitted wheat flour in cookie processing and did not use cassava alone to prepare cookies, instead slenderleaf and cassava flour were combined and used to process cookies. This brings forth a new idea of using a combination of cassava roots flour and slenderleaf vegetables to prepare cookies (cassava-slenderleaf cookies) besides wheat which has traditionally been used to prepare cookies.

5.3.2. Cassava-Fingermillet Noodles

Noodles are made from simple ingredients (wheat flour, water and salt) and lack essential minerals as they are lost during wheat flour refinement (Choo & Aziz, 2010; Onyema et al., 2014). Noodles nutritional value and functional properties have been improved by preparing them using various composite flours from natural sources like cereal starches (Huang & Lai, 2010), banana flour and β-glucan (Choo & Aziz, 2010), purple yam flour (Li, Huang, Yang, & Wang, 2012), protein from lupine (Mahmoud, Nassef, & Basuny, 2012), green tea powder (M. Li et al., 2012), fingermillet (Kulkarni, Desai, Ranveer, & Sahoo, 2012), broccoli powder (Silva, Sagis, Van-der-Linder, & Scholten, 2013), konjac glucomannan (Zhou et al., 2013), sweet potato, colocasia and water chestnut flours (Yadav, Yadav, Kumari, & Khatkar, 2014).

In addition to these traditional foods, fingermillet is also processed to prepare popped, malted and fermented products like papads, noodles, soups (Shobana et al., 2013). Noodles can also be made from, rice, buckwheat, and starches derived from potato, sweet potato, and pulses, with corn starch as binding agent (Tan, Li, & Tan, 2009; Yalchin & Basmani, 2008). Additionally (Slimak, 1990), invented the use of cassava alone to prepare noodles. However, in this project noodles were prepared from a combination of fingermillet with cassava thus omitting wheat which is the traditionally known ingredient in processing of noodles. This could break the monotony of using wheat flour in noodle processing and also help promote the use of other underutilized crops like fingermillet in food product processing. This study has revealed the possibility to process noodles from a combination of fingermillet with cassava.

5.3.3. Cassava-Simsim Crackers

An invention by (Slimak, 1990), indicated the possibility of using cassava alone to prepare crackers. However, banana pulp, pumpkin pulp, mango pulp and mango peel flour have been used to process crackers (Aziah & Komathi, 2009). Results of this study prove that a combination of cassava and simsim can also be used to process crackers, thus including cassava and simsim among crops that can produce crackers.

5.4. Iron and Zinc Levels in the Modified Food Products

5.4.1. Iron Levels in the Modified Food Products

Among the three modified food products, noodles and cookies had the highest iron level per gram followed closely by crackers. However noodles had the highest iron level per serving followed by crackers while cookies provided the least. The modified food products had iron levels higher than levels in various fancy cakes (0.015mg/g) (Sehmi, 1993) prepared using home baking wheat flour. Similarly noodles had levels higher than levels in noodles prepared using home baking wheat flour (0.01mg/g)) (Sehmi, 1993). Modified cookies had higher iron levels compared to those prepared using home baking wheat flour (0.005-0.09mg/g) (English & Lewis, 1991; Lukmwaji et al., 2008). The modified products contribute at least 1.485mg/g more than fancy cakes, 1.49mg/g more than noodles prepared using wheat flour, and 1.41mg/g more than cookies made form wheat. This indicates that modified crackers, noodles and cookies are more nutritious with regards to iron compared to products processed from wheat flour. If consumed these products could contribute to increase iron intake thus help minimize dietary iron deficiencies in at risk populations.

