MODIFIED DIETS TO IMPROVE IRON, VITAMIN A AND PROTEIN INTAKE AMONG CHILDREN IN BANANA-BASED FARMING SYSTEMS OF KAGERA REGION, TANZANIA

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EXTENDED ABSTRACT

Micronutrient and protein deficiencies are among the major public-health concerns in Tanzania. These deficiencies mainly affect children below five years of age and pregnant women. Malnutrition is a preventable problem if nutrition education and food-based approach strategies are effectively emphasised from the village to the national levels. The banana-based farming system of Kagera region of Tanzania has good edible food diversity. However, households mainly consume monotonous diets, which are energy dense and have inadequate content of micronutrients. Inadequate dietary diversity contributes to unacceptable high levels of under-nutrition, particularly protein energy malnutrition (PEM) and low intake and risks of deficiency of essential micronutrients including vitamin A and iron, particularly in children below five years of age. Popular dishes consumed by the population in Kagera region, are low in vitamin A and iron. Participatory dietary diversification is one of the strategies to address nutrient deficiencies and fight malnutrition. This study modified the local popular recipes to improve the nutrient levels of the foods consumed especially by children below five years of age. The study is a cross sectional design and the objectives included; (i) modify local dishes fed to children below five years of age to improve vitamin A, iron and protein intake; (ii) determine iron, vitamin A and protein content of the modified/improved recipes for children below five years; (iii) determine in vitro bio-accessibility of vitamin A and iron of the modified/improved recipes for children below five years; (iv) assess acceptability and preference of the modified recipes for children below five years. To enrich the preferred energy-rich diets, this study modified the local recipes to improve content of vitamin A, iron and protein to meet requirements for children of age between 6 to 23 months. Fifty mothers were randomly selected from Izimbya ward, Bukoba district participated in a recipe development exercise. Five recipes of banana-based from East

African highland bananas (EAHB) '*nshakala*' and triploid hybrid of *Musa acuminata* and *Musa balbisiana* (AAB) *'bira'* banana varieties and three maize-based porridges were formulated in combination with other ingredients. Other locally available foods included beans, amaranths, red palm oil, pumpkin, groundnut, maize and orange-fleshed sweet potato. The recipe names included 1N ('nshakala' :EAHB, dry red kidney beans, amaranths, palm oil); 2N ('nshakala: EAHB', fresh red kidney beans, pumpkin leaves, sunflower oil); 3B ('bira'' :AAB, dry red kidney beans, amaranths, palm oil); 4B ('bira';AAB', fresh red kidney beans, pumpkin leaves, sunflower oil); 5N (nshakala', pumpkin fruit, groundnuts flour); 6OFSP (Fermented maize flour, orange fleshed sweet potatoes, groundnut flour); 7B (fermented maize, 'bira', groundnut flour); 8E (Fermented maize flour, egg, red kidney beans). Diet modification started with calculation of vitamin A, iron and protein contents of foods by using the Tanzania Food Composition Table (TFCT). The conversion factor of 12:1 for beta-carotene was used. Red palm oil, orange fleshed sweet potato (OFSP), pumpkin fruit and leaves were used to increase vitamin A content in the modified recipes. Furthermore, red kidney beans *(Phaseolus vulgaris*) and groundnut were included to improve protein and iron content of the formulated recipes. Red kidney beans formed a good source of iron, protein and energy when incorporated in complementary foods. The family dishes and children's local popular dishes were made into a purée to improve the consistency (viscosity and density) to increase food intake and therefore vitamin A, iron and protein. The developed recipes contained more than 100% recommended dietary allowance (RDA) for vitamin A and protein. The RDA for iron in the modified diets ranged from 61% to 99%. Vitamin A, iron, protein and energy content of modified recipes ranged from 108-2768 Retinol Activity Equivalent (RAE), 6-17 mg, 28-56 g and 697-1635 kcal, in 500 g consumption portion, respectively. These levels meet the RDAs for breastfed and non-breastfed children. Furthermore, the modified recipes

were subjected to laboratory analysis for nutrient contents and bio-accessibility tests. All samples were analysed in triplicates for vitamin A, iron and protein contents. For vitamin A; three carotenes; all-trans α-carotene, 13-cis-β-carotene and all-trans β-carotene were determined by High Performance Liquid Chromatography. Bio-accessibility was assessed using *in-vitro* bio-accessibility model in three phases; simulated gastrointestinal system oral, gastric and intestinal. The analysed provitamin A Carotenoids (pVACs) were converted into 'Retinol Activity Equivalents' (RAE). Total RAE of the modified diets ranged from 8.8 to 137.4 µg/100g, and after *in-vitro* digestion ranged from 0.87 to 13.3µg/100g. The bio-accessibility of pVACs ranged from 12.2% to 33.6%. In cooked food, pumpkin fruit contributed high amount of provitamin A followed by palm oil, '*bira'* and amaranths. *'Bira*' banana variety contributed high pVACs than local 'n*shakala'* banana variety. Provitamin A Carotenoids (pVACs) from pumpkins leaves were more accessible than those from amaranths and red palm oil fruit. Our results suggest that when carrying out interventions to improve diets, it is very important to take into account the estimation of dietary source of vitamin A and pVCAs and their bio-accessibility to meet nutritional requirements for vitamin A. The contents of iron and protein in separate ingredients and in modified recipes were analysed using flame atomic absorption spectrophotometry and Kjeldahl´s method, respectively, and bio-accessibility of iron was estimated using *in vitro* simulating gastrointestinal digestion method. The contribution of iron ranged from 75 to 458% and protein from 106 to 146% of recommended dietary allowance (RDA) ranged from and in a portion of 500g . Iron bio-accessibility in all recipes ranged from 7.4% to 31.1%. Iron in porridge recipes made from orange fleshed sweet potato porridge and *'bira'* porridge was more bioaccessible. The product might be having high nutritional value but without assessing its acceptability and preference, the product is likely to be not liked by the community. Therefore this study assessed sensory

attributes of the modified/improved recipes for children in two rural villages of Tanzania. Consumer preference of eight recipes was assessed using a nine-point hedonic scale test. The results revealed that the improved *'katogo'* dry beans (recipe 3 OC) and *'katogo'* fresh beans (recipe 4 OD) had the highest scores for colour (7.9 - 8.1), aroma (7.6 - 7.7), taste (7.6 - 7.8), texture (7.7 - 7.8) and overall acceptability (7.8 - 7.9) compared to local '*katogo'* steamed sardines (recipe 1 OA) and improved '*katogo*' with groundnuts and pumpkin (recipe 5 OE). Recipe 3 OD was the most preferred recipe compared to other recipes Porridge prepared using maize flour and orange fleshed sweet potatoes scored highest for all attributes compared to porridge that had eggs in it (recipe 7 OH) and plain local maize porridge (recipe 8 OI). Modified banana-based and porridge-based were widely accepted by panelists. The importance of food diversification for intake of iron, vitamin A and protein is discussed. The communities need to establish home gardens so as to use vegetables and foods which are cheap and good sources of micronutrients and protein. Knowledge on nutrition education to enable community to accept other tastes than their own for better choice of healthy food is highly recommended. Sensory evaluation is important component in developing complementary food. The modified recipes based on locally available and affordable ingredients have a potential to meet RDAs of vitamin A, iron and protein for children aged 6 to 23 months in the banana-based system and other communities in Africa with the same settings.

LIST OF PUBLICATIONS

Mbela, D. E. N., Kinabo, J., Mwanri, A. W. and Ekesa, B. (2018). Modification of Local Recipes to Improve Vitamin A, Iron and Protein Contents for Children Aged 6 to 23 Months. *African Journal of Food, Agriculture, Nutrition and Development* 18(1): 13129 - 13153

Mbela, D. E. N., Kinabo, J., Mwanri, A. W. and Ekesa, B. (2017). Protein and iron contents and bio-accessibility in local modified diets for children aged 6 to 23 months in Bukoba, Tanzania. *African Journal of Food Science Technology* 152:8(9); 162-170. DOI: http:/dx.doi.org/10.14303/ajfst.2017.152

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DECLARATION

I, **Domina Esther Nkuba Mbela**, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work, and that it has not been submitted for a higher degree award in any other University.

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The above declaration is confirmed by:

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Prof. Joyce Kinabo **Date**

(Supervisor)

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(Co-Supervisor)

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LIST OF ABBREVIATIONS AND ACRONYMS

AAB	Triploid hybrid of *Musa acuminata* and *Musa balbisiana*
ANF's	Anti-nutritional Factors
ANOVA	Analysis of Variance
ARI	Agricultural Research Institute
CIP	Consumer Information Processing
DOI	Diffusion of Innovation
EAHB	East African Highland Banana
EAR	Estimated Average Requirement
EStd	External standard
FAAS	Flame atomic absorption spectroscopy
FAO	Food and Agriculture Organization
HPLC	High-performance Liquid Chromatography
IDA	Iron deficiency anaemia
IStd	Internal standard
LSD	Least Significant Differences
LSRD	Least Significant Rank Difference
M(N)	Molecular weight of nitrogen
MoH	Ministry of Health

MoHCDGEC)	Ministry of Health, Community Development, Gender, Elderly and Children
n(HCl)	Morality of hydrochloric acid
NBS	National Bureau of Statistics
NIMR	National Institute for Medical Research
OFSP	Orange- fleshed sweet potato
PCA	Principal Component Analysis
PEM	Protein energy malnutrition
pVAC	Provitamin A Carrotenoids
RAE	Retinol Activity Equivalents
RDA	Recommended Dietary Allowance
RDI	Recommended Dietary Intake
SW	Sample weight
TDHS-MIS	Tanzania Demographic and Health Survey and Malaria Indicator Survey
TEA	Triethylamine
THSD	Turkey Honest Significant Difference
TFCT	Tanzania food composition tables
TN	Total nitrogen
UNICEF	United National Children's Fund

