DIETARY QUALITY OF COMPLEMENTARY FOODS FOR CHILDREN AGED 6 - 23 MONTHS IN BIOFORTIFIED INTERVENTION AREAS OF CHIPATA DISTRICT, ZAMBIA

By

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DECLARATION

I Nancy Sakala do hereby declare that this dissertation represents my own work and that, to the best of my knowledge, it has not been previously submitted for the award of a diploma, degree or any other qualification at this on any other university.

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ABSTRACT

Malnutrition remains high in Zambia with stunting of under-fives at 35 percent and existing micronutrient deficiencies. Poor diets contribute thus the need for strategies to address malnutrition. Thus, Zambia promotes biofortification of crops like vitamin A orange maize, orange fleshed sweet potatoes and iron rich beans. This study aimed at establishing the diet quality of complementary foods for children aged 6 – 23 months in Chipata, a biofortified intervention district.

Consumption patterns of 215 children aged 6 – 23 months were determined using 24 hour. recall. Focus group discussions were conducted among women beneficiaries to document common biofortified complementary food recipes. About 200g of 75 different types of cooked complementary foods were collected and analysed using established laboratory protocols.

About 62.30 percent children did not meet the minimum dietary diversity indicating a higher likelihood of inadequate micronutrient intake. Age influenced dietary diversity with children (12 - 23 months) significantly consuming more of starchy grains, vitamin A rich foods and vegetables such as fresh maize, pumpkins and dark green vegetables which were in season. Consumption of animal source foods was low among children aged 6 – 8 months and 12 - 23 months indicating nutrient inadequacy. Orange maize was mostly utilized due to availability and accessibility of seed.

Using Nutri Survey, intake data was analysed to determine the estimated nutrient intakes of the target children. Older children had adequate estimated intakes of vitamin A, vitamin C, potassium, phosphorus, magnesium, iron and zinc. Adequate intakes of magnesium, phosphorus, folic acid, vitamins B_1 and vitamin B_6 were also observed in children aged 9 - 11 months. However, the intake of vitamin B_1, phosphorus, magnesium and potassium was high for older children mostly contributed by orange maize nshima, fresh nuts, pumpkin leaf relish, pumpkins, cooked green maize and orange fleshed sweet potatoes. The estimated iron intake was lower among children aged 6 - 11 months but increased among those aged 12 – 23 month. There was a higher estimated energy intake among girls aged 9 – 11 months and children aged 12 - 23 months which increased with age. Carbohydrate intake was above 50 percent across all ages. These were based on estimations thus higher intakes observed could be due to overestimations by respondents due to recall bias.

Despite recording high intakes of some key nutrients, the complementary foods analysed retained low quantities of protein, fat, carbohydrates and energy indicating poor quality diets.

The samples still retained adequate amounts of beta carotene (37 -182.03 µg/g), iron (4.61 – 11.44 mg /100g), zinc (16.15 - 91.50mg /100g), ash (0.05 – 2.60 g/100g) , moisture (66.50 – 89.99 %) and fibre (0.27 – 3.96g /100g) respectively. Education of communities on consumption and preparation of diverse foods for quality complementary foods is key. Additionally, stakeholders should ensure increased access and availability of biofortified seed at community level.

DEDICATION

To my late parents who were my source of inspiration to further my education and for their moral, spiritual and financial support. May their souls rest in peace. To my beloved husband Musenga and Son Suwilanji for their support, inspiration and belief in my ability.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BCE - Beta Carotene Equivalents

CSO – Central Statistical Office

FAO – Food and Agriculture Organization

FGD – Focused Group Discussions

HDDS – Household Dietary Diversity Score

NFNC – National Food and Nutrition Commission

RDA – Recommended Daily Allowance

SUN – Scaling Up Nutrition

UNICEF – United Nations Children Emergency Fund

VAD – Vitamin A Deficiency

WHO – World Health Organization

ZDHS – Zambia Demographic Health Survey

DD – Dietary Diversity

FHI – Family Health International

HIV – Human Immune Virus

AIDS – Acquired Immune Deficiency Syndrome

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Undernutrition has remained one of the public health problems in low and middle income countries causing about one – third of deaths among children (Lohia & Udipi, 2014). Meanwhile, globally, about 154.8 million children under-five years of age were stunted by 2016 (WHO, 2018), while more than 2 billion people had micronutrient deficiencies, mainly vitamin A, iron, iodine and zinc (Bailey et al, 2015).

Agricultural investments are seen as a great opportunity for contributing towards the reduction of malnutrition (Gillespie & Bold, 2017) especially if implemented with a specific nutrition objective (Masset & Haddad, 2012). There has been interest particularly on how to leverage agriculture to maximize its impacts not only on production but also on nutrition and health especially among women and children who are the most vulnerable (Hertforth et al., 2012). Additionally, there has been an increase in donor support towards agricultural interventions though there is need for more evidence on what kind of interventions are likely to have positive impact especially on women and children (Masset & Haddad, 2012).

Zambia renewed its focus on nutrition sensitive agricultural programming especially after the country's subscription to the Scaling Up Nutrition (SUN) movement in 2011.Through the development of the first 1000 most critical days programme, fourteen evidence based interventions were prioritized for implementation by sectors key to address stunting in children below two years of age. The priority of the agricultural sector in this case was to promote increased availability and consumption of diverse of locally produced and processed foods with a focus on women empowerment. Among the production strategies that were targeted included the promotion of crop diversification and production of nutrient dense crops such as dark green vegetables and biofortified food crops (NFNC, 2015).

Biofortification is a strategy that seeks to improve the micronutrient content of staple foods consumed by the majority of poor people using conventional plant-breeding techniques

(Meenakshi et al., 2010). In Zambia, Harvest Plus and other research institutions have led the process of biofortification for staple crops such as maize, sweet potato and beans with provitamin A carotenoids, iron and zinc as a measure for addressing micronutrient deficiencies. This is a sustainable, cost-effective and potentially wide-reaching strategy. Studies conducted on Zambian children have indicated that biofortified orange maize is as efficacious as vitamin A supplementation even when there are high liver reserves of vitamin A (Gannon et al. 2014). Thus, the existing evidence coupled with the call for nutrition sensitive agricultural programming contributed to an increase in the adoption of biofortified food crops by government and key partners as a way of supplementing existing efforts aimed at addressing undernutrition.

Given that biofortification is viewed as one of the strategies that may help to mitigate malnutrition in children under five, there is need to investigate the extent to which the biofortified food crops have been adopted and integrated into the diets of the households producing the crops. This study therefore assessed the diet quality of complementary foods for children aged 6 - 23 months in biofortified food crops intervention areas of Chipata district, Zambia.

1.2 Statement of the problem

According to the UNICEF conceptual framework, malnutrition can be an outcome of many factors (Reinhardt & Fanzo, 2016) . These include poor household access to sufficient, safe and nutritious food including poor child care and feeding practices which result in low dietary intake at household level (McDermott et al., 2013). Rah et al (2010) confirms that children are malnourished because of low quality diets that lack in both macro and micronutrients which is strongly associated with poverty. Studies by Disha (2012) and the National Food and Nutrition Commission (NFNC, 2014) reveal that household food insecurity affect nutritional status of children by compromising the quantity and quality of dietary intake. Furthermore, Mofya-mukuka & Kulhgatz (2015) indicate that rural households in Zambia are the most vulnerable to food insecurity since they highly depend on seasonal food production and survive on diets that are deficient in a variety of micronutrients. This clearly shows that most rural households in Zambia are still lacking in micronutrients.

However, biofortification is an opportunity to improve the micronutrient content of staple foods consumed by the majority of poor people using conventional plant-breeding techniques (Meenakshi et al., 2010).Three staple food crops that include vitamin A orange maize, orange fleshed sweet potatoes and iron rich beans have been bred in Zambia and disseminated among communities affected with malnutrition. However, the quality of diets among children 6 – 23 months in the biofortified intervention areas in Zambia has not yet been established.

1.3 Purpose of the study

The purpose of this study was to determine the diet quality of complementary foods for children aged 6 - 23 months in Chipata, a biofortified intervention district in Zambia.

1.4 Research objectives

i. To determine the food consumption patterns of the children aged 6 - 23 months in the biofortified intervention areas of Chipata district
ii. To identify recipes on complementary foods prepared from biofortified food crops.
iii. To assess the nutrient adequacy of the complementary foods given to children aged 6 - 23 months in the biofortified food crops intervention areas of Chipata district.
iv. To determine the nutrient composition of selected complementary foods from the target biofortified food crops intervention areas of Chipata district.

1.5 Research questions

1. To what extent have the biofortified food crops been intergrated into the diets of the households producing the crops?
2. What is the quality of complementary foods given to children aged 6 - 23 months in biofortified food crops intervention areas of Chipata district, Zambia?
3. How are the food consumption patterns of the children aged 6 – 23 months in the biofortified intervention areas of Chipata district

4. What is the nutrient adequacy of the complementary foods given to children aged 6-23 months in the biofortified intervention areas of Chipata district?

5. What complementary food recipes are prepared from the biofortified food crops grown in the intervention areas?

6. What is the nutrient composition of selected complementary foods from the target biofortified intervention areas?

1.6 Justification

Biofortification is a cost effective and sustainable measure of addressing micronutrient deficiencies especially if consumption of the crops is emphasized. The crops have potential to address malnutrition because most interventions target low income groups who are dependent on staples for their energy requirements. Additionally, rural farmers who may have limited access to other micronutrient interventions such as supplementation or fortification can adopt biofortified food crops for all year round consumption. Additionally, efficacy trials done in Zambia on the bioavailability of provitamin A have shown an increase in liver stores of provitamin A after consuming a meal rich in Vitamin A (Gannon et al., 2014). However, there is limited information on how these crops are integrated into the diets of the children aged 6 - 23 months and the actual nutrients consumed. Thus, there is need to assess the quality of the complementary foods given in order to ascertain whether biofortified foods are among the food groups accessed by this target group. Furthermore, documenting and analyzing the foods commonly consumed would provide information on the actual nutrients being supplied by the biofortified food crops to the target group and provide basis for further interventions.

1.7 Significance of the study

This study will contribute towards the generation of evidence on the extent to which biofortified food crops have been integrated and improved the diets of children aged 6 – 23 months in the target intervention areas. It will show the actual nutrients being consumed in those intervention areas and the adequacy of the diets of the target group in relation to WHO recommendations and other authorities. These findings will inform stakeholders on the contribution of biofortified food crops to the diets of children aged 6 - 23 months and how strategies can be developed to improve the diets of the target group using biofortification. Finally, through this study, communities engaged in the production of biofortified food crops will be made aware of the adequacy of the diets of their children in relation to their health.

1.8 Limitations and assumptions

The assumptions of this study were that the biofortified food crops have been adopted and incorporated into the diets of the target households. However, the information generated does not represent the entire district of Chipata since only selected communities were targeted in the study. Additionally, dietary recalls are seldom representative of usual food and nutrient intake since they only assess current intake thus causing a challenge especially that there is limited baseline data on dietary diversity and nutritional status of children 6 - 23 months at country level. Also, intake did not take into consideration the frequency of breastfeeding of the target children. Additionally, dietary intake relied on participant's recall of foods consumed on the previous day which was likely to cause a recall bias through respondents under estimations or over estimations.

Furthermore, seasonality affects availability of food. Therefore, the results might not depict the actual consumption patterns as some of the foods were still in the field awaiting harvest at the time of data collection. Additionally, not all foods consumed by the target communities were available in the Zambian food composition tables. Therefore, composition tables from South Africa, West Africa, Swaziland and Tanzania were used by borrowing missing nutrient values for similar foods consumed in Zambia and inputting in nutri survey for analysis.

CHAPTER TWO: LITERATURE REVIEW

2.1 Under nutrition

Child undernutrition continues to be a global health problem especially in low income countries particularly in Asia and Sub-Saharan Africa (Disha, 2012). Global estimates show that stunting and severe wasting are responsible for one third of under five deaths and about 12 percent of deaths among under 5 children are attributed to the deficiencies of iron, zinc, vitamin A and iodine respectively (Ahmed et al., 2013). In 2001, child malnutrition contributed about 54 percent of child deaths in developing countries (Luchuo et al., 2013). Meanwhile, Zambian estimates show that stunting in under five children stands at 35 percent, wasting 4 percent and underweight 12 percent respectively (CSO, 2018). Furthermore, trends in micronutrient deficiencies for under five children have shown that Vitamin A Deficiency (VAD) and iron deficiency anaemia have remained above 50 percent in the last few years as indicated by the recent national surveys (Haggblade et al., 2016). The trends show that VAD was at 66 percent in 1997 and 54 percent in 2003 whilst anaemia was 53 percent in 2003 and 58 percent in 2011 respectively.

Apart from contributing to the disease burden of children, under nutrition has long lasting effects on physical and cognitive development into adulthood especially if not addressed in the first two years of life (Victora et al., 2008). Malnutrition can be an outcome of many factors which include poor household access to sufficient, safe and nutritious food and poor child care and feeding practices, both of which lead to inadequate dietary intake at household level to support a healthy life (McDermott et al., 2013). The inadequate dietary intake is as a result partly of the low dietary diversity due to dependence on calorie rich diets which contribute to high malnutrition rates especially in Asia and Sub - Saharan Africa (Sharma et al., 2017).

2.2 Micronutrient deficiencies

Micronutrient malnutrition also known as hidden hunger is one of the forms of under nutrition affecting developing countries with an estimated 2 billion people affected globally (Muthayya et al., 2013). They are responsible for about 12 percent of child deaths globally (Ahmed et al., 2012). Hidden hunger is the overall poor quality of nutrition, where one may eat enough calories to live, but the basic diet fails to provide sufficient levels of crucial vitamins and minerals needed for the mental and physical health (Sharma et al., 2017). According to Bouis (2003), such diets are usually high in food staples but low in animal and fish products, fruits and vegetables which are good sources of bioavailable vitamins and minerals.

Hidden hunger has potential to impair the mental and physical development of children and adolescents and can result in low IQ, stunting and blindness. The productivity of adult men and women is reduced due to increased risk of illness and reduced work capacity as well as reduced survival rates of mothers during child birth. The major nutrients identified for these consequences include iron , vitamin A and zinc (Sharma et al., 2008).

