FACULTY OF BIOSCIENCE ENGINEERING

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Major: Public Health Nutrition

Development of local food-based complementary feeding recommendations to improve the diets of 6–12 month-old infants in Southwest Ethiopia

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Abstract

Background: Complementary foods in Ethiopia are predominantly based on cereals and legumes and lack of nutrient-dense foods. Poor complementary feeding practices increase the risk of undernutrition in young children, therefore there is a need to improve diet quality. Formulation of context-specific food-based recommendations (FBR), which promote the consumption of locally available and nutrient-dense foods, has been recommended to improve the diets and consequently the nutritional status of children.

Objective: In this study, how locally available foods can contribute to the diet quality of 6-12-month-old infants in southwest Ethiopia was determined. In addition, the nutrient gaps of these diets, which might need additional interventions to meet the nutrient recommendations, were identified.

Methodology: Data of infants aged 6-12 months, born in Jimma zone (southwest Ethiopia) were collected in two seasons: during the harvest season (October-December 2009) and pre-harvest season (June-August of 2010). Two 24-hour dietary recalls of the infants were conducted in each season. Linear programming analysis using Optifood was conducted to develop FBR for 2 target groups (infants of 6-8 and 9-12 months), as well as identify problem nutrients, for which recommendations cannot be met.

Results: The FBR created could ensure that 10 of the 11 analysed micronutrients important for child growth and development meet their nutrient requirements. Out of these, zinc was identified as the main problem nutrient since no combination of local foods allowed this micronutrient to meet its recommendations. Foods likely to improve the diet adequacy are milk (calcium), banana (vitamin B6, niacin), legumes (niacin, iron) and teff (thiamine, niacin, iron).

Conclusion: Infants' diets can be improved by including more nutrient-dense foods available locally. However, additional approaches, such as fortified foods and micronutrient supplements, are required to ensure diets' adequacy. The next steps are to evaluate the affordability, feasibility, and sustainability of the recommendations, as well as strategies for behaviour change communication.

Keywords: Infant and young child feeding, Ethiopia, Optifood, Food-based recommendations, Recommended nutrient intake

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List of Abbreviations

ASFs	Animal source foods
CFR	Complementary feeding recommendations
EAR	Estimated Average Requirement
EDHS	Ethiopia Demographic and Health Survey
EHNRI	Ethiopian Health and Nutrition Research Institute
ENMS	Ethiopian National Micronutrient Survey
EPHI	Ethiopian Public Health Institute
FANTA	Food and Nutrition Technical Assistance III Project
FAO	Food and Agriculture Organization of the United Nations
FBRs	Food-based recommendations
FDRE	Federal Democratic Republic of Ethiopia
FVs	Fruits and vegetables
GDP	Gross domestic product
GGFRC	Gilgel Gibe Field Research Centre of Jimma University
HDI	Human Development Index
HS	Harvest season
IDA	Iron deficiency anaemia
IHME	Institute for Health Metrics and Evaluation
IU	International Units
IYC	Infant and young child
IYCF	Infant and young child feeding
LAZ	Length-for-age z-score
MDGs	Millennium Development Goals
NFCS	National Food Consumption Survey
NNP	National Nutrition Program
PHS	Pre-harvest season
RAE	Retinol activity equivalents
RDA	Recommended Dietary Allowance
RNI	Recommended Nutrient Intake
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
UNU	United Nations University
USDA	United Stated Department of Agriculture
VAD	Vitamin A deficiency
WAZ	Weight-for-age z-score
WHO	World Health Organization
WLZ	Weight-for-length z-score

1. Introduction

1.1 Problem Statement

Child undernutrition continues to be an important public health problem in developing countries including Ethiopia. Ethiopia has demonstrated promising progress in reducing levels of undernutrition over the past decade. Nevertheless, the baseline levels of undernutrition are still considerably high, making it necessary to continue to substantially invest in nutrition (CSA Ethiopia & ICF, 2017).

A recent meta-analysis of ten cross-sectional studies done in Ethiopia about the risk factors for child undernutrition indicated that complementary food (cereal-based) and dietary diversity, were part of the 9 main risk factors for stunting, underweight and wasting in Ethiopia (Abdulahi, Shab-Bidar, Rezaei, & Djafarian, 2017). Poverty and lack of information or knowledge are two main factors that contribute to low dietary diversity in Ethiopia (UNICEF, 2014). According to the 2016 Ethiopian Demographic and Health Survey (EDHS), only 7.3% of 6–23 months of age children have a minimum acceptable diet (CSA Ethiopia & ICF, 2017).

In rural areas of Ethiopia, 55% of employed women and 83% of employed men are engaged in agricultural work (CSA Ethiopia & ICF, 2017). The large number of rural families who are subsistence farmers emphasizes the importance of food-based solutions for adequate feeding of families (Stoecker & Abebe, 2014).

Homemade complementary foods in Ethiopia are predominantly based on cereals and legumes (Temesgen, 2013). During the preparation, these foods are commonly diluted by the mothers, reducing the energy and micronutrients density, including those labelled by the World Health Organization (WHO) as "problem nutrients", such as iron and zinc (WHO, 2001). Children are introduced too soon to the regular household diet, which might make them not able to eat enough quantity to meet the requirements. Children consuming these foods grow poorly and have higher mortality rates (Temesgen, 2013). In addition, diets lack animal source foods as well as fruits and vegetables. Therefore, the intake of several micronutrients from homemade complementary foods in Ethiopia, such as iron, zinc, and calcium, can be very low (Abeshu, Lelisa, & Geleta, 2016).

1.2 Justification

The first 1000 days of life, from conception until the child's second birthday, are considered the "critical window" of opportunity for preventing undernutrition and its long-term consequences. Poor complementary feeding practices during this critical window (between 6 and 24 months of age) increases the risk of undernutrition, morbidity and mortality in infants and young children (Dewey, 2013).

Micronutrient deficiencies continue to be a major problem among children in low-income countries, contributing to the global burden of disease, impaired child development and stunted growth (Black *et al.*, 2013). Poor quality infant and young child feeding (IYCF) practices are one of the causes for these micronutrient deficiencies, emphasising the importance of identifying ways to improve diet quality (E. Ferguson, Chege, Kimiywe, Wiesmann, & Hotz, 2015).

The evidence suggests a general need to improve the quality of infant and young child (IYC) diets. However, culturally appropriate complementary feeding recommendations (CFR) have never been developed for young infants in Ethiopia. It is also not known whether CFR based on nutrient-dense locally available foods will fill the nutrient gaps in the diets of these children. Therefore, region-specific food-based recommendations (FBRs) may be required in Ethiopia, given the wide range of demographic and cultural influences that affect the availability of foods and their use in IYC diets.

1.3 Objectives

1.3.1 General objectives

The main objective of this study is to determine the potential of local foods to improve the nutrient quality of the diets of 6-12-month-old infants in southwest Ethiopia and identify possible intervention points in the FBRs developed.

1.3.2 Specific objectives

- To assess dietary intake among complementary diets of rural Ethiopian infants 6-12 months of age;
- To develop a set of locally appropriate FBRs to improve the adequacy of nutrient intakes of the infants; and
- To identify nutrient gaps that cannot be filled using local foods as consumed.

1.3.3 Research questions

- Which are the key problem nutrients in the diet of the target population?
- How do locally available foods contribute to the dietary pattern of infants 6-12 months in southwest Ethiopia?
- Could problem nutrients be solved with only using locally available foods among infants 6-12 months in southwest Ethiopia?

2. Literature Review

2.1 Demography of Ethiopia

Ethiopia is the second most populous country in Africa, with a total population of approximately 102 million, most of which are based in rural areas (IHME, 2016). Ethiopia's population has been growing at a rate of 2.3% per year. This rapid population growth exacerbates critical gaps in basic health services, food and nutrition security (UNDP, 2018).

Ethiopia's economy depends deeply on the agricultural sector, which accounts for 83.4% of the labour force, 43.2% of the Gross Domestic Product (GDP) and 80% of exports. Therefore, subsistence agriculture is still the mainstay of livelihood and economic productivity (FDRE, 2016a). Due to regular droughts combined with poor cultivation practices, Ethiopia's economy is very vulnerable (Federal Ministry of Health, 2015).

Although fertility has been declining, children under age 15 represent nearly half of the population (47%), while 4% of Ethiopians are age 65 or older. The broad base of the population pyramid indicates that Ethiopia's population is young, which is typical of countries with low life expectancies and high fertility rates. The total fertility rate in Ethiopia is 4.6 children per woman but there continues to be a notable urban-rural divide – on average, rural women have 2.9 more children than urban women (5.2 versus 2.3 children) (CSA Ethiopia & ICF, 2017).

Ethiopia has undergone significant economic and social changes and has recorded some of the highest growth rates in the world over the past years, with an annual HDI growth of 3.79% between 2000 and 2010, the fastest Human Development Index (HDI) growth in the world. However, between 2010 and 2015 the HDI growth rate slowed down (1.71%) and, according to the 2018 Ethiopia National United Nations Development Report, HDI ranks Ethiopia 174th out of 188 countries. Therefore, Ethiopia is one of the least developed countries in the world and it's still classified as a "low human development" country, with a life expectancy at birth of 64.6 years and mean years of schooling at 2.6 years. It is estimated that 23.5% of the population is currently living below the national poverty line (UNDP, 2018).

2.2 Nutrition situation of children in Ethiopia

Ethiopia has shown significant improvement in the achievement of the Millennium Development Goals (MDGs), including the MDG4 goal of reducing under-five mortality by 2/3 from the 1990 baseline. This goal was achieved in 2012, three years before the 2015 target year (Federal Ministry of Health, 2015). Nevertheless, in 2017, the under-five and infant mortality rates were 58.5 and 41 per 1000 live births respectively (WHO, 2017). Pneumonia, diarrhoea, malaria, neonatal problems, malnutrition, HIV/AIDS, or often a combination of these conditions represent more than 90% of child deaths (Federal Ministry of Health, 2015). According to the study "The cost of hunger in Africa", 27.8% of all child mortality in Ethiopia is associated with undernutrition. With an annual estimated cost associated with child undernutrition equating to 55.5 billion Ethiopian birrs for the year 2009 (16.5% of the country's GDP for that year), the importance of nutrition as an issue of national significance has steadily increased (FDRE, 2013a).

In Ethiopia, protein-energy malnutrition and micronutrients deficiency, such as iron, vitamin A, zinc and iodine deficiencies, are two major nutrition problems (Temesgen, 2013).

Chronic Malnutrition - Stunting

Stunting (low height-for-age) is more than just a measure of undernutrition; it poses irreversible threats to a child's brain development, school performance, and thus, productivity later in life (UNICEF, 2009). It results from chronic or recurrent undernutrition and can be associated with inappropriate infant and young child feeding in early life (WHO, 2018).

In Ethiopia, the rate of stunting has been on a downward trajectory, with a 20% reduction on its prevalence over the past 15 years. However, Ethiopia has a high probability of not being able to accomplish its goals of reducing stunting to 26 % by 2020 and 0% by 2030 (European Union, 2017). About 38.4% of children under the age of five in Ethiopia are stunted and 17.6% severely stunted, with much higher rates in rural areas than in urban areas (39.9% and 25.4%, respectively) (CSA Ethiopia & ICF, 2017).

Stunting sharply increases between age 6 and 23 months, and peaks at age 24-35 months, highlighting the need for more resources during the "critical window" to prevent undernutrition (CSA Ethiopia & ICF, 2017; European Union, 2017).

Acute Malnutrition - Wasting

Wasting (low weight-for-height) usually indicates recent and severe weight loss, normally due to lack of food and/or infectious disease, which increases the risk of death (WHO, 2018). On the contrary, the percentage of children under the age of five who are wasted in Ethiopia changed little over the last 15 years, from 12% in 2000 to 9.9% in 2016, including 2.9% who are severely wasted. Wasting prevalence is also higher among children in rural areas (10.1% vs. 8.7%), areas which are more vulnerable to drought and food insecurity (CSA Ethiopia & ICF, 2017; European Union, 2017).

Micronutrient Deficiencies

Micronutrient deficiencies are a severe public health problem in Ethiopia, representing a major contributor to childhood morbidity and mortality (CSA Ethiopia & ICF, 2017; EPHI, 2013). Iron, vitamin A, zinc and iodine are important micronutrients in global public health terms, and their deficiency can cause severe consequences in the health and development of populations, especially children and pregnant women in low-income countries (WHO, 2018).

Iron

Iron deficiency is one of the primary causes of anaemia, which can impair cognitive development, stunt growth, and increase morbidity from infectious diseases. Iron deficiency anaemia (IDA) can be caused by lack of iron in the diet, due to the low bioavailability of non-haem iron, the type of iron mainly present in the diets, and the phytate and tannins content in the diet (Umeta, West, & Fufa, 2005).

The 2016 EDHS results showed that although between 2005 and 2011 the prevalence of anaemia (haemoglobin levels below 11 g/dl) in children age 6-59 months declined from 54% to 44%, in 2016 the prevalence increased to 57%, remaining a public health concern (CSA Ethiopia & ICF, 2017).

In the 2016 Ethiopian National Micronutrient Survey (ENMS) the prevalence of anaemia was 34.4%. As measured by ferritin and adjusted for inflammation, 17.8% of children had depleted iron stores (serum ferritin ≤12 μg/L) and, as measured by soluble transferrin receptor, 29.6% of children had tissue iron deficiency (serum sTfR ≥4.4 mg/L). IDA was also estimated, by using the corrected serum ferritin and soluble transferrin receptor for inflammation combined with haemoglobin adjusted for altitude. IDA from children who had ferritin and haemoglobin below the cut-off (i.e. FERR<12 μg/L and Hb<11g/dL) was 8.6%, and IDA as measured from elevated sTfR and haemoglobin below the cut-off (sTfR> 4.4 mg/L and Hb<11 g/dL) was 12.3% (EPHI, 2016). These results showed that iron deficiency is the cause of only one part of anaemia cases in Ethiopia.

Vitamin A

Severe vitamin A deficiency (VAD) can cause eye damage and is the leading cause of childhood blindness; increases the severity of infections, such as measles and diarrheal disease; and slows recovery from illness. In Ethiopia, the consumption of foods rich in vitamin A or iron remains low among young children (CSA Ethiopia & ICF, 2017).

According to the 2016 ENMS, the prevalence of VAD estimated based on retinol adjusted for inflammation (Retinol <0.7 μmol/L) was found 13.9% among children age 6-59 months, and 57.9% of the children assessed had received vitamin A supplementation in the last 6 months (EPHI, 2016).

Zinc

Zinc deficiency is also a public health problem worldwide, which can lead to impaired gastrointestinal and immune function as well as stunted growth. To a large extent, it arises from impaired bioavailability of dietary zinc, caused mainly by high phytic acid content of diets (Umeta *et al.*, 2005).

In the 2016 ENMS, the prevalence of zinc deficiency was 35% among children age 6-59 months (serum zinc concentration < 70 µg/dL) (EPHI, 2016).

Iodine

Iodine is another essential mineral, and its deficiency can lead to enlargement of the thyroid (goitre), hypothyroidism and can cause mental retardation in infants and children whose mothers were iodine deficient during pregnancy (EPHI, 2016).

The use of iodised salt is relatively widespread in Ethiopia, which has greatly improved over from 15% (2011) to 89% (2016) (CSA Ethiopia & ICF, 2017). Despite the high national coverage of iodized salt, according to the 2016 ENMS, only about 26% of the surveyed households had salt that was adequately iodized (at ≥15 ppm, measured using a quantitative titration method). In children aged 5 to 14 years, half of the children's (47.5%) had insufficient intake of iodine (urinary iodine levels < 100 µg/L) (EPHI, 2016).

Infant and young child feeding

Appropriate infant and young child feeding (IYCF) practices include exclusive breastfeeding in the first 6 months of life, continued breastfeeding through age 2, the introduction of solid and semisolid foods at age 6 months, and gradual increases in the amount of food given and frequency of feeding as the child grows older. In addition, young children need to receive a diverse diet, which includes foods from different food groups in order to support children's growing micronutrient needs. This is the most critical period for children because children are most vulnerable to malnutrition during this transition (WHO, 2008a).

According to the 2016 EDHS, although breastfeeding is common (96.8% of children are breastfed at some stage), only 73.3% of newborns are breastfed within one hour of being born. Nationally, 57.5% of infants are exclusively breastfed in the first 6 months of life. This suboptimal rate is also consistent with the disproportionately high level of acute malnutrition (15.4%) in children aged 0–5 months. The median duration of breastfeeding is 23.9 months and 60% of children are introduced to solid, semi-solid, or soft foods at 6-8 months. Nevertheless, only 7.3% of children aged 6–23 months are fed in compliance with optimal complementary feeding standards, with the children living in urban areas being more likely to meet the IYCF recommendations (18.5% vs. 5.7%). In addition, the probability that a child receives the minimum acceptable diet increases with the mother's education level and household wealth (CSA Ethiopia & ICF, 2017).

2.3 Mitigation strategies

2.3.1 Food and Nutrition Policies in Ethiopia

In 2008 the Government of Ethiopia developed the National Nutrition Strategy in an effort to accelerate the reduction of undernutrition, especially among children under five as well as pregnant and lactating women, implemented through 5-year National Nutrition Programmes (NNP).

The 2008 NNP was revised in 2013 (NNP 2013–2015) and in 2016 the second NNP was launched (NNP II) (FDRE, 2013b). The NNP II covers the period from 2016 to 2020, focusing on the first 1000 days of life to eradicate chronic malnutrition by 2030 (FDRE, 2016b). The document addresses the multi-sectoral and multi-dimensional nature of nutrition and guides policies, strategies, programmes, and partnerships that deliver evidence-based, cost-effective nutrition interventions. The updated aims of the NNP II include reducing the prevalence of three crucial indicators for children under five by 2020: stunting from 40% to 26%; underweight from 25% to 13% and wasting from 9% to 4.9%. In addition, one of the program's key targets is the control of micronutrient deficiencies in the most vulnerable populations - children under five and pregnant/lactating women.

Several additional initiatives embody the government's commitment to improved nutrition. The Seqota Declaration (2015-2030) was signed in 2015 and aims to eliminate all forms of malnutrition among children under age 2 by 2030. Nutrition has been fully integrated into the Health Sector Transformation Plan that has as major focus the quality, efficiency and equity of the health services (FDRE Ministry of Health, 2015; Federal Ministry of Health, 2015). In a broader context, nutrition indicators are included in the Growth and Transformation Plan (GTP), an economic development plan of the Government of Ethiopia (FDRE, 2016a).

Regarding health financing, the government has been reallocating resources from urban hospital-based curative services towards more preventive and promotive care. The main focus has been on communicable diseases, common nutritional disorders, environmental health and hygiene, and safe and adequate water supply (Federal Ministry of Health, 2015).

Among the national nutrition strategies, dietary diversification (food-based approach) is one highlighted approach for the control and prevention of micronutrient deficiencies. Nevertheless, programs to reach vulnerable groups, living in both peri-urban and rural areas, are very limited. Therefore, the capacity to improve the nutritional status of the population is limited in the short term due to difficulties related to accessibility, availability and behaviours (EPHI, 2013).

Furthermore, the European Union Commission, along with the 20 EU member states represented in Ethiopia and Norway endorsed the "EU+ Joint Cooperation Strategy for Ethiopia" (2016-2020), a strategy that will support the NNP II. It proposes activities that are based on some Member States experiences in nutrition sensitive interventions e.g. in agriculture and social protection, which can help the planning of future programmes. The main objective of this strategy is to contribute to the Ethiopian government's target to reduce childhood stunting prevalence to 26% (NNP II) by 2020 and to 0% by 2030 (Seqota Declaration) and to the European Commission target to reduce globally stunted children by 7 million by 2025 (European Union, 2017).

2.3.2 Complementary feeding recommendations

Exclusive breastfeeding, from birth till 6 months, is important for optimal health, growth and development. From 6 months, as infants grow and become more active, breast milk alone is not sufficient to meet all the nutritional requirements. Therefore, complementary feeding needs to be introduced, with continued breastfeeding (WHO, 2001, 2003).