URT	United Republic of Tanzania
V(HCl)	Volume of hydrochloric acid (ml) needed for titration
VAD	Vitamin A deficiency
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Healthy eating for children aged 6-23 months is very important for them to attain their full physical and mental growth potential. Therefore complementary foods should contain adequate nutrients and energy and free from contaminants. Nutrition is the provision of adequate energy and nutrients to the cells for them to perform their physiological function of growth, reproduction, defence and repair (Alemu, 2013). Micronutrients (minerals and vitamins) are substances required in trace amounts for the normal growth and development of living organisms. Of global concern are deficiencies of iron, vitamin A, zinc, folate, and iodine (Berti *et al.,* 2014). Micronutrient and protein deficiencies are among the major public-health concerns in Tanzania (TDHS-MIS 2015-16). These deficiencies mainly affect children below five years of age and pregnant women. Children aged between 0 and 59 months, also termed as pre-schooler children are most vulnerable to micronutrient deficiency (Ekesa *et al*., 2011). Despite strategies employed to tackle micronutrient malnutrition, limited progress has been achieved in the developing countries (Berti *et al*., 2014). Protein energy malnutrition (PEM) occurs when the body requirements for protein or energy or both cannot be met through diets. Micronutrient malnutrition develops when intakes of bioavailable micronutrients are too low to meet body requirements (Miller and Welch, 2013). Vitamin A deficiency (VAD) and iron deficiency aneamia (IDA) affect over two billion people worldwide and 190 million preschool-age children (Bailey *et al.,* 2015). Consequences of micronutrient malnutrition include increased mortality and morbidity rates; disability; impaired immune function, cognitive abilities and physical development in children (Bailey *et al.,* 2015).

Dietary modification is a process of diet alteration done by nutritionists or dieticians to include or exclude certain components, such as vitamins, minerals, calories, and fat, mainly using available local foods (Kennedy *et al.,* 2010). It is always made during food preparation, processing, and consumption to increase the bioavailability of micronutrients and reduce micronutrient deficiencies in food at the individual and/or household level (Beck and Heath 2013). Diet modification of nutritious complementary foods from local and readily available raw materials has received a lot of attention in many developing countries (Temesgen, 2013). Dietary modification intervention using local food available at community showed to improve the nutritional status of children in rural areas of Indonesia (Susanto *et al.,* 2017).

1.2 Complementary Foods

Complementary foods are any nutrient-containing foods or liquids other than breast milk given to young children during the period of complementary feeding (6-23 months). (Koletzko *et al.* ,2015). Two types of complementary foods include; specially prepared foods and usual family foods that are modified to make them easy to eat and provide enough nutrients. Complementary foods should be adequate, meaning that the complementary foods should be given in amounts, frequency and consistency and using a variety of foods to cover the nutritional needs of the growing child while maintaining breastfeeding.

High cost of fortified complementary foods in many parts of developing countries is beyond the reach of most families (Amankwah *et al.,* 2009). Consequently, many families depend on inadequately processed and low-quality traditional complementary foods for their children (Fikiru *et al.,* 2016). In the first two years of life growth of an infant is very

rapid and breast feeding alone will not meet the child nutritional requirements (Fikiru *et al.*, 2016).

The ability of breast milk to meet the requirements for macronutrients and micronutrients becomes limited with the increasing age of infants (Agostoni *et al.*, 2008). Timely introduction of complementary foods during infancy is necessary for both nutritional and developmental reasons (Agostoni *et al.*, 2008). Thus, dietary modification using cheap local available food is very important for increased intake of nutrient rich diet for children aged 6-23 months. This is the most critical period for children because during this transition, children are most vulnerable to becoming undernourished.

1.3 Dietary Modification

One of the solutions to eradicate micronutrient deficiency is the promotion of micronutrient-rich foods through dietary modifications strategy (Fungo *et al.*, 2010). Dietary modification encompasses a wide variety of interventions that aim at: identifying and increasing the consumption of foods rich in vitamin A, iron and zinc (Fungo *et al.*, 2010); increasing availability and access to foods rich in these micronutrients, and/or increasing the bioavailability of the micronutrients through proper processing techniques (Fungo *et al.*, 2010).

Dietary modification if well effected can lead to a nutritionally secure population. When children below five years are well nourished, their immune systems are boosted, thus reducing their susceptibility to infections (Clements and Carding, 2017; Karacabey and Ozdemir, 2012). In turn, less time and resources will be spent on health care and therefore members of these households will then direct their extra resources towards meeting other

family/individual needs. Furthermore, the better nutrition status, especially in the early years of life helps optimize mental, social and physical development, resulting in increased productivity, high achievement and decreased dependency.

1.4 Interventions Addressing Micronutrient Deficiencies

Nutrition intervention strategies to reduce or eliminate the occurrence of micronutrient malnutrition include: dietary diversification/modification; supplementation; fortification with iron, iodine, zinc, folic acid, vitamin A, and multi-micronutrients, provided that households have access to primary health care (Berti *et al.,* 2014). Dietary diversification or modification strategies employing agricultural interventions aim to improve vitamin A status by introducing cultivation of β-carotene rich-crops, including biofortified crops and promoting consumption of vitamin A-rich foods (Berti *et al.,* 2014). In Tanzania, interventions to address VAD include high-dose vitamin A capsule distribution to children (NBS, 2011) and, to a lesser extent, vitamin A fortification of foods such as vegetable oil and fats. Nevertheless, the magnitude of VAD remains high (Hotz *et al.,* 2012). According to Ruel and Bouis (2004), VAD can be controlled at least to some extent by diets relying mainly on plant foods. Dietary diversity had been shown to translate into better nutrition outcomes, especially among populations dependent on agriculture in developing countries (Kennedy *et al.,* 2010).

1.5 Anti-nutritional Factors

The anti-nutritional factors (ANF's) are substances generated in natural food substances by the normal metabolism of species and by different mechanisms (e.g. inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed) which exert effects contrary to optimum nutrition. Cereals and legumes are rich in minerals but

the bioavailability of these minerals is usually low due to the presence of antinutritional factors such as phytate (phytic acid), trypsin inhibitor, polyphenoles, tannin, amylase inhibitor, trypsin/chymotrypsin inhibitors and hemagglutinins. Phytate is most important anti-nutrient because it is found in most of the cereals and have strong ability to complex multi-charged metal ions, especially Zn, Ca and Fe and make them unavailable for human body utilization (Nadeem *et al.,* 2010). Household food-processing and preparation methods such as soaking, roasting, germination, cooking, and fermentation can enhance the bioavailability of micronutrients in plant based diets by decreasing anti-nutrients phytate content and improving overall digestibility and absorption of nutrients (Gibson and Hortz, 2001; Nadeem *et al.,* 2010). To remove anti-nutrients and to improve bio-accessibility the study used the soaking (for 12 hrs) and spontaneous fermentation (using the microorganisms that are naturally present in food) methods.

1.6 Bio-accessibility of Nutrients

Bio-accessibility, which is the amount of an ingested nutrient that is potentially available for absorption, is dependent only on digestion and release from the food matrix (Etcheverry *et al.,* 2012). Bio-accessibility of minerals can be estimated using *in vitro* method simulating gastrointestinal digestion (Patted, 2010). Bio-availability depends on digestion, release from the food matrix, absorption by intestinal cells, and transport to body cells. To know the potential nutrient available for absorption in the gut, Etcheverry *et al* (2012) assessed bio-accessibility of vitamin A, iron and protein using in vitro method which is more rapid; less expensive; less labour intensive; do not have ethical restrictions and offer better controls of experimental variables than human or animal studies (Minekus *et al.,* 2014). This study used the same method.

1.7 Sensory Evaluation

Food must be culturally and socially acceptable by the consumer. Thus, the product might be having high nutritional value but without being accepted, the product is likely to be rejected by the targeted population group. Sensory evaluation is therefore important in food improvement or development of new products, product modification, formulation of new food products, nutrition enrichment, determination of shelf life, development of quality standards, quality control, determination of product's acceptability, consumer preferences, and determination of market segmentation (Carpenter *et al*., 2000). It is a scientific discipline used to measure, analyze, and interpret sensory attributes to the characteristics of products as they are perceived through the senses of sight/colour, smell/odour, touch, taste and hearing (Lawless and Heymann, 2010; Svensson 2012). Sensory attributes of the product include colour, aroma, taste, texture (mouth feel), and overall acceptability.

The major sensory test methods include; discrimination, descriptive and affective. Discrimination/difference test requires a trained panel to determine the differences between two products. Usually it is used in quality control, food ratings, product development, and product competition (Garruti *et al.,* 2012). Descriptive test describes characteristics of a product and/or measuring any differences that are found between products. Also, it is used in quality control, competitive products, product development and research. It involves the detection and the description of both the qualitative and quantitative sensory aspects of a product. Trained panellists describe the sensory attributes of a sample, often called descriptors (Garruti *et al.,* 2012). Affective/preference or hedonics test does not require a trained panel. The sensory tests that assess subjective personal responses of customers toward a product are called affective tests. Affective tests

measure attitudes such as acceptance and preference. Preference tests determine the customer's preference of a product over the other(s). Acceptance tests quantify the degree of liking or disliking (Garruti *et al.,* 2012). It gives the answer to "how well are the dishes liked or disliked. Typically, an affective test may involve from 50 to 100 consumers in laboratory tests, until 300 to 500 in central location and home use tests. The larger size of an affective test arises due to the high variability of individual preferences and thus a need to compensate with increased numbers of people to ensure statistical power and test sensitivity (Garruti *et al.,* 2012; Lawless and Heymann, 2010). Preference test is used when the objective is to look for the preference of one product or formulation/modified against another. When it becomes necessary to determine how well the product is liked by consumers, acceptance test is used and hedonic scale is employed (Garruti *et al.,* 2012). This study used affective and descriptive tests to evaluate preference and acceptability of the modified recipes.