All the three modified food products contributed more than 50%RDA. Given that the recommended daily allowance for iron is 18mg (Johnson, Smith, & Edmonds, 1998), each serving of the modified food products contributes more than half of it. The modified products had iron levels within ranges recorded by dietary supplements, infant formulas, and ready-to-eat breakfast cereals (0.22–65)mg/serving (Johnson et al., 1998). This therefore indicates that modified crackers, noodles and cookies are comparable to nutritional supplements. They are therefore good sources of iron and could contribute significantly to iron intakes thus contribute toward minimizing iron deficiencies in populations. Although whole-grain bakery products and cereals are valuable sources of dietary trace elements, the presence of phytate, could decreases mineral bioavailability due to its chelating properties (Frontela et al., 2011). In this study iron bioavailability was assumed to be 100%, however, more bioavailability studies in these food products should be carried out in order to determine the amount absorbed from these products.

5.4.2. Zinc Levels in the Modified Food Products

Among the three modified food products, cookies had the highest zinc level per gram, followed by crackers while noodles had the least zinc levels. However, noodles provided the highest zinc level per serving, followed by crackers while cookies provided the least level per serving. The modified cookies and crackers had zinc levels higher than those in cookies and crackers prepared using home backing wheat flour (0.019-0.09mg/g) and (0.018mg/g) respectively (English & Lewis, 1991; Lukmanji & Hertzmark, 2008). The modified products contribute at least 0.91mg/g more than crackers and 0.982mg/g more than cookies prepared using wheat flour. This indicates that modified crackers, noodles and cookies are rich in higher zinc levels compared to home backing wheat flour which has traditionally been used to prepare these products. If consumed these products could contribute to increase zinc intake thus help minimize dietary zinc deficiencies in at risk populations.

Given that zinc RDA is 15mg (Johnson et al., 1998), all the three modified food products contributed more than 60%RDA per serving. Therefore all the three modified food products are good sources of zinc, this resonates with the fact that many grain and plant-based foods are good sources of zinc (IOM, 2001). The modified products had zinc levels within ranges recorded by dietary supplements, infant formulas, and ready-to-eat breakfast cereals (0.085–15)mg/serving (Johnson et al., 1998). This therefore indicates that the modified crackers, noodles and cookies could replace the supplements, infant formulas and other ready-to-eat products. If consumed, the modified products could contribute significantly to zinc intakes thus contribute toward minimizing zinc deficiencies in populations.

Whole-grain bakery products and cereals are valuable sources of dietary trace elements but the presence of phytate, could decreases mineral bioavailability due to its chelating properties (Frontela et al., 2011). In this study zinc bioavailability was assumed to be 100%, however, more bioavailability studies in the food products should be carried out in order to determine the amount absorbed from these products.

5.5. Contribution of the Modified Food Products to Dietary Reference Intakes

5.5.1. Contribution to Percentage Dietary Reference Intakes of Fe per serving

The modified crackers, noodles and cookies contributed more than 100%RDA to most population sub-groups except pregnancy and a few age-groups. Infants (6-12months), children (4-8years), males (14-18years), lactation (14-18years) received a contribution of less than 100%RDA from cookies (IOM, 2001). These groups therefore should consume more servings of cookies in order to get more or include other sources of iron in order to meet the needs of almost all (98%) individuals in these groups. The pregnancy group received less than 100%RDA contribution from all the modified food products, while females (14 -50years) received a contribution of less than 100%RDA from all the food products except noodles which contributed slightly over 100%RDA to females aged 14-18 years within the category of 14-50 years. This is because of high iron losses due to menstrual blood losses in women of child-bearing age, and to maintain iron balance, the sum of these losses plus requirements for growth in adolescents and during pregnancy must be provided by the diet (Hurrell & EglI, 2010).

Research indicates high iron contribution to RDA as high as 575%RDA for adult males and 225%RDA for adult females from cassava four (Adeniji, Sanni, Barimalaa, & Hart, 2007). Based on iron RDI of 18mg, research indicate that some products contribute between 6% -100% RDI (Johnson et al., 1998), these products therefore contribute to iron RDA within reported ranges. All females during pregnancy and majority of females in the age bracket of 14-50 years received the least contribution of dietary reference intakes from the formulated food products due to the fact that these are the periods of high iron requirements both for growth and development of individuals and growing fetus. There are periods when majority of women loss a lot of blood during menstruation and child delivery. However, increased preparation and consumption of modified crackers, noodles and cookies may contribute to control iron deficiency prevailing in Kenya and Africa at large.

