FACULTY OF
BIOSCIENCE ENGINEERING

A DIETARY ANALYSIS OF WOMEN IN THE PASTORAL AND AGRO-PASTORAL LIVELIHOOD ZONES IN TURKANA COUNTY, KENYA

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ABSTRACT

Across the globe, there exists a wide variation of food consumption patterns which are not only influenced by geographical location but also social, economic and cultural factors. More knowledge is still needed about the dietary patterns of different population groups, in order to plan and implement tailored food-based recommendations (FBRs) based on local contexts. In this master dissertation, a dietary analysis is performed and the potential to employ food-based approaches using local foods to improve nutritional adequacy is explored.

Socio-demographic data was obtained using structured questionnaires and dietary data using quantitative 24-hour recalls from 231 women aged 15-49 years living in pastoral and agro-pastoral zones in Turkana, Kenya. The data was analyzed in SPSSS version 24 (IBM Corp, 2016) while making comparisons between the pastoral and agro-pastoral livelihood zones. Diet modelling and formulation of FBRs based on local foods captured from the 24-hour recalls was done using Optifood, a linear programming tool.

The socio-demographic characteristics and dietary patterns of women aged 15-49 years living in pastoral and agro-pastoral zones were comparable. Dietary diversity was low where only four out of ten food groups (fats and oils, added sugars, grain and grain products, legumes and pulses) were consumed by more than 50% of women in both zones. Energy and nutrient intakes of women in both zones were below the recommended nutrient intakes (RNIs). In an attempt to optimize nutrient intakes, FBRs were formulated in Optifood, based on local food and food (sub) group constraints. However, calcium, iron and fat were problem nutrients whose RNIs could not be met by the modelled diets. Hence, the FBRs need to be combined with other interventions such as nutrient supplementation to attain nutritional adequacy.

Key words: *Food-based recommendations, Optifood, food pattern diet, non-food pattern diet, recommended nutrient intake*

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ABBREVIATIONS

ASALS- Arid and semi-arid lands
BMI- Body mass index
FAO- Food and Agriculture Organization
FCS- Food consumption score
FEG- The Food Economy Group
FBRs- Food-based recommendations
FP- Food pattern
GAM- Global acute malnutrition
GDP- Gross Domestic Product
HEA- Household economic approach
MAD- Minimum acceptable diet
MDD- Minimum dietary diversity
MDDS-W- Minimum dietary diversity score- women
NFP- Non-food pattern
NUS- Neglected and underutilized species
RNI- Recommended nutrient intake
SAM- Severe acute malnutrition
SD- Standard deviation
SSA- Sub-Saharan Africa
UNICEF- United Nations Children's Fund
WHO- World Health Organization

1.0 INTRODUCTION

1.1 Background

The world population is on the rise and is expected to reach 9 billion by 2050 (Godfray et al., 2010). As the population grows, issues of food security in particular the efficient use of locally available foods is becoming indispensable (Darmon et al., 2014). Every country in the world is affected by one or more forms of malnutrition; over 800 million people are chronically hungry while two billion people have micronutrient deficiencies (Godfray et al., 2010). In Kenya for instance, the national per capita energy supply per day is less than the recommended 2,250 kcal/day (M'Kaibi, Steyn, Ochola, & Du Plessis, 2015) while the basic diet is insufficient in diversity and quality (Agricultural Sector Coordination Unit, 2011).

Approximately 83% of Kenya's land area consists of arid and semi-arid lands (ASALs) in which about 25% of the population lives. About 60% of Kenya's livestock is found in these ASALs but food production is very limited due to low rainfall and high temperatures. Besides reduced land productivity, ASALs have challenges related to poor infrastructure, lack of access to technology, remoteness and isolation of markets (Shisanya, Recha, & Anyamba, 2011). Consequently, households in ASALs are the most affected by acute and chronic food insecurity with the majority relying on food aid especially during the dry season (Speca, 2013).

Turkana County, the study area, is situated in the ASALs in the North-West of Kenya. Temperatures in Turkana can be as high as 40°C during the dry season with average rainfall ranging between 120-500mmper annum. The main livelihood activity is nomadic pastoralism. However, the pastoralists are faced with challenges of frequent droughts and livestock disease outbreaks (The Food Economy Group, 2016). The livestock which include cattle, camels, goats, sheep and donkeys contribute to dietary supply in form of milk, meat and blood. Sales from livestock also provide cash income to buy other food items such as cereals (Schilling, Opiyo, & Scheffran, 2012).

Women of reproductive age have higher nutritional needs due to increased physiological demands arising from pregnancy and lactation. In poor resource settings, chronic poverty has a negative influence on the quality of diet; coupled with the environmental and economic conditions, which induce an extra burden on the nutritional status of women (Lartey, 2008). Their nutritional requirements are further increased due to heavy workloads as well as short reproductive cycles which cause them to go through pregnancies without adequately replenishing body nutrient stores (Omolo, 2010).

Among non-pregnant women aged 15-49 years in Kenya, 13% are undernourished (BMI<18kg/m^2), 14% suffer from iron deficiency anemia while 31% suffer from folate deficiency. Micronutrient deficiencies are common, with iron, vitamins A and B_{12}, iodine, folate and zinc being of public health importance. Turkana County has a Global Acute Malnutrition (GAM) rate of 23%. Among women of reproductive age, 8% are undernourished with mid-upper arm circumference (MUAC) of $\leq$ 21.0 cm (Turkana County Department of Health, 2016). The consequences of poor maternal nutrition are evident in Turkana County where 8% of infants are born with low birth weight (less than 2,500 grams) (Kenya National Bureau of Statistics, Population Studies and Research Institute, & UNICEF, 2016).

In an effort to address micronutrient deficiencies in Kenya, interventions by the Ministry of Health and other implementers include nutrient supplementation (vitamin A, iron and folate), fortification (salt, maize meal, wheat flour, cooking oil) and promotion of dietary diversification (Ministry of Health, 2011). In Turkana, ongoing nutrition interventions targeting women of reproductive age include iron and folate supplementation during pregnancy and management of acute malnutrition (Turkana County Department of Health, 2016). However, women of reproductive age are among the population groups most vulnerable to undernutrition and micronutrient deficiencies. Hence, more strategies are needed to improve their health and nutrition beyond the routine prenatal care.

Although food consumption surveys have been conducted in a number of population groups in the past, they mostly involve detecting inadequate nutrient intakes but less often do they go ahead to determine whether the inadequacy is due to sub-optimal use of locally available foods or due to constraints related to availability of nutrient-dense foods (Darmon, Ferguson, & Briend, 2002). Local food can be defined in geographical terms in relation to the distance between food producers and consumers combined with other social and supply chain attributes. Hence local food can be described as food which is consumed in close proximity to where it is produced or gathered (Martinez et al., 2010).

To complement nutrient supplementation and fortification efforts, food-based approaches can contribute towards achieving macro and micronutrient adequacy (Blasbalg, Wispelwey, & Deckelbaum, 2011). Food-based dietary guidelines are important in enhancing sustainability of food systems and promoting healthy eating. However, most low income countries lack these food-based dietary guidelines whether at regional or national level(Bioversity International, 2017). Several tools such as Cost of Diet, NutriSurvey, *Pro*PAN and Optifood have been developed over time in an effort to test and formulate food-based recommendations (FBRs). Previous research has shown that FBRs have a higher likelihood of being adopted compared to general guidelines because they are formulated in the context of local diets; whereas general guidelines may sometimes differ from local diets (Talsma et al., 2017).

Optifood is a tool based on linear programming which is used to develop FBRs while using combinations of local foods that match or come as close as possible to meeting the nutrient needs of specific target groups (Crampton, 2011; Ferguson et al., 2006). In terms of its applicability, Optifood has been useful in designing food based interventions for women and children, providing guidance in food value chain interventions as well as regional micronutrient strategy in South East Asia (Darmon et al., 2014).

1.2 Justification

The complexity of nutrition challenges arise because the nutrients required for health are not evenly distributed in the foods people consume (Darmon et al., 2014). Studies indicate that understanding food consumption patterns of different populations not only provides crucial information on types and quantities of foods contributing to energy and nutrients; but also forms the basis for planning food-based recommendations (Auestad et al. 2015). Previous research has shown increasing interest to adopt nutrition interventions that focus on the contribution of local foods to diet quality (Boedecker, Odhiambo, & Termote, 2016).

Due to the existence of a wide variety of foods and highly varied food consumption patterns in different settings, there is a research gap in relation to which combination of foods provides optimum nutrition for any given group in a population (Darmon & Drewnowski, 2015). This master dissertation attempts to address this research gap through a dietary analysis of a specific target group and formulates food-based recommendations in the context of local dietary patterns and constraints. Hence, the findings herein complement ongoing nutrition interventions targeting women of reproductive age in Turkana.

The data analysis provides a detailed explanation of the socio-demographic characteristics and dietary patterns of women aged 15-49 years living pastoral and agro-pastoral zones in Turkana. In order to conduct the dietary analysis, the hypothesis that there is no difference in dietary patterns between women aged 15-49 years living in pastoral and agro-pastoral livelihood zones in Turkana is investigated. The results of the dietary analysis form the basis for diet modelling using the Optifood tool. Consequently, the modelled diets facilitate the formulation of food-based recommendations for women aged 15-49 years living in pastoral and agro-pastoral zones in Turkana.

1.3 Objectives

1.3.1 General objective

To conduct a dietary analysis of women aged 15-49 years living in pastoral and agro-pastoral livelihood zones in Turkana County, Kenya.

1.3.2 Specific objectives

1. To identify the contribution of different foods and food groups to nutrient intake of women aged 15-49 years in Turkana County.
2. To compare dietary intake of women aged 15-49 years living in pastoral and agro-pastoral livelihood zones in Turkana County.
3. To investigate the potential to achieve diet quality using locally available foods and hence formulate food-based recommendations for women aged 15-49 years in Turkana County.

1.4. Research questions

1. What foods and food groups contribute to nutrient intake of women aged 15-49 years living in Turkana?
2. Do dietary patterns of women aged 15-49 years differ between pastoral and agro-pastoral livelihood zones in Turkana?
3. Is there potential to optimize the diet of women aged 15-49 years living in Turkana using local foods?

2.0 LITERATURE REVIEW

2.1 Nutrition situation

2.1.1 Food security

Today nearly 815 million suffer from undernutrition and consume less than the minimum energy requirements for an active lifestyle. Globally, over two billion people suffer from micronutrient deficiencies; particularly one-third of women of reproductive age suffer from anemia (FAO, IFAD, UNICEF, WFP, & WHO, 2017). Nutritional deficiencies affect social and economic development through reduced productivity, impaired learning ability, increased susceptibility to infections, and premature deaths thus contributing to the large health burden (Lim et al., 2012). Nutritional deficiencies are not only caused by inadequate food intake in terms of quantity but also poor dietary quality and diversity (Sibhatu, Krishna, & Qaim, 2015).

Kenya is considered a low-income-food deficit country with an average daily caloric availability below the recommended 2250 kilocalories (M'Kaibi et al., 2015). More than ten million people in Kenya experience chronic food insecurity and poor nutrition while two to four million people rely on food aid. This is attributable to high poverty levels, insufficient diversification of food production and consumption (predominantly maize staple), and limited financial access to both plant and animal protein. Micronutrient deficiencies are common and affect even those who are able to meet their energy requirements with high prevalence among women *i.e.* iron deficiency(60%) and vitamin A deficiency (39%) (Agricultural Sector Coordination Unit, 2011).

While households continue to face high food prices, the main staple, maize, is in short supply and most households have limited choices for other food stuffs (Kenya Agricultural Research Institute, 2012). These factors are not only transforming food consumption, production and markets, but they also make poor people further limit their consumption. In doing so, they shift to less diversified diets and reduced meal frequency which negatively affects their health and nutrition both in the short and long term (Agricultural Sector Coordination Unit, 2011).

Previous findings show that Turkana households are more vulnerable to severity and prevalence of household hunger where 88%have moderate (2-3) and 6% have severe (4-6) hunger. Only 6% of the households have little or no hunger (0-1). In addition, up to one third of the population report having participated in a food program (Vossenaar et al., 2016). In addition, 89% of Turkana households are severely food insecure and have to adopt coping strategies including skipping meals, limiting portions, and eating less preferred foods (Turkana County Department of Health, 2016). Less than 20% of households consume a diversified diet while 80% of women consume less than five out of ten food groups in relation to the minimum dietary diversity score-women (MDDS-W) (Save the Children, 2017a). The MDDS-W is a dichotomous indicator of whether women 15–49 years of age have consumed at least five out of ten defined food groups (Caswell, Talegawkar, Siamusantu, West, & Palmer, 2018).

According to the Turkana Smart Nutrition Survey (2016), dietary diversity in Turkana is poor with 30% of households showing poor to borderline Household Food consumption score (FCS). The Household FCS is a proxy for food security representing dietary diversity and nutrient intake calculated over a 7-day reference period (FAO, 2011). Most households consume a cereal based diet (87%) with less than 20% consuming vegetables, fruits, eggs, fish and organ meat. To further shed light on inadequacy of dietary diversity, the survey showed that dark green vegetables, eggs, fish and vitamin A rich vegetables and tubers are consumed for less than 2 days per week. Most of the food consumed is from purchases *i.e.* starches (77%), legumes (83%), vegetables and fruits (67%) and milk (61%) (Turkana County Department of Health, 2016).

2.1.2 Maternal nutrition

Women of reproductive age are often nutritionally vulnerable because of the physiological demands of pregnancy and lactation. Insufficient nutrient intakes before and during pregnancy and lactation can affect both women and their infants (Mbogori & Murimi, 2017). Yet particularly in developing countries, diet quality for women of reproductive age is very poor, with gaps between intakes and requirements for a number of micronutrients (Arimond et al., 2010).

In Kenya, the first strategic objective of the National Nutrition Action Plan is to improve the nutritional status of women of reproductive age (15-49 years). Improving the nutritional status of women of reproductive age while delaying pregnancy could reduce risk factors that affect the health and survival chances of both mother and child. As highlighted in the Kenya Nutrition Action Plan, the main causes of malnutrition among women of reproductive age include sub-optimal feeding practices especially during pregnancy, heavy workload, and low micronutrient intake during pregnancy (Ministry of Public Health and Sanitation, 2012).

According to the Kenya Demographic and Health Survey, the mean BMI among women 15-49 years is 23.7 kg/m^2. However, 9% of women of reproductive age are undernourished (BMI <18.5 kg/m^2) where 6% are moderately undernourished (17.0-18.4 kg/m^2) while 3% are severely undernourished (<17 kg/m^2). Younger and rural women are more likely to be undernourished (Kenya National Bureau of Statistics, 2014).

In Turkana county, women have to keep pace with seasonal variations, financial constraints and cultural limitations as they make decisions on what foods are suitable for themselves and their households on a daily basis (Omolo, 2010). Economic and decision making empowerment among women in pastoralist communities is limited making them vulnerable (Mckune et al., 2015). In addition, they may be oblivious of their own increased energy and nutrient needs arising from menstruation, pregnancy, lactation and heavy workloads (Save the Children, 2017a).

The Turkana Smart Nutrition Survey used Minimum Dietary Diversity Score- Women (MDD-W) as a proxy indicator for micronutrient adequacy. According to the survey, only 20% of women 15-49 years in Turkana consumed at least five food items from the 10 food groups in the MDD-W. This reflects existence of micronutrient deficiencies among the women and consequently poor birth outcomes (Turkana County Department of Health, 2016).

2.2 Livelihood zones

A livelihood zone is defined in geographical terms as an area within which people share similar patterns with reference to access to food and income. People in the same livelihood zone basically grow crops, rear the same types of livestock and have similar access to markets (The Food Economy Group, 2018).

Turkana County is located in the arid and semi-arid lands (ASALs) and has a poverty index of 94% contributing to 3% on the national poverty index (The Food Economy Group, 2016). There are four livelihood zones in Turkana County *i.e.* 60% pastoral, 20% agro pastoral, 12% fisher folks and 8% urban/peri-urban which includes both formal and informal employment.

Most of the households (83%) have access to income, the main source being from trade (37%), livestock sales (16%) and waged labor (12%) (Turkana County Department of Health, 2016).

Findings according to the Food Economy Group (2016) showed that in the pastoral and agro pastoral zones, staple foods, mainly maize dominate in relation to food traded. Maize is important not only in terms of the amount of money spent on it but also in terms of kilocalorie contributions. Beans, oil, sugar and meat are also commonly traded. Due food access challenges, households also rely on safety net cash transfers as well as relief food (The Food Economy Group, 2016).

2.2.1 Pastoral zone

Households in the pastoral zone are mainly pastoralists considering the hot, dry and arid condition. However, most households engage in other income generating activities such as casual labour, sale of charcoal, firewood and handicrafts such as baskets and brooms (Opiyo, Wasonga, Nyangito, & Schilling, 2015). In the pastoral zone, households obtain most of their food from a combination of market purchases, own livestock production (milk/meat), wild foods and food aid (including school feeding). Wild foods and safety nets are also important in bridging food security challenges for these households. Individuals in this zone mostly consume one to two meals a day (The Food Economy Group, 2016).