Between the age of 6 and 23 months, new foods are introduced in the diet of the infants, which fill the daily energy and nutrient requirements in addition to the amount supplied by breastfeeding. Feeding practices are important to consider, i.e. the moment of introduction of each food, quantity, frequency, hygiene and dietary diversity. Other elements like variety, consistency, and nutritional composition will determine the dietary diversity of the diet. Therefore, all these feeding practices will have an influence on the children's growth and nutritional status (Abeshu *et al.*, 2016).

Age of introduction of complementary foods

Early introduction of complementary foods can have several risks, like a decrease in breast milk intake, chocking, food allergies. On the other hand, delayed introduction of foods in infants increases the risk of malnutrition (USDA, 2009).

The general recommendations of WHO, recommend the introduction of solid foods at 6 months (WHO, 2001). Nevertheless, infants are able to tolerate foods around 4 and 6 months of age. Therefore, the appropriate moment of introduction will depend on different factors, like the development stage of the infants, and on the nutritional and health status (USDA, 2009).

Energy and nutrient composition of complementary foods

An adequate complementary diet is expected to have high energy density; balanced protein composition, containing all essential amino acids; sufficient supply of vitamins and minerals; and no antinutritional components.

Energy requirement

The total energy requirement of healthy breastfed infants is approximately 615 kcal/day at 6-8 months, 686 kcal/day at 9-11 months, and 894 kcal/day at 12-23 months of age. For infants in developing countries with "average" breast milk intake (WHO, 1998), the energy needed from complementary foods is approximately 202 kcal/day at 6-8 months of age, 307 kcal/day at 9-11 months of age, and 548 kcal/day at 12-23 months of age (Dewey & Brown, 2003; WHO, 2001). These values correspond to 33, 45, and 61% of the total daily energy needs, respectively, in accordance with a decreased intake of breast milk per age group. In order to accomplish the infants' energy requirement, is important to consider the energy density of the foods, since this will determine the amount of complementary food required. Assuming a gastric capacity of 30 g/kg body weight and a minimum energy density of complementary foods of 0.8 kcal/g, meals should have a frequency of 2-3 times/day at 6-8 months of age, and 3-4 times/day at 9-11 and 12-24 months of age, with addition of one or two nutritious snacks. The number of meals should increase gradually with age based on development and appetite of the child (Dewey & Brown, 2003; WHO, 2001).

As a result, complementary foods need to be more nutrient-rich than family foods. However, in low-income countries, the opposite is commonly observed: diets with low nutritional value, low energy density, low protein and high bulk (Dewey, 2013). Due to the restricted stomach size of infants and young children, bulk is one major problem of these diets, which makes the covering of energy needs difficult to achieve (WHO, 2001).

Protein requirement

The protein requirement of infants increases with age and is approximately 9.1 g for 6–8 months, 9.6 g for 9–11 months, and 10.9 g for 12–23 months. A significant part of this amount is provided by breast milk so, when average breast milk intake is assumed, the amount of protein needed from complementary foods is approximately 2 g/day at 6–8 months (22%), 3.1 g/day at 9–11 months (33%), and 5.1 g/day (47%) at 12–23 months (Dewey & Brown, 2003).

Fat/Lipids requirement

Fat is an important source of energy, essential fatty acids, and fat-soluble vitamins (A, D, E, and K). The range 30-45% of total energy was recommended for the daily fat intake, and the amount of fat provided by the complementary foods will depend on the amount of breast milk consumed. Therefore, if average breast milk is assumed, complementary foods should provide 0-34% at 6–8 months, 5-38% at 9–11 months, and 17-42% at 12–23 months of dietary fat (WHO, 2001).

Micronutrients

Breast milk contains generous amounts of vitamin A, C, folate, iodine, and selenium, providing the amount needed before 12 months of age (Dewey & Brown, 2003). However, breast milk provides relatively low quantities of several other micronutrients, like iron and zinc. Added to the fact that infants have a limited gastric capacity, diets need to be high in nutrient density (WHO, 2001).

The analysis of the actual nutrient densities of the complementary food diets in most developing countries resulted in the identification of several "problem nutrients", namely iron, zinc, and vitamin B6 (WHO, 2001).

Diets based on locally available food

The preparation of the complementary food is commonly based on locally available staples, which are the basic recipe food items, while the choice of specific food item differs considerably between populations, due to tradition, availability, and accessibility. In developing countries, the staples are normally cereals, roots, and starchy fruits that are an important source of energy and carbohydrates. However, the protein quality is very low compared to animal-based foods (Abeshu *et al.*, 2016).

The use of locally available foods was highlighted in the WHO/UNICEF Global Strategy for Infant and Young Child Feeding as one important strategy to ensure optimal complementary feeding for optimal growth, development, and well-being of infants and young children (WHO, 2003). However, these guidelines are not context-specific. Therefore, in order to focus on locally available, affordable and acceptable nutrient-dense foods, adaptations to local circumstances are required (E. Ferguson *et al.*, 2015). This strategy is more likely to result in long-term improvements in complementary feeding practices than general recommendations and, therefore, is being emphasized as the sustainable option for tackling the co-existence of undernutrition in vulnerable populations (Dewey, 2016).

Besides identifying the most nutritious combinations of local foods, there are other factors for improving dietary quality that could be taken into account, namely by enhancing the micronutrient absorption. This can be achieved by, for example, the reduction of phytate concentration; the reduction of polyphenols intake; increasing the intake of enhancers of iron and zinc absorption; including animal products in the diet; and/or the use of fermentation processes (Dewey & Brown, 2003; Umeta *et al.*, 2005). In essence, the improvement of the nutritional quality and microbiological safety of home-prepared complementary foods can enhance the nutritional status of young children. Therefore, traditional household practices, such as fermentation, need to be encouraged.

2.3.2.1 Complementary foods in Ethiopia

The recommendations for complementary feeding recipes for children of 6-23 months in Ethiopia are based on locally available foods, and three major staple groups form the base of the recipes, including maize/*enset*/*teff*, wheat/barley, and sorghum/maize (Federal Ministry of Health, 2006). Other staples, cereals or starchy tubers are part of the complementary diets such as millet, oat, rice, yam, potato, and yam. These foods are normally served as gruel, porridge, *fetfet, kitta*, and *dabo* (Temesgen, 2013) (Table 1.1).

Table 1.1: Traditional complementary foods

Complementary foods	Raw food items used
Gruel	Teff, sorghum, barley, maize, wheat, emmer wheat, and enset
Porridge	Teff, sorghum, barley, maize, wheat, emmer wheat, and enset
Fetfet	Teff, sorghum, barley, maize, wheat, broad beans, chick-peas, field peas, and lentil
Kitta	Teff, sorghum, barley, maize, wheat, enset and chick-peas
Dabo	Teff, sorghum, barley, maize, wheat and emmer wheat

(Temesgen, 2013)

The Ethiopian diet is mainly composed of cereals (maize, sorghum, and teff), tubers and root crops (enset, potatoes, and sweet potatoes), pulses and oilseeds (FAO, 2008). Despite a large livestock population, animal sourced foods as well as fruits and vegetables intake is rather low (Baye, Guyot, Icard-Verniere, & Mouquet-Rivier, 2013; EPHI, 2013; Temesgen, 2013). In rural areas, animal products consumption is especially low, with the exception of pastoral areas where milk is a major component of the diet (EPHI, 2013).

Traditionally, when the introduction of solid foods starts, gruel made from a variety of cereals is given, being later complemented with porridge until the end of the second year. When the children are about 2 years old, *fetfet, kett* and *dabo* are introduced, followed by the family diet, which consists in thin leavened bread (*enjera*), made from fermented teff, accompanied by a legume or meat based sauce (*wet*) (FAO, 2008; Temesgen, 2013). However, these practices have been changing and by 12 months of age, most children already consume the same diet as adults (Baye *et al.*, 2013).

These traditional gruels or porridge are sometimes viscous and therefore difficult for children to consume, making the mothers dilute it with water. This common practice reduces the energy density of the food and, consequently, children don't meet the energy requirements due to the small gastric capacity (Temesgen, 2013). In addition, these diets are commonly deficient in micronutrients, such as iron and zinc, together with poor bioavailability, given the absence of vitamin C, animal protein and high dietary phytate:zinc ratios (R. S. Gibson *et al.*, 2009; Umeta *et al.*, 2005).

The complementary feeding practices were evaluated in both southern and northern parts of Ethiopia (Baye *et al.*, 2013; R. S. Gibson *et al.*, 2009). The results of both studies showed that these diets contain very low dietary diversity, energy and micronutrient density, providing an energy, calcium and zinc intake lower than the estimated needs. Mothers had the perception that animal source foods aren't needed for infant and child feeding and, despite ownership of livestock, it is considered an asset and it is therefore rarely consumed (R. S. Gibson *et al.*, 2009).

The 2013 National food consumption survey (NFCS) reported similar results for 6-35 months children: cereals/grains contributed most to the consumption pattern; flesh foods (meat and organ meat), eggs, vitamin A rich fruits and vegetables intake was very low across the different regions. Regarding the macronutrient distribution, carbohydrates were contributing with the highest percentage of the daily intake (67.2%) followed by fat (22.9%) and protein (10.5%), with low absolute intakes of energy, carbohydrates and protein.

Concerning the micronutrient intake, according to the 2013 NFCS, the national average intake of iron was 10.0 mg/day (RDA = 11 mg/day, 6-12 months children), highly variable across regions (4.6 to 12.2 g/day); zinc was 1.82 mg/day (RDA = 3 mg/day, 6-12 months children); and vitamin A was 9 µg RAE/day[1] (AI = 500 µg RAE/day, 6-12 months children), also highly variable across regions (1-71 µg RAE/day) (EPHI, 2013; Institute of Medicine (US) Food and Nutrition Board, 2011). Nevertheless, it is important to mention that this survey was conducted during the lean season when there is low availability of different foods, what might be one of the causes for the limited variation in food groups in addition to the cultural eating habits.

2.3.3 Fortified products and vitamin-mineral supplements

Nowadays, targeted strategies, especially to pregnant and lactating women and children under two years of age, are required to address food insecurity and micronutrient deficiencies in a

[1] Measured in µg retinol activity equivalents (RAE).

population, such as micronutrient supplementation for pregnant and lactating women and fortified complementary foods, micronutrient powders and/or drops for children (Thompson & Amoroso, 2011).

In many low-income countries, unfortified homemade complementary foods, normally based on starchy roots, tubers and/or rice, are typically insufficient sources of essential nutrients, like iron, zinc, and calcium, what doesn't allow to meet the nutrient intake recommendations. On the other hand, meals prepared with cereals and legumes have higher zinc and iron content, but with higher phytate content (R. S. Gibson, Bailey, Gibbs, & Ferguson, 2010). Therefore, both scenarios fail to meet the requirements due to either low mineral content or low bioavailability.

One of the solutions can be the inclusion of animal source foods. Nevertheless, it is not feasible for the lowest income groups due to the increased cost of the diet. In addition, the amount needed to be ingested, to meet the recommendations of iron, calcium and sometimes zinc, is also not feasible by 6-12 months infants (Dewey & Brown, 2003).

Products fortified with micronutrients have been widely consumed in industrialized countries. In Africa, fortification programs have been developed and most countries are increasingly fortifying wheat and maize flour with iron, zinc, and folic acid, cooking oils and sugar with vitamin A, and salt with iodine (Harika *et al.*, 2017). In the case of flour, WHO has been recommending its fortification, i.e. maize and wheat, in countries where industrially produced flour is regularly consumed by large population groups. It is considered a simple, inexpensive and effective strategy for supplying vitamins and minerals to a big proportion of the population (WHO, 2009).

Mandatory fortification of wheat flour is present in 26 African countries, maize flour in 9, oil in 15, and salt in 36 countries (Global Fortification Data Exchange, 2018a). However, these products are still not available in all developing countries or are not reached by the poor (Abeshu *et al.*, 2016; WHO, 2001). Therefore, in developing countries, child feeding relies mostly on homemade complementary foods.

An alternative to food fortification is the use of vitamin-mineral supplements that are added and mixed with the complementary food (e.g. "sprinkles") or given directly to the infant (e.g. "drops") (Dewey & Brown, 2003). One example is vitamin A supplementation, which is recommended by WHO, in infants and children 6-59 months of age, in countries where vitamin A deficiency is a public health problem[2], in order to reduce child morbidity and

[2] Populations where the prevalence of night blindness is 1% or higher in children 24–59 months of age or where the prevalence of vitamin A deficiency (serum retinol 0.70 µmol/l or lower) is 20% or higher in infants and children 6–59 months of age.

mortality. A dose of 100 000 International Units (IU) in infants 6–11 months of age and 200 000 IU in children 12–59 months of age is considered to provide adequate protection for 4–6 months. These are considered low-cost interventions (WHO, 2011a).

2.3.3.1 Food Fortification and Supplementation in Ethiopia

Currently in Ethiopia, salt is the only food with mandatory fortification, since 2011. Due to the enactment of the legislation, the rate of salt iodization progressively increased, but the quality of salt iodization still remains a challenge. Therefore, efforts have been made to increase the monitoring capacity of regulatory agencies, promote the consolidation of the salt industry, improve QA/QC protocols and a sustainable supply of KIO3, and raise awareness of iodine deficiency disorders among salt producers, local governments, and consumers (EPHI, 2016).

In addition, in Ethiopia, there is also fortification standards available for the voluntary fortification of wheat flour and oil (Table 1.2).

Regarding supplementation in Ethiopia, Vitamin A supplementation implementation started in 1996, integrated with the Polio National Immunization Days, Sub-National Immunization Days and measles campaign, a house to house strategy delivered by volunteers. Currently, vitamin A is distributed in Ethiopia via the Expanded Program of Immunization (Federal Ministry of Health, 2015). The reception of the supplements should happen every 6 months by children aged 6-59 months. Nevertheless, the coverage of vitamin A supplementation in Ethiopia is still not optimum (EPHI, 2016; Haile, Biadgilign, & Azage, 2015).

Table 1.2: Food Fortification in Ethiopia

Food Vehicle	Type of Legislation	Nutrient	Average Value (mg/kg)	Nutrient Level Comment	Original Source
Salt	Mandatory since 2011	Iodine	30	Iodized common salt: 20-40 Iodized table salt: 30-40	Ethiopian Standards Agency (ESA). Compulsory Ethiopian Standard CES 70 for Iodized edible salt-Specification. ICS.67.220.20. 1/September/2016
Oil	Voluntary since 2018	Vitamin A	35	3.5 mg/100g minimum factory level. Regulatory levels, 2.0-4.0 mg/100g	Ethiopian Standards Agency. Fortified Edible Vegetable fats and oils with vitamin A and D - Specification. (ES 6133:2018). Ethiopia. 2018.
		Vitamin D	0.17	0.167 ppm, 0.15 minimum regulatory level, mg/100g	
Wheat Flour	Voluntary since 2017	Vitamin B6	6	6 mg/kg, recommended factory level	Ethiopian Standards Agency. Ethiopian Standard ES 6132:2017, First edition, Fortified wheat flour-Specification, ICS:67.060. Ethiopia. 21/December/2017.
		Vitamin B12	0.02	0.02 mg/kg, recommended factory level	
		Folate (B9)	2	2 mg/kg, recommended factory level	
		Iron	30	30 mg/kg, recommended factory level for NaFeEDTA or 40 mg/kg, recommended factory level for Ferrous Fumarate	
		Niacin (B3)	50	50 mg/kg, recommended factory level	
		Ribovlavin (B2)	6	6 mg/kg, recommended factory level	
		Thiamin (B1)	9	9 mg/kg, recommended factory level	
		Zinc	80	80 +/- 10 mg/kg, recommended factory level	

(Global Fortification Data Exchange, 2018b)

2.4 Assessing dietary adequacy and formulation of food-based recommendations

Food-based recommendations (FBRs) are dietary recommendations for a particular target group in order to promote the consumption of specific foods or food groups. To improve nutritional status, WHO recommends the formulation of FBRs, which promote the consumption of locally available and nutrient-dense foods to the extent possible and, if necessary, the inclusion of supplements to address critical nutrient gaps (WHO, 2008b).

Different principles are followed when developing FBRs, such as high nutritional value to supplement breastfeeding, acceptability, low price, and use of local food items (Dewey & Brown, 2003). In order to enable this analysis, different tools have been developed to assess nutritional adequacy of diets and to formulate locally appropriate FBRs, including the Optifood Software.

2.4.1 Optifood Software

One of the challenges in developing dietary guidelines for optimizing nutrient intake is the large number of nutrients that have to be considered simultaneously (Dewey & Brown, 2003). To facilitate the development of context-specific and realistic complementary feeding recommendations (CFR) for adoption by caregivers, Optifood was developed (Daelmans *et al.*, 2013).

Optifood is a computer software program, developed by the WHO in collaboration with the London School of Hygiene and Tropical Medicine and the Food and Nutrition Technical Assistance III Project (FANTA). Optifood uses linear programming analysis, a mathematical optimization process, to model realistic diets for the target population (Briend, Darmon, Ferguson, & Erhardt, 2003).

Optifood provides information on the best combinations of local foods to optimize nutrient intakes and can objectively indicate the extent to which these can supply nutritionally adequate diets for an entire population, and if there is a necessity of alternative interventions for meeting micronutrient needs, like adding fortified foods or supplements (Vossenaar *et al.*, 2017).

The strength of Optifood is the capacity to identify CFR that are specific to the local context in terms of actual dietary practices and local food availability, and to identify gaps between intakes and requirements for specific nutrients. The analysis that is done to identify CFR is based on 24-hour dietary recall data (Elaine Ferguson, Darmon, & Fahmida, 2008; E. L. Ferguson *et al.*, 2006). In addition, if data on local food prices are available, it's possible to compare alternative food-based strategies on the basis of cost and to identify the lowest cost nutritionally adequate diet (Crampton, 2011).

Optifood is used to identify "problem nutrients" for which adequacy cannot be reached or would be difficult to reach using local foods as they are usually consumed and develops sets of CFR to best ensure nutrient intake adequacy for the population. Therefore, problem nutrients are defined as those that do not achieve 100% of their Recommended Nutrient Intake (RNIs) in optimized diets, in which the nutrient content was maximized (Daelmans *et al.*, 2013).

Using this approach, it is possible not only to identify which micronutrients are most limiting in local diets but also to identify specific food groups and nutrient-dense foods to be promoted, based on the local foods available in the study area.

3. Methodology

3.1 Data sources

The data analysed in this dissertation were obtained from the PhD of the Dr. Mekitie Wondafrash, with the title "The role of feeding practices, dietary diversity and seasonality and n-3 long-chain polyunsaturated fatty acids in the diet of Ethiopian infants and young children". It was a community-based cross-sectional study done in a district in southwest Ethiopia (Kibebew, 2018).

The study was approved by the Ethics Review Board of Jimma University, Ethiopia (RPGC/104/2002), and the Ethics Committee of Ghent University Hospital, Belgium (B67020109188). Informed consent was secured from the mothers/caregivers before conducting the interviews and assessment.

3.1.1 Study area

Ethiopia is a Federal Democratic Republic composed of 9 National Regional states: Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and People Region (SNNPR), Gambella and Harari; and two administrative states: Addis Ababa (the capital) and Dire Dawa. These states are further divided into eight hundred woredas and around 15,000 kebeles approximately (5,000 urban & 10,000 rural) (FDRE, 2018).

The study took place in Jimma zone, one of the 12 administrative zones of Oromia Regional State. The study was conducted in nine kebeles (smaller government unit) of the catchment area of the Gilgel Gibe Field Research Centre of Jimma University (GGFRC), southwest Ethiopia.

The main source of income for the community is farming and raising livestock. The main food crops produced in the area are maize, sorghum and teff (a species of *Eragrostis* native to Ethiopia).

The rainy season occurs between mid-June and September, followed by a dry season occasionally interrupted in February or March by another short rainy season.

3.1.2 Study population

A census of all infants aged 6-12 months was carried out within the GGFRC of Jimma University.

<u>Inclusion criteria:</u>

Infants aged 6-12 months, born in the GGFRC and have a biological mother or female caregiver. They presented no serious illness which warrant immediate medical attention or referral (e.g. rapid breathing, nasal flaring, reported high fever, abnormal body movement, persistent diarrhoea (≥2 weeks) or vomiting, etc.) or malformation affecting anthropometric measurement, and no intention of leaving the area within the period of the study of 6 months.