1.8 Problem Statement and Justification of the Study

1.8.1 Problem statement

Despite the presence of diversity of edible foods, the populations in Tanzania still consume monotonous diets which are mainly based on energy dense and inadequate micronutrient contents (Muhimbula *et al.,* 2011). This contributes to the burden of malnutrition, particularly micronutrient malnutrition. Kennedy *et al*., (2010) documented that consumption of a wide variety of foods across nutritionally distinct food groups ensures adequate micronutrient intake. In addition, dietary modification based on foods available in a particular locality may be more sustainable, economically feasible, and culturally acceptable, and can be used to alleviate several micronutrient deficiencies simultaneously without risk of antagonistic interactions (Ayoya *et al*., 2010). In Tanzania,

little has been done to improve the micronutrient concentrations of complementary foods (Muhimbula and Issa-Zacharia, 2010; Kinabo *et al.*, 2006). Particularly in banana-based farming systems in Kagera Tanzania, limited studies on dietary modification have been conducted.

In Tanzania, undernutrition and micronutrient deficiencies are still a gross problem to both children under five and women of 15 to 49 years of age. Tanzania Demographic and Health survey report (TDHS-MIS 2015-16) showed that nutritional status of children below five years of age has remained at unacceptable high level. The report further showed that 34% of them are stunted, 14% are underweight and 5% suffered from wasted muscles. About one third of children below five years of age are iron deficient and 58% are anaemic and vitamin A deficient (TDHS-MIS 2015-16). About 45% of women aged 15-49 years are anaemic and 37% are vitamin A deficient (TDHS-MIS 2015-16; NBS, 2011). The banana based farming systems of Kagera region have good food diversity but it has above average of stunted and underweight children. About 42% of children below five years of age are stunted, 2% wasted, and 17% underweight in the region. Also, 58% of children below five years of age in the same region are anaemic; 47% are vitamin A deficient (TDHS-MIS 2015-16; NBS 2011).

1.8.2 Justification of the study

Lack of diversity in the diets has led to inadequate intake and risks of deficiency of essential micronutrients such as vitamin A and iron, particularly in children below five years of age and women. Generally, in Tanzania, most diets are low in diversity, low in animal source of foods and high in plant sources that are rich in anti-nutrients (URT, 2012). The majority of rural farming households in the banana-based farming systems

consume diets made of starchy staple such as bananas, cereals or root and tuber crops with little or no fruits and vegetables or animal source which are rich in vitamin A, iron and protein (Christides *et al.,* 2015; Kennedy *et al.,* 2010). These households lack proper dietary diversity due to the limited knowledge and skills on food preparations, despite the abundance of micronutrient-rich foods in their respective communities (Ekesa *et al.,* 2011). Thus, the families from these farming systems still suffer from VAD, IDA and PEM (NBS, 2011; TDHS-MIS 2015-16). Popular dishes consumed by the population in Kagera region, which include boiled bananas, stiff maize porridge, and boiled fresh cassava, have low iron content when compared to the recommended dietary allowance. In addition, stiff maize porridge with beans and stewed sardines; cassava mixed with beans and mere boiled cassava; are low in vitamin A content (Godson, 2014). From this observation it was clear that there is a need to modify the dishes to improve the nutrient levels of the common foods consumed especially for the children below five years of age.

Dietary modification involves alteration of diet to include certain components such as vitamins, minerals, calories, and fat, coupled with appropriate cooking methods to help individuals and households to access and consume nutrient rich diets using locally available foods. In many agricultural communities there is paucity of information on diet modifications to ensure a greater intake of micronutrient rich foods by vulnerable groups, such as children below five years of age and pregnant/lactating women. Research findings have indicated that children below five years of age are among the population groups most vulnerable to malnutrition. This study focused on children below five years of age particularly age between 6-23 months. This age is within the first 1000 days of life - the time spanning between conception and one’s second birthday - is a unique period of opportunity when the foundations of optimum health, growth, and neurodevelopment

across the lifespan are established. Malnutrition weakens this foundation leading to earlier mortality and significant morbidities. Focusing on improving nutrition during the critical first 1,000 days, much of the serious and irreparable damage caused by malnutrition can be prevented. The study modified locally popular dishes to enhance access to highly nutritious diets among aged between 6-23 months. It also generated information for use by individuals and household members on diet modification to enable them to develop nutritious diets using locally available foods.

1.9 Study Objectives

1.9.1 Overall objective

To improve vitamin A, iron and protein status of children below five years of age through dietary modification using locally available foods

1.9.2 Specific Objectives

i. To modify local dishes fed to children below five years of age to improve vitamin A, iron and protein intake.
ii. To determine iron, vitamin A and protein content of the modified improved recipes for children below five years.
iii. To determine in vitro bio-accessibility of vitamin A and iron of the modified/improved recipes for children below five years.
iv. To assess acceptability and preference of the modified recipes for children below five years.

1.10 Organization of the Thesis

The thesis is organized in three chapters. The first chapter starts with an introductory part, which highlights the background information on nutrient deficiencies and their consequences; dietary modification; interventions to address micronutrient deficiencies; anti-nutritional factors; bio-accessibility of nutrients; and affective/preference or hedonic test. The chapter includes a theoretical framework of the study and the relationship of published papers and their contribution towards the main objective. This chapter also contains overall objective of the thesis, and the methodology used to collect and analyse data. Chapter two comprises four published papers addressing four specific objectives of the study. Chapter three presents the overall conclusion and recommendations of the study by focusing on nutrient modification of local popular diets, their nutrient contents and sensory evaluation of the modified recipes.

1.11 Description of the Commonality of the Concept

Terms used in this study are described in section 1.11.1. This helps to understand the various concepts used in this thesis.

1.11.1 Definition of key concepts

Bio-accessibility is the amount of nutrient released from the food matrix in the gastrointestinal tract and accessible for absorption

Estimated Average Requirement (EAR) is the average (median) daily nutrient intake level estimated to meet the needs of half the healthy individuals in a particular age and gender group. The EAR is used to derive the Recommended Dietary Allowance.

Nutrient analysis refers to the process of determining the nutrient content of foods and food products.

Nutrient requirement refers to the lowest continuing intake level of a nutrient that will maintain a defined level of nutrition in an individual for a given criterion of nutritional adequacy.

Recommended Dietary Allowances (RDAs) are defined conceptually the same as the Recommended Nutrient Intake (RNI), but may have a slightly different value for some micronutrients like iron, vitamin A, zinc and others.

Recommended Nutrient Intake (RNI) is the daily intake that meets the nutrient requirements of almost all apparently healthy individuals in an age and sex-specific population group. It is set at the Estimated Average Requirement plus 2 standard deviations.

1.11.2 Theoretical framework

This study was guided by two theoretical models; Consumer Information Processing (CIP) and diffusion of innovation theory.

1.11.2.1 Consumer Information Processing (CIP)

Consumer Information Processing (CIP) theory, from a CIP perspective, consumer decision making is a multi-stage process of information acquisition and evaluation, decision making, use and learning. Consumer Information Processing (CIP) helps to match the most effective type, format and quantity of information with a specific population. This theory applicable in individual –level interventions and used also to promote awareness of a program. Through the nutrition education activities and materials, the main emphasis is on *"how-to" or* what, how, when and how much- rather than on the "why" (for example, the biological processes by which nutrition affects health) (Glanz and Eriksen 1993). The stage of changes model proposes that people are at various points

along a continuum of change-redness: *precontemplation* (unaware, not interested in change); *contemplation* (thinking about changing); *decision* (actively modifying habits and/or environment); and maintenance (maintaining the new, healthier habits) (Prochaska, and DiClemente, 1982). This model is consistent with the overall sequencing of the interventions, in which initial activities emphasises awareness and motivation, followed by opportunities for action, and later promoting maintenance of change. At individual level, structured self-help guides are being developed that are based on the stages model: individuals can complete a series of questions that will identify their stage (precontemplation; contemplation; decision or maintenance*)* and then direct them to information about nutrition and dietary change strategies that are (1) appropriate for their current stage and (2) likely to move them to the next stage of adopting improved eating patterns. Supportive activities for family members are being built into these materials, to enhance social support and reduce barriers to readiness for active change. At initial stage this study modified the local popular dishes using local available foods at the community. A participatory method was employed whereby mothers/and or caregivers were involved in dietary modification process. Subsequently, mothers/and or caregivers and representative of the community were involved in sensory evaluation for preference and acceptability tests by using a structured questionnaire.

1.11.2.2 Diffusion of innovations theory

Diffusion of innovations (DOI) is a theory that seeks to explain how, why, and at what rate new ideas and technology spread. Diffusion is the process by which an innovation is communicated over time among the participants in a social system (Rogers, 2003). An innovation is an idea perceived by the individual or groups (Rogers, 1995). In the present study the innovations are modification of local popular dishes using local available foods

at the community and participatory of mothers/and or caregivers in the dietary modification process. The four main elements of diffusion that influence the spread of a new idea include: the innovation itself, communication channels, time, and a social system. This process relies heavily on human capital. The innovation must be widely adopted in order to self-sustain. Diffusion of innovation theory concerns how nutrition educators can more effectively spread the adoption of new, healthier eating habits within a community. The categories of adopters are innovators, early adopters, early majority, late majority, and laggards. Innovations that are less risky are easier to adopt as the potential loss from failed integration is lower. Diffusion occurs through a five–step decision-making process. Five stages: knowledge/awareness, persuasion/interest, decision/evaluation, implementation/trial, and confirmation/adoption are integral to this theory. An individual might accept or reject an innovation at any time during or after the adoption process (Rogers, 2003). The present study involved mothers and/or caregivers and representative of the community (including males) in the process of dietary modification by using locally available foods to increase intake of nutrients. The study also conducted sensory evaluation for acceptability and preference of the modified diet by the community. They were asked to sign consent form before they joined the process. From these processes mothers/and or caregivers and representative of the population (including males) gained knowledge and skill on dietary modification, food and dietary diversity and sensory testing.