2.2.2 Agro-pastoral zone

In the agro-pastoral zone which is located along the Turkwel River, most households practice crop production using irrigation to cater for food supply. They grow crops such as sorghum, maize, green grams, cowpeas (leaves serve as vegetables), kale, watermelon, pumpkins, bananas and maize. They also rear livestock for milk, meat and blood (Opiyo et al., 2015). They also engage in other income generating activities such as sale of charcoal and building materials. Individuals in this zone on average consume two to three meals a day (The Food Economy Group, 2016; Turkana County Department of Health, 2016).

2.3 Seasons

The seasonal calendar for Turkana County consists of two seasons namely the wet and dry seasons. The wet season comprises of long rains from March to May and short rains from October to December. The period in between the two rainy seasons (January and February) is characterized by a dry spell whose duration is mostly unpredictable. The dry season runs from June to September and is generally the harvest period (Ember et al., 2012). The seasonal calendar not only affects the economic activities but also sources of food, availability of pasture and migration patterns of pastoral households (Save the Children, 2013; The Food Economy Group, 2016).

The predictability of seasons in Turkana has reduced over the years. According to a study on drought adaptation and coping strategies among Turkana pastoralists (2015), climate change was attributed to unpredictable seasons with increased episodes of droughts. This was found to not only negatively impact on pastoral activities but also associated with increased number of households who experienced hunger (Opiyo et al., 2015). Another study identified drought as one of the most frequent hazards in Turkana, compared to other hazards like conflicts, disease outbreaks and flooding. The study showed that with time, the frequency, duration and severity of droughts had increased over the past decade (Opiyo, Wasonga, & Nyangito, 2014).

2.4 Agro-biodiversity

Agro-biodiversity refers to the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. Food biodiversity includes the diversity of plants, animals and other organisms used for food. A diverse diet is important in ensuring the increased chance of consuming all essential nutrients in optimal quantities as required for our health (Bioversity International, 2017). Recent research shows a positive link between species richness (number of species consumed by an individual) and diet quality in both the rainy and dry seasons in rural areas of low and middle-income countries (Lachat et al., 2018).

Although the mechanisms by which households access food are complex and context specific, a combination of different foods whether cultivated, purchased or gathered from the wild is key in ensuring optimal nutrition (Sibhatu & Qaim, 2017). Therefore, it is necessary to have food-based approaches which provide long- term and sustainable interventions in nutrition (Nair, Augustine, & Konapur, 2016). Food-based approaches focus on food as the vehicle for nutrient supplies and make use of national or regional dietary guidelines to tackle malnutrition. Examples of such dietary guidelines include the Mediterranean Diet Pyramid, the Nordic and Brazilian dietary guidelines (Bioversity International, 2017).

Research has shown a link between wild food biodiversity and their role in contributing to diversified diets and good health (Koppmair, Kassie, & Qaim, 2016). Wild foods can be defined as plants, animals and insects that are not cultivated or reared in captivity (Bioversity International, 2017). The wild foods which are gathered or hunted for food comprise of neglected and underutilized species (NUS) such as roots and tubers, leafy vegetables, fruits, insects, amphibians, reptiles and birds. Wild foods exhibit resilience to harsh environments and therefore enable households to cope during famine. Previous studies show that the consumption of wild food increases when food stores are depleted during periods of famine (Daudet, 2012).

Even though dietary guidelines need to be aligned to local biodiversity and food habits, majority of low and middle-income countries lack food-based dietary guidelines (Darmon & Drewnowski, 2015). There is evidence of local biodiversity playing a role in improving the sustainability of food systems while also promoting healthy eating habits (Bioversity International, 2017). A study in Baringo District, Kenya, demonstrated that wild foods have the potential to provide adequate nutrients while at the same time minimizing the cost of a nutritious diet (Termote, Raneri, Deptford, & Cogill, 2014).

According to the Food Economy Group, wild foods contribute to 5-10% of the annual food needs of poor households in Turkana, in particular during drought. However, the consumption of wild foods in the area is not properly quantified. The most commonly consumed wild foods are *Hyphaene compressa* (eng'ol), *Ziziphus mauritania* (*ngakalalio*), *Salvadora persica* (*esekhon*), *Doberaglabra* (*edapal*), *Bosciaconacea* (*edung*), *Cordia sinensis* (*edome*), and *Balanite sorbiculans* (*ebei*); although their availability is also seasonal (The Food Economy Group, 2016).

2.5 Food-based approaches

In the modern world, nutrition challenges are dynamic and complex with undernutrition coexisting with over-nutrition (WHO, 2017). As a result, many nutrition interventions exist, particularly in the developing countries which aim to address macro-and micronutrient deficiencies. These interventions are categorized into two broad groups namely; nutrition specific and nutrition sensitive interventions (Lawrence, Wingrove, Naude, & Durao, 2016).

Nutrition specific interventions target the immediate causes of undernutrition such as inadequate dietary intake. These interventions focus on directly increasing the intake of specific nutrients for a given group or individual. They include nutrient supplementation *e.g.* iron and folate for pregnant women as well as food fortification *e.g.* iodine fortification of salt (UNICEF, 2014). On the other hand, nutrition sensitive interventions usually address the underlying and basic causes of malnutrition. They require multi-sectoral approaches where nutrition is integrated with in other sectors; for instance agriculture and education (Lawrence et al., 2016).

Although in the past nutrition specific interventions mainly focused on nutrient supplementation, there is increasing evidence on the role food-based approaches to achieve overall diet quality (Nair et al., 2016). However, wide variations exist in relation to types of foods as well as dietary patterns of people in different settings. In addition, the foods we eat do not usually have an even distribution of the nutrients we require for health (Darmon et al., 2014). Consequently, there is need to explore tools that can help optimize diets while ensuring minimal deviations from what is locally acceptable. Diet modelling is one of the tools being used to develop FBRs in both high-income and low-income countries (Untoro et al., 2017).

Studies have shown the importance of increased dietary diversity in addressing micronutrient deficiencies (Nair et al., 2016). Besides supplying health promoting components, food also provides a matrix which enhances the bioavailability and absorption of nutrients. More so, the risk of nutrient toxicity is minimal in food matrices compared to nutrient supplements (Blasbalg et al., 2011). With food-based approaches, adequacy of several macro- and micronutrients can be achieved simultaneously while also allowing for variation of portion sizes according to specific individual needs (Fahmida, Santika, Kolopaking, & Ferguson, 2014).

Food-based approaches help us to investigate what possible food combinations can provide optimal nutrition for an individual or population group (Darmon et al., 2014). This can be done through diet modelling based on linear programming. Diet modelling allows us to formulate optimal food patterns under a variety of constraints (nutritional, behavioral, and economic). This can help to identify foods and food combinations that are affordable, nutrient rich, and culturally acceptable to a population (Darmon & Drewnowski, 2015).

Diet modelling puts into consideration nutrient recommendations as well as dietary habits of the target group. Hence FBRs are formulated while ensuring minimal deviations from the local diet (Blasbalg et al., 2011). Previous studies have suggested that FBRs are more likely to be adopted compared to general guidelines; this is because general guidelines may sometimes deviate significantly from local diets (Talsma et al., 2017).

In an attempt to test and formulate FBRs, several tools have been developed *e.g.* Cost of Diet by Save the Children UK, NutriSurvey (the English translation of a German software: EBISpro), *Pro*PAN by Pan American Health Organization, and Optifood by World Health Organization. The Cost of Diet calculates the lowest cost of a diet that meets recommended nutrient intakes for individuals or households from local foods (Deptford et al., 2017). NutriSurvey helps to design diets at the lowest cost, putting into account local dietary habits while still meeting nutrient recommendations (Briend & Erhardt, 2018). *Pro*PAN is used to assess local contexts in relation to young child nutrition, identify gaps in children's diet, formulate and test locally acceptable feeding recommendations (Daelmans et al., 2013).

A few studies based on linear programming have been conducted in Kenya. One study was on effects of wild foods in reducing the minimum cost of diet using linear programming in Turkana. According to the study, wild foods were linked to reduced cost of diet as well as compensation for nutrient shortages (Sarfo, Termote, Keding, Boedecker, & Pawelzik, 2017). While iron deficiency was found in the locally adapted cost optimized nutritious diet without wild foods, diets modelled to include wild vegetables/foods were found to compensate for these shortages. In addition, the diet modelled with wild vegetables was found to be the least costly locally adapted cost optimized nutritious diet (Sarfo et al., 2017).

Another study on Cost of Diet Analysis in the agro-pastoral livelihood zone in Turkana showed that although families could be able to achieve a nutritious diet using local foods, vitamin C, iron and calcium were problematic nutrients and it was difficult to meet requirements. Based on household food habits and non-food expenditure patterns, it was also shown that foods rich in these nutrients were associated with increased cost of diet. (Save the Children, 2013).

A different study on the Cost of Diet analysis in the pastoral zone showed increase in dietary diversity, portion sizes and meal frequency (three meals per day) during the rainy season in comparison to the dry season. In the dry season, households consumed only one meal per day (dinner) while in the morning they only took black tea. Wild foods were found to be an important part of the diet of households in the pastoral zone. However, dietary habits were also characterized by taboos which could be restrictive in relation to some foods for specific groups in the community; for instance women of reproductive age and children (Save the Children, 2017a).

Optifood is a tool based on linear programming which was developed by the London School of Hygiene and Tropical Medicine in partnership with WHO and Food and Nutrition Technical Assistant III project (FANTA III). It is used to develop FBRs at lowest cost, based on locally available foods (Daelmans et al., 2013). It provides a set of optimal, population-specific FBRs and practical information regarding key "problem nutrients" in the local diet. Optimization analyses are applied to develop combinations of local foods at the lowest cost to either match or come as close as possible to meeting the nutrient needs of specific target groups (Crampton, 2011; Ferguson et al., 2006).

Optifood allows users to set up target groups, formulate and test FBRs while factoring their nutrient needs and other constraints such as food availability. By doing so, Optifood identifies gaps in current diets and provides suggestions on how to fill these gaps using nutrient dense locally available foods (FANTA, 2014). It also tests FBRs to establish their applicability in terms of nutritional adequacy suppose they are implemented. Optifood also provides information on limitations of locally available foods by identifying key problem nutrients. These are nutrients which are likely to remain inadequate based on the local food supply, hence prompting further interventions such as food fortification or micronutrient supplementation (Crampton, 2011).

The workflow in Optifood is done in four steps namely: create target group, enter food and diet data, check the data entered and perform analysis. When creating the target group, details such as group name, country, local region and Recommended Nutrient Intake (RNI) group data are entered (FANTA, 2014). The RNI refers to the daily intake that meets the nutrient requirements of almost all (97.5%) of apparently healthy individuals in an age and sex-specific population group (Daelmans et al., 2013). Secondly, local foods available to the target group as well as their constraints are entered. Constraints are set based on number of servings per week from each food group and food subgroup to ensure modeled diets are within the observed dietary patterns of the target group (FANTA, 2014). The "check diets" step ensures that solutions are possible based on the foods and constraints captured in Optifood. Lastly, when the "check diets" is run, the data is locked and allows for further analysis facilitating formulation of FBRs (Crampton, 2011).

3. METHODOLGY

3.1 Data sources

The data was obtained from an ongoing study by Bioversity International in Turkana County, Kenya. The study which started in 2016, was investigating innovative, participatory tools for dietary assessment and nutrition education considering local agrobiodiversity in Turkana County, Kenya. The aim of the project was to improve the dietary quality for women of reproductive age (15-49 years) and small children aged 6 to 36 months in Turkana County. Ethical clearance, development of data collection instruments and the research protocol was done by Bioversity International (Boedecker et al., 2016).

Loima sub-county within Turkana County was purposively selected because it is one of the project areas for the “Food and Nutrition Security-Enhanced Resilience” (FNS-ER). Secondly, Loima sub-county is closer to the county headquarters which made it ideal for research planning activities. Lastly, in relation to security in sub-counties where FNS-ER project was being implemented, Loima sub-county was considered more secure (Boedecker et al., 2016).

The study was conducted in the month of September which was during the dry harvest season. The study adopted a cross-sectional design where two surveys were conducted in Loima sub-county in Turkana County. Loima sub-county was stratified into two livelihood zones *i.e.* pastoral and agro-pastoral livelihood zones. Three villages were selected from each of the two livelihood zones. The three sampled villages from the pastoral zones included Lokiriama, Namoruputh and Lorugum. The agro-pastoral villages were Lobei, Kablokor and Nadapal (Boedecker et al., 2016).

The study population comprised of women of reproductive age (15-49 years). The sample comprised of 240 women who were randomly selected using lists composed at village level with the help of village heads and elders. Of the total sample, 120 women were from pastoral and 120 from the agro-pastoral livelihood zones. Socio-demographic information was obtained using structured questionnaires. Food intake data was obtained using enumerator based multiple-pass quantitative 24-hour recalls on two non-consecutive days (Boedecker et al., 2016). Obtaining 24-hour recall data on two non-consecutive days was important to cater for intra-personal variation (Gibson & Ferguson, 2008).

In contrast to the traditional chronological way of collecting food intake data, the multiple pass technique is designed to encourage individuals to report all their foods and beverages as they recall them throughout the interview process. The multiple pass method yields better cues for the respondents' cognitive processes in 3 steps. First the respondent lists all the foods eaten on the previous day using any recall strategy of their choice which does not have to be necessarily in a chronological order. Secondly, the interviewer acquires a more detailed list by probing for additional information while granting the respondents an opportunity to recall food items they may have initially omitted from the list. Lastly, the interviewer reviews the list of food items thus allowing any additional foods and eating instances to be included where necessary (Rutishauser, 2005).

Data collection was carried out by trained enumerators who were supervised by researchers from Bioversity International. Portion sizes were estimated using household measures *i.e.* plate (500g) bowl (350g), saucer (150g) cup (200g), glass (250g), tablespoon (15g) and teaspoon (5g). Data from the quantitative 24h recall was entered and processed in Lucille, dietary intake software developed by Ghent University, Belgium. Lucille was developed by the UGent Research Group Food Chemistry and Human Nutrition in partnership with the Nutrition and Child Health Unit of the Institute of Tropical Medicine, Belgium, to provide customized solutions for researchers when processing food intake data (Research Group Food Chemistry and Human Nutrition 2017).

Lucille offers flexibility in processing data from food intake studies by allowing users to upload user defined food composition tables, variables and nutrients of interest. Users can also define their own portion sizes, recipes or composite recipes based on the food composition tables used. Descriptive variables can also be added to characterize the food intake *e.g.* price, place of consumption etc. Lucille generates results in comma separated value format hence facilitating further analysis in other software such as SPSS and Stata (UGent Research Group Food Chemistry and Human Nutrition, 2017).

Currently, Kenya does not have its own food composition tables and the study had to find composition tables as close to Kenyan food patterns as possible. The Tanzania food composition tables were therefore used in this study. However, for the foods that were missing in the Tanzanian food composition tables, the nutrient composition for similar foods already existing in the Optifood database was used to cover for the missing data. These foods included camel, antelope and hare meat and fermented milk. Nutrient composition for wild fruits *i.e. Boscia conacea* (edung) and *Hyphaene compressa* (eng'ol) was obtained from literature from previous studies (Save the Children, 2017a). The food composition tables were uploaded to Lucille where quantitative food intake data per person per day was also entered. Lucille combines the quantitative food intake data with data from food composition tables to generate the actual nutrient intakes per person per day (Boedecker et al., 2016).

3.2 Data analysis

A total of 231 women were included in the final analysis, 116 from pastoral and 115 from agro-pastoral zone. The analysis excluded 4 women from pastoral and 5 women from agro-pastoral zone due to incomplete or missing dietary and socio-demographic data.

3.2.1 Socio-demographic characteristics

Socio-demographic data was analyzed in SPSS 24 while making comparisons between the pastoral and agro-pastoral zones. Age of the women and household size were analyzed in terms of means (± SD) while other socio-demographic characteristics such as marital status, education level and household sources of income were analyzed in terms of percent frequencies.

3.2.2 Dietary analysis

Quantitative dietary data from Lucille was exported to SPSS 24 for analysis. Based on the two recalls, lists of all foods were generated which were analyzed in terms of proportion of consumers and amounts consumed while comparing the two zones. Food items were further categorized into ten food groups (based on FAO guidelines) namely fats and oils, added sugar, dairy, fruits, vegetables, grains and grain products, legumes, pulses and seeds, meat and eggs, starchy roots and condiments (FAO, 2011). The categorization of food items into food groups was necessary to allow for correlations with dietary diversity (Koppmair et al., 2016). Comparisons were made between the pastoral and agro-pastoral zones in relation to these food groups.

