University of Abomey-Calavi

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Faculty of Agronomic Sciences

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Nutrition, Food Science and Technologies School

Research thesis submitted in partial fulfilment of the requirements for obtaining the degree of Master

Major: *Agro-Food Sciences and Technologies*

TOPIC: Formulation of infant foods fortified with baobab (*Adansonia digitata*) fruit pulp and/or moringa (*Moringa oleifera)* leaf powder for under-five-years old children in Benin

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Academic year: 2016-2017

Université d'Abomey-Calavi

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Faculté des Sciences Agronomiques

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Ecole de Nutrition des Sciences et Technologies Alimentaires (ENSTA)

***Mémoire pour l'Obtention de Master en* Sciences Agronomiques**

Spécialité: *Sciences et Technologies Agricoles et Alimentaires*

THEME: Formulation d'aliments fortifiés avec de la pulpe de fruit de baobab (*Adansonia digitata)* et/ou de la poudre de feuilles de moringa (*Moringa oleifera*) pour les enfants de moins de cinq ans au Bénin

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Année Académique: 2016-2017

CERTIFICATION

We, thereby, certify that this study entitled "Formulation of infant foods fortified with baobab (*Adansonia digitata*) fruit pulp and/or moringa (*Moringa oleifera)* leaf powder for under-five-years old children in Benin" was carried out by Marius AFFONFERE, Master student of the Faculty of Agronomic Sciences (FSA) as partial fulfilment of the requirements for obtaining the degree of Master, Major Agro-Food Sciences and Technologies.

Supervisor	**Co-Supervisor**
Professor Paulin AZOKPOTA	**Dr. Ir. Flora Josiane CHADARE**
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DEDICATION

- To my mother **KOUNKOUN Odjoti** and my father **AFFONFERE Kotchikpa Philippe** who supported me since my childhood and gave me the opportunity to become who I am today.
- To all undernourished children.

"I hope that one day, inequality of food supply in the world will end and a solution to fight under-nutrition in Africa will be initiated", **Kayi Kristina Kouevi**

ACKNOWLEDGEMENTS

→ To my God, the almighty for giving me life and health to carry out this research;

→ To the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) through the Competitive Grants System. Thanks for providing us a financial support through the Graduate Research Grant No. RU 2015 GRG125, locally named BARINGA, for conducting our master research.

→ I'm very grateful to the full professor Paulin AZOKPOTA for supervising this work despite his busy schedule.

→ I'm highly grateful to my co-supervisor Dr. Ir. Flora Josiane CHADARE for showing me how wonderful food science is, what lead me to my current path. Thanks for giving me the opportunity to perform my MSc research under this project. Your patience, your availability and advice are well appreciated;

→ I can't forget Dr. Ir. Yann Emeric MADODE for his wonderful advice especially for laboratory analyses.

→ I would also like to extend my gratitude to the other researchers who worked under the BARINGA project, namely Dr. Ir. Eunice NAGO-KOUKOUBOU, Dr. Saturnin HOUNDJI and Dr. Ir. Ismaël MOUMOUNI, for their permanent support.

I would also like to express my gratitude to:

→ all the survey team members, especially Kévin FASSINOU, Bérénice TANDJI, Olivia EGUE and Edmond SACLA. You have been helpful to reach efficient data collection;

→ Julienne AGOSSADOU and Axel SOMESSI for the nice work atmosphere we shared;

→ Dr. Ir. Valère SALAKO, Nadejda BARO and Jean-Eudes DEKPEMADOHA for statistical analyses;

→ local populations of surveyed areas, especially the under five years old children as well as the local authorities for their collaboration;

→ the laboratory technicians, Mathias HOUSSOU, *MSc* and Christin SOGBOSSI, *MSc*

→ Colette, Laure, Hermine, Irène, Elisabeth and Christophe AFFONFERE for their patience and courage, tomorrow will be better. Be brave and keep going!

→ all my Food Science and Nutrition Master classmates from cohort 4 especially Linérolle Sêtondji Grâce FASSINOU;

→ all those who contributed one way or another to this research. May the Lord bless you all.

ABBREVIATIONS

ANOVA	:	Analysis of Variance
BARINGA	:	BAobab moRINGA
BFP	:	Baobab Fruit pulp
DFE	:	Dietary Folate Equivalents
EAR	:	Estimate Average Requirement
FAO	:	Food and Agriculture Organization
FSA	:	Faculty of Agronomic Sciences
GRG	:	Graduate Research Grant
FDD	:	Focus Group Discussion
ICP-AES	:	Inductively Coupled Plasma–Optical Emission Spectrometer
ID	:	Iron Deficiency
IVS	:	In Vitro Solubility
LSA	:	Laboratory of Food Sciences
MMN	:	Multi Micro Nutrient
WHO	:	World Health Organisation
PFMo	:	Moringa leaf powder
RDI	:	Recommended Daily Intakes
RAE	:	Retinol Activity Equivalents
RE	:	Retinol Equivalents
RUFORUM	:	Regional Universities Forum for Capacity Building in Agriculture
UAC	:	University of Abomey-Calavi
WU	:	Wageningen University

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Abstract

Malnutrition is one of the most serious problems throughout the world and children are especially vulnerable to it. The aim of this research is to formulate foods fortified with baobab fruit pulp and moringa leaf powder for under-five-years old children. Specifically, the research aimed at: (i) mapping the local food matrices candidate for food formulation and (ii) designing food-to-food fortification formula using baobab fruit pulp and moringa leaf powder. The mapping was performed using literature review and field survey. Food matrices were selected based on consumption frequencies and three fortification formula were proposed. There were sorghum porridge dual fortified with moringa leaf powder (PFMo) and baobab fruit pulp, maize porridge fortified with PFMo and *Cochlospermum tinctorim* root powder sauce (koata sauce) fortified with PFMo. A digestibility study and acceptability tests were respectively performed using (Kiers *et al.*, 2000) method and the facial expression of children. Results indicate that moringa leaf powder and baobab fruit pulp are traditionally used in infant diet in Benin with a consumption frequency varying significantly from one biogeographical zone to another ($p<0.05$). Fortification increases significantly ($p<0.05$) calcium (445.1±14mg/100 g dry weight to 4561.3±92.4mg/100 g dry weight) and iron (26.4±2.1 mg/100 g dry weight to 101.2±1.5 mg/100 g dry weight) content for maize porridge. For sorghum porridge, a significant increase ($p<0.05$) was observed for calcium (43.6±1.9 mg/100 g dry weight to 3454.5±86.4 mg/100 g dry weight), iron (7.3±0.2mg/100 g dry weight to 88.4±1.2mg/100 g dry weight) and zinc (88.2±3.8 mg/100 g dry weight to 202.4±3.1mg/100 g dry weight) content. As far as koata sauce is concerned, a significant increase was noticed only for iron content (85.7±0.4 mg/100 g dry weight to 91.2±0.5 mg/100 g dry weight). Furthermore, there is a significant difference between fortified and unfortified sorghum porridge and between fortified and unfortified koata sauce in term of calcium, iron and zinc In Vitro Solubility (IVS) ($p<0.05$). For fortified and unfortified maize porridge, no significant difference was observed in term of calcium and iron IVS ($p>0.05$) but a significant difference was observed for zinc IVS ($p<0.05$). The acceptability test indicates that sorghum porridge dual fortified with moringa leaf powder and baobab fruit pulp (fortification rate, 17.0 %, dry weight) and koata sauce fortified with moringa leaf powder (fortification rate, 12.3 %, dry weight) were the most accepted.

Keywords: Fortification, baobab fruit pulp, moringa leaf powder, In-vitro digestibility.

Résumé

La malnutrition est l'un des problèmes les plus sérieux dans le monde et les enfants sont particulièrement vulnérables. Le but de cette étude est de formuler des aliments fortifiés avec la pulpe de fruit de baobab et la poudre de feuilles de moringa pour les enfants de moins de cinq (05) ans. Plus spécifiquement, cette étude vise à (i) identifier les véhicules alimentaires candidats pour la formulation et (ii) développer des formules de fortification avec la pulpe du fruit de baobab et la poudre de feuilles de moringa comme fortifiants. Pour le recensement des véhicules alimentaires, une revue de littérature et une enquête ont été faites. Les véhicules alimentaires sont ensuite sélectionnés sur la base de leur fréquence de consommation. Trois formules ont été proposées. Il s'agit de la bouillie de maïs fortifiée avec la poudre de feuilles de moringa, la bouillie de sorgho fortifiée avec la poudre de feuilles de moringa et la pulpe de fruit de baobab et la sauce de poudre des racines de *Cochlospermum tinctorium* (sauce koata) fortifiée avec la poudre de feuilles de moringa. L'étude de la digestibilité a été faite en utilisant la méthode de (Kiers *et al.*, 2000). Le test d'acceptabilité des formules a été effectué en utilisant l'expression faciale des enfants. Les résultats indiquent que la poudre de feuilles de moringa et la pulpe du fruit de baobab sont utilisées dans l'alimentation des enfants de moins de cinq ans avec une fréquence de consommation variant significativement d'une zone biogéographique à une autre ($p<0,05$). La fortification augmente significativement ($p<0,05$) la teneur en calcium (445,1±14 mg/100 g base sèche à 4561,3±92,4 mg/100 g base sèche) et en fer (26,4±2,1 mg/100 g base sèche à 101,2±1,5 mg/100 g base sèche) de la bouillie de maïs. Pour la bouillie de sorgho, une augmentation significative ($p<0,05$) a été observée pour les teneurs en calcium (43,6±1,9 mg/100 g base sèche à 3454,5±86,4 mg/100 g base sèche), en fer (7,3±0.2 mg/100 g base sèche à 88,4±1,2 mg/100 g base sèche) et en zinc (88,2±3,8 mg/100 g base sèche à 202,4±3,1 mg/100 g base sèche). En ce qui concerne la sauce koata, une augmentation significative ($p<0,05$) n'est observée que pour la teneur en fer (85,7±0,4 mg/100 g base sèche à 91,2±0,5 mg/100 g base sèche). En considérant, les Solubilités In-Vitro (IVS) de fer, de zinc et de calcium, il y a une différence significative entre la bouillie de sorgho et la sauce koata fortifiées et non fortifiées ($p<0,05$). Aucune différence significative n'est observée entre la bouillie de maïs fortifiée et non fortifiée en terme des IVS de calcium et de fer ($p>0,05$) tandis qu'une différence est observée pour le zinc ($p<0,05$). Le test d'acceptabilité indique que la bouillie de sorgho fortifiée avec la poudre de feuilles de moringa et la pulpe de fruit de baobab (taux de fortification 17,0 %, base sèche) et la sauce koata fortifiée avec la poudre de feuilles de moringa (taux de fortification 12,3 %, base sèche) sont les plus acceptées.

Mots clés : fortification, pulpe de baobab, poudre de feuilles de moringa, digestibilité in-vitro

INTRODUCTION

1. Introduction

1.1. Rationale

Vitamins and minerals are essential micronutrients for human growth and well-being. Worldwide, more than 2 billion people are deficient in key vitamins and minerals, especially vitamin A, iodine, iron and zinc (Das et al., 2013). Among them, young children are highly vulnerable because of their rapid growth occurring while subject of inadequate dietary practices (De-Regil et al., 2011). Micronutrient malnutrition is widely spread not only in industrialized countries, but even more in the developing countries (FAO/OMS, 2006). Alleviation of these nutritional concerns can be achieved efficiently through food fortification, one of the most cost-effective strategies to deliver micronutrients to large populations (Bhagwat et al., 2014). Food fortification has the advantage of enabling nutrients delivery to large segments of the population without requiring radical changes in food consumption patterns (FAO/OMS, 2006). However, in areas with high micronutrient deficiency rates and high levels of poverty, the use of fortification formula from chemical ingredients is difficult and poorly sustainable, particularly in the developing countries. Therefore, a food-to-food fortification could be an alternative in countries where highly nutritious food ingredients are available and accepted as foods. In this perspective, the BARINGA project entitled ‘’ *Food-to-food fortification with baobab fruit pulp and moringa leaf powder as a pathway to improve food and nutrition security among women and children in Benin, West Africa*’’ was funded by Regional Universities Forum for Capacity Building in Agriculture (Ruforum) through Graduate Research Grant (GRG). This research focused on the development of food-to-food fortification formula with high micronutrient bioavailability for under five years old children. In this context, nutrient rich local food resources such as moringa (*Moringa oleifera)* leaves and baobab (*Adansonia digitata*) pulp are good candidates to be used as food fortificants. Moringa leaves are known to be efficient to alleviate malnutrition, especially among infants and nursing mothers. *Moringa oleifera* quantitatively provides more nutrients per gram than many other plant species (Rockwood et al., 2013). Its leaves can be eaten fresh, cooked or stored as dried powder for many months without nutritional losses (Hopkins et al., 2005). Moringa leaf powder contains up to 28 mg/100 g iron, 8000 µg/100g vitamin A and 26% of digestible protein (Moringa Association of Ghana, 2010). *Moringa oleifera* leaf powder (per 100 g) is rich in calcium (1443.90 ± 11.03 mg), magnesium (176.72 ± 0.73 mg), iron (53.75 ± 5.07 mg), zinc (17.58 ± 0.89 mg) and β-carotene (624.40 ± 0.41 µg ER) (Kayalto et al., 2013). As far as baobab is concerned, 100 g of baobab fruit pulp dry weight contains on average 1.1-10.4 mg of iron, 390-700.9 mg of calcium, up to 350 mg of vitamin C and 1.7 mg of zinc (Chadare et al., 2009). Baobab fruit pulp contains all of the essentials amino acid (Diop et al., 2005). Past trials worldwide revealed the health benefits of food fortification with moringa leaf powder or baobab fruit pulp. A daily consumption of 10 g of moringa leaf powder for 6 months induced a reduction of stunting among under-five-years old children (Houndji, 2013). Well-known African food products were previously used as food vehicles in successful food-to-food fortification. For instance, moringa leaf powder fortified maize-ogi, baobab fruit pulp fortified yoghurt (Abdullahi et al., 2014) and baobab fruit pulp fortified maize ogi (Adejuyitan et al., 2012, Salem et al., 2013, Abdullahi et al., 2014, Abioye et Aka., 2015) improved essential micronutrient (calcium, iron zinc, vitamin A and protein contents) composition of fortified foods. Nevertheless, high nutrient content does not mean much if bioavailability is low (Hambidge, 2010, Schonfeldt et al; 2016). Therefore, the current research intends to assess iron, calcium and zinc bioaccessibility in food-to-food fortified formula with moringa leaf powder and/or baobab fruit pulp. Moreover, several studies investigated the contribution of moringa as food fortificant to nutritional status improving. However, these studies did not necessarily focus neither on the food habits of the population nor on the use of traditional foods as food vehicles when children feeding is concerned. Considering the aforementioned thoughts, the following research question arose:

- What are the traditional infant food matrices using moringa leaf powder and baobab fruit pulp in the three biogeographical zones of Benin?
- What is the adequate food-to-food fortification formula using moringa leaf powder and baobab fruit pulp to alleviate micronutrients deficiencies for under-five-years old children?
- How bio-accessible are micronutrients in the fortified formula?

