Hochschule für Angewandte Wissenschaften Hamburg

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Studiengang Ökotrophologie

A study on Moringa oleifera leaves as a supplement to West African weaning foods

Bachelor Arbeit

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Vorgelegt von:

Kayi Kristina Kouevi

Betreuende Prüferin: Prof. Dr. Silya Ottens

Zweiter Prüfer: Prof. Dr. Michael Häusler

Foreword

I hope that one day the inequality of food supply in the world will end and a solution to fight under-nutrition in Africa will be initiated.

I want to thank my mother who has supported me from a young age and for giving me the opportunity to grow into the person I have become. I am grateful to my biology high school teacher for showing me how wonderful life sciences are, which lead me to my present path.

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List of abbreviations

AI	Adequate intake
D-A-CH	Deutschland, Österreich, Schweiz
DGE	Deutsche Gesellschaft für Ernährung
DM	Dry mass
EBISpro	Ernährungsanamnese Beratungs- und Informationssystem
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
HDRA	Henry Doubleday Research Association
HIV	Human Immunodeficiency Virus
ICP-AES	Inductively coupled plasma – atomic emission spectroscopy
ICP-OES	Inductively coupled plasma – optical emission spectroscopy
IRD	Institut de Recherche pour le Développement
LD50	Lethal dose 50%
NOAEL	No-observed-adverse-effect level
NPU	Net Protein Utilisation
UN	United Nations
ULs	Tolerable Upper Intake Levels
WHO	World Health Organization

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1 Introduction

1.1 Aim of the study

The welfare inequality throughout Africa is ever more present in today's world. This is emphasised by Plutarch who famously quoted: "an imbalance between rich and poor is the oldest and most fatal ailment of all republics". (Institut for policy studies n.d.) The existence of inequality has resulted in a high mortality rate of 109 deaths per 1,000 live births of infants under the age of five in the sub-Saharan region. (UN Inter-agency Group 2012, 1) Although these deaths are caused by several factors, it is established that "more than a third of under-five deaths are attributable to under-nutrition". (UN Inter-agency Group 2012, 9) However, the question which must be raised is why is there still under-nutrition in the 21st century?

Under-nutrition is defined as "an inadequate intake of dietary energy" (Shetty 2003, 18). For sufficient nutrition, it is important that an infant receives a balanced diet to cover the essential needs for growth. Protein-malnutrition and the deprivation of essential micronutrients are two main causes of under-nutrition in Africa. Many studies have been completed to increase the nutritional value of weaning foods produce in Africa using locally available raw materials. Some were successful, such as the introduction of soya beans and dried fish to increase the protein content of complementary foods. However, child mortality still exists in high figures and new interventions through innovative methods and technologies must be introduced to reduce the high data of death rates.

Moringa oleifera is a plant discovered across various continents, portrayed as "the new wonder" in the food world and is believed to hold a very high protein value. The leaves can be grounded to a uniform powder and eaten as a supplement in various dishes. There are many claims relating to the dried leaves, such as 17 times more calcium than cow's milk or 8.8 times more iron than fillet beef, (Barta 2011, 19) providing an ideal that the plant could end malnutrition in developing countries. (Fuglie 2001)

The overall aim of this study is to investigate the uses of Moringa oleifera as a supplement to West African weaning food produce, in terms of raising the missing nutrients levels.

The specific objectives are:

- Evaluate commercial and traditional weaning foods produced in different countries of West Africa.
- Identify and assess Moringa oleifera leaves in terms of nutritional values and anti-nutritional factors.
- Perform an analysis related to Moringa oleifera as a supplement to West African complementary foods.
- Falsify and verify given hypothesis.

1.2 Scope of the study

Moringa oleifera is a multipurpose medium sized tree which can be found in dry and hot climates, such as sub-Saharan regions or India. (Pandey, et al. 2010, 453).

The plant consists of leaves, pods, immature seeds, flowers, fruits and young roots which are all edible. (T.K. 2012, 455) This paper focuses solely on dried Moringa oleifera leaves. Through various studies, it is illustrated that the leaves have the highest true protein content compared to the stems and twigs. Therefore as this study partially aims to increase the protein value in weaning foods, the leaves are the optimal option. (Makkar and Becker 1996, 319) The seeds of Moringa oleifera are also acknowledged as a highly nutritious part of the plant because of their composition of fatty acids which has much resemblance to olive oil. However, studies derived to investigate the compositional and nutritional attributes of the seeds, indicate that the essential amino acid profile is scarce and precaution must be considered when the seeds are eaten without previous treatment, which can lead to toxicological effects in both adults and infants. (Oliveira, et al. 1998, 819)

This paper aims to target infants from the age of 6 to 12 months. The study vitally focuses on the age period when an infant requires a higher energy level than that of what the mother can supply by breastfeeding, the weaning period, and therefore must obtain a complementary source of food to satisfy the requirements. The profile of the weaning food produce must be rich in proteins and essential micronutrients and must not contain any toxicological substances.

The geographical location in the study is West Africa. This includes 18 different countries which are related by similar weather conditions and comparable economical statuses.

1.3 Outline

This paper is divided into 6 main chapters:

Section 1 investigates the nutrient requirements of infants from the age 6 to 12 months and explores complementary foods.

Section 2 assesses West Africa's geographical, economical and nutritional situation and describes the different types of weaning foods in terms of technological properties found in various locations of West Africa.

Section 3 identifies the two different methods used in this study: literature research for a specific data collection and analysis of the weaning food produce using nutritional analysis software, EBISpro, with given recipe formulations.

Section 4 is based on reviewing Moringa oleifera leaves in terms of botanical description, uses and primarily nutritional and anti-nutritional factors. This segment briefly evaluates two studies made concerning the supplementation of Moringa oleifera in baby foods.

Section 5 is devoted to present the results of the weaning food analysis with and without the supplementation of Moringa oleifera leaves.

Section 6 discusses the results and evaluates the different hypothesis to conclude the paper.

2 Infant nutrition

Factual nutritional information surrounding infants aged 6 to 12 months is required to understand the resulting issues in West African weaning food. In the first six months a baby is ideally exclusively fed with breast milk, this period of six months can vary amongst societies, cultures and individuals.

A study made in the late 1970s revealed that in Nigeria, breastfeeding in rural areas persisted for more than 1 year of an infant's birth, however amongst urban and middle class societies, just one third of the mothers are still breastfeeding at 6 months. (Walker and Rolls 1994, 67) This study shows that the specific duration of the lactation time cannot be set and will always vary, making it difficult to have singular comparable results for the weaning period.

2.1 Nutrient requirements

The nutrient requirements of infants are complex to examine compared to adults. An infant craves additional nutrients required for growth other than the basic demands of an adult. This must be emphasised due to the fact that a low nutrient intake can lead to severe impact on health, reduced development and insufficient growth. (Koletzko 2008, 482).

The data set for the nutritional requirements of an infant aged 6 to 12 months are estimated values taken from studies on adequate intake (AI) in developed countries, such as Canada, Sweden and the United States, and may not resemble the actual values in developing countries.

For the micronutrients assessment, Tolerable Upper Intake Levels (ULs) can be used to consider maximum and minimum levels of micronutrients needed given by the World Health Organisation (WHO). ULs are defined as "the highest level of daily nutrient intake that is likely to pose no risk of adverse health for almost all individuals." (Nestel, et al. 2003, 320) For this study a combination of both AI and ULs are used. For the exact standards of adequate intake, the Deutschland, Österreich, Schweiz (D-A-CH) values of the Deutsche Gesellschaft für Ernährung, (DGE) a German organisation for nutrition, (DGE 2001) is taken as estimation to analyse the requirements of an infant aged 6 to 12 months. Nevertheless it must be remembered that these values are in accordance with the German standards and may be different from those in developing countries.

2.2 Complementary feeding

At the latest age of six months, an infant is introduced to complementary foods which must be of a high nutritional value. It is recommended to continue breastfeeding until two years of age, (World Health Organization 2002, 11) especially in developing countries where malnutrition is present. Walker and Rolls emphasise several positive reasons for breast milk, including “nutritional, immunological, contraceptive, psychological and economical” (Walker and Rolls, Infant Nutrition:Issues in Nutrition and Toxikology 2 1994, 61).

There are several sources relevant to the amounts of breast milk that are provided to infants. This however varies depending on case by case basis and individual. Four main references are found and state respectively that the daily amount of breast milk is 550, 600, 675 and 750ml (Dewey 2001, 10, Massamba and Treche 1994, 5, Walker 1990, 35, DGE 2001, 18).

An identified issue with human milk is the large variation of nutrients depending on the individual. (DGE 2001, 18) For the purpose of simplicity, this study rounds the amount of mother milk to an average of 600ml per day and takes the nutritional values given by the German Organisation for Nutrition (DGE).

Complementary food is defined as the additional food added to breast milk or breast milk substitutes to meet the increased demand of energy and essential nutrients and achieve an “optimum growth and development” (Chander Vir 2011, 225) at the age of 6 months to 2 years. Some recent literatures define weaning as the termination of breast milk, however in this study weaning food has the same definition as complementary food since traditionally the meaning is similar. (Chander Vir 2011, 226)

Global requirements on appropriate feeding of an infant from the age of 6 months emphasise factors which influence the complementary intake of a baby:

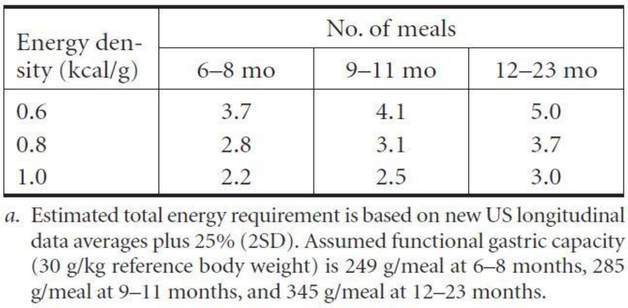
- *Time:* the introduction of complementary food is predominantly at the age of 6 months. After the introduction, the number of feeding occasions must increase with time, for example at the age of 6 to 8 months an infant may be fed 2 to 3 times a day and after the 8th month 3 to 4 times a day. (WHO 2010)

- *Adequacy:* the food must provide sufficient nutrients and a high energy density. (WHO 2010)

- *Safety:* the porridge must be free from microorganisms (World Health Organization 2002, 1). Safety is a huge issue in developing countries because of low hygiene and high temperatures.

The amount of complementary food needed is also variable depending of the source. Assuming the D-A-CH requirement of 700kcal of energy per day and knowing that human milk has an energy density of 70kcal/100ml. (Massamba and Treche 1994, 4) We can determine that at a consumption rate of 600ml of breast milk per day, an infant will acquire 420kcal. A calculation can be made to identify the additional calorie intake required from a complementary food. An additional calorific value of 280kcal per day is required to satisfy the energy needed of an infant aged 6 to 12 months.

The main factor affecting the intake of a complementary food is the energy density. Energy density is defined as the energy amount in kcal or kJ per food mass (g, 100g)[1]. (DGE 2001, 14) As shown in Figure 1, the higher the energy density of porridge, the less number of daily meals are required. Therefore the aim is to produce porridge with high energy density.



Energy density (kcal/g)	No. of meals		
	6–8 mo	9–11 mo	12–23 mo
0.6	3.7	4.1	5.0
0.8	2.8	3.1	3.7
1.0	2.2	2.5	3.0

a. Estimated total energy requirement is based on new US longitudinal data averages plus 25% (2SD). Assumed functional gastric capacity (30 g/kg reference body weight) is 249 g/meal at 6–8 months, 285 g/meal at 9–11 months, and 345 g/meal at 12–23 months.

Figure 1: Correlation of energy density and daily number of meals

Source: (The United Nations University 2003)

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[1] "Die Energiedichte wird definiert als Energiegehalt (in kcal oder kJ) pro Gewichtseinheit (g, 100g) Lebensmittel." Translated by Kayi Kristina Kouevi

3 Weaning foods in West Africa

3.1 Overview

West Africa is composed of 18 different countries and illustrates a sectional part of the continent Africa, as shown in Figure 2.

Figure 2: West African countries

Source: (United Nations 2005)

There are three different climate zones in West Africa. Situated in the North you will find an arid zone and includes countries like Mali and Mauritania and located along the coast of the Atlantic Ocean you will find a semi-arid zone and a humid/sub-humid zone, which comprises countries like Togo and Nigeria. Almost 75 % of the total population of West Africa live in the humid zone. This is a result of a higher economical status and more favourable climate conditions for agriculture. (Bossard 2009, 91)

The economical status of West Africa is dominated by agriculture which generates half of the region’s gross domestic product (GDP). Other contributions to GDP come from livestock, farming, forestry, fishing, tourism and transport. (Bossard 2009, 97) As this study focuses on locally produced commercial and traditional weaning food, it is important to acknowledge which of the agricultural crops have the highest production rate in the West African region.

In 2005, the most produced crops were roots and tubers with a quantity of 106 million tonnes, followed by cereal, including corn, millet, rice and sorghum at 43.2 million tonnes of production. As depicted in Figure 3, this trend continued through to 2011illustrating that the first five top productions consist of tubers and cereals. This explains that the high use of cereals and tubers used in the production of complementary foods are related to the highest section of crop production in West Africa.

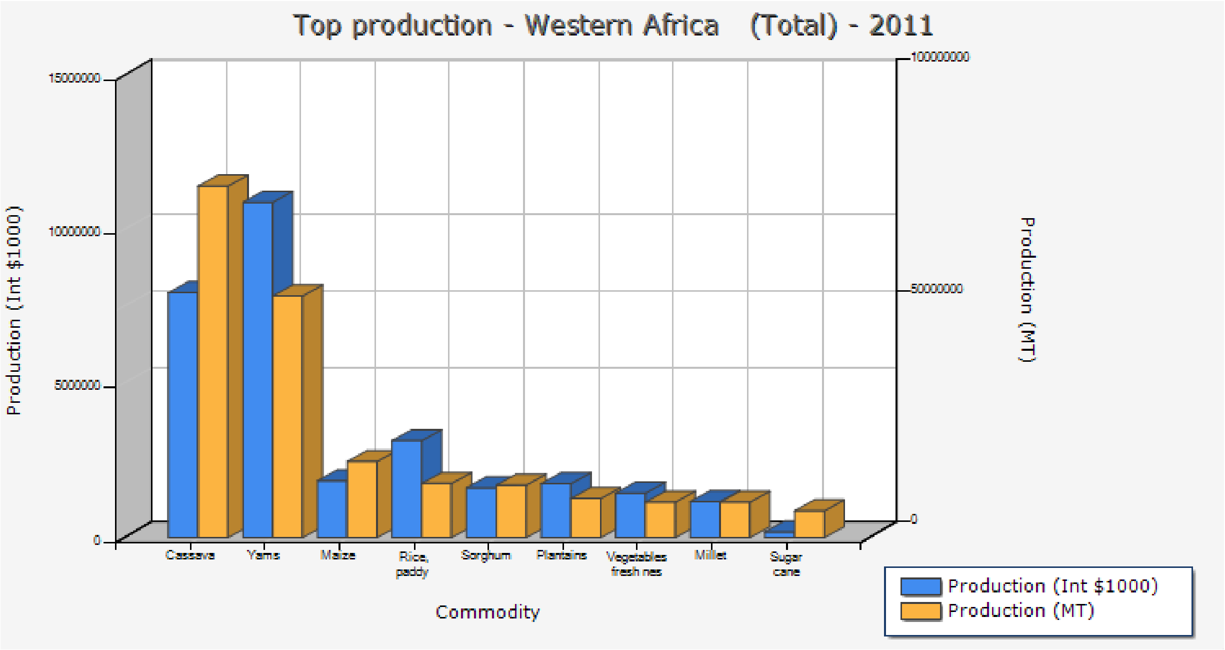


Figure 3: Top agricultural crop production in West Africa

Source: (Food and Agriculture Production n.d.)