1.11.3 Conceptual Framework of the Study

Figure 1.1 shows the conceptual representation of local popular recipes modification; nutrient analysis and sensory evaluation of the modified recipes for increased nutrient intake by children below five years of age and populations. The framework explores the

activities which led to outputs such as acquiring knowledge and skills, increased nutrient intake, determination of nutrient contents and acceptability of the modified recipes. The outcomes include increased ownership of the modification process, access to recommended nutrient intake; nutrient content database improved and increased consumption of the recommended modified recipe. These outcomes will lead to improved nutritional status of children below five years of age and the entire population.

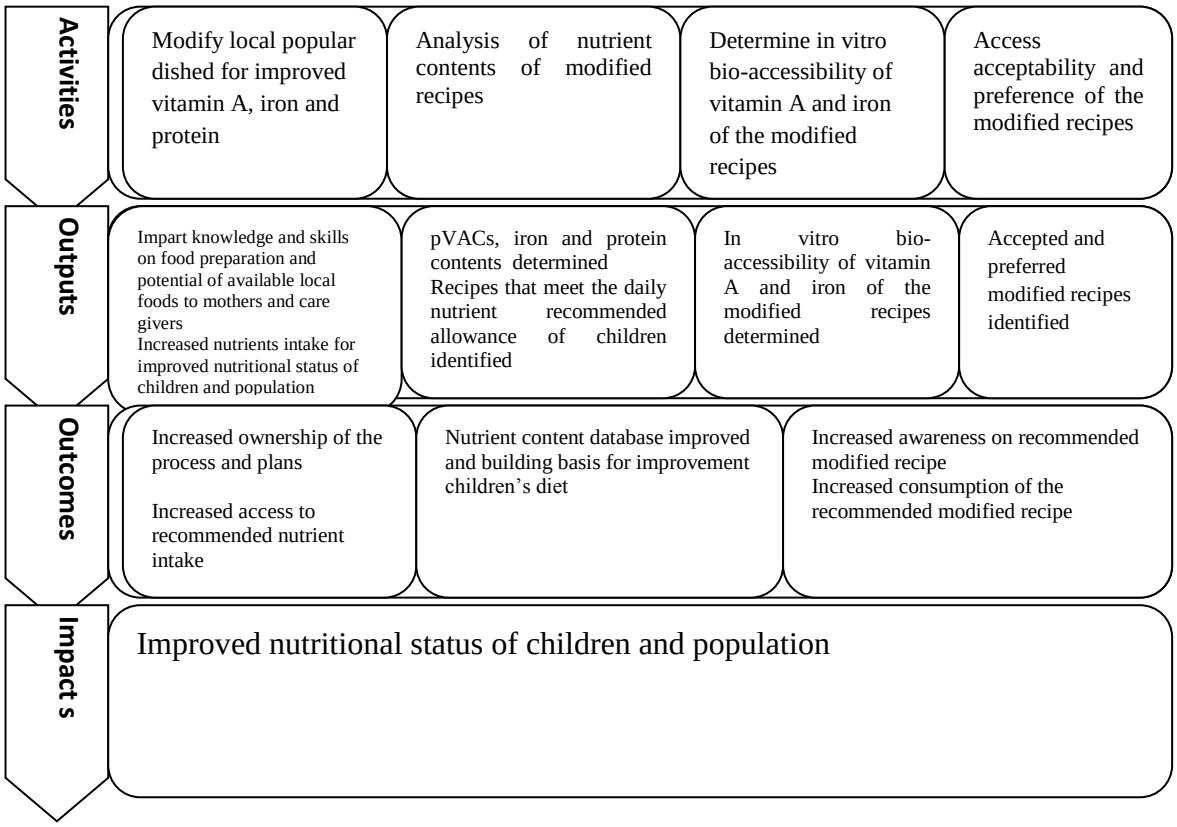
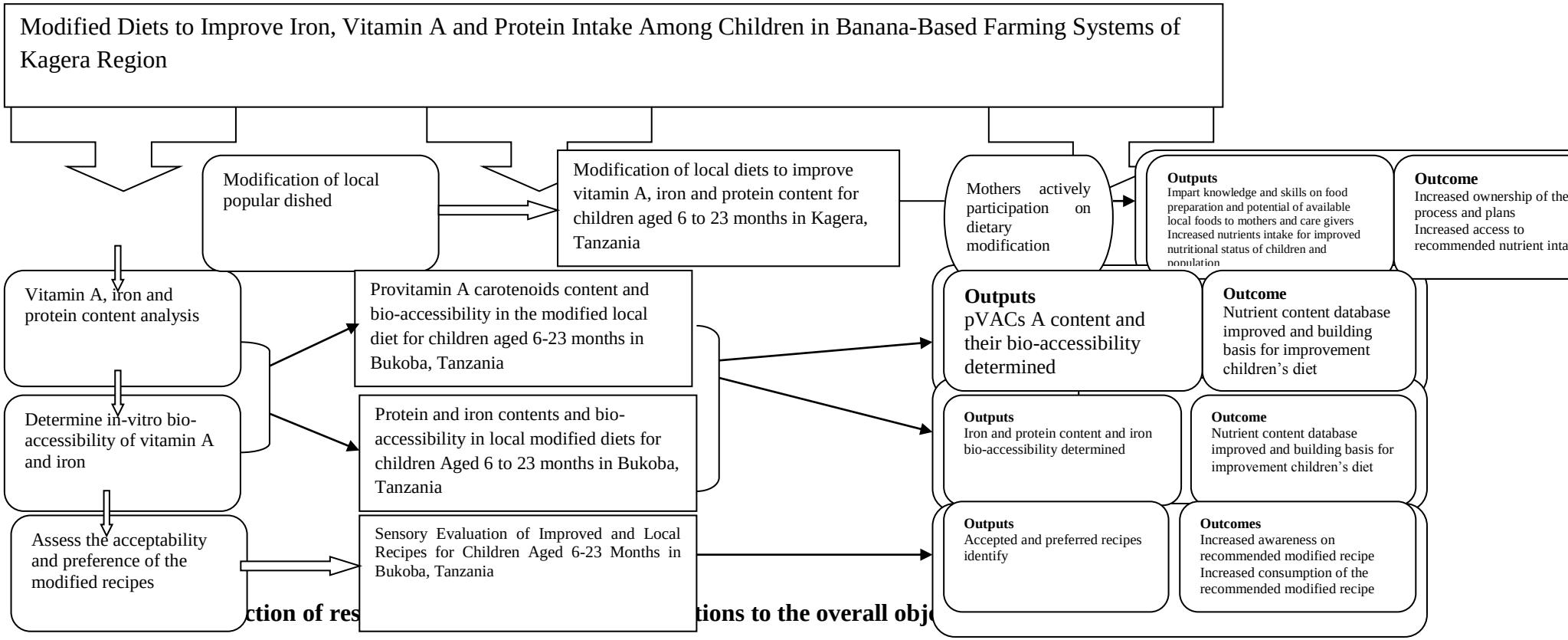


Figure 1.1: Conceptual representation of modified recipes, for increased nutrient intake,

1.11.4 Connection of research papers and their contributions

The connection of research papers and their contributions to the overall objective is presented in Figure 2. This study gives fundamental contribution of knowledge on dietary modification of local popular recipe for increased nutrient contents to meet recommended dietary nutrient intake for children below five years of age.


Modified Diets to Improve Iron, Vitamin A and Protein Intake Among Children in Banana-Based Farming Systems of Kagera Region
Modification of local popular dished
Modification of local diets to improve vitamin A, iron and protein content for children aged 6 to 23 months in Kagera, Tanzania
Mothers actively participation on dietary modification
Outputs
Impart knowledge and skills on food preparation and potential of available local foods to mothers and care givers
Increased nutrients intake for improved nutritional status of children and population
Outcome
Increased ownership of the process and plans
Increased access to recommended nutrient inta
Vitamin A, iron and protein content analysis
Provitamin A carotenoids content and bio-accessibility in the modified local diet for children aged 6-23 months in Bukoba, Tanzania
Outputs
pVACs A content and their bio-accessibility determined
Outcome
Nutrient content database improved and building basis for improvement children's diet
Determine in-vitro bio-accessibility of vitamin A and iron
Protein and iron contents and bio-accessibility in local modified diets for children Aged 6 to 23 months in Bukoba, Tanzania
Outputs
Iron and protein content and iron bio-accessibility determined
Outcome
Nutrient content database improved and building basis for improvement children's diet
Assess the acceptability and preference of the modified recipes
Sensory Evaluation of Improved and Local Recipes for Children Aged 6-23 Months in Bukoba, Tanzania
Outputs
Accepted and preferred recipes identify
Outcomes
Increased awareness on recommended modified recipe
Increased consumption of the recommended modified recipe
ction of res
tions to the overall obj

1.12 Material and Methods

1.12.1 Brief Description of the study area

The study was conducted in Izimbya ward of Bukoba district in Kagera region of Tanzania. According to the 2012 National census, Kagera region had a population of 2,458,023. The region is located in the north-western Tanzania, west of Lake Victoria. Bukoba district with the population of 418,493 is one of the 6 districts in the Region. The district covers an area of 7,780 square kilometres (NBS, 2011). The main farming system is banana based farming system usually intercropped with coffee and annual crops such as maize, cassava, beans (including common beans and red kidney beans), sweet potatoes (including orange fleshed sweet potatoes), groundnuts, bitter tomatoes, and yams. Other crops include; pumpkins, amaranths, and palm oil. Important livestock kept are cattle, goats, sheep, chicken, and ducks. All these crops and livestock provide important sources of micronutrients and protein at household level.

