EFFICACY OF QUALITY PROTEIN MAIZE-BASED SUPPLEMENTARY FOODS ON REHABILITATING UNDERNOURISHED CHILDREN IN MVOMERO DISTRICT, TANZANIA

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A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2016

EXTENDED ABSTRACT

Child undernutrition is a persistent problem in Africa, especially in areas where the poor largely depend on starchy staples with limited access to diverse diets. Despite the fact that Tanzania has given attention to undernutrition, the prevalence rate is still high. Inappropriate feeding practices may account for approximately one-third of undernutrition. Traditional supplementary feeding of infants and young children in Tanzania and much of Africa is commonly based on maize porridge, usually made from plain maize. Low energy density of maize-porridge, linked with its low quality protein, low micronutrients and low lysine and tryptophan, make maize porridge a poor supplementary food for infants and young children. One intervention in mitigating these limitations was biofortification of maize initiated by International Maize and Wheat Improvement Center. The intervention involved developing maize cultivars with protein high in lysine and tryptophan, known as quality protein maize. Despite the fact that utilization of quality protein maize as part of a family diet is growing steadily in Tanzania, there is little information on the use of quality protein maize in supplementary feeding. The current study therefore, was designed to fill this gap by evaluating the efficacy of quality protein maize-based composite supplementary foods on rehabilitation of undernourishedchildren in Mvomero District. Three composite diets were prepared from quality protein maize, namely quality protein maize-soybeans; quality protein maize-soybeans-common beans and quality protein maize-soybeans- cowpeas. Two control diets were prepared from plain quality protein maize and common maize. These diets were extruded atan average temperature of 125^{o}C with retention time of 2 minutes. The formulations were made to meet the greatest amino acid score and the desired amount of energy and fat according to the FAO/WHO (1985) recommendation for pre-school children. The third control diet (Chesta®) used for rat was made from maize, soybeans, fish, bone and blood meal. Albino rats were used in evaluating the protein quality of the formulations, whereas 150 children (2-5 years) were used to evaluate the rehabilitation potential of the formulations from undernutrition. Results showed that, protein digestibility-corrected amino acid scores were 80% (quality protein maize-soybeans-common beans), 80% (quality protein maize-soybeans-cowpeas), 87% (quality protein maize-soybeans), 100% (common maize alone) and 98% (quality protein maize). Baseline study of the undernourished children showed that pre-lacteal feeding was common in the study area (40%). Children were introduced to complementary foods too early (<6 months) and plain maize porridge was the first food to be introduced. Mostchildren (57.2%, n=86) were on the lowest tercile (≤3 food groups per day) of dietary diversity score. Furthermore, logistic regression analysis revealed that, family's source of income and breastfeeding frequency were among the factors that influenced stunting of children significantly. Other factors such as age of the child, age at introduction of complementary food, dietary diversity score ≤3 food groups, consumption of animal foods, family size and use of non- potable water were also risk factors that predicted child stunting. A randomized longitudinal study with intention to rehabilitate the undernourished children showed that, quality protein maize-based diets had positive effects ($p<0.05$) on weight, height, weight-for-age, height-for-age, weight-for-height Z-scores and haemoglobin concentrations but not on mid-upper arm circumference. Children consuming conventional maize porridge progressively faltered in growth with weight-for age decreasing from -1.9 to -2.1 SD, height-for age from -2.0 to -2.9 SD, weight for height from -1.2 to -1.9 SD and haemoglobin levels decreasing from 10 to 9.9 (g/dL). During the 16 weeks of rehabilitation, 68% (n=27) of children receiving quality protein maize-soybeans-common beans diet grew back to normal weight for age Z-score of ≤ -2SD. For children receiving quality protein maize-soybeans-common beans diet, 50% (n=23) of the undernourished children grew back to normal weight for age and only 19.5% (n=9) of the children receiving conventional porridge diet grew back to normal weight for age Z-score. Quality protein maize-soybeans-common beans diet had higher potential to support growth than the other diets. The growth velocities for children in various groups were 0.39 g/month for quality protein maize-soybeans-common beans, 0.28 g/month for quality protein maize-soybeans-cowpeas and 0.13 g/month for conventional maize diets. Quality protein maize-soybeans-common beans and quality protein maize-soybeans-cowpeas met RDA for both energy (360 kcal) and protein (16 g) for children 2-5 years. Amino acid scores for quality protein maize-based diets were higher than the recommended amino acid scores (≥65%) for optimal growth of children. Concentrations of fumonisin B1 and total fumonisin were 1687.82 and 1717.16 μg/kg in plain quality protein maize and 1625.08 and 1745.22 μg/kg in plain common maize, respectively. These values were all above the maximum tolerable limit of 1000 μg/kg recommended by the European Commission. Consumer evaluation revealed that, quality protein maize-soybeans-common beans porridge was rated higher ($p<0.05$) for aroma and taste than quality protein maize-soybeans-cowpeas and conventional porridge. All the porridges (quality protein maize-soybeans-common beans; quality protein maize-soybeans-cowpeas and conventional porridge), were however equally acceptable ($p>0.05$) by the test panel. Experimental porridge was distinguished in principal component 1 by the sensory attributes of colour, oiliness, aroma, sweetness, liking and aftertaste from the control. However, all the porridges could be described by viscosity, sweetness and colour in principal component 2. Two diets quality protein maize-soybeans-common beans and quality protein maize-soybeans-cowpeas showed the greatest potential for rehabilitation of undernourished children. Public awareness on the use of quality protein maize as an ingredient in making complementary food is therefore recommended.

Key words: quality protein maize, supplementary feeding, rehabilitation, undernutrition

LIST OF PUBLICATIONS

1. Maseta, E., Mosha, T.C.E., Nyaruhucha,C.N.andLaswai, H. (2016). Nutritional quality of quality protein maize-based supplementary foods. *Journal of Nutrition and Food Science (Accepted).*

2. Maseta, E., Mosha, T.C.E., Laswai, H. and Nyaruhucha, C.N. (2016). Infant and young child feeding practices and the risk factors associated with stunting among children in rural Tanzania.*African Journal of Food, Agriculture, Nutrition and Development (Submitted).*

3. Maseta, E., Mosha, T.C.E., Nyaruhucha, C.N. and Laswai, H. Efficacy of Quality Protein Maize-based Supplementary Foods for Rehabilitation of Undernourished Children. *Tanzania Journal of Health Research (submitted).*

4. Maseta, E., Mosha, T.C.E., Laswai, H. and Nyaruhucha, C.N. (2016). Nutritional quality, mycotoxins and antinuntritional factors in quality protein maize-based supplementary foods for children in Tanzania.*International Journal of Sciences* 5:37-44.

5. Maseta, E., Mosha, T.C.E., Nyaruhucha, C.N. and Laswai, H. (2016). Sensory evaluation of extruded quality protein maize-based supplementary foods. *African Journal of Food Science* 10 (7): 105-116.

DECLARATION

I,ElinaMaseta, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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ACKNOWLEDGEMENTS

I express my sincere gratitude to the Almighty God for His guidance and protection during my study at Sokoine University of Agriculture (SUA). I am also grateful to the World Bank and The Open University of Tanzania for the financial support to undertake this study.

I am grateful to all people who contributed to the successful completion of this thesis. Though I may not be able to mention them all my sincere gratitudes should go to all who made this thesis a reality. Special thanks go to my supervisors who ensured that I reach this end. I particularly thank Prof. Theobald C.E. Mosha who assisted from the conceptualization of the researchable idea to the submission of this work. Prof.Mosha, thank you for your assistance in diverse ways and for your guidance anytime I needed and that you were always there to guide. I also thank Professor Henry Laswai for your guidance in my studies. You were such a good father who could not hesitate to assist his daughter. I also extend my gratitude to Professor Cornelio Nyaruhucha for his timely comments and inputs that I received all the time during my studies. I really appreciate the kind of treatment you provided to me. I am also grateful to Dr. Dale Romsos of Michigan State University for support in conducting amino acid analysis of the food formulations used for this study.

I also acknowledge the support provided by the staff of the Pest Management and Control Centre, SUA when I was doing experiments in their laboratory. I am also thankful to my research comrades in the Department of Food Technology, Nutrition and Consumer Sciences, SUA for their guidance and encouragements. Special thanks should go to Zahra Majili,Dr. Richard Mongiand Mr. Mufuifor the support theyextended to me during my study. I also appreciate the support from Dr. ZubedaMduluma in making sure that I got the right variety of quality protein maize for my study. I deeply thank all the women and children from Magubike and Turiani, Morogoro who agreed to participate in the study.

Many thanks should go to Dr. Leonard Fweja for his advice and support that he provided to me during my study. Special thanks go to Dr. MatobolaMihale for his time support and assistance during my study.

I am also deeply indebted to FestoOmpeshi and his family for accommodating me and sometimes with my children, especially at circumstances I had no time to visit them in Dar es Salaam. You truly made sure that we had a pleasant stay here in Morogoro under your custody. To Otieno's family, thank you for being there for our family, you really took your precious time to make sure that my children were happy despite my absence.

Last but not least, I would like to thank my lovely husband Alex Chiliko and my children Sospeter and Socelyne for their patience, support, encouragement and love during my study.

DEDICATION

This work is dedicated to my mother PaskaliaSenyeMasetawho laid the foundation of my education. Her tireless struggles made me what I am today.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
Cas	Cassava flour
CC	Control diet known as Chesta®
CIMMYT	International Maize and Wheat Improvement Center
CM	Conventional Maize
CP	Conventional Porridge
CRD	Complete Randomized Design
FAO	Food and Agriculture Organisation
GLM	General Linear Model
HAZ	Height for-Age Z-Scores
IDDS	Individual Dietary Diversity Score
LSM	Least Square Means
MTL	Maximum Tolerable Limit
NAR	Nutrient Adequate Ratio
NIMR	National Institute for Medical Research
ns	not significant
p	Probability
PCA	Principal Component Analysis
PDCAAS	Protein Digestibility Corrected Amino Acid Score
QBCF	Quality Protein Maize-Based Complementary Food
QPM	Quality Protein Maize
QQ	Quality Protein Maize Diet
QS	Quality Protein Maize-Soybean

QSB	Quality Protein Maize-Soybean-Common Beans
QSC	Quality Protein Maize-Soybean-Cowpeas
RCH	Reproductive and Child Health
RDA	Recommended Daily Allowance
SUA	Sokoine University of Agriculture
WAZ	Weight-for-Age Z-Scores
WHO	World Health Organisation
WHZ	Weight-for-Height Z-Scores
2SD	95% of values are less than two standard deviations away from the mean value

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Maize (*Zea mays)* is an important staple food in Sub Saharan Africa. It is an important source of energy, protein, and other nutrients for both human and livestock. In animals, maize is used as a feed ingredient in making varieties of animal feeds. Maize accounts for up to 60% of the daily human protein supply (Sofi *et al.,* 2009). It contains 4–10% protein, 2-4% fat and some of the important vitamins and minerals (Enyisi *et al.,* 2014). Common Maize (CM) varieties are deficient in two essential amino acids, lysine and tryptophan (Serna-Saldivar *et al.,* 2008; Mila´ N-Carrillo *et al.,* 2007) which are nutritionally essential for humans and animals. Despite this limitation, maize is widely used as the main ingredient in complementary foods (CF) for children. In areas where diets consist largely of maize, protein deficiency is common.

To address this problem, in the year 1960s, researchers from International Maize and Wheat Improvement Center (CIMMYT) successfully developed a maize variety, higher in the deficient amino acids lysine and tryptophan (Shobha *et al.,* 2011;Akalu *et al.,*2010). This maize variety was called quality protein maize (QPM). This QPM has similar characteristics to CM. Since then, QPM varieties have been disseminated all over the world, particularly in Sub-Saharan Africa (Krivanek *et al.,* 2007).

In the year 2001, QPM was introduced in Tanzania (DeGroote *et al.,*, 2010). It is now available in local markets and is recognized as 'nutritious maize" (*MahindiLishe*). Although QPM has been produced and consumed in Tanzania for more than a decade, little research has been done on it. A study on extension and adoption of QPM in East

Africa revealed that, the major factors which influenced QPM adoption were farmers' participation in extension activities, post-harvest stability of QPM versus CM, and their understanding of the nutritional benefits of QPM (De Groote *et al.,* 2010).A study by Kiria *et al.* (2010)showed that consumer ranked the sensory attributes of QPM higher than those of CM. Consumers found the QPM more appealing and hence more acceptable than the CM. Likewise, consumers were willing to pay more for QPM flour compared to CM. Krivanek *et al.* (2007) reported three QPM cultivars that were common in Tanzania namely Lishe-K1, Lishe-H1 and Lishe-H2. Despite wide adoption of QPM in many parts of the country, there is limited information on the potential of using QPM-based diets in rehabilitating undernourished children. This study was designed to evaluate the efficacy of QPM-based composite foods on rehabilitating undernourished children in Mvomero District, Tanzania.

1.1.1 Extrusion cooking

Extrusion is a widely used food processing operation, which utilizes high temperature and high shear force to produce a product with unique physical and chemical characteristics. Extrusion cooking technology uniquely combines mechanical shear, high pressure and inter-particulate frictional heat to transform raw materials into cooked products in a very short time (Navale*et al.,* 2015). Extrusion technology is one of the contemporary food processing technologies applied to foods and can be applied to mitigate the problems associated with processing of traditional cereal based products in terms of improvement in functionality, physical state and shelf stability.

Extrusion technology has many advantages, including its versatility, high productivity, low cost and the ability to produce unique product shapes and high quality products. Precooking is important in developing countries where quick cooking saves scarce fuel and simplifies preparation. To achieve precooking, targeting enzymes denaturation, food sterilization and improved product acceptability, extrusion cooking presents the best option. However, the effect of extrusion cooking on antinutritional factors (ANFs) has not clearly been ascertained. Purushotham*et al*. (2007) reported that, no change of trypsin inhibitor activity (TIA) in extruded soybean, contradicting studies by Singh *et al. (*2000) which showed complete destruction of TIA in the extruded blends. In addition, extrudates are microbiologically safe (Nikmaram *et al.,* 2015) and can be stored for long periods because of low moisture content (Guy, 2001).

1.1.2 Protein quality evaluation by biological assay

Quality of a protein is determined by assessing its essential amino acid composition, digestibility and bioavailability of amino acids. There are several ways that are used to evaluate the quality of protein. The most common ones are:

Protein Efficiency Ratio: Protein efficiency ratio (PER) determines the effectiveness of a test protein in supporting animal growth. This method utilises an *invivo* assay to estimate protein quality by measuring rat growth per gram of protein consumed. The PER, however, is limited in application because it is time consuming and does not account for the maintenance requirement of the weanling rats.

Biological Value: Biological value (BV) measures protein quality by calculating the ratio of nitrogen used for tissue formation to the nitrogen absorbed from food. This product is expressed as a percentage of nitrogen utilized. Biological value does not take into consideration several key factors that influence the digestion of protein and interaction with other foods before absorption. Biological value also measures the protein's maximal potential quality and not its estimate at requirement level. Therefore, scientists do not have a lot of confidence on BV as a biological marker of protein quality.

Net Protein Utilization: Net protein utilization (NPU) is similar to the biological value except that it involves a directmeasureof retention of absorbed nitrogen. Net protein utilization and biological value both measure the same parameter of nitrogen retention, however, biological value is calculated from nitrogen absorbed whereas net protein utilization is calculated from nitrogen ingested.

Protein Digestibility Corrected Amino Acid Score: The FAO/WHO (1991) expert group replaced the rat growth assay PER with Protein Digestibility Corrected Amino Acid Score (PDCAAS). The PDCAAS is determined by multiplying the limiting amino acid score (i.e. the ratio of the first-limiting amino acid in a gram of target food protein to that in a reference protein or requirement value) by protein digestibility. The difference with PER is that PDCAAS is based on human amino acid requirements and is more appropriate for the estimation of protein quality than an animal assay. The reference values used are based upon the essential amino acids requirements of preschool-age children (2-5y). Although the PDCAAS is currently the most accepted and widely used method, limitations still exist: the method does not credit extra nutritional value to high quality proteins, it overestimates protein quality of products containing antinutritional factors and does not adequately take into account the bioavailability of amino acids. The method overestimates the quality of poorly digestible proteins supplemented with limiting amino acids, and the quality of proteins co-limiting in more than one amino acid (FAO, 2013). Based on these considerations, FAO is moving towards a new method of protein quality determination: digestible indispensable amino acid score (DIAAS) (FAO, 2011). Studies are underway to collect data on true ileal amino acid digestibility. In the interim, digestible individual dietary amino acid values are calculated using faecal crude protein digestibility values applied to dietary amino acid contents.

1.1.3Antinutritional factors

Antinutritional factors (ANFs) are compounds present in an extensive variety of plant based foods. In high concentrations, ANFs may cause toxic reactions and/or interfere with the bioavailability and digestibility of some nutrients. Research findings have indicated that, various processing methods such as fermentation, soaking, boiling, extrusion and germination reduce the levels of ANFs (Kumar *et al.,* 2010).

Legumes and cereals are good sources of cheap and widely available proteins for human consumption. They are staple foods for many people in different parts of the world and extensively used in making complementary foods for children. Plant-based complementary foods inherently have high levels of ANFs such as phytic acid, tannin, amylase inhibitor, trypsin/chymotrypsin inhibitors and hemagglutinins. To improve the nutritional quality and to improve utilization of legumes, it is essential that ANFs be inactivated or reduced.

1.1.4 Mycotoxin contamination

Mycotoxins are secondary metabolites produced by a wide variety of filamentous fungi, including species from the genera *Aspergillus, Fusarium* and *Penicillium*(Kanora and Maes, 2009). In some agricultural food commodities, mycotoxins contamination may seriously impact human and animal health and reduce the commercial value of crops (Shephard, 2008). Mycotoxin contamination can lead to growth retardation in children and neural tube defects in developing foetus(Marasas *et al.,* 2004). The economically most important mycotoxins in foods and feeds are aflatoxins,ochratoxin A and patulinproducedmainly by *Aspergillus,Penicillium* spp. and *Fusarium*toxins. Occurrence of mycotoxin contamination in foods is more prevalent in the tropical and subtropical countries resulting in acute and chronic mycotoxicoses in humans and animals. Mycotoxins can invade the seeds before the actual harvest, while the crop is still in the field, or alternatively, mould growth can occur during storage at the feed mill or on the farm. As a result, high numbers of mycotoxins may already be present in the ingredients before they are received in feed mills or farms. Hence, preventing the occurrence of mycotoxins in feed ingredients can be a very difficult task. Maize and other cereals contain aflatoxins, which exist in four different forms namely aflatoxin B1 (AFB1), B2 (AFB2), G1 (AFG1) and G2 (AFG2). Aflatoxin B1 is the most potent form of the aflatoxins(Liu and Wu, 2010). According to research conducted in Tanzania, the level of mycotoxin contamination in maize ranged from 61-11,048 µg/kg (Kimanya*et al*., 2008). Therefore, children consuming maize based complementary foods in Tanzanians may be exposed to unacceptably high levels of multiple mycotoxins. The most obvious measure to prevent mycotoxin production is to reduce the moisture content of the commodity. Limitation of bird and insect damage can also be used to minimize mycotoxin contamination (Dowd, 2003). Another method of minimizing mycotoxin contamination is by creating anaerobic conditions by storing and promoting crop rotation (Atanda *et al.,* 2013) .