The present study aimed at filling these gaps.

1.2. Research objectives

The present research aimed at providing adequate baobab fruit pulp and/or moringa leaf powder fortified food formula to alleviate micronutrient deficiencies among under-five years old children. Specifically, it aimed at:

- **(i)** mapping the local food matrices using moringa leaf powder and baobab fruit pulp as ingredients and
- **(ii)** designing food-to-food fortification formula using baobab fruit pulp and moringa leaf powder for under-five years old children.

LITERATURE REVIEW

2. Literature review

2.1. Food fortification

Food fortification is defined as a practice of deliberately increasing the content of essential micronutrients in a food to improve the nutritional quality of the food supply and to provide the public health benefit with minimal risk to health (Dary et Hainsworth, 2008). We have the classical food fortification (using chemical fortificants) and food-to-food fortification (using food fortificants).

2.1.1. Classical food fortification

Some foods are used for classical food fortification. We have the classical food fortification using a micronutrient and the Multi Micro Nutrient (MMN) classical food fortification. For the classical food fortification using a micronutrient, we have : fish sauce, wheat flour and maize meal, soy sauce, rice, cereals flour, margarine, milk and food usually consumed as dietary item in the population either in a raw or cooked form which are used as food vehicles. For multi micronutrient fortification we have: dairy products (such as natural low-fat cheese, lactose-reduced), yogurt, maize grain, wheat flour, soybean oil and milk. The classical food fortification with iron is more done because of the important of this micro nutrient and it deficiencies noted among population. Beinner et al., (2010) have reported that iron deficiency (ID) is estimated to affect 3.5 billion people, most of whom are young children and women of reproductive age living in developing countries. Iron is used in different form for classical food fortification. The forms that are used are: sodium iron ethylenediaminetetraacetate (NaFeEDTA), ferrous fumarate or ferrous sulfate, electrolytic iron and ferric pyrophosphate. Fortification levels are variable and in the fortified food a quantity of 5 mg to 20 mg are consumed per day. In the most of case, the significantly reduced of iron deficiency and iron-deficiency anaemia is observed. The classical food fortification with zinc is very remarkable in the case of flour and there is a recommended maximum level of zinc fortification. For the case of wheat flour this level is 100 mg zinc/kg wheat flour (Brown et al., 2010). Under this level of fortification, any significantly effect is not observed (Brown et al., 2009). The greater levels of fortification may adversely affect the sensory properties of food items prepared with such flour but studies suggest that there are no disadvantages of the recommended ranges of zinc fortification with regard to the sensory properties of zinc-fortified foods, and there are no adverse effects of zinc fortification on the utilization of other minerals (Brown et al., 2010). Also, some technological operation such as fermentation of flour affects the zinc fortification level (Brown et al., 2009, Brown et al., 2010,). We can therefore note that the fortification level can be influenced by the fortification process due to the bioavailability of the nutrient in the fortificant. For the specific case of zinc, FAO/OMS, (2006) noticed that, the bioavailability of zinc is dependent on dietary composition, in particular, on the proportion of high-phytate foods in the diet.

Products are also fortified with vitamin A with consumption of 27 g of vitamin A food fortified per day and 60 g vitamin A food fortified 5 days/week (Solon et al., 2000, FAO/OMS, 2006). It is likely that vitamin A fortification as a strategy to improve vitamin A intake will be most efficacious if many different food fortified are consumed with modest amounts of vitamin A (Solon et al., 2000). In general, it is advised that the amount of vitamin A supplied through fortification meets at least 15% of the Recommended Daily Intakes (RDIs) for the target group and this amount divided by the daily ration determines the minimum level of fortification estimated at the household level (Dary et Mora, 2002). Food fortification is also done with Multiple Micronutrient (MMN). Some micronutrients are used together: calcium and vitamin D, iron and vitamin A, multiple micronutrients Iron, folic acid, zinc, vitamin A, iodine, vitamin D and calcium, iron and vitamin D, thiamine, niacin, vitamin B6, folic acid and iron. These programs of multi-micronutrient fortification are important because according to FAO/OMS, (2006), micronutrient deficiencies are common in several parts of the world, in certain population group and are more likely to coexist in individuals who consume diets that are poor in nutritional quality, or who have higher nutrient requirements. Multiple micronutrient fortification appears more benefit because multilple micro nutrient deficiencies coexist in many cases. In addition to treating and preventing some micronutrients deficiencies, fortification affords a good opportunity to control other micronutrient deficiencies that are likely to coexist in many populations. These considerations justify why many programs of fortification are oriented on multimicronutrient fortification and then, vehicles must be chosen adequately for a good acceptability of the food fortified by the target groups.

2.1.2. Food-to-food fortification

2.1.2.1. Why food-to-food fortification?

Food fortification is a process which includes: the selection of micronutrients, the selection of food vehicles, deciding on the levels of fortification and selection of delivery channels (Bhagwat et al., 2014). Likewise, food fortification is done to deliver micronutrients for large segments of the population without requiring radical changes in food consumption patterns

(FAO/OMS, 2006). Thus, food fortification must provide for the target population foods which are accessible considering the fortification techniques and the price of the fortificants. But classical food fortification, although it provides micronutrients for population, presents some limits, only the synthetic nutrients are used. These synthetic micro nutrients are not always available especially in the developing regions. Yet, micronutrient malnutrition (MNM) is even more widespread in these developing regions (FAO/OMS, 2006). It is then important to find techniques using food fortificants with high accessibility (financial accessibility and physical accessibility). In this way, the food-to-food fortification uses foods that are available in the targeted area. Moreover, Food-to-Food fortification can be done using low-cost technologies at household level.

2.1.2.2.Food-to-food fortification techniques

Several local food resources such as leaves (moringa), fruit (pawpaw, mango, plantain), seed (seeds of *Citrullus lanatus*), leguminous (soybean) and even edible (mushroom) are used as fortificants to fortify some poor foods like gari, tapioca, wheat flour bread. Whatever the type of the fortificant, it used to fulfill a nutritional gap, but also the sensory, biological and physical gaps. The nutrients that are generally improved by food-to-food fortification are essentially: proteins, phosphorus, iron, zinc, potassium, fat, manganese, vitamin C, fiber, energy, sodium, calcium, and carbohydrates. The acceptable rate of fortification formula varies considerably between 1 to 50 % according to the compatibility between fortificants and the food vehicles. This fortification rate is not the same when we consider the same fortificant and different food vehicles. Indeed, Nadeem et al., (2012) found that cheese fortified with dry leaves of *Moringa oleifera* was acceptable up to 2 %. This same dry leaves of *Moringa oleifera* can be used up to 3 % to formulate fortified butter milk with increase of nutritional value. In these two cases, despite the low rate of substitution, the products tended to have the color (appearance) greener. Abioye and Aka, (2015) have used dry moringa leaves until 15 % of substitution but the food fortified is maize-ogi. Thus, the substitution rate considering the same fortificant varies according to the food vehicles. It is then important to take into account the physical property of the fortificants in the fortification process because when the color of the fortified food changes more it will affect the acceptability of the fortified foods. It is why sensorial evaluation is done after laboratory food fortified formulation in order to know the acceptability level of the food fortified. However, ogi produced from sorghum after fortifying with pawpaw fruit at substitution levels of 0, 20, 40, 60, 80 allows noticing that blend with 40% pawpaw and beyond was acceptable with improving the nutritive value of ogi without affecting the sensory quality (Ajanaku et al., 2010). According to Sankhon et al., (2013), the sensory evaluation indicated that 5%, 10% and 15% parkia flour bread was the most acceptable bread. The substitution rate of 15% of the wheat flour by the mushroom powder to produce bread was also acceptable in terms of sensorial and physical properties with increase of nutritional value (Okafor et al., 2012). Although these rates of fortification are high respectively 40%, 5%, 10%, 15%, the sensory properties are not affected.

The substitution rate of 20% of the wheat flour by the seeds of *Citrullus lanatus*, was acceptable in terms of sensorial and physical properties with improvement of nutritional qualities but the carbohydrate content in fortified bread is low than the one content in bread made by 100% of wheat flour. Ogi produced from maize fortified with baobab fruit pulp was found to be acceptable up to 50% with also a decrease of protein, crude fibre, fat and carbohydrate (Adejuyitan et al., 2012). It is appear obvious that, fortification carries away the loss of certain nutrients in the basic food (vehicle) and improves others. Therefore, the aim of the fortification must be clear before starting fortification. So, it is important to know correctly the nutrient that we want to improve by food fortification. That will allow choosing the more appropriate fortificant considering the food habit of the target population and the most appropriate techniques for fortification. The choose of the basic food (vehicle) must share some or all of the following characteristics: vehicle must be consumed by a large proportion of the population, including (or especially) the population groups at greatest risk of deficiency, they must be consumed on a regular basis in adequate and relatively consistent amounts, they can be centrally processed , they allow a nutrient premix to be added relatively easily using low-cost technology and in such a way so as to ensure an even distribution within batches of the product (FAO/OMS, 2006).

In the food-to-food fortification process, some agent can be added to the food fortified to improve it sensory properties (Lelana et al., 2003) and prevent some reaction as mallard reaction (Adenuga, 2010). The step where fortificant is adding to the food vehicle has also an impact on the physical properties of the fortified food. That is the case of gari fortified with soybean flour where soybean flour is adding to the gari before and after toasting (Oluwamukomi et Jolayemi, 2012).

It can be concluded that not only the food-to-food fortification has some advantages (relative to nutritional, sensory, biological and physical property) but also it presents some limits. The sensory quality (color) and physical property (relative volumetric expansion) are partially affected sometimes due to the incompatibility between the fortificant and the food vehicle, the rate of substitution and the step where fortificant is added. Sometimes, the food-to-food fortification can make decreasing the nutrients contents (carbohydrate, protein, crude, fiber and fat) of the basic food.

In the special case of food-to-food fortification with moringa leaf powder, the color is an important sensorial quality that we have to control. The natural green color of moringa leaf powder stretches to change the color of the food fortified that can cause the unacceptability of this food (Nadeem et al., 2012, Salem et al., 2013, Abioye and Aka, 2015) . For the food-to-food fortification not only, the nutritional improvement of the fortified food must be our objective but also the acceptability of the food fortified. Thus, the fortification rate must be chosen with precaution (it must take into account the sensorial aspects). Food can be fortified with two foods (dual food-to-food fortification). Sweet potato based infant weaning food is fortified by cowpea and peanut (with in specific ratios sweet potato: 60, 65, 70%; cowpea: 25, 15, 15% and peanut 15, 25, 15%) (Adenuga, 2010). Tapioca is fortified by Acerola (*Malpighia emarginata*) and mango fruit pulp or soy extract (de Brito et al., 2007). This approach of food-to-food fortification allows having a food fortified with high nutritional quality. In this case, the substitution rate constitutes a very important challenge in order to assure the acceptability of the food fortified. Furthermore, after fortification, an important aspect to be considered is the bioavailability of the nutrient but food-to-food fortification can increase the bioavailability of nutrients (Abdullahi et al., 2014). For example, *Adansonia digitata* fruit pulp increased the bioavailability of nutrients, minerals and volatile metabolite with medicinal properties when it used to fortified yoghurt (Abdullahi et al., 2014).

2.2.Description of the food fortificants: *Adansonia digitata* and *Moringa oleifera*

2.2.1. Baobab (*Adansonia digitata)*

Adansonia digitata L. belongs to the Bombacaceae family (Diop et al., 2005, Cissé, 2012). As far as phylogenetic classification concern, this tree belongs to the Malvaceae family (Kébenzikato et al., 2015). African baobab is very long-lived trees: some trees are over 1000 years old (Chadare, 2010). According to Cissé (2012), *Adansonia* digitata has a massive size, reaching to a height of 30 m while Kébenzikato and al, (2015) reported that the African baobab tree size is between 18-25 m. This very big tree is clearly distinguishable from the other Adansonia species endemic in Madagascar and Australia, mainly by its very large trunk (up to 10 m in diameter)(Diop et al., 2005, Chadare, 2010). Cissé (2012) has reported that this diameter can vary from 2 to 10 m.

Leaves: Leaves are 2-3 foliates at the start of the season, early deciduous; more nature ones are 5-7(9) foliates (Chadare, 2010) and can reach up to 20 cm in diameter (Diop et al., 2005). Leaves are alternate, long-stalked (8-16 cm), digitately compound, 5 or 9 leaflets (5-16 x 2-6 cm), 13-20 pairs of secondary veins, in whole or denticulate blade (Kébenzikato et al., 2015). The leaves contain up to 15 % of protein, 70 % of glucid, 16 % of fiber and 10 % of lipid as far as concern dry matter (Cissé, 2012). According to Chadare, (2010), leaves are rich in good quality proteins, vitamin A. It also rich in minerals especially in calcium, potassium, magnesium, iron (Diop et al., 2005). The youngest can be consumed as vegetables, but they are often dried and then reduced into powder (Diop et al., 2005, Chadare, 2010,).

Flowers: The flowers of the African baobab are large (10 to 20 cm of length), white, pendulous, solitaire or paired in leaf axils, and hermaphrodite (Chadare, 2010, Kébenzikato et al., 2015). According to Diop and al, (2005), the flower diameter is from 8 to 20 cm. Flowers possess numerous white stamens (700 to 1600) and an ovary of 5 to 10 stalls (Diop et al., 2005, Kébenzikato et al., 2015). The plant phenology depends on the rains profile, flowering and foliation occurring during the rainy season (Diop et al., 2005, Kébenzikato et al., 2015). The flowering time varies greatly; in West Africa, flowering period is from May to June (Chadare, 2010). Pollination is done by bats (Diop et al., 2005,Chadare, 2010, , Kébenzikato et al., 2015). The tree can also be propagated by seeding or vegetative multiplication (Diop et al., 2005).