Analysis was done for energy and seven selected nutrients *i.e.* protein, carbohydrate, fats, iron, folate, calcium and vitamin A. In relation to the selected nutrients, energy intake is important and deficits are linked to undernutrition. Protein, carbohydrate and fats comprise macronutrients consumed in larger quantities to meet nutritional requirements. Fat is also important in the absorption of fat soluble vitamins. Iron, folate and vitamin A are micronutrients of public health importance in Kenya. In addition, findings from the National Micronutrient Survey (2011) indicated a high (84%) prevalence of dietary inadequacy for calcium among women of reproductive age in Kenya (Ministry of Health, 2011).

The Shapiro-Wilk test in SPSS was used to check for normality for energy and nutrients. In both zones, the energy and nutrient data was non-normally distributed ($P<0.05$ at 95% confidence interval). Consequently, non-parametric test (the independent samples Mann-Whitney U test) was used to determine whether energy and nutrient intakes were significantly different between the pastoral and agro-pastoral zones. Nutrient intakes were determined in terms of mean, median, maximum and minimum while comparing zones.

3.2.3 Diet modelling in Optifood

Data entry into Optifood consisted of the following variables:

- Target group details
- List of food items and serving sizes
- Number of serving per week of the food items
- Food group and food subgroup constraints

The Optifood inbuilt RNIs of adult females 19-50 years (premenopausal) with active or moderately active lifestyle were used. The Optifood RNIs are based on WHO/FAO recommendations (Crampton, 2011). The WHO/FAO RNIs were applicable to the study population of women aged 15-49 years living in Turkana because they are internationally accepted and already adjusted for corrections related to physiological and dietary factors as well as inter-individual variability (FAO/WHO, 2002). The study did not measure iron bioavailability of the women's diet but instead used the FAO/WHO recommendations for developing countries *i.e.* iron bioavailability of 5% (FAO/WHO, 2002), which was applicable to the target population. Energy and six nutrients were included in the Optifood model *i.e.* protein, fat, iron, folate, calcium and vitamin A. Optifood settings do not include analysis for carbohydrate and water. **Table 1 shows** the target group details as entered in Optifood.

Table 1: Target group details as created in Optifood

Country	Kenya	Local region	Turkana County
Demographic	Adult females 19-50 years (premenopausal)	Average weight	50kg
PAL	Active or moderately active lifestyle	1.85	
Iron bioavailability	5%	Model cost	No
RNI authority	Optifood		
Nutrient	Units	RNI Value/Day	
Food Energy	kcal/day	2271	
Protein	g/day	41.5	
Fat	g/day	75.7	
Calcium	mg/day	1000	
Folate	µg Dietary Folate Equivalents/day	400	
Vitamin A RAE	µg Retinol Activity Equivalents/day	500	
Iron 5%	mg/day	58.8	

A total of 29 food items in the pastoral zone and 29 food items in agro-pastoral zones were entered in Optifood for analysis (see **Appendices 1 and 2**). The quantity of food items was entered as median serving size per day basis. Iodized salt, tea leaves and Royco were excluded because they were condiments consumed in small amounts (FANTA, 2014). Cost was not included in the model. Food sub group and food group constraints were also entered in terms of lowest, average and highest servings per week based on the 5th, 50th, and 95th percentiles (FANTA, 2014). The lowest, average and highest number of servings had to be different values. Therefore, for food (sub) groups whose 5th and 50th percentiles were zero, a value of 1 was entered for average servings (50th percentile) for mathematical reasons to enable calculations (Crampton, 2011). The food subgroup and food group constraints are illustrated in **Appendices 3 and 4**. The food (sub) group constraints as well as percentage of women who consumed the food were the basis for minimum and maximum number of servings per week that a food item could be consumed.

Module 1: Check diets

This was done to check for any validation errors before running the subsequent analyses to ensure solutions were possible (Crampton, 2011). Hence this step ensured that model parameters generated realistic diets (Darmon et al., 2014).

Module 2: Identify draft recommendations

In this step, individual food items contributing to at least 5% of different nutrients were selected which would later form the basis for identifying draft FBRs that could cover >70% of RNI for the different nutrients (Talsma et al., 2017). By incorporating individual as well as combinations of different foods and food groups, two best diets were generated for the target group based on the dietary constraints captured (FANTA, 2014):

- Food pattern optimized (FP diet): This diet followed average food pattern that came as close as possible to meeting the women's RNIs with minimal deviations from their actual average dietary patterns.
- Non-food pattern optimized (NFP diet): This diet was as close as possible to meeting the women's RNIs though allowing for some deviations from the actual average dietary patterns.

Consequently, this module generated 28 possible diets which included 14 maximized diets (best-case scenario) and 14 minimized diets (worst-case scenario). The maximized diets were based on maximizing intakes (*i.e.* from nutrient-rich foods per food group) to obtain the highest achievable percentage of RNI for each specific nutrient; for instance a diet providing the highest achievable folate content (Talsma et al., 2017). On the other hand, minimized diets were based on the lowest possible intake for each specific nutrient (*i.e.* from less nutrient-rich foods per food group) given the constraints; for instance a diet providing the lowest possible iron content (Talsma et al., 2017). The nutrient levels of the maximized diets (best-case scenario) were the basis for identifying absolute and partial problem nutrients (FANTA, 2014).

Nutrients for which 100% RNIs could not be achieved in the best-case scenario were classified as absolute problem nutrients *i.e.* the RNIs for these nutrients could not be met in the context of the locally available foods and the local dietary habits (Crampton, 2011). The absolute problem nutrients were more likely to be inadequate in the modelled diets within the given dietary constraints (FANTA, 2014). Nutrients for which 100% RNIs could be achieved in the best-case scenario but only less than 70% could be achieved in the worst case scenario were classified as partial problem nutrients (Crampton, 2011). Consequently, it would be possible to develop FBRs based on improving the intake of partial problem nutrients (FANTA, 2014).

4. RESULTS

4.1 Socio-demographic characteristics

Socio-demographic data for 231 women were analyzed. The results for socio-demographic characteristics in pastoral and agro-pastoral zones are shown in **Table 2**. Although a few statistical differences were observed between pastoral and agro-pastoral zones, socio-demographic characteristics of women in the two zones were generally comparable. More households (49%) had access to land in agro-pastoral zone compared to pastoral zone (16%) with $P<0.01$ (see **Table 2**). In terms of water and sanitation, more households (92%) in agro-pastoral zone had access to piped water or protected well/borehole/spring compared to pastoral zone (58%) with $P<0.01$ (see **Table 2**).

Table 2: **Socio-demographic characteristics of pastoral and agro-pastoral zones**

Variable		**Pastoral**	**Agro-Pastoral**	**p-value (Chi-Square tests)**
Age (mean ± SD)		28 (± 11.9)	27 (± 12.2)	0.48
Marital status	Married monogamous	41%	46%	0.01
	Married polygamous	57%	46%	
	Widowed	0%	6%	
	Single	2%	2%	
Sex of household head	Male	84%	76%	0.18
	Female	16%	24%	
Number of household members (mean ± SD)		7 (± 2.9)	7 (± 2.7)	0.90
Education level	No schooling	68%	66%	0.09
	Primary	26%	24%	
	Secondary	3%	1%	
	Higher than secondary	0%	2%	
	Others	3%	7%	
Source of household income[a]	Sale of own crops	8%	4%	0.28
	Sale of own animals/animal products	22%	33%	0.05
	Sale of own produced goods/crafts	35%	45%	0.13
	Daily wage	24%	21%	0.55
	Small business	35%	39%	0.55
	Regular salary	2%	4%	0.67
	Remittances	19%	12%	0.16
	Public transfers	6%	7%	0.78
Floor material of the main residence	Earth floor	95%	100%	0.02
	Cement	4%	0%	
	Wood	1%	0%	
Wall material of the main residence	Wood	36%	17%	<0.01
	Earth Wall	55%	78%	
	Iron sheet	1%	1%	
	Cement	2%	0%	
	Others	6%	4%	
Roof material of the main residence	Straw/grass	28%	51%	<0.01
	Iron sheet	14%	9%	
	Others	58%	40%	
Household access to land for agriculture	Yes	16%	49%	<0.01
	No	84%	51%	
Household access to livestock, farm animals, poultry	Yes	59%	58%	0.96
	No	41%	42%	
Source of drinking water during rainy season	Piped water into dwelling, tube well /borehole, protected spring	58%	92%	<0.01
	Unprotected spring, unprotected dug well, cart with small tank/pond	42%	8%	
Household access to latrine	Yes	21%	17%	0.52
	No	79%	83%	

[a] Categories are not mutually exclusive

4.2 Dietary analysis

4.2.1 Foods

A total of 40 food items were identified from the two 24-hour recalls in both zones (see **Appendix 5**). The number and percentage of consumers for each food item as well as the median serving per day in the two zones are shown in **Appendix 5**. Food items consumed by more than 50% of the women in both zones included vegetable oil, table sugar, dry maize, maize flour, beans, iodized salt and tea leaves. Some food items were consumed only in one zone and by less than 5% of the women. These included (*Boscia conacea,* lentils ,eggplant, game meat, beef, camel meat and eggs in pastoral zone; and camel milk, ripe banana, *Hyphaene compressa,* sorghum, green peas, capsicum, pigeon peas and beef tripe in agro-pastoral zone. Sorghum was consumed by 6% of women in agro-pastoral zone.

The minimum, maximum and mean ±SD with reference to quantities of the different food items are shown in **Appendix 6**. For most food items, mean quantities consumed by women in pastoral and agro-pastoral zones were comparable (see **Appendix 6).** A few differences were observed for some food items namely: vegetable oil (pastoral 24 ±22g and agro-pastoral 27 ±23g; $P<0.05$) full-cream milk powder (pastoral 31 ±28g and agro-pastoral 22 ±29g; $P<0.001$), tomatoes (pastoral 38 ±23g and agro-pastoral 61 ±36g; $P<0.005$) and goat meat (pastoral 94 ±97g and agro-pastoral 126 ±78g; $P<0.05$) as illustrated in **Appendix 6**.

4.2.2 Food groups

Quantities

The median quantity of food groups consumed by women in pastoral and agro-pastoral zone was comparable except for meat and eggs which was higher in agro-pastoral zone (113g) compared to pastoral zone (72g) with $P=0.024$ as shown in **Table 3.**

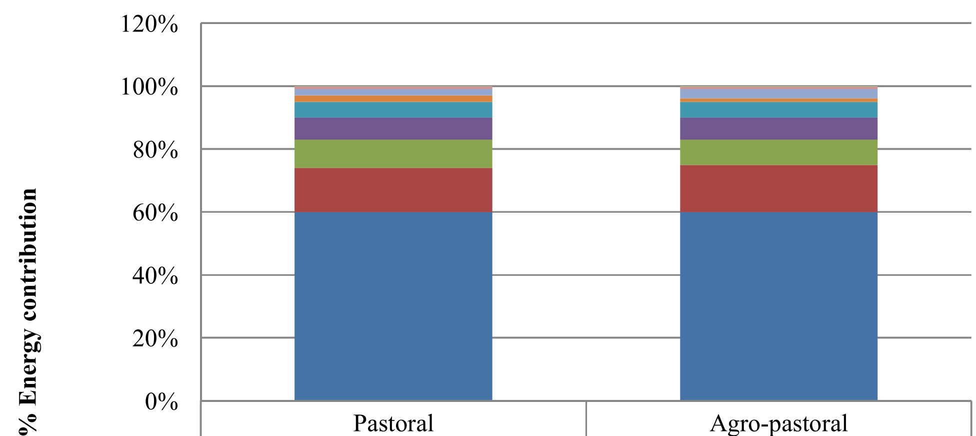
Table 3: Median intake (grams) in pastoral and agro-pastoral zones

Food group	Pastoral zone	Agro-pastoral zone	P-value[a]
Fats and oils	18	21	0.046
Added sugars	39	34	0.063
Dairy	27	25	0.169
Fruits	43[b]	300[c]	-[d]
Vegetables	26	33	0.071
Grain and grain products	172	177	0.247
Legumes and pulses	87	94	0.608
Meat and eggs	72	113	0.024
Starchy roots	99	130	0.146

[a] Non parametric independent samples Mann-Whitney U test
[b] n=1
[c] n=6
[d] Non-parametric test not computed since there was no variability in pastoral zone

Energy contribution from food groups

Percent energy contribution from the different food groups was comparable in pastoral and agro-pastoral zones as shown in **Figure 1**.



	Pastoral	Agro-pastoral
Fruits	0.1%	0.2%
Vegetables	0.9%	0.8%
Starchy roots	2%	3%
Meat and eggs	2%	1%
Legumes and pulses	5%	5%
Dairy	7%	7%
Added sugar	9%	8%
Fats and oils	14%	15%
Grains and grain products	60%	60%

Figure 1: Percent energy contribution from the different food groups in pastoral and agro-pastoral zones

4.2.3 Energy and nutrient intake

Plant sources were the main contributors of energy and other nutrients in both pastoral and agro-pastoral zones as shown in **Table 4**.

Table 4: Percent energy and nutrients from plant and animal sources

Zone	Source	Energy (%)	Protein (%)	Fat (%)	Calcium (%)	Iron (%)	Folate (%)	Vitamin A (%)
Pastoral	Animal	10	28	19	81	4	9	36
	Plant	90	72	81	19	96	91	64
Agro-pastoral	Animal	9	22	15	77	2	7	23
	Plant	91	78	85	23	98	93	77

The median nutrient intake from the different food groups in pastoral and agro-pastoral zones is shown in **Table 5**.

Table 5: Median nutrient intake from different food groups in pastoral and agro-pastoral zones

Zone	Food group	CHO (g)	Protein (g)	Fat (g)	Calcium (mg)	Iron (mg)	Folate (µg)	Vitamin A (µg RAE)
Pastoral	Fats and oils	0.0	0.0	17.7	0.0	0.0	0.0	0.0
	Added sugar	0.0	0.0	0.0	0.4	0.0	0.0	0.0
	Dairy	11.2	7.7	7.9	251.1	0.2	11.2	120.1
	Fruits	0.8	3.7	0.0	4.7	7.4	0.0	0.0
	Vegetables	1.7	0.3	0.0	3.5	0.1	4.6	0.0
	Grain and products	129.8	13.6	5.0	11.5	4.8	7.9	90.0
	Legumes and pulses	20.1	7.6	1.3	24.5	2.6	113.7	0.0
	Meat and eggs	10.0	17.9	6.0	2.9	1.2	4.3	11.0
	Starchy roots	38.6	3.8	1.4	8.6	0.7	76.9	5.0
Agro-pastoral	Fats and oils	0.0	0.0	20.6	0.0	0.0	0.0	0.0
	Added sugar	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	Dairy	9.0	6.2	6.3	201.7	0.2	9.0	96.5
	Fruits	112.2	0.0	0.0	8.4	5.8	30.3	0.0
	Vegetables	2.0	0.4	0.0	4.1	0.1	6.0	3.4
	Grain and products	132.4	13.5	5.3	12.2	5.3	9.1	196.0
	Legumes and pulses	21.6	8.2	1.4	26.3	2.8	121.9	0.0
	Meat and eggs	40.5	28.2	9.5	2.9	1.2	6.8	40.5
	Starchy roots	47.1	4.4	15.0	9.9	0.8	97.7	20.0

CHO- carbohydrate
RAE- Retinol activity equivalents

The median energy intake of women in both pastoral and agro-pastoral zones was 1715kcal. Median nutrient intakes were comparable between pastoral and agro-pastoral zones except for vitamin A. Median intake for vitamin A in agro-pastoral zone was 541µg RAE which was higher compared to 322µg RAE in pastoral zone (P<0.001). The mean, median, minimum and maximum energy and nutrient intakes are shown in **Table 6**.

Table 6: Energy and nutrient intake per zone

Zone	Nutrient intake	Energy (kcal)	CHO[a] (g)	Protein (g)	Fat (g)	Calcium (mg)	Iron (mg)	Folate (µg)	Vitamin A (µgRAE)[b]
Pastoral	Mean	1873	269.86	44.2	52.2	303.7	12.5	166.9	407.4
	SD	1030	163.51	25.1	37.5	334.1	8.4	158.7	300.5
	Median	1715	241.06	38.8	44.9	229.3	10.9	140.9	322.0
	Minimum	312	56.27	7.6	5.7	11.0	0.5	8.3	0.0
	Maximum	5068	835.08	142.4	275.1	2179.4	54.6	1132.0	1221.8
Agro-pastoral	Mean	1970	291.82	47.0	61.8	342.8	13.5	194.4	646.9
	SD	1173	178.19	30.1	44.6	354.2	9.0	156.7	432.5
	Median	1715	267.03	38.2	51.7	220.3	11.0	161.2	540.8
	Minimum	298	41.36	6.5	5.3	10.9	1.7	6.0	6.5
	Maximum	6733	1066.47	157.4	196.3	1698.3	50.5	849.6	2408.8
P-value[c]		0.671	0.361	0.722	0.128	0.360	0.57	0.153	<0.001

[a] Carbohydrate
[b] Retinol Activity Equivalents
[c]non parametric test ((Mann-Whitney U test) at 95% confidence interval

4.3 Diet modelling using Optifood

After entering data into Optifood, the "check diets" function gave the go ahead for further analysis by checking for any validation errors and confirming solutions were possible.