In 2008, there were 315 million inhabitants of West Africa and this number is steadily increasing. It is estimated that in 2030 the population will rise to 500 million, consisting mostly of young people. (Bossard 2009, 24) Although the number of the population is rising, there is still a high mortality rate in children less than five years old compared to western countries. West Africa is a zone where the rate of a child surviving over the age of 5 is approximately 1 in 10, compared to western countries where there are less than 49 deaths per 1000 live births. (Unicef- Child Info 2012) Almost two thirds of all under-five deaths are caused by infectious diseases and conditions such as pneumonia and malaria which are all communicable diseases. The other one third comprises other causes which includes under-nutrition. (Unicef- Child Info 2012)

Under-nutrition is a major problem because it leads to a weak immune system and the probability to get a communicable disease is higher, thus building a vicious cycle. As a result, a decrease in under-nutrition will also diminish the rate of mortality caused by communicable diseases, such as malaria.

3.2 Nutrients deficiency

There are two main reasons for under-nutrition amongst infants in West Africa: inadequate intake of energy and a poor dietary quality of weaning foods, as shown in Figure 4. Inadequate intake occurs when an infant’s food intake is not sufficient, this leads to low energy intake and can aid in illnesses, such as marasmus. On the other hand, a child can obtain their energy requirements but foods may be of a low nutrient quality, resulting in “hidden hunger” from issues such as a low protein diet or a low iron diet. It is important to distinguish between the two in order to correctly analyse the weaning food. Some diets may have high energy content but very low protein, which can lead to diseases like Kwashiorkor.

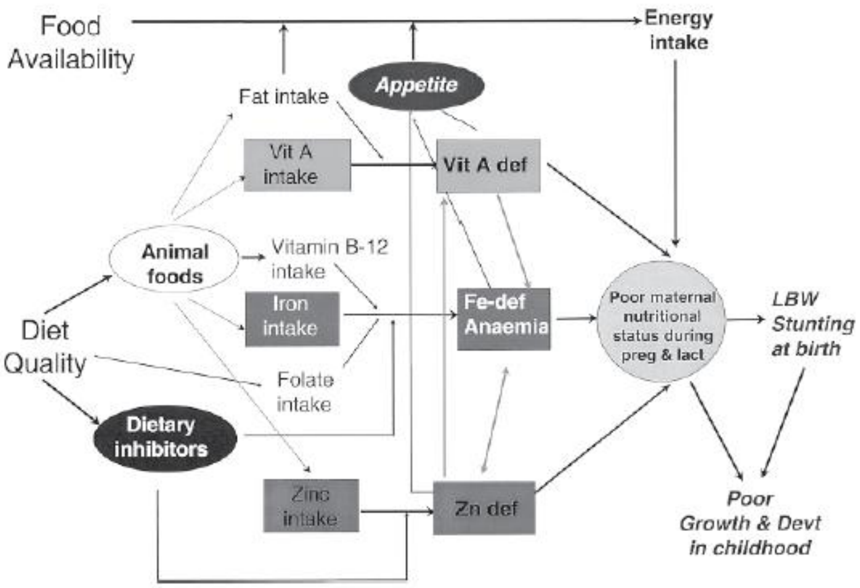


Figure 4: Causes of under-nutrition in West Africa

Source: (Ramakrishnan and Huffman n.d)

3.2.1 Inadequate energy intake

The ideal daily amount of energy an infant needs is 700kcal. There are 3 major causes of low energy intake from weaning food:

- Feeding practice: Due to the differences in the practice of breastfeeding in Africa amongst rural and urban regions, variations of the lactation period exists. It is encouraged throughout West Africa that an infant must be exclusively breastfed in the first 6 month and that the lactation should last at least 24 months. In Mali, it is said that “when a child is ready, it will begin”. (Dettwyler 1986, 656) The introduction of complementary foods may vary according to beliefs. Introduction may take place before 4 months of age, where it is normally recommended to exclusively feed with breast milk. For instance, in sub-Saharan Africa the rate of exclusively breastfeeding is about 7 percent among infants under 4 months of age. (Lopriore and Muehlhoff n.d.) It was surveyed that in Nigeria and Ghana, 2 and 1% respectively were exclusively breastfed less than four months of age. (Huffman and Martin 1994, 134) Contrary in other countries of West Africa such as Senegal, 24% of infants aged 6-11months are not yet receiving any complementary food. (Huffman and Martin 1994, 135) Both can correspondingly lead to a reduction in the intake of breast milk and can cause an insufficient intake of energy.

The other issue is the infrequent feeding practices which may be due to several reasons, such as working mothers. This can lead to an insufficient energy intake due to the fact that most porridge in West Africa has a low energy density and frequent meals are required. Other issues that may influence the energy intake are unhygienic cooking and feedings methods. (Huffman and Martin 1994, 133)

- Viscosity: The use of tubers and cereals as staple foods are very common for the production of weaning foods in West Africa as they utilise the main crop production, as shown in the previous chapter. The high content of starch in tubers like cassava and cereals like maize lead to a high viscose and gelled porridge when it is cooked. At about 85°C, starch granules disperse in water leading to a rise of viscosity. (Walker and Rolls 1994, 211) It is illustrated that an acceptable consistency of porridge contains 100g dry mass millet flour per litre. However knowing that an infant eats approximately 500ml of complementary food per day, (Walker 1990, 38, Brown, Creed-Kanashiro and Dewey 1995) 50g of millet flour is used to obtain an acceptable consistency. With an approximate energy value of 172kcal, the energy value from 50g of millet flour does not meet the required levels of approximately 300kcal per day (Linkages 2004). Viscosity also suffers from issues relating to the tolerance of solid foods in infants. The higher the viscosity of porridge, the less intake of energy is gained per each meal which is due to the fact that infants do not tolerate solid foods.

- Energy density: The porridge made from local staple produce tends to have a low energy density and higher quantities must be ingested to reach the daily needs of an infant. This is inversely related to viscosity due to high viscose foods having a higher volume but a lower energy density. (Walker and Rolls 1994, 211) This illustrates that decreasing the viscosity of infant foods will lead to a higher energy density per gram.

3.2.2 Protein malnutrition

The lack of proteins found in the weaning food of developing countries pose major problems for infants' growth, as proteins are used for growth and repair. It is confirmed through a study made in West Africa that "protein-energy malnutrition is a major risk for all-causes of mortality in West African children". (Müller, Garenne, et al. 2003, 511) A low protein intake ensures an under development both physically and mentally and may have a severe impact on health. Ideally, a child of age 6 to 12 months requires 1.1 g of protein per kg of body weight or approximately 10g per day. (DGE 2001) Protein malnutrition is often related with a low energy intake and it may be difficult to distinguish both in practice. (Latham 1979, 113)

Kwashiorkor is the most well-known disease as a consequence of severe protein malnutrition. The main reason for the lack of protein found in weaning food is due to cereals and tubers being the primary ingredients and also the lack of animal protein used. Animal proteins are easily digestible compared to plant protein, as some vegetable proteins cannot be used by the body, for example maize has a digestibility rate of 89%. (Huffman and Martin 1994, 132) Nonetheless for economical reasons, animal proteins are not often used.

The amino acids composition is also relevant in the availability and absorption of protein. Animal proteins contain more essential amino acids than plant protein and have a higher Net Protein Utilization of 100%. For an infant, a Net Protein Utilization is relevant as this suggests a higher amount of proteins used for body building. (King, et al. 1972, 3.10)

3.2.1 Micronutrients shortage

The demands of proteins correlate with the vitamin and mineral requirements, as most foods are mixtures of nutrients. (King, et al. 1972, 4.4) The lack of a diverse diet can lead to a deficiency in micronutrients. Kalimbira states that the leading micronutrient deficiencies in Africa are vitamin A, iron, iodine and zinc (Kalimbira 2007). Other vitamins and minerals, such as vitamin C, vitamin B and calcium must also be considered.

3.2.1.1 Vitamin A

Xerophtalmia is the general term used for vitamin A deficiency which causes blindness and infectious diseases. (Latham 1979, 103)Vitamin A deficiency is a common problem amongst infants in West Africa due to the low intake of leafy vegetables and dairy products beside breast milk at that early age. This is closely linked to protein-energy malnutrition.

The concentration of vitamin A also depends on the mother's vitamin A status. The risk of deficiency is increased if the mother's feeding nutrients lack in animal produce. The rate of mortality in children under five is relatively high and it is estimated that over 228,000 deaths occur in communities throughout West Africa which can be attributed to vitamin A deficiency. (Lopriore and Muehlhoff n.d., 7)

3.2.1.2 Iron

The reported frequency of anaemia in West Africa spans from 38 to 58% among children under five years old. (Smith 2000, 533) Anaemia is a common problem around the world affecting both women and children. Iron can be found in meat, green leafy vegetables and legumes and it is found in every cell of the body, for instance the erythrocytes.

There are three main causes of iron deficiency: insufficient iron contained within the diet, a low bioavailability and high inhibitors, such as calcium and phytates. (Linkages 2005) Therefore an introduction of leafy vegetables could enhance the iron content in weaning food. It is also relevant to know that vitamin C increases iron absorption. One source for obtaining vitamin C is breast milk but an addition of fruits in porridges may also increase the bioavailability of iron and may aid in diminishing anaemia in West Africa.

3.2.1.3 Iodine

Iodine is a mineral found in very small amounts in water and some food like eggs and saltwater fish. (American Tyroid Association 2012) Iodine quantities in water can vary depending on the soil and deficiency can lead to a disease called goitre. This is when the thyroid glands swell and become visible. (King, et al. 1972, 4.9-13) The iodine content in diets is mainly influenced by adding it to salt, as it is found in very low amounts in food.

This study does not focus deeply on iodine deficiency as this is a worldwide problem amongst all population groups and not specifically related to infants.

3.2.1.4 Zinc

The low intake of animal products and diets based on refined cereals are attributed to inadequate consumption of zinc. It is important to note the difference between the intake and the absorption of zinc. An adequate ingestion of zinc does not indicate the level of zinc which is absorbed. The levels of inhibitors in plant products, such as phytates can deeply influence the zinc levels in blood. (Caufield and Black 2004) Zinc is essential for the production of many enzymes and is relevant to the immune system, thus a deficiency in zinc, can lead to diseases like diarrhoea and malaria. (Müller and Krawinkel 2005, 282) Therefore zinc is essential to infants as these diseases can lead to death.

3.3 Infant formulas in West Africa

Sanogo states in her book that an ideal homemade West African infant formula must contain four different types of ingredients. At first, there must be a main constituent of cereals like millet, rice or sorghum. The second portion is a complementary ingredient rich in protein, such as milk powder or dry beans. Thirdly, an energy dense food, such as coconut oil can be added to increase the overall caloric value. Finally a supplement of minerals and vitamins such as fruits or vegetables must be included. (Sanogo 1994, 15) However, traditional weaning diets often just contain staple starchy food. These are heated with water and form a thick porridge due to the gelatinisation of starch. (Walker 1990, 35) To combat the problems of under-nutrition, commercial infant flours have been introduced into the market using locally available raw materials like millet, soya beans or peanuts. However, these are often too expensive and are not accessible to all rural habitants.

3.3.1 Traditional weaning foods

Traditional West African weaning foods often comprise staples as the main ingredient. Nonetheless, cereals often have limited amino acids such as lysine and have a low protein digestibility compared to animal proteins, partly due to the presence of fibre. (Sanni, Onilude and Ibidapo 1999, 35)The most acknowledged porridge is a fermented gruel called Ogi made from maize, sorghum or millet flour and cooked for approximately 10 to 15 minutes in water. (Adesokan, et al. 2011, 3144) Other tubers such as cassava, yams, sweet potatoes or plantains are also used. However around West Africa, it is recognised that four main staple foods are used for the fabrication of instant porridges: maize, sorghum, millet and cassava. These ingredients can be combined, but for the purpose of simplicity and analysis, this paper studies one raw material per recipe.

3.3.1.1 Raw materials

- Maize (*Zea mays*): For more than 1.2 billion people in sub-Saharan Africa and Latin America, maize is the most important cereal crop, partially due to the fact that all components can be used for food and non-food products. (International Institute of Tropical Agriculture n.d.) Protein is the largest chemical element after starch. However because of the deficiency of some essential amino acids, such as lysine or tryptophan the overall protein quality is low. (FAO 1992)

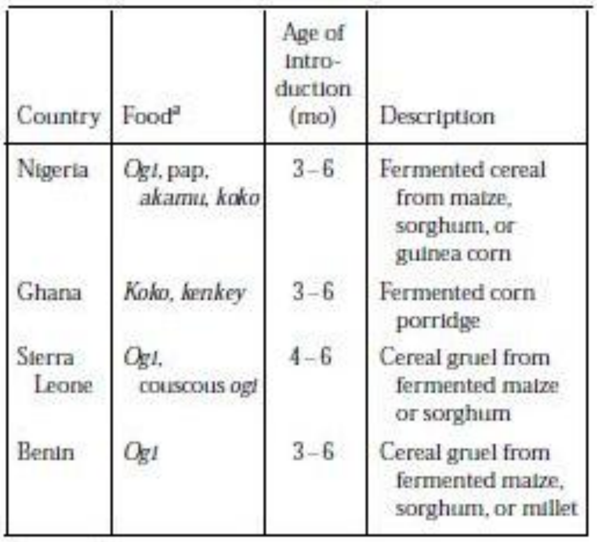
- Sorghum (*Sorghum bicolor*): Twenty million tonnes of sorghum is produced in Africa making it the second most influential cereal on the continent. As maize, the quality of sorghum’s protein is poor due to deficiency in essential amino acids and low digestibility. For this study, the gelatinisation of the starch is also important and it is illustrated that sorghum has a higher starch gelatinisation than maize and wheat which can lead to low energy density. Sorghum is often dry milled like maize and traditionally fermented as this improves protein digestibility (Taylor 2003) and lowers the overall viscosity.

- Millet (*Eleusine coracana Gaertn.*): Finger millet is the most cultivated millet type in Africa since ancient times. (Oniang'o, Mutuku and Malaba 2003, 333) It is emphasised that compared to other cereals, millet is nutritionally superior because of the high level of amino acids, such as methionine and the high micronutrients content, such as zinc and iron. However, the high content of fat minimises the shelf life opposed to other cereals, reducing the quality of the flour made. (Obilana 2003)

- Cassava (*Manihot esculenta*): Cassava is often called poor stable due to the fact that it has only 1 to 2% protein compared to cereals like maize or millet having 8 to 10% protein content. (King, et al. 1972, 3.6) The tubers and the leaves are the two essential parts, both suitable for human consumption. Cassava is often combined with other cereals but this study focuses only on the tubers of the crop.