1.12.2 Study design

The study was divided in two parts. The first part was a cross sectional design which involved households with children below five years of age. It involved participatory modification of the local dishes and testing of both modified recipes and local dishes. The exercise was done by mothers or caregivers of children below five years of age in the selected households. The second part was the laboratory food analysis that was carried out at BOKU University, Vienna in Austria.

1.12.3 Selection of the study population

Kagera region was purposefully selected because is one of the oldest and sustainable banana based farming system in the country. Likewise Izimbya ward of Bukoba rural

district was also selected because it is a rural farming area with comparative high fertile land and malnutrition is a dominant problem (URT, 2014). Mothers (n = 50) with children aged between 6 and 23 months were randomly selected from Rugaze and Izimbya villages and participated in the recipe formulation exercise. They were from four sub-villages of Kakindo and Kyelima (Izimbya village) and Rugaze A and Kikagati (Rugaze village). In each village 25 mothers and/or caregivers were recruited for the exercise.

1.12.4 Data collection

1.12.4.1 Dietary modification

This part involved formulation of eight recipes to enhance intake of vitamin A, iron and protein for children below five years of age. Five recipes were from the traditional banana-based '*katogo'/'matoke'*[1] and three types were of porridges-based recipes. Diet modification process included participatory techniques whereby mothers gathered at one center per village. During discussions and with researcher guidance, mothers and/or caregivers were asked to suggest options of improving the porridge intended for children as well as to propose means of improving the local banana diets. The mixtures and proportions for the 8 recipes and their formulations were based on: WHO guideline; 70:30 carbohydrates: protein ratio. Recommended dietary allowance (RDA) for children aged between 6-24 months (this was the base for guidance for the calculation of mixture and proportions of recipes); Tanzania food composition table (TFCT) (used to estimate nutrient contents per ingredients before laboratory analysis. During diet modification process mothers/and or care givers with their children tested the modified dishes. Children accepted to eat the modified dishes. Children were involved in pre-testing in order to have an idea on their acceptance to eat the modified dishes.

[1] '*katogo'or 'matoke'* is a local recipe prepared from bananas, beans and other ingredients

To reduce phytic acid in cereals and legumes and enhance the content and bio-accessibility of micronutrients, beans were soaked and maize flour fermented for overnight (8-12hrs), addition of cooking oil for vitamin A absorption in all banana recipes was done. To increase food and nutrient intake the family and children's local popular dishes were made into puree. Food ingredients for cooking modified recipes were bought from the local market in Izimbya ward. Food ingredients for the modified recipes are shown in the Table 1.1

Table 1.1: Improved and local recipe name and their ingredients

Recipe name	Ingredients
'Katogo' steamed sardines	Local *'katogo'* with banana, bean and steamed sardines (*luompo''*)
'Katogo' stewed sardines	Local '*katogo*' with banana, bean and stewed sardines
'*Katogo*' dry beans	'*Katogo*' with *'nshakala'* (East African Highland Banana-EAHB) variety dry red kidney beans, amaranths, palm oil
'*Katogo*' fresh beans	*'Katogo*' with *'nshakala'* , fresh red kidney beans, pumpkin leaves, sunflower oil,
'*Katogo*' nuts pumpkin	'*Katogo*' with *'nshakala'* variety, pumpkin fruit, groundnuts flour,
OFSP porridge	Porridge made from fermented maize flour, Orange- fleshed sweet potato (OFSP), groundnuts, and sugar
Egg porridge	Porridge made from fermented maize flour, eggs, dry red beans, and sugar
Local maize flour porridge	Local porridge made from maize and water (*'obushesha')*

Data for price of food ingredients per kilogram were collected from two markets of Izimbya ward where most households buy food. A total of 40 vendors were involved. Price per kilogram per portion of formulated food ingredients was calculated to get the total cost per cooked portion, but excluding cost for processing. The processing costs were

excluded due to the fact that it is a normal routine for mother and/or caregivers to have time for preparing food for their children. The average cost was computed by excel software. Cooking methods and procedures for both modified '*katogo'* and porridge were described. Two banana varieties were used because the '*nshakala'* (East African Highland Banana-EAHB) is the local widely available variety while '*bira*'(Triploid hybrid of *Musa acuminata* and *Musa balbisiana*-AAB) variety has been recently introduced into the community as a rich source of vitamin A.

1.12.4.2 Nutrient contents analysis of the formulated recipes

Nutrients analysis process entailed collection of fresh food stuffs from the local market of Izimbya ward known in local name as '*mjajalo'* in Bukoba district of Kagera region, Tanzania. Food stuffs were packed and sent to Vienna, Austria at the Food Science and Biotechnology department of BOKU University for laboratory analysis. In Vienna, each raw ingredients was freeze-dried and stored at -24ºC until analysis (storage did not exceed 48 hours). To understand which food contributes more nutrients to the modified recipes, the raw ingredients were analysed for vitamin A, iron and protein content. All the recipes were prepared using local ingredients following the procedures described in the modified recipes (Mbela *et al*., 2018). After cooking, food samples were freeze-dried and stored at -24ºC until analysis and in vitro digestion. The modified recipes were both analysed in triplicate for vitamin A, iron and protein contents. Carotenoids contents were determined by High Performance Liquid Chromatography (HPLC) and protein content by Kjeldahl method using conversion factor of 6.25. Iron was analyzed by using atomic absorption spectroscopy (AAS); (AAnalyst 200, Perkin Elmer, Brunn am Gebirge, Austria).

1.12.4.3 Determination of in vitro bio-accessibility of vitamin A, and iron of modified recipes

The study intended to know what will be absorbed in the gut after digestion and to ascertain nutritional efficiency of the modified children's recipes, therefore in vitro bio-accessibility was conducted according to the methods described by Fernández-Garcia *et al.*, 2009. The modified recipes were assessed by in vitro bio-accessibility model (see Appendix 1). The same method was used by Patted (2010) in India to assess bio-accessibility of iron and zinc from green leafy vegetable based products. Bio-accessibility was calculated using the following formula:

$$bioaccessibility\ (\%) = \frac{content\ of\ bioaccessible\ fraction\ (\mu g/100\ g)}{total\ content\ of\ nutrient\ (\mu g/100\ g)} * 100$$

1.12.4.4 Preference of the modified recipes for children

Sensory evaluation was carried out to ensure that the modified recipes are tested for acceptability and preference by the consumer. Affective test was conducted for modified recipes only, the food recipes were organoleptically evaluated for preference test using 85 (females = 58, males = 27) untrained panelists. Descriptive test conducted for modified and unmodified diets. A panel of 41 (30= females, 11 = males) of breastfeeding mothers/and or caregivers and male and female from different sub-villages were recruited to evaluate the preference of the improved and local diets. The panelists were trained on how to use the reference scales to ensure consistency between them across repeated evaluations.

Preference test was carried out in two sites of Izimbya and Rugaze village in Izimbya ward in Bukoba district. The test was conducted in two days per village and it involved adults instead of the targeted recipients (children), because of their ability to objectively

evaluate the sensory attributes of the modified recipes. The hedonic 9 point ranking scale tests were employed to quantify the consumer acceptability/liking of the recipes (1='dislike extremely' and 9='like extremely') and 5 point ranking scale used to quantify the consume preference of the modified recipes (most preferred to least preferred (1= most preferred, 5= least preferred). The panelist included mothers and/or caregivers and non-breastfeeding mothers and male as representatives of the consuming population. The study used 88 females and 38 males with age range between 17 and 78 years making a total of 126 panelists. Food samples were coded with one number and two letters. The codes were clearly placed on the samples without being very prominent. All this were done to minimize biasing factors. Panelists were served with one table spoon per products and they were given 40 ml of porridge. Panelists were from Kakindo, Kyerima (Izimbya village) and Kikagati, Rugaze A and Rugaze B sub-villages (Rugaze village). Triploid hybrid of *Musa acuminata* and *Musa balbisiana* (AAB) *'bira'* banana variety were not included in the sensory test because during the test time no mature fruit bunches were available in the area. For laboratory test this variety was obtained from neighboring country, Burundi which has banana based farming systems like those of Bukoba district in Tanzania.

1.12.5. Ethical Clearance and Consenting

Permission to conduct the study in Kagera Region was obtained from regional, district and ward authorities, thus community local authority and individuals were informed about the study through village assembly meetings and a written consent to participate in the study was obtained from all participants. Similarly ethical clearance was obtained from the National Institute for Medical Research (NIMR) as per permit number NIMR/HQ/R.8a/Vol.IX2202.

1.12.6 Data analysis

Statistical analyses were performed using GenStat 14th Edition software. Means were separated by Turkey mean separation test using Least Significant Differences (LSD) at $p \leq 0.05$. Differences in mean content of total and individual iron, provitamin A Carotenoids and protein, from laboratory analysis were tested using one way analysis of variance (ANOVA). Determination of the significant difference between food samples using p-values was obtained by homogenous sets. Microsoft Excel 2007 was used to compute the data.

CHAPTER TWO

PAPER ONE

Modification of local Diets to Improve Vitamin A, Iron and Protein Contents for Children Aged 6 to 23 months in Kagera, Tanzania

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Figure 2.1: Nutrient contents by percentage RDA children for 12-23 months per modified '*katogo*' recipe per 100g (ingredients per modified recipe are given in Table 1)

Figure 2.2: Nutrient content by percentage RDA for children for 12-23 months of the modified porridge recipe per 100ml (ingredients per modified recipe are given in Table 1)

Table 2.1: Banana recipes composition and preparation technique

Table 2.2: Porridge recipe composition and preparation technique

Table 2.3: Energy and nutrient needs from complementary foods for breastfed children with average breast milk intake

Table 2.4: Costs for Ingredients and Modified Recipes July 2016

PAPER TWO

Provitamin A Carotenoids Content and Bio-accessibility in the Modified Local Diet for Children Aged 6-23 Months in Bukoba, Tanzania

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Table 2.1: Food recipes and their ingredients used in the study

Table 2.2: Provitamin A Carotenoids (pVACs) in Raw Food Ingredients µ/100g

Table 2.3: pVACs Content (in 100g) in the Optimized (modified) Diets for Children Aged 6 -23 months in Bukoba Rural

Table 2.4: Means of carotenoid (in the form of beta, alpha and 13-cis) content in the 8 modified recipes

Figure 2.1: Percentage RDA for pVACs in 100g for children aged 6-23months in different recipes analysed in this study

Table 2.5: Percentage retinol equivalent (RAE) RDA if 250g and 500g consumed Per day by a child aged between 6 to 12 months and 12 to 23 months, respectively.