2.2.1 Iron deficiency

Iron deficiency is the most common nutritional problem both in children and adults worldwide. It affects more than 2 billion people globally whilst iron deficiency anaemia remains the top cause of anaemia worldwide (Camaschella, 2015)). Meanwhile, Africa and Asia bear a mortality burden of about 71 percent (Desalegn et al ., 2014).This is consistent with the Zambian situation as statistics show that iron deficiency rates have remained high in the last few years (Haggblade et al., 2016). It is worth noting that except for project specific data, there is limited national level data on the micronutrient status of the population since the last survey was conducted in 2003 which showed that iron deficiency was at 52 percent (NFNC, 2014). Meanwhile the micronutrient status survey conducted in Luapula and Northern Provinces show that iron deficiency, defined as serum ferritin either 15µmg/l or ≥15µg/l and CRP>10mg/l and/or AGP >1g/L, was found in 35 percent of subjects; while 27 percent suffered from iron deficiency anemia (iron deficiency and Hb <11mg/dl). There was no significant difference observed between the two provinces (NFNC, 2014)**.**

During childhood, iron deficiency impairs physical growth, mental development and learning capacity. Furthermore, it reduces the capacity of adults to conduct physical activities whilst the risk of women dying during child delivery and post-partum period is increased (Bouis, 2003). The major risk factors are low intake of meat, fish or poultry and high intake of cereals and legumes, low birth weight and pregnancy. Anemia is worsened by infectious diseases such as malaria, HIV/AIDS, hook-worm infestation, schistosomiasis and tuberculosis among others.

2.2.2 Vitamin A deficiency

The worldwide survey data estimates that about 30% of children less than 5 years are vitamin A deficient and about 2 percent of all deaths in this age group are attributed to vitamin A deficiency (Wirth et al., 2017). Furthermore, studies by Stevens et al.,(2015) show that the prevalence rates of vitamin A deficiency in 2013 were highest in sub-Saharan Africa (48%; 25–75) and south Asia (44%; 13–79) respectively (Stevens et al., 2015). . Meanwhile, Zambian statistics show that vitamin A deficiency in underfive children has remained above 50 percent in the last 10 years (Haggblade et al., 2016). The 2003 impact study indicates that 54 percent of children 6 to 59 months of age had serum retinol of < 0.70 mol/l which is still above the global figure of 10 percent (NFNC, 2008)**.** However, the food consumption and micronutrient status survey conducted in Northern and Luapula provinces showed that 25.8 percent of the children were vitamin A deficient with no difference between the provinces (NFNC, 2014).

Vitamin A is essential for the immune system and individuals with sub clinical vitamin A deficiency experience anemia, impaired linear growth (Villamor & Fawzi, 2000) and morbidity from respiratory and diarrheal infections (Sommer & West, 1998) **.** Low intake of dairy products, eggs, fresh fruits and vegetables are among the reasons for such deficiency. Vitamin A deficiency can increase the severity of infection which, in turn, can reduce intake and accelerate body losses of vitamin A to aggravate the condition.

Xerophthalmia is the leading cause of preventable childhood blindness which is a consequence of long-term or severe vitamin A deficiency (Ahmed et al., 2012).

2.3 Strategies to address micronutrient deficiencies

Following the health and economic effects of micronutrient deficiencies in adulthood, it is imperative that the deficiencies are controlled. A number of approaches for controlling micronutrient deficiencies exist which use a range of interventions such as fortification including biofortification, supplementation, dietary diversification, other food based approaches and health interventions (Laillou et al., 2012). However, there is no single approach that is appropriate to cover all population segments and therefore, the need to design complementary approaches in order to address the deficiencies.

2.3.1 Fortification

Fortification is a long term strategy recommended for increasing the dietary intake of certain micronutrients in the general population (Tam et al., 2020). It becomes successful if mandated by the government with support from the food industry. Different approaches can be used which include mass, targeted and market driven fortification. Mass fortification involves foods that are widely consumed by a population such as staples, salt and sugar whilst targeted fortification involves foods consumed by specific age groups such as complementary foods. Meanwhile, market driven fortification is when manufacturers fortify a particular brand for a specific consumer niche (Das et al., 2013). Some examples include salt iodization, sugar fortification with vitamin A and zinc and iron fortification of flour and complementary foods.

The advantage of food fortification is that it can reach a wider population of those at risk through the delivery of food systems without pausing major changes in existing consumption patterns. If fortified foods are consumed regularly, this strategy has the potential to maintain adequate stores in humans and thus address micronutrient deficiencies However, fortified foods may not provide sufficient micronutrients to individuals consuming small quantities such as young children, this is due to safety regulations limiting the amount of added micronutrients to those below the tolerable upper intake (Tam et al., 2020).

2.3.2 Micronutrient supplementation

Micronutrient supplementation is an effective short-term solution for preventing and addressing micronutrient deficiencies in specific groups that are at risk. It involves the provision of a single micronutrient (iodine, iron, folic acid, vitamin A, vitamin B12, vitamin D and zinc) or multiple micronutrients in the form of capsules, tablets, drops or syrup. Multiple micronutrient (MMN) supplements are said to be a single administration of three or more different micronutrients (Tam et al., 2020).

2.3.3 Biofortification

Biofortification is the breeding of crops to increase their nutritional value, including increased contents of micronutrients or their precursors (Moura et al., 2014). The process aims at increasing the nutrient density in crops during plant growth rather than during food processing. It is done through conventional plant breeding (not genetic modification) to have higher levels of the desired micronutrient which ultimately addresses micronutrient deficiencies (Gunaratna et al, 2016).

Biofortification is a food - based strategy for improving dietary quality to complement other approaches such as supplementation and food fortification. In their study on consumption patterns, Howarth & James (1990) established that dietary quality was the underlying cause of micronutrient malnutrition and that rural households affected were dependent on production of staples for their energy requirements. There was need therefore for a sustainable and readily available source of micronutrients to improve dietary intake. This means therefore that biofortified food crops have greater chances of adoption and impact because they are familiar crops already being cultivated, prepared, and consumed in the target areas. As a result, they are likely to require little behavior change.

Furthermore, food crops biofortied with vitamin A precursors are likely to have a positive impact on nutritional and functional health outcomes. This is because evidence from both animal and human studies have shown their bioavailability and capacity to improve vitamin A status (Tumuhimbise et al., 2013). Additionally, interventions on biofortified iron showed improved indicators of iron status, including hemoglobin and serum ferritin concentrations and total body iron thereby increasing the likelihood of resolution of iron deficiency. The effects of iron biofortification interventions on iron status were greatest among individuals who were iron deficient at baseline. This therefore suggests that iron biofortification approaches are efficacious in improving iron status in women and children, with the additional potential to benefit iron - deficient individuals (De Moura et al., 2014).

Meanwhile, study findings from South Africa suggest that provitamin A biofortified maize has the potential to address vitamin A deficiency especially among children of preschool age. However, this strategy is unlikely to be successful among older groups unless coupled with nutrition education on the value of the maize and ensuring that the availability of the produce on the shelf is increased (Pillay et al.,2011). In addition, (Gannon et al., 2014) revealed that provitamin A maize is as efficacious as vitamin A supplementation even in the presence of high liver reserves of vitamin A.

2.3.3.1. Factors that affect acceptability of biofortified food crops

1. The method of breeding

Biofortification can be achieved either through conventional breeding or genetic engineering, though the latter is not usually accepted because most people relate such foods with consumption of genes which are associated with many fears. However, crops that are conventionally bred are easily accepted especially if the breeding process involves the farmers. In Uganda, biofortified orange fleshed sweet potatoes were easily accepted due to the involvement of the farmers in the breeding process (Chowdhury et al, 2011).

2. Visual appearance

The process of biofortification changes the colour of the crop and sometimes flavor and aroma which becomes a consideration for most communities since they are culturally used to white coloured staples. Studies conducted by Chowdhury et al., (2011) showed that except among children, the introduction of orange fleshed sweet potatoes in Uganda initially received resistance due to the strange orange colour resulting from the low dry matter content. Similarly, organoleptic studies of yellow maize conducted in Eastern and Southern Africa showed that there is a cultural preference for white maize to yellow maize, which seems to be due to the unacceptable sensory properties of the yellow maize. Despite the initial resistance, recent studies have shown that the potential of biofortified food crops in addressing micronutrient deficiencies especially among children have increased chances of their acceptance. However, there is still need for intensive nutrition education on their benefits if they are to gain acceptance among adults (Tumuhimbise et al., 2013).

3. Nutrition education

This is an important factor that affects the acceptability of biofortified food crops. Nutrition education conveys the messages on the nutritional and health benefits of the crops thereby fostering adoption. In most countries, adoption of biofortified food crops was partly as a result of the nutrition messages given to the communities which convinced them that the change in the colour of the crop was likely to have nutritional and health benefits (Tumuhimbise et al., 2013).There is need therefore for targeted nutrition messaging and education in order to increase the likelihood of the adoption of the crops and for farmers to prioritize production for home consumption (Lividini & Fiedler, 2015).

4. Economic potential

Mostly farmers adopt new varieties if they have assurance of getting an economic benefit. Most crops in developing countries are not only staples but also sources of income, and hence crops with low economic value receive less attention especially by men who abandon such crops to women. Thus production of provitamin A crops will increase when communities have accepted to grow biofortified food crops to ensure constant supply in the market. The enterprise should make economic sense to a farmer and biofortified food crops must be regarded as commercial crops. For instance orange fleshed sweet potatoes could be used to produce flour which can complement wheat in the confectionery industry whilst vitamin A orange maize could be used in livestock feed production (Low & van Jaarsveld, 2008) (Krishna et al., 2014).

2.3.3.2 Biofortification and dietary diversity

Nutritionists have observed that biofortification strategies appear to be counter to increasing dietary diversity (Lindsay, 2003) and the dependency on existing food systems by most poor people (Bouis, 2003). This is because the strategy aims at concentrating more nutrients in few staple foods thus further simplifying diets that are already overly dependent on a few carbohydrate staples. This further suggests that biofortification promotes a narrow range of foods that people are already over - consuming at the expense of other more diverse and nutritious foods. Shrimpton (2012) also shows evidence that biofortification contributes to a neglect of those food-based approaches that depend on existing food systems. These include access to and consumption of the diverse crop varieties, plant and animal species available within local environments and food cultures.

However, dietary diversity is a predictor of micronutrient adequacy and overall diet quality whilst biofortification is an efficient and cost - effective way of bringing more micronutrients to the diets of the poor. Biofortification therefore contributes to improving the diet quality of populations and can be viewed as an integral part of dietary diversity (Moursi et al., 2008). Furthermore, biofortification does not promote increased consumption of staples but is used to substitute some or all of the non - biofortified equivalent staples from the diet with better and more micronutrient - rich varieties. The strategy recognizes that there are limits on how much energy should be derived from carbohydrates thereby discouraging sole dependence on biofortified staples as they cannot provide the full array of nutrients (Moursi et al., 2008).

In order to address these concerns on dietary simplification caused by biofortification programs, efforts should be made to ensure biofortification complements other food based approaches with components that will lead to dietary diversity. This is because diets that are inadequate in quantity and / or quality of foods lead to multiple and synergistic deficiencies which can be avoided through complementarity with other approaches (Allen et al., 2001). Thus, other than addressing only issues of bioavailability of biofortified food crops, there is need to promote synergistic food combinations such as those recognizing the role of fat in vitamin A absorption. This therefore entails promoting diets that have good sources of fat such as legumes including animal source foods. Furthermore, Moursi et al.,(2008) show that providing nutrition education to consumers on the benefits of a diverse diet and promoting other locally available foods within food systems is key in ensuring dietary diversity.

2.3.4 Dietary diversity

Promotion of diverse diets is one of several approaches to improving micronutrient nutrition especially for vulnerable groups. Diverse diets should be characterized by a balance in intake of protein, carbohydrates and fat including moderation in intake of foods low in nutrient density and likely to increase the risks of chronic diseases. Dietary Diversity (DD) is a qualitative measure of food consumption that reflects household access to a variety of foods as well as a proxy for nutrient adequacy for the diet of individuals (FAO, 2013b). The information is collected using a questionnaire at either household or individual level after which it is scored and analyzed.

Food group diversity indicators can be measured using two main methods namely open recall and list-based. In the open recall method, the enumerator asks a series of probing questions to help the responded recall all the foods and beverages consumed the previous day and night including all the ingredients added to the mixed dishes. In the list based method however the enumerator reads a list of foods to the respondent who responds yes to each of the foods consumed during the specified period. However, the open recall method is recommended as it leads to a more accurate and complete recall of all foods consumed whilst the list based method is evidenced to be incomplete as it only focuses on the list of foods consume and not the quantities and the method of preparation (FAO and FHI 360, 2016).

The household dietary diversity score (HDDS) reflects the economic ability of a household to access a variety of foods whilst the individual dietary diversity scores aim to reflect nutrient adequacy. Studies in different age groups have shown that an increase in individual dietary diversity score is related to increased nutrient adequacy of the diet (FAO, 2013b) whilst the indicator can also reflect food security if the household is targeted. However, there are a lot of factors that need to be considered as to whether dietary diversity score is an indicator for food security or dietary quality (Ruel, 2002). Dietary diversity scores have been validated for several age or sex groups as proxy measures for macro and or micronutrient adequacy of the diet. Thus, indicators that define the dietary quality of different sexes and age groups have been defined to estimate the micronutrient adequacy of the diet of women (15 - 49 years) and children (6 - 23 months) and the difference is only in the assessment of the number of food groups consumed in the last 24 hours.

2.3.4.1 Minimum dietary diversity

The minimum dietary diversity is the proportion of children aged 6 to 23 months who received food from four or more out of the standard seven food groups in the last 24 hours (Gebremedhin et al., 2017). Several studies have shown that dietary diversity in children is an important predictor of acute malnutrition, stunting and micronutrient intake as it shows the quality of their diet and how that affects their nutritional status (Moursi et al., 2008). In many low income countries, meeting the minimum dietary diversity has been a major challenge. A summary of many Demographic and Health Surveys (DHS) conducted in developing countries showed that only a quarter of children met the requirement with figures as low as 5 percent in countries like Ethiopia (Dangura & Gebremedhin, 2017).

However, few studies have assessed the level of dietary diversity during the period of complementary feeding in Zambia, and thus limited evidence is available regarding its determinants especially in food-insecure areas. The Zambia Demographic Health Survey showed that only 19 percent among breastfed children aged 6 - 23 months were given foods from four or more food groups in the 24 hours preceding the survey whilst 46 percent were fed the minimum number of times in the previous 24 hours (CSO, 2016). Thus, the combined proportion of children who were both given foods from four or more groups and fed the minimum number of times per day was 12 percent. The results further show that the proportion of breastfed children given a variety of foods at least three times daily increased with age, from 8 percent among children aged 6 - 8 months to 14 percent among those aged 18 - 23 months. In addition, children living in urban areas are more likely to consume a diverse diet than those living in rural areas (CSO, 2016). Furthermore, only 12 percent of the children aged 6 – 23 months were able to meet the minimum acceptable diet in the recent demographic health survey (CSO, 2018).