3.3.1.2 Fermentation

Most of the traditional porridges analysed in this study are fermented as this technique is highly used in West Africa as Figure 5 shows:



Country	Food[a]	Age of introduction (mo)	Description
Nigeria	*Ogi*, pap, *akamu*, *koko*	3–6	Fermented cereal from maize, sorghum, or guinea corn
Ghana	*Koko*, *kenkey*	3–6	Fermented corn porridge
Sierra Leone	*Ogi*, couscous *ogi*	4–6	Cereal gruel from fermented maize or sorghum
Benin	*Ogi*	3–6	Cereal gruel from fermented maize, sorghum, or millet

Figure 5: Summary of traditional weaning foods in West Africa

Source: (Onofiok and Nnanyelugo 1998, 28)

Fermentation is seen as a strategy for solving some of the problems faced by weaning foods in West Africa. A study made in Nigeria illustrates that protein contents increase with fermentation due to the breakdown of the substrate nutrients. (Sanni, Onilude and Ibidapo 1999, 35) Other positive aspects of fermentation are flavour enhancement, preservative properties, detoxification and antibiotic activity. (Chelule, Mokoena and Gqaleni 2010, 1162)

Ogi is the most famous staple porridge as shown in Figure 5. It is traditionally made by soaking the used cereal for 1 to 3 days, followed by wet milling, sieving and lastly the fermentation of the filtrate for 3 to 4 days. Various bacteria and yeasts are responsible for the fermentation, such as the lactic acid bacterium, *Lactobacillus plantarum,* or yeast, *Candida mycoderma*. Ultimately, the procedures of traditional fermentation undergo 5 main stages: Pre-fermentation (grains are sun-dried and washed), softening, wet milling, sieving and the final fermentation with the help of major organisms for 3 to 4 days. (Haard, et al. 1999)

3.3.2 Commercial weaning foods

This paper analyses five different commercial weaning produce, sold in five various countries of West Africa: Togo, Burkina Faso, Benin, Niger and Cape Verde (Treche, Benoist, et al. 1995). Commercial weaning foods produced in West Africa mainly use a combination of two main cereals, such as sorghum and maize combined with a complementary ingredient, such as beans or soya. Fruits, vegetables and energy dense ingredients are often lacking, thus decreasing the energy and vitamin content. This deficit may however help increase the shelf life and decrease risks of contamination, as most weaning products are made of instant flours.

The production of commercial weaning food in Africa can be summarised in 7 steps:

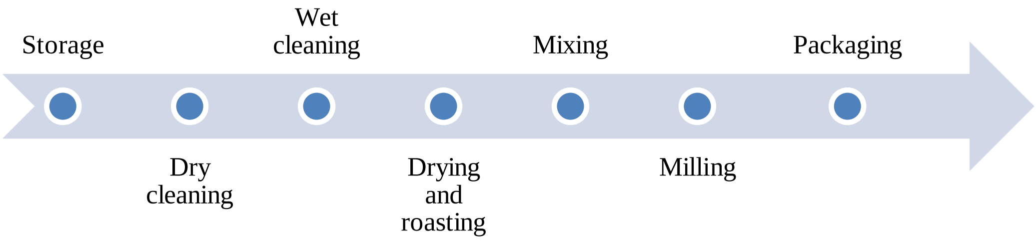


Figure 6: Weaning food technological procedures

Source: “Author’s own visualisation”

This process can vary depending on the recipe, the raw materials and the wealth of the region. (Sanogo 1994, 27) The principal advantages of commercial foods are derived from a variety of components used and the addition of complementary ingredients which are generally high in proteins, such as soya. One point to consider is the lack of information found on the packages, such as the amount of water needed to produce the mixture. A high amount of water may be used which will lower the viscosity and thus decrease the overall energy density and energy intake and vice versa.

4 Research methodology

4.1 Materials

For the creation of this paper, two resources are mainly used to research, evaluate and analyse the required facts. The literature research enables the acquisition of information from a broader knowledge base in the specific field and the software permits the analysis of the data found.

4.1.1 Literature research

There are three different steps in writing the paper:

I. *Research formulation and outline:* Basic ideas are collated to attain a logical procedure of the research paper. The first question asked is, “How Moringa oleifera can optimise West African weaning food?” The relevant topics are then summarised, such as reviewing the weaning food situation in West Africa and evaluate studies made on the plants in terms of nutritional values. These steps are completed through general research using the internet to find exciting studies. This procedure helps determine the literature research and keywords needed.

II. *Literature search*: During this stage, two problematic issues surfaced which are related to the limitations of the literature. Due to the fact that Moringa oleifera is not a popular plant around the world, books cannot be located in libraries of the two main universities in Hamburg: the University of Hamburg and the University of Applied Sciences. Therefore, the information gained from journals, articles and abstracts are the main sources which provide information about this plant.

   Other limitations lie with the various names of the organic plant. The Latin name is officially “Moringa oleifera Lamk”. However there are various other names in different languages. Other common names in English for this tree are drumstick, horseradish or cabbage. (T.K. 2012) The variety in names has made this research difficult in terms of keyword composition.

   There are three main sources used throughout this dissertation. Research articles and journals found online through various databases, are the most relevant to find information about Moringa oleifera. Databases accessible from the various libraries are used to acquire the relevant sources, such as Science Direct (http://www.sciencedirect.com), Springer (http://link.springer.com), Science Citation Index and PubMed (http://www.ncbi.nlm.nih.gov/pubmed).

The secondary sources used, are books from the library of the University of Applied Sciences in Bergedorf. These provide nutritionally relevant information on weaning foods in general and also the recommendations of infant nutrition.

The last relevant sources are the websites used, such as Google (https://www.google.de) and Google Scholar (http://scholar.google.de/). These are employed for overall information, such as recommendations of organisations like WHO and FAO.

The keywords used throughout the dissertation were “Moringa oleifera”, “Moringa?”, “Drumstick tree”, “weaning food in Africa” etc.

III. *Literature review*: all relevant articles and books are selected by reading the abstracts and sorting by significant information. The selected resources are then reviewed, summarised and relevant quotes are outlined for a later use.

4.1.2 Software

EBISpro is a system used for the study and analysis of food and nutrition. This software is used in the analysis of weaning foods in Africa and the supplementation of Moringa oleifera.

This system uses the requirement of DGE 2000 and evaluates the missing nutrients in several recipes.

4.2 Recipes formulation

Traditional and commercial complementary foods are the main types of recipes which are analysed. Table 1 illustrates the percentage of ingredients in each commercial recipe found in five different countries of West Africa and Table 2 emphasises the amount of dry mass per 100g in each recipe given by the manufacturer.

Table 1: Summary of nutrients in commercial foods (%)

Recipe (Countries)	Millet (%)	Rice (%)	Maize (%)	Wheat (%)	Sorghum (%)	Beans (%)	Soya (%)	Peanut (%)	Sugar (%)	Salt (%)	Baobab Fruit (%)	Total
Nutrimix (Togo)		11	63				26					100
Misola (B.Faso)	60						20	10	9	1		100
Ouando (Benin)			33		13	23	23		11			100
Micaf (Cap Verde)			40	40		20						100
Bitamin (Niger)	67					20		10			3	100

Source:”Author’s own visualisation” adapted from (Treche, Benoist, et al. 1995, Sanogo 1994)

Table 2: Summary of weaning foods dry mass ratio in 100g total porridge

Recipes	Dry mass (g)	Total weight of porridge (g)
Maize flour	14	100
Cassava roots	16	100
Millet flour	14	100
Sorghum flour	14	100
Nutrimix	10	100
Misola	20	100
Ouando	10	100
MIcaf	20	100
Bitamin	20	100

Source: “Author’s own visualisation” adapted from (Treche 1995)

Firstly, the total dry mass is analysed to compare complementary food requirements according to energy and energy density. Each formula is calculated in 500g given the information in Table 2. For instance in 500g of porridge where the composition is of cassava roots, there is a total of 80g dry mass.

The daily requirements of infants are then analysed with the addition of breast milk specifically for energy, proteins and micronutrients, such as iron, zinc and vitamin A. Moringa oleifera powder is then supplemented at five different levels at 5, 10, 15 and 20% of the total dry mass in the porridge. For example if a recipe has a total dry mass of 80g, an addition of 10 % Moringa powder is 8g. The results illustrate whether or not the nutritional value changes with the supplement of Moringa.

4.3 Hypothesis

Moringa oleifera is seen as a wonder to fight malnutrition in Africa (Fuglie 2001). Therefore, this paper aims to question these assumptions critically.

- Hypothesis 1: Low nutritional valued weaning foods are the cause of under-nutrition in West Africa.

- Hypothesis 2: Moringa oleifera is a solution to fight under-nutrition in West Africa.

- Hypothesis 3: Moringa oleifera is not unhealthy for an infant.

These three hypotheses will be falsified or verified using the results of the analysis.

5 Literature review: Moringa oleifera

5.1 Botanic description

Moringa oleifera Lamk commonly referred to as the drumstick tree is a plant from the Moringaceae family, which can be found widely throughout the tropics in Africa, South America and India. (T.K. 2012, 455) There are about 13 species in the Moringaceae family, of which Moringa oleifera is the species most widely known. The tree is often called 'multipurpose' due to the fact that all parts including the leaves, pods, seeds, flowers, fruits and roots are edible.

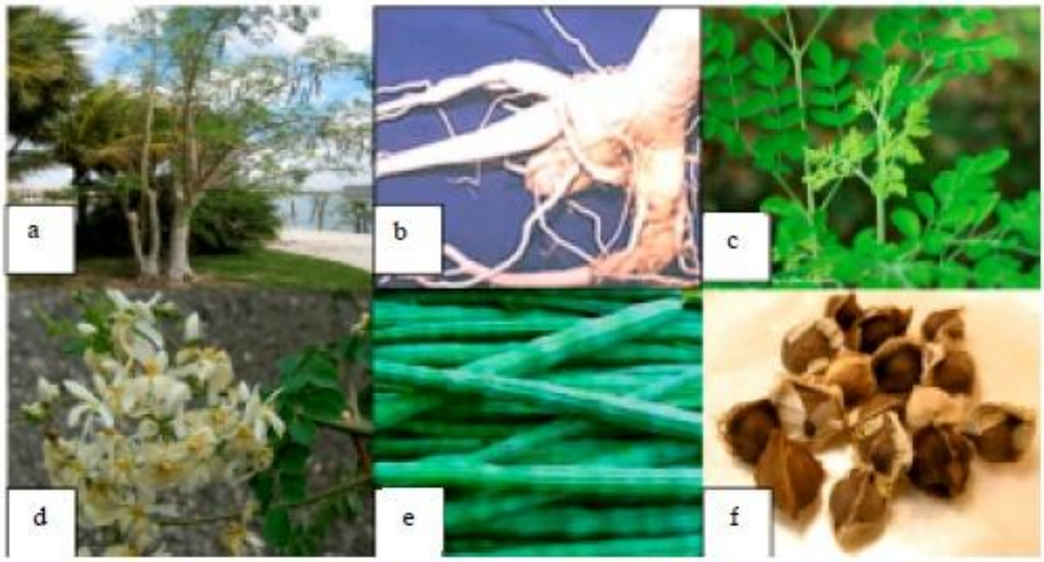


Figure 7: Moringa oleifera: a. tree, b. root, c. leaves, d. flowers, e. pods, f. seeds

Source: (Paliwal, Sharma and Pracheta 2011, 320)

Moringa can be described as a 'much-branched plant' around 10 meters in height, with grey thick bark and a thin crown. (T.K. 2012, 456) The tree requires an annual rainfall of between 250mm and 3000mm and survives in a temperature range of 25 to 40°C which makes it suitable for tropical climates. (HDRA-the organic organisation 2002, 2) The yield is often low in the first two years and it is discovered that in South India, flowers and fruits appear twice a year, enabling two annual crops. Another advantage is that the tree is somewhat resistant to serious diseases as observed in India, although pests like caterpillars have been noticed. (Ramachandran, Peter and Gopalakrishnan 1980, 281)

5.2 Different uses

The different parts of the plant can be used for human consumption, animal silage, water purification and natural medicines. (HDRA-the organic organisation 2002, 3) As this study concentrates on the human consumption aspect, it is useful to illustrate the different functions and ways to consume the diverse parts of the plant.

Leaves can be either used as fresh leaves or as dry powder. Fresh leaves are often used in the same way as spinach or as a supplement for sauces. Dried leaves are frequently milled and can be added to sauces or porridges. Flowers are either cooked or fried and may be combined with relishes. Seeds are used in different ways: they can be either removed from pods and boiled like peas, can be fried and eaten like peanuts or the oil can be refined and consume as edible oil. (HDRA-the organic organisation 2002, 4)

The second most important benefit is the medicinal properties of the plant and various studies illustrate a choice of activities, such as antioxidant, anticancer, antiviral, cardio-protective, anti-inflammatory, anti-asthmatic and others. Other applications of the seeds are for the purification of water and for the production of biodiesel. (T.K. 2012)

5.3 Nutritional values of dried leaves powder

This paper focuses on the leaves of the plant as they have the highest amount of crude protein content as identified by a study carried out in Germany. Makkar and Becker discover that the crude protein content of leaves, soft twigs and stems are respectively 260, 70 and 60g per kg, pointing out the high amount of crude protein in the leaves. They also demonstrate that the leaves have a superior percentage of true protein at about 87% compared to 60 and 53% in twigs and stems respectively (Makkar and Becker 1996, 311).

The leaves have also been subject to other various studies using individuals with special nutritional needs. For instance, two research studies which analysed the impact of Moringa dry leaf powder on iron values of lactating women and undernourished HIV positive children show no adverse symptoms of the plant. (Idohoz-Dossou, et al. 2011, Tété-Bénissan, et al. 2012)These studies apply the leaves as a supplement for human consumption, enabling them to be considered as tolerable for infants as no side effects have been identified.

The leaves are described as “feathery with a green to dark green elliptical leaflet [about] 1-2cm long.” (Paliwal, Sharma and Pracheta 2011, 320) Various small technological procedures are used to obtain a uniform dry powder.

There are seven main steps for obtaining Moringa leaf powder. First the leaves must be stripped from the petiole and branches. Steps two and three are washing the obtained leaves in water and draining for 15 minutes. The fourth step is the drying, which can be either in a room, solar or mechanical. It must be emphasised that the plant is sensitive to UV-light and can lose high amounts of vitamins. It is estimated that if leaves are sun dried, almost 50% of vitamin C is lost after two days, so a drying room is preferential. (Barta 2011, 61)The last three steps are milling, sieving, which may be from 0.2 to 1.5 mm particle size and lastly, drying the final powder to decrease overall moisture content and increase shelf life. (Moringanews/ Moringa Association of Ghana 2010, 39)

The following section reviews the main nutrients found in dried Moringa powder including macronutrients, micronutrients and essential amino acids.

Five main steps are taken before analysing the leaves: washing, drying, milling, sieving and storage. There are some differences in the drying methods, including time and temperature amongst the studies. Temperatures can vary from room temperature of around 30 to 40 °C and leaves are either dried in the shade, sun dried or oven-dried. Through various research studies carried out mostly in West Africa and Asia, a summary of results can be complied.