5.5.2. Contribution to Percentage Dietary Reference Intakes of Zn per serving

All other population sub-groups received over 100%RDA contribution from all the modified food products except pregnant women, lactating women, and men aged between 14 to over

70years whose groups received a contribution of less than 100%RDA from all the three modified food products (IOM, 2001). This is due to the high needs of zinc for milk production, growth and development of fetus and sex hormones in men. Contribution of more than 100%RDA from the modified food products may not cause nutrient overload because zinc bioavailability from plant sources is known to be low (IOM, 2001). However, 250g of cassava flour contributes to 19.3%RDA for adult males and 26.6%RDA for adult males (Adeniji et al., 2007). Based on zinc RDI of 15mg, some products contribute between 8% -100% RDI (Johnson et al., 1998), these products contribute within reported ranges. Therefore increased preparation and consumption of modified crackers, noodles and cookies may contribute to control zinc deficiency prevailing in Kenya and Africa at large.

5.6. Microbiological Load and Moisture Content in the Modified Food Products

5.6.1. Mean Microbiological Load in Raw and Processed Food Crops

Microbiological spoilage is often the major factors limiting the shelf life of bakery products, it causes economic loss for both manufacturers and consumers (Saranraj & Geetha, 2012). Results indicated that processing reduced the microbiological load in all the selected food crops but the reductions were not significant ($P \geq 0.182$). More effort should be put to enhance sanitary conditions of the working environment, equipment and personnel in order to minimize levels of microbiological load.

5.6.2. Microbiological Load in Crops and Food Products Compared to Acceptable Levels

5.6.2.1. Total Plate Count (37^{o}C)

Total plate count (37^{0}C) recorded insignificant (P=0.200) reductions in raw samples upon processing, however, all the recorded levels were within recommended maximum limit (<10^{4}cfu/g) (MQGREF, 2009), except cassava which recorded more than acceptable maximum limit. Total plate count levels in all the modified food products were within the recommended maximum limit of (<10^{4}cfu/g) in the category of baked food products (MGREF, 2007). This indicates that working environment, equipment and personnel observed high hygiene standards Therefore with regards to total plate count (37^{o}C), all three modified food products were safe for consumption. However, more effort should be made to improve the hygienic standards during crop processing and handling in order to increase product safety with regards to total plate count.

5.6.2.2. Total Coliform Count (MPN 37^{o}C)

Processed insignificantly (P=0.445) reduced total coliform count in selected underutilized crops. The processed crops recorded Total coliform count levels below recommended maximum limit (<100mpn/g) (MGREF, 2007). Some coliforms are found naturally in the environment (Caplenas & Kanarek, 1984) and detection of coliform is a general indicator of sanitary conditions in the food processing environment (American-Public-Health-Association, 1992). Total coliform count levels in cookies, crackers and noodles were within the acceptable maximum consumption limit of (<100mpn/g) (MGREF, 2007). Detection levels ranging between 4 - 75 MPN are not harmful to human consumption as some aid in digestion of plant materials (https://www.securewebexchange.com/watertestinglabs.com/infosheets.html). The levels detected in the modified products (<100mpn/g) are not harmful to human consumption (MGREF, 2007). However, in certain cases a small percentage of fecal coliform bacteria may cause intestinal distress, nausea, vomiting, and even death in very old, very young and the immune-suppressed individuals (MGREF, 2007). The detected coliform in this study could be from processing equipment, working environment and/or humans involved in processing. The three modified food products were safe for human consumption based on total coliform count (MPN 37°C). However, more effort is needed to improve the working environment, equipment and humans involved in food processing.