Table 2.6: Amount of RAE after in-vitro digestion in 100g of optimized (modified) diets for children aged 6-23 months in Bukoba rural

Table 2.7: Bio-accessibility of pVAC of optimized (modified) diets for children aged 6-23 months in Bukoba rural

PAPER THREE

Protein and Iron Contents and Bioaccessibility in Local Modified Diets for Children Aged 6 to 23 Months in Bukoba, Tanzania.

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Table 2.1: Food recipes and their ingredients used in the study

Table 2.2: Mean iron and protein content in 100g in sample weight of raw ingredients

Table 2.3: Mean iron and protein contents and iron bio-accessibility (in 100g of edible portion) in the modified foods for children aged 6-23 months in Bukoba rural

Table 2.4: Means of protein and iron content in the 8 modified recipes at $p \leq 0.05$

Table 2.5: Percentage RDA if 250g and 500g consumed per day by a child aged between 6 to 12 months and 12 to 23 months respectively.

Figure 2.1: Percentage RDA for iron and protein in 100g for children aged 6-23 months (ingredients per recipes are given in Table 1)

PAPER FOUR

Sensory evaluation of improved and local recipes for children aged 6 to 23 months in Bukoba, Tanzania.

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Table 4.1: Local and improved recipes composition and preparation technique

Table 4.2: Characteristics of consumer panelists 1 (n = 41) and 2 (n = 85)

Table 4.3: Mean hedonic values of porridge recipes (improved and local) (n = 41)

Table 4.4: Sensory attributes of local and improved banana recipes (n = 41)

Figure 4.1. PCA Bi-plot showing systematic variation of recipes and liking of sensory attributes

Table 4.5: Median and rank sum values of local and improved recipes (n = 41)

Figure 4.2. PCA Bi- plot showing systematic variation of porridge recipes and liking of sensory attributes

Table 4.6: Median and rank sum of porridge local and improved recipes (n = 41)

Table 4.7: Sensory attributes of improved banana recipes (n = 85)

Table 4.8: Median and rank sum of improved banana recipes

Table 4. 9: Mean hedonic values of the improved porridge recipes

Limitation for the study

The modified diets were analysed for *in vitro* bio-accessibility. The effects of morbidities which are common problem in the age group 6-23 months were not taken care off. The in-vitro bio-accessibility cannot measure these effects. Children can consume nutrient rich diets but if she/he is sick nutrient absorption will be affected. Therefore in vitro bio-availability is needed. Bio-accessibility, which is the amount of an ingested nutrient that is potentially available for absorption, is dependent only on digestion and release from the food matrix. Bio-availability depends on digestion, release from the food matrix, absorption by intestinal cells, and transport to body cells. Therefore, to determine true bioavailability, appropriate animal experiments and observational studies on human subjects who will be consuming the modified diets are needed.

Challenges in Child Feeding Practices

i. Mothers have limited knowledge on preparation of diversified food for increased nutrient intake for their children and family, despite the abundance of micronutrient-rich foods in their respective communities.

ii. Mothers who are responsible for preparing food for their children have low economic status and low access to land therefore they cannot prepare nutritious food for their children

CHAPTER THREE

3.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

The study formulated and tailored local diets to increase intake of vitamin A, iron and protein for children aged 6 to 23 months. From the results estimated using Tanzania food composition table, red palm oil contributed high amount in recipe 1N (banana puree with *'nshakala*', dry red kidney beans, amaranths, palm oil). Dry red kidney beans contributed to the high amount of iron in the same recipe. Recipe 5N with '*nshakala'*, pumpkin fruit, and groundnuts flour) and recipe 2N *('nshakala,* fresh red kidney beans, pumpkin leaves, sunflower oil) they had enough vitamin A, iron and protein to meet RDA of children. Furthermore, recipe 1N *('nshakala'*, dry red kidney beans, amaranths, palm oil) had high amount of vitamin A, iron and protein. Orange fleshed sweet potato contributed significant amount of pVACs in porridge recipe 6OFSP. Bean and groundnuts were a good source protein and iron in porridge recipes. Egg in porridge recipes contribute to protein, iron and vitamin A in porridge recipe 8E. All the modified recipes meet the RDA for vitamin A, iron and protein. This is because they had more than 15%RDA for vitamin A, iron and protein for children.

One food can be a source of more than one nutrient. Different food ingredients were used as source for different nutrients.

These results might not give the true amount of some foods, because the TFCT does not differentiate the nutrient contents by food varieties. This stage of the study estimated the nutrient contents of the modified diets. The cost for preparing the modified diets is affordable and even low during bean season and high peak of banana harvest. The

estimated costs for the modified diets help mothers/caregivers and other stakeholders on costs implications of the diet.

Dietary modification stage followed by analysis of provitamin A carotenoids and iron with their bio-accessibility and protein content. Chronologically palm oil fruit and orange fleshed sweet potato showed high amount of provitamin A carotenoids (pVAC's). Recipe 5N had the highest content of pVACs whereby pumpkin fruit was the main source of vitamin A. Recipe 7B had low pVACs, whereby AAB *'bira' variety* was the main source of pVACs. Recipe 4B had high bio-accessibility. The bio-accessibility of pVACs ranged from 12.2% to 33.6% in the modified local diets. With the recently reported existence of banana varieties rich in vitamin A substituting the white-fleshed banana with the vitamin A rich banana could make significant contribution to vitamin A needs especially among communities in banana-based system and other communities in Africa with the same settings. The modified diets are good source of vitamin A for children as well as adults combating Vitamin A deficiency. Results suggest that it is very important to take into account the estimation of dietary source of vitamin A and their pVACs bio-accessibility to meet nutritional requirements of children aged 6-23 months.

Fresh and dry red kidney beans were a good source of iron. Groundnut and dry red kidney bean showed relatively high protein content. Banana had the lowest iron and protein content. In order to enhance intake of iron and protein in the diet; consumption of eggs, red kidney beans, groundnut should be recommended and generally food diversity should be given priority. Recipe 1N with composition of EAHB *'nshakala'* variety, dry red kidney beans, amaranths, palm oil had higher iron content than other diets. Recipe 5N had higher protein content with groundnut as the main source of protein in the recipe.

Fermented porridge recipes had more bio-accessible iron than banana recipes. Thus cereal fermentation and food diversity (mixture orange-fleshed sweet potato, fermented maize flour, and groundnut flour) would contribute significantly to the bio-accessibility of iron in recipes.

Therefore, both methods (nutrient estimation by using the Tanzania food composition table and laboratory analysis) showed that bean is a good source of iron and protein; fresh red kidney beans had more iron compared to dry red kidney beans; ground nuts are a good source of protein. Hence, common beans can be considered a good source of iron and help fight anaemia in low-income populations, especially in infants and lactating and pregnant women. For that reason production and consumption of kidney bean, groundnuts, red palm oil and orange fleshed sweet potato should be promoted to increase nutrient intake.

Feeding children with the modified recipes at different time of the day will diversify their nutrient intake. The modified recipes based on locally available and affordable ingredients have a potential to meet RDAs of vitamin A, iron and protein for children aged 6 to 23 months in the banana-based system and other communities in Africa with the same settings. Food diversity and seasonality was considered to enhance mothers/community to plan on availability of nutrient rich foods. With regard to sensory evaluation the improved recipes as complementary foods which are nutrient-dense were accepted by the panelists. Banana recipes were preferred to local recipes. Mothers liked the new recipes and were willing to adopt and continue using them to feed their children because they are prepared from local foods which are easily available, culturally appropriate and acceptable. Consumption of the improved complementary foods by children aged 6-23 months could help to minimize the problem of vitamin A, iron and protein energy malnutrition. Thus,

the community needs nutrition education for better choice of healthy foods for their children.

Participatory approach led mothers to own the modification process and plans. The locally available modified foods have an impact to increase nutrient intake by children and population. The study helps the community to have access to and consumption of nutrient rich diets. The study has added value to nutrient content database for building basis for improvement children's diet.

3.2 Recommendations

i. Food composition table alone is not enough to provide information about nutrient contents of cooked recipes; rather it is good for estimation for dietary formulation before laboratory analysis. Therefore laboratory analysis is important to be conducted to correctly quantify the nutrient content of improved complementary foods.
ii. Nutrition education on food, dietary diversity and food ingredients for a particular recipe with their health benefits is important for the community to make appropriate choices of food combination for healthy diets. In addition, communities need to be guided on better food choice especially for children.
iii. Participatory approach for nutrition intervention can increase ownership of the practice and sustainability. Therefore the study suggests that mothers and/or care provider and male at household level to be included in the implementation process of the any nutrition intervention stage.
iv. Interventions to test effectiveness and /or impact of the developed modified recipes in improving micronutrient status of children are necessary.

v. Production and consumption of nutrient rich foods and/or bio-fortified food crops such as iron and zinc rich bean, orange fleshed sweet potato, orange maize, groundnuts, red palm oil should be promoted to increase nutrient intake by population. Policy makers have a chance to help on this.

vi. Sensory evaluation is an important component in developing complementary food. The recipes might be energy- and nutrient-dense and affordable but if not accepted by the intended communities due to some reasons like cultural or social or sensory aspects, it will not be accepted or consumed. It is therefore recommended that sensory evaluation must be considered during and after modification of recipe.

vii. Compilation and publication of recipe book is very important for sustainability of the practice and dissemination of information which contributes to increased consumption of nutrient rich foods by the community.

viii. This study approach can be scaled out to non-banana farming systems and other area in Tanzania or communities with under- nutrition and macronutrient deficiency problem.

ix. For future studies it is recommended to devise a sensory evaluation tool of the children too to corroborate the findings by adults.