Fruit: The fruit develops 5-6 months after flowering and tend to fall from the late rainy season onwards (Chadare, 2010). The shape of fruit can be subspheric, globular or ovoid and it length is between l7.5 and 54 cm (Kébenzikato et al., 2015) while Diop and al, (2005) and Cissé (2012) found that the fruit measure [(7 à 20) cm × (7 à 54) cm]. The shell of the fruit (pericarp), which thickness is from 0.5 to 1 cm, is hard, brownish-green or yellowish-gray and filled with a whitish pulp pale-pink (Kébenzikato et al., 2015). It consists of 14 to 28 % of pulp with a low moisture content, acidic, starchy, rich in vitamin C, in calcium and magnesium (Diop et al., 2005).

Pulp: Baobab fruit pulp is a powdery product. Its extraction is achieved by dry or wet manual operations. After breaking the fruit, the whole content of the pulp (consisting of pulp, fibers and seeds) is crushed using mortar and pestle; the crushed product is sieved to separate pulp from seeds and fibers (Chadare, 2010). The pulp contained in the capsule is obtained after pounding and sieving the content of the capsule (Cissé, 2012). After separating of the seeds, the pulp is traditionally used as an ingredient in various preparations or to make beverages (Diop et al., 2005). According to Diop and al, (2005), African baobab pulp is characterized by its low water content, usually close to 15% while Chadare, (2010) reported the average of water content to be 11.6%. The protein content is about 1.5 $g \cdot 100\ g^{-1}$ (Diop et al., 2005). The pulp is relatively rich in fiber (with an average of 7 $g \cdot 100\ g^{-1}$) in minerals (Diop et al., 2005) and vitamin C (Chadare, 2010).

Seeds: Seeds are reniform and embedded in the pulp, dark brown to reddish black with a smooth testa (Chadare, 2010). Their shape are round, oval or irregular (Kébenzikato et al., 2015) and their size are variable (10-13x 8-10x 4-5mm) (Cissé, 2012). The average weight of the seed is 2 to 3g,with 200-300 seeds /Kg (Cissé, 2012). For Diop et al, (2005), the seed represents about 60 % of the weight of fruit without cockle. The protein content is high and contains all the essential amino acids apart from the lysine which is limited (Diop et al., 2005). The seed contains palmitic acid, oleic acid and oleic acid was reported to be in high quantity (Chadare, 2010). In spite of some deficiency in lysine and the presence of some anti-nutritional factors, the seeds are an interesting protein source (Diop et al., 2005).

Kernel: The kernel is obtained after seed decortication and it is rich in fat (Chadare, 2010).

2.2.2. Moringa *(Moringa oleifera)*

Moringa oleifera, tropical tree, belongs to the Moringaceae family, order of Capparidacées and this family of Moringaceae has only one genus (Moringa), which includes 14 species native to the West and the sub-Himalayan region, India, Pakistan, Asia Minor, Africa and Arabia (Houndji, 2013). According to Luqman et al, (2011), *Moringa oleifera* (Lam.) commonly known as “The Miracle Tree,” “Horseradish-tree,” or “Ben oil tree” is the best known and most widely distributed species of Moringaceae family and it has an impressive range of medicinal uses with high nutritional value throughout the world. Regarding human micronutrient and macronutrient needs, *Moringa oleifera* quantitatively provides more nutrients per gram of plant material than many other plant species (Rockwood et al., 2013). Luqman et al, (2011) have also reported that Organizations such as Trees for Life, Church World Service and Educational Concerns for Hunger Organization have advocated Moringa as “Natural Nutrition for the Tropics”. In various parts of the world and almost every part of this highly esteemed tree have long been consumed by humans and used for various domestic purposes (animal forage, biogas, fertilizer, sugar cane juice clarifier, ornamental plantings, pulp, water purification, machine lubrication...etc). It is reported that in Benin and more especially in the south part, the *Moringa oleifera* is consumed regularly by the pregnant women to warn anemia (Houndji, 2013). Moringa trees have been used to combat malnutrition, especially among infants and nursing mothers and the leaves can be eaten fresh, cooked, or stored as dried powder for many months without refrigeration and without loss of nutritional value (Hopkins et al., 2005). Also, Moringa is especially promising as a food source in the tropics because the tree is in full leaf at the end of the dry season when other foods are typically scarce (Hopkins et al., 2005). Moringa is an important food source for people, especially in rural areas and it is consumed in various African countries (Ghana, Senegal, Malawi), Latin America (Nicaragua, Bolivia) and even New Zealand (Zongo et al., 2013). The leaves of *Moringa oleifera* have been reported to be a valuable source of both macro and micronutrients, rich source of β -carotene, protein, vitamin C, calcium, and potassium and act as a good source of natural antioxidants; and thus enhance the shelf-life of fat containing foods. The fruit (pod)/drum sticks and leaves have been used to combat malnutrition, especially among infants and nursing mothers (Luqman et al., 2012). Houndji (2013) has reported the different parts of *Moringa oleifera* (Lam.) with some characteristics.

Plant: The height of the tree can reach between 12 and 15 meters, but usually it does not exceed 10 meters. Its growth is impressive, up to 8 meters in the first year. Its top is clear and spread parasol. It is resistant to drought and it has a general trunk, it reaches 1.5 to 2 meters high before branching; these branches are pending, and intertwined, the canopy is shaped umbrella. Despite the fact that the wood is very tender and virtually useless in carpentry, it is popular firewood in savannah regions.

Leaves: Leaves separated into two or three leaflets are arranged in spiral and are developed mainly in the end portion of the branch and measure 20 to 70 centimeters length. Flow diagram for processing moringa leaf powder is presented in figure 1. According to de Saint Sauveur et Broin (2010), 100 grams of *Moringa oleifera* leaf powder per day cover about 30% of the recommended daily intake for children between 1-3 years, about 25% of the recommended daily intake for children between 4-9 years old and for adult women and about 15% of the recommended daily intake for adolescents and women over 55 years for calcium. As iron is concerned, 100 grams of *Moringa oleifera* leaf powder per day cover about 30% of the recommended daily intake for children between 1-12 years, 15% of the recommended daily intake for adolescents, 20% of the recommended daily intake for adult men and women over 55 years, 12% of the recommended daily intake for adult women and 7% of the recommended daily intake for pregnant women.

Flowers: The flowers are white or cream, with yellow dots to the base. Sepals, five in number, are symmetrical with the exception of lower petal. There are 10 stamens including 5 with anthers. The ovary is superior and unilocular.

Fruits: The fruits are clove trilobal, measuring 20 to 60 centimeters long and hanging branches. They open into three parts when drying. In rural areas, the number of seeds varies between 12 and 35 per pod. Fruits contain a series of winged seeds which characterize their three wing-shaped expansions.

Seeds: The seeds are round, with a semi-permeable brown shell. A tree can produce 15 000 to 25 000 seeds per year; a seed weights in average 0.3 gram.

Roots: Roots form tubers with strong smell and taste of radish. *Moringa oleifera* is not a leguminous plant and the presence of the tree would bring a recovery of phosphorus from soil to surface horizons.

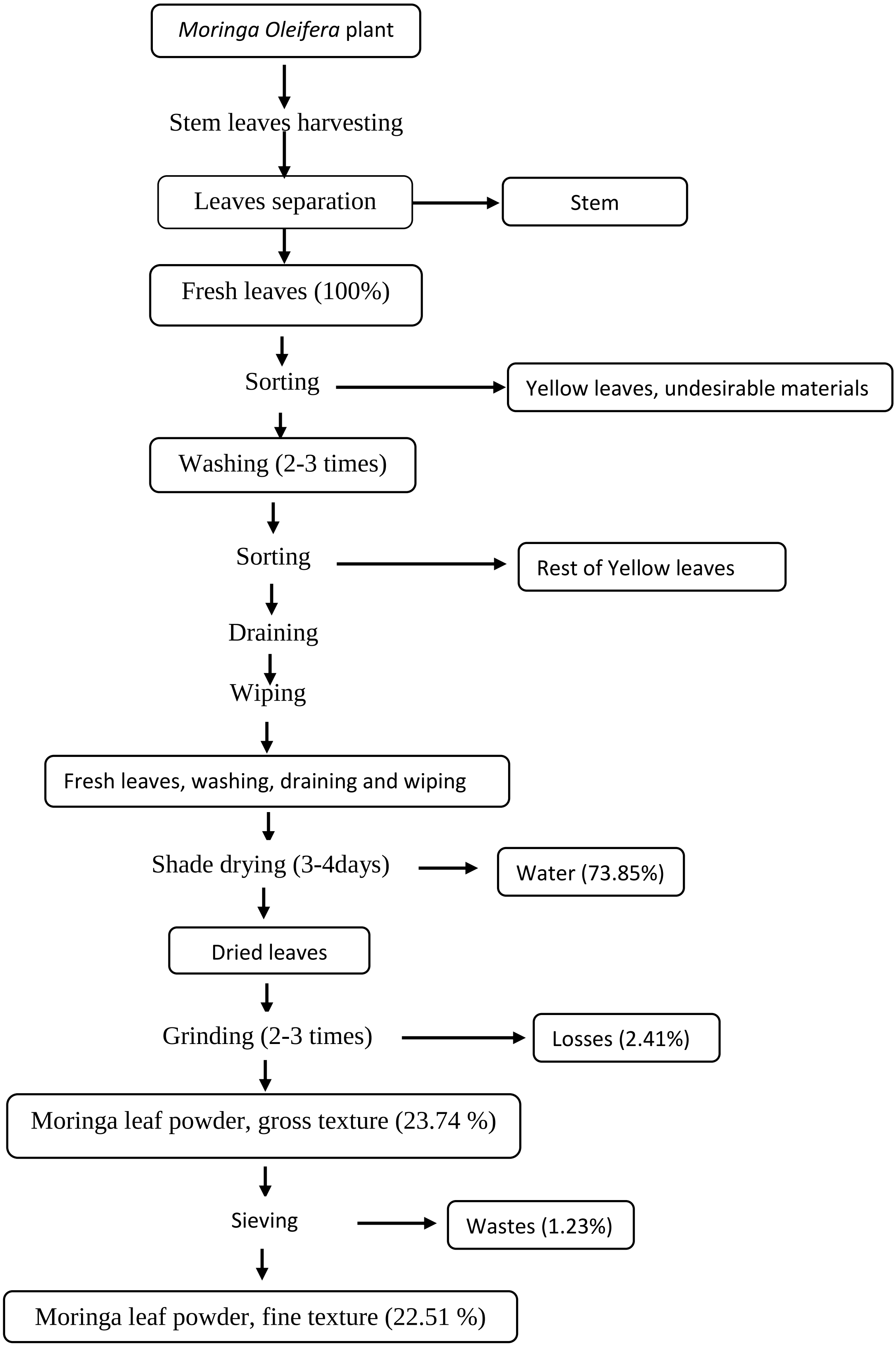

Figure 1: Flow diagram of *Moringa oleifera* leaf powder

Source: Houndji et al. 2013

2.3.Digestibility and bioavailability of minerals

Bioavailability is the technical term used to convey the fact that not 100% of nutrients ingested will be absorbed, irrespective of whether consumed in the form of food or supplements. Bioavailability aims to describe the effect of a sequence of metabolic events, including digestion, solubilization, absorption, organ uptake and release, enzymatic transformation, secretion and excretion, on nutrient utilization (Schonfeldt et al; 2016).

The supply of nutrients to the human body thus not only depends on the amount of the nutrient in a food, but also on its bioavailability. Understanding nutrient bioavailability helps to optimize diets and set appropriate nutrient recommendations. Furthermore, Gibson et al, (2006) reported that bioavailability can be defined as the proportion of an ingested trace element in food that is absorbed and utilized for normal metabolic and physiological functions or storage. Bioavailability aims to describe the effect of a sequence of metabolic events on nutrient utilization. The bioavailability of nutrients is highly variable and can be influenced by numerous factors. Different nutrients (including protein, iron and vitamin A), and the forms in which they exist in the ingested medium, will react in different ways to inhibitors and enhancers and the hosts nutritional status, all contributing to the complex variability of nutrient bioavailability (Schonfeldt et al; 2016). The bioavailability of a nutrient can be defined as its accessibility to normal metabolic and physiologic processes.

Diet-related factors in plant foods that affect bioavailability include: the chemical form of the nutrient in food and/or nature of the food matrix; interactions between nutrients and other organic components (e.g. phytate, polyphenols, dietary fibre, oxalic acid, protein, fat, ascorbic acid); pretreatment of food as a result of processing and/or preparation practices (Gibson and al; 2006). According to Schonfeldt et al; (2016) the bioavailability of nutrients is highly variable and can be influenced by numerous factors, including physiochemical properties such as chemical binding form; the matrix in which the nutrient is incorporated; the presence or absence of other food components that enhances or inhibits absorption; metabolization after absorption; host related factors (including state of health, genetic factors, age and lifestyle); as well as other individual factors. More specifically, they reported that, nutrients can interact with one another or with other dietary components (enhancers and/or inhibitors) at the site of absorption, resulting in either a change in bioavailability. Enhancers can act in different ways such as keeping a nutrient soluble or protecting it from interaction with inhibitors. For example, since carotenoids are fat-soluble, adding small quantities of fat or oil to meal (3 to 5g per meal) improves their bioavailability. Similarly, meat, fish and poultry, while containing highly bioavailable iron themselves, are also known to enhance the absorption of iron from other foods ingested at the same time. Although this ‘meat factor’ has yet to be identified, it has been suggested that muscle protein exerts an influence. Inhibitors, on the other hand, may reduce nutrient bioavailability by binding the nutrient in question into a form that is not recognized by the uptake systems on the surface of intestinal cells, rendering the nutrient insoluble and thus unavailable for absorption, or competing for the same uptake system. As an example, phytic acid is highly abundant in certain plant foods (e.g. pulses, whole-grain cereals, seeds, nuts) and strongly binds minerals such as calcium, iron and zinc in soluble or insoluble complexes that are unavailable for absorption.

Ways to reduce the phytic acid content of foods include fermentation (e.g. extensive leavening of whole meal bread dough) or the soaking and germination of pulses. The inhibitory effect of food constituents can also be used advantageously, as is done in the case of phytosterols. These natural compounds are extracted from certain plant foods and added in higher doses (about 2 g per portion) to various other foods (for example enriched spreads, fermented milk drinks) to lower the absorption of cholesterol.

In vitro methods have been used to estimate the bioavailability of Fe, Zn and Ca in plant foods. These methods are based on a two-stage simulated digestive process of the food or test meal, followed by determination of the dialysable Fe, Zn or Ca released. In general, the magnitude of the responses measured using these methods are not the same as those observed in human subjects, but some of these methods have been used to rank foods with respect to the effect of processing and preparation practices on mineral bioavailability. There are several methods used to study digestibility of micronutrients such as iron, zinc and calcium contained in the food. Between these methods, the methods of Kiers et al. (2000) and luten et al. (1996) appear as the best because, each of these methods can be used to determine all of these micronutrients (iron, zinc and calcium). There also simulate the human digestion conditions. Table 1 shows the digestibility and bioavailability assessment methods of minerals.