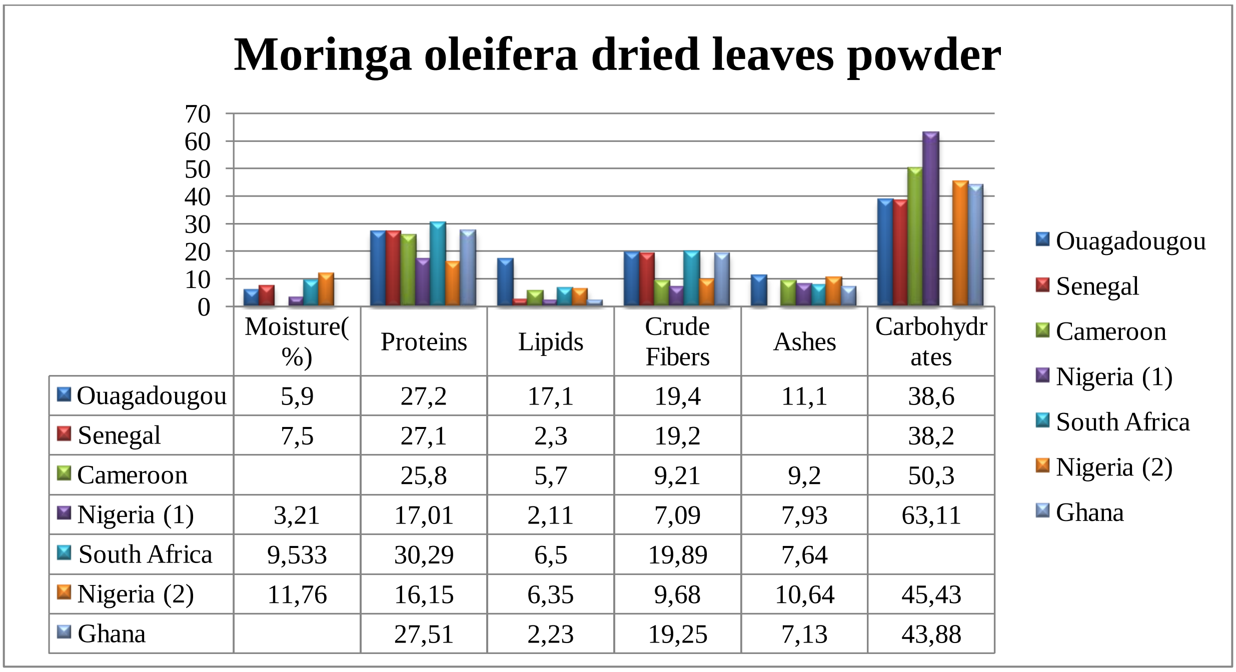
5.3.1 Macronutrients

The six main relevant macronutrients of Moringa oleifera dried leaves are: proteins, lipids, carbohydrates, fibres and additionally ash and water content. Due to the fact that there is a large variation of results amongst all data, maximal and minimum values are taken for the analysis. Variations in data can relate to several reasons, such as differences in analytical methodology, agroclimatic conditions and different stages of leaves’ maturity. (Makkar and Becker 1996, 319)

Two main methods are used to analyse nutrients in Moringa leaves: AOAC methods (Association of Official Analytical Chemists) used by six sources (Moyo, et al. 2011, Ejoh, et al. 2010, Ogbe and Affiku 2011/2012, Oduro, Ellis and Owusu 2008, Oluduro 2012, Price 2000) and AOCS methods (American Oil Chemists Society) (Yameogo, et al. 2011, 265). For occurrence, specific chemical procedures, such as Soxhlet or Kjedahl are applied to examine respective lipids and proteins. For the simplification of the data collection, standard deviation of each result is not acknowledged and mean values of studies are taken as actual numbers.

A summary of macronutrients is shown in Figure 8 and illustrates the wide variation of values found. Using standard deviation, singularities are calculated. One dismissed value is found in the study made in Ghana, as the moisture value is 76.53% although the mean overall values of the other studies are around 7.6 %.

All evaluations are converted to g/100g dried leaves which is equivalent to a percentage. The graph shows that some studies have missing values which may be due to failure during the analysis or high singular estimations.



	Moisture(%)	Proteins	Lipids	Crude Fibers	Ashes	Carbohydrates
Ouagadougou	5,9	27,2	17,1	19,4	11,1	38,6
Senegal	7,5	27,1	2,3	19,2		38,2
Cameroon		25,8	5,7	9,21	9,2	50,3
Nigeria (1)	3,21	17,01	2,11	7,09	7,93	63,11
South Africa	9,533	30,29	6,5	19,89	7,64	
Nigeria (2)	11,76	16,15	6,35	9,68	10,64	45,43
Ghana		27,51	2,23	19,25	7,13	43,88

Figure 8: Macronutrients of Moringa oleifera dried leaves (g/100g)

Source: “Author’s own visualisation”

For the analysis, maximum and minimum values are taken as shown in Table 3. The total energy of the leaves is calculated using the Atwater methods given by FAO, which is the sum of protein, fat and carbohydrate having an energy value of 4, 9 and 4kcal/g respectively. (Food and Agriculture Organization 2003, 23)

Table 3: Maximum and minimum values of macronutrients in dried leaves (g/100g)

Nutrients	Maximum	Minimum
Moisture (%)	11.8	3.2
Proteins (g)	30.3	16.2
Lipids (g)	17.1	2.1
Crude fibres (g)	19.9	7.1
Ashes (g)	11.1	7.1
Carbohydrates (g)	63.1	38.2
Energy (kcal)	355.7	144.0
Energy (kJ)	1488.2	602.5

Source: “Author’s own visualisation”

As this study mainly focuses on the protein content of the dried leaves, it is relevant to consider the values found. As exposed in Table 3, the highest protein content found is 30.3g/100g and the lowest 16.2 g/100g. These are crude protein values which do not consider the bioavailability, loss during cooking and net protein utilisation, thus these values may be lower than expected.

Another restraint might be the use of the Kjedahl analysis, as it assumes that dietary carbohydrates and fats do not contain nitrogen, this means that the leaves may have overall higher nitrogen content. The use of the conversion factor 6.25 to change nitrogen into protein content may also give an unspecified data, therefore FAO encourage using the sum of amino acids residue when analysing protein content as this is more specific. (Food and Agriculture Organization 2003) Nonetheless, this analytical method is cost intensive.

It is interesting to compare the protein maximum and minimum values found, compared to other supplements used to increase protein levels in West Africa. Whole milk powder, peanuts, dried fish and soya beans protein values are evaluated in percentage using the software EBISpro.

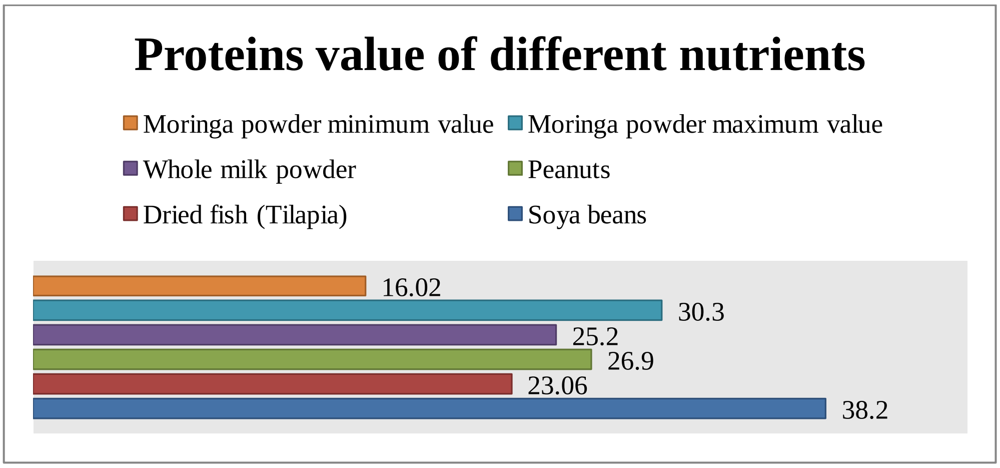


Figure 9: Proteins value of different nutrient

Source: “Author’s own visualisation” adapted from EBISpro

Soya beans have the highest protein content followed by the maximum value found in Moringa leaf proteins. However, the minimum value of Moringa has the lowest protein content compared to all nutrients, which suggests on the other hand, that Moringa may not be a suitable supplement to increase protein levels in infant food.

5.3.2 Micronutrients

There are various assumptions involving the micronutrient value of Moringa oleifera, such as having 1.3 times more zinc than pork steak and 8.8 times more iron than fillet beef. (Barta 2011, 19) Therefore critical views on the results found are essential. Ten sources are found on elementary analysis of minerals including calcium, magnesium, potassium, sodium, iron, zinc, phosphor, copper and manganese. (Barminas, Charles and Emmanuel 1998, Yameogo, et al. 2011, Aslam, et al. 2005, Sena, et al. 1998, Melesse, et al. 2012, Ogbe and Affiku 2011/2012, Moyo, et al. 2011, Freiberger, et al. 1998, Oluduro 2012) Most analyses are done using atomic absorption spectroscopy (AAS) or atomic emission spectroscopy (ICP-OES or ICP-AES). However, these vary depending on the mineral analysed, for instance phosphorus is an exception and must be determined using colorimetric methods. The data for vitamins A, Bs, E and C are only found in one study taken in Senegal (Price 2000, 5). Therefore these data must be viewed delicately as no analysis methods are given.

5.3.2.1 Minerals

Due to the variety of values found, a significant mean of the results cannot be calculated. Therefore maximum and minimum amounts are also taken for the analysis. Figure 10 illustrates the broad range of different values, including calcium, magnesium, potassium, sodium, phosphor and sulphur.

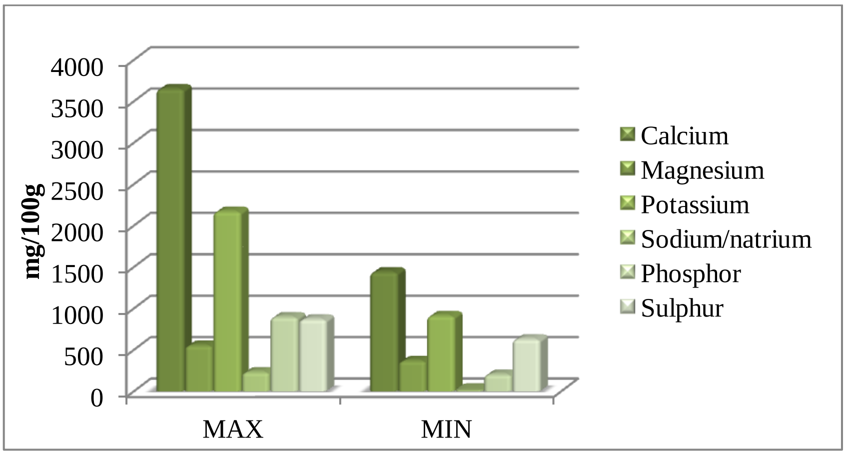


Figure 10: Maximum and minimum minerals value of Moringa oleifera (mg/100g)

Source: "Author's own visualisation"

The graph clearly emphasises that maximum values are almost double the minimum values. Numbers which are too low compared to the overall results were not comprised, such as magnesium. A study carried out in Pakistan identifies the value of magnesium at 10.24mg/100g, however in comparison to the overall values which lie between 300 and 550mg/100g, this value of magnesium is an anomaly.

Iron and zinc are the most deficient minerals in West Africa. Table 4 illustrates the mean, maximum and minimum values of iron found in 100g and 15g Moringa dried leaves. In various studies, 15g of Moringa powder is often illustrated as the maximum value to be supplemented with no significant change in taste or texture. (Barta 2011, 124)

Table 4: Zinc and iron content in Moringa dried leaves (mg/100g) and (mg/15g)

	mg/100g			**mg/15g**	
	Mean	**Max**	**Min**	**Max**	**Min**
Zinc	4.0	6.1	2.3	0.92	0.34
Iron	33.5	57.6	10.7	8.64	1.61

Source: "Author's own visualisation"

The daily requirement of an infant between 6 to 12 months is 3mg and 8mg of zinc and iron respectively. (Barta 2011, 153) Thus, 15g of dried leaves will attain a maximum and minimum value of 30.7 and 11.3% of the total daily zinc requirement. Nonetheless, the maximum value found of iron covers the required daily demand of 8mg but supplies only 20% at its minimum value. These drastic variations in values are important in the analysis and therefore both maximum and minimum standards must be used.

5.3.2.2 Vitamins

A single source is found relevant to the amounts of vitamins A, E, B1, B2,C. Lowell Fuglie (Price 2000) is the most stated author pertaining to Moringa oleifera, thus making the results reliable to use even though no analytical methods are given. The study, conducted in Senegal, found a wide amount of minerals and vitamins in the pods, leaves and leaf powder. Vitamin E, B1, B2, and C have the values of 113, 2.64, 20.5 and 17.5 mg/100g respectively. (Price 2000, 5)

Beta carotene is a molecule which is changed to vitamin A in the body. The mean value of beta-carotene found in leaf powder is 17.6mg /100g. (Barta 2011, Price 2000) Vitamin A content is found to be 3.15mg/100g, suggesting that 15g of powder contains 0.47mg. This amount fulfils almost 80% of the daily requirement for an infant of the age 6 to 12 months. (Barta 2011, 159)

5.3.3 Amino Acids

The main methods used in the studies to determine the values of amino acids are acid hydrolysis followed by ion exchange chromatography. A detailed review on the methods is not given because some sources do not state the exact procedures and depending on the amino acid, (tryptophan or cysteine) different selections of hydrolysis can be used. These “methods can provide values within- laboratory coefficient of variation of about 5% and between laboratories of about 10% for most amino acids.” (Food and Agriculture Organization 2013, 22)The variability is nonetheless considered as acceptable for the calculation of amino acid score.

All essential and semi-essential amino acids are found in different amounts in Moringa’s powdered form. Mainly, four sources are detected (Barta 2011, Moyo, et al. 2011, Sena, et al. 1998, Freiberger, et al. 1998), therefore maximum and minimum values are established as shown in table 5. The values are given in mg/100g total dried Moringa powder. The FAO however, recommends that amino acid results should be reported as mg/g nitrogen or mg/g protein. (Food and Agriculture Organization 2013, 22)

Table 5: Maximum and minimum amino acids content in Moringa oleifera

Essential and semi-essential AS	Maximum (mg/100g)	Minimum (mg/100g)
Arginine	1890	1325
Lysine	1637	917
Isoleucine	1190	782
Methionine	350	234
Cysteine	387	10
Phenylalanine	1640	1050
Valine	1480	1063
Histidine	716	378
Threonine	1357	709
Trytophan	753	425
Tyrosine	2650	833
Leucine	2050	1550

Source: “Author’s own visualisation”

Through a supplementation of Moringa at both its maximum and minimum values, an explorative analysis can emphasise how amino acid content increase overall in the infant weaning foods.

5.4 Anti-nutritional factors

Anti-nutritional factors are defined as naturally generated substances in feed stuffs which exert effects contrary to optimum nutrition. (Kumar 1992, 145) The presence of high amounts of anti-nutritional factors can affect the digestibility of proteins, can have an effect on carbohydrates’ digestion and may inactivate vitamins. Therefore, it is important to evaluate a plant anti-nutritional factor to access potential inhibitors.