2.3.4.2 Factors that determine dietary quality of complementary foods

The diets of children in their first years are determined by the choices and behaviors of their mothers or care givers. Thus, the breastfeeding and complementary feeding practices of care givers are key to the health and development of children in early life (Jones, 2016). Therefore, there is need for education and counseling of mothers and care givers on appropriate complementary feeding practices so that growth faltering in early childhood is prevented. The following are some of the factors that predict the dietary quality of complementary foods:

2.3.4.2.1 Household food security status

Agricultural production has an influence on the quality of infant and young child feeding practices that the mother or care giver provides to the child. This is because the diversity of crops grown and livestock reared at household level influences the diet of the child (Gillespie et al, 2012). This suggests therefore that household food security, an indicator of food accessibility is associated with dietary adequacy (Contreras et al., 2015) as was concluded in a study in northwest Ethiopia that households with home gardens were twice as likely to provide diversified food to their children (Gebremedhin et al., 2017). Furthermore, the income realized from agricultural enterprises can be used to access other foods not produced by the household though this is dependent on who controls the income. This could be in form of household wealth or assets, as indicators of the household economy which has also been independently associated with infant and young child feeding. Additionally, the amount and nature of labour which caregivers devote to agriculture and other household chores can affect the available time for feeding including type of food fed to the children (Jones, 2013). The health and feeding environment as well as the nutritional status of the care giver herself can also be affected by the amount and nature of work devoted to agriculture and household chores (Jones, 2016).

2.3.4.2.2 Nutrition education

It is clear that exposure to information on infant and young child feeding has a positive influence on the diet of the children. Studies have shown that mothers who received nutrition counseling through frontline health workers, participated in cooking demonstrations and were exposed to infant and young child feeding messages showed positive predictors of dietary diversity score (Gebremedhin et al., 2017). These findings are based on the understanding that cooking demonstrations benefit resource poor rural communities with limited formal education by providing hands-on learning experiences based on available recipes (Dangura & Gebremedhin, 2017).

2.3.4.2.3 Child's age

According to Jones (2016), children's feeding patterns change with age since they adapt to different food textures and require more frequent meals and a larger variety of foods. This is because from six months of age, breast milk alone is no longer sufficient to maintain the child's recommended daily allowances of nutritional requirements and enhance growth. The children are to be fed small quantities of solid and semisolid foods while continuing to breastfeed up to age 2 or beyond. The amount of food is supposed to be increased gradually from 6 to 23 months as family meals are introduced into the child's diet. However, this period is characterized by an increase in the prevalence of malnutrition because of poor feeding practices in terms of quality and quantity of meals and infections (CSO, 2016). The proportion of breastfed children given a variety of foods at least three times daily increased with age, from 12 percent among children aged 6 - 8 months to 14 percent among those aged 9 - 11 months and 16 percent among those aged 12 - 17 months except for those aged 18 - 23 whose proportion was 6 percent respectively (CSO, 2018). Similarly, studies conducted in Ethiopia showed that child's age is a predictor of dietary diversity (Gebremedhin et al., 2017).

2.3.4.2.4 Maternal education

Maternal education has an influence on the quality and diversity of food the child receives. Studies have shown that mothers with lower levels of education have the opportunity to exclusively breastfeed since they don't usually work outside home as is the case with highly educated mothers (Contreras et al., 2015). Furthermore, studies have shown that children whose mothers were well educated and had secondary level education or higher were more likely to meet the minimum dietary diversity than those whose mothers had no formal education (Khanal et al., 2013). The Zambia Demographic Health Survey (ZDHS 2014) results show that by province, the percentage of children given a variety of foods at least three times each day ranges from 3 percent in North Western to 20 percent in Southern. This percentage is lowest among children of mothers with no education or a primary education (10 - 11 percent) and highest among children of mothers with a secondary education or higher (29 percent) (CSO, 2016).

2.3.4.2.5 Maternal age

Maternal age is one of the factors that determine the quality of diets received by children as it determines the amount of exposure or experience that the mother or care giver has in child care practices. Khanal et al., (2013) suggests that children with mothers aged 35 years and above at pregnancy are more likely to meet the minimum dietary diversity than those whose mothers were 15 – 19 years at pregnancy.

2.4 Nutrient quality of complementary foods

The poor quality of complementary foods given to infants in most developing countries is one of the major causes of malnutrition. Most mothers have inadequate knowledge on adequate child feeding practices leading to poor food quality and frequency which results in poor nutrition and health (Moramarco et al., 2017). In their study conducted in Lusaka, Owino et al., (2008) show that most complementary foods are introduced too early or too late and the quality and quantities are insufficient, leading to a great risk of nutritional deficiencies during the second half of infancy. Furthermore, most of them are unfortified cereal - based gruels characterized by low energy and nutrient density and are often inadequate in micronutrients such as iron, zinc, riboflavin, niacin, calcium, thiamine, folate, ascorbic acid and vitamin A among others. Another study conducted in Malaysia had similar findings which showed that in compliance with WHO IYCF indicators, lower proportions of children (56.3 percent) attained the recommendations of energy whilst their intake of micro nutrients was generally poor (Khor et al., 2016).

According to the World Health Organization, Dietary Diversity (DD), defined as the sum of food groups consumed over a period of 24 hours, is a key indicator to assess child feeding practices. It shows the dietary adequacy and predicts the dietary quality among infants and young children. Higher dietary diversity has been positively associated with nutrient intake, micronutrient intake and adequacy and child nutritional status. Contrary, poor dietary diversity has been associated with growth faltering and all forms of child malnutrition (Moramarco et al., 2017).

Furthermore, WHO stipulates that for developing countries, a breastfed child 6 - 8 and 9 - 11 months of age needs only 200 and 300 kcal respectively from all complementary foods in addition to breast milk whilst a breastfed child aged 12 - 23 months needs 550 kcal in addition to breast milk (Ng et al., 2012).

2.4.1 Nutrient retention of biofortified foods during cooking and processing

Studies have shown that the retention of beta carotene in maize based products after cooking is high unlike during storage. In their studies on the carotenoid retention of biofortified maize after traditional methods of milling, cooking and storage, Mugode et al., (2014) showed that most of the degradation of provitamin A in biofortified maize occurs during the first 15 days of storage compared with cooking. The study showed that the Beta Carotene Equivalents (BCE) retention was high (>100 percent i.e. above 8.69 μg/g) for most genotypes when the maize was cooked into thick (nshima) and thin porridge, but showed a lower BCE retention (53 − 98 percent) when cooked into samp (dehulled kernels).

Another study which assessed the impact of popular home cooking techniques and different cooking parameters (temperature, time and pH) on the final cooked product showed that carotenoid levels were preserved and enhanced. Díaz-Gómez et al, (2017) suggest that the carotenoid content was increased when temperatures ≤ 95 °C were combined with short cooking times (10 – 60 min). Furthermore, the carotenoid content of the maize porridges doubled the initial content to 88 μg/g dry weight when treated under high temperatures at pH 5 but also when unfermented thin porridges were prepared. This therefore shows that biofortified maize may contribute to enhancing the vitamin A status of rural populations who depend on maize as a staple food.

Meanwhile, studies that examined blended foods such as chapattis, porridges and mandazi's made with 30% orange-fleshed sweet potato (OFSP) flour showed a retention and bioaccessibility of beta carotein in the products. Even if the retention of all – trans - Beta Carotene in porridges (69 to 93%) and chapatis (70 to 97%) varied between the processors engaged, there was no overall difference between the two products. Additionally, beta carotene retention in mandazis was similar to that of chapatis and porridges (Bechoff et al., 2011).

In the case of biofortified beans , studies have shown that iron and zinc can be retained if the beans is soaked and cooked without discarding the soaking water and broth. However, frying may reduce the mineral bioavailability as it causes an increase in the phytic acid content (Ongol et al., 2018).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Research design

The study used both qualitative and quantitative design approaches. A descriptive survey was used to collect data on socio economic status, demographic characteristics and consumption patterns of children aged 6 – 23 months from households in biofortified food crops intervention areas. Different biofortified based complementary food samples were collected and analysed for nutrient composition using approved laboratory procedures.

3.2 Description of the study site

The study was conducted in Chipata district of Eastern province. The site was chosen because it is one of the areas where biofortified food crops are being promoted in selected agricultural camps. Additionally, the site has moderate and severe stunting rates of 15.6 percent whilst statistics on micronutrient deficiencies in the area are still unavailable due to limited micronutrient surveys that have been conducted.

3. 3 Target population

The study targeted households with children aged 6 – 23 months that had participated in the production of biofortified food crops in the target camps of Chipata district during the 2014 - 2017 farming seasons. The mothers to the children were the main respondents.

3.4 Sample and sampling techniques

3.4.1 Calculation of sample size

The sample size was calculated using the following formula:

$$n = \frac{z^2 p (1-p)}{d^2}$$

Where:

z^2 = 1.96 at 95% Confidence Interval

P = Proportion of severely stunted children in Chipata which is 15.6 %.

d^2 = 5 % margin of error

$$n = \frac{1.96^2 \times 0.156\ (1 - 0.156)}{0.05^2}$$

n = 202 (minimum sample size)

n = **215** (adjusted for attrition at 6.5 %)

Total sample size = 215

3.4.2 Sampling techniques

Multistage sampling technique was used to select the study sites as follows:

Stage 1: Three (3) agricultural blocks namely western, southern and chiparamba were purposively selected because of being biofortified food crop intervention areas.

Stage 2: Five (5) agricultural camps were purposively sampled from the three (3) agricultural blocks because of being biofortified intervention areas as follows:

i. Western Block – Chiwoko camp
ii. Southern Block – Chikando and Manjakazi camps
iii. Chiparamba Block – Kapita and Chiparamba camps

Stage 3: A total of 215 households with children aged 6 – 23 months among farmers participating in the production of biofortified food crops were randomly selected for the study which included lead farmers, members of cooperatives or women groups. The following selection criteria was used:

- A sampling frame of households having children aged 6 – 23 months was developed in each camp prior to the visit using the lists of farmers who had been trained and received inputs for biofortified food crops. These lists were provided by the Agricultural Camp Extension Officers.
- Using the sampling frames prepared, a total of 43 households with children aged 6 - 23 months were randomly selected in each camp for participation in the study. The selected households were grouped by village or locality (for ease of identification) and were identified through the help of a camp extension officer or zone leader who guided the process of locating the households. Meanwhile, a replacement list was prepared beforehand using random procedures so that households that may have relocated or refused to participate could be replaced immediately.

3.5 Data collection techniques

A semi structured questionnaire was used to collect data on socio economic status of the households, demographic characteristics and food consumption patterns. This was a researcher administered questionnaire which was responded to by the mothers to the target children. Consumption patterns were determined using 24 hr dietary recall method (both list based and open recall methods) as per FAO 2016 guidelines for infants and young children (FAO and FHI 360, 2016). The two approaches were utilized in order to collect adequate data to address study objectives. The data was collected from March to April 2017.

In the list based method, a questionnaire with seven (7) food groups recommended for minimum dietary diversity (FAO,2016) was administered to the mother or care giver to assess the number of food groups consumed by the child in the last 24 hrs. The following food groups were used in the list based method to assess minimum dietary diversity:

1. Grains, roots and tubers
2. Legumes and nuts
3. Dairy products
4. Flesh foods (meat, fish, poultry and liver or organ meats)
5. Eggs

6. Vitamin A- rich fruits and vegetables
7. Other fruits and vegetables

The challenge with this tool is that it only shows healthy diversity in unfortified foods and is not designed for assessing coverage or impact of biofortification programmes. Thus separate questions on consumption of biofortified food crops (orange maize, orange fleshed sweet potatoes and iron rich beans) by the household and children aged 6 - 23 months were added to the questionnaire. In addition, the biofortified maize and sweet potatoes were placed under the group for grains, roots and tubers whilst iron rich beans was considered under the group for legumes and nuts.

The open recall method however required the mother to give details about the actual foods and estimate quantities of foods consumed and the methods of preparation of foods consumed. Household measures and food models were used to assist mothers to do the estimations.

3.6 Documentation of recipes on complementary foods

Three (3) Focus Group Discussions (FGD's) were conducted in Kapita, Manjakazi and Chiwoko camps respectively (one FGD in each camp). The purpose of this exercise was to collect and document common methods of preparing complementary foods using biofortified food crops as ingredients. Each focus group discussion comprised an average of 8 to 10 women that had participated in the production of biofortified food crops and were utilizing the crops in complementary feeding as trained. In each camp, group leaders were used to randomly select participants for the discussions. The focus group discussions were guided by a set of questions and were conducted in local language (Nyanja). Among the areas of focus were the types of crops commonly grown in the target camps including the biofortified food crops. Other questions focused on how the crops were utilized for complementary feeding, types of complementary foods (including those from biofortified food crops) commonly prepared and the common recipes, whether training in preparation of complementary foods was received and who conducted the training.

3.7 Nutrient analysis of complementary foods

About 75 samples (15 samples per camp) of porridge were randomly selected from the different complementary foods collected from the participating households as consumed by the target children. These porridges were prepared using different ingredients which mainly included white and orange maize meal (refined or whole) prepared in their plain form or enriched with pumpkin leaves, beans and eggs. The collected samples were packed in labelled air tight plastic containers which were transported in ice packed cooler boxes prior to refrigeration at -20 degrees celcius. Laboratory analysis using standard procedures (AOAC 2006) were performed on these foods to determine their nutrient content as described below. The results were reported as a range of nutrients contained in the different complementary foods which is in accordance with the study by Kulwa et al,.(2015) who documented various ranges of nutrients contained in the different complementary foods studied.

3.7.1 Proximate composition

Crude moisture, crude fat, crude protein, total ash and crude fiber were determined using AOAC official methods of 934.01, 920.39 (A), 984 (A – D), 942.05 and 978.10 as described below (AOAC, 2006).

3.7.1.1 Determination of Moisture

Moisture was determined using AOAC official methods of 934.01 (AOAC 2006).

The moisture and dry matter content were determined by measuring the loss of weight after heating the sample at 105 – 130 ^{o}C according to the WILLIAMS, S. (1984) Official Methods of Analysis, AOAC. Two dishes were weighed with their covers to which 3.0 grams of the complementary food was added and weighed again and weights taken note of. The covers were loosened and placed in the oven for 4 hours at 105^{o}C. The dishes were removed from the oven and cooled in a desiccator for 20 to 30 minutes. The samples were then weighed and the amount of water evaporated was determined by obtaining the difference between the weight before and after drying. The percentage moisture content was calculated as follows:

% moisture content (on dry basis) = $\frac{(W_1 + W_2) - W_3}{W_1} \times 100$

Where;

W_1 =Weight of sample before drying (g)

W_2 = weight of aluminum dish (g)

W_3 = weight of sample + aluminum dish after drying (g)

3.7.1.2 Determination of crude oil content

Crude oil content was determined using the soxhlet method as stipulated in the AOAC Official Methods 920.39 (A) (AOAC 2006).

3.7.1.2.1 Principle

Chemical exclusion of the bound fat is done by boiling the sample with diluted hydrochloric acid. This is followed by filtration of the excluded fat over pre - wetted filter paper until acid free. The filter paper is then dried on air to extract the fat with petroleum ether according to the soxhlet method. The solvent is then evaporated and the dried fat residue weighed.