1.1.5Taste and preference studies

Sensory evaluation has been defined as a scientific method used to evoke, measure, analyze, and interpret panelists responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Lawless and Heymann, 2010). Sensory evaluation has three test methods; the first one is discrimination method that looks at perceived differences among food products. Another method is descriptive, establishing differences in specific sensory attributes such taste, smell, touch, sound and sight.The third one is affective or hedonic method looks at the products' preference. Several research studies have been conducted on taste and preference (Okafor and Ugwu, 2014; Kocherla *et al.,* 2012;Konyole*et al.,* 2012). These studies are used in measuring taste and preference in various food products namely; porridge, juice, milk, water and many other foods. Sensory studies describe how consumers are likely to perceive and react to food products in real life. It provides important and useful information to product developers, food scientists, and managers about the sensory characteristics of their products prior to public use (Singh-Ackbarali and Maharaj, 2014).

1.2 Problem Statement and Study Justification

Malnutrition, particularly undernutrition, which is reflected by stunting, underweight and wasting is among the major nutritional problems affecting infants and young children (Akalu *et al.,* 2010). Throughout the developing world, 34% of the children under the age of five years are stunted, 25% are underweight while 10% are wasted (Fanzo, 2012;Black *et al.*, 2008)**.** Although Tanzania has made many efforts in reducing child undernutrition, the prevalence of child underweight, stunting and wasting is still high. A study by NBS and Macro (2011) showed that, 44.4% of children under the age of five years are stunted, 5% are wasted while 16% are underweight. Furthermore, the findings showed that, prevalence of stunting, wasting and underweight have remained constant at 43-44, 3-4 and 29-31% respectively for the past five years. Various authors have associated child malnutrition with inadequate food intake especially when coupled with high rates of infections during the first two years of life (Katepa-bwalya *et al.,* 2015;Lohiaand Udipi, 2014;Nti and Lartey, 2007). Throughout the developing world, early nutrient complementation is common (Tessema*et al.,* 2013;Lander *et al.,* 2009). Likewise, in Tanzania, children are introduced to complementary foods early in life (<6 months). A study by NBS and Macro, (2011) showed that, 11% of breastfeeding children are introduced to some kind of solid or semi-solid foods in the first two months of life. Furthermore, children were introduced to complementary foods by 2-3 months (34%) and 4-5 months (65%).

The most common type of food given to children is light gruel (porridge) made from maize, sorghum, pearl millet or finger millet flours (Kulwa *et al.,* 2015; Nordang *et al.,* 2015;Lander *et al.,* 2009;Mamiro *et al.,* 2005). These kinds of foods are known to contain low protein, low nutrients and energy density and are highly bulky(Kulwa *et al.,* 2015;Shiriki *et al.,* 2015;Kehlet *et al.,* 2011). In addition, if prepared under unhygienic conditions, complementary foods become contaminated with various pathogens and this causes diarrhoeal diseases and consequently malnutrition and sometimes deaths(Hussein, 2005;Ehiri *et al.,* 2001).

Different works have been reported on the existence of ANFs on the ingredients used for making cereal-based complementary foods at the household level. Such foods are high in phytate, tannins, amylase and many other ANFs which limit digestibility and bioavailability of nutrients, including minerals and in some cases proteins. Proteins are crucial for the growth and development of infants. To remove ANFs, various processing methods have been devised. Dehulling, soaking, germination and extrusion cooking are some of the methods which significantly reduce the levels of phytic acid, condensed tannins and polyphenols in foods (Alonso *et al*., 2000).

Several strategies have been developed to address the problem of undernutrition globally. These include nutrient supplementation, dietary diversity and food fortification. Moreover, efforts have been made to increase the level of essential nutrients in crops by genetic engineering (biofotification), natural selection and gene editing. Some of the biofortifiedcrops include, sweet potato, (Low *et al.,* 2007) and maize (to improve Pro-vitamin A) (Muzhingi *et al.,* 2011), rice (to improve zinc and Pro-vitamin A) (Babu, 2013) and wheat (to improve zinc) (Bouis *et al.,* 2013). Other crops are finger millet (to improve iron and zinc)(Kodkany *et al.,* 2013) and beans (to improve iron) (Bouis *et al.,*2013). Biofortification of maize was initiated by the International Maize and Wheat Improvement Center (CIMMYT) in 1960s and involved developing maize cultivars with protein high in lysine and tryptophan, called quality protein maize (QPM). Quality protein maize has approximately twice the lysine and tryptophan levels of common maize and increased levels of histidine, arginine, aspartic acid, and glycine. On the other hand, it has reduced levels of the amino acids-glutamic acid, alanine, and leucine. A lower leucine level, however, is considered an advantage because it results in a more balanced leucine-isoleucine ratio, which, in turn, helps to liberate more tryptophan (Lauderdale, 2000).

Children in Tanzania are commonly given plain maize porridge as complementary food. In most cases, nothing else is added to improve its nutrient quality. Traditionally, ingredients for processing complementary foods in Tanzania are usually washed, dried and milled to make flour. In some few cases, roasting and dehulling of soybeans are done. No further processing is carried out. Various studies have documented nutritional challenges of using plain maize meal as complementary food (Okoth *et al.,* 2016;Shiriki *et al.,* 2015;Ukegbu and Anyika, 2012). Maize is low in amino acids lysine and tryptophan concentrations. In improving the protein quality of porridge made from plain maize, the use QPM-based composite supplementary food is proposed. This study was designed to investigate the efficacy of QPM-based composite supplementary foods in rehabilitating undernourished children.

1.3 Objectives

1.3.1 Overall objective

To develop QPM-based composite supplementary foods on rehabilitating undernourishedchildren in Mvomero District, Tanzania.

1.3.2 Specific objectives

i. To determine nutrient composition of QPM-based composite supplementary foods

ii. To determine the protein quality of QPM-based composite supplementary foods

iii. To determine the efficacy of QPM-based composite supplementary foods in rehabilitating undernourished children

iv. To determine antinutritional factors (phytates and tannins) and mycotoxin levels (aflatoxin and fumonisins) in the QPM-based composite foods

v. To evaluate the sensory quality and acceptability of the QPM-based composite supplementary foods

1.4 Organisation of the Thesis

The thesis is organized in three chapters. The first chapter is introduction which highlights the background information of maize, overview of extrusion cooking, protein quality evaluation, antinutritional factors, mycotoxin contamination and sensory evaluation of the food products developed. Chapter two comprises of published papers/ manuscripts addressing objectives of the study. Chapter three presents the overall conclusions and recommendations focusing on the potential of QPM-based complimentary foods to rehabilitate undernourished children.

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CHAPTER TWO

PAPER ONE

Nutritional Quality of Quality Protein Maize-based Supplementary Foods

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(Acceptedto Journal of Nutrition and Food Science)

Abstract

Background/objectives: Childundernutrition is a persistent problem in Africa, especially in areas where the poor largely depends on starchy staples with limited access to diverse diets. This study was carried out to determine the protein quality, growth and rehabilitation potential of composite foods made from quality protein maize.

Subjects/methods: Three composite diets were prepared from quality protein maize namely quality protein maize-soybeans; quality protein maize-soybeans-cowpeas and quality protein maize-soybeans-common beans. A fourth diet was prepared from plain quality protein maize and fifth diet from plaincommonmaize. The six diet (Chesta®) was made from maize, soybeans, fish, bone and blood meal. The seven diet was cassava meal, a low protein diet that was used in calculating protein quality of the test diets. The formulations were made to meet the greatest amino acid score and the desired amount of energy and fat according to the FAO/WHO/UNU (1985) recommendation for pre-school children. Albino rats were used in evaluating the quality indices namely, protein efficiency ratio, net protein ratio, true protein digestibility, biological value and protein digestibility corrected amino acid score.**Results:** The food intake was significantly different *($p<0.05$)* among diets; with a trend of intake decreasing from quality protein maize-based to plainquality protein maize diets. Food intake order was quality protein maize-soybeans> quality protein maize-soybeans-common beans > quality protein maize-soybeans-cowpeasandquality protein maize. Protein efficiency ratio and net protein ratio varied significantly *($p<0.05$)* across the experimental diets. Protein digestibility-corrected amino acid scores were 80% (quality protein maize-soybeans-cowpeas), 87% (quality protein maize-soybeans), 98% (plain quality protein maize), 80% (quality protein maize-soybeans-common beans) and 53% Chesta®. **Conclusions:** Two diets;quality protein maize-soybeans-common beans and quality protein maize-soybeans-cowpeas showed the

greatest potential to support growth and rehabilitation of undernourished rats. Human trial is proposed in order to validate the findings.

Key words: Protein digestibility-corrected amino acid scores, quality protein maize

Introduction

Undernutrition is a persistent problem in Africa, especially in areas where the poor largely depend on starchy staples with limited access to animal protein-based diets. Throughout the developing world, 32% of children are stunted and 20% are underweight (Black *et al*. 2008). According to Tanzania Demographic and Health Survey 2010 report, 44% of children under the age of five years are stunted, 16% are underweight while 5% are wasted NBS and Macro (2011). The major causes of underweight, stunting and wasting have been associated with inadequate intake of protein, calories and micronutrients, often from the staple foods and diseases. In most areas of developing world, especially in Sub-Saharan Africa, maize is the major staple food that provides calories for the population. Maize is a cereal low in the essential amino acids lysine and tryptophan, which are needed for optimal growth of children. Maize flour is commonly used to prepare porridge that is used as complementary food for infants, often with nothing else added to it to improve its nutritional value (Katepa-bwalya *et al*., 2015:Amagloh *et al.,* 2012:Hussein 2005).Many studies have associated intake of porridge as a meal with undernutrition among children (Shinsugi *et al*., 2015:Amagloh *et al.,* 2012).

Due to high rates of undernutrition globally, several strategies were devised to improve the nutritional value of some of the staple foods. These included dietary diversity, fortification, supplementation and biofortification. Biofortification of maize was initiated by the International Maize and Wheat Improvement Center (CIMMYT) in 1960s and it involved developing improved maize cultivars known as quality protein maize (QPM), containing almost twice the amount of the limiting amino acids lysine and tryptophan in the conventional maize (Nuss & Tanumihardjo 2011:Sofi *et al.,* 2009:Vivek *et al.*, 2008). Globally, QPM has been adopted as a maize variety that can be used to address the problem of protein energy undernutrition among children especially in Central America and parts of Africa. QPM is also high in histidine, arginine, aspartic acid, and glycine but has reduced levels of glutamic acid, alanine, and leucine(Sofi *et al.*, 2009). Besides carbohydrate (70%) (Enyisi *et al.,* 2014), maize contains a significant quantity of protein (8-12%). This protein, however, is still limiting in the essential amino acid lysine and tryptophan (FAO/WHO 2013). Combining cereals with legumes and/or pulses, which are higher in the limiting amino acids, can complement each other resulting in balanced high quality protein. QPM has low levels of micronutrients (Diaz 2003),many of which are lost during processing into various food products. Animal sources are excellent for supplying nutrients in the diet but are too expensive and unaffordable by the poor families. Remedy to this high cost is the use of legumes that are inexpensive and affordable by most families. Legumes are important sources of protein, calories, vitamins and minerals but their nutritional quality may be impaired by the presence of antinutritional factors. Therefore, proper processing is required to inactivate the antinutritional factors. Composite diets were made from QPM in combination with legumes namely soybeans, common beans and cowpeas to improve maize's nutritional profile. The formulations made targeted children aged 2-5 years.

Little has been done on QPM utilization in Tanzania. A study on extension and adoption of QPM in East Africa found that, stiff porridge made of QPM was highly appreciated (Kiria *et al.,* 2010). Another study was on QPM cultivars that are commonly grown in Tanzania. Three varieties, namely Lishe-K1, Lishe-H1 and Lishe-H2 were reported (Krivanek *et al.,* 2007). Despite adoption of QPM in several parts of the country, there are no studies that have been done to determine the potential of QPM to support optimal growth and rehabilitation of undernourished children. The objective of this study was therefore to evaluate the protein quality, growth and rehabilitation potential of composite foods made from QPM by using rats. Rats are used in this study because they are similar in several key areas to human. Both are monogastric, the gastrointestinal anatomy, physiology and metabolism of the rat is very similar to those in the human. Furthermore, the growing human subject closely resembles the growing rats in nutrient requirements and metabolic utilization of essential nutrients (Osborne *et al.,* 1919).

Materials and Methods

Materials

Quality protein maize (NATAK6Q) was purchased from Seliani Research Station in Arusha, Tanzania. Common maize (*Zea mays*), cassava (*Manihotesculenta*) flour, soybeans (*Glycine max*), common beans (*Phaseolus vulgaris*), cowpeas *(Vignaunguiculata*), palm oil and sugar were purchased from Morogoro Municipal central market. The control diet (Chesta®) (CC) was purchased from one of the animal feed shops in Morogoro Municipal.

Methods

Product processing, formulation and composition

Separately, QPM, CM, soybeans, common beans and cowpeas were sorted to remove extraneous materials and pebbles and washed in distilled water. Then, QPM and CM were separately dehulled. Thereafter, each of these ingredients was separately milled into fine flour (mesh size 0.4 mm) using a commercial hammer mill (Intermek, Tanzania) to fine flour. Three formulations were made namely: QPM-soybeans (QS), QPM-soybeans-cowpeas (QSC) and QPM-soybeans-common beans (QSB). The fourth and fifth products namely plain QPM (QQ) and plain common maize (CM) were also formulated. Each formulation was extruded using a commercial twin-screw extruder (Model JS 60 D, Qitong Chemical Industry Equipment Co. Ltd, Yantai, China). The following extrusion conditions were adopted: Temperatures 130^{o}C (Zone 1) and 122^{o}C (Zone 2), main motor speed was set at 10.48 rpm and feeder speed at 10.26 rpm. The extruder consisted of two electrically heated zones. Desired barrel temperature was maintained by circulating tap water. Temperature was controlled by inbuilt thermostat and a temperature control unit. After extrusion, the extrudates were allowed to cool and dry at room temperature, thereafter milled, fortified and packaged in polyethylene packets.After extrusion, five products namely QPM-soybeans (QS), QPM-soybeans-cowpeas (QSC), QPM-soybeans-common beans (QSB), plain QPM (QQ) and plain common maize (CM) were formulated. The formulations were made in order to meet the greatest amino acid score and the desired amount of energy and fat according to the FAO/WHO/UNU (1985) Codex Alimentarius guidelines for supplementary foods for infants and young children (Table 1). Each diet was divided into two portions, the first portion was used for chemical assay while the second portion was used for protein quality assessment using rat model. Diet CC, a usual rat feed was made from maize, soybeans, fish, bone and blood meal.

Nutritional evaluation

Experimental study

In vivo study was conducted using albino rats *(Rat rattus*) aged 21 days with average weight 24.14 g. These animals were obtained from Faculty of Veterinary Medicine, SUA, Tanzania. Husbandry for these animals has been described in AOAC (1995), procedure 45.3.06. A total of 77 rats (eleven for each diet), housed individually in cages were involved in the study.

Table 1: Composition of the maize-based supplementary food formulations

	Formulations(g/100 g) [1]				
Ingredient	QS	QSC	QSB	QQ	CM
QPM	68	46	45	82	-
Soybean	14	6	7	-	-
Cowpeas	-	30	-	-	-
Common beans	-	-	30	-	-
Common maize	-	-	-	-	82
Cooking oil	10	10	10	10	10
Multi-mix[2]	3	3	3	3	3
Sugar	5	5	5	5	5
Total	100	100	100	100	100

[1] QS=Quality protein maize-Soybean; QCS=Quality protein maize-Cowpeas-Soybean: QBC=Quality protein maize-common Beans-Soybean QQ=Quality protein maize; CM= Common Maize

Animals were kept at room temperatures (25±5^{o}C), on a 12:12 light: dark cycle. The animals were acclimatized to the test diet for three days. After acclimatization, the rats were weighed and those with extreme weights (over and underweight) were excluded from the study.The remaining animals were randomly assigned to seven groups of eleven animals each. Five diets namely QS, QSB, QSC, QQ and CM were fed to each group. The sixth group (control) received Chesta®, a usual rat feed. The seventh group received cassava meal (low protein diet). Food and water were given *ad libitum* for 28 days. Food intake and weights were recorded daily. Faeces were collected from individual rats on days 25-28 of the feeding trial, except for protein free diet (day 3-5). Faecal protein and metabolic faecal protein were determined using the protein intake and faecal output data.

Nutritional evaluation

Nutritional qualities of the diets for the rats were evaluated using the following computations:

Protein Efficiency Ratio (PER) = Gain in body weight (g) / Protein intake (g)

Net Protein Ratio (NPR) =Gain in body weight + average weight loss of control diet /Protein consumed by the test animal

True Protein Digestibility (TPD) = 1– (F – F_0) / I

Biological value (BV): = [I - (F - F_0) - (u - E)] / [I - (F - F_0)]

Where;

I = Nitrogen intake in the test diet

F = Faecal nitrogen in the test diet

F_0= Faecal nitrogen of the N free diet

u = nitrogen excreted in urine (g)

E = endogenous urinary N of N free diet

Protein Digestibility Corrected Amino Acids Score (PDCAAS) = true protein digestibility x lowest amino acid score (FAO, 2013).

Rehabilitation was carried out for rats on low protein diet (QQ and CM), which did not show satisfactory growth. Rats on diets QQ and CMwere rehabilitated by feeding them the diets that showed the greatest potential to support growth, namely diets CC, QSB and QSC. The animals were rehabilitated for 14 days. Food and water were given *ad libitum* with their food intake and weight being collected daily.