Legumes like soya beans or peas are a rich source of anti-nutrients, though methods such as cooking, roasting, milling, fermentation can be used to reduce this high amount. (Khokhar and Owusu Apenten 2003) Makkar and Becker evaluate several anti-nutritional factors in their study of Moringa oleifera leaves comprising tannins, trypsin inhibitors, lectins, saponins, phytates, cyanogenic glucosides, alpha-amylase inhibitors, glucosinolates and alkaloids.

Table 6: Anti-nutritional factors in Moringa oleifera leaves

Total phenols (g/kg)	Tannin (g/kg)	Saponin (g/kg)	Phytate (g/kg)	Lectin (g/kg)	Cyanogenic glucoside (mg/kg)	Glucosinolate (µmol/g)
44.3	12.0	81.0	21.0	Not detectable	Not detectable	Not detectable

Source: "Author's own visualisation" adapted from: (Makkar and Becker 1996, 318)

The results illustrate that only saponins are found in considerable amounts, 81g per kg, as shown in Table 6. Saponins are steroids or triterpenoid glycosides attached to a carbohydrate. (Kumar 1992, 148) They are characterised by their bitter taste, foaming properties and affect membrane integrity. It is estimated that in Europe the daily amount of saponins is around 15mg, however in traditional African or Asian cuisine, the value increases to 110 to 240mg depending on the amount of legumes eaten. (Watzl 2001, 253)

Nonetheless, saponins are poorly absorbed and are mostly excreted unchanged. The value of saponins in Moringa leaf powder, used in this study, may also be inferior since technological procedures like milling or drying are used. The generated bitter taste may be an issue in relevance to the consumption acceptance of the fortified porridge. Using Makkar and Becker's study, it can be concluded that Moringa leaves' anti-nutritional factors are not significant and protein-inhibitors like tannins or phytates, which can affect the protein value were found in very low amounts, thus irrelevant for the analysis.

5.5 Potential toxicity

A novel synergistic composition of Moringa oleifera and two other plants are analysed relating to acute oral toxicity, acute dermal toxicity, primary skin irritation, primary eye irritation and dose dependent 28-day sub acute toxicity. (Krishnaraju, et al. 2010) As this paper concentrates on the consumption of Moringa oleifera, acute oral toxicity and the NOAEL (No-observed-adverse effect level) are the most relevant values to be emphasised.

Krishnaraju highlights that the acute oral LD50 (Lethal dose 50%) is greater than 5000mg per kg in female standard rats and no change of weight is observed. The NOAEL is detected to be greater than 2500mg/kg body weight. (Krishnaraju, et al. 2010) Assuming a toddler's weight is about 8 kg at the age of 6months, the NOAEL consumption is around 20g of Moringa oleifera. It must be stated that there are always limitations due to different factors such animal species used or environmental factors. Therefore these values can be used as estimations since no other toxicological tests have been conducted.

5.6 Case study review: Supplementation of Moringa oleifera

Two main organisations carried out research using Moringa as a supplement for weaning food in Africa. IRD is a French organisation aiming to improve development through research and ITRA is a Togolese organisation for agronomical research.

5.6.1 IRD

Melanie Broin, author of the research paper, illustrates that four different baby flour formulas using local raw materials are supplemented with an altered amount of Moringa leaf powder. These formulas are analysed with software (Alicom) in terms of children’s nutritional needs from 6 months to 2 years old, given by WHO.

The four made formulas using Moringa cover the proteins, fats, carbohydrates and amino acids needs of infants, although some micronutrients cannot be covered. (Broin n.d.)

The main limitation of this examination is the lack of scientific evidence, as no research articles credit this study. The investigation also states that less than 15% of Moringa powder is accepted by mothers and infants, however in two of the flours made, more than 15% of Moringa powder is used decreasing the probability of intake. To conclude, this study can be used as a model to illustrate other baby flour formulas in Africa, however due to the lack of scientific evidences it cannot be used as reference.

5.6.2 ITRA

The ITRA study aims to produce new complementary foods with high mineral values. Moringa oleifera is used as a supplement in amounts of 5, 10, and 15% to a mixture of maize, rice and soya.

The level of acceptance of both infants and mothers decrease as the amount of Moringa powder increased. For instance, at a supplementation of 5% almost 50% reject the porridge and at 15%, 80 % of the 77 women and children reject the food. However, it is stated that the values of iron and zinc increase with the addition of Moringa. (Institut Togolais de Recherche Agronomique 2011) The decrease of consumption acceptance of both mothers and children may be due to changes in viscosity, smell, colour or taste. The study is interesting as it shows the acceptance of Moringa in porridges. Nevertheless it also lacks scientific evidences and thus cannot be used as reference.

6 Results

6.1 Analysis of weaning foods

This segment aims to analyse the different traditional and commercial infant food products used in West Africa, using the EBISpro software. The analyses are based on various assumptions made in different studies:

- An infant eats around 500g of complementary food per day
- The total amount of breast milk consumed per day is around 600ml

The first stage of the analysis is to explore the different recipes in dry mass relating to energy, protein and energy density content and compare the results with complementary food requirements.

The next stage is to analyse the total daily consumption using the nine recipes, taking into account both assumptions.

6.1.1 Nutritional values of traditional and commercial food (dry mass)

Sorghum and baobab fruit nutritional values are missing in the EBISpro software and must be added in the database using the data given by the FAO (FAO 2010). The energy density for each dry mass is calculated from dividing the energy by the total weight of porridge eaten (500g).

Table 7: Energy, protein and energy density value of complementary foods

	Traditional complementary foods (g)				**Commercial complementary foods (g)**				
	Cassava roots (80g)	Maize flour (70g)	Millet flour (70g)	Sorghum flour (70g)	Bitamin (100g)	Micaf (100g)	Misola (100g)	Nutrimix (50g)	Ouando (50g)
Energy (kcal)	109.94	230.71	239.91	257.48	370.46	300.2	350.15	153.32	164.08
Energy density (kcal/g)	0.22	0.461	0.480	0.515	0.741	0.600	0.700	0.307	0.328
Protein (g)	0.8	6.06	4.06	5.53	14.3	17.44	15.57	9.24	7.94

All traditional foods and two commercial foods (Nutrimix and Ouando) are below the required calorific value of 300kcal and are very low in protein and energy density. In the other hand, it can be observed that in the tests carried out on commercial foods, three of them (Bitamin, Micaf, Misola) achieve the recommended amount of calorific values.

6.1.2 Total daily nutritional values of traditional and commercial foods

The resultant data illustrates the daily amount of nutrients eaten, assuming a daily 600ml of the mother's milk and supplementation 500g total mass of complementary food.

Table 8: Results: Daily intake of traditional complementary foods and human milk

	Energy (kcal)	**Protein (g)**	**Vit. A (µg)**	**Vit. B1 (mg)**	**Vit. B2 (mg)**	**Vit. B6 (mg)**	**Vit. C (mg)**	**Calcium (mg)**	**Magnesium (mg)**	**Iron (mg)**	**Zinc (mg)**	**Phosphor (mg)**
D-A-CH requir-	700	10	600	0.4	0.4	0.3	55	400	60	8	2	300
Cassava roots	508.6	8	418	0.17	0.26	0.22	48	211.6	76	1.54	1.33	120.4
Maize flour	629.37	13.26	449	0.43	0.33	0.1	24	198.6	56.9	2.28	2.64	269.2
Millet flour	638.58	11.26	414	0.29	0.37	0.48	24	214	129	4.8	1.59	272
Sorghum flour	656.14	12.73	414	0.12	0.24	0.3	24	193	110.8	2.98	2.29	297.9

All traditional foods analysed are below the required energy level intake of 700kcal, although only cassava roots have a low protein value. The table also interprets that vitamin A, C, iron and phosphor are found in very low amounts in all of the porridges. Thus a supplementation of Moringa powder is the next step to evaluate if these deficiencies can be adjusted.

The commercial nutritional values are also calculated using the recipes given from the manufacturer (see Recipes formulation) in each 500g.

Table 9: Results: Daily intake of commercial foods and human milk

	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
D-A-CH requir-	700	10	600	0.4	0.4	0.3	55	400	60	8	2	300
Bitamin	769.12	21.5	427	0.52	0.46	0.71	30.85	295	203	6.43	2.87	422
Micaf	698.85	24.64	436	0.62	0.38	0.31	24	283	146	4.69	3.42	464
Misola	748.8	22.77	415	0.44	0.41	0.58	24	295	208	6.32	2.36	428
Nutrimix	551.98	16.44	431	0.35	0.31	0.16	24	255	84	2.62	2.09	264.5
Ouando	562.74	15.14	423	0.27	0.29	0.14	24	250	91	2.64	1.93	259

The main nutritional issues in commercial foods are vitamin A, iron and calcium. The analysis also shows remarkable deficiencies in two recipes: Ouando and Nutrimix.

6.2 Analysis of weaning foods with supplement: Moringa oleifera

Due to the reason that all traditional foods are low in energy and specific micronutrients, an evaluation on the supplementation of Moringa oleifera at 5, 10, 15 and 20% is completed. Nonetheless, considerable differences in the nutritional quality of commercial food can be observed and a significant low amount of nutrients are found in only Nutrimix and Ouando.

The following sections analyse the potential effects of Moringa oleifera on the observed low valued complementary foods: cassava roots, maize, millet, sorghum flour, Nutrimix and Ouando. The results use both maximum and minimum values found in Moringa oleifera leaves.

6.2.1 Results: Supplementation of Moringa oleifera at 5, 10, 15 and 20%

a. Cassava roots

Table 10: Cassava roots with supplementation of Moringa oleifera (5, 10, 15, 20%)

	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
Cassava roots + 5% Mo MAX	522.83	9.21	544	0.27	1.08	0.29	48.69	357.6	98.16	3.84	2.35	156.28
Cassava roots + 5% Mo MIN	514.37	8.65	544	0.27	1.08	0.29	48.69	269.2	90.72	1.97	2.18	128.56
Cassava roots+ 10% Mo MAX	537.06	10.42	670	0.38	1.9	0.36	49.38	503.6	120.32	6.14	3.37	192.16
Cassava roots + 10% Mo MIN	520.13	9.29	670	0.38	1.9	0.36	49.38	326.8	105.44	2.4	3.03	136.72
Cassava roots + 15% Mo MAX	551.28	11.63	796	0.48	2.72	0.42	50.08	649.6	142.48	8.45	4.39	228.04
Cassava roots + 15% Mo MIN	525.9	9.94	796	0.48	2.72	0.42	50.08	384.4	120.16	2.83	3.88	144.88
Cassava roots + 20% Mo MAX	565.51	12.85	922	0.59	3.54	0.49	50.77	795.6	164.64	10.75	5.41	263.92
Cassava roots + 20% Mo MIN	531.66	10.58	922	0.59	3.54	0.49	50.77	442	134.88	3.26	4.73	153.04

There is a slight increase in energy on the whole with a maximum amount of 60kcal at a supplementation of 20%. Protein and vitamin A daily requirements are achieved with an addition of 10% in both maximum and minimum values. A steady increase in vitamin C is attained at around 2mg at 20% supplementation, though lower than the required amount of 55mg. The variance in maximum and minimum iron values in Moringa oleifera is emphasised through these results with a difference of almost 70%.

b. Maize flour

Table 11: Maize flour with supplementation of Moringa oleifera (5, 10, 15, 20%)

	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
Maize flour + 5% Mo MAX	641.82	14.32	559.25	0.52	1.05	0.16	24.61	326.35	76.29	4.3	3.53	300.6
Maize flour + 5% Mo MIN	634.42	13.83	559.25	0.52	1.05	0.16	24.61	249	69.78	2.66	3.38	276.34
Maize flour + 10% Mo MAX	654.27	15.38	669.5	0.61	1.77	0.22	25.21	454.1	95.68	6.31	4.42	331.99
Maize flour + 10% Mo MIN	639.46	14.39	669.5	0.61	1.77	0.22	25.21	299.4	82.66	3.03	4.13	283.48
Maize flour + 15% Mo MAX	666.72	16.44	779.75	0.71	2.48	0.28	25.82	581.85	115.07	8.33	5.32	363.39
Maize flour + 15% Mo MIN	644.51	14.96	779.75	0.71	2.48	0.28	25.82	349.8	95.54	3.41	4.87	290.62
Maize flour + 20% Mo MAX	679.16	17.5	890	0.8	3.2	0.34	26.42	709.6	134.46	10.34	6.21	394.78
Maize flour + 20% Mo MIN	649.55	15.53	890	0.8	3.2	0.34	26.42	400.2	108.42	3.78	5.62	297.76

A progressive increase of energy is achieved, however below the daily required intake. The level of vitamin C and iron at minimum values are 50% below the daily requirements with the supplementation of Moringa oleifera. The results indicate the leaves as very nutritious in terms of vitamins A, B1, B2 and calcium at both minimum and maximum values found.

c. Millet flour

Table 12: Millet flour with supplementation of Moringa oleifera (5, 10, 15, 20%)

	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
Millet flour + 5% Mo MAX	651.02	12.32	524.25	0.39	1.09	0.54	24.61	341.75	148.39	6.82	2.48	303.4
Millet flour + 5% Mo MIN	643.62	11.83	524.25	0.39	1.09	0.54	24.61	264.4	141.88	5.18	2.33	279.14
Millet flour + 10% Mo MAX	663.47	13.38	634.5	0.48	1.81	0.6	25.21	469.5	167.78	8.83	3.37	334.79
Millet flour + 10% Mo MIN	648.66	12.39	634.5	0.48	1.81	0.6	25.21	314.8	154.76	5.55	3.08	286.28
Millet flour + 15% Mo MAX	675.92	14.44	744.75	0.57	2.53	0.66	25.82	597.25	187.17	10.85	4.27	366.18
Millet flour + 15% Mo MIN	653.71	12.96	744.75	0.57	2.53	0.66	25.82	365.2	167.64	5.93	3.82	293.42
Millet flour + 20% Mo MAX	688.37	15.5	855	0.66	3.24	0.72	26.42	725	206.56	12.86	5.16	397.58
Millet flour + 20% Mo MIN	658.75	13.52	855	0.66	3.24	0.72	26.42	415.6	180.52	6.3	4.57	300.56

d. Sorghum flour

Table 13: Sorghum flour with supplementation of Moringa oleifera (5, 10, 15, 20%)

	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
Sorghum flour + 5% Mo MAX	668.59	13.79	524.25	0.21	0.96	0.36	24.61	320.75	130.19	5	3.18	329.29
Sorghum flour + 5% Mo MIN	661.19	13.3	524.25	0.21	0.96	0.36	24.61	243.4	123.68	3.36	3.03	305.04
Sorghum flour + 10% Mo MAX	681.04	14.85	634.5	0.3	1.67	0.42	25.21	448.5	149.58	7.01	4.07	360.69
Sorghum flour + 10% Mo MIN	666.23	13.86	634.5	0.3	1.67	0.42	25.21	293.8	136.56	3.73	3.78	312.18
Sorghum flour + 15% Mo MAX	693.48	15.91	744.75	0.4	2.39	0.48	25.82	576.25	168.97	9.03	4.97	392.08
Sorghum flour + 15% Mo MIN	671.28	14.43	744.75	0.4	2.39	0.48	25.82	344.2	149.44	4.11	4.52	319.32
Sorghum flour + 20% Mo MAX	705.93	16.97	855	0.49	3.11	0.54	26.42	704	188.36	11.04	5.86	423.48
Sorghum flour + 20% Mo MIN	676.32	14.99	855	0.49	3.11	0.54	26.42	394.6	162.32	4.48	5.27	326.46