3.1.3 Data collection

This study was conducted in two seasons: during the harvest season (HS) from October-December 2009, and pre-harvest season (PHS) from June-August of 2010. Data of 320 and 312 infants, in the HS and PHS respectively, were collected. The survey was done in two seasons to capture seasonal dietary variations.

Data were collected on socioeconomics and demographics, and infant feeding practices using pre-tested interviewer-administered questionnaires. Demographic and Health Survey questionnaires (CSA Ethiopia & ORC Macro, 2006) and the WHO guidelines for the assessment of infant and young child feeding (WHO, 2010) were used as a reference for the formulation of the questions.

A multiple pass 24-hour recall questionnaire was used to collect dietary intake, which was adapted for commonly consumed foods in the study area (R. Gibson & Ferguson, 2008).

Data collectors were fluent in local languages (Amharic and Afan Oromo), had previous experience in data collection, and received a five-day intensive training from the principal investigators.

Dietary intake assessment

Two 24-hour recalls of the infants' diet were conducted in each season.

Spoons and graduated bowls were provided to mothers/caregivers weeks before the interview, with respective instructions of usage, which should be used in the subsequent weeks.

Collection of recipe data was done in order to convert composite dishes to ingredients. First, data of common composite dishes were collected by asking five mothers to prepare them. Secondly, the average recipe data in the Ethiopia traditional recipe table (Ethiopian Nutrition Institute, 1980) was collected. During the 24-hour recall, the recipes were evaluated qualitatively and matched with the best recipe available. Foods that come in discrete units were recalled and converted into weights by using conversion lists that were compiled from weighing all such foods. For the recording of weights of the different sizes of household measures, a 1g precision laboratory scale (Ohaus Corp., USA) was used.

During the interview, all the foods and respective quantity the infant had consumed in the last 24 hours were shown or described by the caregiver. A pre-recorded conversion table that converts volumetric estimations of gruels and porridges to weight equivalents according to three reported consistencies (thin, medium, and stiff) was used.

In the final sample, all days of the week were represented. The two collection days of the 24-hour recalls were separated by ±15 days in both seasons and they were not announced to avoid systematic error or bias.

Anthropometry

Anthropometric measurements were standardized through repetitive exercises.

For the measurement of the recumbent length, an infant measuring board was used and recorded to the nearest 0.1cm (SECA 210, Hamburg, Germany).

For the measurement of the infants' weight, a mother-child digital scale was used and recorded to the nearest 0.1kg (SECA Uniscale, Hamburg, Germany), with the infant naked or using very light clothes.

Birth certificates or immunization cards were consulted for the collection of the infants' age. If the ages were missing, local events calendars were used to help the mother/caregiver estimate the approximate age of the child.

The anthropometric measures were converted into Z-scores of weight-for-age (WAZ), length-for-age (LAZ), and weight-for-length (WLZ), based on the WHO 2006 Growth Reference (WHO, 2006, 2011b). Underweight, wasting, and stunting are defined as <-2 WAZ, WLZ and LAZ respectively. Severe underweight, wasting, and stunting are defined as <-3 WAZ, WLZ and LAZ respectively.

3.2 Data analysis

Data were analysed with Stata 14.2 for Windows (StataCorp, College Station, TX, USA), MS Excel 2013, MS Access 2010 and Optifood.

3.2.1 Linear programming analysis using Optifood

3.2.1.1 Data preparation for Optifood

Optifood requires 3 main components (Crampton, 2011):

1. Data of the target group, which are firstly processed in MS Access data preparation programme for Optifood;
2. The food composition table which matches the food items of the target group data;
3. Recommended nutrient intakes of the target population.

1. Data of the target group

First, the 24-hour recall intake data were processed in Stata 14.2 and MS Excel. The original target group of children 6–12 months old was split into two groups (6–8 months and 9–12 months). Almost all of the children were breastfeeding, so those who were not breastfeeding were excluded. Children who were breastfed in only one of the days were classified as breastfed children. Since the breast milk was not measured during the survey, average breast milk intake of children aged 6-8 and 9-11 months of developing countries estimated by WHO was used (WHO, 1998). In addition, children who had incomplete dietary intake data i.e. only one day represented, were excluded.

Secondly, the data were introduced into the MS Access data preparation programme in the format required, to prepare input data for the Optifood programme. The data used included: subject identification, observation day, time of consumption, meal number, food name, food code, amount of food in grams. The MS Access was used for recipe disaggregation, which required the food code of recipe, recipe name, food code of ingredient, ingredient name, and proportion of raw ingredient in total cooked weight, expressed in percent (Wiesmann & Ferguson, 2012). All food items were assigned to a food group and subgroup, in accordance with Optifood.

After processing the data in MS Access, each target group (6-8 and 9-12 months) was selected, and the programme generated different output tables, with the following data:

- List of food items.
- Number and percentage of children who consumed each food.
- Median serving size of each food, expressed in grams per day (g/day) and grams per meal (g/meal).
- The 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles for the number of food servings (daily or meal-based) consumed per week from Optifood specific foods groups.
- The 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles for the number of food servings (daily or meal-based) consumed per week from Optifood specific food subgroups.

List of food items

A list of foods for each target group was entered into Optifood. The inclusion criteria for these lists were (FANTA, 2014):

- Food items consumed by ≥ 5% of the target group;
- Food items consumed by < 5% of the target group, if it was a good source of nutrients, and a similar food wasn't already included in the first criteria.

In order to be able to build similar recommendations between target groups, food groups were added for all age categories if they were consumed by ≥ 5% of another age group so that in the Optifood analysis the same food groups were present in both target groups.

In addition, breast milk was added to the food lists.

Food serving sizes

The median observed serving size of each food was entered into Optifood. Food serving sizes were defined on a meal basis (g/meal) in order to get a better estimation of the food pattern of each target group. On the other hand, breast milk was defined on a daily basis (g/day) since its intake was assumed to be the same daily (FANTA, 2014).

Food frequency

The minimum frequency for all foods was zero, i.e., a diet can be selected without the food in it. The exception was breast milk which was consumed by all children thus the minimum frequency for breast milk was 6.9 servings per week and the maximum frequency was 7.1. For each food, the maximum frequency was defined as the 95th percentile of the respective food' subgroup frequency distribution.

Food group and subgroup constraints

In Optifood, food group and subgroup constraints are set on the number of servings per week to ensure that the diets modelled are close to the target group's food pattern observed.
For food groups, the labels minimum, average, and maximum number of servings per week are used to define the constraints. These corresponded to the 5th, 50th, and 95th percentiles generated by the MS Access programme. In cases where the 50th percentile was zero, a value of 1 was entered instead in Optifood, to make sure the minimum, average, and maximum number of servings per week differed with each other.
For food subgroups, the labels minimum and maximum number of servings per week are used to define the constraints. These corresponded to the 5th and 95th percentiles generated by the MS Access programme.
For food groups and food subgroups, when the minimum number of servings per week equals to zero, it means that the diet can be selected without these foods. All the food groups and subgroups were defined on a meal basis, with the exception of human milk (food group) and breast milk (food subgroup) which were defined on a daily basis.

2. The food composition table which matches the food items of the target group data

A food composition table was created under the Optifood format, which included food name in both English and local name, food group, food subgroup, country, sources of reference, energy, protein, water, fat, carbohydrate, calcium, iron, zinc, vitamin C, B1 (thiamine), B2 (riboflavin), B3 (niacin), B6, B12, folate, and vitamin A Retinol Activity Equivalents (RAE). Food composition data were obtained from various sources, including Ethiopian food composition table (EHNRI, 1998a, 1998b), FAO's food composition table for East Africa (West, Pepping, & Temalilwa, 1989), an analysis paper (Abebe *et al.*, 2007) and the USDA food composition database (A. R. S. USDA, 2010). Missing nutrient values were imputed using the formula by Gibson and Ferguson (R. Gibson & Ferguson, 2008).

Since breast milk intake was not measured directly, the observed nutrient intakes were analysed assuming every child had an "average" breast milk intake (g/day), as proposed by WHO for each age group (WHO, 1998). Therefore, the "average" breast milk intake assumed was 674 g/day for 6-8 months and 616 g/day for 9-12 months infants. The WHO breast milk nutrient concentration values were used (WHO, 1998) (Appendix 1).

3. Recommended nutrient intakes of the target population

The RNI[3] values from WHO/FAO were used for all nutrients. In the case of zinc low bioavailability was assumed, and 5% bioavailability was assumed for iron as recommended by WHO and FAO for developing countries. Some reasons include the high phytate content and the low amount of animal source foods of these diets (WHO & FAO, 2004).

For energy and protein, constraints were used to ensure all modelled diets provided the average energy and protein requirements for the target group, estimated using children's mean body weights and the FAO/WHO/UNU equations (FAO/WHO/UNU, 2004, 2007). For fat, the average requirement of 30% of total energy from FAO was used as a minimum target (FAO, 2010).

The data compiled from the food composition tables were further analysed per median food serving size in order to identify food sources of each micronutrient, which was defined as items that provided at least 15% of a nutrients' RNI[4].

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[3] Recommended nutrient intake (RNI) is the daily intake which meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population. RNI is based on an estimated average nutrient requirement (EAR) plus two standard deviations above the mean: $RNI = EAR + 2SD_{EAR}$. The definition of RNI used in this work is equivalent to that of recommended dietary allowance (RDA) as used by the Food and Nutrition Board of the US National Academy of Sciences (Institute of Medicine (US) Food and Nutrition Board, 2011).

[4] These cut-offs were based on the following documents: Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011; Regulation (EC) no 1924/2006 of the European Parliament and of the Council of 20 December 2006, which define when a food product is considered a source of vitamins and/or minerals.

3.2.1.2 Data analysis in Optifood

This Optifood analysis comprises three steps (FANTA, 2014, 2015):

1. To check that model parameters ensure realistic diets.
2. To identify two realistic diets that meet or come as close as possible to meeting the nutrient needs of the target population. One of the diets is based on current dietary patterns and the other one requires dietary changes.
3. To test alternative sets of food-based recommendations (FBRs) to select which dietary recommendations may be the best for the target population, taking into consideration nutrient needs, in order to cover at least 70% of the RNI for most nutrients.

1. Module 1: Check Diets

After entering the data for each target group into Optifood, Module 1 was run, and the outputs were examined. This module tests the constraints set in the food groups, food subgroups and food lists to ensure that variability in food choices is possible when modelling diets and to ensure that the modelled diets can realistically be consumed by the corresponding target population. If solutions were not possible, changes were made in the input target data.

2. Module 2: Identify Draft Recommendations

Module 2 generates two optimized diets for the target population:

- Food pattern optimized diet – the diet that comes as close as possible to meet the target population's recommended nutrient intakes while adhering to the set dietary patterns as much as possible.
- Non-food pattern optimized diet – the diet that comes as close as possible to meet the target population's recommended nutrient intakes without taking dietary patterns into account.

The selected nutrients for both diets included protein, calcium, iron, zinc, vitamins A, C, B1, B2, B3, B6, B12, folate, and achievement of 30% of energy from fat.

From the analysis of this Module, it was possible to identify the problem nutrients i.e. nutrients that couldn't meet 100% RNI in the optimized diets. Therefore, for these nutrients, the requirements are difficult to achieve by consuming only local food sources and within the constraints set.

3. Module 3: Test of Food-Based Recommendations

Module 3 allows the entering of further input data describing food recommendations and conduct the respective analysis, which can be run multiple times for different sets of recommendations.

Serving recommendations per week can be entered for food groups, food subgroups and food items. The recommendations have to be within the constraints set initially i.e. equal or lower than the maximum number of servings per week and equal or higher than the minimum number of servings per week.

Before testing the draft food-based recommendations (FBRs), Module 3 was first run without adding any new constraints to provide a benchmark diet against which to compare nutrient levels of different FBRs. Therefore, it was possible to observe if there was an improvement when testing each FBR compared with the "worst-case scenario" i.e. diet with the lowest possible level of a nutrient (% RNI) possible.

In Module 3 analysis, 32 diets were generated. On one hand, 16 of these diets have maximized levels of each nutrient (% RNI), to show the levels that could be achieved in the "best-case scenario". This diet allowed to distinguish between problem nutrients – "absolute" and "partial" problem nutrients.

An absolute problem nutrient is defined as a nutrient whose "best-case scenario" level is lower than its RNI i.e. the RNI can't be met using local food sources and/or local food patterns. Therefore, its intake will probably remain inadequate given the local food supply and the target's food consumption patterns.

A partial problem nutrient is defined as a nutrient whose "best-case scenario" meet or exceed its RNI but remained lower than 70% RNI in the "worst-case scenario". This means that, in order to meet the RNI of these nutrients, changes are needed in the diet pattern, what might require replacing certain foods and consequently affecting negatively the intake of other nutrients.

On the other hand, the other 16 diets are generated, which minimize the levels of each nutrient, to show the "worst-case scenario" nutrient levels.

The results of this Module, after inputting the food recommendations, display the minimum percentage of each nutrient RNI that would be met if an FBR or set of FBRs was put into practice. The criterion to determine if the FBRs assure nutrient adequacy of a particular nutrient is coverage of at least 70% of its RNI, in order to guarantee that a low percentage of the population is at risk of inadequate intakes (Buttriss *et al.*, 2014).

The analysis was done in different steps. Firstly, a set of FBRs was determined which represented nutritionally the best diet for the target population. Individual draft FBRs were selected based on the maximum servings/week of the food groups and, if necessary, specific food subgroups and individual foods, sources of specific problem nutrients that were not covered by food groups only. Each FBR was tested and the “worst-case scenario” of each FBR was compared based on the number of nutrients that met ≥ 70% of its RNI. When no FBR tested achieved 70% of the RNI of a nutrient, the FBR with the highest RNI percentage was selected. Subsequently, the FBRs were tested together and the “worst-case scenario” results were again compared. This step was continued until a final set of FBRs was determined for each target group. During the analysis, when the selection of specific foods was needed to meet the RNI of particular nutrients, foods consumed by both target groups were favoured over foods consumed by only one of the target groups. In addition, other criteria used to select the final FBRs was the consistency and similarity to FBRs selected for other target groups i.e. similar recommendations for breastfed children 6-8 and 9-12 months, to facilitate their promotion. In the end, the number of servings a week was reduced in the final set of FBRs, when possible, taking into consideration that no nutrient fells below 70% of the RNI.

Secondly, to the set of FBRs selected for each target group, each FBR was individually removed from the set, in order to assess the nutritional importance of each one of them. It was analysed which nutrients fell below 70% of their RNI if an FBR was removed from the set. This step allowed to understand which nutrient requirements each FBR helped to meet.

In each target group, the analysis only included foods reported to be consumed by the infants and it did not include the analysis of other nutrient-dense foods, micronutrient powders, fortified foods or other supplements.

Furthermore, the cost analysis of the diets was not performed due to lack of data.

4. Results

4.1 Characteristics of the infants

Data were collected from 632 infants; 320 in harvest season (HS) and 312 in pre-harvest season (PHS). Out of these, a total of 61 children were excluded from the analysis, due to insufficient intake data (only one 24-hour recall) (n=33 in HS, n=21 in PHS) and also, because they were not breastfed (n=5 in HS, n=2 in PHS). Therefore, the final data of participants used for analysis were that of 571 children (n=282 in HS, n=289 in PHS).

The mean age of the infants surveyed was 9.16 months (SD=1.77), and 216 and 355 infants were in the 6-8- and 9-12-months age group respectively (Appendix 2). Also, their average weight was 7.23 kg (SD=1.17) and 7.97 kg (SD=1.19) for the 6-8- and 9-12-months target group respectively.

A total of 19.6% of infants were stunted, 21.2% were underweight, and 13.8% were wasted. When comparing the prevalences between target groups, stunting and underweight showed to be higher in the 9-12 months age group (13.0% vs. 23.7%; 18.5% vs. 22.8%) whereas wasting showed to be slightly higher in the 6-8 months age group (Table 4.1).

With regards to exclusive breastfeeding, the average duration was close to 4 months. Furthermore, the breastfeeding frequency was higher in the 6-8 months target group (9.00 vs. 8.20 times/day) whereas the meal frequency was higher in 9-12 months target group (1.92 vs. 2.31 times/day).

With respect to the household, the main source of income was farming (84.7%) and 90.4% had at least one type of livestock, such as cows (62.5%), chickens (53.7%), and sheep/goats (45.0%).

4.2 Dietary intake analysis

4.2.1 Food items consumed: number, type and portion sizes

The total number of food items consumed ranged from 62 in the 6-8 months target group to 67 in the 9-12 months target group, with a total of 80 different food items. On the other hand, the number of food items consumed by >5% of the infants ranged from 20 in the 6-8 months group to 24 in the 9-12 months group, with a total of 25 different food items. All the items consumed by the 6-8 months infants were also consumed by 9-12 months infants, with the exception of whole grain wheat flour.

Table 4.1: Characteristics and nutritional status of breastfed children 6-12 months included in the analysis

Variables	6-8 months	9-12 months	Total
Total number	216	355	571
Season, n and %			
HS	149 (69.0)	133 (37.5)	282 (49.4)
PHS	67 (31.0)	222 (62.5)	289 (50.6)
Sex, n and %			
Male	105 (48.6)	192 (54.1)	297 (52.0)
Female	111 (51.4)	163 (45.9)	274 (48.0)
Weight, mean and SD	7.23 (1.17)	7.97 (1.19)	
LAZ, mean and SD	- 0.57 (1.43)	- 1.11 (1.29)	
Stunting, n and %			
LAZ <-2	28 (13.0)	84 (23.7)	112 (19.6)
LAZ <-3	12 (5.6)	20 (5.6)	32 (11.3)
WAZ, mean and SD	-0.95 (1.25)	-1.07 (1.24)	
Underweight, n and %			
WAZ <-2	40 (18.5)	81 (22.8)	121 (21.2)
WAZ <-3	12 (5.6)	20 (5.6)	32 (5.6)
WHZ, mean and SD	-0.84 (1.31)	-0.63 (1.28)	
Wasting, n and %			
WHZ <-2	33 (15.6)	46 (13.0)	79 (13.8)
WHZ <-3	10 (4.6)	12 (3.4)	22 (3.9)
Meal frequency, mean and SD	1.92 (1.90)	2.31 (1.68)	
Breastfeeding frequency, mean and SD	9.00 (2.12)	8.20 (2.20)	
Duration exclusive breastfeeding, months, mean and SD	4.05 (1.38)	4.20 (1.54)	

For the Optifood analysis, 23 and 25 food items were chosen to be included for the 6-8- and 9-12-months children respectively, to have the same food groups present in the analysis of both target groups. In the case of the 6-8 months children, 3 foods were included to have the food groups “Meat, fish and eggs” and “Starchy roots and other starchy plant foods” in the analysis. In the case of 9-12 months children, one food was included i.e. boiled egg, to complement the food group “Meat, fish and eggs”. These food items additionally included were consumed by >2.5% of the children in both target groups. The list of foods included in each target group, with their respective median serving size, number and percentage of consumers are shown in Appendix 3 and 4, for 6-8- and 9-12-months infants, respectively. The six most frequently consumed foods were the same for both target groups, in addition to breast milk, which was consumed by all infants (Table 4.2).

Table 4.2: The six most frequently consumed foods by 6-8- and 9-12-months target groups

Food	**% of 6-8 months consuming the food**	**% of 9-12 months consuming the food**
Whole cow milk	50.46	29.58
Pea flour wet, shiro wet	49.07	50.42
Sugar, refined	39.81	32.39
Milk, cow, fresh	36.11	43.66
Mixed porridge flour (no maize) - Mitin	30.56	34.93
Teff Enjera	29.17	31.27

In summary, there were 3 food groups consumed by more than 50% of the children in both target groups, which were "Grains & grain products", "Dairy products", and "Legumes, nuts & seeds". On the other hand, "Meat, fish and eggs" was rarely consumed and, within this food group, the subgroup "Eggs" was the only present in their diets, with <10% of the infants consuming them. The food group "Vegetables" could not be included in the analysis since only one infant consumed one food item from this food group i.e. pumpkin.

The main food items consumed from each food group by the infants are summarized in Table 4.3. The main cereal grains consumed in both age groups were teff, barley, maize and sorghum. These cereals were frequently consumed in the form of *enjera*, together with cow´s milk or mostly with *wet*, a stew prepared with pea flour (*shiro wet*) or potato (*dinniche wet*).