The soxhlet extractor consists of an extraction flask, an extraction tube with siphon, an extraction thimble and a reflux condenser. The solvent vapour travels through the bypasses of the extractor and the trap, and then in the condenser. The condensed solvent falls through the trap siphons into the flask carrying with it the fat.

3.7.1.2.2 Procedure

The filter on air was dried (at approximately 60 ^{0}C), transferred to the extraction thimble and plugged lightly with cotton wool. The fat was extracted with 200 ml of petroleum ether for about 6-7 hours in a previously dried and weighed extraction flask. After 6 - 7 hours, the solvent was evaporated with the rotary evaporator and the fat residue dried until constant weight at 105 ^{o}C, cooled down and weighed. The fat content of the test sample, expressed as a percentage by mass, is equal to

$$\textbf{FAT (\%)} = \frac{\textbf{(G3 – G2)}}{\textbf{G1}} \textbf{ X 100}$$

Where:

GI is the mass, in grams, of the test portion

G2 is the mass, in grams, of the extraction flask

G3 is the mass, in grams, of the fat – containing extraction flask

3.7.1.3 Determination of protein content (kjeldah Method)

About 0.2g of sample, 1 tablet of catalyst (potassium II sulphate + copper II sulphate) and 12ml of concentrated H_2SO_4 were added to the kjeldahl flask. The flask was then put in a digester and the sample left to digest for an hour to a bright green colour. It was then cooled to room temperature and 75ml of tap water and 50ml of NaOH were added. The flask was then put in a distillation unit. 25 - 40ml of distillate was collected in 25ml of boric acid and titrated against 0.1N HCL to an end point of light pink.

The results were then expressed as follows:

$$\text{\% protein} = \frac{1.4007 \times (V_S - V_B) \times M}{W} \times 100$$

Where;

Vs is the volume of HCL used in the titration (ml)

V_B is the volume of the blank used (ml)

M is the molarity of HCL solution used

W is the mass of sample (g)

3.7.1.4 Determination of total ash

Ash was determined using the AOAC official method 942.05 (AOAC 2006)

Total ash was determined using the De vleesh auwer method of 1948. Previously ignited crucibles were weighed to into which about 2.0000g of the sample was weighed to. The crucibles were transferred to a muffle furnace, which is heated at about 550 ^{0}C until the ash was nearly white (4 hours). The furnace was cooled to about 100 ^{0}C, crucibles removed and placed in the desiccator for 30 minutes after which they were weighed to 4 decimals. The difference in weight between the empty crucible and the crucible with ash gives the ash content of the sample. The percentage ash content was calculated as follows:

$$\% \text{ Ash content} = \frac{C - A}{B} \times 100$$

Where;

A = Weight of crucible (g)

B = Weight of sample before ashing (g)

C = Weight of crucible + sample after ashing (g)

3.7.1.5 Determination of Calcium

Calcium was determined using the permanganate method which depends on the precipitation of calcium containing solution with excess ammonium oxalate to form a calcium oxalate precipitate, which is insoluble in water. The precipitate is then filtered and washed with hot water to remove the excess ammonium oxalate. The filtrand is dissolved in bench sulphuric acid forming oxalic acid, which is then, titrated with standard potassium permanganate to a pink end point, which lasts about a minute and later disappears due to atmospheric oxidation of permanganate.

3.7.1.5.1 Acid extraction

About 2.0000g of samples were weighed into each crucible and transferred to a cool muffle furnace. The furnace was then heated to about 550 ^{0}C until the ash was nearly white (4 hours). The furnace was cooled to about 100 ^{0}C and the weight of the crucible weighed. The minerals were extracted by adding 10 mls of 3N HCL to the crucible and bringing it to the boil on a hot plate. The filtrate was then collected in a 100ml volumetric flask. Thereafter, the crucible and filter paper were washed 3 times with hot 3N HCL combining with the filtrate and adding to the mark with distilled water.

3.7.1.6 Determination of crude fibre

Determination of the (Crude) fibre content by the Weende method in grains, meals and flours is as stipulated in the AOAC Official method 978.10 (AOAC 2006). Crude fiber is loss in ignition of dried residue remaining after digestion of sample with 1.25% sulphuric acid and 1.25% sodium hydroxide solutions under specific conditions.

About 2g of the sample were accurately weighed and placed in a clean graduated beaker of about 250 capacity conical flasks. Thereafter, 150 ml of 1.25% sulphuric acid was added and contents brought to the boil for exactly 30 minutes. The boiled residue was removed from the heat source and filtered through the sintered crucibles and rinsed with 100 mls hot water. The contents were washed back into the flask with about 10 mls sodium hydroxide. Furthermore, 150 ml of 1.25% Sodium hydroxide was added and the beaker and its contents were brought to the boil again, continued boiling gently for another 30 minutes. The residue was mixed well with a glass rod and particles rinsed back from the sides of the flask. The boiled residue was then removed from the heat source and filtered through the sintered crucibles and rinsed with another 100 ml hot water. The crucibles were then dried in the oven for 3 - 4 hours at 105 ^{0}C**,** cooled in a desiccator and weighed. These were finally placed in a muffle furnace at about 550 ^{0}C for approximately 1 hour to burn off the remaining organic matter**.** The loss in weight on burning represented the fibre in the original sample. The fibre content was calculated as follows:

$$\text{fiber} = \frac{W_2 - W_3}{W_1} \times 100$$

Where:

W_1 = weight of fresh sample (g)

3.7.1.7 Determination of carbohydrates

The total carbohydrate content was calculated by difference as described in the equation below (Kulwa et al., 2015) :

Carbohydrate content (%) = 100 – [(crude protein content (%) + crude fat content (%)) +

total ash (%) + crude fibre (%) + crude moisture content (%)]

Furthermore, the Atwater factors were used to calculate the energy content and then expressed as kcal/100g of the sample (Kulwa et al., 2015) .

3.7.2: Mineral Analysis

The mineral content was determined using two methods. The GBC Atomic Absorption Spectrophotometer was used to measure the contents of calcium. Whilst the Perkin-Elmer 2001 Model Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used for assaying iron and zinc. About 2g of the grounded food was used for each determination and the experiment was performed in triplicate

3.7.3 Beta carotene determination

The presence of beta carotene in the complementary foods was determined by the Harvest Plus method (Delia et al, 2004). About 3.000g of the complementary food sample was weighed and homogenized. The carotenoids were extracted using 40ml of acetone followed by filtration using a sintered glass funnel. The filter paper was fitted well so that the fine sample particles did not pass.

After filtration, partitioning followed by adding 50 mls of petroleum ether to the filtrante and water was added gently along the walls of the funnel to avoid formation of emulsions. The two layers separated and the lower aqueous phase was discarded. The petroleum ether phase was washed 4 times with 200 mls of water each to remove residual acetone. After partitioning, the solution was dried with anhydrous sodium sulphate, made up to the mark with petroleum ether and the absorbance taken at 450 nm. The carotene content was calculated using the formula bellow:

Carotene content (µg/g) = 1.25

$$\frac{A_{fr1} \text{x volume (mL)x } 10^4}{A_{1cm}^{1\%} \text{ x sample weight (g)}} \text{ x } 1.25$$

where Afr 1= absorbance; volume = volume of fraction 1 (5 mL); = absorption coefficient of β−carotene in PE (2592). Multiplying by 1.25 accounts for the use of a 20 mL aliquot taken from a total extract of 25 mL.

3. 8 Data management and analysis

Data was managed and analysed as stipulated bellow:

To address objective 1, dietary data collected using the list based questionnaire were entered and analysed using the Statistical Package for Social Sciences (SPSS) version 20. The proportion of children consuming 4 out of 7 food groups was calculated and interpreted according to the 2010 WHO guidelines on the minimum dietary diversity of consuming not less than four (4) food groups. Furthermore, associations between dietary diversity score and selected household characteristics were obtained using chi square tests.

To address objective 2, dietary data on estimated quantities consumed in the previous 24 hours was entered in Nutri survey (2007) and analysed in order to determine the adequacy of the nutrients. The results were compared with the FAO and WHO guidelines on infant and young child feeding (Dewey & Brown, 2003) ; FAO,WHO & UNU, 2014; FAO & WHO,1998).

To address objective 3, the data collected from the focused group discussions were compiled into recipes on biofortified complementary foods as outlined in Appendix A.

Finally, objective 4 was addressed through laboratory analysis using approved protocols in order to determine the real nutrients consumed by the children. The laboratory data was statistically analysed using SPSS and the range of values obtained was compared with the standards for codex alimentarius on complementary foods (FAO, 2013).

3.9 Ethical considerations

The University of Zambia, Department of Food Science and Nutrition approved the proposed research whilst ethical clearance was obtained from ERES CONVERGE IRB (Reference No. 2017 - Jan - 006). Authority to conduct the study in the villages comprising the target camps in Chipata district was sought from the District Agricultural Coordinator's (DACO's) office. At household level, informed consent was sought from the respondents who were guaranteed confidentiality and informed that the information provided was only for research purposes. Confidentiality was assured by not including respondent names on the questionnaires but only identity numbers.

The results of the study would be shared with ERES CONVERGE and relevant stakeholders promoting biofortified food crops such as government ministries (Agriculture and Health) and NGO'susing appropriate means. The purpose would be to inform future interventions on the contribution of biofortified crops to the diets of infants 6 - 23 months and how future programmes can be designed to improve their nutritional status. Furthermore, the outcomes of this study would be shared with the participants through their local leadership and agricultural extension officers who are on the ground for dissemination during group meetings.

CHAPTER FOUR: RESULTS

Introduction

This section reports the demographic characteristics of the target households, the mother and the child aged 6 to 23 months. The consumption patterns of the children which includes the breastfeeding status, time of introduction of complementary foods, consumption of biofortified foods, diversity of diets and their mean nutrient intakes are included. Furthermore, associations between individual dietary diversity score and selected household characteristics have been shown. Additionally, the section shows the biofortified food recipes commonly used in the target areas including the nutrient composition of the complementary foods collected.

4.1 Demographic and social economic characteristics

A total of 215 households with children aged 6 - 23 months participated in the study as presented in Table 1. About 86 percent (n = 185) of the households surveyed were male headed. The mean age of the mother was 27.03, mostly aged between 20 - 29 years (n = 110) of which 41.40 percent (n = 89) had not completed primary education. Out of the 215 children enrolled in the study, more than half were boys (51.60 percent, n =111) and mostly aged between 6 - 8 months (39.50 percent, n = 30).

Table 1 : Household demographics and social economic status

	n	%
Sex of the household head		
Male	185	86
Female	30	14
Households surveyed per camp		
Chiparamba	43	20
Chikando	43	20
Manjakazi	43	20
Chiwoko	43	20
Kapita	43	20
Characteristics of mothers		
Mean age	27.03	
Age distribution of the mother		
11 - 19	33	15.30
20 - 29	110	51.20
30 - 39	56	26.00
40 - 49	16	7.40
Education level of the mother		
None	25	11.60
Primary not completed	89	41.40
Primary completed	29	13.50
Secondary not completed	65	30.20
Secondary completed	7	3.30
Tertiary Education	0	0
Number of children by sex		
Male	111	51.60
Female	104	48.40
Age (Months)		
Mean age	14.54	
6 - 8	78	36.30
9 -11	58	27.00
12 - 23	79	36.70

4.2. Breastfeeding and complementary feeding status of the children

Regarding breastfeeding, 63.30 percent (n = 136) of the mothers reported having exclusively breastfed their children for six months as presented in Table 2. Furthermore, more than half of the children (77.20 percent, n = 166) were still breastfeeding at the time of the visit. The number of children breastfeeding decreased with age and the time of introduction of complementary foods ranged from 2 months to 8 months with 61.90 percent (n = 133) of mothers introducing other foods at the age of 6 months.

Table 2 : Breastfeeding and complementary feeding status

	n	%
Duration of exclusive breastfeeding		
2 months	5	2.30
3 months	6	2.80
4 months	16	7.40
5 months	44	20.50
6 months	136	63.30
7 months	8	3.70
Total	**215**	**100**
Breastfeeding status		
Still breastfeeding		
6 - 8	76	35.30
9 - 11	49	22.80
12 - 23	41	19.10
Subtotal	**166**	**77. 20**
Children not breastfeeding		
6 - 8	2	0.90
9 - 11	9	4.20
12 - 23	38	17.70
Subtotal	**49**	**22.80**
Total	**215**	**100**

Time of introduction of complementary foods		
2 months	4	1.90
3 months	5	2.30
4 months	11	5.10
5 months	22	10.20
6 months	133	61.90
7 months	36	16.70
8 months	4	1.90
Total	**215**	**100**

4.3 Food consumption patterns

4.3.1 Consumption of food groups by children aged 6 - 23 months

The consumption of different food groups by the children aged 6 - 23 months is presented in Table 3. The results show that the day preceding the survey, vitamin A rich fruits and vegetables were the most highly consumed (89.90 percent, n = 193) followed by grains, roots and tubers (80.90 percent, n = 174). The third most highly consumed group were the legumes and nuts (70.70 percent, n =152) followed by other fruits and vegetables (47.90 percent, n = 103). However, consumption of protein rich foods which constituted flesh foods (43.70 percent, n = 94), dairy products (22.30 percent, n = 48) and eggs (31.20 percent, n = 67) was low.

Table 3: Consumption of food groups by children aged 6 - 23 months

Food groups consumed	n	%
Grains, roots and tubers	174	80.90
Legumes and nuts	152	70.70
Dairy	48	22.30
Flesh foods	94	43.70
Eggs	67	31.20
Vitamin A rich fruits & vegetables	193	89.80
Other fruits and vegetables	103	47.90

4.3.2 Consumption of food groups by age of the children

As presented in Table 4, more than 50 percent of children in all age groups consumed foods from vitamin A rich fruits and vegetables, staples (grains, roots and tubers) and legumes and nuts respectively. However, consumption of animal source foods was low in all age groups especially consumption of dairy products which was low among children aged 12 - 23 months (6.10 percent, n =13) and flesh foods among children aged 6 - 8 months (34.60 percent, n = 27) respectively. Chi - square tests showed significant differences in the proportion of children consuming starchy staples (grains, roots and tubers) (P = 0.004) and those consuming vitamin A rich fruits and vegetables (P = 0.005) with a higher proportion of children aged 12 - 23 months consuming more of each food group respectively.