The mineral composition of both results of sorghum and millet flours unravel that vitamin C and iron at minimum values are below the daily requirement. Nonetheless, at the leaves maximum values the energy value of sorghum is increased to meet the requirement and iron content increases at almost 40% in both flours at the maximum value (20%)

e. Ouando

Table 14: Ouando with supplementation of Moringa oleifera (5, 10, 15, 20%)

	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
Ouando + 5% Mo MAX	571,63	15,9	501,25	0,34	0,8	0,18	24,43	309,75	100,35	4,08	2,55	281,42
Ouando + 5% Mo MIN	566,34	15,54	501,25	0,34	0,8	0,18	24,43	254,5	95,7	2,9	2,45	264,1
Ouando + 10% Mo MAX	580,52	16,65	580	0,4	1,31	0,22	24,86	401	114,2	5,52	3,19	303,85
Ouando + 10% Mo MIN	569,95	15,95	580	0,4	1,31	0,22	24,86	290,5	104,9	3,17	2,98	269,2
Ouando + 15% Mo MAX	589,41	17,41	658,75	0,47	1,83	0,26	25,3	492,25	128,05	6,96	3,83	326,27
Ouando + 15% Mo MIN	573,55	16,35	658,75	0,47	1,83	0,26	25,3	326,5	114,1	3,44	3,51	274,3
Ouando + 20% Mo MAX	598,3	18,17	737,5	0,54	2,34	0,31	25,73	583,5	141,9	8,4	4,46	348,7
Ouando + 20% Mo MIN	577,15	16,76	737,5	0,54	2,34	0,31	25,73	362,5	123,3	3,71	4,04	279,4

f. Nutrimix

Table 15: Nutrimix with supplementation of Moringa oleifera (5, 10, 15, 20%)

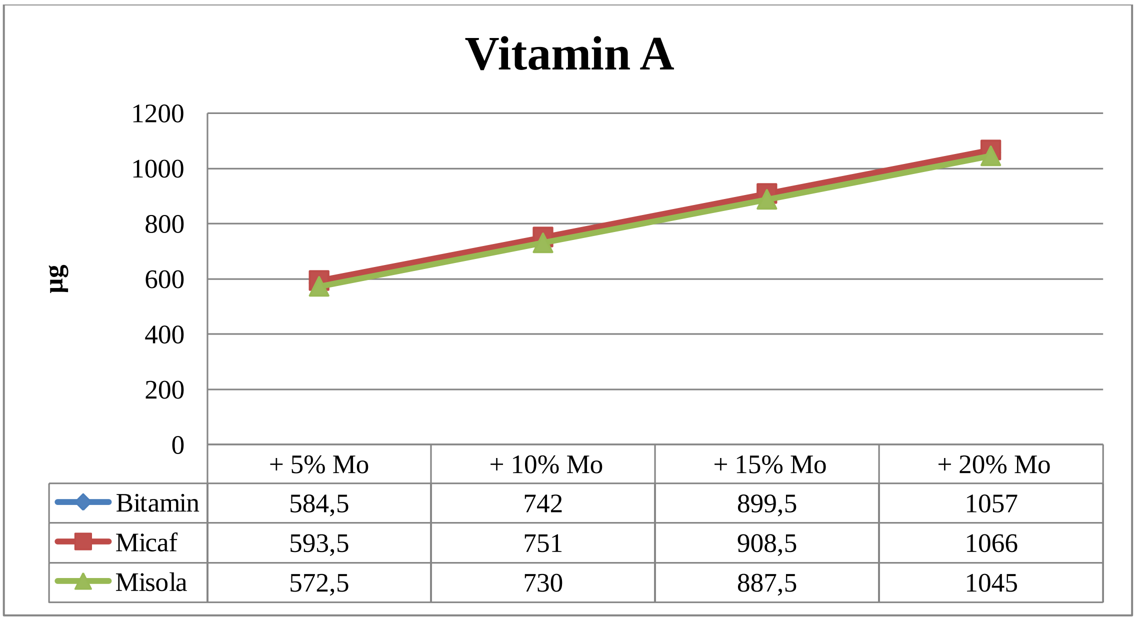
	Energy (kcal)	Protein (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
Nutrimix + 5% Mo MAX	560,87	17,2	509,25	0,42	0,83	0,2	24,43	314,75	93,35	4,05	2,71	286,92
Nutrimix + 5% Mo MIN	555,59	16,85	509,25	0,42	0,83	0,2	24,43	259,5	88,7	2,88	2,61	269,6
Nutrimix + 10% Mo MAX	569,77	17,96	588	0,48	1,34	0,25	24,86	406	107,2	5,49	3,35	309,35
Nutrimix + 10% Mo MIN	559,19	17,25	588	0,48	1,34	0,25	24,86	295,5	97,9	3,15	3,14	274,7
Nutrimix +	578,66	18,72	666,7	0,55	1,85	0,29	25,3	497,25	121,05	6,93	3,99	331,77

15% Mo MAX			5									
Nutrimix + 15% Mo MIN	562,79	17,65	666,75	0,55	1,85	0,29	25,3	331,5	107,1	3,41	3,67	279,8
Nutrimix + 20% Mo MAX	587,55	19,47	745,5	0,62	2,37	0,33	25,73	588,5	134,9	8,37	4,62	354,2
Nutrimix + 20% Mo MIN	566,4	18,06	745,5	0,62	2,37	0,33	25,73	367,5	116,3	3,68	4,2	284,9

Table 14 and 15 reveal a failure in increasing energy using Moringa oleifera. However the required amount of vitamins A, B1 and B2 are achieved with an addition of 10%. Iron and vitamin C are still an issue with the addition of Moringa oleifera at its minimum values.

6.2.2 Nutrients analysis in Bitamin, Misola and Micaf

i. Vitamin A



	+ 5% Mo	+ 10% Mo	+ 15% Mo	+ 20% Mo
Bitamin	584,5	742	899,5	1057
Micaf	593,5	751	908,5	1066
Misola	572,5	730	887,5	1045

Figure 11: Vitamin A in Bitamin, Micaf and Misola with supplementation of Moringa oleifera (5, 10, 15, 20%)

An addition of only 5% of the leaves powder adjusts the daily required amount of 400µg. An increase of around 200µg is achieved with addition of 5% of powder in recipes.

ii. Vitamin C

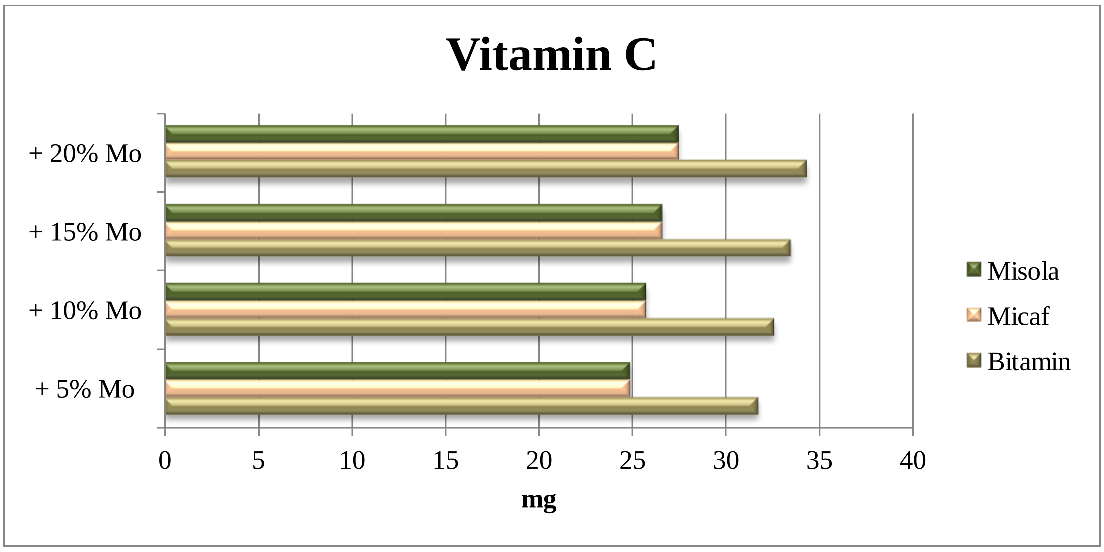
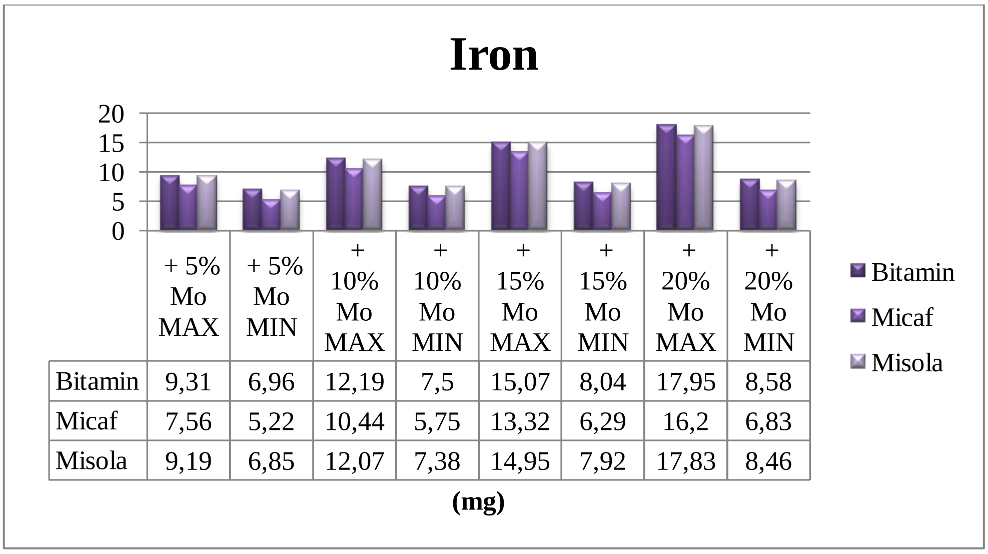


Figure 12: Vitamin C difference with addition of Moringa in Bitamin, Micaf and Misola

The graph illustrates that an addition of 5% Moringa powder increases the overall amount to about 2mg with no significant changes in the intake.

iii. Iron



	+ 5% Mo MAX	+ 5% Mo MIN	+ 10% Mo MAX	+ 10% Mo MIN	+ 15% Mo MAX	+ 15% Mo MIN	+ 20% Mo MAX	+ 20% Mo MIN
Bitamin	9,31	6,96	12,19	7,5	15,07	8,04	17,95	8,58
Micaf	7,56	5,22	10,44	5,75	13,32	6,29	16,2	6,83
Misola	9,19	6,85	12,07	7,38	14,95	7,92	17,83	8,46

Figure 13: Difference in iron content with addition of Moringa in Bitamin, Micaf and Misola

At the maximum value of iron in Moringa powder, the requirement is subsequently met at 10%, compared to the minimum values found in the leaves. An addition of at least 20% of Moringa powder is required to meet the iron requirements of 8mg.

7 Discussion

The recommended energetic value of weaning food is suggested to be around 300kcal (Linkages 2004), it is however observed that only three of the total nine weaning food products analysed meet this requirements.

Cassava, having the lowest energy of 110kcal, is followed by the commercial foods, Nutrimix and Ouando, with almost half of the required energy lacking. A calculation to find out the energy density underlines the rate of meals an infant needs to ingest, to cover its basic needs. Cassava has an energy density of 0.22kcal/g which is extremely low, suggesting that an infant may need to eat roughly seven times per day to meet the requirements. The results for Bitamin, Micaf and Misola illustrate a practical feeding scheme of three times per day as outlined in Figure 1 and correlate with the feeding habits of West African mothers. These results point out that the main issue of weaning food is the ratio of dry mass to the total porridge given by the mothers. The Nutrimix packaging informs us that 50g of dry mass is used for 500ml of porridge (Agbo and Agbere 1995, 216); this severely decreases the energy density, as the amount of dry mass is extremely low in comparison to the total porridge used. The low amounts of dry mass in the two given recipes (Nutrimix and Ouando) may be due to the high viscosity of the flours, which may also influence the infants feeding practice.

The level of protein in cassava is 0.8g. This is also extremely low compared to the other recipes. It is also observed that all traditional recipes have a protein value below the daily requirement and therefore the addition of breast milk is necessary. In the other hand, high values of protein levels in commercial foods are positively perceived due to the use of soya, beans and peanuts in the recipes.

The daily requirements are calculated using a figure of 500g as a daily amount of weaning food eaten and 600ml as the quantity of breast milk consumed in a day. It must be clarified that these figures are all estimations established through various studies and may be variable depending on the environment or individual.

The nutritional values of breast milk are acquired from the DGE as revealed in the table below:

Table 16: Mother's milk nutritional value (DGE)

Energy (kcal)	Protein (g)	Vit.A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Phosphor (mg)
398.7	7.2	414	0.1	0.2	0.1	24	186	24	0.6	0.9	90

Source: EBISpro (DGE 2000)

The figures emphasise the importance of breast milk for an infant aged 6 to 12 months. The table shows high energy, protein, vitamin A and calcium values, which are all essential for the growth of a toddler. Through the addition of human milk, the overall nutritional value can be increased, though it must be considered that these values can also vary depending on the individual (DGE 2001, 18).

Allen and Gillespie state that the nutrient requirements from complementary foods, for an infant consuming an average intake of breast milk, must have an energy percentage of around 50 to 70%, 20 to 45% protein, 5 to 30% vitamin A, 85% zinc, and almost 100% iron. They also illustrate that an addition of almost no vitamin B12 and C in complementary food is needed, as breast milk is high in these vitamins. (Allen and Gillespie 2001, 29) The results therefore show whether or not an average daily intake of breast milk can satisfy these requirements.

The traditionally made foods are low in energy, thus higher in protein. Cassava roots cover only 70% of the energy required and 80% of protein. Vitamin A, B2, C and iron are found in low values in all traditional foods which support the literature facts about the micronutrient deficiency in Africa. (Kalimbira 2007)

Every commercial food meets the daily protein requirements of 10g. However Nutrimix and Ouando are very low in energy and in almost all other nutrients. Bitamin which is produced in Niger covers almost all nutritional demands, expect iron and vitamin C.

The analyses of both commercial and traditional complementary foods help to identify the deficient nutrients in West African weaning food. The main issues are vitamin A, C, calcium and iron as these are low in almost all complementary foods. However, protein and zinc content is higher than expected in all weaning foods. The high protein value in the recipes may suggest that there is not protein-malnutrition in West Africa. (Müller, Garenne, et al. 2003, 511) Yet, to be able to deeply understand the protein deficiency in

Africa, the amino acid content of some recipes must be analysed to find out if the most essential amino acids are covered.