Table 1: Digestibility and bioavailability assessment methods of minerals

Micro-nutrients	Methods used				References
	Methods	**Description**	**Advantages**	**limits**	
Iron	**Kiers et al, 2000**	Digestibility was assessed after simulated gastro-intestinal enzymatic digestion.	-	-	(Chadare et al., 2014)
	Luten et al(1996)	This method simulates gastrointestinal digestion with suitable modifications. The dialyzable portion of the total mineral present in the sample represented the bioaccessible mineral.	-	-	(Hemalatha, 2006)
	Jacobs et Greenman (1969)	Iron has been extracted from 25 common foods under conditions resembling those prevailing in the stomach under physiological conditions. In most cases less than half the iron in the foods is released into solution. The soluble iron is mainly in ionizable form, except in the case of meat products and black pudding.	-	This method does not consider human intern pH important for iron solubility and ionisation	(Jacobs et Greenman, 1969)
	Miller et al. (1981)	The method involves simulated gastrointestinal digestion followed by measurement of soluble, low molecular weight iron. Mixtures of foods were homogenized and exposed to pepsin at pH=2. Dialysis was used to adjust the pH to intestinal	It eliminates the problems encountered when using centrifugation to	-	(Miller et al., 1981)

		levels and digestion was continued after the addition of pancreatin and bile salts. Iron from the digestion mixture which diffused across a 6 to 8000 molecular weight cut off semi permeable membrane was used as an indicator of available iron. Results were similar when intrinsic food iron or added extrinsic radio iron was measured.	separate soluble and insoluble components. It is rapid and inexpensive.		
	Narasinga Rao and Prabhavati	It is based on the liberation of the ionisable iron of foods after a pepsique digestion at pH = 1.35 and the adjustment of this at pH = 7.5.	The conditions chosen is similar to those met in the duodenum and in spindly intestine	-	(Dehah, 2004)
Zinc	**Isotope Techniques**	Minerals metabolic in a specific diet can be distinguished from the same minerals from other sources by using isotopic tracers, either radio or stable isotopes. The isotopes of zinc are of atomic mass 64, 65, 66, 67, 68, 69, 70 and 71. Zinc65 is a radio isotope with a half-life of 244	-	It exposes the subject to long durations of radiation	(Hemalatha, 2006)
	Luten et al (1996)	This method simulates gastrointestinal digestion with suitable modifications. The dialyzable portion of the total mineral present in the sample	-	-	(Hemalatha, 2006)

		represented the bioaccessible mineral			
	Kiers et al, 2000	Digestibility was assessed after simulated gastro-intestinal enzymatic digestion.	-	-	(Chadare et al., 2014)
	Plasma Appearance /Circulating zinc response	In this method, the appearance of an element in plasma after its oral ingestion is measured. The source should be highly concentrated and must be sufficient enough to create an observable plasma tolerance curve, i.e. plasma appearance must exceed disappearance over the period of absorption from the gut.	-	The disadvantage of this method is that it is not applicable to most food sources of trace elements	(Hemalatha, 2006)
Calcium	**Kiers et al, 2000**	Digestibility was assessed after simulated gastro-intestinal enzymatic digestion.	-	-	(Chadare et al., 2014)

2.4.Estimated Average Requirements for under-five years old children

An Estimated Average Requirement (EAR) is the average daily nutrient intake level estimated to meet the requirements of half of the healthy individuals in a group. EARs have not been established for vitamin K, pantothenic acid, biotin, choline, chromium, fluoride, manganese. Table 2 presents EARs for under five years old children.

Table 2: Estimated Average Requirements for under-five years old children

Nutrients	Children (6-12m)	Children (12-36 m)	Children (36-59m)
Fe (mg/d)	6.9	3	4.1
Zn (mg/d)	2.5	2.5	4
Ca (g/d)	NA	0.5	0.8
CHO (g/d)	1.0	100	100
Protein (g/Kg/d)	NA	0.87	0.76
Vitamin A (µg/d)[a]	NA	210	275
Vitamin C (mg/d)	NA	13	22
Vitamin D (µg/d)	NA	10	10
Vitamin E (mg/d) [b]	NA	5	6
Thiamin (mg/d)	NA	0.4	0.5
Riboflavin (mg/d)	NA	0.4	0.5
Niacin (mg/d) [c]	NA	5	6
Vitamin B_6 (mg/d)	NA	0.4	0.5
Folate (µg/d) [d]	NA	120	160
Vitamin B_{12}(µg/d)	NA	0.7	1.0
Copper (µg/d)	NA	260	340
Iodine (µg/d)	NA	65	65
Magnesium (mg/d)	NA	65	110
Molybdenum (µg/d)	NA	13	17
Phosphorus (mg/d)	NA	380	405
Selenium (µg/d)	NA	17	23

Source: Ross AC et al., (2011), **NA**: Not available, **d:** day, **m:** month

[a]As retinol activity equivalents (RAEs). 1 RAE= 1 µg retinol, 12 µg β-carotene, 24 µg α-carotene, or 24 µg β-cryptoxanthin. The RAE for dietary provitamin A carotenoids is two-fold greater than retinol equivalents (RE), whereas the RAE for preformed vitamin A is the same as RE.

[b]As α-Tocopherol includes *RRR*-α-tocopherol, the only form of α-tocopherol that occurs naturally in foods, and the *2R*-stereoisomeric forms of α-tocopherol (*RRR*-, *RSR*-, *RRS*-, and *RSS*-α-tocopherol) that occur in fortified foods and supplements. It does not include the *2S*-stereoisomeric forms of α-tocopherol (*SRR*-, *SSR*-, *SRS*-, and *SSS*-α-tocopherol), also found in fortified foods and supplements.

[c]As niacin equivalents (NE). 1 mg of niacin = 60 mg of tryptophan.

[d]As dietary folate equivalents (DFE). 1 DFE = 1 μg food folate = 0.6 μg of folic acid from fortified food or as a supplement consumed with food = 0.5 μg of a supplement taken on an empty stomach.

MATERIAL AND METHODS

3. Material and methods

3.1. Study area

Surveys were carried out in the Republic of Benin (West Africa), between 6° and 12°50 N and 1° and 3°40 E, in the three biogeographical zones (Sudanian, Sudano-Guinean and Guinean zones). In these areas various ethnic groups characterized by their culture and food habits were present. In each biogeographical zone, interviews were conducted in two municipalities and two villages per municipality considering the use of moringa leaf powder and/or baobab fruit pulp in the infant diet. The municipalities covered were: Dangbo and Zakpota in the guinean zone (southern Benin), Dassa-Zoume in the sudano-guinean zone (central Benin), Pèrèrè and Tanguieta in the sudanian zone (northem Benin).

3.2. Mapping of local foods using moringa leaf powder and baobab fruit pulp as ingredients

A literature review on staple foods used in infant feeding in Benin and a survey on local foods using moringa leaf powder and baobab fruit pulp as ingredients were performed to mapp local food matrices.

3.2.1. Literature review

Documentation available on the internet and in the libraries were used. The documents consulted are the MSc thesis reports, books and agricultural engineer thesis.

3.2.2. Surveys

Focus group discussions and structured interviews were conducted. The focus group discussions targeted mothers with at least a child aged 6-59 months or persons in charge of infant feeding. Data were collected using a checklist (Annex 1). Structured interviews were performed with experienced women and key persons. Data were collected using a structured questionnaire (Annex 2) and a consumption frequency questionnaire (Annex 3)

3.2.2.1. Sampling of informants

The informants were selected in the three biogeographical zones on voluntary basis.

→ **Sampling for focus group discussions**

Mothers of under-five years old children and grandmothers were selected in villages. In each village, two focus group discussions were performed. Group of discussion gathered 8 to 10 women which were selected among women with at least one under-five years old child on a voluntary basis.

→ **Sampling for food consumption frequency survey**

The number of children considered for the food consumption frequency survey in each municipality was determined using a spot check with 50 randomly selected under-five-years old children with the help of their mother (Annex 4). The spot check estimated the proportion of children who consume baobab fruit pulp and/or moringa leaf powder in the surveyed municipality. This proportion was used to compute the sample size (Ni) for each municipality, using the following formula, $\mathbf{Ni} = \frac{\mathbf{4Pi\,(1-Pi)}}{\mathbf{d^2}}$ (Dagnelie, 1998) with:

Ni: the total number of under five years old children to be considered for the survey;

Pi: the proportion of children who consume baobab fruit pulp and/or moringa leaf powder among 50 selected children;

d: the expected error margin which was fixed at 0.07.

→ **Sampling of key persons**

Five key persons from major institutions (CARDER, Nutritional Rehabilitation Centre, Social Promotion Centre) and experienced mothers were randomly selected per village on a voluntary basis.

3.2.2.2.Data collection

Data were collected on various aspects related to the food vehicles that use baobab fruit pulp and moringa leaf powder as ingredients in the three biogeographical zones of Benin.

- **Focus group discussions:** collected information focused on the different uses of moringa and baobab and the perceptions of the interviewees in infant feeding.
- **Food Consumption frequency survey**: this survey targeted the consumption frequency (number of day per week) of foods using moringa leaf and/or baobab fruit pulp as ingredients.
- **Resource person interviews**: the collected informations were related to the different uses of moringa leaf powder and baobab fruit pulp as food ingredients in infant feeding practices.

3.2.3 Selection of candidate food vehicles for formulation

The survey provided a large number of foods that use moringa or baobab fruit pulp as ingredients. Selection of a limited number of foods for this study was performed using their consumption frequencies as selection criteria. In fact, a score of consumption frequency was defined and computed (formula below) per food vehicle in each biogeographical zone.

$$\text{Score} = \text{average consumption frequency} \times \text{Number of children}$$

The two food vehicles which have the highest consumption frequency score per biogeographical zone were selected.

3.3. Formulation of infant food fortified with moringa leaf powder and baobab fruit pulp

Fortification assays were performed using the selected food vehicles. Moringa leaf powder and/or baobab fruit pulp were used as compulsory ingredients in the fortification formula. In the laboratory, fortification rates were defined according with the local population practices and those identified in the literature review (quantity of fortificant consumed per day).

3.3.1. Processing follow up and sampling of foods as produced in surveyed areas

A processing follow-up study was performed with three experienced women in Benin rural areas for each of the selected food vehicles per biogeographical zone. Sampling from these experienced women for each selected food vehicles per biogeographical zone was performed to take into account the variability within applied technologies from one processor to the other. The collected food vehicles were packed in plastic bags and kept at 4°C during transportation to the laboratory for analyses. The fortificants (moringa leaf powder and baobab fruit pulp) were bought from experienced distributors.

3.3.2. Formulation/fortification assays

Lab formulation/fortification assays were performed with two different porridges (fermented flour maize porridge and fermented sorghum ogi porridge) and one sauce (koata sauce). For 100g fermented farina maize porridge, 10g of moringa leaf powder was used as fortificant. For 100g koata sauce, 10g of moringa leaf powder was also used as fortificant. As far as fermented sorghum ogi porridge was concerned, a dual food-to-food fortification was performed. Indeed, 10g and 5g respectively of moringa leaf powder and baobab fruit pulp were added to 100 g of fermented sorghum ogi porridge.

3.3.3. Pretreatment of samples for laboratory analysis

Before laboratory analysis, samples were pretreated. Figure 2 shows the pretreatment plan of samples for laboratory analysis.

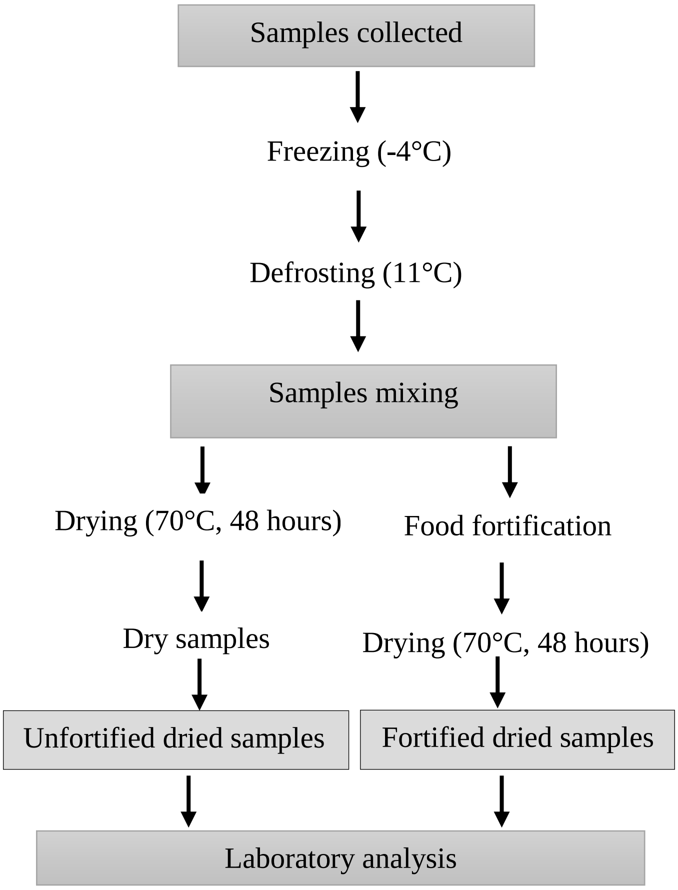

Figure 2: Pretreatment plan of samples for laboratory analysis.

3.3.4. In vitro digestion

Digestibility studies on food-to-food formula were performed using in-vitro digestion (with enzymes similar to those found in the human digestive system) at laboratory scale. The in-vitro-digestion (Kiers et al., 2000) was performed with minor modifications as reported by Chadare et al. (2014). Indeed, duplicate food-to-food formula (approximately 2 g) were suspended in 30 mL distilled water and were digested under simulated gastro-intestinal conditions with the use of artificial saliva containing human saliva α-amylase (A6948,0500), artificial gastric juice containing lipase (AY30), pepsin (A4289,0025), artificial pancreatic solution consisting of pancreatin (A0585,0100) and bile (Sigma B-3883-100G). In short, the mixture of food-to-food formula with water Erlenmeyer was kept in a 37°C water bath while shaking (about 400-500 rpm) for 5-10 min. 2 mL artificial saliva was added after 30 min of incubation while shaking, the Erlenmeyer was put on ice. pH was measured and adjusted to pH = 4 using 5M HCl. After about 5 min of incubation at 37°C in the water bath, 8 mL artificial gastric juice was added followed by 60 min incubation while shaking; the Erlenmeyer was afterwards put on ice; pH was noted and adjusted to pH 6 using 3M $NaHCO_3$; the samples were further incubated at 37°C for about 5 min and 10 mL pancreatic solution was added and they were incubated for 30 min while shaking. After digestion, the suspension was kept on ice and centrifuged for 40 min at 20,292 x g at 4°C (centrifuge –EBA21 Zentrifugen Heltich). The supernatant was recovered and the pellet was washed twice with 20 mL distilled water and centrifuged again. A blank consisting of 30 mL distilled water was digested and centrifuged as mentioned above. Supernatants were dried for determination of calcium, iron and zinc contents

3.3.5. Food samples analysis

Dry matter, calcium, iron and zinc contents were quantified. The analyses were performed in the Laboratory of Food Sciences (LSA) of University of Abomey-Calavi (UAC) in Benin and in the Laboratory of soil sciences of Wageningen University in the Netherlands.