4.3.1 Current energy and nutrient intake

The results obtained from the dietary analysis indicated that current intakes for energy and nutrients for women in both zones were below the Optifood inbuilt RNIs for adult females aged 19-50 years. The median intakes for energy and nutrients in the two zones in comparison to the RNIs are shown in **Table 7**.

Table 7: The median intake per day of women in pastoral and agro-pastoral zones compared to RNIs

Nutrient	Units	Median intake/day		RNI value/day
		Pastoral zone	Agro-pastoral zone	
Food energy	kcal/day	1715	1715	2271
Protein	g/day	39	38	41.5
Fat	g/day	45	52	75.7
Calcium	mg/day	229	220	1000
Folate	µg Dietary Folate Equivalents/day	141	161	400
Vitamin A RAE	µg Retinol Activity Equivalents/day	322	541	500
Iron (5% bioavailability)	mg/day	11	11	58.8

RNI- Recommended Nutrient Intake

4.3.2 Recommendations based on weekly food group servings

After entering food group and food subgroup constraints into Optifood, two optimized diets were generated *i.e.* the food pattern optimized (FP diet) and non-food optimized (NFP diet) (Crampton, 2011). The servings per week for the two best diets for women in pastoral and agro-pastoral zone are shown in **Table 8**. For mathematical reasons, the average consumption of some food groups was entered as 1 even though in reality it was 0 (Crampton, 2011). These food groups included fruits, starchy roots and meat, fish and eggs. Therefore this should be interpreted with caution to avoid the assumption that the average consumption of these foods was acceptable without any modifications in the current consumption patterns.

Table 8: Food group patterns (servings/week) for two best diets in Module 2 in pastoral and agro-pastoral zones

Group	Pastoral			Agro-pastoral		
	Median [a]	FP diet[b]	NFP diet[c]	Median[a]	FP diet[b]	NFP diet[c]
Fruits	1	1	2	1	1	1
Added sugars	7	7	0	7	7	0
Vegetables	14	14	28	14	14	21
Dairy products	7	7	14	7	7	21
Added fats	7	7	14	7	7	14
Bakery & breakfast cereals	1	1	1	1	1	0
Starchy roots & other starchy plant foods	1	1	0	1	1	0
Meat, fish & eggs	1	1	7	1	1	7
Grains & grain products	14	14	14.4	14	19.7	19.3
Legumes, nuts & seeds	7	7	14	7	7	14
Staples	14	14	15.4	14	26.7	18.3
Snacks	1	1	7	**1**	7	0

[a] median (50th percentile) is included in the table to show the current average food pattern in both zones hence allow for comparisons with recommendations (FP and NFP diets)

[b] FP diet followed average food patterns that came as close as possible to meeting the women's RNIs with minimal deviations from their actual average dietary patterns.

[c] NFP diet was as close as possible to meeting the women's RNIs though allowing for some deviations from the actual average dietary patterns.

FBRs were generated based on the NFP diets of women in pastoral and agro-pastoral zones as shown in **Table 9**. The NFP diet recommendations did not include bakery and breakfast cereals in agro-pastoral zone. Added sugars were also not included in the NFP diet recommendations for both zones. Based on the constraints in both zones, it was not feasible to develop daily recommendations for fruits.

Table 9: FBRs for women in pastoral and agro-pastoral zones

Food group	Servings per day	
	Pastoral zone	Agro-pastoral zone
Vegetables	4 servings	3 servings
Dairy and dairy products	2 servings	3 servings
Fats and oils	2 servings	2 servings
Meat, fish and eggs	1-2servings	1serving
Grains and grain products	2 servings	2-3 servings
Legumes, nuts and seeds	2 servings	2 servings

4.3.3 Food group sources of nutrients in the NFP diet

A list of food subgroups with percentage RNIs of the nutrients they contributed to the NFP diet was also generated in module 2. The list comprised of food subgroups with their percent contribution to each specific nutrient. The top 3 food subgroups contributing at least 5% of the nutrient's RNI are illustrated in **Table 10**. In spite of a few differences in ranking, there were similarities in terms of nutrient sources from food subgroups in the two zones which formed the basis for formulating FBRs for both target groups. Only two food subgroups (vitamin A source dark green leafy vegetables and milk) contributed at least 5% of vitamin A in both zones.

Table 10: Top three food subgroup sources of nutrients in ranked order in the NFP diet of pastoral and agro-pastoral zones

Nutrient	Pastoral zone	Agro-pastoral zone
Energy	Whole grains and products, unenriched/unfortified	Whole grains and products, unenriched/unfortified
	Cooked beans, lentils, peas	Vegetable oil (unfortified)
	Vegetable oil (unfortified)	Cooked beans, lentils, peas
Protein	Red meat	Red meat
	Cooked beans, lentils, peas	Whole grains and products, unenriched/unfortified
	Whole grains and products, unenriched/unfortified	Cooked beans, lentils, peas
Fat	Vegetable oil (unfortified)	Vegetable oil (unfortified)
	Red meat	Fluid or powdered milk (non-fortified)
	Fluid or powdered milk (non-fortified)	Red meat
Calcium	Fluid or powdered milk (non-fortified)	Fluid or powdered milk (non-fortified)
	Vitamin C-rich vegetables	Vitamin C-rich vegetables
	Vitamin A source dark green leafy vegetables	Vitamin A source dark green leafy vegetables
Folate	Cooked beans, lentils, peas	Vitamin C-rich vegetables
	Vitamin C-rich vegetables	Cooked beans, lentils, peas
	Whole grains and products, unenriched/unfortified	Vitamin A source dark green leafy vegetables
Vitamin A	Vitamin A source dark green leafy vegetables	Vitamin A source dark green leafy vegetables
	Fluid or powdered milk (non-fortified)	Fluid or powdered milk (non-fortified)
	-	-
Iron	Cooked beans, lentils, peas	Red meat
	Whole grains and products, unenriched/unfortified	Whole grains and products, unenriched/unfortified
	Vitamin C-rich vegetables	Cooked beans, lentils, peas

4.3.4 Problem nutrients

Module 2 also generated results which classified problem nutrients based on modelled constraints for locally available foods which the women were consuming. In the pastoral zone, the two best diets met 100% RNIs for protein, folate and vitamin A. However, fat was a partial problem nutrient for which 100% RNI could be achieved in the NFP diet (best-case scenario) but only 61% RNI could be achieved in the FP diet (worst-case scenario). Calcium and iron were absolute problem nutrients in the pastoral zone where the NFP diet (best-case scenario) could only achieve 88% RNI for calcium and 57% RNI for iron (see **Figure 2**).

In the agro-pastoral zone, the two best diets met 100% RNIs for protein, folate and vitamin A. Calcium was a partial problem nutrient for which 100% RNI could be achieved in the NFP diet (best-case scenario), whereas only 98% RNI could be achieved in the FP diet (worst-case scenario). Fat and iron were absolute problem nutrients where the NFP diet (best-case scenario) could only achieve 95% RNI for fat and 46% RNI for iron (see **Figure 3**).

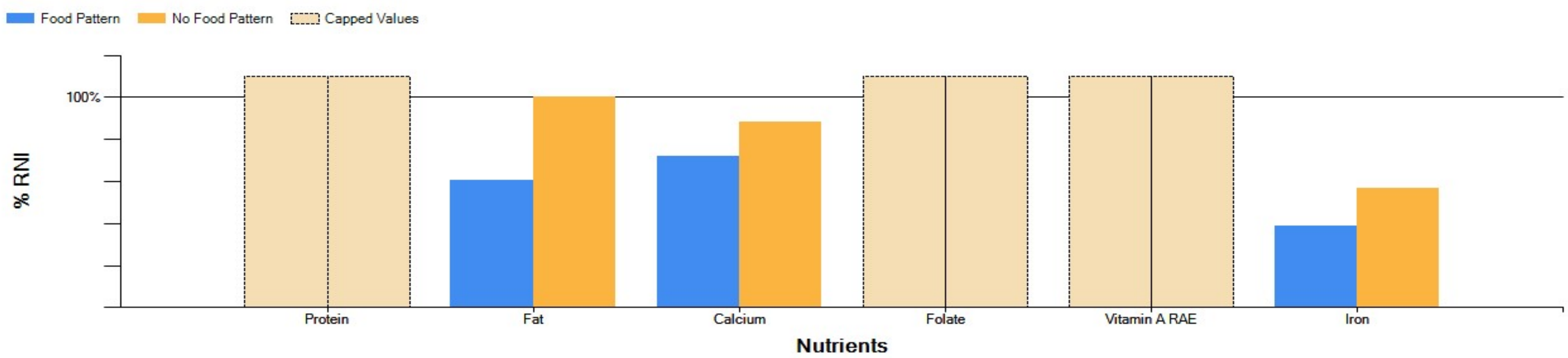


Figure 2: Percentage RNIs for two best diets generated in module 2 of pastoral zone

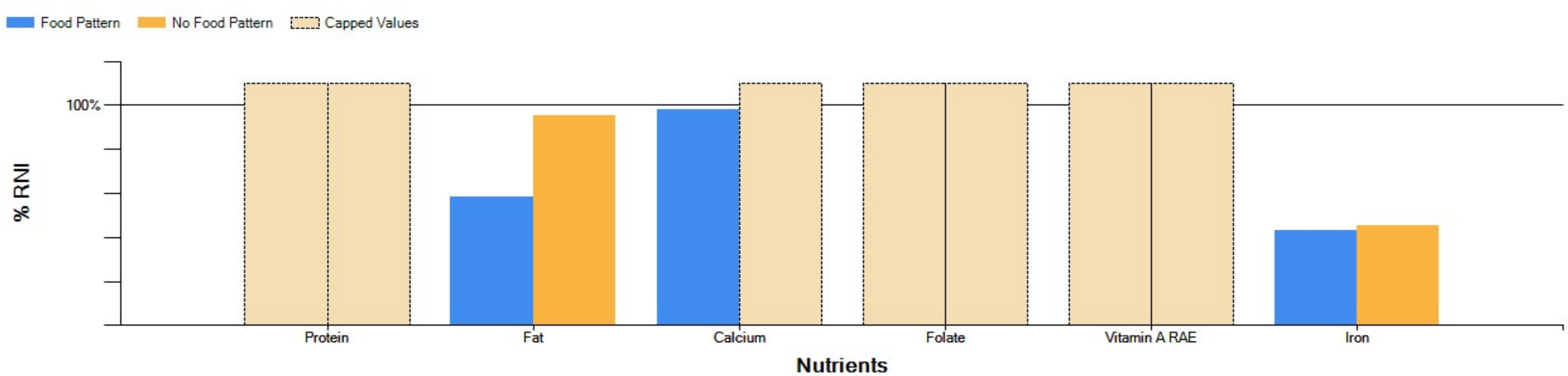


Figure 3: Percentage RNIs for two best diets generated in module 2 of agro-pastoral zone

5. DISCUSSION

In this master thesis, a dietary analysis of women aged 15-49 years living in Turkana County, Kenya was conducted. Previous studies indicated that understanding food consumption patterns of different populations not only provides crucial information on types and quantities of foods contributing to energy and nutrients; but also forms the basis for planning food-based dietary guidelines (Auestad, Hurley, Victor, & Schweitzer, 2015). This study explored the hypothesis that there is no difference in dietary patterns between women aged 15-49 years living in pastoral and agro-pastoral livelihood zones in Turkana County. To test this hypothesis, the contribution of different foods and food groups to the energy and nutrient intake of these women was assessed while at the same time comparing the pastoral and agro-pastoral livelihood zones. The dietary analysis indicated that the dietary patterns of women aged 15-49 years living in pastoral and agro-pastoral livelihood zones in Turkana were comparable. Once the energy and nutrient intakes for women in both zones were determined, the potential to optimize their diet using locally available foods was investigated using Optifood; which facilitated formulation of FBRs (Crampton, 2011).

The first research question that this study set out to answer was what foods and food groups contributed to nutrient intake of women aged 15-49 years living in Turkana. The findings of this study indicated that mainly five food items were consumed by more than 50% of the women in both pastoral and agro-pastoral zones including vegetable oil, dry maize, maize flour, beans and table sugar. In relation to food groups, only four out of the ten food groups were consumed by 50% of the women during the recall period in both pastoral and agro-pastoral zones *i.e.* fats and oils, added sugars, grain and grain products, legumes and pulses. The second research question was to find out whether dietary patterns of women aged 15-49 years differ between pastoral and agro-pastoral livelihood zones in Turkana. The results from this study showed that dietary patterns of women aged 15-49 years living in pastoral and agro-pastoral livelihood zones were comparable.

The third research question was to investigate whether the diet of women aged 15-49 years living in Turkana could be optimized using locally available foods. Results from the dietary analysis indicated that energy and nutrient intakes of women aged 15-49 years living in pastoral and agro-pastoral zones in Turkana were below the RNIs. Consequently, to help improve nutritional adequacy, FBRs were formulated based on the food and food (sub) group constraints of women aged 15-49 years living in pastoral and agro-pastoral livelihood zones of Turkana. However, some problem nutrients including calcium, iron and fat were encountered in the formulation of FBRs which implied that within the context of the dietary constraints of these women, other interventions such as food fortification and nutrient supplementation were necessary to be able to meet requirements (Untoro et al., 2017).

5.1 Socio-demographic characteristics

The socio-demographic characteristics of households in pastoral and agro-pastoral zones were comparable. The results in this study with reference to socio-demographic characteristics were consistent with other previous studies in Turkana (The Food Economy Group, 2016; Turkana County Department of Health, 2016). There is evidence from other studies showing that socio-demographic characteristics including, gender, education, income, access to agricultural land and livestock ownership influence households' dietary diversity and food security (Jones, Shrinivas, & Bezner-kerr, 2014). For instance increase in wealth status is associated with more consumption of meat and milk from own livestock (Opiyo et al., 2014). Additionally, higher income increases access to a variety of micronutrient rich and fortified foods hence lowering the risk of micronutrient deficiencies (Allen, Benoist, Dary, & Hurrell, 2006).

The results of this study indicate diversification of economic activities in both pastoral and agro-pastoral zones. Although the main livelihood of Turkana is nomadic pastoralism, challenges of hot, dry and arid conditions often lead to inadequate pasture and consequently low livestock yields; forcing households to engage in other income-generating activities (Waila, Mahero, Namusisi, Hoffman, & Robertson, 2018). Other studies in West and East African countries have indicated that although pastoralists and agropastoralists depend on livestock and livestock products, self employment is becoming more important to help cushion them from shocks such as famine (Barahona, 2015).

Access to agricultural land was higher in agro-pastoral zone (49%) compared to pastoral zone (16%); $P<0.01$; this was consistent with findings from a previous (Kenya National Bureau of Statistics et al., 2016). The low access to agricultural land in the pastoral zone can be explained by the existence of a communal land tenure system which is applied as a strategic coping mechanism to allow the pastoralists to utilize the seasonal pasture and water resources in an efficient way (Opiyo et al., 2015).

In terms of water, sanitation and hygiene, the agro-pastoral zone had better access to piped/protected boreholes (92% households) compared to agro-pastoral (58% households) with $P<0.01$. Proximity of the agro-pastoral zone to the Turkwel River explains the better access of water facilities (Turkana County Department of Health, 2016). Poor access to water and sanitation is one of the underlying causes of malnutrition in many developing countries and is linked to diarrheal diseases and inadequate nutrient utilization (Malapit & Quisumbing, 2015). Studies have shown that in most poor-resource settings, it is women who bear the responsibility of fetching water over long distances which not only increases their workload but also their energy requirements (Hotz et al., 2016; Mckune et al., 2015).

5.2 Dietary patterns

5.2.1 Foods

This study identified a total of 40 food items from pastoral and agro-pastoral zones (see **Appendix 5**) which indicates limited food availability in terms of variety. Similar findings were reported in a previous study on Cost of Diet (2013) which found that markets in Turkana were characterized by mainly cereals, pulses and cooking oil. Previous research shows that a positive relationship exists between market access and dietary diversity; particularly in relation to fresh fruits and vegetables and dairy products which have shorter shelf life (Koppmair et al., 2016).

Of the 40 food items identified, only seven were consumed by more than 50% of the women in both pastoral and agro-pastoral zones. Of the seven food items, two were condiments consumed in small amounts *i.e.* iodized salt and tea leaves. Hence the most common food items were vegetable oil, dry maize, maize flour, beans and table sugar. These findings were consistent with previous findings from the Turkana SMART nutrition survey (2016). Other studies have shown that although diverse diets are vital for macro and micronutrient adequacy, the majority of households in low-income countries consume monotonous staple-based diets which are inadequate in essential micronutrients (Jones, 2017).