The amino acid patterns of four different recipes including cassava roots, maize flour, Bitamin and Nutrimix, are analysed in comparison to the amino acids composition of a whole egg. Lasztity and Hidvegi (1983) suggest that the basic way to evaluate amino acid patterns is to make a comparison with reference proteins, such as eggs or human milk. (Lasztity and Hidvegi 1983, 295)

The figures found below suggest that cassava roots have the most limited amounts of amino acids as expected. It also illustrates that Lysin, which is essential for growth and covers almost 10% of the protein muscles, (Schreier 1959, 634) is signifantly limited in all the recipes analysed.

Bitamin has the most similar amino acids composition associated with an egg and this may be due to the high protein values found. Nonetheless, the other three recipes have a low scoring pattern compared to a whole egg, which may lower the quality of the proteins, as these amino acids are all essential for the infant growth and metabolism.

Table 17: Amino acids sequence in four different recipes compared to whole egg in 100g

	Proteins (g)	**Isoleucin (g)**	**Leucin (g)**	**Lysin (g)**	**Methionin (g)**	**Cystin (g)**	**Phenylalanin (g)**	**Tyrosin (g)**	**Threonin (g)**	**Tryptophan (g)**	**Valin (g)**	**Arginin (g)**	**Histidin (g)**	**Alanin (g)**
Egg	12,56	0,671	1,086	0,91	0,38	0,272	0,68	0,499	0,556	0,167	0,858	0,82	0,309	0,735
Cassava roots	1	0,03	0,05	0,05	0,01	0,03	0,03	0,02	0,03	0,02	0,04	0,16	0,02	0,05
Maize flour	8,66	0,36	1,08	0,28	0,17	0,19	0,41	0,36	0,35	0,07	0,45	0,37	0,23	0,7
Bitamin	14,3	0,67	1,24	0,58	0,23	0,21	0,71	0,46	0,52	0,18	0,71	0,95	0,31	0,84
Nutrimix	8,13	0,4	1,2	0,27	0,19	0,16	0,49	0,4	0,34	0,09	0,51	0,44	0,23	0,67

Source: “author’s own visualisation”, adapted from (Harper 1981)

The main weakness of the scoring procedure is that it does not take into account the digestibility and bioavailability of amino acids in the human body. The World Health Organisation (WHO) suggests three methods to predict the protein quality in food: protein digestibility, which is the fraction of food protein absorbed, biological value, which emphasises the effectiveness of utilisation of absorbed dietary nitrogen and finally the amino score to compare the limited amino acids in a diet. (WHO 2007, 94-96) These three methods must be applied to evaluate the protein quality in food.

Another unexpected result lies with the high value of zinc found in almost every recipe, implying that zinc is not deficient in West African complementary foods. The high values observed can be explained through the use of unrefined cereals, as refining lowers the zinc bioavailability. On the other hand, unprocessed cereals are very high in phytates and fibre which limit the absorption and utilisation of zinc in human cells. (Cakmak, et al. 1996, 165) Therefore a high value of zinc in cereals does not emphasise the amount absorbed in the blood as zinc is very sensitive to inhibitors, such as phytates and it is recommended to rather use red meat as a zinc source in diets.

The introduction of Moringa oleifera is achieved in six different recipes low in energy and micronutrients. A similar pattern of results are found amongst these recipes. The results, using the maximum nutritional values of Moringa oleifera, demonstrate that the powder cannot be used to increase the energy values. However the protein value can be raised up to 75%.

Using maize flour as an example, the amino acids values can be analysed with and without the leaf powder, showing that the essential amino acids in maize flour increase overall at a supplementation of 10 and 20%. This increase varies from 0.5 to 0.11g at a supplementation of 10% of the maximum value, depending on the amino acids.

Table 18: Amino acids composition of maize flour with the addition of Moringa oleifera

	Protein (g)	Isoleucin (g)	Leucin (g)	Lysin (g)	Methionin (g)	Cystein (g)	Phenylalanin (g)	Tyrosin (g)	Threonin (g)	Tryptophan (g)	Valin (g)	Arginin (g)	Histidin (g)
Maize flour	13,26	0,71	1,68	0,85	0,33	0,34	0,64	0,61	0,67	0,21	0,85	0,26	0,16
Maize flour+10% Mo max	15,38	0,79	1,82	0,96	0,35	0,37	0,76	0,79	0,77	0,27	0,96	0,39	0,21
Maize flour+10% Mo min	14,39	0,76	1,78	0,91	0,35	0,34	0,71	0,66	0,72	0,24	0,93	0,35	0,19
Maize flour+20% Mo max	17,5	0,87	1,96	1,07	0,38	0,39	0,87	0,98	0,86	0,32	1,06	0,53	0,26
Maize flour+20% Mo min	15,53	0,82	1,89	0,97	0,36	0,34	0,79	0,72	0,77	0,27	1	0,45	0,22

The results confirm that Moringa oleifera not only increases the protein value but also the essential amino acids value. However due to the reason that no exact standards of amino acid requirements of infants between 6 to 12 months are found, these cannot be compared to daily requirements.

In terms of vitamins, it is observed that vitamin A and B2 values are subsequently increasing at the different levels of the Moringa oleifera powder. For instance, all recipes at an enrichment of 10% cover the vitamin A daily required amount of 600µg and for vitamin B2 a supplementation of only 5% is enough to meet the daily demand. Still, the values of vitamin C are perceived to have an increase of only 1 to 2 mg depending on the recipes, thus the daily required amount cannot be covered, suggesting that the leaves must not be used as a vitamin C source.

The values of minerals including calcium, magnesium, iron, zinc and phosphor all increase with the supplementation of Moringa oleifera. Due to the significant change between the maximum and minimum values of calcium and iron discovered in the leaves, the results of these two differ significantly.

The daily required amount of calcium is met at a supplementation of 10% of the leaves maximum values, although at the minimum value at 20% indicates more is needed to meet the daily demand of 400mg and iron too suffers from these same issue. For instance, a percentage of 15 to 20% Moringa oleifera leaves maximum value are needed to cover the demands of 8mg per day, though at the minimum value, only Bitamin, Micaf and Misola meet the required amount. The analysis therefore suggests that depending on the mineral value in the leaves, an exact statement of the augmentation of micronutrients is impossible.

WHO defines the tolerable upper intake levels (ULs) for micronutrients, as an evaluation of the highest level of daily nutrient intake that poses no risk of adverse health effects to an individual. (Nestel, et al. 2003, 320) Micronutrients such as vitamin B1 and B2 have no toxicity because of either renal clearance or limited intestinal absorption. It is observed that the daily prophylactic doses of vitamin A should not exceed 900 µg per day. Yet through the supplementation of Moringa oleifera leaves, some recipes including Bitamin or Micaf surpass this amount. Therefore an analysis of the specific flour must be completed before an addition of Moringa oleifera.

Vitamin C, calcium, magnesium and zinc have daily upper limits of 1g, 3g, 65mg, and 23 to 28mg respectively. It must be emphasised that the D-A-CH daily required amount of magnesium is 60mg, which suggest that the upper limit is only 5mg more. Most of the porridges with or without the addition exceed the magnesium UL given by the WHO and further investigations must be carried out to conclude if this figure of 65mg/day is significant for an infant between 6 to 12 months. (Nestel, et al. 2003, 320)

Another limitation of the WHO source is the lack of information on the iron upper limit dose, with the reason being that further analysis is yet to be undertaken. Using another source, it is illustrated that iron's upper limit intake is around 40mg per day (Institute of Medicine, Food and Nutrition Board 2001, 290) which is important to acknowledge as iron fortification in complementary food is widely used.

Four main hypotheses are emphasised at the start of the thesis and a final evaluation can be accomplished using the given analysis:

- ✓ Hypothesis 1: Low nutritional valued weaning foods are the cause of under-nutrition in West Africa.

The analyses illustrate the difference between traditional and commercial foods given in West Africa. All traditional foods have an energy density between 0.2 and 0.5kcal/g. In order to meet the daily requirements between 0.7 and 1kcal/g, a daily feeding practice of more than 5 times per day must be employed.

The daily energy is found to be lower than 700kcal in every traditional recipe analysed and a low micronutrients level is observed. Regardless, the protein demands in 3 recipes are covered. On the other hand, three out of five commercial foods meet the daily intake and protein requirement is sufficient in all recipes. Essential micronutrients such as iron, calcium, vitamin A, and vitamin C are all lower than the daily required intake. These results suggest that protein malnutrition is not a dietary problem in Africa. However, energy intake inadequacy and micronutrients deficiency may be the cause of under-nutrition.

The hypothesis cannot be verified as some evaluation of complementary foods, such as Bitamin emphasise that there are high nutritional valued weaning foods in Africa. However a falsification is also not achievable as most of the foods analysed are low in energy and micronutrients.

- ✓ Hypothesis 2: Moringa oleifera is a solution to fight under-nutrition in West Africa.

The results of the present study emphasise that Moringa oleifera nutritional values differ according to the leaves, countries and analytical methods used. Therefore the analyses concerning the supplementation of the leaves in weaning foods vary extremely.

Overall, it can be observed that the leaves can be used to increase the protein values and specific micronutrients such as vitamin A, B2, B6 and theoretically iron and calcium at a maximum value. However a consideration must be noted that Moringa oleifera does not provide energy and is low in vitamin C.

Malnutrition in West Africa is either caused by inadequacy of energy or insufficient protein amount linked to micronutrients deficiency. The results illustrate that the leaves can be used as an addition to a protein, vitamin A, B2 and calcium source, however if a food is low in energy, other supplements which are far more dense in energy may be added, such as palm oil.

Iron is also found in low amounts in all complementary foods. A lack of sufficient iron can delay the development of the central nervous system and may result in morphological or bioenergetics alterations. (Beard 2008) An increase of iron is achieved in almost every recipe with the addition of Moringa oleifera at its maximum value. However at the minimum value, coverage of the daily amount is not achieved. It must also be considered that the iron found in Moringa is non-heme, hence iron may not be absorbed efficiently by the body, which may lower iron intake in the blood.

The lack of fruits and vegetables in all complementary foods emphasise the lack of vitamin C and this low value cannot be increased with the addition of Moringa powder. Both vitamin C and iron must be increased with an addition of fruit and meat respectively, thus indicating financial implication for West Africans wishing to add fruit and meat into their diets.

Moringa oleifera is therefore a considerable option to increase protein levels and various other nutrients. However it is not the only supplementation needed to increase the overall nutritional values in West African weaning foods. A combination of the leaves, fruits, animal sources and energy dense foods, such as oil may be necessary to cover all requirements in West African complementary foods.

- ✓ <u>Hypothesis 3:</u> Moringa oleifera is not unhealthy to infants.

Toxicity and high anti-nutritional factors are not found in high amounts in Moringa oleifera. However, due to the scarcity of studies concerning the toxicity of Moringa oleifera no specific conclusions can be made. The considerable amount of saponins and phytate may affect the overall quality of the food including a bitter taste, but this does not determine if it is unhealthy for the infant. Further studies are needed to evaluate the anti-nutritional effect in combination with other food such as cereals or legumes. Using the results found the third hypothesis can be verified, although further studies may be needed.

The study identifies a number of limitations, such as the energy requirement values and the limited factors surrounding the supplementation of Moringa oleifera. The daily energy requirements used in this analysis are taken from the DGE. These demands are summarised from the broadly observed estimations of dietary intake of healthy children in developed countries and comprises an additional five percent for possible methodological bias. (DGE 2001)

The values therefore might be higher than the expected requirement for infants in developing countries and may show a falsified inadequacy of nutrients. In practice these recommendations and estimations may not be covered daily but a weekly requirement is sufficient. (DGE 2001)

Other limitations are the use of assumptions to analyse an infant’s daily requirements. As an infant’s feeding practice consists of breast milk and complementary food, a single analysis of complementary food cannot be done, as values are not given. Therefore an estimation of breast milk intake is carried out to estimate the daily overall intake. However the amount and nutritional values differ according to an individual, feeding habits of the mothers and the environmental factors. Thus, the values found are estimations and may fluctuate.

The main issue of supplementing Moringa oleifera powder in porridges is in the change of viscosity. Theoretically the amount of water used in the recipes remains constant and thus the dry mass ratio increases and a rise in viscosity is likely. Therefore a further practical study is necessary to evaluate the viscosity with the addition of Moringa oleifera powder at different levels. The results will demonstrate the effect Moringa oleifera has on viscosity and the amount of water necessary to keep the viscosity constant. However, increasing the water content will result in a reduced energy density. This has already been identified as an issue in West African foods.

The sensory changes with the supplementation of Moringa oleifera must also be studied, as the only study found, made by ITRA, shows a significant decrease of feeding intake with the enrichment of Moringa. Therefore a further analysis must be established with both children and mothers living in West Africa to evaluate the levels of acceptance.

The last consideration is the absence of micronutrient bioavailability evaluation and nutrient interaction in the recipes and leaves. Phytate is found in low amounts at 21g/kg in the leaves and is known to reduce the bioavailability of iron and zinc. Nonetheless further studies must be achieved to evaluate the exact effect. Interaction between iron and vitamin C or the negative effect of calcium on iron must also be observed in such studies. (Higdon 2006)

Through the various complementary foods analysis, it can be reviewed that the future steps which must be taken, are mainly to increase diet diversity and decrease the viscosity to raise the overall energy density of porridges.

A new technological procedure introduces the enzyme, amylase, in cereals based food. This increases the proportion of water to dry mass and decrease the overall viscosity.

Amylase can be added separately or through germination. Mosha and Svanberg describe that germination can be used to reduce the viscosity. Their studies describe that germinated cereals contain active amylolytic enzymes which degrade the starch. (Mosha and Svanberg 1983) If added separately, amylase can be added to a cooked mixture, however must first be dissolved in sugar, as this enzyme is insoluble in water. A study made in Burkina Faso illustrates that the proportion of dry mass compared to water must be two or three times higher than the usual ratio. (Laurent and Sawadogo 2002) This resulted porridge is higher in energy density and has a consistent viscosity due to the breakdown of the starch polysaccharides. Still, the use of more flour also implies that more infant flours must be bought. This however may not be possible due to financial reasons.

These two approaches might have limitations, such as the concerns about microbiological safety of foods treated with amylase or the high risk of bacterial contamination in the germination procedure, (Ashworth and Draper 1992, 35) yet regardless of this we are a step forward to enhance high energy dense foods.

8 Conclusion

It is challenging to meet all nutrient requirements using home based foods (Allen and Gillespie 2001), therefore an optimisation and evaluation is necessary to increase the general quality.

Using the recipes provided, the results demonstrate that most of the weaning foods analysed could not supply adequate energy and were low in most of the essential micronutrients such as vitamin A, C, iron, and calcium. On the other hand, the protein and zinc contents studied appear to be adequate.

The best complementary food analysed is Bitamin which is a combination of millet, bean, peanut and baobab fruit. Bitamin provides high energy, protein and a source of several micronutrients, yet low in iron and vitamin C.

The worst three complementary foods found in terms of dietary quality are cassava roots, Nutrimix and Ouando, therefore it is advisable to not use staple foods as a single source of a diet. Concerns surrounding two of the commercial foods highlight that due to their low proportion of dry mass, further enquiries must be provided from the manufacturer to increase the low ratio. The results therefore validate that West African weaning foods are nutritionally poor, albeit that some commercial foods are proven to meet the overall dietary quality. Further enquiries are required to investigate the variation of price and accessibility of both commercial and traditional foods.