3.3.5.1.Dry matter content

The dry matter of samples were measured by thermo-gravimetric method according to AOAC (1995). Samples (5 grams) were used for determination of dry matters by weighting in crucible and drying in oven at 105°C during 72 hours. The dry matter content was computed through formula below:

$$\boldsymbol{TMS} = \frac{\mathbf{P2 - P1}}{\mathbf{Pe}} \times \mathbf{100}$$

TMS: Dry matter content

P1: Crucible weight

P2: Weight (sample + crucible) after drying in oven at 105°C during 72 hours

Pe: Weight of sample

3.3.5.2.Mineral content and in vitro solubility (IVS)

Mineral content of samples was determined at the laboratory of soil sciences of Wageningen University (WU) using an inductively coupled plasma–optical emission spectrometer (ICP-AES) according to Temminghof (1997). The In vitro Solubility (IVS) was computed through the formula below:

$$\boldsymbol{In - vitro}\ \textbf{Solubility (IVS, \%)} = \frac{\textbf{(Fe , Ca or Zn in supernatant – Fe, Ca or Zn in blank)}}{\textbf{Fe, Ca or Zn in undigested sample}} \times \textbf{100}$$

3.3.6. Acceptability test

An acceptability test of the developed formula with variation of fortification rate for under-five-years old children was performed. Indeed, fifty (50) under-five years old children was randomly selected on voluntary basis (approval and consent of their mothers) and the facial expressions were recorded for children to appreciate the acceptability level of the fortified foods. Five (05) levels of facial expressions were used (Annexes 5, 6 and 7).

3.4. Data processing and statistical analysis

An access database of the information collected from the survey data were elaborated. Statistical analysis were performed with Minitab 14. A Chi square test was used to check for the difference between biogeographical zones of the consumption frequency of traditional foods using moringa leaf powder and baobab fruit pulp as ingredients. Analyses of variance followed by a Turkey test was performed to assess the difference between fortified and unfortified foods (fortification effect) in terms of micronutrient content and IVS. Acceptability test results were analysed using R software version 3.3.2. and the boxes width for appreciation scores were drafted.

RESULTS

4. Results

4.1. Food habits and infant feeding practices related to moringa leaf powder and baobab fruit pulp

Moringa leaf powder and baobab fruit pulp are used in the infant diet for food fortification in Benin. In the three biogeographical zones, the proportion of children consuming these resources is variable. Literature review revealed the main foods derived from staple foods in the three biogeographical zones of Benin (Table 3), though it was not clear which ones were traditionally fortified with baobab fruit pulp and/or moringa leaf powder for infant foods. The survey allowed identifying local infant food matrices that play such a role in the three biogeographical zones of Benin.

Thus, considering the sudanian (northern Benin) and the sudano-guinean (central Benin) zones, about 15 % of the food vehicles identified in the literature as derived from staple foods are consumed together with baobab fruit pulp. For the guinean zone (southern Benin), no food vehicle is identified using baobab fruit pulp as ingredient. Concerning combination with moringa leaf powder, about 30 % of the food vehicles identified in the literature as derived from staple foods are used both in northern and central zones of Benin against approximately 15 % in the southern zone. Some new food vehicles were identified through field survey in each biogeographical zone, two new food vehicles in guinean zone, five in the sudanian zone and five in the sudano-guinean zone. The difference between food vehicles identified in the literature as staple foods and those revealed by the survey as foods vehicles indicates that there is a preferential food vehicles for food combination with baobab fruit pulp and moringa leaf powder especially for infant foods.

Table 3 : Staple foods and vehicles consumed with baobab fruit pulp and moringa leaf powder

Biogeographical zones	Staple foods	Vehicles using baobab fruit pulp	Vehicles using moringa leaf powder	Synthesis
Guinean zone (southern Benin)	Maize paste, ''akassa'', cooked cassava, gari, tapioca, bean (cooked), maize flour, rice, maize flour porridge, cooked bean combined with gari and palm oil, peanut, ''atassi'' (rice+ bean) , djongoli (cooked bean+ roasted maize flour + palm oil)	-	Maize porridge, sorghum porridge, palm nut sauce; fresh tomato sauce	**15.4 %** of the vehicles identified in the literature are used for the fortification with moringa leaf powder. Two new vehicles are identified (sorghum porridge and fresh tomato sauce)
Sudano-guinean zone (central Benin)	Maize paste + sauce (fresh tomato, vegetables), paste of maize and cassava flour + sauce (fresh tomato, vegetables), Akassa, maize porridge, gari, rice, vegetables sauce	Maize porridge	Maize porridge; millet porridge ; soya porridge, sorghum porridge, sauce of ''goussi'', fresh tomato sauce, peanut sauce	**16.7%** of the vehicles identified in the literature used baobab fruit pulp as fortificant against **33.3%** for the fortification with moringa leaf powder. Fortification with moringa leaf powder revealed five new vehicles (millet porridge ; soya porridge, sorghum porridge, sauce of ''goussi'', peanut sauce)
Sudanian zone (northern Benin)	Pounded yam, wassa wassa (yam couscous), fried yam (chips of yam), maize porridge, sorghum porridge, rice, dried cassava, ''waché''(rice+ bean), sorghum+ maize porridge, sorghum+ maize paste, sorghum+ maize+ millet porridge , sorghum+ maize+ millet paste , vegetables sauces (baobab leaf , *vernonia amygdalina* and *amaranthus hybridus*), fresh tomato sauce	Maize porridge; soya porridge ; sorghum porridge, maize + sorghum porridge	Maize porridge; sorghum porridge; millet porridge ; soya porridge, peanut sauce ; fresh tomato sauce, bean sauce	For the fortification with baobab fruit pulp, **14.3%** of the identified vehicles (in the literature) against **28.6%** for the fortification with moringa leaf powder are used. Two new vehicles (soya porridge, maize+ sorghum porridge) are identified for the fortification with baobab fruit pulp against three (soya porridge, peanut sauce, bean sauce) for the fortification with moringa leaf powder.

Source: (Morou, 1996; Akele, 2000; Mama, 2003; Adisso, 2006) and field work data (2016)

4.2. Consumption frequency of food vehicles using moringa leaf powder or baobab fruit pulp as ingredients

The survey allowed identifying the consumption frequency of food vehicles using moringa leaf powder or baobab fruit pulp as ingredients.

- **Consumption frequency of traditional moringa leaf powder food vehicles**

The survey showed that the weekly consumption frequency of traditional foods using moringa leaf powder as ingredients for under five years old children can be classified from 1 to 2 days per week to 7 days per week (Figure 3). In the guinean zone, 32.3 % of children consume traditional foods using moringa leaf powder as ingredients 1-2 days per week while about 24% of them consume those foods 3-4 days per week. In the sudano-guinean zone, 46.1% of children consume almost every day traditional foods using moringa leaf powder as ingredients followed by 42% who consume it 3-4 days per week. In the sudanian zone, the frequency of 3-4 days per week is noticed for 35.4% of children while 25.6% consume 7 days per week and 17.1% 1-2 days per week. A Chi square test showed that this frequency varies significantly from one biogeographical zone to another ($p<0.05$, Chi-Sq = 49.8).

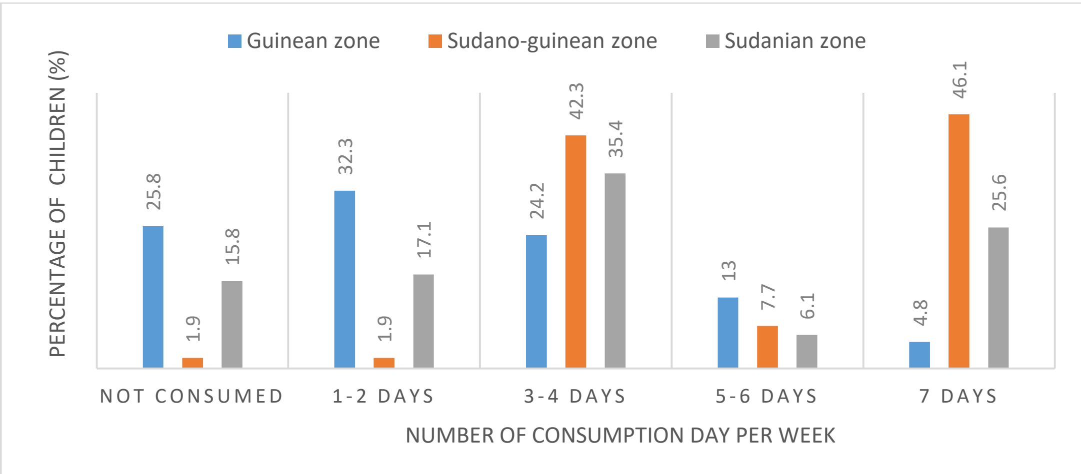

Figure 3: Frequency of consumption (number of day per week) of the foods using moringa leaf powder as ingredients for under five-years-old children

- **Consumption frequency of traditional baobab fruit pulp food vehicles**

The survey showed that the weekly consumption frequency of traditional foods using baobab fruit pulp as ingredient can be classified from 1 to 2 days per week to 7 days per week (Figure 4). Figure 4 reveals that in the guinean zone no food using baobab fruit pulp as ingredient is consumed. In the sudano-guinean zone there is a low but equal proportion children (1.9%)

who consume foods using baobab fruit pulp as ingredient 1-2 days per week, 5-6 days per week and 7 days per week. In the sudanian zone 14.6% of children consume traditional foods using baobab fruit pulp as ingredient 1-2 days per week followed respectively by 12.2% and 11.0% as the percentage of children who consume 3-4 days per week and 7 days per week. A Chi square test performed showed that this frequency varies significantly from one biogeographical zone to another ($p<0.05$, Chi-Sq = 50.42).

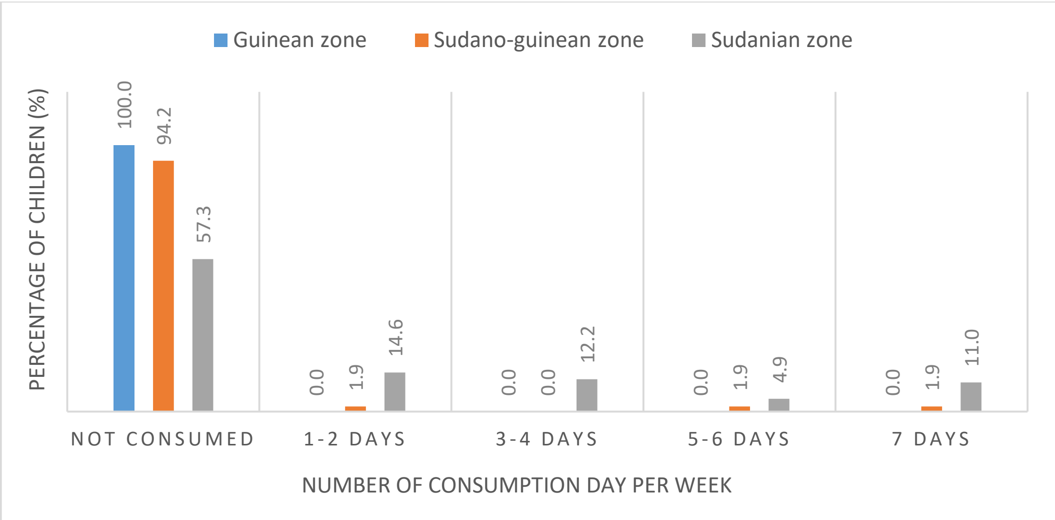

Figure 4: Frequency of consumption (number of day per week) of the food vehicles using baobab fruit pulp as ingredient for under five-years- old children.

It comes out that the foods using moringa leaf powder as ingredient are more consumed by a large proportion of children in sudano-guinean zone with 7 days per week as frequency and those using baobab fruit pulp as ingredient are more consumed by the children in sudanian zone with 1-2 days per week as frequency. The proportion of children who do not consume food using moringa leaf powder or baobab fruit pulp as ingredient is the highest in Guinean zone.

4.3. Selection of food vehicles for food fortification

Table 4 shows the two food vehicles which have the highest consumption frequency scores per biogeographical zone. These food vehicles were the ones selected for food fortification.

Table 4: The two food vehicles selected per biogeographical zone for fortification assays and digestibility study.

Biogeographical zones	1st selected food vehicle	2nd selected food vehicle
Guinean zone	Maize porridge **(57)**	Sorghum porridge **(17)**
Sudano-guinean zone	Maize porridge **(251)**	Sorghum porridge **(74)**
Sudanian zone	Sorghum porridge **(97)**	**Koata sauce* **(37)**

( ): Consumption frequency scores, *: *Cochlospermum tinctorium* root powder sauce

For the fortification assays, maize porridge was collected in sudano-guinean zone because its score is higher in sudano-guinean zone. Moreover, sorghum porridge and koata sauce were collected in sudanian zone due to their higher scores in this zone.

4.4. Flow diagrams for the processing of the selected food vehicles to be fortified

Figures 5, 6 and 7 show respectively the flow diagrams for processing fermented maize flour porridge, fermented sorghum ogi porridge and koata (C*ochlospermum tinctorium*) root powder sauce. It comes out that processing fermented maize flour and sorghum ogi porridges does not follow the same step. As far as koata sauce is concerned, the preparation includes steps such as removing the superficial part of the root, crushing, sun drying and cooking.

4.5. Characteristics of the fortified and unfortified foods

Fortified foods were designed using moringa leaf powder and/or baobab fruit pulp as compulsory ingredients. The formulated foods are fermented sorghum ogi porridge dual fortified with moringa leaf powder and baobab fruit pulp, fermented maize porridge fortified with moringa leaf powder and koata sauce fortified with moringa leaf powder.