This study was conducted during the dry harvest season when there was increased availability for maize. However, this season is characterized by diminishing pasture hence low milk production coupled with lack of fresh produce such as vegetables (Save the Children, 2013, 2017a). This explains the low consumption of milk, meat, vegetables and fruits as reported in this study. Similar observations have been reported in other studies where seasonality has been shown to have an impact on dietary diversity of households; with low dietary diversity being reported in the dry season (Koppmair et al., 2016).

Although previous studies in Turkana show that the agro-pastoral zone has more access to fruits (mangoes, oranges, bananas), vegetables (mainly cabbage, onions and tomatoes) and fish because of proximity to irrigation activities (Save the Children, 2013), this study reported low or lack of consumption of these food items in this zone. This can be attributed not only to the dry season but also to the fact that food availability does not necessarily translate to nutrition security; which explains the persistently high malnutrition rates in Turkana county (Turkana County Department of Health, 2016). Although small dried fish are nutrient rich and available in the agro-pastoral zone (Save the Children, 2013), consumption was not reported which can be attributed to cost. Previous research indicates that to a great extent, more diversified diets are correlated with higher expenditure (Liu, Shively, & Binkley, 2014).

Previous studies in Turkana identified more variety of wild fruits including *Ziziphus mauritania* (*ng'akalaleo*) *Salvadora persica*(*esekhon*) *Dobera glabra* (*edapal*), *Cordia sinensis* (*edome*), and *Balanite sorbiculans* (*ebei*) (Save the Children, 2017a). However, only two wild fruits were reported in this study *i.e. Boscia conacea* in the pastoral zone and *Hyphaene compressa* in the agro-pastoral zone. The availability of these two fruits during the study period can be explained by the fact that they are less rain sensitive and can survive the dry season (The Food Economy Group, 2016). However, these fruits were consumed by less than 5% of the women in both zones. The importance of wild foods has been demonstrated in other studies which have shown that adding wild foods to the diet of all age groups (non-pregnant women, pregnant and lactating women, infants and young children) not only reduces the cost of diet but also helps to meet the recommended intakes for iron among these groups (Termote et al., 2014).

5.2.2 Food groups

This study categorized food items into ten food groups namely fats and oils, added sugar, dairy, fruits, vegetables, grains and grain products, legumes, pulses and seeds, meat and eggs, starchy roots and condiments. Other studies show that the more food groups consumed, the higher the dietary diversity which not only plays a key role in promoting good health but is also a proxy indicator for food security (Taruvinga, Muchenje, & Mushunje, 2013). Increased number of food groups not only shows appositive correlation with dietary diversity, but is also inversely correlated to malnutrition (Azadbakht & Esmaillzadeh, 2010).

The median quantity of food groups consumed by women in pastoral and agro-pastoral zone was comparable except for meat and eggs food group which was slightly higher in agro-pastoral zone (113g) compared to pastoral zone (72g) with P=0.024 (see **Table 3**). This can be attributed to the proximity of the agro-pastoral zone to local markets (The Food Economy Group, 2016). Previous studies indicate that although dietary diversity focuses more on quality of diet (number of food groups), the actual quantity of food items consumed is equally important (Sibhatu & Qaim, 2017). More so, calorie contribution from non-staple foods is associated with increased dietary diversity (Osarfo, Senadza, & Nketiah-Amponsah, 2016).

Only four out of the ten food groups were consumed by 50% of the women during the recall period in both pastoral and agro-pastoral zones *i.e.* fats and oils, added sugars, grain and grain products, legumes and pulses. This corresponds to previous findings in Turkana indicating poor dietary diversity (Women's Dietary Diversity Score of below 3); which is a proxy indicator for micronutrient inadequacy. Poor dietary diversity is a problem in sub-Sahara Africa as shown in other studies in Ethiopia, Ghana, Malawi and Tanzania (Jones et al., 2014; Malapit & Quisumbing, 2015; Ntwenya, Kinabo, Msuya, & Mamiro, 2015; Workicho et al., 2016). A review of dietary surveys in South Africa demonstrated that fruits, vegetables and dairy were the most deficient food groups among the adult South African population (Mchiza et al., 2015).

The low consumption of vegetables in this study can be attributed not only to the dry season during the study period but also the lack of home gardens among households in Turkana particularly those in agro-pastoral zone with access to irrigation activities (Save the Children, 2017b). Previous studies in Africa and South Asia show a positive correlation between ownership of home gardens and household dietary diversity which is linked to improved micronutrient intake mainly from horticultural produce such as vegetables and fruits (Ochieng, Afari-sefa, Lukumay, & Dubois, 2017; Pandey, Dev, & Jayachandran, 2016; Taruvinga et al., 2013)

Plant source foods were the main source of energy and nutrients in both zones except for calcium which was mainly from animal sources (81% pastoral; 77% agro-pastoral). Previous findings show that although animals are an important source of food and income in Turkana, this is largely dependent on herd size where households with larger herd size have more access to milk and meat as well as other essential food and non-food items (The Food Economy Group, 2016). Animal source foods are less commonly consumed in most sub-Saharan African settings; for instance a study in Ethiopia indicated that household diets were mainly plant based while animal source foods were rarely reported (Workicho et al., 2016). Results from a South African study show low consumption of animal source foods which are rich in iron and vitamin A, particularly among women of reproductive age (Chakona, 2017). Studies have shown that low intake of animal source foods among women increases vulnerability to micronutrient deficiencies which can lead to increased risk of maternal mortality, poor birth outcomes and decreased immunity (Allen et al., 2006).

Similar to previous studies in Turkana and Baringo, this study identified the following food groups as main sources of different nutrients based on the women's dietary patterns: grain and grain products (carbohydrate and iron), meat and eggs (protein), fats and oils (fat), dairy (calcium and vitamin A), and legumes and pulses (folate) (Save the Children, 2013, 2017a; Vossenaar et al., 2016). Although wild fruits *(Boscia conacea* in pastoral zone and *Hyphaene compressa* in agro-pastoral zone) were observed to be rich sources of iron, these fruits were consumed by less than 5% of the women. Other studies show that diets among women of reproductive age in low-income countries comprise of cereals, fats and oils, legumes, nuts and seeds, sweets and beverages with fewer households consuming fruits, dairy, meat-based products, eggs and fish (Liu et al., 2014; Ochieng et al., 2017; Sibhatu et al., 2015). As is the case with Turkana, the most affected areas are usually remote areas with limited access to markets which are characterized by low consumption of animal products, fresh vegetables and fruits (Allen et al., 2006).

The percent energy contribution from the different food groups was comparable for women aged 15-49 years living in pastoral and agro-pastoral zones. Grain and grain products contributed 60% of total energy. Other studies also illustrate that diets in sub-Saharan African countries comprise mainly of carbohydrates which contribute more than 55% of total energy (Abrahams, Mchiza, & Steyn, 2011). While most developing countries especially Africa and Asia depend on cereals for energy, evidence from developed countries such as the UK show that cereals provide 30% of total energy (Kearney, 2010). In both zones, fat contributed to less than 15% of total energy while legumes contributed 5% (see **Figure 1**), which is consistent with findings from other studies in sub-Sahara Africa and South Asia (Arimond et al., 2010; Pandey et al., 2016).

Sugars contributed to 9% and 8% of total energy in pastoral and agro-pastoral zones respectively which was above the Kenya National Guidelines for Healthy Diets and Physical Activity (2017) which recommend less than 5% energy contribution from sugars. In other studies, diets in developing countries have not only been characterized by starchy staples and limited animal products, but also high sugars pointing more to the problem of diet quality rather than lack of calories (Carletto, Zezza, & Banerjee, 2013).

Dairy products contributed 7% of total energy in both zones. Meat and eggs contributed 2% of total energy in pastoral zone and 1% in agro-pastoral zone. The low consumption of dairy and meat can be attributed to the nomadic lifestyle. Studies have shown that pastoralist families have long periods of separation from their livestock which would otherwise provide milk and meat if their settlements were more permanent (Mckune et al., 2015). Additionally, low consumption of milk and dairy products in African countries is linked to socio-economic and cultural factors including price, number of young children, income level, education level, gender and age (Bousbia et al., 2017). On the contrary, studies in developed countries show a balanced spread in terms of energy contribution from different food groups, which reflects more dietary diversity (Auestad et al., 2015). However, other studies show a downward trend in milk consumption in the United States and Asia in the past few decades which has been attributed to increased consumption of soft drinks and juices (Kearney, 2010).

Energy contribution from vegetables and fruits combined was significantly low (1%) in both zones. Previous studies have shown that low intake of fruits and vegetables is not only influenced by lack of availability and access but also budget constraints, education level, attitudes and beliefs which impact on purchase intention and intake (Huang, Edirisinghe, & Burton-Freeman, 2016). In another study, cost was identified as an important barrier in the consumption of fruits and vegetables among low-income Americans in addition to other factors such as availability, taste and perishability (Sisson, 2002). Studies have also shown that pastoral communities are more vulnerable to undernutrition due to reduced availability of plant species as well as disadvantaged trade between animals and grain products (Mckune et al., 2015).

5.2.3 Energy and nutrient intake

The median energy intake in both zones was 1715kcal which is below the WHO/FAO RNI of 2271kcal for this target group (FANTA, 2014). A previous review associated low energy intake with the high rates of undernutrition in 40 sub-Saharan African countries (Abrahams et al., 2011). However, it is also possible that energy intake was underreported. There is evidence illustrating that observational studies experience limitations related to underreporting of energy intake as well as recall bias; for instance underestimation of portion sizes (Arimond et al., 2010; Auestad et al., 2015; FAO, 2010; Jomaa, Naja, Cheaib, & Hwalla, 2017).

In both zones, high standard deviations were observed with reference to the mean energy intake (pastoral 1873 ±1030kcal; agro-pastoral 1970 ±1173kcal). Studies show that although true inter-individual variations in energy intake exist depending on factors such as basal metabolic rate and physical activity level, variations can also be attributed to measurement errors (Lam & Ravussin, 2017). Other studies in South Asia also illustrate low energy intake among adult non-pregnant women which is not only linked to inadequate dietary consumption but also inadequate empowerment among women which hinders them from making appropriate food choices in relation to household expenditure (Vir, 2016). Additionally, energy intake coupled with micronutrient deficiencies not only leads to reduced adult work productivity but also poses high economic costs (up to 11% of gross domestic product) to affected countries; in particular sub-Sahara and South Asia (Ochieng et al., 2017).

Median intake for all the analyzed nutrients namely; protein, fat, iron, calcium, folate and vitamin A were also below the WHO/FAO RNIs (see **Table 9**). Similar findings were reported in the National Micronutrient Survey (Ministry of Health, 2011). Evidence from sub-Sahara Africa shows that majority of women have intakes below their daily requirements for energy, protein and micronutrients which is linked to low farm and dietary diversity (Jones et al., 2014; Sibhatu et al., 2015). Other studies have shown that women living in rural areas have intakes below RNIs in terms of energy, protein and micronutrients compared to women living in urban areas; which is attributed to higher dietary diversity among urban women (Liu et al., 2014). More evidence suggests that women living in food insecure areas are at higher risk of inadequate nutrient intake because they are more likely to adopt coping mechanisms such as skipping meals to ensure their children have adequate food; this leads to deficiencies and compromised nutritional status (Jomaa et al., 2017).

5.3 Diet modelling using Optifood

5.3.1 Food subgroup and food group constraints

In this study, the food (sub) group constraints for both pastoral and agro-pastoral zones were comparable. Whole grains and grain products (mostly dried maize and maize flour), legumes, added fats and added sugars had the lowest constraints and were consumed by more than 50% of the women. These food (sub) group constraints were consistent with other previous studies in Turkana which associated the high constraints for animal-based foods to high rates of undernutrition in the area (Save the Children, 2013, 2017a). While these diets are largely plant-based, other studies have shown that such diets with limited animal-source or fortified foods have reduced bioavailability of micronutrients and high content of anti-nutrients; which result in micronutrient deficiencies (Demment, Young, & Sensenig, 2003).

Some food (sub) groups including fruits, special/wild fruits, eggs, other animal parts (*e.g.* offal*),* poultry and rabbit were seldom consumed (0-1 maximum weekly constraints) in both pastoral and agro-pastoral zones. Meat, fish and eggs were consumed by less than 50% of women in both zones; hence an average weekly constraint of 1 was assigned for mathematical reasons. Evidence from other studies suggests that consumption of these food groups has a positive correlation with cost which not only explains the high constraints but also the low number of consumers (Darmon et al., 2014). A systematic review including studies from developed countries also illustrated similar findings where increased consumption of meat, fish, vegetables and fruits was associated with higher diet costs (Darmon & Drewnowski, 2015).

Although livestock ownership would be expected to translate to high dairy consumption, this was not the case as demonstrated from the average constraints for dairy (seven). Previous studies in Turkana indicate that fresh milk consumption is affected by lack of pasture and recurrent droughts (Waila, Mahero, Namusisi, Hoffman, & Robertson, 2018). Studies from Ethiopia and Tanzania among pastoralist communities have indicated that during the dry season, the majority of women have to make a trade-off between consuming the little available milk and feeding it to the infants and young children (Ntwenya et al., 2015; Workicho et al., 2016).

5.3.2 Food-based recommendations

After completing the dietary analysis, energy and nutrient intake of women in both pastoral and agro-pastoral zones were found to be below the RNIs (see **Table 9**). The FBRs developed from the NFP diet for women in pastoral and agro-pastoral zones were comparable (see **Table 11**); which can be linked to similarities observed in terms of socio-demographic characteristics as well as food (sub) group constraints in the two zones (see **Appendices 3 and 4**). The FBRs were formulated based on the food (sub) group constraints of women aged 15-49 years living in pastoral and agro-pastoral zones of Turkana as entered in Optifood (Crampton, 2011). The FBRs were consistent with the Kenya National Guidelines for Healthy Diets and Physical Activity (2017) with the exception of fruits and vegetables. This illustrates that although national dietary guidelines are important for improving the nutrition of a population, such guidelines may not necessarily be feasible at regional/local levels; hence they should be tailored further based on the local context/constraints to increase their adaptability (Bioversity International, 2017).

In the context of current dietary patterns and food (sub) group constraints of women aged 15-49 years living in Turkana, daily FBRs for fruits were not possible. Hence the generated FBRs for fruits, based on NFP diet included two servings per week in pastoral zone and one serving per week in agro-pastoral zone. These FBRs were lower than the national recommendations of five servings of vegetables and fruits per day (Ministry of Health, 2017). Similar studies in Southeast Asia also indicated high constraints particularly for fruits (Santika, Fahmida, & Ferguson, 2009; Skau et al., 2014). In addition, studies have shown that constraints for fresh produce such as vegetables and fruits are higher in the dry season (FANTA, 2014). Although the potential to improve micronutrient intake was high with wild fruits, their consumption was reported by less than 5% of the women in both zones which made the feasibility of including them in the FBRs a challenge. Other studies have shown that including wild foods in modelled diets not only lowers the cost of diet but also helps to meet the recommended iron intakes for women (Termote et al., 2014).

The FBRs for fats and oils based on NFP diet were two servings per day in both pastoral and agro-pastoral zones. As shown in the dietary analysis results (see **Figure 1),** fats and oils contributed 14% of total energy intake in pastoral zone and 15% of total energy intake in agro-pastoral zone. This is below the national recommendations of 30% (Ministry of Health, 2017) as well as the WHO minimum recommendations of 20% energy contribution from dietary fat (FAO, 2010). Although the FBRs suggest more fat intake, emphasis should be given to healthy unsaturated fat including plant oils, nuts, seeds, soya beans and oils from fish (Nair et al., 2016).

FBRs for meat and eggs were quite ambitious (1-2 servings per day) compared to the national recommendations of two servings per week of lean meat, fish, poultry, insects and eggs (Ministry of Health, 2017). Although the FBRs for meat and eggs may not be feasible, they are based on the NFP diet's best possible combination to improve the intake of protein and micronutrients which are more abundant in animal-based foods (Raymond, Kassim, Rose, & Agaba, 2017).

5.3.3 Food subgroup sources of nutrients in non-food pattern diet

The three main food subgroup sources for each of the analyzed nutrients in both zones were as follows: energy (whole grains and grain products, legumes and vegetable oil, protein (red meat, legumes and whole grains and grain products, fat (vegetable oil, milk and red meat), calcium (milk, vitamin C-rich vegetables and vitamin A source dark green leafy vegetables), folate (legumes, vitamin C-rich vegetables and whole grains and grain products), vitamin A (vitamin A source dark green leafy vegetables and milk) and iron (legumes, whole grains and grain products and vitamin C-rich vegetables). These results are consistent with findings from other studies in developing countries which identify starchy plant foods, legumes and milk as the main sources of nutrients; with low consumption of animal-source foods as well as fresh fruits and vegetables (Fahmida et al., 2015; FANTA, 2014; Talsma et al., 2017; Vossenaar et al., 2016).