The median serving sizes of the food items consumed were almost equal among the target groups, which ranged from 4.4 g for vegetable oil to 193.25-206 g for fresh cow milk. Regarding the most consumed food groups, the median serving size per meal ranged from 16-55.68 g for "Grains & grain products", 123-206 g for "Dairy products", and 63.75 g for "Legumes, nuts & seeds" (Appendix 3 and 4).

Table 4.3: Main foods consumed by 6-12 months infants per food group

Food group	Food item
Added fats	Butter from cow's milk, Vegetable oil
Added sugars	Refined sugar
Bakery & breakfast cereals	Biscuit
Dairy products	Fresh cow milk, Whole cow milk
Fruits	Banana, Orange, Papaya
Grains & grain products	Teff, Barley, Maize and Sorghum
Legumes, nuts & seeds	Pea flour wet (*shiro wet*)
Meat, fish & eggs	Egg
Starchy roots & other starchy plant foods	Potato sauce (*dinniche wet*)

The amounts of nutrients that would be derived from breast milk based on the average level of consumption for 6-8- and 9-12-months infants are present in Appendix 5. For niacin, vitamin B6, iron and zinc, the breast milk provides only a small portion of the daily requirements.

4.2.2 Foods group and subgroup constraints

The minimum, average, and maximum number of servings per week per food group entered on Optifood are shown in Appendix 6 and 7, for 6-8- and 9-12-months infants, respectively. For mathematical reasons, for most of the food groups, it was necessary to put one as the average consumption instead of zero, except for “Dairy products”, “Grains and grain products” and “Human milk” for both target groups, and “Legumes, nuts and seeds” for the 9-12 months target group.

For food subgroups, the minimum and maximum number of servings per week entered on Optifood are shown in Appendix 8 and 9, for 6-8- and 9-12-months infants, respectively.

Due to the low number of foods consumed by the infants, some food groups/subgroups represent only one food item. The number of servings a week increased or remained the same with increasing age.

4.2.3 Food items sources of micronutrients

The food items consumed by the infants and selected for the analysis were checked to identify food sources of each micronutrient, which was defined as the foods that provide per portion >15% RNI of a particular micronutrient.

Among the food items included in the analysis, about 21 of them were sources of at least one micronutrient (>15% RNI per portion) in the diets of the target groups. In Table 4.4, it is listed the food items that are a source of at least 3 nutrients, as well as breast milk (in detail in Appendix 10 and 11).

Table 4.4: Food items that are a source of at least 3 nutrients (>15% RNI per portion)

6-8 months infants		**9-12 months infants**	
Food item	**Number of nutrients [a]**	**Food item**	**Number of nutrients [a]**
Breast milk	9	Breast milk	9
Whole cow milk	6	Whole cow milk	6
Milk, cow, fresh	5	Milk, cow, fresh	5
Banana , ripe	5	Banana , ripe	5
Egg, whole, boiled	5	Egg, whole, boiled	5
Orange, Citrus sinensis, fresh	4	Orange, Citrus sinensis, fresh	4
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	4	Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	3
Corn(maize), Zeamays L., white, flour	3	Corn(maize), Zeamays L.: white, flour	3
Papaya, ripe	3	Papaya, ripe	3
Pea flour wet, shiro wet	3	Pea flour wet, shiro wet	3
Biscuit, generic type [b]	3	Mixed porridge flour (with maize) – Mitin [b]	3
Wheat flour, whole grain [b]	3		

[a] Number of nutrients each food item is considered a source, by providing >15% RNI of a micronutrient per portion consumed
[b] Food items that are sources of nutrients in only on target group

4.2.4 Main food sources per micronutrient

The main food sources of each micronutrient in the diets of the 6-8- and 9-12-months infants are shown in Appendix 12. In Table 4.5, the summary of the main food sources that are common for the diets of both target groups can be found. These results guided the construction and selection of the food-based recommendations (FBRs) in Module 3.
It is observed that most of the food items are relatively consistent across target groups with at least one being common for each micronutrient. These results were helpful to formulate similar recommendations between target groups.

It is clear from these results that food items belonging to particularly 3 food groups are frequently present as important sources of micronutrients i.e. fruits, dairy products and grains.

With regards to zinc, no food item was a source of >15% RNI. In addition, breast milk provides only around 9% RNI for this micronutrient. This finding, while preliminary, suggests that will be hard to cover the needs for this micronutrient with the local food sources available.

Table 4.5: Main food sources of each micronutrient in the diets of both target groups (6-8 and 9-12 months breastfed children) (per portion)

Micronutrient	Food item
Calcium	Whole cow milk Milk, cow, fresh
Vitamin C	Papaya, ripe Orange, Citrus sinensis, fresh Banana , ripe
Thiamine	Tef, Eragrostis tef(Zucc)Trott.: mixed, flour Corn(maize), Zeamays L., white, flour Teff Enjera
Riboflavin	Milk, cow, fresh Whole cow milk Banana , ripe
Niacin	Banana , ripe
Vitamin B6	Banana , ripe Milk, cow, fresh Orange,Citrus sinensis,fresh
Folate	Papaya, ripe Banana , ripe Orange, Citrus sinensis, fresh
Vitamin B12	Egg, whole, boiled Milk, cow, fresh Whole cow milk
Vitamin A	Papaya, ripe Whole cow milk Butter from cow's milk
Iron	Maize(90%)+tef(10%): enjera - Kosho Teff Enjera Tef, Eragrostis tef(Zucc)Trott.: mixed, flour
Zinc	Barley, white, Hordeum vulgare L.: flour Tef, Eragrostis tef(Zucc)Trott.: mixed, flour Egg, whole, fried with fat

4.3 Optifood analysis

4.3.1 Results from Module 1: Check Diets

After entering the data for each target group into Optifood, Module 1 was run and the data was accepted, allowing the continuation of the analysis on the software.

4.3.2 Results from Module 2: Identify Draft Recommendations

In Module 2, two optimized diets were generated i.e. the food pattern optimized diet (FP diet) and the non-food pattern optimized diet (NFP diet). The number of servings per week of each food group, of these two diets, for 6-8- and 9-12-months infants are shown in Table 4.6.

Regarding the FP diets, not much has changed in the diet comparing to the average food pattern, except for the decrease in the number of "Grains and grain products" for the 6-8 months target group and "Dairy products" servings for both target groups. Nevertheless, it is noteworthy that for most of the food groups the average pattern was originally 0 instead of 1, which does not make the diet a true representation of the actual food pattern.

In the NFP diets, the results showed an increase in the number of servings of fruits for both target groups (from 1 serving/week to 6.4-7 servings/week i.e. approximately 1 serving/day) in order to optimize the nutritional content of the diets. For "Grains and grain products" the number of servings remained as 1 serving/day for the 6-8 months target group and increased to 1.5 servings/day for the 9-12 months target group. Concerning the number of dairy servings, it decreased for 6-8 months infants whereas it remained almost the same for 9-12 months infants. Apart from these 3 food groups, no other food group was included on these diets.

4.3.2.1 Problem nutrients in the optimized diets

The problem nutrients i.e. nutrients which are difficult to meet using only local food sources and/or local food patterns, were identified by analysing the results of Module 2 in Optifood. These nutrients were defined as the ones that could not meet 100% RNI in both optimized diets. The results are illustrated in Figure 1 and 2 for 6-8- and 9-12-months infants, respectively (see more details in Appendix 13 and 14).

Table 4.6: Servings per week of the two optimized diets generated by Optifood and the average (50th percentile) food pattern [a]

Food Group	6-8 months			9-12 months		
	FP diet	NFP diet	Average [c]	FP diet	NFP diet	Average [c]
Fruits	1	6.4	1 [b]	1	7	1 [b]
Added sugars	1	0	1 [b]	1	0	1 [b]
Dairy products	0.5	0.6	3.5	3.5	3.7	3.5
Added fats	1	0	1 [b]	1	0	1 [b]
Bakery and breakfast cereals	1	0	1 [b]	1	0	1 [b]
Starchy roots and other starchy plant foods	1	0	1 [b]	1	0	1 [b]
Meat, fish and eggs	1	0	1 [b]	1	0	1 [b]
Grains and grain products	4.2	7	7	7	11.2	7
Legumes, nuts and seeds	1	0	1 [b]	3.5	0	3.5
Human milk	6.9	6.9	7	6.9	6.9	7

[a] The number of servings a week were set at meal-based for all food groups except "Human milk" at daily-based.
[b] The value 1 was entered instead of 0 as the 50th percentile for mathematical reasons.
[c] 50th percentile of consumption observed by the target group

Starting with 6-8 months infants (Figure 1), it can be observed that only 2 nutrients met 100% RNI in both optimized diets i.e. vitamin C and vitamin B12. In the case of folate and vitamin A, changing the average dietary pattern can lead to these nutrients completely meeting the recommended intake (100% RNI). However, for the rest 7 nutrients i.e. calcium, thiamine, riboflavin, niacin, vitamin B6, iron and zinc, the 100% RNI was not met in both optimized diets. Therefore, these 7 nutrients are classified as problem nutrients of the diets of the 6-8 months target group.

In the case of 9-12 months infants (Figure 2), 4 nutrients achieved 100% RNI in both optimized diets i.e. vitamin C, riboflavin, vitamin B12 and vitamin A. On the other hand, folate could be met if some changes were made in the average dietary pattern. Nevertheless, as observed in the 6-8 months target group, calcium, thiamine, niacin, vitamin B6, iron and zinc, were also problem nutrients of the diets of the 9-12 months target group.

In summary, several problem nutrients were found in the diets of both target groups i.e. 7 and 6 in the diets of 6-8- and 9-12-months infants respectively, highlighting the need for changes in the local food pattern.

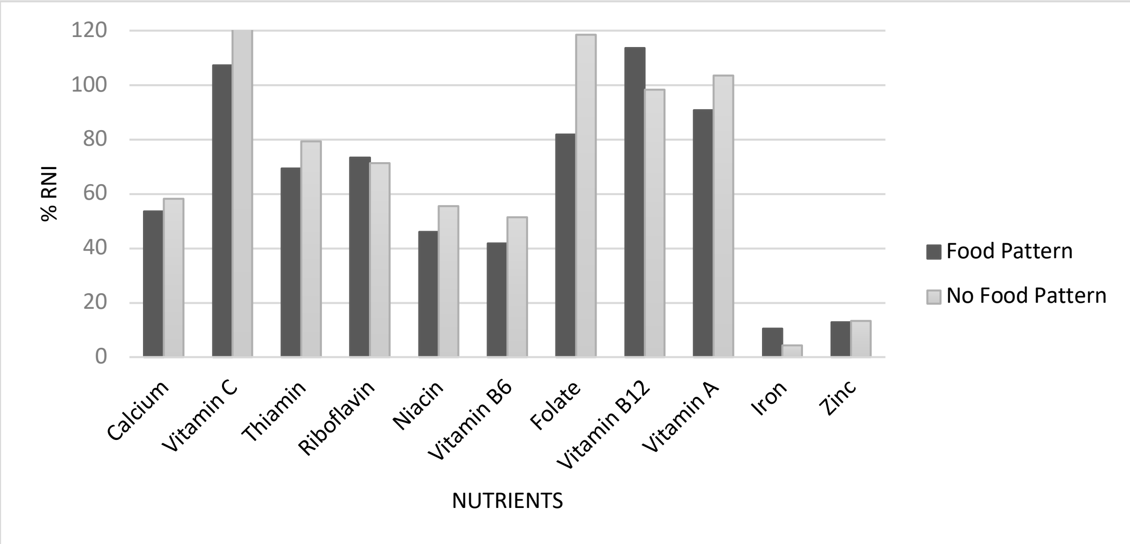

Figure 1: % RNI of the 2 optimized diets from Module 2 of 6-8 months infants

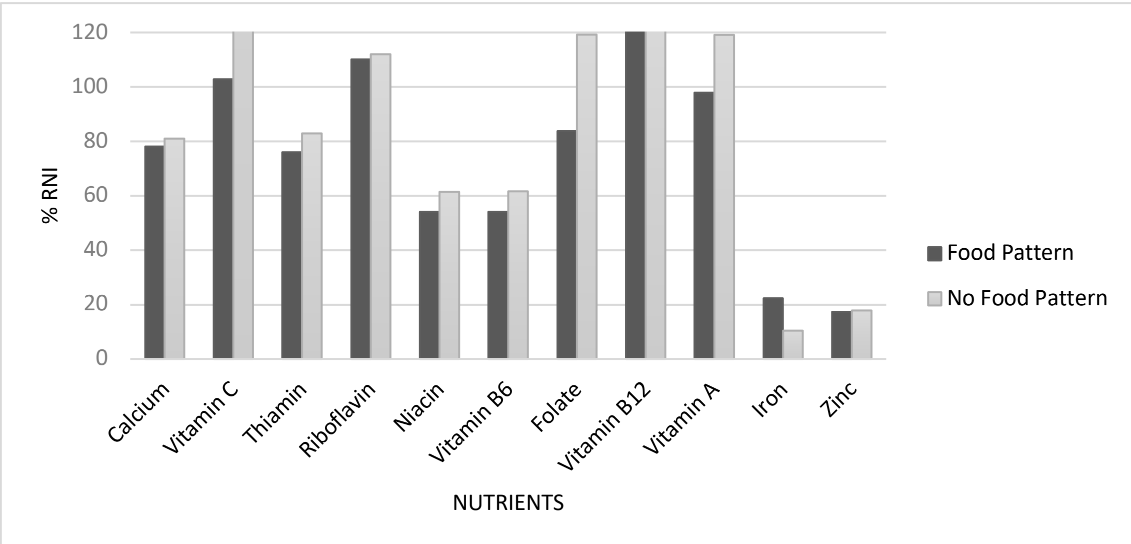

Figure 2: % RNI of the 2 optimized diets from Module 2 of 9-12 months infants

4.3.3 Results from Module 3: Test of Food-based Recommendations

4.3.3.1 Absolute and partial problem nutrients

Module 3 was firstly run without adding constraints and 32 diets were generated: 16 of them had the "worst-case scenario" level of each nutrient (i.e. lowest %RNI) and other 16 diets had the "best-case scenario" level of each nutrient (i.e. highest %RNI). In figure 3 and 4, these scenarios are illustrated for the 6-8- and 9-12-months infants, respectively.

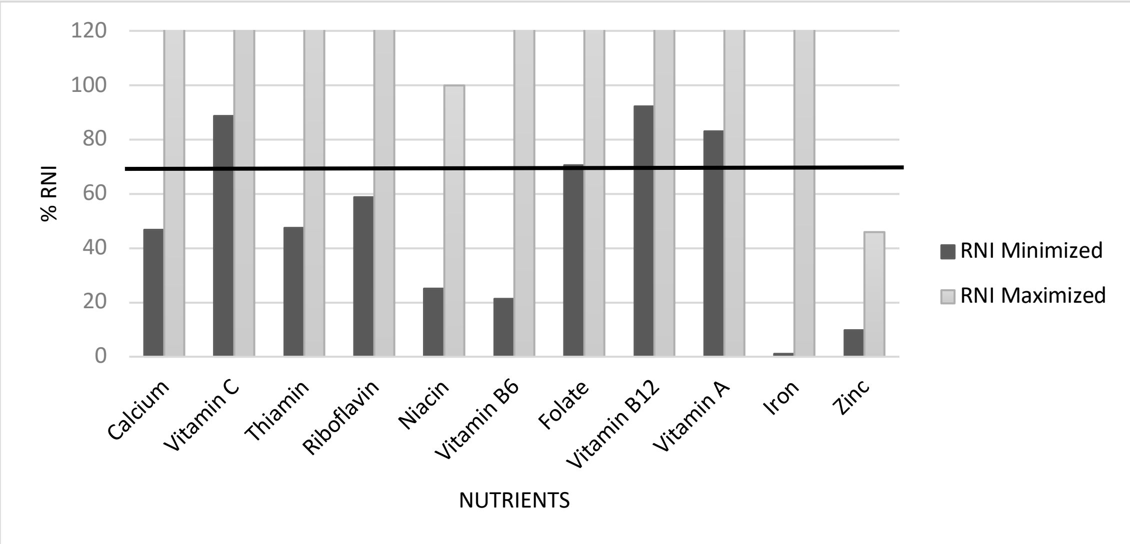

Figure 3: % RNI of the "worst-case scenario" (RNI minimized) and "best-case scenario" (RNI maximized) diets of 6-8 months infants

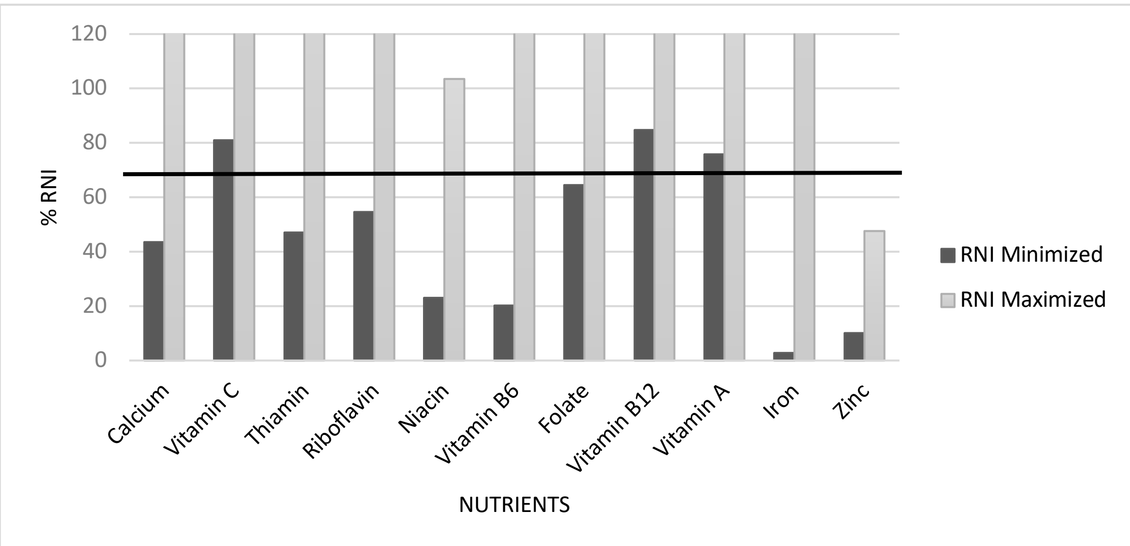

Figure 4: % RNI of the "worst-case scenario" (RNI minimized) and "best-case scenario" (RNI maximized) diets of 9-12 months infants

These results allowed to identify the absolute and partial problem nutrients (see more details in Appendix 13 and 14). In the diets of both target groups, zinc was an absolute problem nutrient (highest %RNI was 45.9% and 47.6% for 6-8- and 9-12-months target groups, respectively). This means that the RNI of this micronutrient can't be met using only local food sources and/or local food patterns.

Furthermore, calcium, thiamine, riboflavin, niacin, vitamin B6 and iron were identified in both target groups as partial problem nutrients, as well as folate in the 9-12 months target group. These micronutrients were able to achieve 100% RNI in the "best-case scenario" diets but remained lower than 70% RNI in the "worst-case scenario" diets. Therefore, these partial problem nutrients were important to focus on during the development of FBRs in the following steps of Module 3.

4.3.3.2 Formulation of Food-Based Recommendations

During the formulation of the food-based recommendations (FBRs) for both target groups, 11 micronutrients were taken into account, with the aim of maximizing particularly the intake of problem nutrients in the diets. Firstly, FBRs were built at a food group/subgroup level. Subsequently, individual food items were included in the FBRs in order to improve the intake of some partial problem nutrients.

1. Breastfed 6-8 months infants

FBRs food group/subgroup level

Individual FBRs were selected and introduced with the maximum servings/week set in the constraints. Therefore, 6 food groups were selected for both target groups: "Fruits", "Grains and grain products", "Meat, fish and eggs", "Dairy products", "Legumes, nuts and seeds", "Starchy roots and other starchy plant foods" (Table 4.7). The food groups "Bakery and breakfast cereals", "Added fats" and "Added sugars" were not added due to the low nutritional value of their respective food items (see more details in Appendix 15).