Crude protein and amino acid analysis

Total nitrogen was determined in food and faeces according to Kjeldahl's method (AOAC 1995) procedure 960.25. Crude protein was calculated as total nitrogen x 6.25. Essential amino acid concentrations (except tryptophan) were determined by high performance liquid chromatography using the Waters Pico-Tag method (Cohen *et al.,* 1989). For all essential amino acids except methionine, cysteine and tryptophan, food samples were hydrolysed in 6 N HCl. The methionine and cysteine in foods were oxidised by performic acid to methionine sulfone and cysteic acid prior to hydrolysis by 6 N HCl. All amino acids (except tryptophan) were derivatised by phenylisothiocayanate and detected at 254 nm. Tryptophan was analysed by ion exchange chromatographic method as described in the (AOAC, 1995) method 988.15. The protein in the food was hydrolysed under vacuum with 4.2 N NaOH. After pH adjustment and clarification, tryptophan was separated by ion exchange chromatography (DC5A cation exchange resin) with measurement of the ninhydrinchromophore. The essential amino acid profile of the composite products was compared with essential amino acid requirement pattern for pre-school age (2-5 year) children to compute the amino acid scores (FAO/WHO/UNU, 1985).

Statistical analysis

The data were analyzed by using General Linear Model (GLM) procedure of Statistical Analysis System (SAS) Version 9.1 (SAS, 2003). Multivariate analysis of variance (MANOVA) was used to calculate partial correlation coefficients among the protein quality variables of the diets. Differences were considered significant at $p \leq 0.05$.

Ethical considerations

This study was approved by the Postgraduate Committee Senate of Sokoine University of Agriculture(SUA).Ethical clearance was obtained from the National Institute for Medical Research (NIMR).

Results

Amino acid composition

The amino acid composition of the experimental and control diets in relation to FAO/WHO/UNU (1985) reference patterns for children aged 2-5 years is presented in

Table 2. The amino acid composition of the experimental diet ranged between 15 mg/100g for tryptophan (QQ diet) and 109 mg/100g leucine (CM diet). It was observed in this study that lysine and tryptophan contents of the experimental diets increased with QPM and soybeansupplementation. Lysine content in QPM-based diets ranged from 67 to 74 mg/100 g protein in QS and QSB, respectively. Tryptophan content ranged from 16 to 18 mg/100 g protein in QS and QSB, respectively. Lysine and tryptophan contents of QSB and QSC were higher than the reference pattern for children 2-5 years (FAO/WHO/UNU, 1985). Diet CC contained lower concentration of all essential amino acids than the reference pattern for children 2-5 years.

Table 2: Amino acid profile and scores of the various foods designed for children aged 2-5 years

Amino acids	**Formulation[a]**					**FAO/WHO /UNU (1985)[b]**
	CM	**QQ**	**QS**	**QSB**	**QSC**	
Amino acid (mg/g)						
Histidine	31	41	36	34	37	19
Threonine	29	41	43	44	43	34
Valine	45	60	59	58	59	35
Leucine	121	106	103	96	98	66
Lysine	26	50	67	74	73	58
Tryptophan	7	15	16	18	17	11
SAA	41	46	37	44	42	25
AAA	76	73	91	91	88	63
PDCAAS[c]	103	98	87	80	80	
Limiting AA[c]	Trp	Trp	Trp	Trp	Trp	

[a] CM= Common maize: QQ= Quality protein maize: QS= Quality protein maize- soy bean: QSB= Quality protein maize-soy bean-common Bean: QSC= Quality protein maize-soy bean-cow peas: SAA= sulphur containing amino acid (methionine and cysteine): AAA= aromatic amino acids (phenylalanine and tyrosine)

[b] FAO/WHO/UNU(1985) amino acid reference pattern for children aged 2–5 year.

[c]Protein digestibility-corrected amino acid scores with respective limiting amino acids based on FAO/WHO/UNU(1985) amino acid reference pattern for children aged 2–5 years.

Growth performance of experimental ratsand evaluation of rehabilitation potential

Rats fed on diet CC as well as soybean supplemented diets (QS, QSB and QSC) exhibited higher values of food intake, protein intake and growth. The food intakes were significantly different ($P<0.001$), with a trend of reduced intake in plain cereal diets (Table 3). Apart from the control diet, the maximum and minimum mean daily food intakes were observed in diets QSB and CM whereby the average of 8.05 g and 3.55 g, respectively, were consumed per day.

Table 3: Least Square means (± SE) for the effect of diet, feeding period and sex against food intake, protein consumed and weight gain1

Diet	**Food intake (g)**	**Protein consumed (g)**	**Daily weight gain (g)**
CC	8.10 ± 0.1 ^{c}	1.88 ± 0.02^{d}	1.74 ± 0.12^{b}
CM	3.52 ± 0.13 ^{a}	0.22 ± 0.02^{a}	0.20 ± 0.12^{a}
QQ	4.34 ± 0.13 ^{b}	0.33 ± 0.02^{b}	0.32 ± 0.12^{a}
QS	8.05 ± 5 c	1.04 ± 0.02^{c}	1.60 ± 0.13^{b}
QSB	8.01 ± 0.13^{c}	1.04 ± 0.02^{c}	1.73 ± 0.12^{b}
QSC	7.78 ± 0.13 ^{c}	1.04 ± 0.02^{c}	1.63 ± 0.12^{b}
P value	<0.001	<0.001	<0.001
Period (week)			
Week 1	5.22 ± 0.11^{a}	0.69 ± 0.02 ^{a}	0.89 ± 0.09^{a}
Week 2	6.43 ± 0.11^{b}	0.88 ± 0.02^{b}	1.39 ± 0.09^{b}
Week 3	7.75 ± 0.11^{d}	1.20± 0.02^{d}	1.31 ± 0.09^{b}
Week 4	7.13 ± 0.11 ^{c}	1.13 ± 0.02^{c}	1.23 ± 0.09^{b}
P value	<0.001	<0.001	0.001
Sex			
Male	6.63 ± 0.07	0.94 ± 0.01^{b}	1.26 ± 0.06
Female	6.63 ± 0.08	0.91 ± 0.01^{a}	1.15 ± 0.07
P value	0.985	0.048	0.278

[1] CC= Control: CM= Common maize: QQ= Quality protein maize: QS= Quality protein maize- Soy bean: QSB= Quality protein maize-Soy bean-common Bean: QSC= Quality protein maize-Soy bean-Cow peas

Mean values with different superscripts in a column are significantly different at p <0.05

High protein content diets (CC, QS, QSB and QSC) were consumed more by rats compared to the diets with low protein values (CM and QQ). Body weights of rats fed various diets are presented in Figure 1. Significantly, rats on CC and QPM-based diets had higher mean daily weight gain than the ones on plain maize (QQ and CM), $p<0.001$.

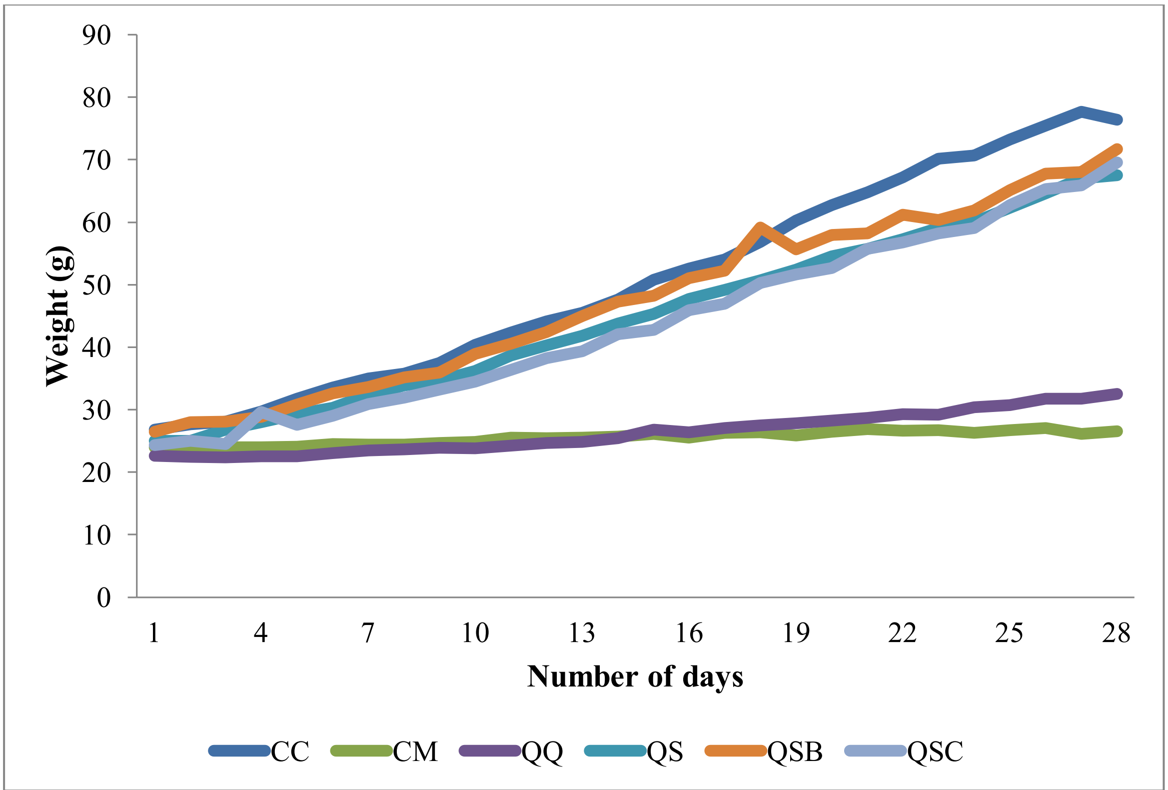

Figure 1: Growth performance of rats receiving various diets- re label C, Q

Rehabilitation phase

After the four weeks of feeding trial, a 14 day recovery period was carried out for the animals which did not show satisfactory growth. Rehabilitation was carried out using diet CC as well as the best two diets namely, QCB and QSC. Mean daily weight gain for rats receiving various diets was 1.99±0.4 g (CC), 1.54 ±0.4 g (QSB) and 1.66±0.9 g (QSC). During rehabilitation (Figure 2), average weight gain per day was not significantly different. ($p=0.417$).

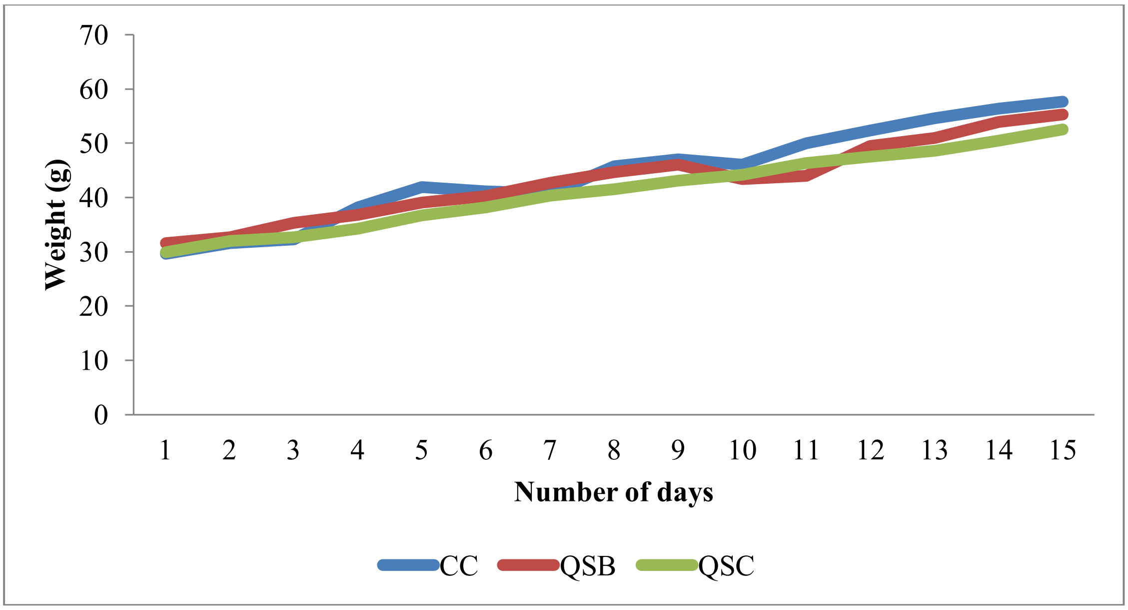

Figure 2: Growth performance of the rats during rehabilitation phase same as above

Protein quality evaluation

Table 4 shows the various parameters of protein quality of the test diets namely True protein Digestibility (TD), Protein Efficiency Ratio (PER), Net Protein Ratio (NPR) and Biological Value (BV). All protein quality parameters except PER and NPR varied significantly ($p>0.05$) across the diets. Apart from the control, QPM-based diets had the highest values compared to the plain QPM diet. In addition, TD differed significantly ($p>0.05$) among different experimental diets. Apart from the control diet, protein in diet QQ was highly digestible (68.14%) ($p=0.001$) compared to the other diets. Conversely, diet QSB was the least digestible ($p>0.05$). The PER ranged from 0.79 (QQ) to 1.60 (QS) among the different experimental diets. Protein efficiency ratio differed significantly ($p>0.05$) among the soybean supplemented diets. Net Protein Ratio (NPR) was significantly higher ($p>0.05$) in QPM-based diets than in QQ diet. Diet QS had the highest NPR. Improved protein quality was observed in diets QS, QSB and QSC in which QPM was supplemented with soybeans. Biological value of the test diets varied significantly ($p>0.05$). The differences in the test diets ranged from 69.9 (QQ) to 76.9% (QS).

Table 4: Least Square means (± SE) for true protein digestibility, protein efficiency ratio, net protein ratio and biological evaluation of various formulations[a]

Diet	True digestibility (%)	Protein efficiency ratio	Net protein ratio	Biological value (%)
CC	76.11 ± 0.34^{e}	0.87 ± 0.2^{b}	0.86 ± 0.22^{c}	87.61 ± 0.08^{f}
CM	63.60 ± 0.36^{ab}	0.09 ± 0.21^{a}	0.06 ± 0.21^{a}	68.54 ± 0.07^{a}
QQ	68.14 ± 0.36^{d}	0.79 ± 0.21^{b}	0.79 ± 0.21^{b}	69.85 ± 0.07^{b}
QS	64.81 ± 0.40^{c}	1.60 ± 0.24^{c}	1.59 ± 0.24^{d}	76.90 ± 0.08^{e}
QSB	62.61 ± 0.36^{a}	1.44 ± 0.21^{c}	1.47 ± 0.21^{d}	72.89 ± 0.07^{d}
QSC	$64.11 \pm 0.36b^{c}$	1.55 ± 0.21^{c}	1.53 ± 0.21^{d}	70.79 ± 0.07^{c}
P value	<0.001	<0.091	<0.028	<0.001

[a]Means within a column with different letters are significantly different at $p < 0.05$.

[b]CC= Control: CM= Common maize: QQ= Quality protein maize: QS= Quality protein maize- soybean: QSB= Quality protein maize-soybean-common Bean: QSC= Quality protein maize-soybean-cowpeas

This study revealed that, there was a positive correlation ($p<0.05$) between PER and NPR. Table 5 shows correlation matrix for the various diets versus food intake, protein intake, weight gain, PER and NPR. All the parameters were positively correlated ($p<0.05$), implying that all parameters, except biological values increased with feeding period (weeks).

Discussion

The study revealed that histidine, threonine, valine, leucine, lysine, tryptophan, sulphur containing amino acid (methionine and cysteine) and aromatic amino acids (phenylalanine and tyrosine) were present in adequate levels in the QPM-based diets when compared with the recommended values for children 2-5 years by FAO/WHO/UNU (1985).

Table 5: Correlation matrix for the protein quality attributes against various diets

Parameter	Food intake	Protein intake	Weight gain	PER	NPR	BV	TD
Food intake	1						
Protein intake	0.95***	1					
Weight gain	0.32**	0.32***	1				
PER	0.11***	0.07**	0.65***	1			
NPR	0.11***	0.07**	0.65***	0.99***	1		
BV	0.00ns	0.00ns	0.04ns	0.04ns	0.04ns	1	
TPD	0.77***	0.66***	0.26***	0.17***	0.16***	0.01ns	1

***= Correlation is very highly significant at p <0.0001; **= Correlation is highly significant at p <0.001; ns= not significant; TPD= True Protein Digestibility; PER= Protein Efficiency Ratio; NPR= Net Protein Ratio; BV= Biological Value

Protein Digestibility Corrected Amino Acid Score was adopted by FAO/WHO as the preferred method for the measurement of the protein value in human nutrition. It is based on human amino acid requirements. Protein Digestibility Corrected Amino Acid Score of QPM-based diets were >70% which is above the requirement pattern (≥65%) recommended by FAO/WHO/UNU (1985).This PDCAAS rating indicated that the protein content of the QPM-based supplementary food formulations evaluated in this study would be bioavailable to meet the growth needs of infants and young children. The limiting amino acids, lysine and tryptophan observed in the diet CM was in agreement with findings by other researchers (Nuss & Tanumihardjo 2011:FAO/WHO/UNU, 2002).

Animals on QQ diet had low food intake compared to the QPM-based diets. This could be attributed to a number of factors namely deficiency of amino acids in the food and reduced palatability of the diet as compared to QPM-blended diets. Findings of the current study support various studies which reported that, foods containing low and / or imbalanced protein suppress food intake and protein deficiency caused reduced growth, muscular wasting, emaciation and death if sufficiently severe(Blatt *et al.,* 2011: Ijarotimi and Keshinro, 2006). Apart from the reference diet, rat on QPM supplemented diets (QSB, QSC and QS) showed the greatest growth potential than QQ. The observed higher weight gain for rats on legume supplemented diets is in agreement with Ijarotimi & Keshinro (2012)who reported higher growth patterns of rats on blended diets than those on *ogi*, a porridge prepared from fermented maize, sorghum or millet in West Africa. The practice of supplementing legumes in improving nutritional value of supplementary foods has been studied elsewhere (Bekele, 2011). The added protein improved appetite and hence food intake.

Rats that were fed on non-protein diet did not grow, had very low food intake and were losing weight drastically. Similar findings were reported by (Ekpo, 2011). Both food intake and protein adequacy strongly affect growth. As pointed out, low protein quality results in reduced food intake and therefore reduced growth. Another study, however, reported that, animals fed on plain maize showed a constant growth (Ijarotimi & Keshinro, 2012). These finding, have not been corroborated by any other study.