Table 4: Consumption of food groups by children from different age groups

Food groups consumed	Children aged 6- 8 months (n=78)		Children aged 9 -11 months (n=58)		Children aged 12 - 23 months (n=79)		P Value
	n	%	n	%	n	%	
Grains, roots and tubers	55	70.50	47	81.00	72	91.10	0.004
Legumes and nuts	46	59.00	45	77.60	61	77.20	0.017
Dairy	19	8.80	16	7.40	13	6.10	0.262
Flesh foods(meat, poultry & fish)	27	34.60	30	51.70	37	46.80	0.108
Eggs	24	30.80	20	34.50	23	29.10	0.795
Vit A rich fruits & vegetables	63	80.80	55	94.80	75	94.90	0.005
Other fruits and vegetables	38	48.70	30	51.70	35	44.30	0.680

4.3.3 Consumption of food groups by children of different sex

The consumption of food groups by sex is presented in Table 5. A higher proportion of male children consumed grains, roots and tubers (81.10 percent, n = 90), legumes and nuts (71.20 percent, n = 79), dairy products (22.50 percent, n = 25), and flesh foods (45.00 percent, n = 50) respectively. On the other hand, a higher proportion of female children consumed vitamin A rich fruits and vegetables (93.30 percent, n = 97), other fruits and vegetables (45.00 percent, n = 50) and eggs (35.60 percent, n = 37) respectively. Chi square tests showed no significant difference in the consumption of foods from the seven food groups by children of different sex.

Table 5: Consumption of food groups by children of different sex

Food groups consumed	Males		Females		P-Value
	n	%	n	%	
Grains, roots and tubers	90	81.10	84	80.80	0.954
Legumes and nuts	79	71.20	73	70.20	0.875
Dairy	25	22.50	23	22.10	0.943
Flesh foods	50	45.00	44	42.30	0.686
Eggs	30	27.00	37	35.60	0.176
Vitamin A rich fruits & vegetables	96	86.50	97	93.30	0.078
Any other fruits and vegetables	50	45.00	53	51.00	0.385

4.3.4 Consumption of biofortified food crops

The consumption of biofortified food crops (orange maize, orange fleshed sweet potatoes and iron rich beans) by children aged 6 - 23 months was determined.

4.3.4.1 Consumption of biofortified food crops by children

More than half (74.90 percent, n = 161) of the children consumed orange maize, 29.80 percent (n = 64) consumed orange fleshed sweet potatoes whilst 13.00 percent (n = 28) of the children consumed iron rich beans three months preceding the survey as presented in Table 6.

Table 6: Consumption of biofortified food crops by children

	n	%
Orange maize	161	74.90
Orange fleshed sweet potatoes	64	29.80
Iron rich beans	28	13.00

4.3.4.2 Consumption of biofortified food crops by children of different age groups and sex

To establish if there was any relationship between the consumption of biofortified food crops among children of different age groups and sex, associations were conducted using chi square tests. Table 7 shows that there was an association between the consumption of orange maize and the age of the children ($p = 0.000$) with a higher proportion of children (88.60 percent) aged 12 – 23 months consuming orange maize in form of porridge and nshima than those aged 6 - 8 months (60.30 percent) and 9 – 11months (75.90 percent). Furthermore, consumption of biofortified food crops was not associated with the sex of the children as presented in Table 8.

Table 7: Consumption of biofortified food crops by children of different age groups

Biofortified food crop consumed	Age of the child (Months) 6 - 8 n = 78		9 -11 n = 58		12 - 23 n = 79		Chi - square P - Value
	n	%	n	%	n	%	
Orange maize	47	60.30	44	75.90	70	88.60	0.000
Orange fleshed sweet potato	17	21.80	15	25.90	32	40.50	0.028
Iron rich beans	8	10.30	8	13.80	12	15.20	0.642

Table 8: Consumption of biofortified food crops by children of different sex

Biofortified food crop consumed	Sex of the children Male n = 111		Female n = 104		Chi square P- value
	n	%	n	%	
Orange maize	88	40.90	86	40.00	0.524
Orange fleshed sweet potato	37	17.20	38	17.70	0.622
Iron rich beans	15	7. 00	15	7.00	0.847

4.4.4.3 Biofortified based complementary foods commonly consumed

During complementary feeding, the biofortified food crops were either grated (if fresh) or milled into flour and mixed with other ingredients to make different products as presented in Tables 9, 10 and 11 respectively.

4.4.4.3.1 Common orange maize based complementary foods

Orange maize based complementary foods that were commonly consumed are as presented in Table 9. More than half of the children (56.30 percent, n = 121) consumed orange maize and groundnuts porridge followed by orange maize nshima (21.80 percent, n = 47) then orange maize and vegetable porridge (15.30 percent, n = 33).

Table 9: Common orange maize based complementary foods

Type of complementary food	Frequency	Percentage of children consuming complementary foods
Orange maize and groundnut porridge	121	56.30
Fresh orange maize and fresh groundnut porridge	9	4.20
Orange maize and cowpea porridge	14	6.50
Orange maize and Bambara porridge	2	9.00
Orange maize and fish porridge	16	7.40
Orange maize and vegetable porridge	33	15.30
Fresh orange maize cob	24	11.40
Orange maize nshima	47	21.80
Plain orange maize porridge	12	5.60

4.4.4.3.2: Orange fleshed sweet potato based complementary foods commonly consumed

The orange fleshed sweet potato based complementary foods that were commonly consumed are as presented in Table 10. Fresh boiled sweet potatoes were commonly consumed (27.20 percent, n = 54) followed by orange fleshed sweet potatoes in groundnut sauce (11.20 percent, n = 24), whilst fried sweet potatoes were the least consumed (0.50 percent, n = 1).

Table 10: Common orange fleshed sweet potato based complementary foods

Type of complementary food	Frequency	Percentage of children consuming complementary foods
Orange fleshed sweet potato in groundnut sauce	24	11.20
Orange fleshed sweet potato soup	2	0.90
Orange fleshed sweet potato, soy and cassava porridge	16	7.40
Fresh boiled sweet potatoes	58	27.20
Fried sweet potatoes	1	0.50

4.4.4.3.3: Bean based complementary foods commonly consumed

Table 11 summarises the iron rich bean based complementary foods that were commonly consumed. About 10.40 percent (n = 22) of the children consumed orange maize nshima with beans, 4.20 percent (n = 9) consumed orange maize and bean porridge whilst 0.50 percent (n = 1) consumed bean snacks.

Table 11: Common bean based complementary foods

Type of complementary food	Frequency	Percentage of children consuming complementary foods
Iron rich beans and sweet potato puree	4	1.90
Orange maize nshima with beans	22	10.40
Bean snack	1	0.50

4.4.4.4.1 Biofortified food crops preferred for complementary feeding

About 76.70 percent (n = 165) of the mothers preferred feeding orange maize to their children, 8.40 percent (n = 18) preferred orange fleshed sweet potatoes whilst 10.20 percent (n = 22) preferred iron rich beans respectively (Figure 1).

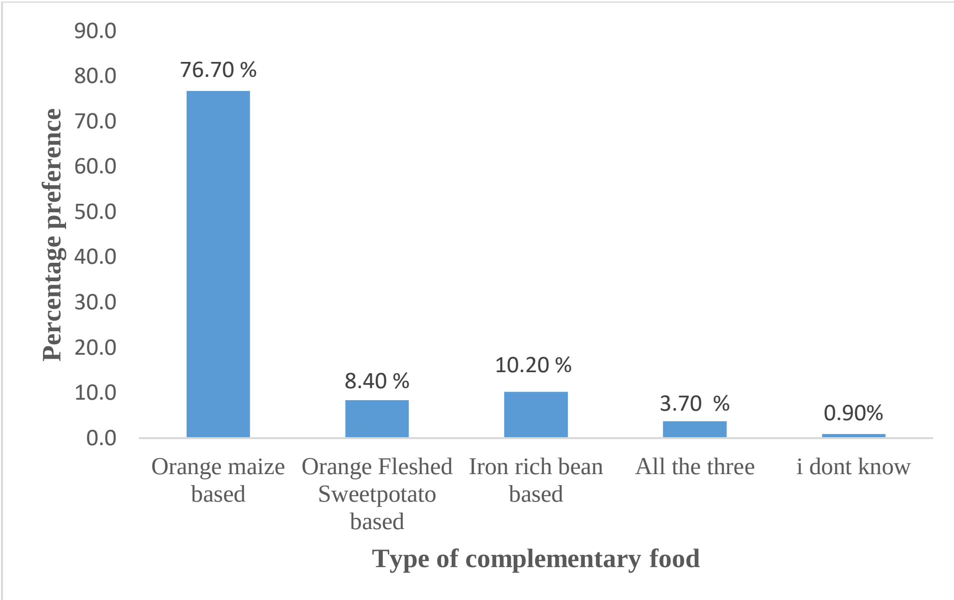

Figure 1: Type of biofortified food crop preferred for complementary feeding

4.4.4.4.2 Reasons for preference of particular biofortified food crops for complementary feeding.

The reasons given for preference of particular biofortified food crops for complementary feeding are presented in Table 12**.** About 35.80 percent (n = 77) of the respondents preferred orange maize for complementary feeding because of the presence of provitamin A whilst the least were 5.10 percent (n = 11) who showed preference because of its alleged effect on child's intelligence. Furthermore, only 4.70 percent (n = 10) had preference for orange fleshed sweet potatoes whilst 0.50 percent (n = 1) indicated that the sweet potatoes were readily available for feeding the children. Additionally, 7.00 percent (n = 15) preferred iron rich beans for complementary feeding because of its richness in proteins whilst the least were 0.50 percent (n = 2) who preferred the beans because of its cognitive effect and its availability. Only 2 .80 percent (n = 6) preferred all the three food crops for complementary feeding.

Table 12: Reasons for preferring specific biofortified food crops in complementary feeding

Reasons for preference	Orange maize		Orange fleshed sweet potato		Iron rich beans		All the three	
	n	**%**	n	%	**n**	**%**	**n**	**%**
Makes baby healthy	56	26.10	3	1.40	7	3.30	1	0.50
Good for eyes	33	15.40	2	0.90	0	0	2	0.90
Rich in Vit A	77	35.80	10	4.70	0	0	0	0
Rich in Proteins	22	10.20	0	0	15	7.00	1	0.50
Nutritious	19	8.80	0	0	0	0	6	2.80
Makes child intelligent	11	5.10	0	0	1	0.50	0	0
Readily available	30	14.00	1	0.50	1	0.50	1	0.50
Others	39	18.10	3	1.40	5	2.30	3	1.40

4.5 Diversity of diets

4.5.1 Mean individual dietary diversity score

A total of 215 children were surveyed and the results showed that the mean individual dietary diversity score was 3.87 (+/-1.433). Figure 2 shows classification of children by number of food groups consumed from less than 4 food groups and those that consumed more than 4 food groups. Out of the 215 children aged 6 – 23 months, a high proportion (62.30 percent, n = 134) did not meet the minimum dietary diversity since they consumed less than 4 food groups 24 hrs preceding the survey. Only 37.70 percent (n = 81) of the children met the minimum dietary diversity as they had consumed more than 4 food groups.

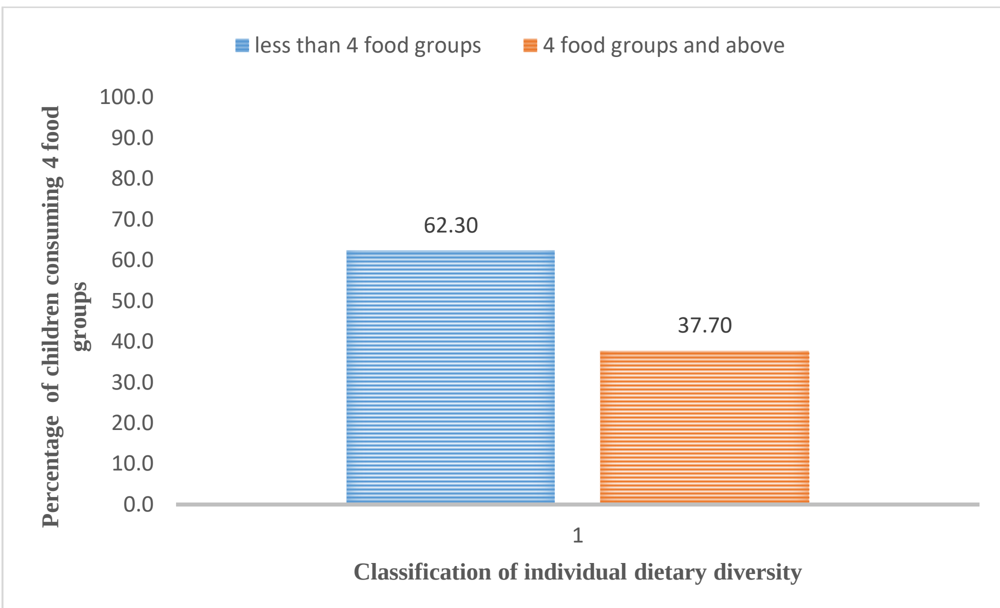

Figure 2: Classification of children by individual dietary diversity score

The classification of children by individual dietary diversity score for each camp is as presented in Table 13. Manjakazi camp had the highest proportion of children (9.77 percent, n = 21) who met the minimum DDS followed by Kapita Camp which had 8.84 percent, (n = 19) respectively. Similarly, the proportion of children who did not meet the minimum dietary diversity score was high in Chikando and Chiwoko camps which had 13.95 percent (n = 30) of children consuming less than 4 food groups respectively.

Table 13: Classification of children by individual dietary diversity score per camp

Camp Name	Classification of IDDS for Children			
	Less than 4 food groups		4 or more food groups	
	n	%	n	%
Chikando	30	13.95	13	6.05
Chiparamba	28	13.02	15	6.98
Chiwoko	30	13.95	13	6.05
Kapita	24	11.16	19	8.84
Manjakazi	22	10.23	21	9.77
Total	**134**	**62.31**	**81**	**37.69**

4.6 Association between individual dietary diversity score and selected household characteristics

In order to determine if there was a relationship between individual dietary diversity score and selected household characteristics, Pearson chi - square test was conducted at 95% confidence level. The results showed that IDDS was positively associated with the age of the child (P = 0.000) and was not associated with the age of the mother, mother's level of education, marital status of the mother or sex of the child .

4.7 Mean nutrient intake of children aged 6 - 23 months

The distribution of nutrient intakes and their adequacies for each age group in relation to the recommended daily intakes are as shown in Tables 14, 15 and 16.

Higher intakes of energy (1126.42 kcal and 1122.02 kcal), protein (45.93g and 41.61g) and carbohydrates (131.98g and 131.51g) were observed among children aged 12 – 23 months. For children aged 9 – 11 months, the intake of energy among girls (798.24 kcal) and boys (695.72 kcal) including that of protein among girls (114.70g) was relatively high. In terms of micronutrients, there was adequate intake of vitamin B_1 and magnesium across all age groups. Furthermore, older children had adequate intakes of vitamin A, vitamin C and vitamin B_6 whilst the intakes of potassium, phosphorus, magnesium, iron and zinc were relatively high in relation to the RDA. Higher intakes of magnesium, phosphorus, folic acid, vitamins B_1 and vitamin B_6 were also observed in children aged 9 - 11 months. Furthermore, the intake of iron for children aged 6 - 8 months and those aged 9 - 11 months ranged between 51.20 percent and 69.00 percent of the Recommended Daily Allowance (RDA) whilst that of children aged 12 - 23 months averaged 135.25 percent of the RDA. The intake of calcium was below 50 percent of the RDA in all age groups.