5.6.2.3. Staphylococcus aureas (BPA 37^{0}C)

Processing insignificantly (P=0.182) reduced *S. aureas* in selected underutilized crops. Minimal levels of *S. aureas* are inevitable because even minimal handling of foods can result in coagulase positive *S. aureas* being present in foods at low levels (MQGREF, 2009). Minimal levels (<10 Mpn/g) of *S. aureas* were detected in the processed food crops and modified food products, these levels were below the recommended maximum consumption limit of ($<10^2$Mpn/g). Although insignificant (P=1.614), *S. aureas* (37 °C) was also reduced upon processing the selected crops, therefore grilling, blanching and backing contributes to safety of foods from *S. aureas*. Crackers, cookies and noodles recorded levels within the recommended level of <100cfu/g. Coagulase +ve staphylococci of ($<10^2$cfu/g) is good, ($10^2$to$<10^3$cfu/g) is acceptable, ($10^3$to$<10^4$cfu/g) is unsatisfactory, while ($\geq 10^4$cfu/g) is potentially hazardous (MQGREF, 2009). All the three modified food products were therefore safe for human consumption as with regards to *S. aureas.*

5.6.2.4. E. coli

The raw and processed food crops used to prepare modified food products were free of *E. coli*. *E. coli* is an organism that is part of the normal micro flora of the intestinal tract of humans and warm-blooded animals. Therefore, their presence in ready-to-eat foods (fully cooked or raw fruits & vegetables) can be an indication of poor hygiene and sanitation or inadequate heat treatment (MQGREF, 2009). The modified food products recorded no *E. coli* and therefore safe for consumption with regards to *E. coli*. This could be due to the food prepared in more hygienic conditions and adequate sanitation standards with regards to *E. coli*.

5.6.2.5. Molds (PDA 35°C)

Processing insignificantly ($P=0.242$) reduced mold levels in selected underutilized crops. Apart from fingermillet and simsim which recorded mold levels within the recommended maximum limits ($<10^5$pda/g) (MQGREF, 2009), grilled cassava, blanched *C. ochroleuca* and blanched *C. brevidens* recorded mold level more than acceptable maximum limits thus not acceptable for human consumption. This is an indication of poor sanitary conditions during processing.

The selected food crops used in food product processing in this study recorded higher mold levels compared to the food products, however, these levels reduced upon processing the crops. These reductions could be due to heat treatment of baking employed on the processed crops to modify the food products as research indicates that cooking processes reduces mold levels (ICMSF, 1986), therefore the enhanced drying minimized growth of molds. Mold spores are generally killed by the baking process (Knight & Menlove, 2006). The minimal mold levels could be due to the fact that molds can invade and grow on virtually any type of food at any time including crops such as grains and nuts in fields, before harvesting and during storage (Pitt, Hocking, Samson, & King, 1992). High levels of molds in blanched *C. brevidens* could cause various degrees of deterioration and decomposition of foods (Cole, 1986) but could be reduced by increased drying and keeping food dry in a dry environment because mold require moisture and a food source to grow (Curtis, Lieberman, Stark, Rea, & Vetter, 2004).

All modified products recorded mold levels below recommended limits. This findings agree with those by (ICMSF, 1986), which indicate that levels of mould propagules found in food quality grains and flours vary between approximately 10^2 and 10^5pda/g depending on the type of grain, growing, harvesting, drying, and storage time and conditions. Among the three processed food products, there were no molds in cookies but noodles and crackers recorded acceptable levels of $<10^5$pda/g (MGREF, 2007). This indicated the food products were safe for human consumption with regards to molds. The drier the products, the lower the mould levels and the safer the foods for human consumption.