Limitations of the Study

Protein quality of the test diets were evaluated using albino rats. These rats are quite similar to humans. They are both monogastric and are physiologically similar to human. However, protein bioavailability observed in rats may not be exactly similar to the bioavailability in human.

Conclusions and Recommendations

Two diets namely, QSB and QSC were highly digestible and showed greatest potential to promote normal growth and rehabilitation of undernourished rats. Blending QPM and legumes improved amino acid profile of QPM-based diets. Protein Digestibility Corrected Amino Acid Scores for QSB and QSC diets were higher (≥ 70) than the one recommended for young children 2-5 years. Apart from the control, QPM-based diets had adequate levels of lysine and tryptophan. Furthermore, diet QQ had adequate levels of lysine and tryptophan compared to CM. It is suggested that, QSB and QSC diets should be evaluated using undernourished children to ascertain their efficacy in rehabilitation of undernourished children in Tanzania, where maize is a staple food.

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PAPER TWO

Infant and young child feeding practices and the risk factors associated with stunting among children in rural Tanzania

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(Manuscript submitted to African Journal Food, Agriculture, Nutrition and Development)

Abstract

Undernutrition has been a major problem in developing countries including Tanzania, contributing to more than a third of underfive deaths. It may later in lifeimpair physical growth and cognitive development. Undernutrition may result into lifelong impacts such as poor educational attainment reduced productivity and impaired intellectual and social development. The aim of this study was to identify child feeding practices and determinants of stunting in children under the age of five years. A cross sectional study involving 150 subjects was carried out in Turiani ward between February and April 2015. Bivariate regressionanalysiswas used to determine factors associated with stunting. The factors were socio-economic and demographic information, pregnancy and delivery, child feeding practices, child immunization, child morbidity, potable water use and sanitation. Pre-lacteal feeding was common in the study area (40%). Children were introduced to complementary food too early (<6 months) and plain maize porridge being the first food introduced.Many children (57.2%) were on the lowest tercile (≤3 food groups per day) of dietary diversity score. Family's source of income and breastfeeding frequency were among the factors that influenced stunting of children significantly. Other factors such as age of the child, age at introduction of complementary food, dietary diversity score ≤3 food groups, consumption of animal foods, family size and use of non- potable water were also risk factors that predicted child stunting. Dietary deficiency reported in this study was partly due to low consumption of food rich in energy, protein and minerals. Energy and nutrient dense foods are proposed.

Key words: Breastfeeding, complementary feeding, children, malnutrition, anthropometry, determinants, undernutrition, Mvomero

Introduction

It is estimated that globally, undernutrition contributes to more than a third of underfive deaths and disability [1,2]. Undernutrition may later in life cause impaired physical growth and cognitive development.Lifelong impacts of undernourished children include poor educational attainment, reduced productivity and impaired intellectual and social development. This can also lead to a lifetime diminished earning capacity and an elevated risk of non-communicable diseases [2]. Well-nourished children perform better in school, grow into healthy adults and in turn give their children a better start in life and continue to be healthy adults [3].

Despite the fact that Tanzania has given some attention to undernutrition, the prevalence rate is still high. A study conducted in Tanzania shows that 44.4% of the children are stunted, 5.3% are wasted while 16 % are underweight[4]. The reduction of the incidences of these undernutrition rates also forms an important component of the Millennium Sustainable Goals (MSGs) on child health. This could be done by ensuring a health start in life. Inappropriate feeding practices may account for approximately one-third of undernutrition. In many countries, poor breastfeeding and complementary feeding practices are widespread. In Tanzania for example, 31% of children are given pre-lacteal feeds [5]. On the other hand, too early complementation is common (50%). Although many children receive complementary foods too early, others (2.3%) receive too late. These foods are often nutritionally inadequate and unsafe [6].

Although there are several risk factors responsible for underfive malnutrition in developing countries that have been used in planning nutritional interventions [7,8] . In Tanzania, however, there is limited information on the risk factor predicting undernutrition among children under the age of five years. This study was designed to fill this gap. A cross-sectional study was undertaken to determine the role of selected child factors (breastfeeding and complementary feeding, immunization and number of children less than 5 years in a household, morbidity), household (economic status, households' size) and maternal (food consumption during pregnancy and delivery history) factors on the nutritional status of children below five years of age in Mvomero District, Tanzania.

Methodology

Study area

This study was conducted as part of an intervention study that involved assessing the efficacy of quality protein maize-based supplementary foods for rehabilitation and recovery of undernourished children in Tanzania. It was a cross sectional study carried out in Turiani division, Mvomero District. Mvomero District is located at latitudes 5°47'09''-7°23'40''S, and longitudes 37°11'09''-38°01'33''E. Administratively, Mvomero District is divided into 4 divisions namely Turiani, Mgeta, Mlali and Mvomero. Turiani division has five wards and a total of 27 villages [9]. It has a population of 312,109 people, with household size of 4.3 [10]. Mvomero District has 3 hospitals, 4 health centers, 44 dispensaries has 3 hospitals, 43 dispensaries and 4 public health centers. Agriculture is the main source of livelihood with maize, paddy, sweet potatoes, bananas and cassava being the major food crops. Main cash crops include sugarcane and sesame. The climate and soil are very favourable for farming activities. Mvomero District was selected as the study area due to the fact that, despite its high agricultural potential, the area has high prevalence of child undernutrition. This study was conducted in Kilimanjaro, Kisala and Kichangani villages of Turiani division.

Sampling frame

Sampling frame consisted of all households with children between 6 and 59 months in the study area. Inclusion criteria were households having lived in the area for at least three months prior to the study and will continue staying in the same area for not less than six months. Other inclusion criteria were age 6-59 months and WAZ -1 to-2SD with a child attending reproductive and child health (RCH) clinic. Exclusion criteria were children born to mothers who were mentally unfit. In addition, a child whose caregiver was unwilling to participate in the study was excluded. Study children were purposively selected into the study based on the WAZ -1 to -2SD criteria.

Sample size

The sample size was based on the assumptions that there will be 95% power to detect the error with an overall type II error of 5%. A sample size of 150 subjects was calculated for this study [11].

Data collection

Qualitative and quantitative methods of data collection were employed in this study. One hundred and fifty children aged 6-59 months, with their respective households, were selected for this study. A questionnaire was used to collect information on socio-economic and demographic information, pregnancy status and delivery history, child feeding practices and child immunization. Other information collected included child morbidity, water and sanitation and anthropometric measurements. Focus group discussions and key informants' interviews with mothers and key village/street leaders were also carried out. Key informants' interviews were conducted to community health workers, village elders, traditional health attendants and traditional healers. Members of FGDs were purposively and conveniently selected to take part. This ensured that participants who were easily accessible and had adequate information regarding infants feeding in the study area were selected. Five FGDs comprising of 5-9 mothers with children below 2 years who were not part of the main sample were chosen. Researcher moderated the discussions while one of the assistants took notes. Each FGD lasted between 45 and 90 minutes and the discussions were noted down and non-verbal communication documented. The FGDs were held in both villages after quantitative data had been collected.The questionnaire was then pre-tested at Mikese ward, Morogoro rural district and corrections were made where necessary. Three enumerators were training on the tools used for three days. After training, actual data collection was carried out between February and April 2015. The data was collected by face to face interview through visits to their homes during early hours of the day. Various measurements were taken during data collection, namely weight, height and food intake records. Weight was measured using standard procedures using a 25 kg Salter scale, with children wearing light clothes and recorded to the nearest 0.1 kg. Recumbent length/ height was measured without shoes and recorded to the nearest 0.1 cm using a wooden length/height board (UNICEF scale). Information on food records was used to determine the amount of nutrient consumed by the child using Tanzania Food Composition Table [12]. Nine food groups namely,cereal /roots/tubers, vegetables, fruits, meat, pulses, legumes, nuts, eggs, milk and milk products, fat and oils, others-such as sugar, beverages and condiments were used to determine DDS. These foods were categorized to three groups of DDS; ≤3 food groups (Low), 4-6 (medium) and ≤7 (high) DDS. Individual dietary diversity scores (DDS) were calculated by summing the number of food groups consumed during the last 24 hour [13]. The nutrient adequacy ratio (NAR) for each nutrient was calculated as actual nutrient intake of a day divided by the Recommended Daily Allowance of that nutrient [14]. Nutrient adequacy ratio > 1 meant the requirement has been met and if <1 it may be sufficient as the RDA was set at the mean requirement of 0.77 of the RDAs. The lower the NAR values the higher the chance the diet will fail to meet individual needs.

Statistical analysis

Statistical analysis was performed using the IBM Statistical Product and Service Solutions (SPSS) version 20. The Z-score values of height for age (HAZ) were computed using the ENA for SMART program (Version 3.2.2, 2011). Descriptive analysis was computed to compare the socio-economic characteristics, household food security status, child's dietary intake, and healthcare and caregiver variables in the study area. Means and standard deviations were computed for continuous variables. Counts and percentages for categorical variables were also computed. Binary logistic regression analysis was performed to examine the association between households, mother and child characteristics with or without stunting in children 6–59 months. To determine factors associated with stunting the dependent variable was expressed as a dichotomous variable, i.e. category 0 (not stunted) and 1 (stunted). The odds ratios with 95% CIs were calculated in order to assess the adjusted risk of independent variables. Mean values were considered significant when $p \leq 0.05$. Data from FGDs information collected wascoded and common themes established. Selected responses from FGDs were also directly quoted to exemplify common perceptions among the respondents. Conclusions were finally drawn and triangulated with quantitative data from the questionnaire.

Ethical Considerations

This study protocol received ethics approval from National Institute for Medical Research (NIMR). Informed verbal and/or written consent was obtained from the mothers/care providers before enrollment.

Results

Characteristics of the study sample

With regard to household composition, 86.7% of the households were headed by males. Mothers in the sample were relatively young. Their ages ranged between 16 and 46 years (mean 28.3 years). Many mothers (84.4%) were married, while 15.6% were either separated or divorced. The mean household size was 5.5±2.6 (range 2-15). Of the households interviewed, 80% of the household's heads had attained formal education and only a few (6.7%) had not attained any formal school. Farming was the main occupation (66.8%) of the household members. Other socio-economic characteristics are summarized in Table 1.

Table 1: Socio-economic and demographic characteristics of the study sample

Characteristics	Frequency	%	Characteristics	Frequency	%
Education level of the household head			*House roofs*		
None	10	6.7	Grass/'makuti'	20	13.3
Primary school	120	80	Wood, planks	10	6.7
Secondary school	10	6.7	Iron sheets	120	80
Post-secondary school	3	2.2	Total	150	100
Standard 4 old school	7	4.4			
Total	150	100	*Cooking fuel*		
			Wood	83	55.3
Child <5y in household			Charcoal	67	44.7
1	124	82.6	Total	150	100
2	13	8.7			
3	13	8.7	*Person collecting fuel*		
Total	150	100	Wife	66	81.5
			Daughter	15	18.5
			Total	81	100
House walls					
Thatch, straw	10	6.7	*Source of lighting*		
Mud and poles	70	46.6	Kerosene	127	84.7
Bricks	30	20	Electricity	23	15.3
Cement blocks	40	26.7	Total	150	100
Total	150	100			
			Sources of income		
House floor			Sales of crops	127	84.7
Earth	95	63.3	Business income	3	2
Cement	55	36.7	Salaries/wages	20	13.3
Total	150	100	Total	150	100

Of 150 index children involved in the survey, 68.9% were females while 31.1% were males with age range between 8.1 and 53.4 months and mean age of 28.3 and 12.1 months for females and males, respectively. Almost all the children (95.6%) had been fully immunised as per the Tanzania Ministry of Health and Social Welfare guidelines. A small proportion (4.4%) of children were not immunized against measles. Nearly a quarter (22.2%) of the children had some illness within two weeks preceding the survey. Of the children reported to be sick, 70% had malaria, 20% had skin rashes while 10% had respiratory tract infection (RTI). Nearly all children (95.6%) who felt sick had sought treatment from a nearby dispensary, health centre or hospital. Only a handful of the sick children (4.4%) used medicines without consulting a physician and/or may have consulted a traditional healer.

Breastfeeding and complementary feeding practices

Among the children studied, 40.9% were still being breastfed. More than three quarters (88.6%) of the study children were breastfed within one hour after birth. All the children were given colostrum. Pre-lacteal feeding was common in the study area (Table 2). This practice was also reported by the mothers who participated in the focus group discussions:

"On the first days, when a child cries continuously, it implies that the baby is not getting enough milk, hence we give them other foods".

"On the first days, breast milk does not usually come out, so we give water to complement breast milk".

Child breastfeeding was mostly on fixed schedule (83.3%), with few (11.1%) being breastfed on demand while 5.6% of children were breastfed when the baby cries. Furthermore, breastfeeding frequency was less practiced in the study area. On average, children were breastfed four times a day. Eighty two percent of the interviewed mothers reported to have breastfed their children three times during the day and once during the night. Despite that 55.3% of the mothers knew the proper time for introducing complementary food to children, too early food complementation existed in the study area. This was confirmed by following statements from mothers:

"Breast milk alone was not enough to sustain the baby up to six months".

"In some cases, a single breast may not produce milk, so I get forced to complement earlier than recommended".

More than three quarters (88.9%) of the children were breastfed for 24 months. Generally, most of the mothers (93.3%) who reported to have stopped breastfeeding, fed their children with three meals per day. This was also supported by the focus group discussions and key informants interviews;

"Honestly speaking, we have food to cook for our children in additional to family meals but we rarely cook for them".

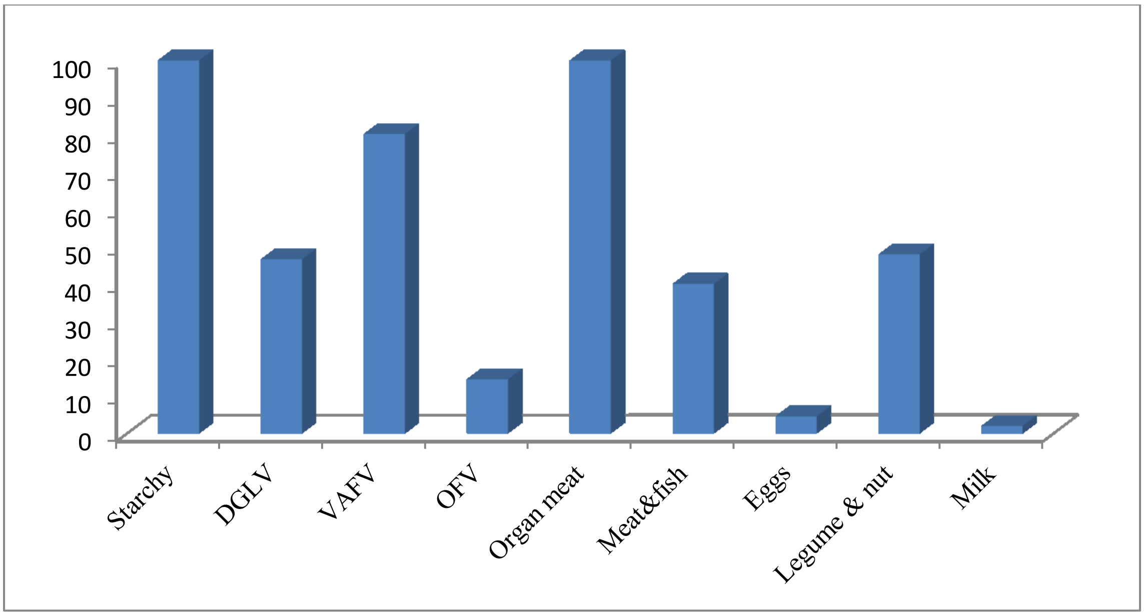
In the current study, only 50.4% of the households met the recommended daily water per capita consumption of 20 litres[15]. Amongst the households studied, 39% reported to dispose off the child's excreta within the compound/farm surrounding the home. Conversely, more than 88.9% of the households disposed off their solids and liquid wastes within the compound/farm.

Table 2: The percentage distribution of child feeding practices and water use of the study households

Variable	Frequency	%	Variable	Frequency	%
Pre-lacteal feeding			*Exclusive breastfeeding*		
Yes	60	40	<six months	130	86.7
No	90	60	Six moths	7	4.7
Total	150	100	>six months	13	8.6
			Total	150	100
Breastfeeding practical support/advice					
			Breastfeeding duration		
Yes	3	2	1 year	3	5.6
No	147	98	2 years	48	88.8
Total	150	100	<2 years	3	5.6
			Total	54	100
Breastfeeding frequency					
Day			*Sources of drinking water*		
2	3	5.9	Potable water	93	62
3	42	82.4	Non potable water	57	38
4	6	11.7	Total	150	100
Total	51	100			
Night			*Drinking water treatment*		
1	42	82.4	Yes	140	6.7
2	9	17.6	No	10	93.3
Total	51	100	Total	150	100

Dietary diversity, food consumption and nutrient adequacy

Mean DDS of nine food groups was 3.4±0.9 meals. Many children (57.2%) were on the lowest tercile (≤3 food groups) of the DDS while 42.8% of the children were in the medium tercile (4 and 5 food groups) of the DDS. There was no child in the high (≥7 food groups) DDS tercile. All children had starchy staples in the previous day. It was also noted that 46.7% had eaten dark green leafy vegetables in the day preceding the survey. Meat, especially, offals and sardines were consumed by 41.1% of the children. Only few children, 4.6 and 2% were given eggs and milk, respectively, in the previous day (Fig. 1).



DGLV= Dark Green Leafy Vegetables; VAFV = Vitamin A rich Fruits &Vegetables; OFV= Orange fleshed Fruits & Vegetables

Figure 1: Consumption pattern of various food groups in the previous 24 hours

The common item that was sold by the study households was chicken (79.5%). The reason for selling out chicken was to get money to pay for medical bills, clothes, utilities and buying other household assets.

"Chicken are kept for sale so as to buy clothes, foods, pay bills, and not for home consumption".

Nutrients intake and adequacy are summarized in Table 3. The proportion of the children who met the recommended daily allowance (RDA) for protein was (55%). However, only 7.9% of the children were able to meet the RDA for iron [16, 17].