Annex 1: Picture for dietary modification and sensory evaluation

Mothers with their child taking photo with their kids before training on dietary improvement at Rugaze A villages in Bukoba rural district in Kagera region, Tanzania

Mothers with their children during trainees on dietary diversity and modification at Izimbya village in Bukoba rural district in Kagera region, Tanzania

Some ingredients and preparation of ingredients at Rugaze A village

Preparation of pumpkin for making banana recipes at Izimbya village

Preparation of groundnuts flour for porridge and banana recipes

OFSP preparation for porridge making

Ingredients for banana recipe ready to cook

Addition of palm oil to banana recipe

Mothers receiving some instructions during dietary modification at Izimbya and Rugaze A villages

Mothers and/or care givers testing recipes during dietary modification at Izimbya and Rugaze A villages

Discussion with nutritionists on diet modification

Some food prepared after incorporation of comments from nutritionist and other stakeholders

Pictures Preparation of sensory evaluation samples

Preparation of food ingredients for sensory evaluation by researchers at Izimbya and Rugaze A villages

Researchers cooking food sample for sensory evaluation at Izimbya and Rugaze A villages

Food sample ready for serving for sensory evaluation by panelists at Izimbya and Rugaze A villages

Preparation of local popular banana with steamed sardines recipe (”l*uompo*”) for sensory test

Local popular recipe “banana with stewed sardines”

Preparation for training the panelist on preference test

Training of panelist for sensory test at Izimbya and Rugaze A Villages

Banana-based and porridge recipes sample ready for testing at Izimbya and Rugaze A villages

Panelist and researcher during sensory test at Izimbya and Rugaze A villages

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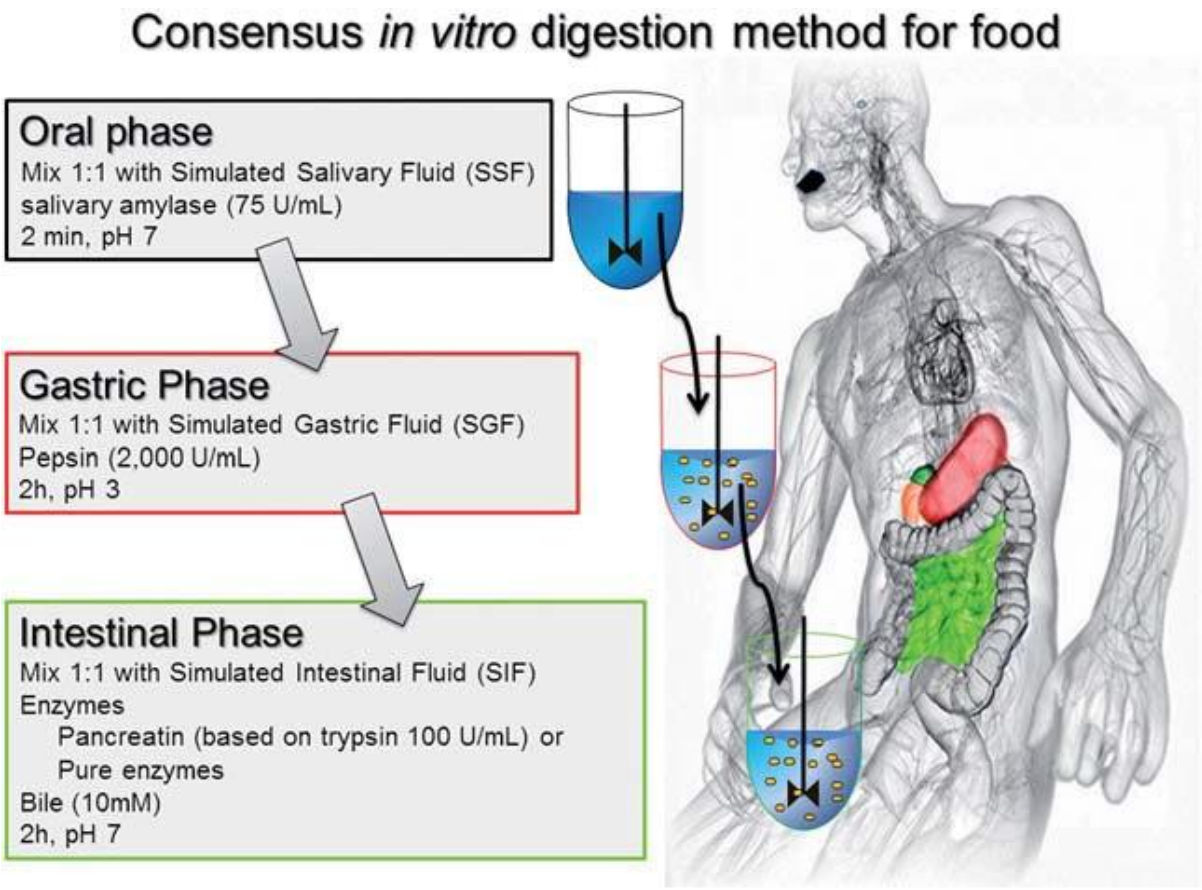
APPENDIXES

Appendix 1: *In vitro* digestion model



Minekus *et al.*, 2014

Appendix 2: Energy content

Food recipe	Protein (kcals)	Fat (kcals)	Carbohydrate (kcals)	Total energy (kcals) in 100g	kcals/250g	kcals/500g
IN	13.76	12.60	381	407	1018	2035
2N	11.04	9.00	385	405	1013	2025
3B	13.37	13.50	381	408	1019	2038
4B	11.19	8.10	385	405	1011	2023
5N	15.14	31.50	371	418	1044	2088
6OFSP	14.81	36.90	369	421	1051	2103
7B	13.90	36.00	370	420	1050	2100
8E	12.06	11.70	383	407	1016	2033

Appendix 3: Consent form dietary modification

CONSENT FORM

Investigator: Domina Esther N. Mbela, Sokoine University of Agriculture, dominankuba@yahoo.com

Title of Study: Enhancing Availability and Utilization of Iron, Vitamin A and Protein rich Foods for Children in Banana Based Farming Systems of Kagera Region

Introduction:

Micronutrient and protein deficiencies are among the major public-health concerns in Tanzania. These deficiencies mainly affect children below five years of age and pregnant women. Studies show that dietary diversification/modification can help to reduce micronutrient and protein deficiencies in the community. This study will develop and do chemical analysis of modified foods focusing on vitamin A, iron and protein. Recipe modification will be done based on food nutrient rich sources available in your community. No new food variety will be used during modification. This study will empower individuals and households members with knowledge on diet modification to enable them to develop quality diets using locally available foods.

Purpose of Study

We would like to humbly invite you to participate in the dietary modification process. You will also be asked your opinion on how to improve the local popular dishes in order to enhance intake of iron, vitamin A and protein. We want to establish the best options for improving dietary diversity as well as nutrition and health status of children 6 months to two years of age in this _____ village.

Cultural values

Your cultural and/or religious values will be observed, you are free to ask any question for further clarification.

Risks and Precautions

No risks are involved testing food. These are food you are used too. Because it is all found here in your community. However, if you have any food allergy let us know before testing the food.

Confidentiality

Any records relating to your participation will be strictly confidential. Your names will not be used in any reports from the study and you will receive a copy of this consent form.

Other information

- Participation to this study is entirely voluntary
- You may withdraw from participating in the study at any time. No risks can be foreseen.
- Please feel free to ask any questions or any clarification after you have read and had the consent form explained to you.

Participant statement

I the undersigned have understood the above information, which has been fully explained to me by the investigator, I had the opportunity to ask questions, all of which were answered to my satisfaction. I understand that at any time I may withdraw from this study without giving reason.

I agree to take part in this study

Participant's Name: ……

Participant's

signature…….Date……..

Investigator's Name…….

Signature……..Date…….

Appendix 4: Consent form Sensory evaluation

CONSENT FORM

Investigator: Domina Esther N. Mbela, Sokoine University of Agriculture, dominankuba@yahoo.com

Title of Study: Enhancing Availability and Utilization of Iron, Vitamin A and Protein rich Foods for Children in Banana Based Farming Systems of Kagera Region

Introduction:

Micronutrient and protein deficiencies are among the major public-health concerns in Tanzania. These deficiencies mainly affect children below five years of age and pregnant women. Studies show that dietary diversification/modification can help to reduce micronutrient and protein deficiencies in the community. This study will develop and do chemical analysis of modified foods focusing on vitamin A, iron and protein. Recipe modification was done based on food nutrient rich sources available in your community. No new food variety used during modification. The study will test the modified recipes to determine the preference of the improved dishes as compared to the original dishes. This study will empower individuals and households members with knowledge on diet modification to enable them to develop quality diets using locally available foods.

Purpose of Study

We would like to humbly invite you to participate in this sensory evaluation test that is looking at various recipes, new and old with a view of establishing the best options for

improving dietary diversity as well as nutrition and health status of children 6 months to two years of age in this _____ village.

Procedures

If you grant consent to participate in this study, you will be asked to test food recipes. You will be provided with a total of five dishes prepared by different recipes and grouped into two i.e. Porridges and Katogo purées and you will be requested to further provide your honest opinion on each of the dishes based on four key attributes namely:

- Colour (your impression of the Appearance)
- Texture (Mouth feel (Softness/ smoothness)
- Taste (your opinion on flavour)
- Aroma (your impression on smell/odour)
- Overall liking (Your overall rating of the dish based on the above four attributes)

Your rating will follow a simple 9-point ranking scale with the lowest point on the scale rated as '**Dislike extremely'** and the highest point as **'Like Extremely'**

I will ask you to humbly provide information about your perception on sample dishes provided.