5.6.3. Moisture Content in the Crops and Modified Food Products

5.6.3.1. Moisture Content in Raw and Processed Food Crops

Among the raw crops, raw dried cassava recorded the highest moisture content of 10.2%, followed by C. brevidens, C. ochroleuca and fingermillet which recorded 8% moisture content each. Raw simsim recorded the least moisture content of 3.2%. Among the processed crops C. brevidens and C. ochroleuca recorded the highest moisture content of 9.4% and 9.2% respectively, followed by grilled cassava which recorded 7.8%; grilled fingermillet recorded 6.8% while grilled simsim recorded 2.4% moisture content. The recorded moisture content levels are within acceptable levels, as flour having maximum moisture content level of 10% is suitable for storability and extended shelf life (Nasir et al., 2003). The recorded levels are within levels (11.4%-13.5%) reported in Japanese noodle flour (Toyokawa, Rubenthaler, Powers, & Schanus, 1989). Moisture is of great importance for the safe storage of cereals and their products regarding microorganisms, higher moisture content favors mould growth (Nasir et al., 2003).

There was no trend in the effect of processing on selected food crops; some crops particularly vegetables (*C. brevidens* and *C. ochroleuca*) recorded increments in percentage moisture after blanching. This findings concur with those by (Ahenkora et al., 1996) which indicated that boiling increased the moisture content of plantain pulp. On the other hand Cassava, fingermillet and simsim recorded reduction in percent moisture content after processing. Increments in vegetable moisture content after blanching could be due to the additional moisture from the water used for blanching the vegetables, even though the vegetables were dried after blanching, the drying may not have been intense enough to eliminate all the moisture acquired by the vegetables during blanching. The degree of water activity reduction is of practical significance in making a food non-perishable (Saranraj & Geetha, 2012), this explains why *C. brevidens* recorded mold levels above the recommended limits. On the other hand, processing of cassava, fingermiller and simsim by grilling reduced their moisture content, this could be because moisture in these crops evaporated upon grilling.

5.6.3.2. Moisture Content in the Modified Food Products

Noodles recorded the highest percentage moisture content at 11.8%, among the three formulated products followed by cookies at 7.9% while crackers recorded the least percentage moisture content at 4.7%. However, noodles recorded moisture content levels within reported levels (3.65%-15.46%) of noodles sold in Nigeria (Onyema et al., 2014) but lower than levels (15.24%-15.46%) reported for noodles prepared from edible canna starches (Chansri, Puttanlek, Rungsadthong, & Uttapap, 2005). These differences could be due to the differences in ingredients and preparation processes. Noodles were not baked but were dried in the open for 2hrs while cookies and crackers were baked at 175^{o}C each as indicated in chapter 3. As a result noodles recorded higher percentage moisture, followed by cookies, while crackers recorded the least content. Therefore different processing methods affect moisture content differently where drying in the open retained more moisture in the product, while baking at 175^{o}C drained more moisture from products. These findings concur with those by (Ahenkora et al., 1996) which indicated that processing decreased the moisture content of plantain pulp. The differences in percentage moisture content between cookies and crackers could have been due to the differences in amount of water used as ingredient in the processing of these products. While 14mls of water was used in processing the crackers, 50mls were used in processing the cookies. Because of exposure to similar baking temperature (175^{o}C) and time (10minutes), cookies retained a little more moisture due to the higher water 50mls used in its processing compared to crackers in which only 14mls was used. Therefore if cooking method, time and temperature are held constant, the higher the liquid content of ingredients in food ingredients results to higher percentage moisture content of the processed food product.

Differences in moisture content of the processed food products resonated with differences in the findings of certain microbiological load parameters. Just like the differences in percentage moisture content, noodles recorded higher Total coliform count followed by cookies and finally crackers. The same order was displayed in *S. aureas* where noodles recorded higher levels followed by cookies while crackers recorded the least levels. This could be due to an explanation that, the response to a given degree of water activity varies greatly among microorganisms in different environments and that the degree of water reduction is of practical significance in making a food non-perishable (Saranraj & Geetha, 2012). This indicates that the higher the moisture content the higher the microbiological load in food products and vice versa. However, moisture content can be reduced by addition of salt to the products because of the fact that salt creates ufavourable environment for microbial growth by removal of moisture (Garbutt, 1997). Therefore reduction in moisture content reduces perishability of food products and could increase the food's keeping quality and increase its safety for human consumption.