Table 3: Nutrients intake and adequacy for the study children1

Nutrient	Min-Max	$\bar{X}$± SD	RDA	%NAR
Energy (kcal)	126-950	771 ± 320.8	765-1362	53.8
Protein (g)	0.3 -25.4	12.8±4.3	2-11	55.3
Iron (mg)	1.1-25	12.3 ± 10.0	10.8-18	7.9
Zinc (mg)	1.1-5.6	1.7 ± 0.3	2.2-2.8	10.5
Calcium (mg)	400-600	476 ± 54.2	500-800	10.5
Lysine (mg)	19.8-97.6	42.8 ± 51.5	58	34.2
Tryptophan (mg)	4.6-18.9	5.2 ± 1.9	11	26.3

[1]NAR= nutrient Adequacy Ratio, RDA= Recommended Daily Allowance

It was also found that, daily consumption of orange fleshed fruits and vegetables was not frequent. Few children (8.8%) consumed fruits, mainly oranges one day preceding the survey. On the other hand, cereal-based foods, mainly maize, were consumed daily by most (68.4%) of the studied children. Vegetables, mostly, amaranth leaves were consumed by 41% of the children on a daily basis.

Factors contributing to stunting in children

Results from regression analysis showed the factors that significantly predisposed children to stunting. The rates of stunting for children who were born to households whose source of income was unfixed (wages, petty business and casual labourers) were higher (adjusted OR = 7.36, 95%CI: 2.11, 25.75; p=0.001) than the households with salaried employments. Breastfeeding for less than four times during the day was more likely to be associated with stunting (adjusted OR = 0.68, 95% CI: -0.13-0.32; p = p=0.002). Children who received complementary foods early (<6 months) were more likely to be stunted compared to their peers who were complemented at 6 months or thereafter (adjusted OR = 2.26, 95%CI: 0.11, 0.60; p=0.002). Furthermore, younger children (6-24 months) had a higher risk of suffering from chronic undernutrition (stunting) compared to the older age group (25–59 months) (adjusted OR = 3.08, 95%CI: 0.15, 0.53; p = 0.001) . Regarding family size, children from families with more than four members were likely to be stunted (adjusted

OR = 2.86, 95%CI: -0.12-0.05: p=0.01) compared to those coming from smaller families. Children who did not eat animal source food in the day preceding the survey were more likely to be stunted than those who consumed animal source foods (adjusted OR = 5.04, 95%CI: -0.26 -0.60: p=0.02). Minimum DDS of ≤3 food groups was associated with stunting in children (adjusted OR = 3.47, 95%CI: -0.33, 0.68; p = 0.001). This study showed that, children from households using potable had a higher risk of becoming stunted compared to their peers using non-potable water (adjusted OR = 1.11, 95%CI: -0.28-0.07; p = 0.001). It was also noted that, factors such as place of delivery (home versus health facility), household's land size ownership and food preservation practices were not associated with stunting. Family owning a house, sell of household assets and borrowing of money were found not to be associated with stunting in children.

Discussion

This study showed that, most child feeding practices were sub-optimal except for initiation of breastfeeding within one hour after delivery. Pre-lacteal feeding was a common practice in the studied community. Liquids such as water and tea were given to children in the first three days. Prevalence of pre-lacteal feeding practice (40%) in the study area was even higher than the prevalence at national level (30%). These findings were in agreement with work by Nordang*et al.* [5]. The use of pre-lacteal feeds is not recommended as it can make the infant ill, interferes with breastfeeding and leads to lactation failure. Children in the studied community also consumed fewer numbers of meals (<4) per day than recommended. One of the reasons for giving few meals to children was laziness in cooking additional meals for children. The three meals mentioned by mothers were those obtained from the family meals. This was contrary to World Health Organisation recommendations that due to small stomach size, children should be given smaller but frequent meals in order to meet their body demands [18] . The breastfeeding and complementary feeding practices observed in this study were similar to those reported by NBS and Macro[4]. Meal frequencies including snacks were lower than the recommended values of two to three for 6–8 months-old and 3 to 4 meals for 9–24 months-old breastfed infants, with additional nutritious snacks (once or twice a day at 12 months) [19].

This study revealed low food consumption except for protein source. Furthermore, organ meat, fruits and vegetables were frequently consumed among the study population. This could be attributed to the fact that those foods were inexpensive and affordable. Foods such as animal organ example offals were considered inferior, hence relatively cheaper compared to other meat cuts. This situation was also similar to green vegetables. Although some of the households interviewed kept chicken, consumption of eggs was very low. Chicken were kept for commercial purposes and not for household consumption. Consumption of cow's milk was rare in the area. Growing children with prolonged low intake of cow's milk were associated with poor bone health. Low intake of milk [20, 21] and eggs [22] among children has been reported elsewhere. Furthermore, low intake of milk and dark green leafy vegetables, which are good sources of calcium, could be related with its low nutrient adequate ratio observed..

For children to grow into healthy adults, they need well balanced meals. Carbohydrate, protein and fat are mainly required for growth and development. The findings of this study revealed that, intake of these nutrients was low, probably contributed to low body weight observed [23]. Adequate protein intake is essential for growth, development and repair of body tissues in children. Foods naturally rich in protein include meat, fish, chicken, eggs, beans, pulses and nut. Given the vital role of zinc in human health, growth and development, this widespread deficiency has public health implications. Zinc is a critical component in over 300 multiple enzyme systems in the body and is involved with RNA and DNA synthesis, critical to cellular growth and differentiation [24]. In spite of low intake of zinc and iron in this study, their availability is also questionable. Frequent consumption of vegetables and legumes experienced in this study predispose the child to antinutritional factors. These antinutritional factors tend to bind protein and minerals and form complex compounds, thereby causing protein and mineral indigestibility.

Parents play a major role in the development of healthy eating habits of their children through a variety of mechanisms including a healthy diet, the availability and accessibility of nutritious foods at home. Parent's income is one of the primary indicators of socio-economic status. The findings showed a significant association between father's occupation and stunting. In other studies, father's occupation was also mentioned as one of the factors linked with stunting among children [25]. It is recommenced that, a child should be introduced to foods other than breast milk at the age of six months. This age is important because, at this point, there is increased demand for nutrients, which breast milk alone cannot provide in the required amounts. It was noted in this study that, early introduction of complementary foods (<6 months) was common and this practice was associated with stunting among children. Poor quality and quantity of complementary foods given to the children could be the reason for linear growth faltering and failure. These findings were consistent with other research works [26].

It is well known that the first thousand days are a window of opportunity for a child to develop his/her full potential. Anything that is likely to affect the child in this period is likely to spoil the entire future of the child. It was noted that, the risk of undernutrition decreased with age. Children in the youngest age groups (6-24 months) were at a significantly higher risk of stunting than children in the older age group (25-59 months). The increased risk could be due to the fact that, children in the study area were introduced to complementary food too early and the types of complementary food given were nutritionally poor. Low feeding frequency also increased the risk of food inadequacy at the early stage of life. This contradicts a study in rural Ghana which indicated that the older children (24-35 months) were at a higher risk for stunting [27].

The findings that lager household sizes (≥4 members) were associated with more stunting in children were in agreement with earlier work[28] .The possible reason for this could be that, children from large families (≥4) competed for food and other services such as care at the households. This was more pronounced in the low income families due to limited household resources. Furthermore, families with more children devoted less time to take care of the older children. The current study however, did not find a significant relation between stunting and number of children below five years at the household, contradicting other studies [29].More children from households using non-potable water were stunted relative to their peers using potable water. Access to safe drinking water is a pre-condition for good hygiene and later nutrition among children, thereby reducing incidences of infections, which might result in water borne and water related illnesses. Similar results were reported in Iran [30].

Limitations of the Study

This study being a survey is limited due to various reasons. One of the limitations was that there was no way of telling how truthful a respondent was. Another limitation was that recall was based on memory, so the response was based on respondents' ability to recall.

Conclusions

The present study attempted to assess child feeding practices and identify risk factors for chronic childhood undernutrition in rural Tanzania. Pre-lacteal feeding was common in the study area. Fluids such as warm water, sugary water and tea were given to infants in the first three days. Too early nutrient complementation also existed, plain maize porridge being the first food introduced to the studied children. Many children were on the lowest tercile of dietary diversity score, indicating that, they were getting ≤3 food groups per day.Family's source of income and breastfeeding frequency were among the factors that influenced stunting of children significantly. Other factors such as age of the child, age at introduction of complementary food, DDS ≤3 food groups, consumption of animal foods, family size and use of non-potable water were also risk factors that predicted child stunting.

Recommendations

Programs to address stunting in communities must be planned, considering the risk factors identified. Such programs may involvedevelopment of high energy and nutrient dense supplementary foods for children less than five years of age.

Acknowledgments

This study was supported by The World Bank and The Open University of Tanzania. The authors would like to thank caregivers and children for accepting to participate in the study. The authors are also indebted to the following home based care providers namely, Nicholaus, Semndi and Adelina for assisting in data collection.

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PAPER THREE

Efficacy of Quality Protein Maize-based Supplementary Foods on Rehabilitating Undernourished Children

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(Manuscript submitted to Tanzania Journal of Health Research)

Abstract

Low energy density of maize-porridge, linked with its low quality protein, low micronutrients and low lysine and tryptophan make maize porridge a poor supplementary food for infants and young children. This study was designed to evaluate the efficacy of quality protein maize-based composite supplementary foods in rehabilitating moderately underweight children in Mvomero District, Tanzania. This was a randomized longitudinal study with intention to treat undernourished children. Two formulations were developed from quality protein maize namely quality protein maize -soybeans-common beans and quality protein maize -soybeans-cowpeas. A third diet, which was prepared from conventional maize, was used as a control. Children with weight-for-age Z score ≥ -2 SD from the reference population were selected to receive either a composite supplementary food (quality protein maize-soybeans-common beans and quality protein maize-soybeans-cowpeas) or common maize porridge (control). A total of 132 children were fed on the diets for a period of 16 weeks. On the course of feeding, weight, height, Mid-Upper Arm Circumference and haemoglobin concentrations were determined. Results showed that, quality protein maize-based diets had positive effects ($p<0.05$) on weight, height, weight-for-age, height-for-age, weight-for-height Z-scores and haemoglobin concentrations but not on mid-upper arm circumference. Children consuming conventional maize porridge progressively faltered in growth with weight-for age decreasing from -1.9 to -2.1 SD, height-for age from -2.0 to -2.9 SD, weight for height from -1.2 to -1.9 SD and haemoglobin levels from 10 to 9.9 (g/dL).During the 16 weeks of rehabilitation, 68% (n=27) of children receiving quality protein maize-soybeans-common beans diet grew back to normal weight for age Z-score of ≤ -2SD. For children receiving quality protein maize-soybeans-cowpeas diet, 50% (n=23) of the undernourished grew back to normal weight for age and only 19.5% (n=9) children receiving commonmaize porridge grew back to normal weight for age Z-score. Quality protein maize-soybeans-common beans diet had higher potential to support growth than the other diets.Sixteen weeks of supplementation resulted in significant ($p<0.05$) improvement in height, weight, weight-for-age, height for-age, weight-for-height Z-scores and haemoglobin levels for children receiving quality protein maize-based composite diets. Growth velocities for study children in various groups were 0.39g/monthfor quality protein maize-soybeans-common beans, 0.28g/monthfor quality protein maize-soybeans-cowpeas and 0.13 g/monthfor conventional porridge. It is concluded from this study that, areas affected by undernutrition, quality protein maize-based composite foods can be used for rehabilitating undernourished children. It is recommended that, a large scale study involving larger number of children should be conducted to ascertain the findings of this study.

Keywords: Composite supplementary foods, undernourished, rehabilitation, randomized controlled trial, children, Tanzania

Introduction

Undernutrition in children continues to be a major public health problem throughout the developing world, particularly in sub Saharan Africa (Fanzo, 2012)and Tanzania (NBS and Macro, 2011) in general.It is estimated that, globally, undernutrition contributes to more than a third of under-five deaths and disability (Black *et al*., 2011). A study conducted in Tanzania in 2010 showed that, 44% of children were stunted, 5% were wasted while 16 % were underweight NBS and Macro (2011). These statistics were comparable with those reported from Morogoro in which 44% of the children were stunted, 5% were wasted and 16% were underweight (NBS and Macro 2011).

Improper child feeding practices have negative impact on growing children (Nathan, 2008). Poor feeding practices such as low adherence to exclusive breastfeeding and too early or too late introduction of complementary foods are common among children in

Tanzania NBS and Macro (2011). Several studies have linked improper feeding practices with child nutritional status (Sreedhara and Banapurmath, 2014)Korir, 2013;Khatoon *et al.,* 2011; Ramji, 2009). Traditional supplementary feeding of infants and young children in Tanzania and much of Africa is commonly based on plain maize porridge. Low energy density of maize-porridge, linked with its low quality protein, low micronutrients and low lysine and tryptophan make maize porridge a poor supplementary food for infants and young children (Vasal, 1999). In some cases, the mother may opt to add other cereals and legumes such as rice, wheat, millet, and soybean to improve the nutrient content. Intake of animal based foods is limited due to unavailability and high prices which many families cannot afford (Kulwa *et al.,* 2015:Nordang *et al.,* 2015). Nutritional problems associated with the use of starch staples in supplementary foods are widely reported (Katungwe, 2015: Badake *et al.*, 2014). Several strategies have been devised to improve the nutritional value of some of the staple foods. Biofortification of maize was initiated by International Maize and Wheat Improvement Center (CIMMYT) in 1960s and it involved developing maize cultivars with protein high in lysine and tryptophan, called quality protein maize (QPM). Despite the fact that utilization of QPM as part of a family diet is growing steadily in Tanzania, there is little information on the use of QPM in complementary feeding. The current study is therefore designed to fill this gap by evaluating the efficacy of quality protein maize-based composite supplementary foods in rehabilitating moderately underweight children in Mvomero District, Tanzania. In order to improve protein content, soybeans, common beans and cowpeas were used in making the formulations.

Materials and Methods

Materials

Quality protein maize (NATAK6Q) was purchased from Muheza Innovation Platform for Technology Adoption (IPTA), Tanga. Common maize (*Zea mays*), soybeans (*Glycine* *max*), common beans (*Phaseolus vulgaris*), cowpeas *(Vignaunguiculata*), palm oil and sugar were purchased from Morogoro Municipal central market. Micronutrients powder (MNP) to fortify the products was purchased from TuboresheChakula Project, Dar es Salaam.

Methods

Product processing and formulation

Separately, QPM, soybeans, common beans and cowpeas were cleaned by winnowing, removal of pebbles and chaff and washed. QPM and soybeans were thereafter dehulled, cleaned and dried under the sun until a moisture content of 10% was attained. All ingredients were separately milled to fine flour (mesh size 0.4 mm). The flours were then extruded. After extrusion two products namely QPM-soybeans-common beans (QSB) and QPM-soybeans-cowpeas (QSC) were formulated as indicated in Table 1. Formulations were fortified with vitamin and mineral in order to improve micronutrient content.

Table 1: Composition of the QPM-based supplementary food formulations

Ingredients	**Formulations**[1]		
	QSB	**QSC**	**CP**
QPM	52	54	-
Soybean	8	6	-
Cowpeas	-	34	-
Common beans	34	-	-
Common maize	-	-	94
Micronutrient powder	1	1	1
Sugar	5	5	5
Total	**100**	**100**	**100**

[1]QSB=quality protein maize-soybean-common beans: QSC=quality protein maize-soybean-cowpeas: CP= Conventional porridge

The formulations were designed to meet the highest amino acid score and the desired amount of energy and fat according to the FAO/WHO/UNU (1985) *Codex*

*Alimentarius*guidelines for supplementary foods for infants and young children. Each formulation provided various nutrients as indicated in Table 2. Lipid contents of the products were adjusted to 10% using palm oil. Extrusion of the composite flours was carried out in a commercial twin-screw extruder (Model JS 60 D, Qitong Chemical Industry Equipment Co. Ltd, Yantai, China). The extruder consisted of two electrically heated zones. The following extrusion conditions were adopted: Temperatures 130^{o}C (Zone 1) and 122^{o}C (Zone 2), main motor speed was set at 10.48 rpm and feeder speed at 10.26 rpm. Desired barrel temperatures were maintained by circulating cold tap water. Temperatures were controlled by inbuilt thermostat and a temperature control unit. After extrusion, the extrudates were allowed to dry at room temperature then milled into fine powder (mesh size 0.4 mm). Sugar (5%) was added to the powder and mixed. The flour was packaged in polyethylene moisture proof packets. For the control group, common maize (CM) was dehulled and milled. After milling, 5% sugar and 1% chocolate powder were added. The flour was then packaged in polyethylene moisture proof packets and stored until use.

Feeding study

A total of 150 children aged 2-5 years were recruited in Turiani ward, Mvomero district, Morogoro (100 in intervention group and 50 in a control group). This sample was selected assuming a 30% drop-out rate and 95% power to detect the error with an overall type II error of 5%.

Inclusion criteria were that children must have lived in the area for at least three months prior to the intervention and must continue to live there for the next one year post intervention.

Table 2: Nutrients composition of the composite products

Nutrient	Formulation[1] QSB	QSC	CM
Protein, g/100g	17	16	6
Fat, g/100g	4	3	2
Ash, g/100g	0	0	0
Crude fibre, g/100g	4	3	1
Carbohydrate, g/100g	79	81	91
Energy, kcal/100g	386	389	387
Amino acids (mg/g)			
Histidine	34	37	31
Threonine	44	43	29
Valine	58	59	45
Isoleucine	50	49	52
Leucine	96	98	121
Lysine	74	73	26
Tryptophan	18	17	7
SAA	44	42	41
AAA	91	88	76

[1]QSC=quality protein maize-cowpeas-soybean: QSB=quality protein maize-common beans –soybean: CM=Common maize: SAA= sulphur containing amino acid (methionine and cysteine): AAA= aromatic amino acids (phenylalanine and tyrosine)

Other criteria were age 6-59 months, WAZ= -1 to -2SD with a child attending reproductive and child health (RCH) clinics. Exclusion criteria were children with diarrhoea and vomiting and other infectious diseases such as pneumonia, tuberculosis and malaria at the time of intervention were excluded. Also, children with chronic conditions that needed permanent medication were excluded from the study. In addition, children participating in other clinical studies involving use of dietary therapy or children with nutritional or medical condition which required dietary management were excluded from the study. Allocation to the study groups was made using computer generated random numbers. At enrollment, the research team confirmed eligibility and obtained consent from each participant’s guardian. Baseline assessment of nutritional status was carried out immediately following recruitment.

Study design, interventions and follow up

Study design

This was a longitudinal study, with intention to treat and rehabilitate undernourished children. The feeding study was conducted for a period of 16 weeks. After the mothers had signed to affirm their consent, they were randomized to receive either QSB, QSC or CP diet. Three groups were formed, two of them received treatment diets namely QSB and QSC while the third group received CP (control) diet. The diet was administered for 16 weeks. At baseline, information such as child's weight, height, date of birth, mid-upper arm circumference (MUAC) and haemoglobin levels were collected.