5.3.4 Problem nutrients

Fat was identified as a partial problem nutrient while calcium and iron were the absolute problem nutrients in the pastoral zone (see **Figure 2).** In the agro-pastoral zone, calcium was a partial problem nutrient while fat and iron were absolute problem nutrients (see figure 3). Considering the dietary constraints of women aged 15-49 years living in Turkana, iron deficits can possibly be addressed through supplementation programs. However, other interventions such as food subsidies particularly for vegetable oil and dairy products coupled with nutrition education are necessary to be able to meet requirements for fat and calcium

(Untoro et al., 2017). Other studies in developing countries have also identified iron, zinc, calcium and fat as problem nutrients during the formulation of complementary feeding recommendations developed in Optifood (Fahmida et al., 2015; Ferguson et al., 2006).

5.4 Developmental relevance of the study

This study conducted a dietary analysis of women aged 15-49 years living in the pastoral and agro-pastoral zones in Turkana County, Kenya. Turkana is one of the poorest counties in Kenya which is disadvantaged in terms dry and arid conditions as well as inadequate access to infrastructure such as road networks and markets (Opiyo et al., 2014). Underlying causes of malnutrition such as household food security cannot be tackled in isolation without addressing the basic determinants of malnutrition. For instance, development projects focusing on improving infrastructure such as roads can go a long way in improving food access and availability hence increase the intake of more nutritious diets. Other interventions such subsidies on nutrient-rich foods or fortified foods can also enhance intake of more nutritious diets (Bioversity International, 2017).

Secondly, although this study focused on women, the findings indicate general dietary patterns of households in Turkana. Economic empowerment of women through livelihood interventions such us microfinance can play an important role in increasing their purchasing power for nutritious foods; for instance animal-source foods which are generally expensive (Arimond et al., 2010). This will not only improve the nutrition status of the women but also of the other household members including children who are also vulnerable. As indicated in this study, although most households in both zones own livestock, consumption of animal-source foods is low. This is because the livestock are not easily slaughtered for food (Schilling et al., 2012). In addition, during the dry season, milk production not only decreases but also the livestock are taken away from the family home in search of pasture (Opiyo et al., 2015). In that regard, other initiatives such as projects targeting women to start up activities like chicken rearing and rearing of small animals like rabbits can increase consumption of animal-source foods and improve the nutrition status of household members.

Dietary habits are also influenced by culture including practices such as food taboos. For instance, there may exist restrictions of specific food items to certain groups in the community especially women and children (Deptford et al., 2017). Such food restrictions may involve nutritious foods which may otherwise be important in meeting nutrient requirements of these population groups (Blasbalg et al., 2011). It is therefore necessary to integrate behavioral change communication approaches into nutrition interventions to ensure acceptability and sustainability of such interventions. Nutrition education involving food preparation and preservation such as drying of vegetables for later use can also enhance intake of nutritious foods even during dry seasons (Hotz et al., 2016). This calls for multi-stakeholder approaches involving sectors such as health, agriculture, education and non-governmental organizations.

5.5 Strengths and limitations

Dietary analysis for different population groups provides information on the different food sources for nutrients. It also forms the basis for nutrition status assessment and informs decisions when planning nutrition interventions (Auestad et al. 2015). Optifood provides a good basis for developing FBRs in the context of locally available foods and current dietary patterns of specific target groups; as was the case for women aged 15-49 years living in pastoral and agro-pastoral zones of Turkana in this study. These FBRs are likely to be more acceptable and sustainable for the target group since they are based on the current food and food (sub) group constraints and do not necessarily involve introduction of new/unfamiliar food items (Darmon & Drewnowski, 2015). In addition, the FBRs in this study were given in terms of food groups instead of specific food items. Such FBRs allow flexibility in choices, seasonality, and availability of different foods while ensuring nutrient requirements are met (Nair et al., 2016).

Optifood provides information on whether locally available foods can provide all nutrients for the target population; if this is not possible it helps to identify the nutrient gaps. By identifying the current food patterns of the target group, for instance number of weekly servings of dairy, Optifood can be useful in informing behavioral change interventions to improve nutrient intake (Darmon et al., 2014). By identifying problem nutrients which are unlikely to be met by the current diets, Optifood sheds more light on the existing gaps in relation to food security such as availability and access of nutrient-dense foods (Daelmans et al., 2013).

This study was conducted in the month of September, during the dry harvest season. Although grains especially maize were in plenty during this season, other food items such as milk, vegetables as well as wild foods were in limited supply. Although wild foods were found to have high potential in improving micronutrient intake, it was not possible to optimize the women's diet with these foods at the time due to seasonality. It is therefore possible that different results would be observed if the same study was to be carried out during the rainy season. Seasonality can influence nutrition status as a result of seasonal dietary variability and micronutrient adequacy; for instance dietary diversity score-women (DDS-W) has been shown to be sensitive to seasons (Caswell et al., 2018).

Although food distribution is common in Turkana, this study did not capture information on whether the women were enrolled in this kind of program or not. Therefore, it was not clear to what extent food aid contributes to dietary intake and the kind of food items provided; whether fortified foods or nutrient supplements. Previous research shows that food aid rations provided up to 40% of poor households' energy requirements in Turkana while 70% of households receive food aid (The Food Economy Group, 2016).

Although Optifood formulated FBRs based on local foods, the feasibility and sustainability of these FBRs cannot be guaranteed due to other influencing factors; most importantly cost.
In addition, the modelled diets were still inadequate in some nutrients including iron calcium and fat which were identified as problem nutrients. The problem nutrients are linked to costly food items which are not easily accessible to poor households. The FBRs based on NFP diet (best-case scenario) are also ambitious and stretched beyond the median consumption patterns of the target group. The FBRs are applicable at individual level and may be challenging to implement in real life considering that individuals do not exist in isolation; for instance women of reproductive age in this study. Studies have shown that household size and composition determine dietary patterns and nutrient adequacy of an individual (Taruvinga et al., 2013).

6. CONCLUSION AND FUTURE PERSPECTIVES

6.1 Conclusion

Undernutrition remains a big health problem, particularly in developing countries where mostly children and women of reproductive age are affected. Dietary analysis for individuals or population groups forms an important part of nutrition status assessment. Dietary analysis also provides the basis for food-based recommendations to improve nutrition status and health of a population. Many developing countries are yet to develop food based-dietary guidelines (FBRs) that can be adopted at regional or national level. More research has to be conducted in order to understand dietary patterns of different population groups and hence formulate feasible food-based dietary guidelines.

This study conducted a dietary analysis of women aged 15-49 years living in pastoral and agro-pastoral livelihood zones in Turkana County, Kenya which facilitated the identification of a number of important food sources for energy and nutrients. A total of 40 food items were identified in both pastoral and agro-pastoral zones which did not only indicate limited choices but also low dietary diversity among the women. This was also reflected in the monotonous diets where the majority of women consumed foods from only four food groups namely fats and oils, added sugars, grain and grain products, legumes and pulses. Energy and nutrient intake for women aged 15-49 years living in pastoral and agro-pastoral zones in Turkana County was inadequate. Dietary patterns of women aged 15-49 years living in pastoral and agro-pastoral zones were comparable.

After establishing that energy and nutrient intakes of women aged 15-49 years living in pastoral and agro-pastoral zones in Turkana were inadequate, the potential to optimize their diet was investigated using Optifood. The 40 food items identified from the dietary analysis formed the basis for developing FBRs while putting into consideration the food and food (sub) group constraints in the pastoral and agro-pastoral zones. The FBRs for women in pastoral and agro-pastoral zones were more or less comparable which can be explained by the similarities in their food and food (sub) group constraints as well as socio-demographic characteristics. The FBRs in terms of servings per day for different food groups were as follows: vegetables (3-4 servings), dairy and dairy products (2-3 servings), fats and oils (2 servings), meat, fish and eggs (1-2 servings), grains and grain products (2-3 servings) and legumes and nuts (2 servings).

In the context of the current food and food (sub) group constraints in the two zones, daily FBRs for fruits were not feasible and hence 1-2 servings of fruits per week were recommended. Although two wild fruits were reported in this study *i.e. Boscia conacea* in the pastoral zone and *Hyphaene compressa* in the agro-pastoral zone, their consumption was reported by less than 5% of the women. These wild fruits were therefore excluded from the Optifood model even though they had potential to improve micronutrient intake among the target group. Added sugars, starchy roots and condiments were omitted automatically from the generated FBRs from Optifood.

Although national guidelines for improving nutrition at population level are important this study illustrates that such guidelines may not be necessarily feasible in all contexts across the country. Therefore, it may be necessary to formulate food-based dietary guidelines tailored within the context of local dietary constraints in different regions of the country. Such constraints relate to the four pillars of food security namely availability, access, utilization and stability.

Additionally, although FBRs have the potential to improve the nutrient intake of specific target groups, they may not necessarily ensure dietary adequacy for all nutrients. This was illustrated in this study where modelled diets were still inadequate in problem nutrients such as iron calcium and fat. This calls for combining FBRs with other nutrition specific interventions such as food fortification and micronutrient supplementation as well as nutrition sensitive interventions such food subsidies and cash transfer programs to help in improving access to nutrient rich foods; in particular animal-source foods.

6.2 Future perspectives

This study was conducted during the dry harvest season. Future research should assess dietary patterns in other seasons of the year and determine which foods are available in those seasons. This can allow for formulation of more comprehensive FBRs based on what is locally available during the different seasons. Further research is also required to investigate whether seasonality has an influence on nutrition status. In this study, draft FBRs in Module 2 were based only on food and food (sub) group constraints as reflected in the women's dietary data. Further research should be done to test different sets of FBRs based on different scenarios (*e.g.* adding nutrient-dense foods which were consumed by less than 5% of the target group); this could help address the adequacy of problem nutrients. Finally, due to the limited time frame of this thesis, this study did not include cost in the Optifood model; this can be explored in future research to allow developing FBRs based not only on current dietary patterns but also on cost constraints.

REFERENCES

Abrahams, Z., Mchiza, Z., & Steyn, N. P. (2011). Diet and mortality rates in Sub-Saharan Africa : Stages in the nutrition transition. *BMC Public Health*, *11*(1), 801. https://doi.org/10.1186/1471-2458-11-801

Agricultural Sector Coordination Unit. (2011). *National Food and Nutrition Security Policy*. Retrieved from https://extranet.who.int/nutrition/gina/en/node/11501

Allen, L., Benoist, B. De, Dary, O., & Hurrell, R. (2006). *Guidelines on food fortification with micronutrients*. Geneva. Retrieved from http://www.who.int/nutrition/publications/guide_food_fortification_micronutrients.pdf

Arimond, M., Wiesmann, D., Becquey, E., Carriquiry, A., Daniels, M. C., Deitchler, M., … Martin-prevel, Y. (2010). Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women 's Diets in 5 Diverse, Resource-Poor Settings. *The Journal of Nutrition*, *140*(11), 2059–2069. https://doi.org/10.3945/jn.110.123414.2059S

Auestad, N., Hurley, J. S., Victor, F. L., & Schweitzer, C. M. (2015). Contribution of Food Groups to Energy and Nutrient Intakes in Five Developed Countries. *Nutrients*, *7*, 4593–4618. https://doi.org/10.3390/nu7064593

Azadbakht, L., & Esmaillzadeh, A. (2010). Dietary diversity score is related to obesity and abdominal adiposity among Iranian female youth. *Public Health Nutrition*, *14*(1), 62–69. https://doi.org/10.1017/S1368980010000522

Barahona, C. (2015). How resilient are farming households and communities to a changing climate in Africa ? A gender-based perspective. *Global Environmental Change, Elsevier*, *34*, 95–107. https://doi.org/10.1016/j.gloenvcha.2015.06.003

Bioversity International. (2017). *Mainstreaming agrobiodiversity in sustainable food systems: Scientific foundations for an agrobiodiversity index*. (P. W. Walter de Boef, Marie Haga, Lindiwe Sibanda, Prof. MS Swaminathan & Technical, Eds.). Rome.

Blasbalg, T. L., Wispelwey, B., & Deckelbaum, R. J. (2011). Econutrition and utilization of food-based approaches for nutritional health. *Food and Nutrition Bulletin*, *32*(1), 4–13. https://doi.org/10.1177/15648265110321S102

Boedecker, J., Odhiambo, F., & Termote, C. (2016). *Innovative , participatory tools for dietary assessment and nutrition education considering local agrobiodiversity*. Nairobi. Retrieved from https://www.giz.de/fachexpertise/downloads/giz2016-en-beaf-list-bmz-funded-projects.docx

Bousbia, A., Sofiane, B., Sarra, C., Karima, O., Hanane, A., Mohamed, B., … Sofiane, H. (2017). Analysis of Factors Affecting Consumer Behavior of Dairy Products in Algeria: A Case Study from the Region of Guelma. *International Journal of Agricultural Research*, *12*(2), 93–101. https://doi.org/10.3923/ijar.2017.93.101

Briend, A., & Erhardt, J. (2018). Linear Programming Module of NutriSurvey. Retrieved March 27, 2018, from http://www.nutrisurvey.de/lp/lp.htmhttp://www.nutrisurvey.de/lp/lp.htm

Carletto, C., Zezza, A., & Banerjee, R. (2013). Towards better measurement of household food security : Harmonizing indicators and the role of household surveys. *Global Food Security*, *2*(1), 30–40. https://doi.org/10.1016/j.gfs.2012.11.006

Caswell, B. L., Talegawkar, S. A., Siamusantu, W., West, K. P., & Palmer, A. C. (2018). A 10-Food Group Dietary Diversity Score Outperforms a 7-Food Group Score in Characterizing Seasonal Variability and Micronutrient Adequacy in Rural Zambian Children. *American Society for Nutrition*, *148*(July), 131–139. https://doi.org/https://doi.org/10.1093/jn/nxx011

Chakona, G. (2017). Minimum Dietary Diversity Scores for Women Indicate Micronutrient Adequacy and Food Insecurity Status in South African Towns. *Nutrients*, *9*(812). https://doi.org/10.3390/nu9080812

Crampton, K. (2011). User Manual WHO , FANTA2 Optifood. Retrieved from https://www.fantaproject.org/tools/optifood
Daelmans, B., Ferguson, E., Lutter, C. K., Singh, N., Pachón, H., Creed-Kanashiro, H., … Briend, A. (2013). Designing appropriate complementary feeding recommendations: Tools for programmatic action. *Maternal and Child Nutrition*, *9*(S2), 116–130. https://doi.org/10.1111/mcn.12083
Darmon, N., Buttriss, J. L., Briend, A., Ferguson, E. L., Maillot, M., & Lluch, A. (2014). Diet modelling : How it can inform the development of dietary recommendations and public health policy. *Nutrition Bulletin*, *39*(March), 115–125. https://doi.org/10.1111/nbu.12076
Darmon, N., & Drewnowski, A. (2015). Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: A systematic review and analysis. *Nutrition Reviews*, *73*(10), 643–660. https://doi.org/10.1093/nutrit/nuv027
Darmon, N., Ferguson, E., & Briend, A. (2002). Linear and non-linear programming to optimize the nutrient density of a population's diet: an example based on diets of preschool children in rural Malawi. *American Journal of Clinical Nutrition*, *75*(2), 245–253. https://doi.org/https://doi.org/10.1093/ajcn/75.2.245
Daudet, A. (2012). *"Wild" foods and their potential for undernutrition prevention*. Retrieved from http://www.actionagainsthunger.org/sites/default/files/publications/Wild_foods_and_their_potential_for_undernutrition_prevention_06.2012.pdf
Demment, M. W., Young, M. M., & Sensenig, R. L. (2003). Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries. *Journal of Nutrition*, *133*(March), 3879–3885.
Deptford, A., Allieri, T., Childs, R., Damu, C., Ferguson, E., Hilton, J., … Hall, A. (2017). Cost of the Diet: a method and software to calculate the lowest cost of meeting recommended intakes of energy and nutrients from local foods. *BMC Nutrition*, *3*(1), 26. https://doi.org/10.1186/s40795-017-0136-4
Ember, C. R., Adem, T. A., Skoggard, I., Jones, E. C., Ember, C. R., Adem, T. A., … Jones, E. C. (2012). Livestock Raiding and Rainfall Variability in Northwestern Kenya Livestock Raiding and Rainfall Variability in Northwestern Kenya. *Civil Wars*, *14*(2), 159–181. https://doi.org/10.1080/13698249.2012.679497
Fahmida, U., Kolopaking, R., Santika, O., Sriani, S., Umar, J., Htet, M. K., & Ferguson, E. (2015). Effectiveness in improving knowledge , practices , and intakes of " key problem nutrients " of a complementary feeding intervention developed by using linear programming : experience in Lombok , Indonesia 1 – 3. *The American Journal of Clinical Nutrition*, *101*(3), 445–461. https://doi.org/https://doi.org/10.3945/ajcn.114.087775
Fahmida, U., Santika, O., Kolopaking, R., & Ferguson, E. (2014). Complementary feeding recommendations based on locally available foods in Indonesia. *Food and Nutrition Bulletin*, *35*(4), 174–179. https://doi.org/10.1177/15648265140354S302
FANTA. (2014). SUMMARY REPORT: Development of Evidence-Based Dietary Recommendations for Children, Pregnant Women, and Lactating Women Living in the Western Highlands of Guatemala, (June 2014), 152. Retrieved from www.fantaproject.org
FAO/WHO. (2002). *Human Vitamin and Mineral Requirements*. Rome. Retrieved from http://www.fao.org/docrep/004/Y2809E/y2809e00.htm
FAO. (2010). *Fats and fatty acids in Human Nutrition* (Vol. 91). Geneva. Retrieved from http://www.who.int/nutrition/publications/nutrientrequirements/fatsandfattyacids_humannutrition/en/