4.5.1. Dry matter and mineral content of fortified and unfortified foods

Table 5 shows dry matter (g/100g) and mineral content (mg/100 g dry weight) of the fortified and unfortified foods. Turkey test shows that dry matter of moringa leaf and/or baobab fruit pulp fortified foods is significantly ($p<0.05$) higher than dry matter of unfortified foods. Similarly, fortification increases significantly calcium and iron content of food vehicles except koata sauce where no significant ($p>0.05$) change is observed for calcium content. A significant decrease in zinc content ($p<0.05$) was observed for fortified koata sauce and fortified maize porridge contrary to dual fortified sorghum porridge where a significant increase ($p<0.05$) was noticed.

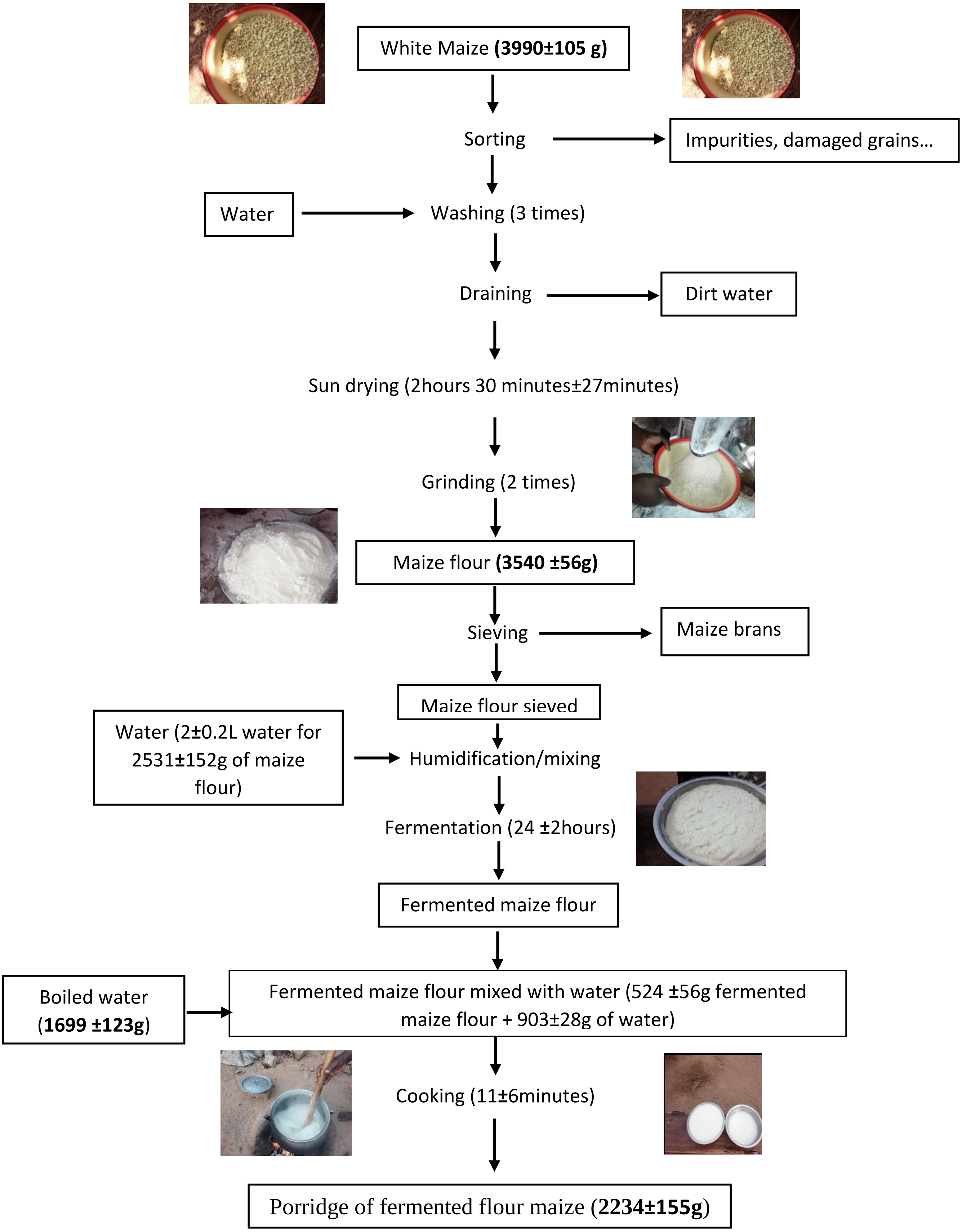

Figure 5: Flow diagram for the processing fermented flour maize porridge

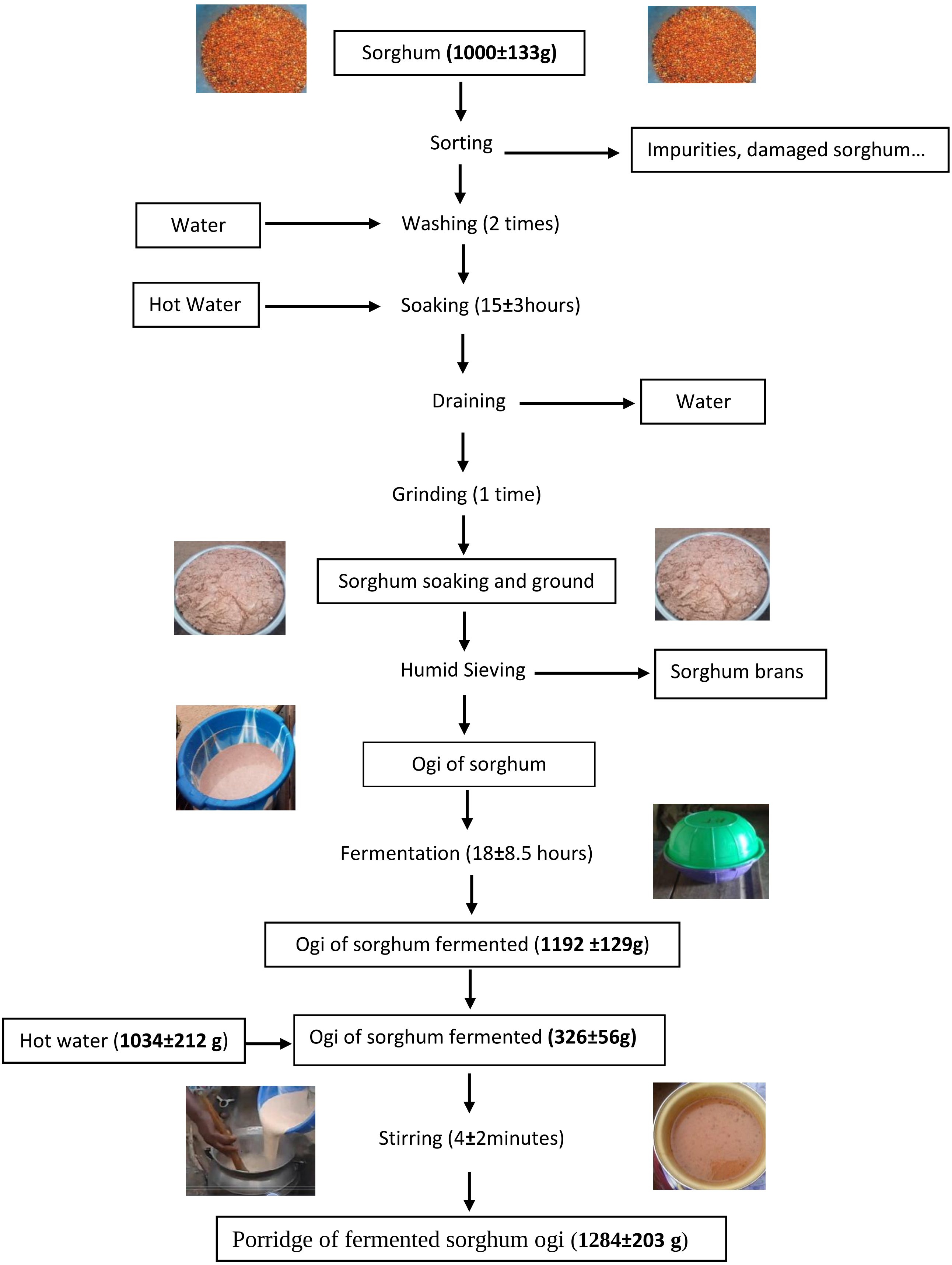

Figure 6: Flow diagram for the processing of fermented sorghum ogi porridge

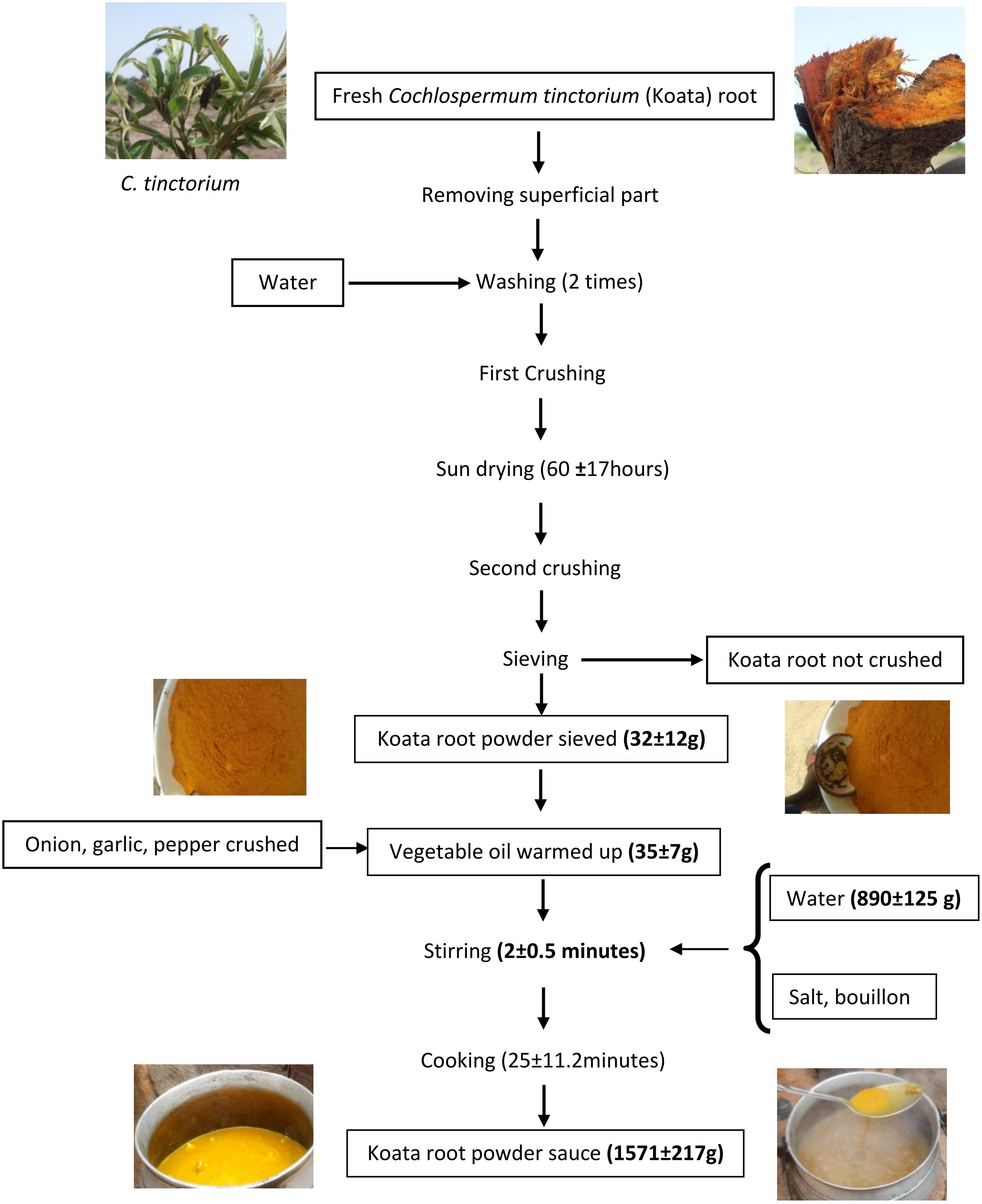

Figure 7: Flow diagram for the processing koata root powder sauce

Table 5: Mineral content of the fortified and unfortified foods

Foods	**DM** (g/100g)	**Ca** (mg/100 g dw)	**Fe** (mg/100 g dw)	**Zn** (mg/100 g dw)
Unfortified maize porridge	11.0±0.4[a]	445.1±14[a]	26.4±2.1[a]	21.8±0.6 [a]
Fortified maize porridge with PFMo	**16.6±0.5[b]**	**4561.3±92.4[b]**	**101.2±1.5[b]**	**14.8±0.9 [b]**
Unfortified sorghum porridge	8.1±1.7[a]	43.6±1.9[a]	7.3±0.2 [a]	88.2±3.8 [a]
Fortified sorghum porridge with PFMo and BFP	**19.9±0.1[b]**	**3454.5±86.4[b]**	**88.4±1.2 [b]**	**202.4±3.1[b]**
Unfortified koata sauce	15.9±0.0[a]	4867.6±8.2 [a]	85.7±0.4 [a]	19.5±0.8 [a]
Fortified koata sauce with PFMo	**21.9±0.3[b]**	**4920.2±25.7[a]**	**91.2±0.5 [b]**	**13.3±0.4 [b]**

For each parameter and each food, means (±standard deviation) with the same letter are not significantly different (p>0.05), dw: dry weight

4.5.2. In Vitro Solubility (IVS) of the fortified and unfortified foods

The In Vitro Solubility (IVS) of the fortified and unfortified foods are presented in table 6. Turkey test shows that calcium and iron IVS of sorghum porridge significantly decrease after fortification while it increases for koata sauce (p<0.05). For zinc IVS, a significant increase was observed both for sorghum porridge and koata sauce after fortification (p<0.05). As maize porridge is concerned, a significant increase was observed for zinc IVS (p<0.05) while a decrease was observed for calcium and iron IVS but not significant (p>0.05).

Table 6: In Vitro Solubility (IVS, %) of the fortified and unfortified foods

Foods	IVS Ca (%)	IVS Fe (%)	IVS Zn (%)
Unfortified maize porridge	5.6±0.1[a]	3.2±0.2 [a]	1.4±0.3 [a]
Fortified maize porridge with PFMo	**5.4±0.2 [a]**	**2.4±0.3 [a]**	**6.9±0.2 [b]**
Unfortified sorghum porridge	24.2±1.1 [a]	3.8±0.4 [a]	0.5±0.1 [a]
Fortified sorghum porridge with PFMo and BFP	**4.7±0.2 [b]**	**2±0.2 [b]**	**2.1±0.1 [b]**
Unfortified koata sauce	72.9±2.5 [a]	12.5±0.2 [a]	35.2±3.2 [a]
Fortified koata sauce with PFMo	**96.8±0.9 [b]**	**17.8±0.2 [b]**	**92.6±0.6 [b]**

For each micronutrient and each food, means (±standard deviation) with the same letter are not significantly different (p>0.05).