Intervention

At every monthly health clinic visit, the subjects received the monthly food rations. The composite flour allocated for a day would provide energy (400 kcal), protein (16g) and iron (14 mg), considered to be 30% of the RDA. Micronutrient powder was added to the porridge fed to children in the treatment groups. During these visits their anthropometric measurements were also taken. For all the groups, the supplementations were given during the mid-morning and mid-afternoon. The porridge was prepared according toMaseta*et al.* (2016). Porridge was made by first mixing 100 g of flour in 300 ml of cold water to make slurry. The slurry was then gradually added, while stirring to 700 ml of boiling water in a 2 L stainless steel saucepan. When the mixture boiled for 5 minutes, the porridge was removed from the cooker. Since the flour for the CP diet was not extruded, it was kept to boil for 20 min, stirring every 5 minutes. Thereafter, the porridge was cooled to about 37^0. Micronutrient powder was then added in 100 ml porridge served in a 250ml cup, stirred well and served to children in the study groups. Micronutrient powder was not added in the porridge for the control group. All mothers were encouraged to continue breastfeeding on demand and to feed their infants as much of the food supplement as they wanted to consume at a time. Mothers were also advised to continue feeding their children the usual family meals.

Monitoring compliance to regimen

During the intervention, the study children were visited by field assistants and the researcher biweekly at their homes to collect information on the use of the treatment diet and possible adverse effects. Field assistants conducted home visits to subjects' homes to monitor compliance on the use of the composite diet. During visits, all used food/ MNP sachets were collected and submitted to the field assistants. The sachets were then related to the number of days that had passed since the last ration. Mothers who failed to return to collect their monthly food ration for two consecutive visits, without good reason were considered to have dropped out of the study.

Measurements taken

At baseline, data on weight, height, MUAC and haemoglobin were collected. Child's weight was measured monthly using a Salter scale (Model 2356M, Tonbridge, UK) and weights recorded to the nearest 0.1kg. Lecumbent length/ height was measured without shoes on using a wooden length/height board (UNICEF, USA) and recorded to the nearest 0.1cm. Mid upper arm circumference was measured using a standard MUAC tape (UNICEF). Mid upper arm circumference was measured at the midpoint of the left arm between the acromion process and the tip of the olecranon and recorded to the nearest 0.1 cm. Haemoglobin concentration was measured from a finger prick blood picked by a microcuvette and read in a HemoCue photometer (HemoCue AB, Angelholm, Sweden) and values recorded to the nearest 0.1 g/dL. Children who had not been dewormed in the preceding three months were given deworming drug (500 mg Albendazol). Figure 1 shows the setup of the study.

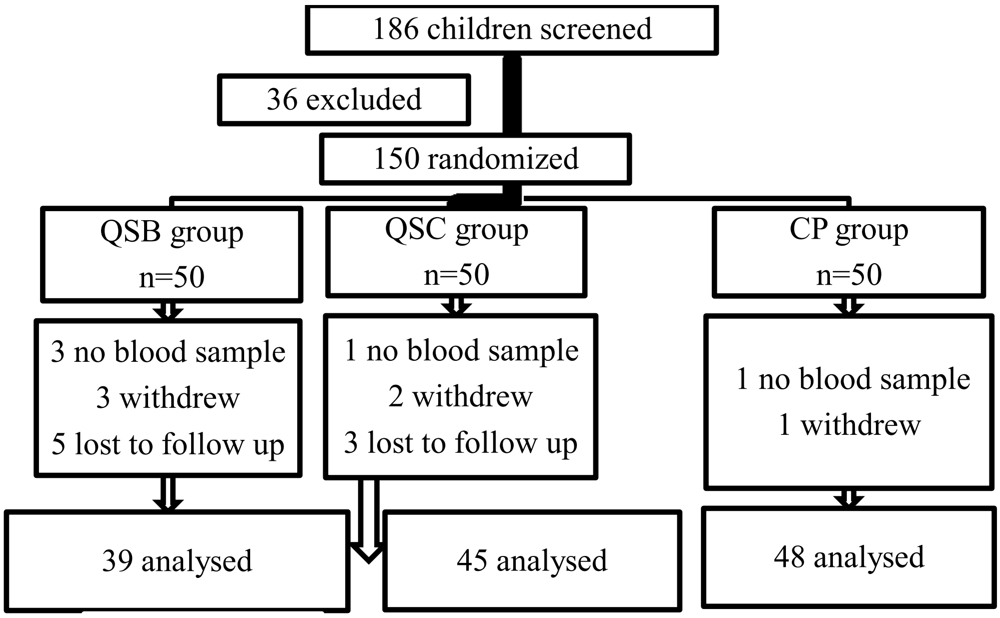

Figure 1: Flow chart of the study

Follow up

Weight, height and MUAC measurements were repeated monthly for four consecutive months. Haemoglobin concentrations were determined at the baseline and at the end line. Anthropometry was done by the same trained field assistants at all-time points. Illness symptoms and signs, such as nausea, vomiting, diarrhoea and presence of any skin rash were assessed on every visit. A questionnaire was administered to the mother of the study child at admission to collect data on socio-demographic characteristics, breastfeeding status, illness and use of any nutritional supplements.

Measurement of outcome indicators

The primary outcome was weight gain during 16-weeks feeding. Secondary outcomes included length/height gain; mean change in the anthropometric indices of weight-for-age (WAZ), height for-age (HAZ), and weight-for-height (WHZ) Z-scores. Other outcome indicators were change in MUAC and hemoglobin concentrations.

Data analysis

Data were entered in Excel and analysed using IBM SPSS Program (Version 20). Anthropometric indices were based on the WHO's 2006 Child Growth Standards, calculated by using ENA for SMART (Version 6.0). Means were compared using t-tests. Comparisons of outcomes between types of supplementary foods were made by using Fisher's exact test for dichotomous variables and Student's t test for continuous variable. Differences were considered significant at $p \leq 0.05$.

Ethical Considerations

This study protocol received ethics approval from National Institute for Medical Research (NIMR). Informed verbal and/or written consent was obtained from the mothers/care providers before enrollment.

Results

Baseline characteristics of the study children

Of the 150 children recruited for the study, 18 children were not included for data analysis as the parents did not bring them to RCH clinics for two consecutive visits, withdrew from the study or no end line blood sample was collected (Figure 1). At the end of the study, 132 children completed the 16 weeks feeding cycle. Of the 132 children who completed the feeding cycle, 39 children were receiving QSB diet, 45 were receiving QSC diet while 48 children were receiving CP diet (control). Table 3 summarizes the characteristics of children receiving the various diets at the beginning of the feeding cycle. The intervention groups did differ significantly ($p<0.05$) with some baseline characteristics (Table 3), except for WAZ, HAZ and diarrhoea episodes in previous two weeks. Female children were the majority 62.1% (n=132) in the study.

Table 3: Characteristics of children receiving the various diets at the beginning of feeding period

Characteristic	QSB (n=39)	QSC (n=45)	CP (n=48)	P value
Child-time				
Age category, n (percent)				
Age (months)	39 (29.5)	45(34.1)	48 (36.4)	0.001
Maternal age (years)	27.0 (0.8)	19.1 (1.5)	19.2 (1.9)	0.03
Sex, n (percent)				
Male, n (percent)	17 (20.5)	9 (6.8)	24 (18.2)	0.000
Weight , kg	9.4 (0.3)	10.5 (0.3)	9.6 (0.3)	0.042
Height , cm	77.4 (1.8)	82.0 (1.1)	80.5 (0.3)	0.082
MUAC , cm	14.1 (0.1)	14.7 (0.1)	14.1 (0.2)	0.007
WAZ	-1.8 (0.2)	-1.9 (0.1)	-1.9 (0.1)	0.178
HAZ	-2.0 (0.1)	-2.7 (0.1)	-2.0 (0.2)	0.113
WHZ	-0.7 (0.1)	-0.5 (0.2)	-1.2 (0.1)	0.001
Hemoglobin, g/dL	9.4 (0.3)	10.4 (0.2)	10.0 (0.2)	0.002
Anaemia (hemoglobin <10 g/dL)	36 (23.7)	33 (25)	36 (23.7)	0.003
Ever received nutrient supplements , n (percent)	18 (13.6)	6 (4.5)	15 (11.4)	0.01
Child breastfeeding, n (percent)	18 (13.6)	12 (9.1)	30 (22.7)	0.002

Data are mean (SD), unless stated otherwise

Changes in study outcomes over time

At the 16[th] week of supplementation, there was significant differences ($p<0.05$) in the parameters tested for the three diets (Table 4). Weight gain on average was 1.4 kg for children receiving QSB, 1.1 for those receiving QSC and 0.03 kg for children receiving CP diet (Table 4). Height gain on average was 1.6 cm for children on QSB diet, 1.6 cm for those in QSC and 0.2 cm for children receiving CP diet, over the 16 week feeding period. The gain in weight and height were reflected in higher WAZ, HAZ and WHZ scores ($p <0.05$) at the end of the feeding period for all trial diets relative to the control diet. At the end of the feeding period, there were also significant differences in haemoglobin concentrations among the children receiving the three intervention diets ($p>0.001$). For children receiving QSB diet, there was a threefold decrease in anaemia, those receiving

QSC diet had two folds decrease in anaemia while those receiving the CP diet had increase in anaemia (6.3%) on the course of the feeding. Overall, recovery rate from underweight was significantly different across the diets (p=0.000). Furthermore, none of the caretakers reported any reaction or side effects associated with consumption of the various trial/control diets.

Table 4: Outcome changes in subjects receiving the trial diets for 16 weeks

Outcome	**QSB n=39**	**QSC n=45**	CP **n=48**	**P value**
Weight gain (g /month)	0.39 (0.0)	0.28 (0.0)	0.13 (0.0)	0.000
Height gain (mm/ month)	0.16 (0.01)	0.13 (0.0)	0.01 (0.0)	0.000
MUAC gain (mm/ month)	0.02 (0.0)	0.00(0.0)	0.03 (0.0)	0.070
Haemoglobin (g/dL/month)	0.1 (0.0)	0.04 (0.0)	-0.01 (0)	0.000
End point mean WAZ (SD)	-1.5 (0.8)	-1.4 (0.7)	-2.1(1.1)	0.000
End point mean HAZ (SD)	-3.1 (1.0)	-2.3(1.1)	-2.9(1.4)	0.640
End point mean WHZ (SD)	0.3 (1.0)	0.2(1.1)	-0.7 (1.2)	0.000
End point mean MUAC (SD)	14.5 (1.0)	14.8(0.7)	14.6(1.1)	0.005
Underweight recovery n (%)	15(58.0)	18(40.0)	6 (19.5)	0.000
Anaemia recovery n (%)	17(43.6)	6 (13.3)	-3 (6.2)	0.000

Data are mean (SD), unless stated otherwise

Nutrient contents of the diets and growth velocities

The energy density and protein contents of the diets were 386 and 17 (QSB), 389 and (QSC) and 387 kcal and 6 g (CP), respectively. Growth velocities are presented in figure 3. Growth of children across the diets was significantly different (p=0.000). Diet QSB had the highest monthly growth rate (0.39 g/month) than QSC and CP diets. Furthermore, weight was positively and strongly (≥70%) correlated with the diet (Fig. 3).

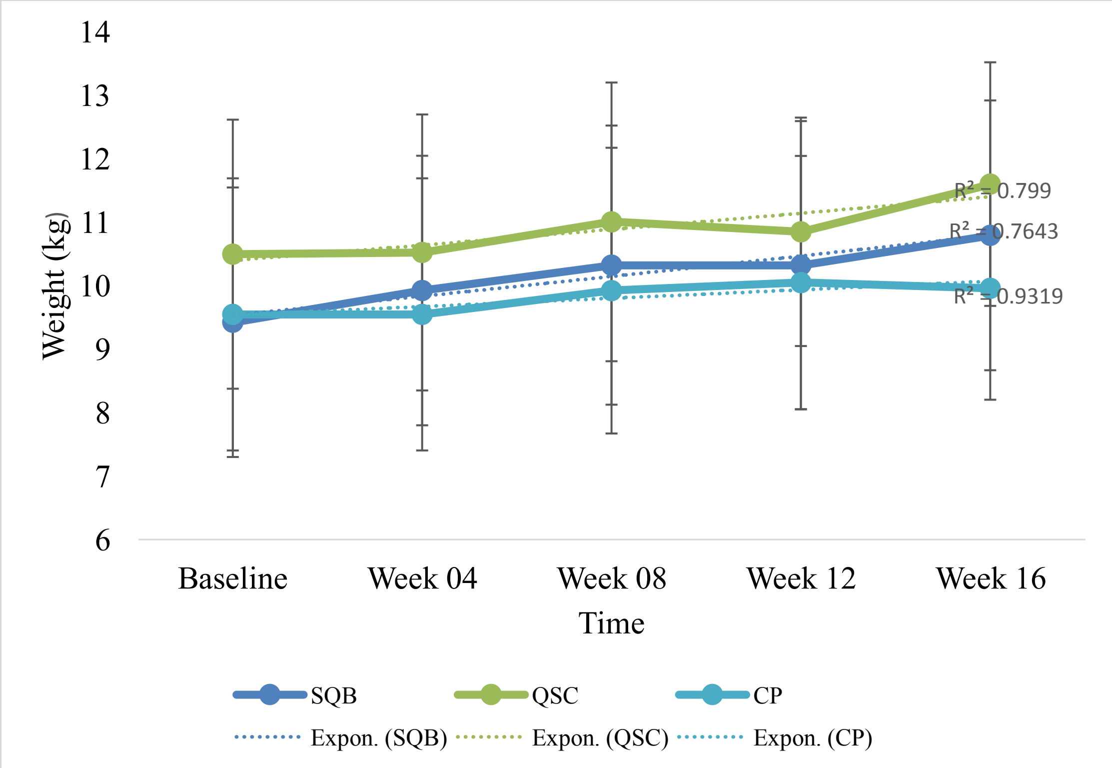

Figure 3: Weight gain of children per month for the various diets

Discussion

The present feeding trial was carried out to evaluate the rehabilitation potential of two composite QPM-based fortified, energy dense supplementary foods (QSB and QSC) for undernourished children aged 0-5 years. Group allocation was random, biweekly and monthly follow-up was identical for all groups. People measuring the outcomes (except the principal investigator) were blinded to diets allocation. The observed results were therefore unbiased and thus representative of the population from which the sample was drawn. In our study, children receiving QSB diet for the 16 weeks gained slightly more weight, length and haemoglobin on average than those receiving QSC diet, however the differences were insignificant ($p>0.05$). This could be contributed by differences in nutrient contents, both QSB and QSC diets met FAO/WHO references for daily energy (360 kcal) and protein (16g) requirements for children less than five years. Home-based dietary therapy using either QSB or QSC was more effective in treating moderately underweight children. In this clinical trial, underweight childrenwho received the trial diets (QSB and QSC) had higher growth velocities compared to the control group. The study has demonstrated that, CP (the control) diet was inferior to the composite diets QSB and QSC in rehabilitating underweight children. Our results were in line with previous studies in Congolese children(Bisimwa*et al.*, 2012). Guidelines provided before the use of the food rations probably influenced the nutritional status of the children receiving the trial diets. Before feeding commenced, mothers were instructed to consider the trial diet as any other medication. Therefore, this minimized sharing of the food rations. Furthermore, follow up for compliance by the Village Health Attendants (VHA) and research team during the study might have also increased the effectiveness to the feeding regimen.

In the study population, like elsewhere in the African societies,quality of the children's diets was generally poor (Sunguya *et al.*, 2014: Tessema *et al.,* 2011). At baseline, it was noted that, study children were mostly eating the normal family foods, with no addition of other meals or snacks for nutrient complementation. Most foods given to children were based on cereals, mainly maize, with limited consumption of protein sources such as legumes or animal-source foods. The fact that the study sample came from an agrarian society (AgriDiet, 2015), the use of QPM was likely to have a greater nutritional impact compared to their normal children diet (CP). Furthermore, introduction of these composite diets may have increased the number of meals (three to six) that the children received per day. This was reflected in the outcomes observed in children receiving QSB and QSC diets. Recovery rates observed in this study were in agreement with results from animal study (Maseta and others) (unpublished). A study involving rehabilitation of malnourished rats showed that rat receiving QSB and QSC diets had higher catch up growth than when the animals were on plain maize diets. Our results were consistent with other reports involving the use of ready to use therapeutic foods (RUTF) and corn soy blends in supplementary feeding programs. A controlled comparative trial among moderately wasted children found that, 58% of children recovered when given RUTF, whereas only 22% recovered when given corn-soya blend (Patel *et al.,* 2005).

In communities where maize is part of the complementary food, nutrient complementation is important. Locally available foods such as legumes and nuts could be used to increase nutrient density of complementary foods. Conventional porridge diet (CP) in this study was not blended with any other food materials such as legume, in order to improve nutrient quantity. Major differences between the trial diets QSB and QSC and the control (CP) included the following: use of maize variety, QPM. Quality protein maize is high in amino acids lysine and tryptophan compared to CP (Nuss & Tanumihardjo, 2011). Another difference was that vegetable oil was added to improve energy density, addition of legumes and micronutrient powder improved the nutrient density. Furthermore, dehulling of QPM and soybeans helped to reduce the dietary fibre hence concentrating the energy while extrusion helped to inactivate the antinutritional factors which could have negative effect on the bioavailability of energy and nutrients in the diets (Golchin-Gelehdooni *et al.*, 2014).

Conclusions and Recommendations

Improvements were observed in weight, height, WAZ, HAZ, WHZ and haemoglobin levels of children receiving QPM-based supplementary foods. Therefore, diets QSB and QSC were superior in terms of recovery from underweight in children. Future research is needed to determine whether QSB and QSC diets will have the same potential to support recovering from underweight children in other settings in which maize is not a common staple food. A larger sample size would have granted more confidence on the generalization of our findings.

Acknowledgements

The authors would like to thank all the women and children who agreed to participate in the study. We also acknowledge with thanks The World Bank and The Open University of Tanzania for funding this study. Dr. ZubedaMduruma is thanked for assisting in outsourcing the quality protein maize.