FAO. (2011). *Guidelines for measuring household and individual dietary diversity*. Retrieved from http://www.fao.org/fileadmin/user_upload/wa_workshop/docs/FAO-guidelines-dietary-diversity2011.pdf

FAO, IFAD, UNICEF, WFP, & WHO. (2017). The State of Food Security and Nutrition in the World. *FAO, Rome, Italy*. Retrieved from http://www.fao.org/state-of-food-security-nutrition/en/

Ferguson, E. L., Darmon, N., Fahmida, U., Fitriyanti, S., Harper, T. B., & Premachandra, I. M. (2006). Design of optimal food-based complementary feeding recommendations and identification of key "problem nutrients" using goal programming. *The Journal of Nutrition*, *136*(9), 2399–404. https://doi.org/http://jn.nutrition.org/content/suppl/2006/08/21/136.9.2399

Gibson, R. S., & Ferguson, E. L. (2008). *An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries*. Retrieved from https://assets.publishing.service.gov.uk/media/57a08bac40f0b64974000cd6/tech08.pdf

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., … Toulmin, C. (2010). Food Security: The Challenge of feeding 9 Billion People. *Science*, *327*(February), 812–818. https://doi.org/10.1126/science.1185383

Hotz, C., Pelto, G., Armar-klemesu, M., Ferguson, E. F., Chege, P., & Musinguzi, E. (2016). Constraints and opportunities for implementing nutrition- specific , agricultural and market-based approaches to improve nutrient intake adequacy among infants and young children in two regions of rural Kenya. *Maternal & Child Nutrition*, *11*, 39–54. https://doi.org/10.1111/mcn.12245

Huang, Y., Edirisinghe, I., & Burton-Freeman, B. M. (2016). Low-Income Shoppers and Fruit and Vegetables. *Nutrition Today*, *51*(5). https://doi.org/10.1097/NT.0000000000000176

Jomaa, L., Naja, F., Cheaib, R., & Hwalla, N. (2017). Household food insecurity is associated with a higher burden of obesity and risk of dietary inadequacies among mothers in Beirut, Lebanon. *BMC Public Health*, *17*(567), 1–14. https://doi.org/10.1186/s12889-017-4317-5

Jones, A. D. (2017). Critical review of the emerging research evidence on agricultural biodiversity , diet diversity , and nutritional status in low- and middle-income countries. *Nutrition Reviews*, *75*(10), 769–782. https://doi.org/10.1093/nutrit/nux040

Jones, A. D., Shrinivas, A., & Bezner-kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi : Findings from nationally representative data. *Food Policy, Esevier*, *46*, 1–12. https://doi.org/10.1016/j.foodpol.2014.02.001

Kearney, J. (2010). Food consumption trends and drivers. *Philisophical Transactions of the Royal Society*, *365*, 2793–2807. https://doi.org/10.1098/rstb.2010.0149

Kenya Agricultural Research Institute. (2012). *Food Security Report (Prepared by Kenya Agricultural Research Institute*. *Food Security Portal*. Retrieved from http://www.foodsecurityportal.org/kenya/food-security-report-prepared-kenya-agricultural-research-institute

Kenya National Bureau of Statistics. (2014). *Kenya Demographic and Health Survey*. Nairobi. Retrieved from https://dhsprogram.com/pubs/pdf/fr308/fr308.pdf

Kenya National Bureau of Statistics, Population Studies and Research Institute, & UNICEF. (2016). *Turkana County , Kenya Multiple Indicator Cluster Survey , 2013/14*. Nairobi. Retrieved from http://microdata.worldbank.org/index.php/catalog/2657/study-description

Koppmair, S., Kassie, M., & Qaim, M. (2016). Farm production , market access and dietary diversity in Malawi. *Public Health Nutrition*, *20*(2), 325–335.

https://doi.org/10.1017/S1368980016002135
Lachat, C., Raneri, J. E., Walker, K., Kolsteren, P., Damme, P. Van, Verzelen, K., … Oduor, F. (2018). Dietary species richness as a measure of food biodiversity and nutritional quality of diets. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(1), 127–132. https://doi.org/10.1073/pnas.1709194115
Lam, Y. Y., & Ravussin, E. (2017). Variations in energy intake : it is more complicated than we think. *American Journal of Clinical Nutrition*, *106*, 2017–2018. https://doi.org/10.3945/ajcn.117.167742
Lartey, A. (2008). *Maternal and child nutrition in Sub-Saharan Africa: challenges and interventions*. *Proceedings of the Nutrition Society* (Vol. 67). https://doi.org/https://doi.org/10.1017/S0029665108006083
Lawrence, M., Wingrove, K., Naude, C., & Durao, S. (2016). Evidence Synthesis and Translation for Nutrition Interventions to Combat Micronutrient Deficiencies with Particular Focus on Food Fortification. *Nutrients*, *8*(555), 1–11. https://doi.org/10.3390/nu8090555
Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., … Ezzati, M. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, *380*, 2224–2260. https://doi.org/10.1016/S0140-6736(12)61766-8
Liu, J., Shively, G., & Binkley, J. (2014). Access to variety contributes to dietary diversity in China. *Food Policy, Esevier*, *49*(P1), 323–331. https://doi.org/10.1016/j.foodpol.2014.09.007
M'Kaibi, F., Steyn, N., Ochola, S., & Du Plessis, L. (2015). Effects of agricultural biodiversity and seasonal rain on dietary adequacy and household food security in rural areas of Kenya. *BMC Public Health*, *15*(1), 1–11. https://doi.org/10.1186/s12889-015-1755-9
Malapit, H. J. L., & Quisumbing, A. R. (2015). What dimensions of women ' s empowerment in agriculture matter for nutrition in Ghana ? *Food Policy, Esevier*, *52*, 54–63. https://doi.org/10.1016/j.foodpol.2015.02.003
Martinez, S., Hand, M., Pra, M. Da, Pollack, S., Ralston, K., Smith, T., … Newman, C. (2010). *Local Food Systems: Concepts, Impacts, and Issues, ERR 97*. *U.S. Department of Agriculture, Economic Research Service*. Retrieved from https://www.researchgate.net/publication/46444627_Local_Food_Systems_Concepts_Impacts_and_Issues
Mbogori, T., & Murimi, M. (2017). Determinants of maternal and child malnutrition among low income households in Turkana County, Kenya. *The FASEB Journal*, *31*(1). Retrieved from https://www.fasebj.org/doi/10.1096/fasebj.31.1_supplement.786.54
Mchiza, Z. J., Steyn, N. P., Hill, J., Kruger, A., Nel, J., Wentzel-viljoen, E., … Africa, S. (2015). A Review of Dietary Surveys in the Adult South African Population from 2000 to 2015. *Nutrients*, *7*, 8227–8250. https://doi.org/10.3390/nu7095389
Mckune, S. L., Borresen, E. C., Young, A. G., Auria, T. D., Russo, S. L., Diao, A., … Ryan, E. P. (2015). Climate change through a gendered lens : Examining livestock holder food security. *Global Food Security, Elsevier*, *6*, 1–8. https://doi.org/10.1016/j.gfs.2015.05.001
Ministry of Health. (2011). *The Kenya National Micronutrient Survey*. Retrieved from http://www.nutritionhealth.or.ke/wp-content/uploads/Downloads/The Kenya National Micronutrient Survey 2011.pdf
Ministry of Health. (2017). *National Guidelines for Healthy Diets and Physical Activity*. Nairobi.

Ministry of Public Health and Sanitation. (2012). *National Nutrition Action Plan 2012-2017-Kenya*. Retrieved from https://scalingupnutrition.org/wp-content/uploads/2013/10/Kenya-National-Nutrition-Action-Plan-2012-2017-final.pdf

Nair, M. K., Augustine, L. F., & Konapur, A. (2016). Food-Based interventions to Modify Diet Quality and Diversity to Address Multiple Micronutrient Deficiency. *Frontiers in Public Health*, *3*(277), 1–14. https://doi.org/10.3389/fpubh.2015.00277

Ntwenya, J. E., Kinabo, J., Msuya, J., & Mamiro, P. (2015). Dietary Patterns and Household Food Insecurity in Rural Populations of Kilosa District , Tanzania. *PLoS Medicine ONE*, *10*(5), 1–13. https://doi.org/10.1371/journal.pone.0126038

Ochieng, J., Afari-sefa, V., Lukumay, P. J., & Dubois, T. (2017). Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. *PLoS ONE*, *12*(12), 1–18. https://doi.org/https://doi.org/10.1371/journal. pone.0189022

Omolo, N. A. (2010). Gender and climate change-induced conflict in pastoral communities : Case study of Turkana in north- western Kenya. *The African Journal on Conflict Resolution*, 81–102. Retrieved from http://www.accord.org.za/ajcr-issues/￼gender-and-climate-change-induced-conflict-in-pastoral-communities/

Opiyo, F., Wasonga, O., Nyangito, M., & Schilling, J. (2015). Drought Adaptation and Coping Strategies Among the Turkana Pastoralists of Northern Kenya. *International Journal of Disaster Risk Science*, *6*(3), 295–309. https://doi.org/10.1007/s13753-015-0063-4

Opiyo, F., Wasonga, O. V, & Nyangito, M. M. (2014). Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya : Implications for resilience programming. *Pastoralism: Research, Policy and Practice*, *4*(10), 1–15. https://doi.org/https://doi.org/10.1186/s13570-014-0010-9

Osarfo, D., Senadza, B., & Nketiah-Amponsah, E. (2016). The Impact of Nonfarm Activities on Rural Farm Household Income and Food Security in the Upper East and Upper West Regions of Ghana. *Theoretical Economics Letters*, *6*, 388–400. https://doi.org/http://dx.doi.org/10.4236/tel.2016.63043

Pandey, V. L., Dev, S. M., & Jayachandran, U. (2016). Impact of agricultural interventions on the nutritional status in South Asia : A review. *Food Policy, Esevier*, *62*, 28–40. https://doi.org/http://dx.doi.org/10.1016/j.foodpol.2016.05.002 0306-9192/?

Raymond, J., Kassim, N., Rose, J. W., & Agaba, M. (2017). Optimal formulations of local foods to achieve nutritional adequacy for 6 – 23-month-old rural Tanzanian children. *Food & Nutrition Research*, *61*(1). https://doi.org/https://doi.org/10.1080/16546628.2017.1358035 ARTICLE

Rutishauser, I. H. (2005). Dietary intake measurements. *Public Health Nutrition*, *8*(7A), 1100–1107. https://doi.org/10.1079/PHN2005798

Santika, O., Fahmida, U., & Ferguson, E. L. (2009). Development of Food-Based Complementary Feeding Recommendations for 9- to 11-Month-Old Peri-Urban Indonesian Infants Using Linear Programming. *The Journal of Nutrition*, *139*(1), 135–141. https://doi.org/https://doi.org/10.3945/jn.108.092270

Sarfo, J., Termote, C., Keding, G., Boedecker, J., & Pawelzik, E. (2017). Effects of Wild Foods and Food Interventions in reducing the minimum Cost of Diet using Linear Programming Modelling: A case study of Turkana in Kenya. In *3rd International Congress Hidden Hunger: Post-2015 Agenda and Sustainable Developmental Goals (SDG): Where are we now? Strategies to improve nutrition quality and combat hidden hunger*. Stuttgart. Retrieved from http://hdl.handle.net/10568/81254

Save the Children. (2013). *A Cost of the Diet analysis in the Kerio agropastoral livelihood zone of Turkana.* Nairobi. Retrieved from file:///H:/Downloads/CoD Turkana Agropastoral Report 2012.pdf

Save the Children. (2017a). *A Cost of the Diet analysis in Turkana County, Kenya: Central Pastoral Livelihood Zone*. Nairobi. Retrieved from https://resourcecentre.savethechildren.net/library/cost-diet-analysis-turkana-county-kenya

Save the Children. (2017b). *A desk review of key determinants of malnutrition in Turkana County , Kenya*. Nairobi. Retrieved from http://www.nutritionhealth.or.ke/wp-content/uploads/Downloads/Desk Review of Key Determinants of Malnutrition in Turkana County - July 2017.pdf

Schilling, J., Opiyo, F. E., & Scheffran, J. (2012). Raiding pastoral livelihoods: motives and effects of violent conflict in north-western Kenya. *Pastoralism: Research, Policy and Practice*, *2*(25). https://doi.org/10.1186/2041-7136-2-25

Shisanya, C. A., Recha, C., & Anyamba, A. (2011). Rainfall Variability and Its Impact on Normalized Difference Vegetation Index in Arid and Semi-Arid Lands of Kenya. *International Journal of Geosciences*, *02*(01), 36–47. https://doi.org/10.4236/ijg.2011.21004

Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, *112*(34), 10657–10662. https://doi.org/10.1073/pnas.1510982112

Sibhatu, K. T., & Qaim, M. (2017). Rural food security, subsistence agriculture, and seasonality. *PLoS ONE*, *12*(10), 1–15. https://doi.org/https://doi.org/ 10.1371/journal.pone.0186406 Editor:

Sisson, A. (2002). Fruit and Vegetable Consumption by Low-Income Americans. *Nutrition Noteworthy*, *5*(1). Retrieved from https://escholarship.org/uc/item/4kc331x6

Skau, J. K. H., Bunthang, T., Chamnan, C., Wieringa, F. T., Dijkhuizen, M. A., Roos, N., & Ferguson, E. L. (2014). The use of linear programming to determine whether a formulated complementary food product can ensure adequate nutrients for 6- to 11-month-old Cambodian infants 1 – 3. *The American Journal of Clinical Nutrition*, *99*, 130–138. https://doi.org/10.3945/ajcn.113.073700

Speca, A. (2013). *Kenya Food Security Brief*. Nairobi. Retrieved from http://www.fews.net/sites/default/files/documents/reports/Kenya_Food Security_In_Brief_2013_final_0.pdf

Talsma, E. F., Borgonjen-van den Berg, K. J., Melse-Boonstra, A., Mayer, E. V, Verhoef, H., Demir, A. Y., … Brouwer, I. D. (2017). The potential contribution of yellow cassava to dietary nutrient adequacy of primary-school children in Eastern Kenya; the use of linear programming. *Public Health Nutrition*, *21*(2), 365–376. https://doi.org/10.1017/S1368980017002506

Taruvinga, A., Muchenje, V., & Mushunje, A. (2013). Determinants of rural household dietary diversity : The case of Amatole and Nyandeni districts , South Africa. *International Journal of Development Sustainability*, *2*(4), 2233–2247. https://doi.org/IJDS13060305

Termote, C., Raneri, J., Deptford, A., & Cogill, B. (2014). Assessing the potential of wild foods to reduce the cost of a nutritionally adequate diet: An example from eastern Baringo District, Kenya. *Food and Nutrition Bulletin*, *35*(4), 458–479. https://doi.org/10.1177/156482651403500408

The Food Economy Group. (2016). *Livelihood Profiles Baseline Update Six Livelihood Zones in Turkana County, Kenya*. Retrieved from https://kenya.savethechildren.net/sites/kenya.savethechildren.net/files/library/Turkana HEA Baselines Report December2016.pdf

The Food Economy Group. (2018). Livelihood Zoning. Retrieved May 18, 2018, from https://foodeconomy.com/household-economy-analysis-services/livelihood-zoning/

Turkana County Department of Health. (2016). *Turkana SMART Nutrition Surveys*. Retrieved from http://www.nutritionhealth.or.ke/wp-content/uploads/SMART Survey Reports/Turkana County SMART Survey Report - June 2017.pdf

UGent Research Group Food Chemistry and Human Nutrition. (2017). Lucille: software to process your food intake data. Retrieved April 25, 2018, from http://www.foodscience.ugent.be/nutriFOODchem/foodintake

UNICEF. (2014). *Multi-sectoral Approaches to Nutrition :* Retrieved from http://www.unicef.org/eu/files/101322_000_Unicef_Brief_NutritionOverview_A4_v1r15.pdf