From these individual FBRs, some were chosen to be combined in sets of 2 FBRs on the following step. Thus, 5 FBRs were chosen: "Fruits", "Grains and grain products", "Meat, fish and eggs", "Dairy products", and "Legumes, nuts and seeds". On the other hand, the food group "Starchy roots and other starchy plant foods" was excluded due to it being a poorer source of nutrients, which are already covered by other food groups. These 5 FBRs could meet 70% RNI of 6 nutrients, including 2 partial problem nutrients i.e. calcium and riboflavin.

Table 4.7: Individual FBRs of food groups/subgroups included for analysis in Module 3 for 6-8 months infants

FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b c]	FBRs included
Fruits (7 servings/week)	4	Vitamin C, Folate, Vitamin B12, Vitamin A	x
Grains and grain products (10.5 servings/week)	5	Vitamin C, **Riboflavin**, Folate, Vitamin B12, Vitamin A	x
Meat, fish and eggs (3.5 servings/week)	4	Vitamin C, Folate, Vitamin B12, Vitamin A	x
Dairy products (7 servings/week)	6	**Calcium**, Vitamin C, **Riboflavin**, Folate, Vitamin B12, Vitamin A	x
Legumes, nuts and seeds (7 servings/week)	5	Vitamin C, **Riboflavin**, Folate, Vitamin B12, Vitamin A	x
Starchy roots and other starchy plant foods (3.5 servings/week)	4	Vitamin C, Folate, Vitamin B12, Vitamin A	

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario
[c] Nutrients in bold represent the problem nutrients

Combination of individual FBRs

In the next phase, the individual FBRs selected were combined with each other in order to cover, if possible, 70% RNI of all partial problem nutrients.

Firstly, sets of two FBRs were analysed (Table 4.8). At this stage, 70% RNI of niacin, vitamin B6 and iron were not covered. From these results, the set "Dairy Products" (7 servings/week) and "Legumes, nuts and seeds" (7 servings/week) was initially selected, which could meet the requirements of 7 nutrients and was also a good source of niacin and iron (see more details in Appendix 16).

Table 4.8: Set of two FBRs included for analysis in Module 3 for 6-8 months infants

Set of 2 FBRs		**No. Nutrients ≥70%RNI [a]**	**Nutrients [b]**
Grains and grain products (10.5 servings/week)	Dairy products (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Grains and grain products (10.5 servings/week)	Fruits (7 servings/week)	6	Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Grains and grain products (10.5 servings/week)	Legumes, nuts and seeds (7 servings/week)	5	Vitamin C, Riboflavin, Folate, Vitamin B12, Vitamin A
Dairy products (7 servings/week)	Legumes, nuts and seeds (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Dairy products (7 servings/week)	Fruits (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Legumes, nuts and seeds (7 servings/week)	Fruits (7 servings/week)	5	Vitamin C, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Dairy products (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Fruits (7 servings/week)	5	Vitamin C, Thiamine, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Legumes, nuts and seeds (7 servings/week)	6	Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Grains and grain products (10.5 servings/week)	6	Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

Secondly, the selected set of two FBRs was analysed with other individual FBR in order to create a set of three FBRs. The criteria to choose the next individual FBR was the best source of iron, the partial problem nutrient that reached the lowest RNI in the set (31.3%). Therefore, the selected FBR was "Grains and grain products" (10.5 servings/week) (Table 4.9).

Table 4.9: Set of three FBRs included for analysis in Module 3 for 6-8 months infants

Set of 3 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Grains and grain products (10.5 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

Next, one more individual FBR was added in order to increase the intake of nutrients, particularly niacin, vitamin B6 and iron. In the set of 3 FBRs, the results showed that niacin and vitamin B6 reached the lowest RNI (46.1%) comparing to the other nutrients (see more details in Appendix 17). Therefore, “Fruits” (7 servings/week) was added to create a set of four FBRs, which came closer to meet the 70% RNI of vitamin B6 (60.9%) (Table 4.10).

Table 4.10: Set of four FBRs included for analysis in Module 3 for 6-8 months infants

Set of 4 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Grains and grain products (10.5 servings/week) Fruits (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

Finally, “Meat, fish and eggs” (3.5 servings/week) was the last individual FBR incorporated in the set to meet the requirement of vitamin B6 (Table 4.11). In the end, the final combination of FBRs was not able to cover 70% RNI of all partial problem nutrients in the “worst-case scenario” i.e. niacin reached 56.4% RNI, and iron 57.9% RNI. Therefore, in the second part of the analysis, food items were included in the FBRs in order to increase the intake of these 2 nutrients.

Table 4.11: Set of five FBRs included for analysis in Module 3 for 6-8 months infants

Set of 5 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Grains and grain products (10.5 servings/week) Fruits (7 servings/week) Meat, fish and eggs (3.5 servings/week)	8	Calcium, Vitamin C, Thiamine, Riboflavin, Vitamin B6 Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

FBRs including specific food items

The set of 5 FBRs was not able to cover 70% RNI of all micronutrients in the "worst-case scenario", therefore, it was necessary to select specific food items. This situation occurred for niacin and iron. Teff flour was added as it was a main source of both of them, and also a good source of zinc. This food item was also selected based on the fact that it was a main source of these micronutrients in the diets of both target groups. The constraints were set at 7 servings/week, approximately 2/3 of the maximum constraints of the grains' food group, in order not to limit the consumption of other grains.

In addition, it was also observed that was possible to maximize the intake of vitamin B6 by the inclusion of banana in the diet, with the maximum servings/week of its food subgroup set in the constraints (see more details in Appendix 15). Therefore, a new set of recommendations was built, with the inclusion of 2 new food items, teff flour (7 servings/week) and banana (3.5 servings/week) (Table 4.12).

Table 4.12: Additional individual FBRs of food items included for analysis in Module 3 for 6-8 months infants

FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Teff flour (7 servings/week)	7	Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A, Iron
Banana (3.5 servings/week)	6	Vitamin C, Riboflavin, Vitamin B6, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

The same procedure used for the construction of FBRs at food group/subgroup level was used and the results are presented in Table 4.13 (see more details in Appendix 18). This new set, in comparison with the previous set, is able to cover 70% RNI of two extra nutrients, niacin and iron.

Table 4.13: Set of four FBRs included for analysis in Module 3 for 6-8 months infants, comprising food items

Set of 4 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Teff flour (7 servings/week) Banana (3.5 servings/week)	10	Calcium, Vitamin C, Thiamine, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Vitamin A, Iron

[a] [b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

2. Breastfed 9-12 months infants

FBRs food group/subgroup level

The same procedure of selection and construction of FBRs used for the 6-8 months infants was used for this target group. The same 6 food groups used for the 6-8 months target group were included, but "Grains and grain products" were set with different constraints (14 servings/week) (Table 4.14).

Table 4.14: Individual FBRs of food groups/subgroups included for analysis in Module 3 for 9-12 months infants

FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]	FBRs included
Fruits (7 servings/week)	4	Vitamin C, **Folate**, Vitamin B12, Vitamin A	x
Grains and grain products (14 servings/week)	3	Vitamin C, Vitamin B12, Vitamin A	x
Meat, fish and eggs (3.5 servings/week)	3	Vitamin C, Vitamin B12, Vitamin A	x
Dairy products (7 servings/week)	5	**Calcium**, Vitamin C, **Riboflavin,** Vitamin B12, Vitamin A	x
Legumes, nuts and seeds (7 servings/week)	4	Vitamin C, **Riboflavin,** Vitamin B12, Vitamin A	x
Starchy roots and other starchy plant foods (3.5 servings/week)	3	Vitamin C, Vitamin B12, Vitamin A	

[a] [b] Number and name of nutrients that met 70 % RNI in the worst-case scenario
[c] Nutrients in bold represent the problem nutrients

As well as the 6-8 months target group, 5 individual FBRs were chosen: “Fruits”, “Grains and grain products”, “Meat, fish and eggs”, “Dairy products”, and “Legumes, nuts and seeds”. These 5 FBRs could meet in total 70% RNI of 6 nutrients, including 3 partial problem nutrients i.e. calcium, riboflavin and folate (see more details in Appendix 20).

Combination of individual FBRs

After combining the individual FBRs in sets of two, it was observed that 70% RNI of niacin, vitamin B6 and iron were not covered (Table 4.15). The set “Dairy Products” (7 servings/week) and “Legumes, nuts and seeds” (7 servings/week) was chosen, which obtained the requirement of 7 nutrients and was also a good source of niacin and iron.

Table 4.15: Set of two FBRs included for analysis in Module 3 for 9-12 months infants

Set of 2 FBRs		**No. Nutrients ≥70%RNI [a]**	**Nutrients [b]**
Grains and grain products (14 servings/week)	Dairy products (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Grains and grain products (14 servings/week)	Fruits (7 servings/week)	5	Vitamin C, Riboflavin, Folate, Vitamin B12, Vitamin A
Grains and grain products (14 servings/week)	Legumes, nuts and seeds (7 servings/week)	4	Vitamin C, Riboflavin, Vitamin B12, Vitamin A
Dairy products (7 servings/week)	Legumes, nuts and seeds (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Dairy products (7 servings/week)	Fruits (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Legumes, nuts and seeds (7 servings/week)	Fruits (7 servings/week)	5	Vitamin C, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Dairy products (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Fruits (7 servings/week)	5	Vitamin C, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Legumes, nuts and seeds (7 servings/week)	6	Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A
Meat, fish and eggs (3.5 servings/week)	Grains and grain products (14 servings/week)	6	Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

One more individual FBR was incorporated into the set of two FBRs, which corresponded to the FBR that reached the highest RNI of iron, the partial problem nutrient that reached the lowest RNI in the set (39.7%) (see more details in Appendix 21). Therefore, the selected FBR was "Grains and grain products" (14 servings/week) (Table 4.16).

Table 4.16: Set of three FBRs included for analysis in Module 3 for 9-12 months infants

Set of 3 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Grains and grain products (14 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

Furthermore, another individual FBR was added in order to increase the intake of nutrients, particularly niacin and vitamin B6, which reached the lowest RNI (44.8% and 50.5%, respectively) comparing to the other nutrients (see more details in Appendix 22). As a result, "Fruits" (7 servings/week) was added to create a set of four FBRs (Table 4.17).

Table 4.17: Set of four FBRs included for analysis in Module 3 for 9-12 months infants

Set of 4 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Grains and grain products (14 servings/week) Fruits (7 servings/week)	7	Calcium, Vitamin C, Thiamine, Riboflavin, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

Lastly, a set of 5 FBRs was created by adding the individual FBR "Meat, fish and eggs" (3.5 servings/week), in order to meet the requirement of vitamin B6 (Table 4.18). However, the final set of FBRs was not able to cover 70% RNI of all partial problem nutrients in the "worst-case scenario" i.e. niacin reached 56.6% RNI, and iron 66.2% RNI (see more details in Appendix 22).

Table 4.18: Set of five FBRs included for analysis in Module 3 for 9-12 months infants

Set of 5 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Grains and grain products (14 servings/week) Fruits (7 servings/week) Meat, fish and eggs (3.5 servings/week)	8	Calcium, Vitamin C, Thiamine, Riboflavin, Vitamin B6, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

FBRs including specific food items

The same procedure used for the 6-8 months target group to build improved FBRs was followed, by inserting individual food items that made it possible to meet 70% RNI of niacin and iron. Therefore, teff flour (10 servings/week), as a good source of niacin and zinc, and banana (3.5 servings/week), as a good source of vitamin B6, were introduced in the final set of FBRs (Table 4.19 and 4.20) (see more details in Appendix 20 and 23).

Table 4.19: Additional individual FBRs of food items included for analysis in Module 3 for 9-12 months infants

FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Teff flour (10 servings/week)	6	Vitamin C, Thiamine, Riboflavin, Vitamin B12, Vitamin A, Iron
Banana (3.5 servings/week)	6	Vitamin C, Riboflavin, Vitamin B6, Folate, Vitamin B12, Vitamin A

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

Table 4.20: Set of four FBRs included for analysis in Module 3 for 9-12 months infants, comprising food items

Set of 4 FBRs	No. Nutrients ≥70%RNI [a]	Nutrients [b]
Dairy products (7 servings/week) Legumes, nuts and seeds (7 servings/week) Teff flour (10 servings/week) Banana (3.5 servings/week)	10	Calcium, Vitamin C, Thiamine, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Vitamin A, Iron

[a b] Number and name of nutrients that met 70 % RNI in the worst-case scenario

4.3.3.3 Reduction of the number of servings of the final set of FBRs

The number of servings in the final set of FBRs could be further reduced in both target groups, with 10 nutrients (all except zinc) still meeting 70% RNI or higher. Hence, the food item banana could be reduced to 3 servings/week and, the intake of dairy was further reduced to 3 serving/week, in order to be close to the average consumption of this food group by both target groups (see more details in Appendix 18 and 23).

4.3.3.4 Nutritional importance of each individual FBR

The removal of individual recommendations from the set of FBRs resulted in at least one nutrient falling below 70% RNI for both target groups (see more details in Appendix 19 and 24). These results helped in the identification of important sources of partial problem nutrients and showed why is important to include all the individual FBRs in the final set (Table 4.21).

Table 4.21: Effect of removing individual recommendations from the set of FBRs for each target group

Removed FBRs	6-8 months infants		9-12 months infants	
	No. Nutrients <70%RNI [a]	**Nutrients [b]**	**No. Nutrients <70%RNI [a]**	**Nutrients [b]**
Teff flour	3	Thiamine, Niacin, Iron	3	Thiamine, Niacin, Iron
Dairy products	1	Calcium	1	Calcium
Banana	2	Niacin, Vitamin B6	2	Niacin, Vitamin B6
Legumes	1	Niacin	1	Niacin

[a b] Number and name of nutrients that fell below 70 % RNI in the worst-case scenario

4.3.3.5 Iron and Zinc Bioavailability

The final set was analysed with different bioavailability for iron and zinc: 10% bioavailability (9.3 mg/day) was assumed for iron and moderate bioavailability was assumed for zinc (4.1 mg/day). The main changes observed are the zinc intakes, which came closer to meet 70% RNI for both target groups (58.3% for 6-8 and 61.6% for 9-12 months infants) (see more details in Appendix 25).

4.3.4 Final recommendations

Two sets of FBRs were constructed for each target group: one at food group level and other including specific food items to increase the nutrient intake (Table 4.22 and 4.23). This is illustrated in Figure 5 and 6 for the 6-8- and 9-12-months target group, respectively, where both sets can be compared.

The four common messages across all target groups are:

- Continue breastfeeding;
- Consume 1-2 servings of grains every day, especially sources rich in nutrients, such as teff, at least 7 meals of the week;
- Consume fruits every day, with the inclusion of sources of vitamin B6, such as banana or avocado, at least 3 times per week;
- Consume legumes every day;
- Consume dairy products 3 times per week, which can be added in small volumes to complementary foods;
- Consume other animal source foods every week, such as meat, fish, and liver.

In combination with other foods, consuming at least the food items included in the set of FBRs would improve the nutrient intake of the infants' diets (see more details in Appendix 26). For all target groups, the selected set of FBRs would ensure at least 70% RNI of all nutrients, except for zinc.

When comparing the set of FBRs with the average dietary pattern (50th percentile), it's clear that changes are needed to increase the nutrient adequacy of the current diet. The main differences are the number of servings a week of fruits and legumes, which need to be increased. In addition, the inclusion of more nutrient-dense foods, like teff, could improve the adequacy of the diets.

Table 4.22: Final recommendations at food group level for both target groups

FBRs at food group level				
	6-8 months infants should consume at a minimum (this diet does not meet niacin, iron and zinc requirements):		**9-12 months infants should consume at a minimum** (this diet does not meet niacin, iron and zinc requirements):	
Food	**Servings/week**	**Servings/day**	**Servings/week**	**Servings/day**
Dairy products	7	1	7	1
Legumes, nuts and seeds	7	1	7	1
Grains and grain products	7	1	14	2
Fruits	7	1	7	1
Meat, fish and eggs	3.5	0.5	3.5	0.5

Table 4.23: Final recommendations including food items for both target groups

FBRs including food items				
	6-8 months infants should consume at a minimum (this diet does not meet zinc requirements):		**9-12 months infants should consume at a minimum** (this diet does not meet zinc requirements):	
Food	**Servings/week**	**Servings/day**	**Servings/week**	**Servings/day**
Dairy products	3	0,5	3	0,5
Legumes, nuts and seeds	7	1	7	1
Teff flour	7	1	10	1.5
Banana	3	0.5	3	0.5

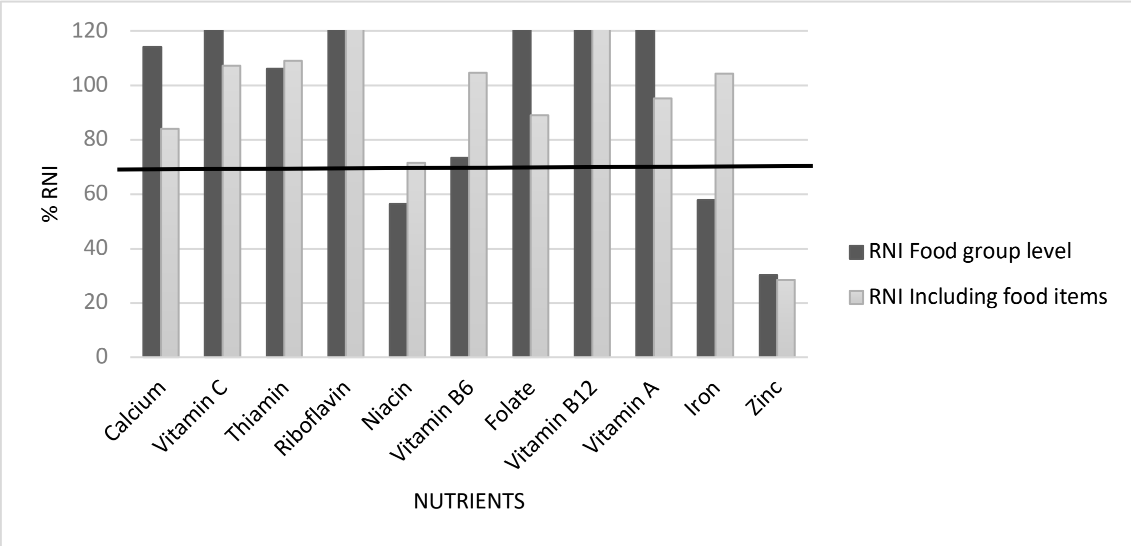

Figure 5: % RNI of the final set of FBRs at food group level (1st set) and including food items (2nd set) of 6-8 months infants

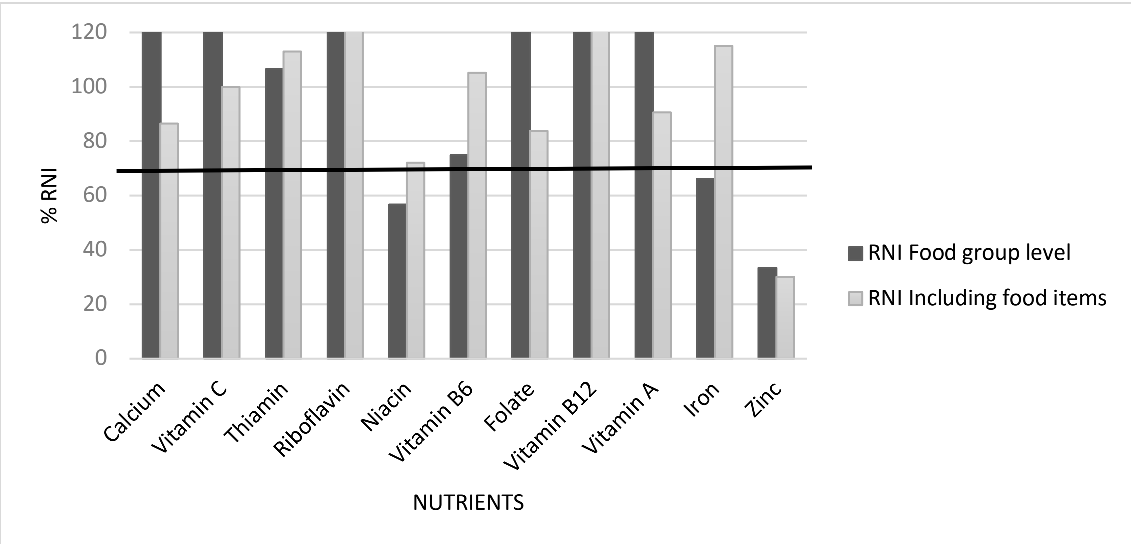

Figure 6: % RNI of the final set of FBRs at food group level (1st set) and including food items (2nd set) of 9-12 months infants

5. Discussion

The main purpose of this study was to develop a set of recommendations using locally available foods, to improve the adequacy of nutrient intakes of 6-12 months infants in southwest Ethiopia and identify nutrients that might need additional interventions to meet nutrient requirements. Linear programming appears to be a promising problem-solving approach by helping in the construction and selection of population- and local-specific food-based recommendations (FBRs).