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PAPER FOUR

Nutritional quality, mycotoxins and antinuntritional factors in quality protein maize-based supplementary foods for children in Tanzania

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PAPER FIVE

Sensory Evaluation of Extruded Quality Protein Maize-Based Supplementary Foods

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CHAPTER THREE

3.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

Maize is widely used as the main ingredient in complementary food for most children in Tanzania and in particular,Mvomero district. Maize is however, limited in two essential amino acids, lysine and tryptophan that are essential for human growth. In line with the foregoing, the populations whose diet is predominantly made from maize, protein deficiencies can occur. To address this problem, maize varieties with higher lysine and tryptophan content (QPM) were developedCIMMYT. This study was aimed at developing QPM-based composite supplementary foods suitable for rehabilitating undernourishedchildren in Mvomero district. The results showed that, food intake in rats was significantly different among diets; with a trend of intake decreasing from quality protein maize-based to common plain maize diets (Chesta®> QS> QSB > QSC > QQ). Protein digestibility-corrected amino acid score was high (≥70%) for all the test diets, except the Chesta® (53%). Pre-lacteal feeding practice was common in the study area. Children were introduced to complementary food too early (<6 months) and plain maize porridge was the first food introduced. The findings revealed that, family's source of income and breastfeeding frequency were among the factors that influenced stunting of children significantly. Other factors such as age of the child, age at introduction of complementary food, dietary diversity score ≤3 food groups, consumption of animal foods, family size and use of non- potable water were also risk factors that predicted child stunting. Sixteen weeks of supplementation resulted in significant improvement in height, weight, weight-for-age, height for-age, weight-for-height Z-scores and haemoglobin levels for children receiving quality protein maize-based composite diets. Children consuming conventional porridge progressively faltered in growth of weight-for age, height-for age, weight for height and haemoglobin levels. During the 16 weeks of rehabilitation, QSB and QSC diets showed higher potential to support growth of undernourished children than CP. Quality protein maize-soybeans-common beans and QSC met RDA for both energy and protein for children aged 2-5 years. A child consuming a daily ration of the test diets (QSB and QSC) weighing 120 g was receiving 17and 16g of protein, respectively. The amino acid scores for QPM-based diets were higher than the recommended scores (≥65%) for supporting optimal growth of children. Concentrations of fumonisin B1 and total fumonisin for plain maize diets (QQ and CM) were above the maximum tolerable limit of 1000 μg/kg recommended by the European Commission.

Quality protein maize-soybeans-common beans porridge was rated higher for aroma and taste than all porridge samples tested. Despite higher rating in aroma and taste, all the porridges (QSB, QSC and CP) were equally acceptable by the panelists. The sensory attributes of colour, oiliness, aroma, sweetness, liking and aftertaste in principal component 1 distinguished test porridges from the control. However, all the diets could be described by viscosity, sweetness and colour in principal component 2. Porridge samples QSB and QSC resembled the control diet by some attributes namely, aroma, aftertaste and sweetness and therefore, had higher potential for acceptance by consumers.

3.2 Recommendations

Based on the research findings, the following recommendations were made:

i. In view of the fewer numbers of mealsgiven to children in the study area, nutrition education is necessary for family members so that the child does not rely on family meals alone which in many cases ranged from two to three meals.

ii. Mother's time spent in caring children is affected by other household activities in which she is engaged. An alternative cooking technology needs to be developed/introducedso as to cut down mothers' time spent in collecting fuel wood for cooking.

iii. QPM-based diets have shown the potential for growth and rehabilitation of undernourished children. QPM-based composite foods could be used in areas affected with childundernutrition.

iv. The findings that maize-based formulations were more affected by fumonisins call for efforts to reduce the levels of these toxicants in maize grain. One way of achieving this is by good agricultural practices such as use of resistant varieties, crop rotation, well-timed planting, weed control, pest control especially control of insect pests and avoiding drought and nutritional stress through fertilization and irrigation. Measures to stop the infection process by controlling the mycotoxin outside the filed could be achieved through post-harvest interventions that reduce mycotoxin. These include rapid and proper drying, proper transportation and packaging, sorting, cleaning, drying, smoking as well as post-harvest insect control.

v. Regarding consumer acceptability, intensities of oiliness, colour, viscosity, aroma and aftertaste of porridge samples were desirable attributes while viscosity, mouthfeel and whiteness were undesirable attributes. It was recommended from this study that, food processors should maintain the desirable sensory characteristics and minimize the undesirable attributes when formulating products for children.

vi. Comparing QPM and CM, QPM was better in the sense that, it had double the amount of lysine and tryptophan that were limiting in CM. Communities should be sensitized to use QPM instead of CM in preparing complementary foods for children.

vii. Extrusion being a relatively newer technology calls for cost effectiveness study so as to determine its affordability to families in low economic status in using extruded CF.

viii. The fact that the formulations were made of legumes and oil, risk for deterioration is high. A study on the shelf life of the test diets is proposed

APPENDICES

Appendix 1: Questionnaire to Evaluate Child Feeding and Nutritional Status of Children in Mvomero District, 2014

Note to Enumerator:Explanation to interviewer

My name is........... This questionnaire asks about the foods you eat. I really appreciate you taking the time to complete this interview. There are no 'right' or 'wrong' answers. Accurate and thoughtful responses will allow us to pinpoint general situation in your household. All of the data collected is anonymous and your answers will be held in strict confidence.

Basic information				**BI**
BI01 Date of survey: _____/_____/_______ *(DD/MM/YYYY)*	BI02ADP Name of respondent __________________	BI03 Village Name ____________	BI04 Qnnr #: ___________	BI05 Name enumerator ________

SECTION 1: SOCIO-DEMOGRAPHIC AND ECONOMIC INFORMATION

1.	Household Head Name (Decision maker)		
2.	Sex of the household head	1. Male 2. Female	
3.	Age of the household head	Enter age in years	
4.	Marital Status of the household head	1. Married – monogamous 2. Married – polygamous 3. Widowed 4. Divorced 5. Single 6. Other (specify)	
5.	What is your education level?	1. None 2. Adult education 3. Primary school 4. Secondary school 5. Post Secondary school 6. Other (specify)	
6.	What is the occupation of the household head	1. Farmer 2. Employed in formal sector 3. Self employed 4. Other (specify)................	

Household size and composition

7.	How many are you in the household?	Enter number e.g. 01, 02…	
8.	How many are below five years of age?	Enter number e.g. 01, 02…	
9.	How many are five years of age and above?	Enter number e.g. 01, 02…	
10.	How many are males?	Enter number e.g. 01, 02…	
11.	How many are females?	Enter number e.g. 01, 02…	
I would like to know about your socio economic information			
Observe and record the following housing characteristics			
12.	**Who owns this house?**(house in which the family lives)	1= owned by family 2= rented 3= given free by relative 4= owned or rented by employer 5= other (specify)	
13.	If rented, indicate the **monthly rental fee in Tanzanian schillings**?		
14.	**How many rooms** (Including living-room and bedrooms) does it have?		
15.	Observe what **the walls are made of:**	1= Thatch, straw 2= Mud and poles 3= Timber 4= Bricks 5= Cement blocks 6= Other (specify)	
16.	Observe what the **roofs are made of?**	1= Thatch/straw 2= Mud 3= Wood, planks 4= Iron sheets 5= Tin 6=cement 7=other	
17.	Observe the **floor material**	1= Earth 2= Cement 3= Tiles 4= Bricks 5= Stone 6= Other (specify)	

Household income

I would like to know about your income and expenditure information			
18.	What is the source of income for your household?	Sales of food crops Sales of cash crops Sales of livestock & products Business income Salaries Wages Other(specify)_____________	
19.	How much do you spend on the following items		
20.	Food per day	Enter number e.g. 1000, 5000, . . .	
21.	Durables (Household assets.i.e. Utensils, furniture) per year?	Enter number e.g. 1000, 5000, . . .	
22.	Medical per month?	Enter number e.g. 1000, 5000, . . .	
23.	Education (year?)	Enter number e.g. 1000, 5000, . . .	
24.	Transport per day	Enter number e.g. 1000, 5000, . . .	
25.	Airtime (voucher) per day?	Enter number e.g. 1000, 5000, . . .	
26.	Others (Specify)…………………………..	Enter number e.g. 1000, 5000, . . .	

SECTION 2: ENERGY SOURCES

27.	What type of fuel do you use most often for cooking?	1.Firewood, *go to qn 30, if not firewood go to qn33* 3. Kerosene 4. Charcoal 5. electricity 6. Other (Specify)	
28.	How long does it take to collect fuel and come back?	Enter time in minutes	
29.	How often per week do you collect fuel?	Enter times	
30.	Who collects the fuel for this household?	1. Wife 2. Husband 3. Daughter 4. Son 5. Other (Specify	
31.	What is the main source of lighting in your dwelling?	1= electricity (UMEME) 2= paraffin, kerosene or gas lantern 3= firewood 4= solar 5=other _______	
32.	What type of cooking technology do you use in your household?	1= traditional 3-stone stove 2= improved firewood stove 3=Charcoal stove 4= improved charcoal stove 5= gas stove 6=paraffin stove 7=other ________	

SECTION 3: PREGNANCY AND DELIVERY

I would like to ask you some questions about your last pregnancy and delivery			
33.	Mother's physiological status	1. Pregnant 2.Breastfeeding 3. Neither pregnant nor breastfeed	
34.	During your last pregnancy with the youngest child, did you visit a health center for prenatal care?	1.Yes 2.No, If No →38	
35.	If yes how many visits	Enter number, e.g 01, 02 ,03…	
36.	If no why did you not attend an ANC?(Choose the correct option and go → 47)	1.Too far to service 2.Don't think I needed to attend 3.Don't like the staff 4. Inadequate service and equipment 5. Other (specify)	
37.	How many months pregnant were you when you went for your first antenatal care visit?	Enter number, e.g 01, 02 ,03…(Month); 2. don't know/don't remember	
	During your last pregnancy, was any of the following done/given at least once		
38.	Were you weighed	1.Yes 2. No 3.Does not remember	
39.	Was your height measured	1.Yes 2. No 3.Does not remember	
40.	Was your blood pressure measured	1.Yes 2. No 3.Does not remember	
41.	Given an injection in the arm to prevent tetanus	1.Yes 2. No 3.Does not remember	
42.	Given iron and folic acid tablets	1.Yes 2. No 3.Does not remember	
43.	Given drugs to prevent malaria	1.Yes 2. No 3.Does not remember	
44.	Others (specify) e.g PMTCT, Hb, mkojo.....	List	
45.	How many children have you given birth to?	Enter number e.g. 02	
46.	How many children do you have now?	Enter number e.g. 02	
47.	Did you reduce your work load because of pregnancy?	1.Yes 2.No (If No → Qn 53)	
48.	If yes why?	1.To rest 2.Sick 3.Advised 4.Norm 5. Others (specify)	
49.	At what stage of pregnancy did you reduce your work load?	1. Entire period 2.1st trimester 3.2nd trimester 4 .3rd trimester	
50.	If no why?	1. No need 2. No helper 3. Obligation/responsibilities 4. Norm 5. Others (Specify)…….	

51.	Do you usually change your diet during pregnancy?	1.Yes 2.No	
52.	If yes, what type of foods did you start to consume during your last pregnancy?	List type of foods	
53.	Are there any taboos that restrict consumption of some foods during pregnancy?	1.Yes 2.No	
54.	If yes, what taboos?	Mention	
55.	Where did you give birth to this child?	1. In a health center, dispensary, private clinic 2. At home assisted by Traditional Birth Attendant; 3. At home with no professional assistance 4. Other, specify:___________________	
56.	Do you consume any special foods after delivery?	1.Yes 2.No (If no go to 60)	
57.	If yes, what type of special foods did you consume after delivery?	List type of foods (reasons for consuming)	

SECTION 4: BREASTFEEDING AND COMPLEMENTARY FEEDING

	Now I am going to ask you some questions regarding breastfeeding and complementary feeding. I would like to know what you fed your baby (reference child) in the first few days after he/she was born, current breastfeeding and complementary feeding practices		
	i. Exclusive breastfeeding (0 - 5) months		
58.	Did you ever breastfeed this child?	1.Yes If no go → 64 2.No	
59.	If no why?	Reasons, and go → 66	
60.	How many hours after birth did you breastfeed this child for the first time?	1. Within 1 hr after birth; 2. 1 to 3 hrs after birth 3. More than 3 hrs after birth; 4. Doesn't know 5. Others (Specify)	
61.	Did you feed colostrum (the first breast milk) to <u>this child</u>?	1.Yes 2.No 3. Doesn't know 4. Others Specify	
62.	During the first 3 days after birth, was <u>this child</u> given anything other than breast milk?	1.Yes 2.No 3. Doesn't know 4. Others Specify	
63.	If yes, what was <u>this child</u> given? (multiple response)	1. Tea 2. Water (includes sugar water); 3. Infant formula; 4. Others Specify	
64.	During the first 3 days after birth, were you offered any practical support or advice to help you start breastfeeding <u>this child?</u>	1.Yes 2.No 3. Doesn't know 4. Others Specify	
	Now I have few questions about breastfeeding <u>this child</u> since this time yesterday		
65.	Yesterday, did you breastfeed <u>this child?</u>	1.Yes 2.No 3. Others Specify (if no go → 71)	

66.	Yesterday, did you breastfeed whenever this child wanted or on a fixed schedule?	1. When the child wanted 2. On fixed schedule; 3. Others Specify	
67.	At what age was the child given water, gripe water, fruit juice, porridge or any food other than breast milk for the first time (pre-lacteal)	1. Enter number of days …….; 2. Enter number of months …….; 3. Never gave anything only breast milk ; go to qn 73 4. Does not know 5. Others Specify	
68.	What are the reasons for not breastfeeding exclusively for six months?	1. Breast milk was not sufficient for the baby; 2. Mother busy with other activities; 3. Cultural norms 4. Other (specify)	
	ii. Complementary feeding practices (6 -23 months)		
	Now I would like to ask about feeding solid or semi-solid foods while continuing breastfeeding.		
69.	Is the child still breastfeeding?	1. Yes 2.No (if no go → 78)	
70.	Who gave you an advice for continuing breastfeeding?	1. Health / nutrition expert 2. Relative 3.Husband 4. Others (specify) ………	
71.	How often do you breast feed your child per day	1.Enter number, e.g 1, 2,3..times 2.Others (Specify)	
72.	How often do you breast feed your child at night	1.Enter number, e.g 1, 2,3..times 2.Others (Specify)	
73.	Until what age do you plan to breastfeed your child?	Enter number, e.g 1, 2,3..Months	
74.	In Case of unexpected pregnancy do you continue to breastfeed	1. Yes 2.No	
75.	At what age did you introduce other foods (complementary foods e.g. porridge, mashed foods etc) to the child?	1. Enter number 1,2,3 …. (month(s) 2. enter number 1,2,3 … days if is less than 1 month 3. Not started; If 3 go → 82	
76.	What was the first complementary food you gave to your child?	1. Porridge 2. Vegetable (e.g mashed potatoes, carrots, etc) 3. Fruits (e.g. pawpaw, orange, etc) 4. Adult/family food 5. Others (specify) …….	
77.	Who mainly decides what this child should and should not eat?	1. Mother; 2. Father 3. Grandparent; 4. Housemaid; 5. Other, specify…….	

	Now we are going to discuss the feeding of this child since yesterday morning.		
	May I have the person who fed this child yesterday?		
78.	Yesterday, what liquids other than breast milk was this child given? (multiple responses are allowed)	1. None 2. Tea 3. Water (includes sugar water); 4. Infant formula 5. Thin porridge 6. Soup/Mtori; 7. Fresh Fruits 8. Fresh fruit juice 9. sweetener and coloured drink 10.Packed fruit juice 11.Does not know 12. Other, specify______________	
79.	Yesterday, did this child have anything to drink from a bottle with a nipple?	**1.** Yes **2.** No **3.** Does not know	
80.	Yesterday, did this child eat any solid or semi-solid foods?	1. Yes 2. No 3. Does not apply (child does not eat solid foods); 4. Does not know	
81.	Yesterday, how frequently did this child eat solid or semi-solid foods?	1, 2, 3… enter number	
	Now I would like to ask some questions about how this child was fed yesterday during the main meal.		
82.	Yesterday, at the main meal, did this child eat enough food you thought he/she should?	1. Yes 2. No 3. Does not know	
83.	Yesterday, during the main meal, did you do anything to encourage this child to eat?	1. Yes 2. No	
84.	What did you do?	1. Offered another food or liquid 2. Encouraged verbally 3. Modeled eating (with or without toy); 4. Ordered strongly or forced the child to eat; 5. Another person helped feed child; 6. Other (specify)	
	If the child is no longer breastfeeding		
85.	For how many months did you breastfeed your youngest child	Enter number, e.g 1, 2,3..Months	
86.	What are the reasons for breastfeeding that long?	1. Cultural norms 2. Received advice 3. Enjoy breastfeeding 4. It is good for my baby 5. Other specify	
87.	What are the reasons for discontinuing breastfeeding?	1. Pregnancy 2. Child Refused 3. Not Enough 4. Diseases 5. Old Enough 6. Advised; 7. Other (Specify) …………	

SECTION 5: FAMILY PLANNING (FOR MOTHERS OF 0-59 MONTH CHILDREN)

88.	Have you heard of family planning, child spacing, contraceptives or birth control?	1= Yes 2= No, skip to 104	
89.	Do you know any place where you could obtain a method of child spacing/family planning?	1 = Yes, 2 = No	
90.	IF Yes, ask “Where did you go last time?” (Fill the answer in the box)	1 = Hospital, 2 = Health Centre, 4 = Pharmacy, 5 = Friend, 6 = Other specify)_____,	
91.	Couples use various ways or methods to delay or avoid pregnancy. Are you currently doing something or using any method to delay or avoid getting pregnant?	1 = Yes 2 = No	
92.	What are you doing to delay or avoid a pregnancy? Circle *all that apply*	1. Female sterilization 2. Male sterilization 3. Iintrauterine device 4. Injectables 5. Implants 6. Oral contraceptive pill 7. Male condom 8. Lactationalamenorrhoea 9. Periodic abstinence/ Rhythm method 10. Other: specify)_____	

SECTION 6: CHILD IMMUNIZATION AND MORBIDITY

93.	Child ID number (*ask the mother to provide the green card given by the project*)		
94.	Child's sex		
95.	Birth date		
96.	Source of birth date	1. Clinic card 2. Father 3. Mother 4. Other (specify)	
97.	Birth Weight (kg)		
98.	Has an index child immunized for age? (confirm from RCH card)	1. Yes 2. No	
99.	If no, record the missing vaccine	Enter name of missing vaccine	
100.	Has an index child suffered from any disease/infection for the past two weeks	1. Yes 2. No	
101.	If yes what type of illness? , (Record any applicable)	1. Fever 2. Diarrhoea 3. Respiratory tract infection (RTI) 4. Malaria 5. UTI 6. Other (specify)__________	
102.	When you, or a member of your household, seek for a health service where do you normally go first?	1. A nearest hospital, health-centre or dispensary, 2. Obtaining medicines and using them without seeing a physician, 3. Consulting a traditional healer, 4. Consulting a fortune teller, 5. No treatment, 6. Others (specify)	