Globally, this study confirms that the implementation of Moringa oleifera is positively correlated with the overall dietary quality of West African weaning foods. However, three key problems are still present: inadequate energy intake, iron and vitamin C deficiency. Through further exploration, such as the incorporation of energy dense food or technological procedures as germination and fermentation, the overall energy intake has the potential to be increased.

The incorporation of animal food is important to increase the overall iron and zinc levels. Vitamin C amounts can be steadily increased with regular breast milk intake, however the results of the analyses emphasise that an intake of fruits may be necessary to meet the daily required amount of 55mg which will also increase the bioavailability of iron.

The challenge is therefore to educate mothers in this area and to provide financial aid and accessibility. It can be concluded that Moringa oleifera is a good source of important nutrients and might be a first step in improving the dietary quality of West African weaning food, though not the single solution.

Future examinations must be completed to explore the bioavailability of Moringa oleifera nutrients and assess the overall efficiency and effectiveness in order to improve the content and bioavailability of micronutrients in complementary foods.

Abstract

Under-nutrition is the cause of more than one third of mortality amongst infants in the sub-Sahara. Inadequate energy, protein malnutrition and micronutrients deficiency in complementary foods are the main causes of under-nutrition. Many researches are conducted to improve the overall dietary quality of weaning foods in Africa to reduce the high mortality rate. A plant called Moringa oleifera is described as ‘the new wonder’ due to its high nutritional values. However, there is a lack of relevant studies in how this can combat under-nutrition.

The overall aim of this study is therefore to conduct an analysis investigating West African weaning food nutritional values and effects of the Moringa oleifera plant leaves.

The nutritional properties of infant weaning foods developed in West Africa were investigated, this included four traditional and five commercial flours. The results illustrated that most flours are low in energy, vitamin A, vitamin C, iron and calcium. The flours were then combined with the maximum and minimum nutritional values found in the Moringa oleifera leaves at specific ratios of: 5, 10, 15 and 20%. The results of the nutritional properties divulge a significant increase of all nutrients, especially vitamin A and B2. However, energy, vitamin C and iron were still lower than the daily requirements of 700kcal, 55mg and 8mg respectively.

This study revealed that fortification with Moringa oleifera at different levels improved the nutritional quality of West African weaning foods. Further research must be accomplished to examine physical and sensory properties of Moringa oleifera.

Zusammenfassung

Unterernährung ist die Ursache für ein Drittel der Säuglingssterblichkeit in Afrika südlich der Sahara. Säuglingsbeikost in Westafrika hat oft einen geringen Energiegehalt und weist einen Mangel an relevanten Mikronährstoffen auf. Viele Versuche, wie die Einführung von Sojaprodukten, werden durchgeführt, um die Qualität von Säuglingsbeikost in Afrika zu verbessern und die hohe Säuglingssterblichkeit zu reduzieren. Eine Pflanze namens Moringa oleifera wird aufgrund des hohen Nährwertes als neues Wunder beschrieben, jedoch gibt es noch nicht genügend wissenschaftliche Untersuchungen dazu.

Ziel dieser Studie ist es daher, zunächst eine Analyse der Nährwerte von westafrikanischer Säuglingsbeikost durchzuführen und dann die mögliche positive ernährungsphysiologische Wirkung von Moringa oleifera nachzuweisen.

Vier traditionelle und fünf kommerzielle Säuglingsbeikostprodukte wurden zunächst auf ihre ernährungsphysiologischen Eigenschaften untersucht. Die dargestellten Ergebnisse zeigen, daß die meisten Produkte einen geringen Energie-, Eisen- und Kalziumgehalt haben sowie arm an Vitamin A und C sind. Die Beikostprodukte wurden dann in bestimmten Verhältnissen mit Moringa oleifera Pulver angereichert (5, 10, 15, 20%). Die Ergebnisse zeigen eine deutliche Steigerung aller Nährstoffe in den untersuchten Produkten, auch wenn die Energiezufuhr, Vitamin C und der Eisengehalt noch unter dem empfohlenen Tagesbedarf von jeweils 700kcal, 55mg und 8mg liegen.

Die Studie ergab, daß Moringa oleifera die Qualität der westafrikanischen Säuglingsbeikost deutlich verbessert. Dennoch sind weitere Forschungen notwendig, um physikalische und sensorische Eigenschaften der Moringa oleifera Pflanze zu untersuchen.

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Statutory declaration

I hereby confirm that I am the author of the thesis presented. I have written the thesis as applied for previously unassisted by others, using only the sources and references stated in the text.

Kristina Kayi Kouevi

Annex

Annex I: Traditional recipes formulations

			Moringa oleifera supplementation (%)			
Simple Porridges (in g)	Dry Mass	Amount per day	5%	10%	15%	20%
Fermented Maize	14	70	3,5	7	10,5	14
Cassava Flour	16	80	4	8	12	16
Fermented Millet	14	70	3,5	7	10,5	14
Fermented Sorghum	14	70	3,5	7	10,5	14
Total Mass per recipe(in mL)	100	500				

	Normal Porridge	5% Moringa	10% Moringa	15% Moringa	20% Moringa
Fermented Sorghum	70	70	70	70	70
Moringa	0	3,5	7	10,5	14
Water	430	430	430	430	430
Total	500	503,5	507	510,5	514

	Normal Porridge	5% Moringa	10% Moringa	15% Moringa	20% Moringa
Cassava root	80	80	80	80	80
Moringa	0	4	8	12	16
Water	420	420	420	420	420
Total	500	504	508	512	516

	Normal Porridge	5% Moringa	10% Moringa	15% Moringa	20% Moringa
Fermented Millet	70	70	70	70	70
Moringa	0	3,5	7	10,5	14
Water	430	430	430	430	430
Total	500	503,5	507	510,5	514

	Normal Porridge	5% Moringa	10% Moringa	15% Moringa	20% Moringa
Fermented Sorghum	70	70	70	70	70
Moringa	0	3,5	7	10,5	14
Water	430	430	430	430	430
Total	500	503,5	507	510,5	514

Annex II: Commercial recipes formulations

	Nutrimix		Moringa 5%	Moringa10%	Moringa15%	Moringa20%
	%	g	g	g	g	g
Rice	11	5,5	5,5	5,5	5,5	5,5
Maize	63	31,5	31,5	31,5	31,5	31,5
Soya	26	13	13	13	13	13
Moringa			2,5	5	7,5	10
Water		450	450	450	450	450
Total	100	500	502,5	505,0	507,5	510,0

	Misola			Moringa 5%	Moringa 10%	Moringa 15%	Moringa 20%
	%	g	g	g	g	g	g
Millet	60	12	60	60	60	60	60
Soya	20	4	20	20	20	20	20
Peanuts	10	2	10	10	10	10	10
Sugar	9	1,8	9	9	9	9	9
Salt	1	0,2	1	1	1	1	1
Moringa			0	5	10	15	20
Water		80	400	400	400	400	400
Total	100	100	500	505	510	515	520

	Ouando		Moringa 5%	Moringa 10%	Moringa15%	Moringa20%
	%	g	g	g	g	g
Maize	33	16,5	16,5	16,5	16,5	16,5
Sorghum	33	16,5	16,5	16,5	16,5	16,5
Soya	23	11,5	11,5	11,5	11,5	11,5
Sugar	11	5,5	5,5	5,5	5,5	5,5
Moringa			2,5	5	7,5	10
Water		450	450	450	450	450
Total	100	500	502,5	505,0	507,5	510,0

	Micaf			Moringa 5%	Moringa10%	Moringa15%	Moringa20%
	%	g	g	g	g	g	g
Maize	40	8	40	40	40	40	40
Wheat	40	8	40	40	40	40	40
Soya	20	4	20	20	20	20	20
Moringa				5	10	15	20
Water		80	400	400	400	400	400
Total	100	100	500	505	510	515	520

	Bitamin			Moringa 5%	Moringa 10%	Moringa15%	Moringa20%
	%	g					
Millet	67	13,4	67	67	67	67	67
Beans	20	4	20	20	20	20	20
Peanuts	10	2	10	10	10	10	10
Baobab fruit	3	0,6	3	3	3	3	3
Moringa				5	10	15	20
Water		80	400	400	400	400	400
Total	100	100	500	505	510	515	520

Annex III: Nutritional values of specific ingredients used

a. Macronutrients

	Energy(kcal)	Water (g)	Protein (g)	Fat (g)	Carbohydr. (g)	Fibre (g)
Baobab fruit	341,3	10,7	2,7	0,7	76,7	6,8
Beans	344,65	9,94	38,2	18,27	6,29	21,96
Cassava root	137,43	62,8	1	0,23	32,07	2,9
Maize flour	329,59	11,65	8,66	2,82	66,29	9,42
Millet flour	342,73	13,3	5,8	1,7	74,85	2
Peanuts	615,44	1,56	26,94	52,95	9,29	7,58
Rice	351,1	11,66	7,36	0,62	77,73	2,1
Sorghum flour	367,83	10,1	7,9	3,3	77,4	6,6
Soya beans	232,31	14,2	47	1,22	7,5	24,5
Wheat flour	304,73	12,09	11,44	1,83	59,55	13,26

b. Micronutrients

Micronutrients	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Vit. E (mg)	Ca (mg)	Mg (mg)	Na(mg)	Fe (mg)	Zn(mg)	P (mg)	S (mg)	K (mg)	Cu(mg)	Mn(mg)	I (µg)
Baobab fruit	0	0	0	0	0	0	251	61	96	8,4	3	80	0	2010	0,7	0	0
Beans	63	1,03	0,46	1	34,25	0,64	200	220	5	6,61	4,19	550	137	1800	1,2	2,7	6,3
Cassava root	5	0,06	0,03	0,2	30	0	32	65	1	1,17	0,55	38	15	344	0,16	0,62	2
Maize flour	50	0,44	0,13	0,06	0	1,11	18	47	1	2,4	2,5	256	60	120	0,18	0,28	2,5
Millet flour	0	0,25	0,19	0,6	0	0,04	40	150	2	6	1	260	130	370	0,7	1,5	2
Peanuts	0	0,27	0,02	0,5	0	8	62	285	18	2,34	3,7	458	395	841	0,7	1,78	0,5
Rice	0	0,06	0,03	0,15	0	0,1	6	32	4	0,93	1,44	110	78	112	0,22	0,99	1,9
Sorghum flour	0	0	0	0,34	0	0	10	124	4	3,4	2	297	0	387	0,26	1,26	0
Soya beans	4	0,69	0,25	0,57	0	0,04	241	300	20	9,24	2,46	674	250	2400	2	3	0,8
Wheat flour	3	0,46	0,09	0,27	0	1	33	97	8	3,18	2,56	342	140	380	0,37	3,1	6,7

Annex IV: Results of Bitamin, Misola and Micaf

	Energie (kcal)	Eiweiß (g)	Vit. A (µg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B6 (mg)	Vit. C (mg)	Calcium (mg)	Magnesium (mg)	Eisen (mg)	Zink (mg)	Phosphor (mg)
Bitamin + 5% Mo MAX	786,9	23,02	584,5	0,65	1,49	0,8	31,72	449,5	226,7	9,31	4,13	466,85
Bitamin + 5% Mo MIN	776,33	22,31	584,5	0,65	1,49	0,8	31,72	339	217,4	6,96	3,92	432,2
Bitamin + 10% Mo MAX	804,68	24,53	742	0,78	2,51	0,88	32,58	632	254,4	12,19	5,41	511,7
Bitamin + 10% Mo MIN	783,53	23,12	742	0,78	2,51	0,88	32,58	411	235,8	7,5	4,98	442,4
Bitamin + 15% Mo MAX	822,47	26,04	899,5	0,92	3,54	0,97	33,45	814,5	282,1	15,07	6,68	556,55
Bitamin + 15% Mo MIN	790,74	23,92	899,5	0,92	3,54	0,97	33,45	483	254,2	8,04	6,05	452,6
Bitamin + 20% Mo MAX	840,25	27,56	1057	1,05	4,56	1,05	34,31	997	309,8	17,95	7,96	601,4
Bitamin + 20% Mo MIN	797,94	24,73	1057	1,05	4,56	1,05	34,31	555	272,6	8,58	7,11	462,8
	Energie (kcal)	**Eiweiß (g)**	**Vit. A (µg)**	**Vit. B1 (mg)**	**Vit. B2 (mg)**	**Vit. B6 (mg)**	**Vit. C (mg)**	**Calcium (mg)**	**Magnesium (mg)**	**Eisen (mg)**	**Zink (mg)**	**Phosphor (mg)**
Micaf + 5% Mo MAX	716,63	26,16	593,5	0,75	1,4	0,39	24,86	437,5	169,7	7,56	4,68	508,85
Micaf + 5% Mo MIN	706,06	25,45	593,5	0,75	1,4	0,39	24,86	327	160,4	5,22	4,47	474,2
Micaf + 10% Mo MAX	734,42	27,67	751	0,88	2,43	0,48	25,73	620	197,4	10,44	5,95	553,7
Micaf + 10% Mo MIN	713,26	26,26	751	0,88	2,43	0,48	25,73	399	178,8	5,75	5,53	484,4
Micaf + 15% Mo MAX	752,2	29,19	908,5	1,01	3,45	0,56	26,59	802,5	225,1	13,32	7,23	598,55
Micaf + 15% Mo MIN	720,47	27,07	908,5	1,01	3,45	0,56	26,59	471	197,2	6,29	6,59	494,6
Micaf + 20% Mo MAX	769,98	30,7	1066	1,14	4,48	0,65	27,46	985	252,8	16,2	8,5	643,4
Micaf + 20% Mo MIN	727,68	27,87	1066	1,14	4,48	0,65	27,46	543	215,6	6,83	7,66	504,8
	Energie (kcal)	**Eiweiß (g)**	**Vit. A (µg)**	**Vit. B1 (mg)**	**Vit. B2 (mg)**	**Vit. B6 (mg)**	**Vit. C (mg)**	**Calcium (mg)**	**Magnesium (mg)**	**Eisen (mg)**	**Zink (mg)**	**Phosphor (mg)**
Misola + 5% Mo MAX	766,59	24,29	572,5	0,57	1,43	0,67	24,86	449,5	231,7	9,19	3,63	472,85
Misola + 5% Mo MIN	756,01	23,58	572,5	0,57	1,43	0,67	24,86	339	222,4	6,85	3,42	438,2
Misola + 10% Mo MAX	784,37	25,8	730	0,7	2,46	0,75	25,73	632	259,4	12,07	4,9	517,7
Misola + 10% Mo MIN	763,22	24,39	730	0,7	2,46	0,75	25,73	411	240,8	7,38	4,48	448,4
Misola + 15% Mo MAX	802,15	27,32	887,5	0,83	3,48	0,84	26,59	814,5	287,1	14,95	6,18	562,55
Misola + 15% Mo MIN	770,42	25,2	887,5	0,83	3,48	0,84	26,59	483	259,2	7,92	5,54	458,6
Misola + 20% Mo MAX	819,93	28,83	1045	0,96	4,51	0,92	27,46	997	314,8	17,83	7,45	607,4
Misola + 20% Mo MIN	777,63	26	1045	0,96	4,51	0,92	27,46	555	277,6	8,46	6,61	468,8