Table 14 : Mean nutrient intake for girls and boys aged 6 – 8 months

Nutrient	Mean Nutrient Intake (girls 6-8 months old)	RDA	Percent of RDA
Energy (kcal)	541.46	629	86.10
Protein (g)	20.48	23.59	86.80
Fat (g)	17.15	47.2	36.30
Carbs (g)	45.88	86.5	53.00
Vit. A (µg)	168.68	375	44.98
Vit. E (mg)	0.06	2.7	2.20
Vit. B1 (mg)	0.31	0.3	**103.30**
Vit. B2 (mg)	0.21	0.4	52.50
Vit. B6 (mg)	0.25	0.3	83.30
tot. fol.acid (µg)	62.46	80	78.10
Vit. C (mg)	10.04	30	33.50
Sodium (mg)	40.94	320	12.80
Potassium (mg)	271.67	700	38.80
Calcium (mg)	78.49	400	19.60
Magnesium (mg)	112.65	54	**208.60**
Phosphorus (mg)	309.71	400	77.40
Iron (mg)10% availability	6.38	9.3	68.60
Zinc (mg)	2.74	4.1	66.80
Vit. B12 (µg)	0.33	0.5	66.00

Nutrient	Mean Nutrient Intake (boys 6-8 months old)	RDA	Percent of RDA	Average Percent of RDA
Energy (kcal)	614.92	680	90.40	88.30
Protein (g)	22.48	25.5	88.20	87.50
Fat (g)	23.91	51	46.90	41.60
Carbs (g)	51.67	93.5	55.30	54.20
Vit. A (µg)	117.27	375	31.27	38.10
Vit. E(mg)	0.79	2.7	29.30	15.70
Vit. B1 (mg)	0.39	0.3	**130.00**	**116.70**
Vit. B2 (mg)	0.38	0.4	95.00	73.80
Vit. B6 (mg)	0.30	0.3	100.00	91.70
Tot. fol.acid (µg)	63.84	80	79.80	78.90
Vit. C (mg)	8.83	30	29.40	31.50
Sodium (mg)	110.90	320	34.70	23.70
Potassium (mg)	361.19	700	51.60	45.20
Calcium (mg)	233.85	400	58.50	39.00
Magnesium (mg)	117.18	54	**217.00**	**212.80**
Phosphorus (mg)	382.42	400	95.60	86.50
Iron (mg) at 10% availability	6.24	9.3	67.1	67.90
Zinc (mg)	3.09	4.1	75.4	71.10
Vit. B12 (µg)	0.45	0.5	90.0	78.00

Table 15 : Mean nutrient intake for girls and boys aged 9 - 11 months

Nutrient	Mean Nutrient Intake (girls 9 -11 months old)	RDA	Percent of RDA	Nutrient	Mean Nutrient Intake (boys 9 -11 months old)	RDA	Percent of RDA	Average Percent of RDA
Energy (kcal)	798.24	694	**115.00**	Energy (kcal)	695.72	752	92.50	**103.80**
Protein (g)	29.86	26.03	**114.70**	Protein (g)	23.59	28.2	83.70	99.20
Fat (g)	25.75	52.1	49.40	Fat (g)	16.56	56.4	29.40	39.40
Carbs (g)	77.58	95.4	81.30	Carbs (g)	96.51	103.4	93.30	87.30
Vit. A (µg)	290.23	400	72.60	Vit. A (µg)	265.99	400	66.50	69.50
Vit. E (eq.) (mg)	0.98	2.7	36.30	Vit. E (eq.) (mg)	1.08	2.7	40.00	38.20
Vit. B1 (mg)	0.52	0.3	**173.30**	Vit. B1 (mg)	0.50	0.3	**166.70**	**170.00**
Vit. B2 (mg)	0.29	0.4	72.50	Vit. B2 (mg)	0.20	0.4	50.00	61.30
Vit. B6 (mg)	0.33	0.3	**110.00**	Vit. B6 (mg)	0.27	0.3	90.00	**100.00**
Tot. folic(µg)	106.40	80	**133.00**	Tot. folic(µg)	71.46	80	89.30	**111.20**
Vit. C (mg)	16.83	30	56.10	Vit. C (mg)	21.66	30	72.20	64.20
Sodium (mg)	86.38	320	27.00	Sodium (mg)	44.53	320	13.90	20.50
Potassium (mg)	463.07	700	66.20	Potassium (mg)	475.20	700	67.90	67.00
Calcium (mg)	107.60	400	26.90	Calcium (mg)	72.94	400	18.20	22.60
Magnesium (mg)	157.96	54	**292.50**	Magnesium (mg)	106.80	54	197.80	**245.20**
Phosphorus (mg)	448.70	400	**112.20**	Phosphorus (mg)	361.16	400	90.30	**101.20**
Iron (mg) at 10% availability	6.42	9.3	69.00	Iron (mg) at 10% availability	4.76	9.3	51.20	60.10
Zinc (mg)	3.40	4.1	82.90	Zinc (mg)	2.94	4.1	71.70	77.30
Vit. B12 (µg)	0.21	0.5	42.00	Vit. B12 (µg)	0.46	0.5	92.00	67.00

Table 16 : Mean nutrient intake for girls and boys aged 12 - 23 months

Nutrient	**Mean Nutrient Intake (girls 12-23 months old)**	**RDA**	**Percent of RDA**	**Nutrient**	**Mean Nutrient Intake (boys 12-23 months old)**	**RDA**	**Percent of RDA**	**Average Percent of RDA**
Energy (kcal)	1126.42	865	**130.20**	Energy (kcal)	1122.02	948	**118.40**	**124.30**
Protein (g)	45.93	32.44	**141.60**	Protein (g)	41.61	35.55	**117.00**	**129.30**
Fat (g)	41.05	64.9	63.30	Fat (g)	35.42	71.1	49.80	56.50
Carbohydrate. (g)	131.98	118.9	**111.00**	Carbohydrates (g)	131.59	130.4	100.90	**106.00**
Vit. A (µg)	436.67	400	**109.20**	Vit. A (µg)	402.66	400	100.70	**105.00**
Vit. E (eq.) (mg)	4.29	2.7	**158.90**	Vit. E (eq.) (mg)	2.25	2.7	83.30	**121.10**
Vit. B1 (mg)	1.06	0.5	**212.00**	Vit. B1 (mg)	0.83	0.5	**166.00**	**189.00**
Vit. B2 (mg)	0.44	0.5	88.00	Vit. B2 (mg)	0.35	0.5	70.00	79.00
Vit. B6 (mg)	0.58	0.5	**116.00**	Vit. B6 (mg)	0.47	0.5	94.00	**105.00**
Tot. fol.acid (µg)	171.16	160	**107.00**	tot. fol.acid (µg)	140.28	160	87.70	97.30
Vit. C (mg)	31.41	30	**104.70**	Vit. C (mg)	31.71	30	**105.70**	**105.20**
Sodium (mg)	175.22	320	54.80	Sodium (mg)	133.75	320	41.80	48.30
Potassium (mg)	1181.10	700	**168.70**	Potassium (mg)	898.05	700	**128.30**	**148.50**
Calcium (mg)	195.22	500	39.00	Calcium (mg)	194.09	500	38.80	38.90
Magnesium (mg)	220.13	60	**366.90**	Magnesium (mg)	183.83	60	**306.40**	**336.60**
Phosphorus (mg)	670.49	270	**248.30**	Phosphorus (mg)	614.96	270	**227.80**	**238.10**
Iron (mg) at 10% availbility	7.86	5.8	**135.50**	Iron (mg) at 10% availability	7.83	5.8	**135.00**	**135.30**
Zinc (mg)	5.29	4.1	**129.00**	Zinc (mg)	4.77	4.1	**116.30**	**122.70**
Vit. B12 (µg)	0.61	0.9	67.80	Vit. B12 (µg)	0.39	0.9	43.30	55.60

4.8 Documentation of recipes on complementary foods

This section highlights the activities undertaken during focused group discussions when recipes on biofortified food based complementary foods commonly prepared in the different camps were collected. Details of the recipes are as stipulated in Appendix A.

4.8.1 Common complementary foods prepared from biofortified food crops in different camps

Table 17 shows the common biofortfied based complementary food recipes which were reported during the focused group discussions held in the different camps. Details are as stipulated in appendix A.

Table 17: Nutrient composition of complementary foods for Chiparamba Agricultural camp

Complementary food recipe	Camps in which the recipes are commonly used
1. Orange maize nshima	Kapita
2. Orange maize samp	Kapita,Chiwoko
3. Orange maize fritters	Kapita,Manjakazi
4. Orange maize porridge with groundnuts	Kapita,Manjakazi,Chiwoko
5. Fresh orange maize porridge	Kapita,Manjakazi
6. Plain orange maize porridge	Kapita,Manjakazi,Chiwoko
7. Orange maize porridge with oil	Kapita,Manjakazi,Chiwoko
8. Orange maize nshima with iron rich beans	Kapita
9. Orange maize and fresh groundnuts porridge	Manjakazi

10. Orange maize with vegetable porridge	Manjakazi
11. Orange maize and egg porridge	Manjakazi
12. Fresh orange maize cobs	Chiwoko
13. Orange fleshed sweet potatoes with groundnuts	Chiwoko
14. Boiled orange fleshed sweet potatoes (with peels)	Chiwoko
15. Boiled orange fleshed sweet potatoes without peels	Chiwoko
16. Orange maize porridge with beans (iron rich)	Kapita,Chiwoko

4.9. Nutrient composition of complementary foods per camp

The nutrient analysis of the different complementary foods sampled was determined and the camp specific means, standard error and standardard deviations are presented in Tables 18, 19, 20 , 21 and 22 respectively.

Table 18 : Nutrient composition of complementary foods for Chiparamba agricultural camp

Type of complementary food	Number of samples	Beta Carotene (μg/g)	Iron (mg/100g)	Zinc (mg/100 g)	Protein (g/100g DW)	Crude fat (g/100g DW)	Ash (g/100g)	Moisture (%)	Crude fibre (g/100g DW)	Carbohydrate (g/100g)	Energy (Kcal)
Orange maize porridge	7	50.17	8.77	36.35	5.18	0.95	0.25	81.08	0.97	11.58	75.58
white maize porridge with pumpkin leaves	4	40.69	4.50	36.87	5.20	1.44	0.43	81.23	1.28	10.43	75.48
White and orange maize blended porridge	3	20.37	6.28	33.53	3.80	0.38	0.17	86.03	1.19	8.43	52.30
White maize porridge with beans	1	53.7	6.95	30.05	2.47	0.09	2.6	82.37	1.09	11.38	56.21
Mean		41.23	6.63	34.20	4.16	0.72	0.86	82.68	1.13	10.46	64.89
Std. Error of Mean		7.48	0.88	1.57	0.65	0.30	0.58	1.15	0.07	0.72	6.19
Std. Deviation		14.95	1.76	3.13	1.30	0.60	1.16	2.31	0.13	1.44	12.39

Table 19: Nutrient composition of complementary foods for Kapita agricultural camp

Type of complementary food	Number of Samples	Beta Carotene (µg/g)	Iron (mg/100g)	Zinc (mg/100 g)	Protein (g/100g DW)	Crude fat (g/100g DW)	Ash (g/100g)	Moisture (%)	Crude fibre (g/100g DW)	Carbohydrate (g/100g)	Energy (Kcal)
orange maize porridge	11	42.19	10.40	36.09	2.93	0.91	0.69	79.04	0.83	15.59	82.31
orange maize porridge with beans	1	61.84	13.7	37.4	4.56	2.08	0.19	80.64	0.64	11.89	84.52
White maize porridge	3	37.82	10.22	34.6	2.67	1.87	0.47	82.98	0.67	11.34	72.83
Mean		47.28	11.44	33.97	3.39	1.62	0.45	80.89	0.71	12.94	79.89
Std. Error of Mean		7.39	1.13	2.80	0.59	0.36	0.14	1.14	0.06	1.33	3.59
Std. Deviation		12.79	1.96	4.85	1.02	0.62	0.25	1.98	0.10	2.31	6.21

Table 20: Nutrient composition of complementary foods for Manjakazi agricultural camp

Type of complimentary food	Number of samples	Beta Carotene (µg/g)	Iron (mg/100g)	Zinc (mg/100 g)	Protein (g/100g DW)	Crude fat (g/100g DW)	Ash (g/100g)	Moisture (%)	Crude fiber (g/100g DW)	Carbohydrate (g/100g)	Energy (Kcal)
Orange and white maize blended porridge	1	39.98	6.45	38	5.1	0.5	0.89	76.9	1.6	15.01	84.94
White maize porridge	2	24.11	3.73	16.40	3.19	0.60	0.65	81.40	1.15	11.77	70.22
Orange maize with pumpkin leaves porridge	1	281.15	4.3	16.4	3.19	2.11	0.98	78.38	1.4	13.94	87.51
Orange maize porridge	10	147.14	4.53	35.19	4.31	1.84	0.47	80.16	1.59	11.62	73.42
Boiled orange fleshed sweet potato	1	417.79	4.05	36.45	3.46	3.02	0.54	82.63	2.29	8.06	73.26
Mean		**182.03**	**4.61**	**28.49**	**3.85**	**1.61**	**0.71**	**79.89**	**1.61**	**12.08**	**77.87**
Std. Error of Mean		**74.75**	**0.48**	**4.95**	**0.37**	**0.48**	**0.10**	**1.03**	**0.19**	**1.19**	**3.48**
Std. Deviation		**167.14**	**1.07**	**11.08**	**0.84**	**1.07**	**0.22**	**2.30**	**0.42**	**2.67**	**7.79**

Table 21: Nutrient composition of complementary foods for chikando agricultural camp

Type of complementary food	Number of samples	Beta Carotene (µg/g)	Iron (mg/100g)	Zinc (mg/100g)	Protein (g/100g DW)	Crude fat (g/100g DW)	Ash (g/100g)	Moisture (%)	Crude fiber (g/100g DW)	Carbohydrate (g/100g)
orange maize porridge	5	45.61	5.34	33.14	4.51	1.5	0.58	80.94	1.54	10.94
Whole orange maize porridge	1	32.85	3.85	28.6	5.23	2.3	0.35	73.4	1.97	16.75
Orange maize and egg porridge	1	49.66	5.35	35.2	4.95	3.85	0.51	72.85	1.97	15.87
White maize nshima with beans	1	51.89	11.1	58.35	5.8	0.53	0.89	66.88	0.96	24.94
Orange & white maize porridge blend	1	14.65	5.55	29.15	5.38	0.97	0.25	78.14	2.1	13.16
White maize nshima and beans	1	11.2	5.1	35.8	5.58	2.44	1.97	66.5	1.21	22.3
White nshima and pumpkin vegetable	1	46.18	5	34.6	4.7	1.78	1.31	76.63	2.1	13.48
white maize porridge	4	46.56	6.05	40.69	5.4	1.85	0.43	79.15	2.32	10.86
Mean		**37.33**	**5.92**	**36.94**	**5.19**	**1.90**	**0.79**	**74.31**	**1.77**	**16.04**
Std. Error of Mean		**5.69**	**0.77**	**3.35**	**0.16**	**0.36**	**0.21**	**1.92**	**0.17**	**1.83**
Std. Deviation		**16.09**	**2.19**	**9.46**	**0.44**	**1.01**	**0.59**	**5.43**	**0.48**	**5.16**