The findings of this study show that some modifications on the dietary pattern of 6-12 months infants from southwest Ethiopia can ensure that ten out of the eleven analysed micronutrients meet their requirements at population-level. The intake of some micronutrients was improved when more nutrient-dense foods were introduced in the analysis. This was observed particularly when banana and teff were introduced, since two additional micronutrients were able to meet 70% RNI i.e. niacin and iron. Zinc was the only nutrient that was unable to meet the recommendations in neither one of the analysis. Therefore, these results show that additional interventions, in addition to changes in the dietary pattern, are necessary to ensure nutritional adequacy.

The inability of the local food sources to meet all the micronutrient' requirements indicates that these sources are limited, either in frequency, quantity and/or number. This may be explained by the fact that the list of foods consumed by ≥ 5% of the target groups was limited, including only 20-24 food items. Another possible explanation is that many nutrient-dense foods, such as vegetables and some animal source foods (ASFs) e.g. meat, poultry, and fish, were not included for analysis because they were not consumed by the target groups. Although both food sources were not mentioned in the 24-hour recall of these infants, it does not reflect their availability in the region.

The inclusion of other ASFs in the diet could be advantageous for these infants mainly due to it being an excellent source of good quality protein and micronutrients with high bioavailability, such as iron and zinc, which tend to be limited in plant-based diets. The high bioavailability of micronutrients in ASFs can be attributed to the presence of heme protein in meat, poultry and fish as well as the lack of inhibitors like phytate found in plant based diets (Neumann, Harris, & Rogers, 2002).

Low availability was assumed for iron and zinc since the diets of these infants were poor in iron- and zinc-rich ASFs and were also high in milk, which is rich in casein that can inhibit iron and zinc absorption (Kibangou *et al.*, 2005; Lönnerdal, 2000). However, it is possible that iron and zinc bioavailability were higher than estimated, thus decreasing their dietary

intake requirements in the population. Yet, it was observed that even if moderate zinc bioavailability was considered, 70% RNI was still not met for this micronutrient in the final set of recommendations.
Regarding niacin and calcium, these two micronutrients showed to be problem nutrients, since there is a discrepancy between the infants' intake and the infants' requirements. However, precaution is needed when analysing the results of this study. The body's requirement of niacin is met not only by nicotinamide and nicotinic acid present in the diet but also by conversion of the amino acid tryptophan present in the dietary protein (60 mg of tryptophan = 1 mg of niacin = 1 mg of niacin equivalents). However, our analysis does not account for the conversion of tryptophan to niacin, therefore, this micronutrient might not be a problem nutrient (Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, 1998). The same tendency might occur with calcium since water intake was not measured, which can be a considerable source of calcium in the infants' diets.

Optifood was used for the development of FBRs for two target groups i.e. 6-8- and 9-12-months infants, due to their differences in RNI and dietary patterns. During the formulation of the sets of FBRs, efforts were made to create similar messages across the target groups to facilitate their promotion and adoption by the caregivers. In addition, only foods consumed by these target groups were included. Nonetheless, including other nutrient-dense foods consumed by other age groups in Jimma, such as vegetables and other ASFs, could be beneficial.
The adoption of the FBRs formulated would require changes in the dietary pattern of the target groups, such as in quantity, frequency or introduction of other foods in the diet. Therefore, the next step would be to examine the affordability, acceptability, accessibility, and feasibility of the selected FBRs in this area. This would determine if the food items selected and recommendations suggested are realistic and appropriate to be promoted among the infants or whether changes are required to facilitate their adoption.
It would also be relevant to evaluate the inclusion of nutrient-dense foods that are available locally but were not consumed by our sample of the population, or other foods not yet introduced in the area (e.g. fortified foods, home fortification products) that would address the problem nutrients identified in the infants' diets.

5.1 Comparison with other studies conducted in Ethiopia

More recent studies conducted in Ethiopia, compared to the data of this study (collected in 2009/2010), have shown similar levels and patterns on complementary feeding practices. For instance, a study conducted by Areja *et al*. (2017) in a rural district in southern Ethiopia also reported that grains, roots and tubers, and dairy products were the two food groups mostly consumed (87.7% and 80.1%, respectively) in the 6-11 months children age group. In addition, eggs (9%), vitamin A rich foods (9.95%) and flesh foods (0.95%) were the lowest consumed food groups (Areja, Yohannes, & Yohannis, 2017).

We observed that milk was the predominant animal food product consumed by the infants. This finding is in line with the fact that dairy products are the most common ASF available in Ethiopia for household consumption and so milk is frequently used to prepare complementary food (Semahegn, Tesfaye, & Bogale, 2014; Tamiru, Aragu, & Belachew, 2013). However, the consumption of dairy products shouldn't replace infants' intake of breast milk, so care should be taken when promoting its intake. Moreover, in a study conducted in Jimma zone, it was observed that dilution of milk and bottle feeding were common practices by some mothers which should be discouraged (Seid *et al.*, 2019). Therefore, besides nutrition concerns, also food safety precautions need to be taken into account by caregivers when milk is provided to infants.

In accordance with the present results, previous studies in Ethiopia have demonstrated that the consumption of other ASFs, such as meat, chicken, fish, liver and eggs, is very low or absent, despite household's ownership of livestock (Gatahun, Abate, & Abyu, 2016; R. S. Gibson *et al.*, 2009; Mengistu, Moges, Samuel, & Baye, 2017). One possible explanation is that the owned livestock is used as an income-generating activity instead of home consumption (R. S. Gibson *et al.*, 2009). Furthermore, a study conducted in Addis Ababa observed that 47% of the consumers surveyed believe that 6 to 24 months-old children should not eat meat (Melesse, Van den berg, de Brauw, & Abate, 2019). A similar misconception was observed for vegetable intake. In studies conducted in southern and southwest Ethiopia, it was observed that even though some households possessed gardens with fruits and/or vegetables, such as mango, papaya, pumpkin, spinach, and kale, it was not a common practice to give them to children under two years old and so their consumption was rather low (R. S. Gibson *et al.*, 2009; USAID, 2011)

There are, however, other possible explanations to the inexistent consumption of some foods and the lack of diversity in the infants' diets. According to the literature, accessibility to markets showed to be one determinant of diet diversity, with households having a more diverse diet when they live closer to markets, which also showed to benefit nutrition knowledge. The distance to a weakly market for the average rural household in Ethiopia has an average of 10.9 kilometres. In contrast to cereals, tubers and dairy, which mainly come from own production, more than half of fruits, vegetables, meat, and eggs consumed come from the markets. In addition, many of the produced vegetables and fruits are destined for international and urban markets, impacting the accessibility to the rural and urban poor (Gebru *et al.*, 2018). This illustrates the importance of strengthening rural markets to increase accessibility to rural households, and consequently possibly influence infants' dietary diversity. An evaluation of the local value chains should be done to understand the constraints these households face to access nutrient-dense foods, such as ASFs, fruits, and vegetables. Therefore, several factors can influence the consumption of nutrient-dense foods, including factors related to household income, price, accessibility, availability, preferences, and consumer knowledge about health benefits of these foods (Abate, Bayeh, de Brauw, & Hirvonen, 2019).

The results of this study further support the findings from previous studies conducted in Ethiopia that used Optifood, particularly regarding the main problem nutrients identified: iron and zinc.

One of these studies conducted by Samuel *et al*. (2019) analysed data of the 2011 Ethiopian National Food Consumption Survey (NFCS), including 6-23 months children (n=2498), from four regions of Ethiopia. Here, the total number of food items consumed by ≥ 3% of the children was 28 and 38, for 6-8 and 9-11 months respectively, which was slightly higher than we observed in our study. In addition, the food portion sizes were reported to be small, with the exception of milk. As seen in our study, milk was consumed in large quantities in all regions, particularly in Oromia, where median serving sizes were > 200 g/d. Moreover, their study found that in all regions, iron and especially zinc were problem nutrients for the 6-11 months infants. Samuel *et al*. (2019) therefore reported that their formulated local FBRs couldn't meet all nutrient requirements, especially due to the lack of foods with adequate iron and zinc contents which is in accordance with our findings.

Comparison between the set of recommendations formulated in our study and those described by Samuel *et al*. (2019) showed some similarities in the foods included. These foods comprising of milk, teff, and legumes, in addition to breast milk, were recommended for most of the regions and age groups. On the contrary, their recommendations didn't include fruits since they were rarely consumed by the children and, therefore, they were not included in their analysis (Samuel *et al.*, 2019).

The results of our study seem to be consistent with other research conducted in Ethiopia using Optifood, which analysed data of Household Consumption and Expenditure Surveys (HCES) from the 2012-2013 Ethiopia Socioeconomic Survey. In accordance with the present results, zinc and iron were identified as problem nutrients in the infants' diets, since their requirements could not be met using any acceptable combination of local foods. The best food sources identified by the authors, in addition to breast milk, were legumes, teff, milk, cheese, green leafy vegetables and other vegetables, red meat, chicken meat, and eggs. In agreement with our findings, consumption of vegetables, especially green leafy vegetables, was extremely low, mainly due to poor access to these foods (Knight, 2016).

5.2 Zinc as a widespread problem nutrient

Based on national food balance sheets, it is estimated that 17.3 % of the world's population is at risk of inadequate zinc intake (Wessells & Brown, 2012). Furthermore, a study by Hess (2017) which looked at national surveys observed that in 13 out of 19 low- and middle-income countries, >20% children had low plasma/serum zinc concentrations (Hess, 2017). In this view, intake of the population based on food balance sheets might underestimate the risk of zinc deficiency, which is a public health concern worldwide.

In our study, the Recommended Nutrient Intake (RNI) of zinc was not attainable with the selected set of FBRs at the end of the analysis. These results were not surprising since the zinc intake in the "best-case scenario diet" (diet modelled to provide the highest amount of zinc possible, based on the local food constraints) was below 70% RNI.

Several food sources contain zinc, but the highest concentrations are found in animal source foods (ASFs). However, zinc intake doesn't depend only on the amount ingested but also on other factors including the presence of dietary phytate, absorption inhibitors as well as competitive absorption in the presence of other minerals (Solomons, 1986). An observed trend in diets from developing countries is the low intake of animal products and high intake of plants and cereals, which are high in these inhibitors, resulting in low available zinc for absorption (Lönnerdal, 2000).

A study conducted in Ethiopia that analysed zinc intake among children of 6-35 months old (n=6752) observed a mean dietary intake of 1.74 mg/day, which represents 20.7% RNI, assuming low zinc bioavailability (Ayana *et al.*, 2018). This is supported by the findings of the Ethiopian Public Health Institute (2016) which reported that 35% of preschool-age children had low serum zinc concentration and are therefore zinc deficient (EPHI, 2016). These inadequate levels in serum further support our deduction that local foods might be insufficient to meet zinc requirements and that zinc is a public health problem in Ethiopia.

Therefore, solutions must extend beyond the food items being used in the diets of these infants. Increasing the availability of ASFs or alternative strategies, such as micronutrient supplementation, might be required to meet zinc requirements (Samuel *et al.*, 2019).

5.3 Challenges of implementation

5.3.1 Food prices and Markets

In Ethiopia, household diets remain subject to significant seasonal stress and price fluctuations. The food prices impact not only the affordability to consumers, but also the revenue to the farmers and producers. Consequently, access to food markets can have a great influence on malnutrition and diet quality as well as food affordability (Gebru *et al.*, 2018).
Regardless of the possible improvement of dietary adequacy via the promotion of FBRs through behaviour change communication or nutrition education, food prices remain one of the major barriers to the consumption of nutrient-dense foods. Since a cost analysis was not performed in this study, it's important to consider the price of the foods promoted as it is a major determinant for the adoption of the recommendations selected.
A study by IFPRI's Ethiopia Strategy Support Program (ESSP) observed that the prices of non-staple foods have been rising over a period of ten years in Ethiopia (2007-2016) (Bachewe, Hirvonen, Minten, & Yimer, 2017). The results showed that the price of vitamin A-rich leafy green vegetables, fruits and vegetables (FVs), legumes and nuts, and ASFs (dairy, eggs, meat) had increased by 80%, 40%, 30% and 30%, respectively, over a 10-year period. On the other hand, the price of staple crops like grains, roots, and tubers remained stable whereas the price of oils, fats and sugar decreased substantially. The financial barrier for low-income households to afford nutritious foods, such as FVs, legumes and nuts, and animal proteins is a concern since the consumption of these foods is already low, as observed in our study. Therefore, diets poor in these foods in rural areas can be partly explained by limited knowledge about the health benefits of diverse diets, by poor access to food markets and the inability to afford nutritionally rich foods.
When looking at the real food prices per kg over the period of 2007 to 2016, using data from the Ethiopian Central Statistical Agency (CSA), it is possible to conclude that, within ASF, cow's milk is the most affordable source, followed by eggs, which have a cost two times higher. In addition, beef has a cost 7.7 times higher than cow´s milk (Bachewe, Minten, & Yimer, 2017). Consequently, it is observed that expenses on dairy products make up almost half of all ASF expenditures (Abegaz, Hassen, & Minten, 2018). Moreover, animal products have the highest income elasticity of all the food categories: a doubling of income leads to

172 and 198 percent increase in expenditures on ASF in urban and rural areas, respectively (Hassen, Dereje, Minten, & Hirvonen, 2016).

In the case of cereals, teff has approximately the same price as cow´s milk, whereas the maize price is two times lower (Bachewe, Minten*, et al.*, 2017). Due to this higher price within cereals, teff purchase increases consistently over expenditure quintiles. The opposite is observed with barley, sorghum and particularly maize, which are mainly purchased by the poorest quintiles (Hassen *et al.*, 2016).

For FVs, high relative prices are an important barrier for their consumption. Hirvonen et al. (2018) observed that an average Ethiopian household would have to spend 11% of their income to meet the international FVs recommendations, this is 2.5 times higher for poorest households (27% of the income) (Hirvonen, Wolle, & Minten, 2018). This indicates that healthy diets may be difficult to be accessed by the poorest Ethiopian households.

As a result, due to the high price of fruits, per week servings of this food group were reduced during the formulation of the FBRs in our study. In order to reduce the number of servings and still be able to meet the recommendations of some micronutrients, the food item banana was selected. This is due to its high content in several micronutrients, particularly niacin and vitamin B6. On the other hand, if other fruits were selected, instead of banana, the FBRs wouldn't meet 70% RNI of these micronutrients.

Despite the local availability of the food items included in the FBRs formulated, such as milk, teff, and banana, it would be important to understand if they are accessible for all the households and respective barriers, such as cost. In addition, alternatives to these foods should be considered, since seasonality can limit their availability all year.

Given the large influence of price on food consumer choice, particularly for low-income consumers, it consequently influences the dietary patterns of Ethiopian households (Melesse *et al.*, 2019). Furthermore, seasonality and price fluctuations showed to have an impact on the diet and body weight of children (Gebru *et al.*, 2018).

Nutrition specific interventions in conjunction with agricultural- and market-based strategies might be required to improve the access to affordable nutrient-dense foods and facilitate the adoption of recommendations that improve nutrient adequacy. The Ethiopian government has been showing a promising increase in cereal production, mainly by the modernization of the agricultural system. Similar transformations are needed in other food sectors, such as for FVs, legumes, and ASF, so it is important to understand the challenges these sectors face (Gebru *et al.*, 2018; Hirvonen *et al.*, 2018). It would also be relevant to consider the feasibility of home production of these foods and respective challenges, including the time burden, cost, and requirements for production e.g. water, seeds, inputs.

5.3.2 Teff – Ethiopia's Cash Crop

In our study, teff (*Eragrostis tef*) showed to be determinant to substantially increase the intake of some micronutrients in our set of recommendations. This finding is consistent with the literature but, however, teff has been referred as the "orphan crop" due to the scant attention it receives from the Ethiopian government (Minten, Taffesse, & Brown, 2018). There has been limited investment for research on teff, resulting in low yields compared to other cereals (VanBuren *et al.*, 2019). However, it is a staple food for over 70% of the Ethiopians and grown on about 3 million hectors of land. This corresponds to 24% of the grain area in the country, the highest allocation of land for cereals cultivation (Cannarozzi *et al.*, 2014; Lee, 2018).

Teff is a very nutritious cereal grain, superior to other cereals in many aspects, such as mineral content (higher iron, calcium, magnesium, and zinc content); well-balanced amino acid composition (higher concentrations of lysine than other cereals); good source of essential fatty acids and fibre. Literature suggests that although a part of iron content is attributed to soil contamination, teff is still a better source of iron than other cereals. Nevertheless, teff contains high amounts of phytate, which can impair the absorption of iron and zinc. Therefore, food-processing techniques like soaking, fermentation, and germination need to be encouraged in order to have a better bioavailability of these minerals (Minten *et al.*, 2018). In addition, due to ascorbic acid chelating properties, the combination with ascorbic acid-rich foods, such as some FVs, increases the solubility of both contaminant and intrinsic iron, thus increasing the iron absorption (Abebe *et al.*, 2007).

There are different varieties of teff: white, red and mixed, which show some variations in nutrient composition and price. The white variety, which is perceived as having higher quality and a better appearance by the consumers, is the most expensive type of teff which in turn is reserved for the high-income earning families in Ethiopia. On the other hand, red teff, due to its lower price, is preferred by the low-income households. Mixed teff appears to have approximately the same share of teff expenditures across the different expenditure quintiles (Hassen *et al.*, 2016). Regarding nutrient composition, the differences in mineral content between and within varieties are wide-ranging, which shows to be influenced by the environment. Despite this variability, some studies have shown that white teff has the lowest content in iron and calcium compared to the other varieties (Minten *et al.*, 2018).

Despite the price increase during 2000-2009, a study has shown that the consumption of teff barely changed, which indicates that Ethiopian households continue to rely upon this crop as the main staple of their diet, regardless of the price (Minten *et al.*, 2018).

Ethiopia is essentially the only major producer and consumer of teff globally. Since teff is scarcely traded on the international market, interventions to stabilize teff prices may be especially difficult (Dorosh, Smart, Minten, & Stifel, 2018). However, it is expected that there will be an increase in demand in the upcoming years in international markets given the unique gluten-free property of teff (Minten *et al.*, 2018).

In sum, this country's leading cash crop, which is a source of livelihood for many Ethiopian smallholders, faces many challenges and thus needs policy changes to improve its production and marketability and consequently impact poverty and ensure food security (Minten *et al.*, 2018).

5.4 Limitations of the study

This study is dependent on the quality of the dietary data collected, the food composition data, the RNIs, the assumed bioavailability of nutrients and breast milk intakes. Therefore, a series of limitations were identified considering the dietary and Optifood analysis conducted.

The intake of breast milk was not measured during 24-hour recall survey, therefore the published average breast milk intake of infants aged 6-8 and 9-11 months of developing countries was used for all the infants in this study. This led to the assumption that all infants of each target group consumed equal amounts of breast milk per day, which could result in a misestimation of nutrient intakes. As a result, since breast milk is an important source of most of the eleven nutrients, differences in actual breast milk intakes could change the findings of our study.

There were some food items for which there were missing nutrient values on the Ethiopian food composition tables, therefore, values of the same food item from another food composition table were introduced. Due to lack of up-to-date and complete food composition table, different food composition tables were used which might have used different analytical techniques to determine the nutrient content of the foods/recipes which potentially introduce bias into the nutrient intake data.