4.6. Acceptability levels of the fortified foods

Figures 8 and 9 show the level of acceptability of porridges fortified with moringa leaf powder and/or baobab fruit pulp and koata sauces fortified with moringa leaf powder respectively. The participants for the acceptability test are the under five years old children of the two sexes in the sudanian zone especially at Tanguieta. The boys represent 53.6 % of the participants and the girls 46.4%.

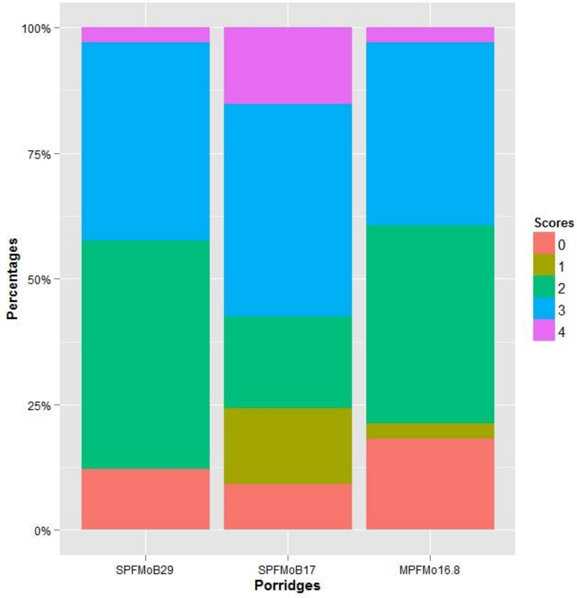

Figure 8: Acceptability level of porridges fortified with PFMo and/or baobab fruit pulp

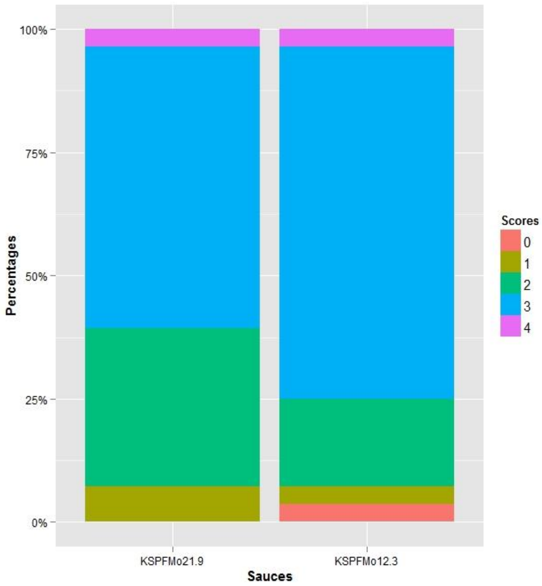

Figure 9: Acceptability level of koata sauces fortified with PFMo

0: very bad, **1:** bad, **2:** maybe good or bad, **3:** good, **4:** very good

Legends: SPFMoB29: sorghum porridge fortified with PFMo and baobab fruit pulp (fortification rate, 29.0% dw), **SPFMoB17:** sorghum porridge fortified with PFMo and baobab fruit pulp (fortification rate, 17.0 % dw), **MPFMo16.8:** maize porridge fortified with PFMo (fortification rate, 16.8 % dw), **KSPFMo21.9:** koata sauce fortified with PFMo (fortification rate, 21.9 % dw), **KSPFMo12.3:** koata sauce fortified with PFMo (fortification rate, 12.3 % dw).

Figure 8 shows that:

- **39.4**% of children found maize porridge fortified with PFMo (fortification rate, 16.8 % dw; formulaMPFMo16.8) good and very good,

- **43.0 %** of children found sorghum porridge fortified with PFMo and baobab fruit pulp (fortification rate, 29.0 dw; formula SPFMoB29) good and very good and
- **57.3** of children found sorghum porridge fortified with PFMo and baobab fruit pulp (fortification rate, 17.0 % dw; formula SPFMoB17) good and very good.

Figure 9 shows that:

- **75.0 %** of children found koata sauce fortified with PFMo (fortification rate, 12.3 % dw; formula KSPFMo12.3) good and very good while **60.7%** of these children found koata sauce fortified with PFMo (fortification rate, 21.9% dw; formula KSPFMo21.9) good and very good.

It then comes out that, sorghum porridge fortified with PFMo and baobab fruit pulp (fortification rate, 17.0 % dw) and koata sauce fortified with PFMo (fortification rate, 12.3 % dw) were the most preferred by the children.

4.7. Contribution of the fortified foods to the Estimated Average Requirements (EARs)

Tables 7, 8 and 9 show the contribution of the fortified foods to the iron, calcium and zinc Estimated Average Requirements (EAR**s**) respectively taking into account the consumption levels of the foods vehicles and the IVS.

Table 7 shows that the indicated consumption level of porridges would cover 57.1% and 54.9 % of iron EARs for 12-36 months old children and less than 30% for 6-12months and 36-59 months old children respectively for maize porridge fortified with moringa leaf powder and sorghum porridge fortified with moringa leaf and baobab fruit pulp. As koata sauce is concerned, the consumption of 138g and 310g fortified with 10g moringa leaf powder respectively by 12-36 months and 36-59 months old children would cover respectively 163.8 % and 269.2 % of iron EARs. For calcium, the indicated consumption level of porridges would cover 33.9% and 29.8 % EARs for 12-36 months old children, 10.8% and 12.2 % for 36-59 months old children respectively for maize porridge fortified with moringa leaf and sorghum porridge fortified with moringa leaf and baobab fruit pulp (Table 8). As koata sauce is concerned, the consumption of 138g and 310g fortified with 10g moringa leaf powder respectively by 12-36 and 36-59 months old children would cover respectively 290.7 % and 408.1 % of calcium EARs. Furthermore, the indicated consumption level of porridges would cover less than 35 % of zinc EARs for target children for maize porridge. For sorghum porridge consumption of 306 g fortified with 10 g moringa leaf powder and 5g baobab fruit pulp would cover 64.6 % of zinc EARs for 36-59 months old children (Table 9). As koata sauce is concerned, the consumption of 138g and 310g fortified with 10g moringa leaf powder respectively by 12-36 and 36-59 months old children would cover respectively 149.6 % and 210.0 % of zinc EARs. It comes out that, fortified koata sauce would cover most EARs for iron, calcium and zinc followed by fortified sorghum porridge and fortified maize porridge taking into account the quantity of food vehicles consumed per target and the bioaccessibility (IVS) of micronutrients. Most of the time, the coverage rate of EARs is theoretical. But in the reality, this is lower. However, looking at the rate of coverage of koata (*Cochlospermum tinctorium*) root powder sauce, one would advise it wise uses for fighting against undernutrition.

Table 7 : Contribution of the fortified foods to the iron Estimated Average Requirements (EARs)

Food vehicles	Target	Consumption level of food vehicles (g/d)	DM in portion consumed /d (g)	Iron (mg) soluble in 100 g DM	Iron (mg) soluble in portion consumed /d (BS)	EARs (mg/d)	Cover rate EARs (%)
Maize porridge fortified with PFMo	Children 6-12 m	480	79.6	2.5	2.0	6.9	28.3
	Children 12 -36 m	426	70.7	2.5	1.7	3.0	57.7
	Children 36-59 m	218	36.2	2.5	0.9	4.1	21.6
Sorghum porridge fortified with PFMo and BFP	Children 6-12 m	522	104.2	1.8	1.8	6.9	26.7
	Children 12 -36 m	466	93.0	1.8	1.6	3.0	54.9
	Children 36-59 m	306	61.1	1.8	1.1	4.1	26.4
Koata sauce fortified with PFMo	Children 6-12 m	NC	NC	NC	NC	6.9	ND
	Children 12 -36 m	138	30.3	16.2	4.9	3.0	163.8
	Children 36-59 m	310	68.0	16.2	11.0	4.1	269.2

DM: Dry Matter, PFMo: Moringa leaf powder, BFP: Baobab fruit Pulp, NC: Not consumed, ND: Not determined, m: month, **d:** day

Table 8: Contribution of the fortified foods to the calcium Estimated Average Requirements (EARs)

Food vehicles	Target	Consumption level of food vehicles (g/d)	DM in portion consumed /d (g)	Ca (g) soluble in 100 g DM	Ca (g) soluble in portion consumed /d (dw)	EARs (g/d)	Cover rate EARs (%)
Maize porridge fortified with PFMo	Children 6-12 m	480	79.6	0.2	0.2	NA	ND
	Children 12 -36 m	426	70.7	0.2	0.2	0.5	33.9
	Children 36-59 m	218	36.2	0.2	0.1	0.8	10.8
Sorghum porridge fortified with PFMo and BFP	Children 6-12 m	522	104.2	0.2	0.2	ND	ND
	Children 12 -36 m	466	93.0	0.2	0.1	0.5	29.8
	Children 36-59 m	306	61.1	0.2	0.1	0.8	12.2
Koata sauce fortified with PFMo	Children 6-12 m	NC	NC	NC	NC	NA	ND
	Children 12 -36 m	138	30.3	4.8	1.5	0.5	290.7
	Children 36-59 m	310	68.0	4.8	3.3	0.8	408.1

DM: Dry Matter, PFMo: Moringa leaf powder, BFP: Baobab fruit Pulp, NC: Not consumed, ND: Not determined, NA: Not available, m: month, **d:** day

Table 9: Contribution of the fortified foods to the zinc Estimated Average Requirements (EARs)

Food vehicles	Target	Consumption level of food vehicles (g/d)	DM in portion consumed /d (g)	Zn (mg) soluble in 100 g DM	Zn (mg) soluble in portion consumed /d (BS)	EARs (mg/d)	Cover rate EARs (%)
Maize porridge fortified with PFMo	Children 6-12 m	480	79.6	1.0	0.8	2.5	32.5
	Children 12 -36 m	426	70.7	1.0	0.7	2.5	28.8
	Children 36-59 m	218	36.2	1.0	0.4	4.0	9.2
Sorghum porridge fortified with PFMo and BFP	Children 6-12 m	522	104.2	4.2	4.4	2.5	176.3
	Children 12 -36 m	466	93.0	4.2	3.9	2.5	157.4
	Children 36-59 m	306	61.1	4.2	2.6	4.0	64.6
Koata sauce fortified with PFMo	Children 6-12 m	NC	NC	NC	NC	2.5	ND
	Children 12 -36 m	138	30.3	12.4	3.7	2.5	149.6
	Children 36-59 m	310	68.0	12.4	8.4	4.0	210.0

DM: Dry Matter, PFMo: Moringa leaf powder, BFP: Baobab fruit Pulp, NC: Not consumed, ND: Not determined, m: month, **d:** day

DISCUSSION

5. Discussion

5.1. Local food vehicles using moringa leaf powder and baobab fruit pulp as ingredients

Moringa leaf powder and baobab fruit pulp are used for food fortification. In the three biogeographical zones, the proportion of children consuming these resources as fortificant is variable. This variation may possibly be due to the availability, the accessibility of these resources and mainly to the food habits of the target. Previous studies showed that food habits are passed from generation to generation and that baobab utilization and knowledge about baobab decreases from northern to southern Benin (Chadare et *al.*, 2008). This is in accordance with the results of the present study which showed that baobab fruit pulp is not used as fortificant in children foods in Southern Benin. Moringa leaf powder, used as fortificant for any type of food vehicle can be considered as a local food supplement to fight against malnutrition (Houndji et *al.*, 2013). However, the use of baobab fruit pulp as fortificants is scarce though some traditional trials were reported for maize ogi (Adejuyitan et al., 2012). The difference between food vehicles identified in the literature as staple foods and those revealed by the survey as food vehicles used for food fortification indicates that there is a preferential food vehicles for food fortification with baobab fruit pulp and moringa leaf powder especially for infant foods. Furthermore, sauces identified as food vehicles using moringa leaf powder as fortificant is very interesting. Indeed, literature hardly tackles the food to food fortification using sauces as food vehicles. Sauce as food vehicle using moringa leaf powder as fortificant may increase the consumption level of the fortificant in comparison with porridges because the green color of moringa leaf powder tends to change the color of porridges which lead unacceptable the fortified porridges with moringa leaf powder (Salem and al. 2013).

5.2.Nutritional benefit of food-to-food fortification

Food fortification is defined as a practice of deliberately increasing the content of essential micronutrients in a food to improve the nutritional quality of the food supply and to provide the public health benefit with minimal risk to health (Dary et Hainsworth, 2008). It had also been reported that, well-known fortified foods such as moringa leaf powder fortified maize-ogi, baobab fruit pulp fortified yoghurt (Abdullahi et al., 2014), baobab fruit pulp fortified maize ogi and moringa leaf powder fortified cheese improved essential micronutrients (calcium, iron zinc, vitamin A and protein contents) of used food vehicles (Adejuyitan et al., 2012, Salem et al., 2013, Abdullahi et al., 2014, Abioye et Aka., 2015). “Ogi’ produced from maize fortified with baobab fruit pulp was found to be acceptable up to 50% fortification with also a decrease of protein, crude fibre, fat and carbohydrate (Adejuyitan, 2012). It appears that fortification improves some nutrients and bring out others. In the present study, a significant decrease of zinc content was observed both for maize porridge and koata sauce fortified respectively with moringa leaf powder. Nevertheless, sorghum porridge fortified with moringa leaf powder and baobab fruit pulp showed a significant increase ($p<0.05$) of zinc content as a result of dual food-to-food fortification. This observation underlined the nutritional benefit of dual food-to-food fortification using moringa leaf powder and baobab fruit pulp which has not reported so far. Probably, this increase can be due to baobab fruit pulp which was reported to contain up to 1.7 mg/100 g dry weight of zinc but which is also an acidulant due to its high vitamin C content up to 350 mg of vitamin C per 100 g dry weight (Chadare et al., 2009). Indeed, acidulants are known to improve iron and zinc bioavailability (Hemalatha et al., 2005). Blending sorghum porridge or maize porridge with moringa leaf powder and baobab fruit pulp appears interesting for zinc content improvement. Dual food-to-food fortification using moringa leaf powder and baobab fruit pulp can be promoted to fight against zinc deficient that remains a great nutritional challenge especially among under five years old children in developing countries.