Table 22: Nutrient composition of complementary foods for Chiwoko agricultural camp

Type of complementary food	Number of samples	Beta Carotene (µ1g/g)	Iron (mg/100g)	Zinc (mg/100 g)	Protein (g/100g DW)	Crude fat (g/100g DW)	Ash (g/100g)	Moisture (%)	Crude fiber (g/100g DW)	Carbs (g/100g)	Energy (Kcal)
Plain white maize porridge	1	39.6	4.6	45.5	2.35	0.66	0.2	77.25	0.77	18.77	90.42
Whole white maize porridge	1	28.41	7.3	36.6	5.63	1.4	0.25	71.07	0.99	20.66	117.76
white and orange maize blended porridge	5	44.85	5.75	46.35	3.29	1.22	0.49	79.7	1.29	14.01	80.2
Whole white maize porridge	1	30.82	4.55	40.4	5.53	1.2	1.99	72.23	0.56	18.49	106.88
Orange maize porridge	7	42.93	5.31	41.44	4.1	1.09	0.56	78.95	1.2	14.47	84.07
Mean		**37.32**	**5.50**	**42.06**	**4.18**	**1.11**	**0.70**	**75.84**	**0.96**	**17.28**	**95.87**
Std. Error of Mean		**3.28**	**0.50**	**1.78**	**0.64**	**0.12**	**0.33**	**1.77**	**0.13**	**1.30**	**7.12**
Std. Deviation		**7.33**	**1.12**	**3.97**	**1.42**	**0.28**	**0.74**	**3.95**	**0.30**	**2.90**	**15.93**

4.9. Range of nutrient composition of complementary foods

Table 23 shows a range of nutrients which the complementary foods contributed to the diets of the target children. The complementary foods had energy values ranging between 64.89 and 102.04 kcal, carbohydrates ranging between 10.46 and 17. 28 g /100g sample, crude fat ranging from 0.72 – 1.9 g/100g sample. Additionally, the crude protein ranged from 3.39 – 5.19 g /100g sample, iron ranged from 4.61 – 11.44 mg /100g sample and beta carotene ranged from 37.32 – 182.03 µg /g sample among others respectively.

Table 23: Range of nutrient composition for all complementary foods

Camp Complementary foods	Energy (Kcal)	Carbs (g/100g)	Crude Fat (g/100g)	Crude Protein (g/100g)	Iron (mg/100g)	Beta Carotene (µg/g)	Zinc(mg/100g)	Ash (g/100g)	Moisture (%)	Fibre (g/100g)
Chiparamba	64.89 (12.4)	10.46 (1.44)	0.72 (0.6)	4.16 (1.3)	6.63 (1.8)	41.23 (15.0)	34.20(3.13)	0.86 (1.16)	82.68 (2.31)	1.13 (0.13)
Kapita	79.89 (6.2)	12.94 (2.3)	1.62 (0.6)	3.39 (1.0)	11.44 (1.9)	47.28 (12.8)	33.97 (4.85)	0.45 (0.25)	80.89 (1.98)	0.71 (0.10)
Manjakazi	77.87 (7.8)	12.08 (2.7)	1.61 (1.1)	3.85 (0.8)	4.61 (1.1)	182.03 (167.1)	28.49 (11.08)	0.71 (0.22)	79.89 (2.30)	1.6 (0.42)
Chikando	102.04 (22.7)	16.04 (5.2)	1.9 (3,3)	5.19 (0.4)	5.92 (2.2)	37.33 (16.1)	36.94 (9.46)	0.79 (0.59)	74.31 (5.43)	1.77 (0.48)
Chiwoko	95.87 (15.9)	17.28 (2.9)	1.1 (0,3)	4.18 (1.4)	5.50 (1.1)	37.32 (7.3)	42.06 (3.97)	0.70 (0.74)	75.84 (3.95)	0.96 (0.30)
Range	**64.89 - 102.04**	**10.46 - 17.28**	**0.72 – 1.9**	**3.39 - 5.19**	**4.61 - 11.44**	**37.32 - 182.03**	**16.15 - 91.50**	**0.05 - 2.60**	**66.50 - 89.99**	**0.27 – 3.96**

CHAPTER FIVE: DISCUSSION

5.1 Food consumption patterns

More than half of the children that participated in the study were exclusively breastfed for 6 months respectively. This is in accordance with the WHO and national recommendations that children should be exclusively breastfed for six months and be given age-appropriate solid or semisolid complementary foods in addition to continued breastfeeding from 6 months of age to at least 24 months (WHO, 2013); CSO, 2018). The proportion of children that were exclusively breast fed was more than 50 percent though lower than the national figure of 70 percent (CSO, 2018).The exclusive breastfeeding rate achieved among study participants could be attributed to the awareness levels of the mothers as a result of their contact with health workers during antenatal visits (Jiang et al.,2012 ; Mituki,2017). There was a steady reduction of breastfeeding with age which is consistent with the findings of the Zambia demographic health survey and this is expected due to the introduction of complementary foods and reduced frequency of breastfeeding (CSO, 2016). More than half of the mothers introduced complementary foods at 6 months of age whilst others introduced complimentary foods after 6 months, that is at 7 or 8 months of age, respectively. Early introduction of complementary foods is common in Zambia (CSO, 2016) and other developing countries due to a number of factors which include maternal age and maternal level of education (Wang et al., 2019).

The Food and Agricultural Organization (FAO, 2013b) recommends consumption of foods from different food groups which relates to nutrient adequacy in terms of micro nutrients as well as to diet variety. In this study, vitamin A rich fruits and vegetables were the most consumed food groups by almost all age groups of children which could have been due to the availability of foods such as pumpkins, dark green vegetables among others which were in season at the time of data collection (end of March-April). This was followed by consumption of starchy staples (cereals, grains, roots and tubers) which was relatively high followed by legumes, respectively. These results are consistent with national statistics which show that the food groups which are mostly consumed by the majority of Zambian communities include starchy staples, vegetables and legumes respectively (CSO, 2016). Meanwhile, there was a low consumption of animal source products such as dairy products, flesh foods and eggs especially among children aged 6 - 8 months and 12 - 23 months, indicating nutrient inadequacy. This is consistent with food consumption studies conducted in Zambia that have shown low consumption of animal source foods among children (Marinda et al, 2018; NFNC 2015). Low consumption of livestock and low dietary diversity has been observed even among households owning livestock (Azzarri et al., 2015; Dumas et al., 2018) . There was a significant difference in the consumption of starchy staples and that of vitamin A rich fruits and vegetables among age groups especially among older children who consumed both food groups probably because they had already transitioned to family diets. There was no significant difference in consumption of food groups by sex.

5.3 Consumption of biofortified food crops

The study further shows low consumption of orange fleshed sweet potatoes and iron rich beans among households compared to that of orange maize respectively. This could be attributed to the low production of sweet potatoes and beans during that farming season as a result of limited availability of seed especially for iron rich beans. Additionally, sweet potatoes were not yet ready for harvest at the time of the visit except for households that planted early. However, Sakala et al., (2018) noted that consumption of orange fleshed sweet potatoes increases at the time of harvest both from own production and purchase. There was a similar trend in the consumption of biofortified food crops among children where a higher proportion consumed orange maize followed by orange fleshed sweet potato and lastly iron rich beans, respectively. There was a significant difference in the consumption of orange maize among age groups with children aged 12 – 23 months consuming more than those aged 6 - 8 months and 9 -11 months. Older children are likely to consume more of orange maize because at this stage they are introduced to other maize based products such as nshima, samp and munkoyo among others as opposed to young children who are mainly fed on porridge. Furthermore, there was no significant difference in the consumption of biofortified food crops between boys and girls who participated in the study.

More than half of the mothers in the study preferred orange maize for complementary feeding in relation to orange fleshed sweet potato and iron rich beans despite all the three crops containing pro vitamin A. This could be due to the fact that most complementary foods in Zambia and other developing countries are cereal based (Owino et al,. 2008) and orange maize has been well accepted in most communities it has been promoted (Tumuhimbise et al; 2013). Thus, maize meal was mainly prepared into porridge (with groundnuts or vegetables) or nshima accompanied by a relish. Orange fleshed sweet potatoes on the other hand were boiled in their fresh form or prepared with groundnuts whilst iron rich beans was cooked as a relish and fed together with nshima or added to porridge. When asked the reasons for preferring biofortified food crops for complementary feeding, mothers cited alleged health benefits of pro - vitamin A such as its ability to improve eye sight whilst the beans were preferred for enhancing growth in children. This relates to the findings of other studies that have shown that availability of information on health benefits of the crops is a determinant for acceptance and adoption (Sakala et al., 2018b; Talsma et al., 2017).

5.4 Diversity of diets

Dietary diversity is an index commonly used for assessing food availability and access at both individual and household level. In their studies, (Rah et al., 2010) suggest that dietary diversity is associated with overall quality and nutrient adequacy of the diet. Since no single food contains all required nutrients for optimal health, consumption of more food groups offers some reasonable diversity in terms of consumption of both macro and micro nutrients and improves the likelihood of meeting the nutrient requirements (Labadarios et al., 2011). The results of this study show that the diet of most children aged 6 - 23 months was not diverse which is an indicator of inadequate access of micronutrients from consumed foods. A lower proportion of the children achieved the minimum dietary diversity suggesting a greater likelihood of having inadequate micronutrient intake among the larger proportion that did not meet the minimum dietary diversity. There was a positive association between the dietary diversity score and the age of the children which is in consensus with studies by Gebremedhin et al (2017) which showed that a child's age is a predictor of dietary diversity. Furthermore, as children get older, their feeding patterns change as they adapt to different food textures and require more frequent meals and a variety of foods (Dangura & Gebremedhin, 2017). This is because from six months of age, breast milk alone is not sufficient to maintain the child's recommended daily allowances of nutritional requirements and enhanced growth. Similarly, national statistics show that the proportion of breastfed children given a variety of foods at least three times daily increased with age, from 12 percent among children aged 6 - 8 months to 14 percent among those aged 9 - 11 months and 16 percent among those aged 12 - 17 months except those aged 18 – 23 months whose proportion was 8 percent (CSO, 2018).

5.5 Mean nutrient intake of children aged 6 - 23 months

There was an adequate intake of vitamin A among older children than young children. There is a likelihood that the vitamin A was consumed in the form of provitamin A contributed by the biofortified food crops introduced in the communities as evidenced by reports from other countries (Hotz et al., 2012) or from foods such as dark green vegetables and pumpkins which were in season at the time of data collection since consumption of animal source foods was low. The adequate intake of vitamin A among older children also conforms with national trends which show that the proportion of children consuming vitamin A - rich foods increases with age, from 35 percent among those aged 6 - 8 months to 88 percent among those aged 18 - 23 months (CSO, 2014). Children aged 6 - 8 months are likely to consume less vitamin A rich foods as they are recently introduced to complementary foods unlike older children who may be used to consuming diverse foods which are part of the family diet.

Furthermore, all age groups consumed adequate amounts of vitamin B_1 and magnesium in relation to the recommended daily allowance. Other micronutrients adequately consumed included vitamin B_6, vitamin C, potassium, zinc and phosphorus especially among children aged 12 - 23 months whilst those aged 9 - 11 months also had adequate amounts of phosphorus, folic acid and vitamin B_6 even if the intake of potassium, phosphorus and magnesium was slightly high in relation to the RDA. The foods which contributed to the high intakes of selected micronutrients such as phosphorus, potassium, magnesium, folic acid and vitamin A included fresh nuts, orange maize meal nshima, pumpkin leaf relish, pumpkins, cooked green maize, orange fleshed sweet potatoes and mixed porridge flour (maize and oil) among others.

Iron is essential for cognitive development and low intakes can contribute to anemia. Iron requirements are greatest at age 6 - 23 months when growth is extremely rapid. Younger children aged 6 – 11 months had slightly lower intakes of iron which could be attributed to the low consumption of animal source foods such as flesh foods, dairy and eggs including low consumption of the biofortified iron rich beans. However, there was a higher intake of iron among older children (12 - 23 months) in relation to the Recommended Daily Allowance (RDA), respectively. Regarding iron intake, this data conforms to trends observed during the Zambian demographic health survey where consumption of iron - rich foods was highest among children aged 18 - 23 months (58 percent) (CSO, 2014). Furthermore, intake of calcium was sub optimal in all age groups probably due to the low intakes of animal source foods such as dairy products. This trend in the consumption of iron and calcium were similar to studies conducted in Mkushi by Caswell et al., (2018) and those by Lander et al., (2009) and Raymond et al., (2017) who also reported low intakes of iron and calcium among children aged 6 - 23 months, respectively.

Older children (12 – 23 months) had a higher estimated average energy intake which increased with age, consistent with studies by Kyttälä et al., (2010). A higher energy intake was also observed among girls aged 9 - 11 months. Furthermore, carbohydrate content contributed more than 50 percent of the total energy intake of children in all age groups. The high energy levels could be attributed to the high intake of carbohydrates as a result of the reliance on cereals such as maize as the main diet component (Raymond et al, 2017).

There was a higher intake of protein among girls aged 9 - 11 months but also among children aged 12 - 23 months respectively. However, despite observing high intakes, the protein quality could be low considering that a higher proportion was from maize and legumes since consumption of animal source foods was low. These results are consistent with other studies conducted in Tanzania and Mkushi district where similar trends were observed (Caswell et al., 2018; Raymond et al., 2017).

Despite observing higher intakes of some key nutrients such as energy, carbohydrates and protein, it is worth noting that the data obtained in nutri survey is based on estimates of the foods consumed and the database is based on standard recipes. Therefore, the high intakes observed could have been as a result of overestimations by the respondents due to recall bias.

5.6 Recipes commonly prepared for complementary feeding

The findings show that orange maize was commonly consumed and preferred for complementary feeding. This is consistent with the findings of Owino et al., (2011) and Raymond et al., (2017) which showed that most complementary foods in developing countries are maize based. Among the maize based products prepared during complementary feeding were soft porridge, thick porridge (nshima) and samp *(boiled dehulled maize)*. The soft porridge was either prepared in its plain form or enriched with protein sources such as legumes, eggs and locally available vegetables. The nshima and samp were also eaten with available protein sources (legumes, animal sources) and different locally available vegetables. Acceptability of orange maize meal was a challenge due to its carotene taste which some households did not appreciate. As a result, some households blended the orange maize with the white maize either at milling or cooking to tone down the carotene flavor in the orange maize meal and improve the texture of the nshima which has a tendency of hardening if nothing else is added. Nevertheless, most households accepted and adopted orange maize despite the changes in colour due to the alleged health benefits the crop is associated with (Amod et al., 2017; Meenakshi et al., 2010). Furthermore, there were limited options of utilizing the orange fleshed sweet potato and the iron rich beans due to their non - availability as a result of low production in terms of beans and seasonality in the case of the sweetpotato. Thus, the sweet potato was mainly boiled or prepared with groundnuts if available whilst the beans was prepared as relish and eaten with nshima or added to the porridge.