5.7. Acceptability of the Modified Food Products through Sensory Evaluation

5.7.1. Appearance Acceptability of the Modified Food Products

Appearance is a very important parameter in judging properly baked biscuits that not only reflect the suitable raw material used for the preparation, but also provides information about the quality of the product (Abu-Salem & Abou-Arab, 2011). The high preference of the appearance of crackers and cookies by judges could therefore be attributed to the baking processes of the two products as opposed to noodles which were not baked and their appearance was the least preferred among all the three modified food products. The appearance of crackers was most preferred than cookies even though both products were baked. This could be attributed to simsim which is bright in colour used in the preparation of crackers as opposed to slenderleaf which is dark green in colour, used in preparation of cookies. The least preference of noodles' appearance could be attributed to the use of fingermillet which is dark brown in colour. This study revealed higher liking for appearance could be due to a product's brighter colour of a food product, the higher the appearance acceptability and vice versa. Therefore colour of a food product contributes to the products preference.

5.7.2. Taste Acceptability of the Modified Food Products

Flavour is the main criteria that makes the product to be liked or disliked (Abu-Salem & Abou-Arab, 2011). Just like appearance, the taste of crackers was the most preferred by all the judges followed closely by cookies while noodles had their taste least preferred by all the judges. High preference of taste in crackers could be attributed to simsim whose taste could have been the contributing factor to its acceptability. This implies that the taste of simsim could be the most liked compared to tast of slenderleaf and fingermillet used in preparation of cookies and noodles respectively.

5.7.3. Smell Acceptability of the Modified Food Products

The sense of smell is considered to be more defined because an individual requires a relatively high concentration of tastant in order to perceive a taste solution (Young & Trask, 2002). Smell acceptability was higher in crackers compared to cookies and least in noodles. This could be attributed to simsim used in processing crackers. If simsim was the reason for better taste in crackers as shown in the flavour and taste results, it could have directly contributed to increased smell acceptability of crackers especially due to the fact that they were subjected to baking. Therefore high acceptability of flavor and taste results to increased liking of a product's smell.

5.7.4. Texture Acceptability of the Modified Food Products

Upon food ingestion the sensors in the mouth detect food texture and consistency, which include mechanical properties (hardness, cohesiveness, adhesiveness, denseness & chewiness); geometrical properties (smooth, gritty, grainy, chalky & lumpy); and moisture properties (juicy, oily or greasy) (Wilkinson et al., 2000). Although noodles were least preferred in all other attributes, their texture was most preferred among all products and all study participants. This could be attributed to processing procedures of extrusion and drying in the open used during the preparation of noodles as opposed to rolling and baking used in processing cookies and crackers. However, noodle texture is probably most important followed by color, taste, surface appearance, and weight and volume upon cooking (Toyokawa et al., 1989). Given that liking of noodle texture matters most compared to appearance, smell and flavor, noodles are therefore highly acceptable even though the liking of the other attributes were least compared to cookies and crackers.

5.7.5. General Acceptability of the Modified Food Products

Cookies were liked by most study participants thus indicated high acceptability. Generally the proportion of individuals who reported to like cookies was higher among male participants compared to female participants. On the other hand, crackers were highly liked all the girls, women and boys but a few men were undecided about their acceptability. Generally this indicated high acceptability for crackers. Noodles were highly liked by men participants compared to women. However, there was high acceptability of noodles. Generally all the modified food products were liked by all the study participants indicating high acceptability for the products.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

Selected underutilized crops contained iron and zinc, however, processing by blanching and grilling reduced iron and zinc levels of these crops. The amounts of iron and zinc reduced after processing the selected underutilized crops differed from one crop to another but the levels recorded were higher than those reported for wheat four. Therefore selected underutilized crops are good sources of iron and zinc and could contribute towards control of iron and zinc deficiencies.