Benefits

By participating in this study, after the testing exercise, explanation on the recipe ingredients and cooking procedures will be given to you. This will help you to prepare the same recipe at your home and will improve your dietary diversity as well as nutrition and health status of you family.

Cultural values

Your cultural and/or religious values will be observed, you are free to ask any question for further clarification.

Risks and Precautions

No risks are involved testing food. These are food you are used too. Because it is all found here in your community. However, if you have any food allergy let us know before testing the food.

Confidentiality

Any records relating to your participation will be strictly confidential. Your names will not be used in any reports from the study and you will receive a copy of this consent form.

Other information

- Participation to this study is entirely voluntary
- You may withdraw from participating in the study at any time. No risks can be foreseen.
- Please feel free to ask any questions or any clarification after you have read and had the consent form explained to you.

Participant statement

I the undersigned have understood the above information, which has been fully explained to me by the investigator, I had the opportunity to ask questions, all of which were answered to my satisfaction. I understand that at any time I may withdraw from this study without giving reason.

I agree to take part in this study

Participant's Name: ……

Participant's

signature…….Date……..

Investigator's Name…….

Signature……..Date…….

Appendix 5: Sensory evaluation questionnaires for modified diets

Enhancing Availability and Utilization of Iron, Vitamin A and Protein Rich Foods for Children in Banana Based Farming Systems of Kagera Region

SENSORY EVALUATION QUESTIONNAIRES FOR **MODIFIED DIETS** IN …….. VILLAGE

Welcome and thank you for participating

Introduction:

Hello, my name is _____ and I work with *Bioversity International*. We would like to humbly invite you to participate in this sensory evaluation test that is looking at various recipes, new and old with a view of establishing the best options for improving dietary diversity as well as nutrition and health status of children 6 months to two years of age in this _____ ward.

a) Acceptance test:

Before you start, rinse your mouth using the water provided and sip little to clear your throat. **REPEAT** the same exercise after each dish and before embarking on the next exercise… the second, third up to the 5th dish. The definitions of each sensory attribute are provided in the tool below. The symbols provided simulate your perceptions.

Note that there are 5 dishes and you will not be provided standard serving but a portion of the dish adequate to establish its sensory attributes. We shall begin with Katogo purées then end with the porridge.

Date of interview (dd/mm/yyyy)	**Study site: (village)**	**Respondent Name**
|__|/|___|___|/ 2016	|_____|	|_____|
Gender	**Age** (YEARS)	**Level of education**
|_M__||__F_|	|___|___|	No formal education|___| pre- primary education|___| Primary education|___| Secondary education|___| Post-secondary education|___|
Relationship to index child/children	**Number /age (months) of children < 5 under his/her care**	**Main Occupation of caregiver (e.g. Farmer, formally employed, informally employed etc.)**	**Residence (Sub-village)**

Mother|___| Father|___| Grand Mother|___| Others (- specify e.g. guardian)…….|___|	Child 1-|___| Child 2-|___| Child 3-|___|	_____ _	_____ ____

Tick the correct answer

Starting time……..		**Food sample CO**							
FOOD ATTRIBUTE									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour: (Look at the colour of the dish very well)									
Aroma: (Before you test, smell for the distinct odour of the dish)									
Taste (Put a scoop or sip in your									

mouth and determine the flavour of the food/dish)- repeat it twice to be sure									
Texture: (Mouth feel when chewing turning by your tongue or swallowing a scoop and sip, determine Softness / smoothness of dish sample)									
Overall liking (acceptability) (Taking into considerations the above attributes rank the dish sample to your liking).									
Comments your choice									
Food sample OD									

	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability)									
Comments your choice									
Food sample EO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour:									

Aroma									
Taste									
Texture:									
Overall liking (acceptability)									
Comments your choice									
Food sample FO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									

Overall liking									
Food sample HO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability)									
Comments your choice									

b) The Preference Test.

Kindly make your preferred choice for Katogo/banana and porridge based dishes presented below based on the four key sensory attributes namely:

- Colour(your impression of the Appearance)
- Texture (Mouth feel (Softness/ smoothness)
- Taste (your opinion on flavour)
- Aroma (your impression on smell/odour)

As a representative of the consuming population (under five children), please taste the samples from left to right, in the order presented, and rank them from most preferred to least preferred (1= most preferred, 5= least preferred). You are allowed to re-taste the samples after trying them all. Remember to rinse your mouth with water in between the samples.

N.B. You will have to make a decision, ties are not allowed. (However, if you find it hard to rank the samples, please note it along with your comments.)

Ranking (1-5)

Banana purée and Katogo We have sample CO, DO and EO. For porridge we have FO and OH rank them from 1-5.

Banana purées and Katogo	**Rank based on preference**	**Comments (kindly provide one comment why you ranked 1 the dish and for the rest why you did not)**
Sample CO		
Sample DO		
Sample EO		
Porridge Dish.		
Sample FO		
Sample HO		

Do you in general like ……..? Yes No

Please give your comments on the tasting session, the questionnaires, etc. In that way improvements can be made.

Ending time……

Appendix 6: Sensory evaluation questionnaires for popular and modified diets

Enhancing Availability and Utilization of Iron, Vitamin A and Protein Rich Foods for Children in Banana Based Farming Systems of Kagera Region

SENSORY EVALUATION QUESTIONNAIRES FOR **POPULAR AND MODIFIED DIETS** IN …… VILLAGE

Welcome and thank you for participating

Introduction:

Hello, my name is _____ and I work with *Bioversity International*. We would like to humbly invite you to participate in this sensory evaluation test that is looking at various recipes, new and old with a view of establishing the best options for improving dietary diversity as well as nutrition and health status of children 6 months to two years of age in this _____ ward.

b) Acceptance test:

Before you start, rinse your mouth using the water provided and sip little to clear your throat. **REPEAT** the same exercise after each dish and before embarking on the next exercise… the second, third up to the 8th dish. The definitions of each sensory attribute are provided in the tool below. The symbols provided simulate your perceptions.

Note that there are 8 dishes and you will not be provided standard serving but a portion of the dish adequate to establish its sensory attributes. We shall begin with Katogo purées then end with the porridge.

Date of interview (dd/mm/yyyy)	**Study site: (village)**	**Respondent Name**	
|__|/|___|___|/ 2016	|_____|	|_____|	
Gender	**Age** (YEARS)	**Level of education**	
|_M__||__F_|	|___|___|	No formal education|___| pre- primary education|___| Primary education|___| Secondary education|___| Post-secondary education|___|	
Relationship to index child/children	**Number /age**	**Main Occupation of caregiver (e.g.**	**Residence (Sub-village)**

	(months) of children < 5 under his/her care	**Farmer, formally employed, informally employed etc.)**	
Mother|___| Father|___| Grand Mother|___| Others (- specify e.g. guardian)…….|___|	Child 1-|___| Child 2-|___| Child 3-|___|	_____	_____ ___

Tick the correct answer

Starting time……..		**Food sample AO**							
FOOD ATTRIBUTE									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour: (Look at the colour of the									

dish very well)									
Aroma: (Before you test, smell for the distinct odour of the dish)									
Taste (Put a scoop or sip in your mouth and determine the flavour of the food/dish)- repeat it twice to be sure									
Texture: (Mouth feel when chewing turning by your tongue or swallowing a scoop and sip, determine Softness / smoothness of dish sample)									
Overall liking (acceptability) (Taking into considerations the above attributes rank the dish									

sample to your liking).									
Comments your choice									
Food sample BO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability									

Comments your choice									
Food sample CO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability									
Comments your choice									

Food sample DO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability									
Comments your choice									
Food sample EO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely

					dislike				
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability									
Comments your choice									
Food sample FO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									

Taste									
Texture									
Overall liking (acceptability									
Comments your choice									
Food sample HO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability									

Comments your choice									
Food sample IO									
	□ Dislike extremely	□ Dislike very much	□ Dislike moderately	□ Dislike slightly	□ neither like nor dislike	□ Like slightly	□ Like moderately	□ Like very much	□ Like extremely
Colour									
Aroma									
Taste									
Texture									
Overall liking (acceptability									
Comments your choice									

b) The Preference Test.

Kindly make your preferred choice for Katogo/banana and porridge based dishes presented below based on the four key sensory attributes namely:

- Colour(your impression of the Appearance)
- Texture (Mouth feel (Softness/ smoothness)
- Taste (your opinion on flavour)
- Aroma (your impression on smell/odour)

As a representative of the consuming population (under five children), please taste the samples from left to right, in the order presented, and rank them from most preferred to least preferred (1= most preferred, 5= least preferred). You are allowed to re-taste the samples after trying them all. Remember to rinse your mouth with water in between the samples.

N.B. You will have to make a decision, ties are not allowed. (However, if you find it hard to rank the samples, please note it along with your comments.)

Ranking (1-5)

Banana purée and Katogo We have sample AO, BO, CO, DO, and EO. For porridge we have FO, HO and IO rank them from 1-5.

Banana purées and Katogo	**Rank based on preference**	**Comments (kindly provide one comment why you ranked 1 the dish and for the rest why you did not)**
Sample AO		
Sample BO		
Sample CO		
Sample DO		
Sample EO		
Porridge Dish.	**Rank based on preference**	**Comments (kindly provide one comment why you ranked 1 the dish and for the rest why you did not)**
Sample FO		
Sample HO		
Sample IO		

Do you in general like ……..? Yes No

☐ ☐

Comments:

Please give your comments on the tasting session, the questionnaires, etc. In that way improvements can be made.

Ending time……