5.7 Nutrient composition of complementary foods

Carbohydrates contribute a lot towards the energy content of complementary foods. The carbohydrate content could be high but must be digestible enough to meet the energy requirements of infants and young children. The carbohydrate content of these complementary foods was low and may not be enough to contribute to the recommended values despite adhering to the recommended feeding frequencies. The Pan American Health Organization (2003) recommends carbohydrate quantities ranging between 137-187 g/day for children aged 6 - 8 months, 206 - 281g /day for children 9 - 11 months and 378 – 515 g/day for children aged 12 - 23 months, respectively. Furthermore, this low carbohydrate content of complementary foods may have contributed to the low energy values observed in this study. Consequently, these energy values are lower than those for maize and maize products indexed in the Zambian food composition tables of between 269 - 366 Kcal /100g. Among the reasons for the low carbohydrate and energy content of the complementary foods could be due to the non - standardization of the proportion of flour to water such that the children received porridge that was too diluted (Nnam & Baiyeri, 2008) coupled with the small amounts of sugar and fat added. The low proportion of flour used could be as a result of the low availability of maize at the time of data collection (end of March - April) when households did not have enough dry maize for consumption except for fresh maize which was not very utilised in infant foods. Unfortunately, prolonged consumption of thin and watery porridges exposes children to inadequate energy and nutrient intakes (Kulwa et al,.2015). According to Ng et al., (2012) and Pan American Health Organization (2003), the energy needs from complementary foods for infants with average breast milk intake in developing countries are approximately 200 kcal per day at 6 - 8 months of age, 300 kcal per day at 9 -11 months of age, and 550 kcal per day at 12 - 23 months of age respectively. However, the range of energy observed in this study would only meet the energy requirements of children aged 6 - 8 months and those aged 9 -11 months provided the recommended feeding frequency of 2 - 3 times for children aged 6- 8 months and 3 - 4 times per day for those 9 – 11 months is adhered to respectively.

The fat content of the complementary foods observed did not meet the codex standards of 20 percent (FAO, 2013) but were within the findings of Kulwa et al.,(2015) of between 0.30 - 2.12g /100g for maize based complementary foods they studied. This however has an implication on the bioavailability of beta carotene because fat enhances the absorption of beta carotene (Van Jaarsveld et al., 2005) and only a minimal amount of oil (about 3-5 g per meal) is required for optimal absorption of beta carotene (Amagloh & Coad, 2014). However, the fat content in these complementary foods may not meet this requirement. These low levels of fat could be attributed to the low utilization of legumes such as groundnuts and soya beans that have potential to contribute to the fat content of complementary foods. Additionally, at the time of data collection, most mothers reported that groundnuts were still fresh and they had limited knowledge on their utilization in complementary feeding. Thus, only older children able to chew were fed with groundnuts and mostly in the form of snacks.

In terms of protein content, the findings of (Ijarotimi & Keshinro, 2013) suggest that the protein content should range between 26.87 and 20.87 g/100g for various blended complementary foods. However, the protein values of the complementary foods in this study were low and did not meet the standards of FAO (2013) of between 6 and 15 percent protein . Except for mothers who used beans in their complementary foods, most samples collected were prepared from plain maize with sugar or oil. This is because during the period of data collection (March – April), most of the foods including groundnuts commonly used for complementary feeding were still fresh and not harvested. A lower percentage of mothers reported having used fresh groundnuts to feed their children during the period under review whilst the rest reported inadequate knowledge on utilization of fresh foods especially groundnuts in complementary feeding.

Beta carotene is essential in the growth and development of infants and young children thus promotion of crops high in beta carotene is key in the fight against vitamin A deficiency (Laryea et al, 2018).The proximate analysis of cooked complementary foods showed a retention of beta carotene across all camps. These results show that despite cooking the porridges at different temperatures, beta carotene was preserved. This is in accordance with the studies by Díaz-gómez et al (2017) which revealed that the carotenoid levels in porridges cooked at 75 ^{0}C were not only preserved but also enhanced making the initial content to double up to 88 ug/g dry weight. Similarly, Mugode et al., (2014) also showed that the genotypes they analysed in their studies had 100% retention of beta carotene when cooked into thick porridge (nshima) and thin porridge but showed a lower retention when cooked into samp (53 - 98 percent). It is worth noting that beta carotene is sensitive to light and heat thus possibilities of losses during storage are high depending on the conditions the grain is subjected to (Mugode et al., 2014).

Furthermore, iron deficiency is common among infants and young children in most developing countries therefore the need to have diets sufficient in iron is critical. Iron is required for mental and physical wellbeing of the children but also for the synthesis of haemoglobin (Laryea et al., 2018). The iron content of the complementary foods observed in this study would be adequate to meet the WHO recommended daily allowance of 9.3 mg per day for children aged 6 - 8 months and 9 -11 months and 5.8 mg per day for those aged 12 - 23 months (Dewey & Brown, 2003) especially if the recommended feeding frequency is adhered to (Pan American Health Organization, 2003). Furthermore, these iron levels would be sufficient to meet the codex standard for complementary foods of 5.8 mg per day at 10% bioavailability (FAO, 2013a).This means a 100g of the complementary food would be enough to meet the daily iron requirements of the infants aged 6 - 23 months.

Following the daily zinc requirements of 4.1 mg/day, a 100g of these complementary foods would be adequate to meet the RDA for all age groups (Dewey & Brown, 2003).

The presence of ash indicates the presence of minerals in a sample (Laryea et al., 2018). However, the bioavailability of these minerals is usually low due to the presence of antinutritional factors such as phytate, trypsin inhibitors and polyphenols. One of the most important anti nutrient is phytic acid which is common in most cereals and has a strong ability to complex multi-charged metal ions, especially Zn, Ca and Fe making them unavailable for human body utilization (Nadeem et al., 2010) (Gilani et al., 2005) .The ash content of these samples was in conformity with the findings of Okafor & Anike (2008) and Anigo & Ameh (2010) who reported values of less than 2.60g /100g sample in their work on complementary foods. Additionally, FAO (2013a) suggests that the ash content of a complementary food should be less than 3 percent, a standard which these complementary foods met .

The crude fibre content of these complementary foods were not very different from the findings of Fikiru et al, (2017) who reported values of not more than 4.1 g /100g sample. Additionally., the recommended daily allowance of crude fibre is less than 5 percent thus the complementary foods in this study met this requirement (FAO, 2013a).

Furthermore, the moisture content of these samples was above 60 percent though some samples were within the range reported by Kulwa et al., (2015) in their studies on complementary foods. They suggest that the high moisture content could be as a result of the high flour to water ratio which ultimately increases the moisture and reduces the nutrient content. Additionally, the high moisture levels in this study could also have been accumulated during storage at - 20 ^{0}C prior to analysis. Especially that the initial moisture values were not determined prior to storage. This was because the samples were collected from Chipata which is over 500 km from the laboratory and they had to be refrigerated within the shortest possible time to maintain sample integrity.

It is clear that despite observing higher estimated intakes of selected nutrients as analysed by nutri survey, the actual nutrient composition of the complementary foods analysed in the laboratory was low. The complementary foods were only adequate in beta carotene, protein, iron, ash, zinc and crude fibre. Depending on the frequency and quantities consumed, the actual nutrients consumed were less and not adequate to meet the recommendations by FAO, WHO or codex allimentarious.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

The diets of the target children were not diverse and only 37.70 percent of the children achieved the minimum dietary diversity. Age influenced dietary diversity with older children (12 - 23 months) consuming more of starchy grains, vitamin A rich foods and vegetables. There was low consumption of animal food sources especially among children aged 6 – 8 months and 12 - 23 months. Orange maize was most consumed by older children and mostly preferred for complementary feeding by mothers compared to the biofortified beans and sweet potatoes. Thus most complementary food recipes were orange maize based respectively.

Furthermore, estimates of food consumed in the previous 24 hours showed that all children had adequate intakes of vitamin B1 and magnesium whilst intake of calcium, B_{12} was low across all age groups. Carbohydrate intake was above 50% in all age groups. Children aged 12 - 23 months had higher intakes of energy, protein, vitamin A, vitamin E, vitamin B6, vitamin C, iron, phosphorus, potassium and Zinc. Additionally, higher intakes of phosphorus, folic acid, and vitamin B6 were also observed in children aged 9 – 11 months. The higher intakes recorded could have been due to recall bias which led to overestimations by the respondents.

Although the intake of some key nutrients was high, laboratory analysis of the complementary foods sampled showed low nutrient composition which is an indication of poor quality diets. The complementary foods given to all age groups were low in key nutrients such as proteins, carbohydrates and energy but adequate in iron, zinc, fibre and ash in relation to the codex and WHO standards.

Based on these findings, it is clear that the biofortified food crops are part of the diets of the target communities going by the number of complementary food recipes adopted especially in the case of orange maize. However, there is need to educate mothers on how the biofortified foods can be combined with other foods to diversify diets for children aged 6 – 23 months and enhance their potential of addressing micronutrient deficiencies. This includes enriching complementary foods with different food groups through use of various food combinations in order to increase access to different macro and micro nutrients. Consumption of animal food sources especially among children aged 6 - 8 months and 12 – 23 months should be promoted. Additionally, government and other relevant stakeholders should promote the utilization of locally produced foods and use of food processing technologies that enhance the bioavailability of nutrients in order to enrich the complementary foods. There is also need to increase access to biofortified seed at community level through establishment of seed multiplication sites and trainings in production and management of biofortified food crops. Furthermore, there is need to implement community based nutrition education programs on optimal child feeding practises including strengthening of education on the benefits of biofortified food crops in addressing micronutrient deficiencies. Further education is required on the production and management of other biofortified food crops than maize in order to increase their availability and access for better incorporation in complementary feeding.

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APPENDICES

Appendix A: Common recipes from biofortified food crops

1. **Orange maize Nshima**

Ingredients

2 cups orange maize meal

4 cups water

Method

Heat the water until almost boiling

Add ¼ cup of the maize meal to make a soft paste and let it simmer for 15 minutes

Add the remaining meal to make a thick paste and let it simmer for 2 minutes

Serve with desired relish

2. **Orange maize samp**

2 cups orange maize samp

Enough water

½ teaspoon salt

4 tablespoons sugar

Method

Put the samp in the pot and add salt and water

Cook the samp until soft

Add sugar to desired taste and serve

3. **Orange maize and groundnut porridge**

Ingredients

1 cup orange maize meal

¼ cup pounded roasted or unroasted groundnuts

2 - 4 teaspoons shredded/pounded green leafy vegetables

4 cups water

Pinch of salt

Sugar to taste

Method

1. Mix orange maize meal with pounded groundnuts
2. Add water and mix into a smooth paste
3. Cook the maize meal/pounded groundnuts mixture and stir constantly
4. After reaching boiling point, cook for 15 minutes
5. Add the pounded vegetables
6. Add salt and sugar to taste

4. Fresh orange maize porridge

Ingredients

3 cobs of orange maize

Peanut butter

Salt to taste

Sugar (optional)

Method

1. Grate or blend orange maize
2. Add water and salt
3. Cook for 15 minutes

4 Add sugar (optional)

5. Plain orange maize porridge

Ingredients

1 cup orange maize meal

3 cups water

Pinch of salt

Sugar (optional)

Method

Add the maize meal to the water and make a smooth paste

Cook the mixture and stir constantly

After reaching boiling point, cook for 15 minutes

Add salt and sugar to taste

6. Orange maize porridge with oil

Ingredients

1 cup orange maize meal

1 tbsp. oil

3 cups water

Pinch of salt

Sugar (optional)

Method

1. Add the maize meal to the water and make a smooth paste
2. Cook the mixture and stir constantly
3. After reaching boiling point, add oil and cook for 15 minutes
4. Add salt and sugar to taste

7. Orange maize and fresh groundnut porridge

Ingredients

2 cups orange maize meal (Alternatively use 2 cobs of fresh orange maize)

¼ cup pounded fresh groundnuts (pounded, dried and pounded again)

1 Teaspoon pounded green leafy vegetables

2 cups water

Pinch of salt

Sugar to taste

Method

1. Mix the maize meal and the groundnuts and make a paste
2. Bring to boil for 15 minutes whilst stirring
3. Add the pounded vegetable
4. Add salt and sugar to taste and serve

8. Orange maize and dry groundnut porridge

2 cups orange maize meal

¼ cup pounded dry groundnuts

3 teaspoons pounded green leafy vegetables

4 cups water

Pinch of salt

Sugar to taste

Method

1. Mix the maize meal and the groundnuts and make a paste
2. Bring to boil for 15 minutes whilst stirring
3. Add the pounded vegetable
4. Add salt and sugar to taste and serve

9. Orange Maize Vegetable Porridge

Ingredients

1 cup orange maize meal

1/4 cup soy flour (or any other legume)

2 tsp. pounded/blended or dried vegetables

4 cups water or soymilk or dairy milk

2 pinches salt

Sugar to taste

Method

1. Mix maize flour with soybean flour
2. Add water or milk into a smooth paste
3. Cook the maize-soybean flour mixture, stirring constantly for 10 minutes
4. Pound and sieve the dried vegetable or pound any fresh dark green vegetable
5. Add to the cooking porridge and simmer for 10 minutes
6. Add salt and sugar to taste

10. Fresh orange maize cobs

Ingredients

2 fresh and tender orange maize cobs

Method

1. Roast on fire until done
2. Serve whilst warm

11. Orange fleshed sweet potatoes with groundnuts

Ingredients

1 kg orange fleshed sweet potatoes

¾ cup pounded roasted groundnuts

Salt to taste

Method

1. Peel and wash the potatoes and cut into cubes
2. Boil the potatoes until almost done
3. Add the roasted pounded groundnuts or peanut butter
4. Add salt to taste and boil for 8-10 minutes
5. Serve whilst warm

12. Boiled orange fleshed sweet potatoes (with peels)

Ingredients

1 kg orange fleshed sweet potatoes

Enough water

Salt to taste (optional)

Method

1. Thoroughly wash the sweet potatoes and cut into cubes
2. Add water and boil until cooked
3. Add salt if preferred
4. Serve whilst warm

13. Boiled orange fleshed sweet potatoes without peels

Ingredients

1 kg orange fleshed sweet potatoes

Enough water

Salt to taste (optional)

Method

1. Thoroughly wash the sweet potatoes and cut into cubes
2. Boil until cooked
3. Add salt if preferred
4. Serve whilst warm