Although wheat has traditionally been used to prepare cookies, crackers and noodles, this study has demonstrated the possibility of using underutilized crops like simsim seeds, fingermillet grains and slenderleaf vegetables each combined with cassava roots to process crackers, noodles and cookies respectively. This study has revealed the possibility of using these combinations to prepare the modified products.

Modified crackers, noodles and cookies recorded iron and zinc levels higher than reported levels of similar products prepared using home backing wheat flour. Therefore crackers, noodles and cookies prepared using cassava in combination with fingermillet, simsim and slenderleaf respectively are better sources of iron and zinc than those traditionally processed using home baking wheat flour. If consumed, the modified crackers, noodles and cookies could contribute significantly to iron and zinc intakes thus contribute toward minimizing these deficiencies.

The modified food products contained iron and zinc levels adequate to contribute to 100% RDA in various population sub-groups except for the pregnant and lactating women who received contributions less than 100%. However, this study did not focus on iron and zinc bioavailability in the selected crops and modified food, there was an assumption of 100% bioavailability. Information on nutrient bioavailability is vital in providing a clear picture of the contribution of these products to recommended dietary allowance.

Heat treatment processing reduced microbiological load in selected underutilized food crops particularly cassava, fingermillet and simsim to levels safe for consumption. All the processed crops recorded microbiological loads within the recommended maximum acceptable limits. This was with an exception of grilled cassava which recorded total plate count levels higher than acceptable limits. On the other hand, blanched *C. brevidens, C. ochroleuca,* and grilled cassava recorded mold levels higher than the acceptable levels. Therefore more efforts should be made to improve sanitary conditions of the food processing environment, equipment and personnel.

Food products comprising of cookies, noodle and crackers processed from cassava, fingermillet, simsim and slenderleaf recorded low and safe levels of microbiological loads. These products were safe for human consumption, however, more effort is needed to increasingly improve the sanitary conditions of food preparation in order to maintain low acceptable levels or further reduce the levels. They were also completely free from *E. coli*, thus safe for consumption with regards to *E. coli*. Therefore the general population preparing these products for consumption could be trained on proper food processing sanitary conditions with regards to environment, personal hygiene and processing equipment. This is to ensure that they consume safe foods to avoid food borne illnesses.

Selected food crops with higher percentage moisture content recorded higher microbiological load compared to those with lower percentage moisture content which recorded lower levels. Even though *C. brevidens* recorded higher mold levels compared to the recommended levels, the cookies modified using *C. brevidens* as one of the ingredients recorded mold levels within the recommended levels thus good for consumptions. This could be attributed to heat treatment during baking which further reduced moisture content and eventually mold levels of vegetables.

Noodles which were dried in the open contained higher moisture content compared to cookies and crackers which were baked. Therefore processing methods used in the processing of food products determine the moisture content of the food products. On the other hand cookies contained higher percentage moisture content compared to crackers even though they were both baked at the same temperature (175^{o}C) and time (10 minutes). This could be attributed to the ingredients used, where cookies were formulated using 50mls of water and 22g margarine, while crackers were formulated using 14mls of water and 10g margarine. Therefore amount of liquid or wet ingredients determine the percentage moisture content of the final product; the higher the quantity of liquid/wet ingredients the higher the percentage moisture content and vice versa.

Differences in moisture content of the modified food products was similar to the differences in their microbiological loads. The drier the food the lower the microbiological load; and therefore the less likelihood of the food to perish due to spoilage or microbiological contamination.

Generally there was high acceptability (>50%) of the modified crackers, noodles and cookies among all the judges. Baking increased preference for the appearance of cookies and crackers compared to noodles which were dried in the open and recorded least acceptability of appearance. Although both cookies and crackers were baked, the appearance of crackers was the most preferred compared to cookies; this could be due to simsim which is bright in colour used in the preparing crackers compared to slenderleaf which is dark green in colour used in the preparation of cookies. Noodles were the least preferred in terms of appearance and this could also be attributed to the use of fingermillet which is dark brown in colour in its preparation.
High preference of taste in crackers could be attributed to simsim used in its formulation which could have contributed to a better tastes compared to slenderleaf and fingermillet used in the modification of cookies and noodles respectively.