The foods included in the linear programming analyses might not include all of the foods that could be consumed by 6-12-month-old infants in this area. Some foods can be missed if, for example, they were not mentioned during the preparation of the food lists or not utilized in infant feeding. As a result, it is possible that some of these excluded foods could be good sources of nutrients. On the other hand, some of the foods included in the analysis may not be accessible to all the families or at all times.

It is important to highlight that the data used in this study was collected in Jimma zone, located in the southwest of Ethiopia and, therefore, it is not representative of the whole country. Consequently, to what extent the recommendations formulated also apply to other areas in Ethiopia need to be further assessed.

Optifood allows the users to compare alternative food-based strategies on the basis of cost, being possible to identify the lowest cost nutritionally adequate diet. However, due to lack of data, this parameter was not assessed.

5.5 Developmental Relevance

Presently, there is a need worldwide to decrease the increased burden of diet-related diseases. 88% of countries experience two or three forms of malnutrition: acute and/or chronic undernutrition, micronutrient deficiencies, and obesity and diet-related diseases (Development Initiatives, 2018). Therefore, quality diets and healthy lifestyles need to be promoted through sustainable food-based approaches. In this sense, FAO has been promoting food-based nutrition interventions that consider food as the basis for action to improve food security within the communities (FAO & WHO, 1998; Moron, 2006).

A present strategy for public health nutrition is the development of food-based recommendations (FBRs). These need to be population-specific to respond to the cultural, social and ethnic determinants of food choices. On the other hand, global guidelines fail to address the complex relation between humans and food, cultural diversity, food traditions, food availability, accessibility, among other factors (Smitasiri & Uauy, 2007).

Ethiopia is a very large and, therefore, diverse country in terms of food cultures. This heterogeneity consequently impacts the dietary patterns and nutrient gaps around the country. This salient how relevant is to study this diversity in order to develop adequate FBRs for the population. This research topic has been supported by different authors as a priority question to improve the diet quality of Ethiopians in a sustainable way (Lee, 2018).

In the present research, we had the opportunity of studying a particular zone of the southwest of Ethiopia, Jimma. The current results have emphasized the importance of researching the potential of local diets to fulfil the nutritional needs of the populations and of identifying the nutrient gaps of these diets that might need additional solutions. Therefore, the FBRs derived from this study have the potential to offer opportunities to promote or alter dietary habits of the population in question to improve their nutritional status, for example, by preventing nutritional deficiencies.

Food-based dietary guidelines have already been developed or are currently being developed in over 100 countries worldwide. Some have also developed specific guidelines for children under 2 years old (FAO, 2019). In Africa, 7 countries have already developed food-based dietary guidelines, with Ethiopia not being included in this number. However, until 2021, Wageningen University and Research (WUR) and the Ethiopian Public Health Institute (EPHI), in collaboration with FAO and other partners, will develop food-based dietary guidelines for the Ethiopian population above 2 years (Hailu & EPHI, 2019). In the future, guidelines for children below 2 years old should be also considered, given the importance and vulnerability of this period of life.

In addition, it is important that dietary guidelines are coherently integrated into the country' policies and programmes to support decision-making and improve food security, food safety, and nutrition and health, by involving a wide range of stakeholders. Monitoring and evaluation is also necessary, and an adequate set of indicators should be selected to measure the impact of FBRs on nutritional and developmental outcomes (FAO, 2019).

6. Conclusion

The current micronutrient adequacy of the diet of 6-12-month-old infants living in Jimma zone, Southwest Ethiopia, is poor since several nutrient gaps were identified. Their diets can be improved by including more nutrient-dense foods available locally, as well as by increasing the frequency and/or quantity of the foods consumed. However, it will be difficult to ensure dietary adequacy for all the "problem nutrients", especially zinc, using only locally available foods. As a result, the inclusion of other nutrient-dense foods or alternative strategies, such as fortified foods and micronutrient supplements, might help to fill the gap to meet recommended levels of intake.

In summary, the present study highlights how context-specific CFR can provide more nutritionally relevant recommendations than general infant feeding guidelines, by taking into account local dietary patterns and available foods. Nevertheless, it is necessary to consider affordability and feasibility of the recommendations, their long-term sustainability, as well as strategies for behaviour change communication.

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Appendices

Appendix 1: Energy and nutrient content of breast milk

Nutrient (units)	Per 100g
Energy (kcal)	68
Lactose (g)	7.2
Protein (g)	1.05
Fat (g)	3.9
Folate (ug)	8.5
Niacin (mg)	0.15
Riboflavin (mg)	0.035
Thiamine (mg)	0.021
Vitamin B6 (mg)	0.0093
Vitamin B12 (ug)	0.097
Vitamin C (mg)	4
Vitamin A (ug RAE)	50
Calcium (mg)	28
Iron (mg)	0.03
Zinc (mg)	0.12

(Dewey & Brown, 2003; WHO, 1998)

Appendix 2: Age distribution of the infants included in the study

Age of the child, months	n and %
6	37 (6.48)
7	88 (15.41)
8	91 (15.94)
9	109 (19.09)
10	86 (15.06)
11	99 (17.34)
12	61 (10.68)
Total	571 (100)

Appendix 3: Food lists entered into Optifood: median serving sizes, number and % of consumers for 6-8 months breastfed children

Food items	**Median serving size (g) [a]**	**No. consuming**	**% consuming**
Breast milk	674	216	100
Whole cow milk	123	109	50.46
Pea flour wet, shiro wet	63.75	106	49.07
Sugar, refined	8.25	86	39.81
Milk, cow, fresh	193.25	78	36.11
Mixed porridge flour (no maize) - Mitin	21	66	30.56
Teff Enjera	52.25	63	29.17
Biscuit, generic type	45	48	22.22
Barley, white, Hordeum vulgare L.: flour	19.75	46	21.3
Butter from cow's milk	12	46	21,3
Banana , ripe	125	41	18.98
Vegetable oil	4.4	37	17.13
Maize(90%)+tef(10%): enjera - Kosho	52.25	29	13.43
Sorghum(50%)+tef(50%): enjera	52.25	29	13.43
Corn(maize), Zeamays L.: white, flour	40	22	10.19
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	40	22	10.19
Orange, Citrus sinensis, fresh	77	19	8.8
Corn(maize), Zeamays L.: white, enjera	55.68	16	7.41
Mixed porridge flour (with maize) - Mitin	29.5	14	6.48
Wheat flour, whole grain	16	14	6.48
Papaya, ripe	135	11	5.09
Potato sauce, Dinniche wet	63.75	8	3.7
Egg, whole, boiled	52.25	6	2.78
Egg, whole, fried with fat	50	6	2.78

[a] Serving sizes were expressed in g/meal for all foods except “Milk, human”

Appendix 4: Food lists entered into Optifood: median serving sizes, number and % of consumers for 9-12 months breastfed children

Food items	**Median serving size (g)** [a]	**No. consuming**	**% consuming**
Breast milk	616	355	100
Pea flour wet, shiro wet	63.75	179	50.42
Milk, cow, fresh	206	155	43.66
Mixed porridge flour (no maize) - Mitin	16	124	34.93
Sugar, refined	8.25	115	32.39
Teff Enjera	52.25	111	31.27
Whole cow milk	154.5	105	29.58
Banana, ripe	125	98	27.61
Barley, white, Hordeum vulgare L.: flour	19.75	84	23.66
Butter from cow's milk	13	79	22.25
Biscuit, generic type	40	72	20.28
Vegetable oil	4.4	68	19.15
Corn(maize), Zeamays L.: white, enjera	52.25	66	18.59
Mango, ripe, Fresh	57.5	63	17.75
Maize(90%)+tef(10%): enjera - Kosho	52.25	49	13.8
Sorghum(50%)+tef(50%): enjera	52.25	47	13.24
Corn(maize), Zeamays L.: white, flour	50	45	12.68
Potato sauce, Dinniche wet	63.75	37	10.42
Papaya, ripe	135	34	9.58
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	31.75	26	7.32
Sorghum(75%)+maize(25%): enjera	52.25	23	6.48
Potatoe Wet - dinnich wet	63.75	21	5.92
Mixed porridge flour (with maize) - Mitin	32	20	5.63
Egg, whole, fried with fat	45	20	5.63
Orange, Citrus sinensis, fresh	77	20	5.63
Egg, whole, boiled	50	13	3.66

[a] Serving sizes were expressed in g/meal for all foods except “Milk, human”

Appendix 5: Energy and nutrient contribution of human breast milk assuming average amount intake by 6-8- and 9-12-months infants

Micronutrients	**6-8 months (674 g)**		**9-12 months (616 g)**		**RNI**
	Estimated intake from breast milk	**%RNI**	**Estimated intake from breast milk**	**%RNI**	
Calcium (mg/day)	189	47.2	172	43.1	400
Iron (mg/day) [a]	0.2	1.1	0.2	1.0	18.6
Zinc (mg/day) [b]	0.8	9.6	0.7	8.8	8.4
Vitamin C (mg/day)	27	89.9	25	82.1	30
Thiamine (mg/day)	0.1	47.2	0.1	43.1	0.3
Riboflavin (mg/day)	0.2	59.0	0.1	53.9	0.4
Niacin (mg/day)	1.0	25.3	0.9	23.1	4
Vitamin B6 (mg/day)	0.1	20.9	0.1	19.1	0.3
Folate (ug/day)	57	71.6	52	65.5	80
Vitamin B12 (ug/day)	0.7	93.4	0.6	85.4	0.7
Vitamin A (ug RAE)	337	84.3	308	77.0	400

(WHO & FAO, 2004)

[a] Low bioavailability was assumed for zinc.
[b] 5% Bioavailability was assumed for iron.

Appendix 6: Minimum, average and maximum servings per week per food group entered into Optifood for 6-8 months infants [a]

Food group	**Min** [b]	**Aver** [c]	**Max** [d]
Added fats	0	1 [e]	7
Added sugars	0	1 [e]	7
Bakery and breakfast cereals	0	1 [e]	3,5
Dairy products	0	3.5	7
Fruits	0	1 [e]	7
Grains and grain products	0	7	10.5
Human milk	6.9	7	7.1
Legumes, nuts and seeds	0	1 [e]	7
Meat, fish and eggs	0	1 [e]	3.5
Starchy roots and other starchy plant foods	0	1 [e]	3.5

[a] The number of servings a week were set at meal-based for all food groups except "Human milk" at daily-based.
[b] 5th percentile, [c] 50th percentile, and [d] 95th percentile of consumption observed by the target group
[e] The value 1 was entered instead of 0 as the 50th percentile for mathematical reasons.

Appendix 7: Minimum, average and maximum servings per week per food group entered into Optifood for 9-12 months infants [a]

Food group	**Min** [b]	**Aver** [c]	**Max** [d]
Added fats	0	1 [e]	7
Added sugars	0	1 [e]	7
Bakery and breakfast cereals	0	1 [e]	3.5
Dairy products	0	3.5	7
Fruits	0	1 [e]	7
Grains and grain products	3.5	7	14
Human milk	6.9	7	7.1
Legumes, nuts and seeds	0	3.5	7
Meat, fish and eggs	0	1 [e]	3.5
Starchy roots and other starchy plant foods	0	1 [e]	3.5

[a] The number of servings a week were set at meal-based for all food groups except "Human milk" at daily-based.
[b] 5th percentile, [c] 50th percentile, and [d] 95th percentile of consumption observed by the target group
[e] The value 1 was entered instead of 0 as the 50th percentile for mathematical reasons.

Appendix 8: Minimum and maximum servings per week per food subgroup entered into Optifood for 6-8 months infants [a]

Food group	Sub food group	Min [b]	Max [c]
Added fats	Butter,ghee,margarine (unfortified)	0	3.5
Added fats	Vegetable oil (unfortified)	0	3.5
Added sugars	Sugar (non-fortified)	0	7
Bakery & breakfast cereals	Pancakes, waffles, scones, crackers	0	3.5
Dairy products	Fluid or powdered milk (non-fortified)	0	7
Fruits	Other fruit	0	3.5
Fruits	Vitamin A source fruit	0	3.5
Fruits	Vitamin C rich fruit	0	3.5
Grains & grain products	Refined grains and products, unenriched/unfortified	0	10.5
Grains & grain products	Whole grains and products, unenriched/unfortified	0	3.5
Human milk	Breast milk	6.9	7.1
Legumes,nuts & seeds	Cooked beans,lentils,peas	0	7
Meat,fish & eggs	Eggs	0	3.5
Starchy roots & other starchy plant foods	Other starchy plant foods	0	3.5

[a] The number of servings a week were set at meal-based for all food subgroups except "Breast milk" at daily-based.
[b] 5th percentile, and [c] 95th percentile of consumption observed by the target group

Appendix 9: Minimum and maximum servings per week per food subgroup entered into Optifood for 9-12 months infants [a]

Food group	Sub food group	Min [b]	Max [c]
Added fats	Butter,ghee,margarine (unfortified)	0	7
Added fats	Vegetable oil (unfortified)	0	3.5
Added sugars	Sugar (non-fortified)	0	7
Bakery & breakfast cereals	Pancakes, waffles, scones, crackers	0	3.5
Dairy products	Fluid or powdered milk (non-fortified)	0	7
Fruits	Other fruit	0	3.5
Fruits	Vitamin A source fruit	0	3.5
Fruits	Vitamin C rich fruit	0	3.5
Grains & grain products	Refined grains and products, unenriched/unfortified	0	14
Human milk	Breastmilk	6.9	7.1
Legumes,nuts & seeds	Cooked beans,lentils,peas	0	7
Meat,fish & eggs	Eggs	0	3.5
Starchy roots & other starchy plant foods	Other starchy plant foods	0	3.5

[a] The number of servings a week were set at meal-based for all food subgroups except "Breast milk" at daily-based.
[b] 5th percentile, and [c] 95th percentile of consumption observed by the target group

Appendix 10: Food items that are a source of at least 3 nutrients (>15% RNI per portion) in 6-8 months infants

Food	**Nutrients**	**Number of nutrients** [a]
Breast milk	Calcium, Vitamin C, Thiamine, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Vitamin A	9
Whole cow milk	Calcium, Thiamine, Riboflavin, Vitamin B6, Vitamin B12, Vitamin A	6
Milk, cow, fresh	Calcium, Thiamine, Riboflavin, Vitamin B6, Vitamin B12	5
Banana , ripe	Vitamin C, Riboflavin, Niacin, Vitamin B6, Folate	5
Egg, whole, boiled	Thiamine, Vitamin B6, Folate, Vitamin B12, Vitamin A	5
Orange, Citrus sinensis, fresh	Vitamin C, Thiamine, Vitamin B6, Folate	4
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	Iron, Thiamine, Riboflavin, Niacin	4
Biscuit, generic type	Thiamine, Niacin, Vitamin B6	3
Papaya, ripe	Vitamin C, Folate, Vitamin A	3
Wheat flour, whole grain	Thiamine, Niacin, Vitamin B6	3
Corn(maize), Zeamays L., white, flour	Iron, Thiamine, Niacin	3
Pea flour wet, shiro wet	Iron, Riboflavin, Niacin	3

[a] Number of nutrients each food item is considered a source, by providing >15% RNI of a micronutrient per portion consumed

Appendix 11: Food items that are a source of at least 3 nutrients (>15% RNI per portion) in 9-12 months infants

Food	**Nutrients**	**Number of nutrients [a]**
Breast milk	Calcium, Vitamin C, Thiamine, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Vitamin A	9
Whole cow milk	Calcium, Thiamine, Riboflavin, Vitamin B6, Vitamin B12, Vitamin A	6
Milk, cow, fresh	Calcium, Thiamine, Riboflavin, Vitamin B6, Vitamin B12	5
Egg, whole, boiled	Thiamine, Vitamin B6, Folate, Vitamin B12, Vitamin A	5
Banana , ripe	Vitamin C, Riboflavin, Niacin, Vitamin B6, Folate	5
Orange, Citrus sinensis, fresh	Vitamin C, Thiamine, Vitamin B6, Folate	4
Corn(maize), Zeamays L.: white, flour	Iron, Thiamine, Niacin	3
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	Iron, Thiamine, Riboflavin	3
Mixed porridge flour (with maize) - Mitin	Thiamine, Niacin, Folate	3
Pea flour wet, shiro wet	Iron, Riboflavin, Niacin	3
Papaya, ripe	Vitamin C, Folate, Vitamin A	3

[a] Number of nutrients each food item is considered a source, by providing >15% RNI of a micronutrient per portion consumed

Appendix 12: Main food sources of each micronutrient in the diets of the 6-8 and 9-12 months-old breastfed children [ab]

Calcium

Food	**%RNI 6-8 months**	**Food**	**%RNI 9-12 months**
Whole cow milk	44.6	Whole cow milk	56.0
Milk, cow, fresh	43.0	Milk, cow,fresh	45.8

Vitamin C

Food	**%RNI 6-8 months**	**Food**	**%RNI 9-12 months**
Papaya, ripe	279.0	Papaya, ripe	279.0
Orange, Citrus sinensis, fresh	136.0	Orange, Citrus sinensis, fresh	136.0
Banana , ripe	36.3	Mango, ripe, Fresh	53.1
		Banana , ripe	36.3

Thiamine

Food	**%RNI 6-8 months**	**Food**	**%RNI 9-12 months**
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	46.7	Corn(maize), Zeamays L.: white, flour	48.3
Corn(maize), Zeamays L., white, flour	38.7	Tef,Eragrostis tef(Zucc)Trott.: mixed, lour	37.0
Teff Enjera	36.7	Teff Enjera	36.7

Riboflavin

Food	**%RNI 6-8 months**	**Food**	**%RNI 9-12 months**
Milk, cow, fresh	101.5	Milk, cow, fresh	108.2
Whole cow milk	64.6	Whole cow milk	81.1
Banana , ripe	31.3	Banana , ripe	31.3

Niacin

Food	**%RNI 6-8 months**	**Food**	**%RNI 9-12 months**
Wheat flour, whole grain	25.6	Corn(maize), Zeamays L.: white, flour	26.3
Mixed porridge flour (no maize) - Mitin	22.0	Mixed porridge flour (with maize) - Mitin	22.4
Banana , ripe	21.9	Banana , ripe	21.9

Vitamin B6

Food	%RNI 6-8 months	Food	%RNI 9-12 months
Banana , ripe	166.7	Banana , ripe	166.7
Milk, cow, fresh	32.2	Milk, cow, fresh	34.3
Orange,Citrus sinensis,fresh	25.7	Whole cow milk	25.8
		Orange,Citrus sinensis,fresh	25.7

Folate

Food	%RNI 6-8 months	Food	%RNI 9-12 months
Papaya, ripe	64.1	Papaya, ripe	64.1
Banana , ripe	31.3	Banana , ripe	31.3
Orange,Citrus sinensis,fresh	28.9	Orange,Citrus sinensis,fresh	28.9

Vitamin B12

Food	%RNI 6-8 months	Food	%RNI 9-12 months
Egg, whole, boiled	121.4	Egg, whole, boiled	121.4
Milk, cow, fresh	110.4	Milk, cow, fresh	117.7
Whole cow milk	70.3	Whole cow milk	88.3

Vitamin A

Food	%RNI 6-8 months	Food	%RNI 9-12 months
Papaya, ripe	45.6	Papaya, ripe	45.6
Whole cow milk	24.6	Whole cow milk	30.9
Butter from cow's milk	19.2	Butter from cow's milk	20.8

Iron

Food	%RNI 6-8 months	Food	%RNI 9-12 months
Maize(90%)+tef(10%): enjera - Kosho	147.2	Maize(90%)+tef(10%): enjera - Kosho	147.2
Teff Enjera	85.7	Sorghum(75%)+maize(25%): enjera	91.6
Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	75.9	Teff Enjera	85.7
		Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	60.3

Zinc

Food	%RNI 6-8 months	Food	%RNI 9-12 months
Tef,Eragrostis tef(Zucc)Trott.: mixed, flour	13.4	Barley, white, Hordeum vulgare L.: flour	11.1
Barley, white, Hordeum vulgare L.: flour	11.1	Corn(maize), Zeamays L.: white, flour	10.7
Egg, whole, fried with fat	10.6	Tef, Eragrostis tef(Zucc)Trott.: mixed, flour	10.6
		Egg, whole, fried with fat	10.6

[a] %RNI per portion of food
[b] The main food sources of the micronutrient were included (>15% RNI). In the case of zinc, no food was a source of the micronutrient (>15% RNI), so a different cut-off was used for the foods included i.e. >10% RNI.