Untoro, J., Rudert, C., Childs, R., Bose, I., Hall, A., & Pee, S. De. (2017). Tools to improve planning , implementation , monitoring , and evaluation of complementary feeding programmes. *Maternal & Child Nutrition*, *13*(August 2016), 1–16. https://doi.org/10.1111/mcn.12438

Vir, S. C. (2016). Review Article Improving women ' s nutrition imperative for rapid reduction of childhood stunting in South Asia : coupling of nutrition specific interventions with nutrition sensitive measures essential. *Maternal & Child Nutrition*, *12*(1), 72–90. https://doi.org/10.1111/mcn.12255

Vossenaar, M., Knight, F. A., Tumilowicz, A., Hotz, C., Chege, P., & Ferguson, E. L. (2016). Context-specific complementary feeding recommendations developed using Optifood could improve the diets of breast-fed infants and young children from diverse livelihood groups in northern Kenya. *Public Health Nutrition*, *20*(6), 971–983. https://doi.org/10.1017/S1368980016003116

Waila, M., Mahero, M., Namusisi, S., Hoffman, S., & Robertson, C. (2018). Outcomes of Climate Change in a Marginalized Population : An Ethnography on the Turkana Pastoralists in Kenya. *American Journal of Public Health*, *108*(S2), 2017–2018. https://doi.org/10.2105/AJPH.2017.304063

WHO. (2017). Malnutrition in the crosshairs. In *The International Symposium on Sustainable Food Systems for Healthy Diets and Improved Nutrition (1-2 December)* (pp. 1–3). Rome. Retrieved from http://www.who.int/nutrition/pressrelease-FAOWHO-symposium-malnutrition/en/

Workicho, A., Belachew, T., Feyissa, G. T., Wondafrash, B., Lachat, C., Verstraeten, R., & Kolsteren, P. (2016). Household dietary diversity and Animal Source Food consumption in Ethiopia : evidence from the 2011 Welfare Monitoring Survey. *BMC Public Health*, 1–11. https://doi.org/10.1186/s12889-016-3861-8

APPENDICES

Appendix 1: Food lists, median serving size and frequency for the pastoral zone as entered into Optifood

Food	Group	Sub Group	Median serving Size (g)	Min #serves/ week	Max #serves/ week
Vegetable oil	Added fats	Vegetable oil (unfortified)	18	0	14
Sugars, granulated	Added sugars	Sugar (non-fortified)	39	0	14
Bread, pita ,white, fresh[a]	Bakery & breakfast cereals	Refined grain bread, unenriched/unfortified	150	0	7
Bread, wheat, refined (white),fresh[a]	Bakery & breakfast cereals	Refined grain bread, unenriched/unfortified	200	0	7
Milk, cow, dry/powder, whole	Dairy products	Fluid or powdered milk (non-fortified)	23	0	7
Milk, cow, whole, 3.25% milk fat, fresh ,fluid	Dairy products	Fluid or powdered milk (non-fortified)	56	0	7
Milk, goat, fresh/fluid	Dairy products	Fluid or powdered milk (non-fortified)	69	0	7
Bosciaconacea (edung)[b]	Fruits	Special Fruits	43	0	7
Rice, white, medium-grain, boiled[a]	Grains & grain products	Refined grains and products, unenriched/unfortified	156	0	7
Spaghetti, wheat, dried, cooked[a]	Grains & grain products	Refined grains and products, unenriched/unfortified	101	0	7
Maize flour, whole, white variety, stiff porridge, boiled[a]	Grains & grain products	Whole grains and products, unenriched/unfortified	175	0	14
Maize grain, whole, white variety, dried, boiled ,drained[a]	Grains & grain products	Whole grains and products, unenriched/unfortified	190	0	14
Millet flour, stiff porridge, boiled	Grains & grain products	Whole grains and products, unenriched/unfortified	111	0	7
Beans, kidney, mature/dried, boiled, drained	Legumes, nuts & seeds	Cooked beans, lentils, peas	89	0	14
Lentils, mature/dried, boiled, drained	Legumes, nuts & seeds	Cooked beans, lentils, peas	186	0	7
Egg, chicken, whole, cooked, scrambled	Meat, fish & eggs	Eggs	67	0	7
Game meat, rabbit/hare, dried, boiled	Meat, fish & eggs	Poultry, rabbit	89	0	1
Beef, composite of trimmed retail cuts, separable lean & fat	Meat, fish & eggs	Red meat	92	0	7
Camel meat	Meat, fish & eggs	Red meat	143	0	7
Game meat, antelope, fresh, roasted	Meat, fish & eggs	Red meat	78	0	1
Goat meat, fresh, boiled, drained	Meat, fish & eggs	Red meat	67	0	7
Potatoes, flesh only, boiled, wo/skin	Starchy roots & other starchy plant foods	Other starchy plant foods	87	0	7
Onion, fresh, raw	Vegetables	Condiment vegetables	11	0	14
Cowpea fresh leaves, simmered	Vegetables	Other vegetables	113	0	7
Eggplant ,fresh, steamed	Vegetables	Other vegetables	34	0	7
Kale, leaves, fresh, raw	Vegetables	Vitamin A source dark green leafy vegetables	112	0	7
Cabbage, green, fresh, fried	Vegetables	Vitamin C-rich vegetables	168	0	7
Tomatoes, red, ripe, fresh, cooked	Vegetables	Vitamin C-rich vegetables	38	0	7

[a] Staple
[b] Snack

Appendix 2: Food lists, median serving size and frequency for the agro-pastoral zone as entered into Optifood

Food	Group	Sub Group	Median serving Size (g)	Min #serves/ week	Max #serves/ week
Vegetable oil	Added fats	Vegetable oil (unfortified)	21	0	14
Sugars, granulated	Added sugars	Sugar (non-fortified)	34	0	14
Bread, pita, white, fresh (chapati)[a]	Bakery & breakfast cereals	Refined grain bread, unenriched/unfortified	90	0	7
Bread, wheat, refined (white),fresh[a]	Bakery & breakfast cereals	Refined grain bread, unenriched/unfortified	72	0	7
Milk, camel, whole, fluid, fresh	Dairy products	Fluid or powdered milk (non-fortified)	152	0	7
Milk, cow, dry/powder, whole	Dairy products	Fluid or powdered milk (non-fortified)	16	0	7
Milk, cow, whole, 3.25% milk fat, fresh ,fluid	Dairy products	Fluid or powdered milk (non-fortified)	41	0	7
Milk, goat, fresh/fluid	Dairy products	Fluid or powdered milk (non-fortified)	134	0	7
Fermented milk	Dairy products	Other dairy excluding butter	62	0	7
Hyphaenecompressa(eng'ol)	Fruits	Special Fruits	300	0	1
Banana, ripe, fresh, raw[b]	Fruits	Other fruit	74	0	1
Rice, white, medium-grain, boiled[a]	Grains & grain products	Refined grains and products, unenriched/unfortified	161	0	7
Spaghetti, wheat, dried, cooked	Grains & grain products	Refined grains and products, unenriched/unfortified	156	0	7
Maize flour, white variety, whole-grain, stiff porridge, boiled[a]	Grains & grain products	Whole grains and products, unenriched/unfortified	205	7	14
Maize grain, whole, white variety, dried, boiled ,drained[a]	Grains & grain products	Whole grains and products, unenriched/unfortified	168	0	14
Millet flour ,stiff porridge, boiled	Grains & grain products	Whole grains and products, unenriched/unfortified	81	0	1
Sorghum flour, stiff porridge,boiled	Grains & grain products	Whole grains and products, unenriched/unfortified	115	0	1
Beans, kidney, mature/dried, boiled, drained	Legumes, nuts & seeds	Cooked beans, lentils, peas	94	0	14
Pigeon peas (red gram), mature/ dried ,boiled, drained	Legumes, nuts & seeds	Cooked beans, lentils, peas	54	0	14
Beef, tripe, fresh, simmered	Meat, fish & eggs	Other animal parts	107	0	1
Goat meat, fresh, boiled, drained	Meat, fish & eggs	Red meat	115	0	7
Potatoes, flesh only, boiled, wo/skin	Starchy roots & other starchy plant foods	Other starchy plant foods	118	0	7
Onion, fresh, raw	Vegetables	Condiment vegetables	13	0	14
Cowpea fresh leaves, simmered	Vegetables	Other vegetables	132	0	7
Kale, leaves, fresh, raw	Vegetables	Vitamin A source dark green leafy vegetables	166	0	7
Cabbage, green, fresh, fried	Vegetables	Vitamin C-rich vegetables	176	0	7
Tomatoes, red, ripe, fresh, cooked	Vegetables	Vitamin C-rich vegetables	57	0	7

[a] Staple
[b] Snack

Appendix 3: Food subgroup constraints as entered into Optifood for pastoral and agro-pastoral zones

	Pastoral		Agro-pastoral	
Food Sub Group	**Low Servings/Week**	**High Servings/Week**	**Low Servings/Week**	**High Servings/ eek**
Vegetable oil (unfortified)	0	14	0	14
Sugar (non-fortified)	0	14	0	14
Refined grain bread, unenriched/unfortified	0	1	0	7
Fluid or powdered milk (non-fortified)	0	14	0	14
Other dairy excluding butter	0	0	0	7
Special Fruits	0	1	0	1
Other fruit	0	0	0	1
Refined grains and products, unenriched/unfortified	0	1	0	7
Whole grains and products, unenriched/unfortified	7	21	7	21
Cooked beans, lentils, peas	0	14	0	14
Eggs	0	0	0	0
Other animal parts	0	0	0	0
Poultry, rabbit	0	0	0	0
Red meat	0	7	0	7
Other starchy plant foods	0	1	0	7
Condiment vegetables	0	14	0	14
Other vegetables	0	7	0	7
Vitamin A source dark green leafy vegetables	0	7	0	7
Vitamin C-rich vegetables	0	14	0	7

Appendix 4: Food group constraints as entered into Optifood for pastoral and agro-pastoral zones

	Pastoral			Agro-pastoral		
Food Group	**Low Servings/ Week**	**Average Servings/ Week**	**High Servings/ Week**	**Low Servings/ Week**	**Average Servings/ Week**	**High Servings/ Week**
Added fats	0	7	14	0	7	14
Added sugars	0	7	14	0	7	14
Bakery & breakfast cereals	0	1	7	0	1	7
Dairy products	0	7	21	0	7	21
Fruits	0	1	2	0	1	2
Grains & grain products	7	14	28	7	14	28
Legumes, nuts & seeds	0	7	14	0	7	14
Meat, fish & eggs	0	1	7	0	1	7
Snacks	0	1	7	0	1	7
Staples	7	14	28	7	14	28
Starchy roots & other starchy plant foods	0	1	7	0	1	7
Vegetables	0	14	28	0	14	28

Appendix 5: List of foods consumed in the pastoral and agro-pastoral zones

	Pastoral			Agro-pastoral		
Food	**Number of consumers**	**% consumers**	**Median serving/ day[a] (g)**	**Number of consumers**	**% consumers**	**Median serving/day[a] (g)**
Vegetable oil	111	96	18	114	99	21
Table sugar	100	86	39	107	93	34
Camel milk	0	0	0	1	1	152
Fermented milk	1	1	23	3	3	62
Goat milk	7	6	69	7	6	134
Milk powder full-cream (edodo)	53	46	23	49	43	16
Milk whole	31	27	56	56	49	41
Banana ripe	0	0	0	1	1	74
Bosciaconacea(edung)	1	1	43	0	0	0
Hyphaenecompressa (eng'ol)	0	0	0	4	3	300
Cabbage	10	9	168	11	10	176
Cowpea leaves	8	7	113	31	27	132
Green peas	0	0	0	1	1	19
Capsicum	0	0	0	1	1	19
Egg plant	1	1	34	0	0	0
Kale (sukuma wiki)	23	20	112	23	20	166
Onion	47	41	11	49	43	13
Tomato	15	13	38	25	22	57
Bread white	1	1	200	1	1	72
Maize dried	84	72	190	79	69	168
Maize flour	90	78	175	94	82	205
Millet	2	2	111	1	1	81
Rice	46	40	156	50	43	161
Sorghum flour	0	0	0	7	6	115
Spaghetti	10	9	101	12	10	156
Wheat flour (chapati)	10	9	150	6	5	90

Food	Pastoral Number of consumers	% consumers	Serving/ day[a] (g)	Agro-pastoral Number of consumers	% consumers	Serving/day[a] (g)
Beans	86	74	86	93	81	94
Vegetable oil	111	96	18	114	99	21
Lentil	2	2	186	0	0	0
Pigeon peas	0	0	0	2	2	54
Antelope meat	3	3	78	0	0	0
Beef	5	4	92	0	0	0
Beef tripe	0	0	0	1	1	107
Camel meat	1	1	143	0	0	0
Egg scrambled	1	1	67	0	0	0
Goat meat	25	22	67	13	11	115
Hare meat	1	1	89	0	0	0
Potato Irish	11	9	87	19	17	118
Royco[b]	38	33	3	25	22	4
Salt. Iodized[b]	106	91	1	114	99	1
Tea leaves[b]	90	78	1	98	85	2

[a] Median

[b] These food items were omitted in the further analysis because they are condiments and usually used in small amounts

Appendix 6: Quantities of foods (grams) consumed in pastoral and agro-pastoral zones

		Pastoral zone			Agro-pastoral zone			
Food groups	**Foods**	**Min[a]**	**Max[b]**	**Mean ± SD[c]**	**Min[a]**	**Max[b]**	**Mean ± SD[c]**	**P-value[e]**
Fats and oils	Vegetable oil	1	172	24 ± 22	1	140	27 ± 23	0.046
Added sugars	Table sugar	2	246	50 ± 39	0	211	45 ± 34	0.063
Dairy	Camel milk	0	0	0	152	152	152 ± 0[d]	*
	Fermented milk	23	23	23 ± 0[d]	49	96	69 ± 24	0.180
	Goat milk	18	448	102 ± 133	30	503	170 ± 154	0.149
	Milk powder full-cream	1	159	31 ± 28	4	231	22 ± 29	0.000
	Milk whole	12	594	77 ± 93	1	283	64 ± 61	0.239
Fruits	Banana ripe	0	0	0	74	74	74 ± 0[d]	*
	B. conacea(edung)	43	43	43 ± 0[d]	0	0	0	*
	H. compressa (eng'ol)	0	0	0	200	350	300 ± 61	*
Vege-tables	Cabbage	75	460	193 ± 112	42	589	227 ± 158	0.725
	Cowpea leaves	15	188	99 ± 65	3	349	135 ± 76	0.179
	Green pea	0	0	0	19	19	19 ± 0[d]	*
	Capsicum	0	0	0	19	19	19 ± 0[d]	*
	Egg plant	34	34	34 ± 0[d]	0	0	0	*
	Kale (sukuma wiki)	38	304	136 ± 71	59	662	196 ± 117	0.14
	Onion	1	116	18 ± 18	1	95	16 ± 16	0.92
	Tomato	6	114	38 ± 23	6	164	61 ± 36	0.003
Grain and grain products	Bread white	200	200	200 ± 0[d]	72	72	72 ± 0[d]	0.317
	Maize dried	43	909	231 ± 159	32	1281	272 ± 239	0.837
	Maize flour	18	1379	225 ± 199	3	1327	271 ± 213	0.035
	Millet	102	120	111 ± 12	81	81	81 ± 0[d]	0.221
	Rice	15	938	184 ± 146	35	434	173 ± 84	0.614
	Sorghum flour	0	0	0	21	334	132 ± 98	*
	Spaghetti	3	212	101 ± 57	61	386	156 ± 85	0.100
	Wheat flour (chapati)	28	316	154 ± 81	50	362	138 ± 127	0.336

Food groups	Foods	Pastoral zone			Agro-pastoral zone			P-value[e]
		Min[a]	Max[b]	Mean ± SD[c]	Min[a]	Max[b]	Mean ± SD[c]	
Legumes and pulses	Beans	13	466	118 ± 85	8	721	137 ± 120	0.455
	Lentil	180	191	186 ± 8	0	0	0	*
	Pigeon peas	0	0	0	36	71	54 ± 25	*
Meat and eggs	Antelope meat	49	224	107 ± 79	0	0	0	*
	beef	14	135	81 ± 54	0	0	0	*
	Beef tripe	0	0	0	107	107	107 ± 0[d]	*
	Camel meat	143	143	143 ± 0[d]	0	0	0	*
	Egg scrambled	67	67	67 ± 0[d]	0	0	0	*
	Goat meat	2	476	94 ± 97	31	388	126 ± 78	0.022
	Hare meat	89	89	89 ± 0[d]	0	0	0	*
Starchy roots	Potato Irish	24	1019	178 ± 270	27	380	136 ± 90	0.600

[a] Minimum
[b] Maximum
[c] Standard deviation
[d] SD of 0 is because the food was consumed by one person
[e] Non-parametric Mann-Whitney U test
* The food item was consumed in one zone only