Smell preference was higher for crackers compared to cookies and least in noodles. This could be attributed to simsim used in cracker preparation. If simsim was the reason for better taste and flavor in crackers as indicated by the flavor/taste results, it could have directly contributed to better smell after crackers were baked. Therefore simsim contributes to the increased acceptability of food products in terms of taste, flavor and smell.

Texture preference was higher for noodles among all the judges. This could be to processing procedures of extrusion and drying in the open used in the preparation of noodles as opposed to rolling and baking used in the preparation of cookies and crackers.

CONCLUSIONS

Selected underutilized food crops are good sources of iron and zinc. They are better sources of iron and zinc compared to wheat which traditionally has been used to process of food products.

Neglected and underutilized food crops like cassava, fingermillet, simsim and slenderleaf are useful in processing food products like noodles, cookies and crackers.

Food products modified using cassava, fingermillet, simsim and slenderleaf are better sources of iron and zinc compared to the same products prepared using home baking wheat flour.

The modified food products contribute to over 100% iron RDA for most populations sub groups apart from women in child bearing age (14-50years) and during pregnancy. These groups need to increase their dietary sources of iron alongside the processed food crops to enable them attain adequate iron intake. On the other hand the modified products contribute to over 100& zinc RDA to females (9->70 years) and children (6months – 13 years). However males (14->70years), during pregnancy and lactation, the contribution of %RDA from the modified products is less than 100%. These groups need to increase their dietary sources of zinc alongside the processed food crops to enable them attain adequate zinc intake.

Blanching increased moisture content of c brevidens and c ochroleuca, while grilling reduced moisture content in cassava, fingermillet and simsim.

If cooking method, time and temperature are held constant, higher amounts of wet ingredients in a food recipe, results in higher moisture content of the final product.

The higher the moisture content the higher the microbiological load in products and *vice versa.*

Baking improves appearance acceptability of crackers, noodles and cookies prepared from a combination of cassava with simsim, fingermillet and slenderleaf respectively.

Modified crackers are brighter in color and were most liked in terms of appearance while noodles which are dark in colour were the least liked in terms of appearance. Modified crackers which were prepared by combining cassava with simsim were most liked in terms of taste and smell alongside appearance. Modified crackers were highly acceptable compared to noodles and cookies which were prepared by combining cassava with fingermillet and slenderleaf respectively. Modified noodles which were prepared by extrusion and drying in the open had their texture most liked compared to modified crackers and cookies which were prepared by rolling and baking. Among all the modified food products, crackers were highly acceptable followed by cookies and finally noodles. However, all products recorded high acceptability.

If promoted, there could be increased consumption of the modified crackers, noodles and cookies and in the long run increase the utilization of selected underutilized food crops. Increased utilization of these crops could increase their shelf-life and marketability. Given that the modified products are better sources of iron and zinc compared to those prepared using home baking wheat flour, increased consumption of these products could increase intake of dietary iron and zinc and in the long run reduce iron and zinc deficiencies in the population.

RECOMMENDATIONS

1. Neglected and underutilized food crops like simsim, fingermillet and slenderleaf should be promoted and included in our diets as they are good sources of Fe and Zn.
2. The use of cassava in combination with simsim, fingermillet and slenderleaf to process crackers, noodles and cookies respectively should be promoted, marketed and recommended for consumption both at household and industrial level. This could increase their consumption and thus increase intake of dietary iron and zinc which could in the long run help minimize iron and zinc deficiencies.

AREAS FOR FURTHER STUDIES

1. Iron and zinc bioavailability studies should be carried out to provide more information on nutrient bioavailability of the modified food crops.
2. Shelf-life study should also be undertaken to help establish the keeping quality of the modified crackers, noodles and cookies.

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APPENDICES