Appendix 13: Results Module 2 and 3: % RNI of the 2 optimized diets; % RNI of the "worst-case scenario" (RNI minimized) and "best-case scenario" (RNI maximized) diets of 6-8 months infants

FBRs	Energy %	Protein %	Fat %	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
FP diet	100	123.8	158	53.6	**107.2**	69.4	**73.4**	46.1	41.9	81.9	**113.6**	**90.7**	10.4	12.9	4
NFP diet	100	118.1	146.8	58.2	**266.9**	**79.3**	**71.3**	55.5	51.4	**118.5**	**98.3**	**103.5**	4.3	13.3	6
RNI Minimized	81.1	84.7	140.7	46.8	**88.6**	47.5	58.8	25	21.3	**70.6**	**92.3**	**83**	1.1	9.7	4
RNI Maximized	225.4	301.5	232.4	**127.5**	**303**	**164.7**	**211.5**	**99.9**	**156.7**	**138**	**228.8**	**153.8**	**167.6**	45.9	10

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 14: Results Module 2 and 3: % RNI of the 2 optimized diets; % RNI of the "worst-case scenario" (RNI minimized) and "best-case scenario" (RNI maximized) diets of 9-12 months infants

FBRs	Energy %	Protein %	Fat %	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
FP diet	100	146.1	157.8	**78.1**	**102.9**	**75.9**	**110.2**	54	54	**83.7**	**146.6**	**97.8**	22.3	17.3	7
NFP diet	100.1	140	146.3	**81**	**250.9**	**82.9**	**112**	61.4	61.6	**119.2**	**133.8**	**119.1**	10.4	17.8	7
RNI Minimized	71.6	81.4	118.5	43.6	**81**	47	54.5	23	20.2	64.5	**84.7**	**75.9**	2.9	10.1	3
RNI Maximized	232.5	283.1	207	**136.5**	**314.6**	**177.8**	**231.8**	**103.5**	**166.6**	**142.8**	**239.2**	**155.2**	**301.8**	47.6	10

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 15: Individual FBRs for 6-8 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Food groups												
Fruits 7	51.8	**176**	51.6	61.9	33.3	36.2	**101.7**	**94.9**	**85.5**	1.7	10.9	4
Grains 10.5	54.1	**89.9**	57.6	**72.7**	25.5	23.5	**71.6**	**94.5**	**84.8**	21.3	18	5
Eggs 3,5	50.4	**89.9**	57.1	66.2	27	21.8	**71.6**	**93.8**	**84.3**	5.2	13.2	4
Dairy 7	**91.7**	**94**	63.6	**123.6**	28.4	40.9	**80.5**	**161.4**	**108**	7.7	15.5	6
Legumes 7	51.6	**89.9**	53.7	**75.1**	42.8	23.2	**71.6**	**94.4**	**84.3**	24.7	11.3	5
Starchy 3.5	49.7	**89.9**	49.7	62.6	25.4	22.3	**71.6**	**94**	**93.4**	11.9	10.7	4
Food items												
Teff flour 7	59.1	**88.6**	**93.2**	**84.1**	42.9	21.9	**70.6**	**92.6**	**83**	**77**	22.9	7
Banana 3.5	48	**108**	49.5	**74.8**	36.2	**104.4**	**87.2**	**94.4**	**84.7**	2.1	11.1	6

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 16: Combined FBRs for 6-8 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Set of 2 FBRs												
Grains 10.5 + Dairy 7	**98.7**	**94**	**74**	**137.3**	28.5	44	**80.8**	**164.8**	**109.4**	27.9	23.9	7
Grains 10.5 + Fruit 7	61.9	**295.5**	**72.4**	**75.3**	33.3	38.2	**117.7**	**96**	**108.3**	21.9	19.3	6
Grains 10.5 + Legumes 7	58.5	**89.9**	64	**88.6**	43	25.6	**71.6**	**95.4**	**84.8**	45	19.7	5
Dairy 7 + Legumes 7	**96.2**	**94**	**70**	**139.5**	45.9	43.5	**80.8**	**164.6**	**108.9**	31.3	17.2	7
Dairy 7 + Fruit 7	**99.6**	**299.5**	**78.3**	**126.2**	36.2	56.1	**126.9**	**165.2**	**132.4**	8.3	16.7	7
Legumes 7 + Fruit 7	59.4	**295.5**	68.3	**77.5**	50.7	37.7	**177.7**	**95.8**	**107.8**	25.3	12.5	5
Eggs 3.5 + Dairy 7	**95**	**94**	**74.4**	**130.4**	30.9	53.9	**88.7**	**224.4**	**118.2**	13.5	19	7
Eggs 3.5 + Fruit 7	58.2	**295.4**	**72.8**	68.5	35.6	48.2	**125.5**	**155.6**	**117.2**	7.4	14.4	5
Eggs 3.5 + Legumes 7	54.8	**89.9**	**64.4**	**81.8**	45.3	35.5	**79.4**	**155**	**93.6**	30.5	14.8	6
Eggs 3.5 + Grains 10.5	57.3	**89.9**	**68.5**	**79.6**	28	36	**79.4**	**155.2**	**94.2**	27.1	21.6	6

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 17: Combined FBRs for 6-8 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Set of 3 FBRs												
Dairy 7 + Legumes 7 + Grains 10.5	**7**	**94**	**80.4**	**153.2**	46.1	46.1	**80.9**	**165.7**	**109.4**	51.6	25.6	7
Set of 4 FBRs												
Dairy 7 + Legumes 7 + Grains 10.5 + Fruits 7	**110.9**	**299.6**	**95.1**	**155.8**	53.9	60.9	**126.9**	**167.2**	**132.9**	52.1	26.8	7
Set of 5 FBRs												
Dairy 7 + Legumes 7 + Grains 10.5 + Fruits 7 + Eggs 3.5	**114.1**	**299.6**	**106**	**162.7**	56.4	**73.3**	**134.8**	**227.9**	**142.3**	57.9	30.3	8

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 18: Combined FBRs for 6-8 months old infants comprising food items

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Set of 2 FBRs												
Dairy 7 + Legumes 7	**96.2**	**94**	**70**	**139.5**	45.9	43.5	**80.8**	**164.6**	**108.9**	31.3	17.2	7
Dairy 7 + Banana 3.5	**92.5**	**112.1**	65.7	**139.2**	39.3	**124.7**	**96.5**	**164.6**	**109.3**	8.7	17	7
Legumes 7 Banana 3.5	52.4	**108**	55.6	**90.5**	53.7	**106.4**	**87.2**	**95.2**	**84.7**	25.7	12.8	6
Teff flour 7 + Dairy 7	**104.4**	**94**	**110.2**	**149.6**	46.6	42.7	**80.8**	**164.3**	**108.9**	**83.6**	28.9	8
Teff flour 7 + Banana 3.5	60.6	**108**	**95.9**	**100.6**	54.2	**105.6**	**87.2**	**94.9**	**84.7**	**78**	24.4	8
Teff flour 7 + Legumes 7	64.2	**89.9**	**100.2**	**100.9**	60.8	24.4	**71.6**	**94.9**	**84.3**	**100.7**	24.7	7
Set of 3 FBRs												
Teff flour 7 + Dairy 7 + Banana 3.5	**105.1**	**112.1**	**112.3**	**165.2**	57.3	**126.1**	**96.5**	**165.1**	**109.3**	**84.6**	30.4	9
Set of 4 FBRs												
Teff flour 7 + Dairy 7 + Banana 3.5 + Legumes 7	**109.6**	**112.1**	**118.7**	**181.1**	**74.8**	**128.2**	**96.5**	**166.1**	**109.3**	**108.3**	32	10

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Reduction of the number of servings in the set of 4 FBRs												
Teff flour 7 + Dairy 7 + **Banana 3** + Legumes 7	**109.5**	**109.5**	**118.4**	**178.9**	**73.3**	**116.3**	**94.2**	**165.9**	**109.3**	**108.1**	31.8	10
Teff flour 7 + **Dairy 3** + Banana 3 + Legumes 7	**84**	**107.2**	**109**	**142**	**71.5**	**104.6**	**89**	**125.8**	**95.2**	**104.3**	28.5	10

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 19: Removal of each individual FBR of the set of FBRs for 6-8 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Teff flour 7 + Dairy 3 + Banana 3 + Legumes 7	**84**	**107.2**	**109**	**142**	**71.5**	**104.6**	**89**	**125.8**	**95.2**	**104.3**	28.5	10
Dairy 3 + Banana 3 + Legumes 7 **(removed teff flour 7)**	**71.4**	**107.2**	62.4	**116**	53.5	**103.2**	**89**	**125.2**	**95.2**	28.4	15.1	7
Teff flour 7 + Banana 3 + Legumes 7 **(removed dairy 3)**	64.9	**105.4**	**102**	**114.3**	**70.2**	**95.8**	**85**	**95.6**	**84.7**	**101.5**	26	9
Teff flour 7 + Dairy 3 + Legumes 7 **(removed banana 3)**	**83.4**	**91.7**	**107.3**	**128.6**	62.1	33.1	**75.6**	**125**	**94.8**	**103.5**	27.2	8
Teff flour 7 + Dairy 3 + Banana 3 **(removed legumes 7)**	**79.6**	**107.2**	**102.7**	**126**	54	**102.4**	**89**	**124.9**	**95.2**	**80.7**	26.8	9

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 20: Individual FBRs for 9-12 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Food groups												
Fruits 10.5	49.1	**266.3**	59.9	**72.7**	42.1	**114.9**	**118.2**	**87.9**	**101**	3.9	12.5	6
Dairy 7	**89.4**	**87.3**	66.4	**135.4**	27	26.3	65.5	**88.4**	**77**	10.7	17.5	5
Grains 14	44.8	**82.1**	53.6	55.1	23.4	20.6	65.5	**86**	**77**	6.7	14.1	3
Legumes 7	48.2	**82.2**	52.5	**70.7**	40.8	22.1	65.5	**86.6**	**77**	26.1	11.8	4
Eggs 3.5	47	**82.2**	55.9	61.8	24.9	20.6	65.5	**86**	**77**	6.5	13.7	3
Starch 3.5	45.7	**82.2**	48.6	58.2	23.4	21.2	65.5	**86.2**	**77**	4.3	10.2	3
Food items												
Teff flour 10	57.4	**82.1**	**96.2**	**83.5**	43.5	20.7	65.5	**86.1**	**77**	**87.1**	24	6
Banana 3.5	44.5	**100.3**	48.3	**70.4**	34.3	**103.3**	**81.1**	**86.6**	**77.5**	3.4	11.6	6

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 21: Combined FBRs for 9-12 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Set of 2 FBRs												
Grains 14 + Dairy 7	**108.3**	**87.3**	**77.7**	**153.3**	27.2	48.3	**77.1**	**175.1**	**108.6**	36.3	27.4	7
Grains 14 + Fruit 7	57.1	**248.2**	68.9	**81.1**	32.7	34.4	**102.6**	**88.2**	**103.2**	28.5	20.8	5
Grains 14 + Legumes 7	56.8	**82.2**	63.4	**88.1**	40.9	24.7	65.5	**87.8**	**77.7**	51.6	21.7	4
Dairy 7 + Legumes 7	**105.9**	**87.3**	**73.6**	**155.5**	44.6	47.8	**77**	**174.9**	**108.1**	39.7	20.6	7
Dairy 7 + Fruit 7	**105**	**253.3**	**80.8**	**145.8**	44.5	61.8	**117.3**	**175.1**	**133.5**	11.2	18.3	7
Legumes 7 + Fruit 7	52.8	**248.2**	64.1	**79.3**	50.1	33.6	**102.6**	**87.9**	**102.5**	26.6	12.7	5
Eggs 3.5 + Dairy 7	**102.9**	**87.3**	**79**	**142.6**	34.8	59	**85.7**	**234.5**	**117.3**	16.5	21	7
Eggs 3.5 + Fruit 7	51.6	**248.2**	68.7	**70.3**	35.1	44.1	**110.4**	**147.7**	**111.9**	8.7	14.5	5
Eggs 3.5 + Legumes 7	51.2	**82.2**	**63.2**	**77.3**	43.2	34.3	**73.3**	**147.2**	**86.4**	31.8	15.4	6
Eggs 3.5 + Grains 14	55.5	**82.2**	**67.9**	**79.1**	25.9	35.1	**73.3**	**147.6**	**87.1**	33.7	23.5	6

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 22: Combined FBRs for 9-12 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Set of 3 FBRs												
Dairy 7 + Legumes 7 + Grains 14	**112.8**	**87.3**	**84**	**169.2**	44.8	50.5	**77.1**	**176.1**	**108.6**	59.5	29	7
Set of 4 FBRs												
Dairy 7 + Legumes 7 + Grains 14 + Fruits 7	**116.9**	**252.2**	**95.2**	**177.3**	53.8	62	**113.2**	**176.2**	**133**	60.4	29.7	7
Set of 5 FBRs												
Dairy 7 + Legumes 7 + Grains 14 + Fruits 7 + Eggs 3.5	**120.7**	**253.4**	**106.7**	**185**	56.6	**74.8**	**122**	**238.1**	**143.5**	66.2	33.4	8

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 23: Combined FBRs for 9-12 months old infants comprising food items

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Set of 2 FBRs												
Banana 3.5 + Legumes 7	48.8	**100.3**	54.3	**86**	51.6	**105.1**	**81.1**	**87.4**	**77.5**	27.1	13.1	6
Dairy 7 + Legumes 7	**103.3**	**86.2**	**74.4**	**150.9**	52.1	51.6	**79.3**	**172.3**	**106.6**	33.9	18.9	7
Dairy 7 + Banana 3.5	**99.7**	**103.9**	**70.2**	**150.5**	45.5	**130.8**	**94.6**	**172.5**	**107.1**	11.6	18.7	8
Teff flour 10 + Banana 3.5	58.2	**100.3**	**98.1**	**99**	54.4	**103.9**	**81.1**	**86.9**	**77.5**	**88.1**	25.5	8
Dairy 7 + Teff flour 10	**113.4**	**87.3**	**116.6**	**164.5**	47.4	46.6	**77**	**174.3**	**107.9**	**95.4**	31.3	8
Legumes 7 + Teff flour 10	61.9	**82.2**	**102.4**	**99.3**	61	22.7	65.5	**86.9**	**77**	**110.7**	25.6	6
Set of 3 FBRs												
Dairy 7 + Banana 3.5 + Teff flour 10	**114.2**	**105.4**	**118.7**	**180.1**	58.3	**129.7**	**92.7**	**175.2**	**108.4**	**96.4**	32.8	9
Set of 4 FBRs												
Dairy 7 + Banana 3.5 + Teff flour 10 + Legumes 7	**118.7**	**105.4**	**125.1**	**196.1**	**75.8**	**131.8**	**92.7**	**176.1**	**108.4**	**120**	34.5	10

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Reduction of the number of servings in the set of 4 FBRs												
Teff flour 10 + Dairy 7 + **Banana 3** + Legumes 7	**118.5**	**102.9**	**124.8**	**193.8**	**74.3**	**119.9**	**90.4**	**176**	**108.3**	**119.9**	34.3	10
Teff flour 10 + **Dairy 3** + Banana 3 + Legumes 7	**86.5**	**99.9**	**113**	**147.5**	**72.1**	**105.2**	**83.8**	**125.5**	**90.6**	**115.1**	30.1	10

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 24: Removal of each individual FBR of the set of FBRs for 9-12 months old infants

FBRs	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
Teff flour 10 + Dairy 3 + Banana 3 + Legumes 7	**86.5**	**99.9**	**113**	**147.5**	**72.1**	**105.2**	**83.8**	**125.5**	**90.6**	**115.1**	30.1	10
Dairy 3 + Banana 3 + Legumes 7 **(removed teff flour 10)**	**72.7**	**99.9**	63.9	**118.2**	55	**104**	**83.8**	**125**	**90.6**	30.5	16.2	7
Teff flour 10 + Banana 3 + Legumes 7 **(removed dairy 3)**	62.5	**97.7**	**104.2**	**112.7**	**70.4**	**94.2**	**78.9**	**87.7**	**77.4**	**111.6**	26.9	9
Teff flour 10 + Dairy 3 + Legumes 7 **(removed banana 3)**	**85.9**	**84.4**	**111.2**	**134.1**	62.7	33.8	**70.4**	**124.8**	**90.2**	**114.3**	28.8	8
Teff flour 10 + Dairy 3 + Banana 3 **(removed legumes 7)**	**82.1**	**99.9**	**106.7**	**131.5**	54.5	**103.1**	**83.8**	**124.6**	**90.6**	**91.5**	28.4	9

[a] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 25: Iron and Zinc Bioavailability comparison for the two target groups

FBRs	Energy %	Protein %	Fat %	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [c]
6-8 months infants															
Teff flour 7 + Dairy 3 + Banana 3 + Legumes 7 [a]	134.1	180.5	175.2	**84**	**107.2**	**109**	**142**	**71.5**	**104.6**	**89**	**125.8**	**95.2**	**104.3**	28.5	10
Teff flour 7 + Dairy 3 + Banana 3 + Legumes 7 [b]	134.1	180.5	175.2	**84**	**107.2**	**109**	**142**	**71.5**	**104.6**	**89**	**125.8**	**95.2**	**208.7**	58.3	10
9-12 months infants															
Teff flour 10 + Dairy 3 + Banana 3 + Legumes 7 [a]	120.3	167.9	152	**86.5**	**99.9**	**113**	**147.5**	**72.1**	**105.2**	**83.8**	**125.5**	**90.6**	**115.1**	30.1	10
Teff flour 7 + Dairy 3 + Banana 3 + Legumes 7 [b]	120.3	167.9	152	**86.5**	**99.9**	**113**	**147.5**	**72.1**	**105.2**	**83.8**	**125.5**	**90.6**	**230.3**	61.6	10

[a] iron 5% and zinc low bioavailability
[b] iron 10% and zinc moderate bioavailability
[c] Number of nutrients that met 70 % RNI in the worst-case scenario

Appendix 26: Optimized diets and the final sets of FBRs for the two target groups

FBRs	Energy %	Protein %	Fat %	Calcium %	Vit C %	Thiamine %	Riboflavin %	Niacin %	Vit B6 %	Folate %	Vit B12 %	Vit A (RAE) %	Iron %	Zinc %	Nº Nutrients ≥70% RNI [a]
6-8 months infants															
FP diet	100	123.8	158	53.6	**107.2**	69.4	**73.4**	46.1	41.9	81.9	**113.6**	**90.7**	10.4	12.9	4
NFP diet	100	118.1	146.8	58.2	**266.9**	**79.3**	**71.3**	55.5	51.4	**118.5**	**98.3**	**103.5**	4.3	13.3	6
Dairy 7 + Legumes 7 + Grains 10.5 + Fruits 7 + Eggs 3.5	151.6	267	205.7	**114.1**	**299.6**	**106**	**162.7**	56.4	**73.3**	**134.8**	**227.9**	**142.3**	57.9	30.3	8
Teff flour 7 + Dairy 3 + Banana 3 + Legumes 7	134.1	180.5	175.2	**84**	**107.2**	**109**	**142**	**71.5**	**104.6**	**89**	**125.8**	**95.2**	**104.3**	28.5	10
9-12 months infants															
FP diet	100	146.1	157.8	**78.1**	**102.9**	**75.9**	**110.2**	54	54	**83.7**	**146.6**	**97.8**	22.3	17.3	7
NFP diet	100	140	146.3	**81**	**250.9**	**82.9**	**112**	61.4	61.6	**119.2**	**133.8**	**119.1**	10.4	17.8	7
Dairy 7 + Legumes 7 + Grains 14 + Fruits 7 + Eggs 3.5	143.8	269.2	184.6	**120.7**	**253.4**	**106.7**	**185**	56.6	**74.8**	**122**	**238.1**	**143.5**	66.2	33.4	8
Teff flour 10 + Dairy 3 + Banana 3 + Legumes 7	120.3	167.9	152	**86.5**	**99.9**	**113**	**147.5**	**72.1**	**105.2**	**83.8**	**125.5**	**90.6**	**115.1**	30.1	10

[a] Number of nutrients that met 70 % RNI in the worst-case scenario