103.	What is the type of service normally sought?	1. Treatment; 2. Medical checkup; 3. Lab service; 4. Guidance/Counselling 5. Other (specify)	
104.	Reason(s) of going for that particular service (multiple response)	1. There is no other health facility; 2. It is relatively cheap; 3. The prices are negotiable; 4. It is closer to my place 5. I trust their services; 6. Many people are doing the same; 7. Others (specify:	
105.	Which constraints do you face when seeking health services?	1. Health facilities are very far away from my home, 2. The costs are too high, 3. Inadequate income, 4. Poor quality of health services, 5. Shortage of medicines, 6. Shortage of facilities, 7. Unfriendly personnel, 8. Incompetent personnel, 9. Others (Specify)	

SECTION 7: WATER AND SANITATION

106.	What is the main water source?	1. Borehole 2. Well 3. River/stream 4. Tap/piped water 5. Harvested rain water 6. Spring 7. Other ____________	
107.	How long does it take to go get water and come back? Record number of minutes. (Inquire to get approximate time)		
108.	Who usually fetches the drinking water?	1. Adult females 2. Adult males 3. Boy children 4. Girl children 5. Other (specify)	
109.	Do you pay for the water from this source?	0=No 1=Yes	
110.	If yes, what is your average daily payment (TSH)?		
111.	How much water (20 litres bucket) did your household spend yesterday? (Estimate using household measures and convert to litres)	Enter number 01, 02, 10......... liters	
112.	Total number of people who used the water collected yesterday	Enter number 01, 02, 10......... people	
113.	What is your opinion on the amount of water spent yesterday in your HH	1. Excess for the HH 2. Sufficient for the HH 3. Not Sufficient for the HH	
114.	If the response to 124 is "Not sufficient for the HH", what are the constraints for not getting adequate water?	Give reasons	

115.	Do you take any measures to ensure the safety of drinking water	1. Yes 2. No, *go to qn 129*	
116.	If yes, what measures do you take?	1. Boiling 2. Filtering 3. Boiling and filtering 4. Use of chemical purification; 5. Others (specify)_______	
117.	Who taught you on this water purification method? (Multiple responses accepted)	1. Government Health personnel 2. Project workers from Development Partner 3. Self initiative 4. more than one combination 5. Others (specify)_____________	
118.	Which type of toilet facility is used by your household members? **Tick only one.**	1. None/bush 2. household larine 3. Communal latrine 4. Ventilated improved pit latrine (has a vent pipe & wire mesh) 5. Other (specify)	
119.	Where do you take your children to defecate?	mention	
120.	What do you do to the faeces when a child defecates?	1. Take to the toilet 2. Throw in the bush/surrounding 3. Other (specify)____	
121.	Where do you dispose of households solid wastes?	1. A rubbish pit or disposal unit for waste 2. Surrounding 3. Other (specify)________	
122.	When do you think you have to wash your hands? <u>Circle all that apply. Should ve more than one answer</u>	1. After cleaning child 2. After going to the toilet 3. After waste disposal 4. Before eating food 5. After eating food 6. Before preparing food to children 7. Before cooking/ preparing food 8. After caring for animals 9. Other (Specify)	

SECTION 8: FOOD CONSUMPTION

123.	How many meals did ***adults*** in your household **eat yesterday**	Enter number e.g 01, 02.....	
124.	Mention the meals (including snacks) eaten by ***adults*** in your household **yesterday**		
125.	How many meals did ***an*** index child in your household **eat yesterday**	Enter number e.g 01, 02.....	
126.	Mention the meals (including snacks)eaten by ***an*** index child in your household **yesterday**		

I: 24-HOUR RECALL

Please let me know the meals you prepared and the amount given to (mention the child's name) in the last 2 hours

Meal	**Name of dish**	**Ingredients**	**Amount**	**Total amount of dish**	**Amount served to the index child**	**Amount consumed by the index child**	**Food source**
Breakfast							
Snack							
Lunch							
Snack							
Supper							

II:INDIVIDUAL HOUSEHOLD DIETARY DIVERSITY SCORE

***Note to Enumerator**: **Explanation to interviewer**: Now I would like to ask you about the types of foods that your child /adults ate yesterday during the day and at night. **Start with the first food eaten in the morning to the last one in the night before going to bed.** Place a 1 in the Box if the child ate the Food in question; place a 0 in the box If the child did not eat the food. If the foods are used in small amounts for seasoning or as a condiment, include them under the condiments food group.*

Qn	Food group	Examples	Child	Adult
	CEREALS	Corn/maize, rice, wheat, sorghum, millet or any other grain products) add other local dishes		
127.	VITAMIN A RICH VEGETABLES AND TUBERS	Pumpkin, carrots, squash or sweet potatoes that are orange inside, other locally available vitamin A rich vegetable (eg. Red sweet pepper)		
128.	WHITE TUBERS AND ROOTS	White potatoes, white yams, white cassava, or other foods		
129.	DARK GREEN LEAFY VEGETABLES	Dark green/leafy vegetables, including wild ones, locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach etc		
130.	OTHER VEGETABLES	Other vegetables (eg. Tomato, onion, eggplant, etc)		
131.	VITAMIN A RICH FRUITS	Ripe mangoes, apricots, (fresh or dried), ripe papaya, peaches + other locally available vitamin A rich fruits)		
132.	OTHER FRUITS	Other fruits including wild fruits		
133.	ORGAN MEAT (IRON-RICH)	Liver, kidney, heart or other organ meats or blood based foods		
134.	FLESH MEAT	Beef, pork, lamb, goat, rabbit, wild game, chicken, duck + any other flesh meats		
135.	EGGS	Chicken, duck, guinea hen or any other eggs		
136.	FISH	Fresh or dried fish or shellfish		
137.	LEGUMES, NUTS AND SEEDS	Beans, peas, lentils, nuts, seeds or foods made from these		
138.	MILK ANS MILK PRODUCTS	Milk, cheese, yogurt, or other milk		
139.	OILS AND FATS	Oil, fats or butter added to food or used for cooking		
140.	RED PALM PRODUCTS	Red palm oil, palm nut or palm nut pulp sauce		
141.	SWEETS	Sugar, honey, sweetened soda or sugary foods such as chocolates, candies (pipi), cookies and cakes		
142.	SPICES, CONDIMENTS, BEVERAGES	Spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages or local alcoholic beverages		
143.	Did (Child name) eat anything (meal or snack) OUTSIDE of the home yesterday?	1= Yes 2= No		N/A

III. FOOD FREQUENCY

Major source: 1=Own production 2=Purchased/bought 3=transfers (gifts, loans, remittance) 4=Relative assistance 5=Butter/exchange 6=Food aid 7=food for work, 99=others (specify

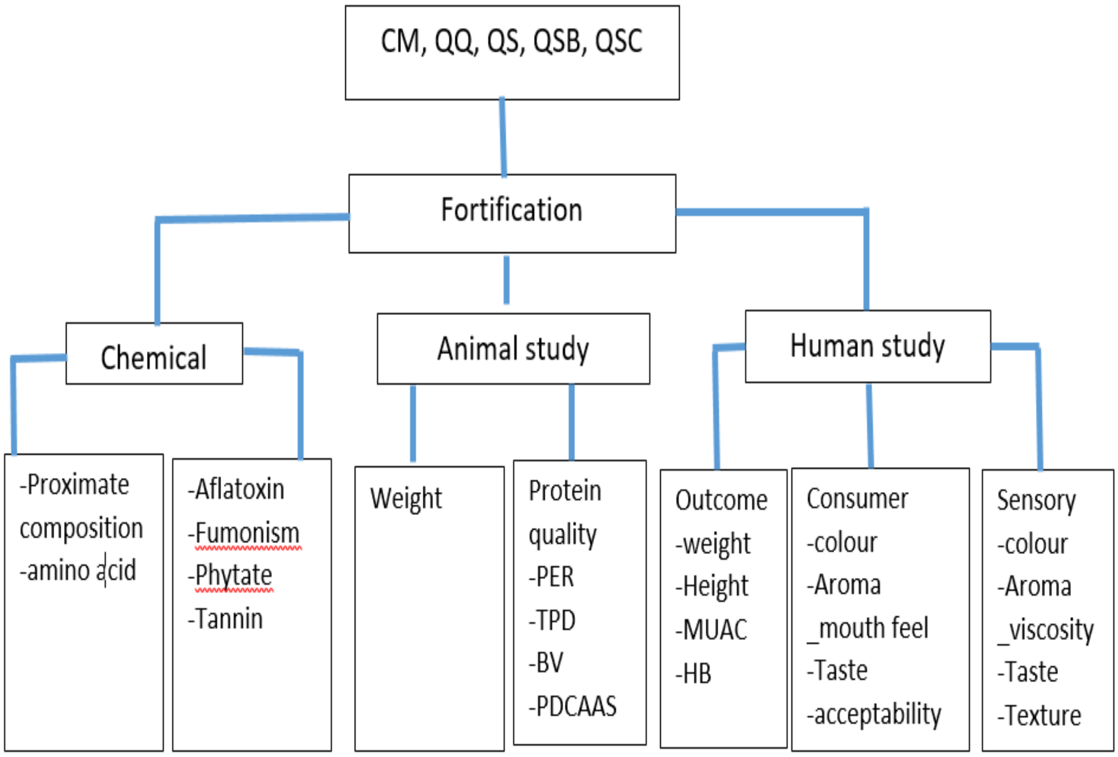
Food item	**Frequency of consumption**				
	Never	Rare	Per day	Per week	Per month
Cereals					
Maize					
Sorghum					
Finger millet					
Wheat					
Rice					
others (specify)					
Roots, tubers, plantain					
Cassava					
Sweet potatoes					
Round potatoes					
Yams					
Green bananas					
others (specify)					
Legumes					
Beans					
Peas					
Cowpeas					
Pigeon peas					
Green grams					
Chickpeas					
Soybeans					
Njugumawe					
others (specify)					
Nuts and seeds					
Groundnuts					
Bambara nuts					
Coconut					
Cashew nut					
Sunflower					
Simsim /Sesame					
others (specify)					
Meat, poultry, fish, eggs					
Cow-beef					
Liver					
Other organ meats					
Goat					
Sheep-lamb					
Pork					
Wild game meat					
Poultry-chicken/duck					
Eggs					
Fish					
others (specify)					
Milk and milk products					
Milk					
Butter/lard					
others (specify)					
Vegetables					
Cabbage					
Amaranth leaves					
Sweet potato leaves					

Food item	Frequency of consumption				
	Never	Rare	Per day	Per week	Per month
Cassava leaves					
Pumpkin leaves					
Carrots					
Pumpkin fruit					
Tomatoes					
Spinach					
Chinese cabbage					
African eggplant					
Eggplant					
Cowpea leaves					
Kale leaves					
others (specify)					
Fruits					
Citrus e.g oranges					
Mangoes					
Passion fruit					
Water melon					
Bananas					
Pineapple					
Papaya					
Avocado					
others (specify)					
Sugar					
Honey					
Sugar					
others (specify)					
Spices and/condiments					
Garlic					
Cloves					
Cardamom					
Cinnamon					
Ginger					
Mixed spices					
Pepper					
Lemon grass					
others (specify)					
Beverages					
Tea					
Coffee					
Carbonated drinks/soda					
Alcohol					
others (specify)					

Name of a person interviewed (If interested) __________________telephone number____________

Thank you for your cooperation

Appendix 2: schematic presentation of my research plan



Appendix 3: Consent form

SOKOINE UNIVERSITY OF AGRICULTURE

Informed consent form for the subjects, who will be participating in the research project (PhD Thesis) titled "Efficacy of Quality Protein Maize-based Supplementary Foods to Support Growth and Rehabilitation of Undernourished Children in Mvomero District, Tanzania**".**

Name of Principal Investigator ElinaMaseta
PhD student
Name of Organization: Department of Food Science and Technology
Sokoine University of Agriculture

This Informed Consent Form has two parts:
- Information Sheet (to share information about the research with you)
- Certificate of Consent (for signatures if you agree to take part)

You will be given a copy of the full Informed Consent Form.

PART I: Information Sheet
Introduction
I am ElinaMaseta, PhD candidate from Sokoine University of Agriculture (SUA), going to give you information and invite you to be part of this research. Before you decide, you can talk to anyone you feel comfortable with about the research. There may be some words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them and get yourself clarified.

Purpose of the study
Purpose of the study is to assess the efficacy of Quality Protein Maize (QPM)-based supplementary foods to support growth and rehabilitation of undernourished children in Mvomero District, Tanzania. This research is done in collaboration with Department of Food Science and Technology (Sokoine University of Agriculture) and RCH Clinic at Mafiga Health Centre - Morogoro.

Voluntary Participation
Your participation in this research is entirely voluntary. It is your choice whether to participate or not. Whether you choose to participate or not, it will not affect you in anyway. You have every right to withdraw from the study at any stage in the research process.
Study design
It is a longitudinal study in a time period of four months and you will be enrolled in this study after providing informed consent to participation.

The first phase of the research will be observational, starting in September 2013 until December 2013. As parents you will be interviewed regarding household, parents, and child characteristics. Your infants will be assessed for malaria and haemoglobin status, and growth measurements, at the beginning (September 2013). Information on community and household factors, motivations and behaviours that influence breastfeeding and complementary feeding will be collected through focus group discussions. Results of Phase I will facilitate the design, approach and implementation of Phase II.

The second phase of the research, starting in January 2014 until May 2015 will be an intervention study. The research would like to compare the effect of three different diets in supporting growth of normal children and recovery of undernourished children. Monthly provision of treatment diets will be compared to normal family diets. In this case there will be six groups, three from a well nourished arm and another three from undernourished arm. Seventh group will save as a control.

The study will involve feeding selected children a QPM-based complementary food for four months. In every RCH visits, the following information will be collected, height, weight, body mass index, BIA finger-prick blood for malaria and haemoglobin assessment. Other information about breastfeeding status, intake of household meals, illness/morbidity, and health-seeking information will be collected as well. Finger-prick blood for haemoglobin assessment. Mothers and fathers will be requested to provide information about themselves and their household.

Risks

There are no risks or any inconvenience of being in this study

Benefit(s) of the research

Results obtained are expected to generate information about benefits of QPM-based complementary food in supporting normal growth and recovery of undernourished children. This information will aid in the development of a dietary intervention strategy to enhance growth and overall health of children in Tanzania.

Compensation

You will not be given any compensation or gifts to take part in this research

Privacy and confidentiality

The obtained information is confidential and will not be accessed by any other person except the research team. The information will be kept until when the objectives of the study are realized.

Confidentiality

The information that we collect from this research project will be kept confidential. The information will not be accessed by any other person except the research team and will be kept until when the objectives of the study are realized. In reporting any information about you, a number on it instead of your name will be used.

Sharing the Results

The knowledge that we get out of this research will be shared with you at a community forum.

We will publish the results in order that other interested people may learn from our research. After the research is completed, research results will be presented to you in aggregate form at a community forum.

Right to Refuse or Withdraw

You do not have to take part in this research, if you wish to do so and can withdraw from the same any time you wish to. It is your choice and all of your rights will still be respected.

Who to Contact

If you want more information or have any queries about anything concerning the research, please feel free to contact the researcher (E. Maseta) on the phone numbers 0713-297846 and 0768-687572, or the research supervisor (Prof T.C.E.Mosha) on the phone number 0715-844024, or write a letter to our address: Sokoine University of Agriculture, Department of Food Technology, Nutrition and Consumer Sciences, P.O. Box 3006 Chuo Kikuu, Morogoro.

PART II: Certificate of Consent

Statement of consent to participate in the study

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant in this research.

…………………………	……………………	…………………
Name of the mother	**Signature/thumb print**	**Date**
………………………	……………………	…………………
Name of the researcher	**Signature**	**Date**

Appendix 4: Porridge evaluation form

a. Hedonic study evaluation form
Panelist's name…………………………………………………………
Sex…………………………..…Age……………………………………
Time…………………………Date……………………………………
INSTRUCTIONS: Please circle the number that best fits your description
COLOUR: How do you like its colour?
1 2 3 4 5 6 7 8 9
Dislike extremely Neither like or dislike Like extremely
AROMA/SMELL: How does you feel on the smell?
1 2 3 4 5 6 7 8 9
Dislike extremely Neither like or dislike Like extremely
TASTE: How does the food taste?
1 2 3 4 5 6 7 8 9
Dislike extremely Neither like or dislike Like extremely
MOUTH FEEL: How does your mouth feel after eating the food?
1 2 3 4 5 6 7 8 9
Dislike extremely Neither like or dislike Like extremely
OVERALL ACCEPTABIITY: How do you generally rate the food?
1 2 3 4 5 6 7 8 9
Dislike extremely Neither like or dislike Like extremely

Any Comments
………………………………………………………………………………………….....
..................…………………………………………………………………………….

Appendix 5: Quantitative descriptive study evaluation form

Sensory Evaluation Form
Quantitative descriptive Analysis (QDA) of Complementary foods

Sample code..Panelist No..

Sex………………..Age……………………Time……..................

Please evaluate each coded ample in the order they are listed. Circle appropriate number in a scale from 1 to 9, where 1 is low intensity and 9 is high intensity. How do you find the following characteristics for complementary foods. Put the appropriate number against each characteristic.

Whiteness

Grey 1 2 3 4 5 6 7 8 9 Very white

Colour

Faint 1 2 3 4 5 6 7 8 9 Very concentrated

Sweetness

Not sweet 1 2 3 4 5 6 7 8 9 Very sweet

After taste

No after taste 1 2 3 4 5 6 7 8 9Very strong taste

Mouth feel

No mouth feel 1 2 3 4 5 6 7 8 9Very strong mouth feel

Aroma

Not aromatic 1 2 3 4 5 6 7 8 9 Very aromatic

Viscosity

Not viscous 1 2 3 4 5 6 7 8 9 Very Viscous

Oil-like aroma

Oily 1 2 3 4 5 6 7 8 9 Very oily

What is your total liking of the product?

Don't like it 1 2 3 4 5 6 7 8 9Like it a lot95