5.3.In-Vitro Solubility (IVS) of the fortified foods

The IVS is an estimate of nutrient bioaccessibility, and in this case micronutrients. It represents the quantity of micronutrient potentially available for absorption after ingestion of foods and depends on the food matrices and the digestion (CRNH, 2013). Bioaccessibility is considered as the fraction of a compound that is released from its matrix in the gastrointestinal tract and thus becomes available for intestinal absorption (Dwivedi et al., 2012). It includes the entire sequence of events that take place during the digestive transformation of food into materials that can be assimilated by the body, the absorption/assimilation into the cells of the intestinal epithelium and lastly the metabolism.

For porridges, the decrease in mineral IVS is probably due to the presence of antinutrients in moringa leaf powder and/or baobab fruit pulp that will act as binding factors. In fact, baobab fruit pulp contains naturally occurring antinutritional factors like tannin (0.0051% to 0.0062%), (Chadare, 2010). *Moringa oleifera* was reported to contain some antinutritional factors like phenolic compound and tannins (Mumtaz and Fatima, 2017). Soetan and al., (2016) found that *Moringa oleifera* leaves contain phytate (1.58±0.02%), tannin (0.05±0.01%) and phenol (0.12±0.001%). It can be assumed that fortifying maize and sorghum porridges with moringa leaf powder and/or baobab fruit pulp does not improve calcium and iron IVS. Lestienne, (2004) studied the digestibility of zinc and iron on fourteen fermented millet porridge in Burkina-Faso. She found 13.1±2.8% for zinc and 10.9±4.5% for iron. These values are higher than those found in this study for maize and sorghum fermented porridges (2%-3.8% for iron and 0.5-6.9% for zinc). This difference observed can be due to the food matrices used and the digestibility method applied by the author. In fact, Lestienne (2004) has performed the digestibility study according to Lönnerdal *et al*. (1993) method modified by Glahn *et al*., (2000); Bermejo *et al*., (2000) and Wolfgor *et al*., (2002) which differs from Kiers et al., (2000) method. The difference between these methods is relative to the incubation times, solution used to adjust pH, amount of product used for digestion and amount of enzymatic solution used. Also, it was well known that cereals contain high Anti Nutritional Factors (ANF) such as phytates and polyphenols compound which reduce the bioavailability of micronutrients (Lestienne, 2004; Zimmermann et al., 2005). Lestienne, (2004) has reported that maize contains from 0.8 to 2.2 % of phytates and 0.4% of polyphenols while sorghum contains from 0.7 to 1.4 % of phytates and from 0.2 to 10.3 % of polyphenols. Despite the process (fermentation, soaking, cooking) applied, the IVS are relatively low in maize porridge and sorghum porridge for calcium, iron and zinc. These low IVS let hypothesize that antinutritional factors were not highly eliminated through the applied process.

It can be expected that in sorghum porridge dual fortified with moringa leaf powder and baobab fruit pulp, iron bioaccessibility be high due to high vitamin C content of baobab fruit pulp up to 350 mg/100g dw (Chadare et al; 2009). But no IVS increase was observed. Nevertheless, it is relevant to know that vitamin C increases iron absorption (Kouevi, 2013). More specifically, Zimmermann and al., (2005) have reported that an ascorbic acid (vitamin C) to- iron molar ratio of 4:1 is needed to increase iron absorption from diets high in phytic acid. In this study, sorghum porridge fortified with moringa leaf powder and baobab fruit pulp had ascorbic acid (vitamin C) to-iron molar ratio of 3.3:1 less than 4:1 molar ratio; that is probably reason for why any iron IVS increasing was not observed. Further study can be designed to change fortification rate as a pathway to optimize iron bioaccessibility.

For koata (*Cochlospermum tinctorium*) root powder sauce, the IVS of calcium, iron and zinc are higher than the ones of porridges. Fortification increase the bioaccessibility of micronutrient in koata root powder sauce. This observation is then in accordance with the findings of Abdulahi and al; (2014) who underlined that fortification can increase the bioavailability of foods. This high bioaccessibility of micronutrients in koata root powder sauce can be probably due to its low antinutritional factors content. Previous findings show that koata root powder is rich in zinc and iron (Ayosso, 2016) but no study investigate the bioavailability of these micronutrients. Nevertheless, the molar ratios [IP6]/ [Zn], [IP6]/ [Fe], [IP6]/ [Ca] were reported to be respectively 0.37, 0.01 and 0.001 for koata root powder (Ayosso, 2016). These low molar ratios could explain the high bioaccessibility of micronutrients in koata sauce. Further study on antinutrionnal factors of koata root powder need to be designed as a way for better understanding of the high bioaccessibility of micronutrients in koata sauce.

5.4.Nutritional potential of koata (*Cochlospermum tinctorium*) sauce

Unfortified koata root powder sauce was revealed to be rich in calcium (4867.6±8.2 mg/100 g dw), iron (85.7±0.4mg/100 g dw) and zinc (19.5±0.8mg/100 g dw), as a consequence of the high micronutrient content of koata root powder. Indeed, previous findings show that koata root powder is rich in zinc and iron (Ayosso, 2016). This high micronutrient content of koata root powder and/or koata root powder sauce allows to hypothesize that koata root powder can be promoted as a food supplement. In fact, koata root powder can be added to porridges and/or any type of sauce in order to improve the nutritional value of these food vehicles. It appears obvious that koata root powder can be considered as a food fortificant like moringa leaf powder and baobab fruit pulp. Furthermore, koata sauce can be used (due to its iron content) to fight against iron deficiencies among population especially among under five years old children and women in reproductive age. In fact, it has been reported that more than 2 billion people are deficient in key minerals especially iron and zinc (Das et al., 2013) and children are highly vulnerable (De-Regil et al., 2011). Koata root powder becomes a good source of nutrients that deserve thorough investigations.

CONCLUSION AND RESEARCH PERSPECTIVES

6. Conclusion and research perspectives

The present study allows identifying the food vehicles that use moringa leaf powder and baobab fruit pulp as ingredients for infant foods in Benin. The consumption frequencies of the food vehicles using moringa leaf powder and baobab fruit pulp as ingredients vary significantly from one biogeographical zone to another. In addition, food vehicles identified in the literature as staple foods and those revealed by the survey as food vehicles using moringa leaf powder and/or baobab fruit pulp as ingredients were not exactly the same. It appears obvious that there is a preferential food vehicles for food fortification based baobab fruit pulp and moringa leaf powder for infant foods. Fortification with moringa leaf powder and baobab fruit pulp improve significantly the micronutrients content (calcium, iron and zinc) of the food vehicles. Both fortified and unfortified foods, the bio-accessibility of micronutrients are low for porridges but relatively high for koata sauce. Acceptability test indicates that sorghum porridge dual fortified with moringa leaf powder and baobab fruit pulp (fortification rate, 17.0 % dw) and koata sauce fortified with moringa leaf powder (fortification rate, 12.3 % dw) were the most accepted.

For the local population, we suggest that dual food-to-food fortification using moringa leaf powder and baobab fruit pulp for porridges be promoted to fight against micronutrients deficiencies especially zinc deficiencies. In the same way, *Cochlospermum tinctorium* root powder can be promoted as a food supplement. Finally, we suggest that further studies focus on:

- Nutritional intervention using the developed fortification formulas;
- Sanitary quality of the fortified foods;
- Producing fortificants under controlled conditions;
- Techniques to enhance the bioavailability of micronutrients in developed fortified porridges (optimization);
- Assessment of koata (*cochlospermum tictorium*) root powder: composition, processing and quality and
- Developing digestibility model for fortified food vehicles.

REFERENCES

References

Abdullahi, M. A., Zainab, F. A., Pedavoah, M. M., Sumayya, U. B. & Ibrahim, A. D. 2014. Evaluating the suitability of Adansonia digitata fruit pulp for the production of yoghurt. *International Journal of Biology Chemistry. Science,* 8**,** 508-516.

Abioye, V. F. & Aka, M. O. 2015. Proximate Composition and Sensory Properties of Moringa Fortified Maize-Ogi. *Nutrition & Food Sciences***,** S12, 1-4.

Adenuga, W. 2010. Nutritional and sensory profiles of sweet potatoes based infant weaning food fortified with cowpea and peanut *Journal of Food Technology,* 8**,** 223-228.

Adisso, M. D. 2006. Identification des déterminants agronomiques de la disponibilité alimentaire dans les UDPC de la commune de klouekanme: cas du village de Mademe. *Faculté des Sciences Agronomiques (FSA),* Agronomic Engeneer thesis**,** 99p.

Ajanaku, K. O., Ogunniran, K. O., Ajani, O. O., James, O.O. & Nwinyi, O. C. 2010. Improvement of nutritional value of Sorghum-ogi fortified with pawpaw (Carica papaya L.). *Fruit, vegetable and Cereal Science and Biotechnology*, 4, 98-101

Akele, D. O. A. 2000. Evaluation du niveau de sécurité alimentaire des populations de la sous-préfecture de Bopa : Analyse des déterminants et proposition d'un plan d'action. *Facuté des Sciences Agronomiques (FSA),* Agronomic Engeneer thesis**,** 142p.

Association of Official Analytical Chemists (AOAC). 1995. Analyses bromatologiques. *16ème édition.*

Ayosso, J. O. G. 2016. Diversité et valeur nutritionnelle des ressources alimentaires locales pour l'alimentation des enfants de 6 - 24 mois. *FSA/EPAC/FAST,* Master**,** 109p.

Beinner, M. A., Velasquez-Melendez, G., Pessoa, M. C. & Greiner, T. 2010. Iron-Fortified Rice Is As Efficacious As supplemental Iron drops in infants and young children, *The Journal of Nutrition***,** 49-53.

Bhagwat, S., Deepti Gulati, D., Sachdeva, R. & Sankar, R. 2014. Food fortification as a complementary strategy for the elimination of micronutrient deficiencies: case studies of large scale food fortification in two Indian States. *Asia Pacifique Journal of Clinical Nutrition,* 23**,** 4-11.

Brown, K. H., Hambidge, K. M., Ranum, P. & Zinc, F. W. G. 2010. Zinc fortification of cereal flours: Current recommendations and research needs. *Food and Nutrition Bulletin,* 31**,** S62-S74.

Brown, K. H., Peerson, J. M., Baker, S. K. & Sonja, Y. H. 2009. Preventive zinc supplementation among infants, preschoolers, and older prepubertal children. *Food and Nutrition Bulletin,* 30**,** S12-S40.

Chadare, F. J., Hooiveld, G. J. E. J., Linnemann, A. R., Nout, M. J. R. & Hounhouigan, D. J. 2014. Effect of cooking on in vitro solubility of minerals and carotenoids in adansonia digitata leaves. *Annales des sciences agronomiques* 18**,** 1-19.

Chadare, F. J., Hounhouigan, J. D., Linnemann, A. R., Nout, M. J. R. & Van Boekel, M. A. J. S. 2008. Indigenous Knowledge and Processing of Adansonia Digitata L. Food Products in Benin. *Ecology of Food and Nutrition,* 47**,** 338 - 362.

Chadare, J., Linnemann, A. R., Hounhouigan, J. D., Nout, M. J. R. & Van Boekel, M. A. J. S. 2009. Baobab Food Products: A Review on their Composition and Nutritional Value. *Food and Nutrition Science,* 49**,** 254-274.

Chadare, J. F. 2010. *Baobab (Adansonia digitata L) f*oods from Benin : composition, processing and quality.PhD thesis, Wageningen University, 182p

Cissé, I. 2012. Caractérisation des propriétés biochimiques et nutritionnelles de la pulpe de baobab des espèces endémiques de Madagascar et d'Afrique continentale en vue de leur valorisation. Doctorat, Montpellier supagro, 158p

CRNH 2013. Impact des traitements technologiques sur la qualité nutritionnelle des aliments et ingrédients: Quelle méthodologie pour étudier la biodisponibilité des nutriments dans un aliment transformé ?**,** 32p.

Dary, O. & Hainsworth, M. 2008. The Food Fortification Formulator: Technical Determination of Fortification Levels and Standards for Mass Fortification, 29p.

Dary, O. & Mora, J. O. 2002. Proceedings of the XX International Vitamin A Consultative Group Meeting. *Journal of Nutrition,* 132**,** 2927S–2933S.

Das, J. K., Salam, R. A., Kumar, R. & Bhutta, Z. A. 2013. Micronutrient fortification of food and its impact on woman and child health: a systematic review. *systematic review,* 2**,** 2-24.

De-regil, L. M., Suchdev, P. S., Vist, G. E., Walleser, S. & Peña-Rosas, J. P. 2011. Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age (Review). *Cochrane review journal* 8**,** 112–201.

De brito, E. S., Garruti, D. D. S. & Silva, D. S. 2007. Development of a new tapioca product with tropical fruit pulp and soy extract. *Tropical Science,* 47**,** 52-56.

Dehah, C. M. E. O. 2004. Etude de la biodisponibilite du fer des repas mauritaniens et anemie chez la femme en age de procreer au gorgol. Université Cheikh Anta Diop de Dakar, Faculté des Sciences et Techniques, 127p

Diop, A. G., Sakho M, Manuel Dornier M., Cissé M., Reynes M. & Casamatta D.A. 2005. Le baobab africain (Adansonia digitata L.) : principales caractéristiques et utilisations. *EDP Sciences,* 61**,** 55–69p.

Dwivedi, S. L., Kanwar, L. S. & Rai, K. N. 2012. Nutritionally Enhanced Staple Food Crops. 124.

FAO/OMS 2006. Guidelines on food fortification with micronutrients, 376.

Gibson, R. S., Perlas, R. S. & Hotz, C. 2006. Improving the bioavailability of nutrients in plant foods at the household level. *Proceedings of the Nutrition Society* 65**,** 160–168.

Hambidge, K. M. 2010. Micronutrient bioavailability: Dietary Reference Intakes and a future perspective. *American Journal of Clinical Nutrition,* 1430-1432.

Hemalatha S., Platel K. and Srinivasan K. 2005. Influence of food acidulants on bioaccessibility of zinc and iron from selected food grains, *Molecular Nutrition & Food Research*, 49, 1-7

Hemalatha, S. 2006. Studies on the bioavailability of the micronutrients from the indian foods. PhD thesis , University of Mysore, 208p

Hopkins, J., Lewis B & Cullman D 2005. Moringa oleifera: A Review of the Medical Evidence for Its Nutritional, Therapeutic, and Prophylactic Properties. *Trees for Life Journal Part* 1, 15

Houndji, B. V. S., Bodjrenou, S. F., Londji, S. B. M., Oouetchehou, R., Acakpo, A., Amouzou, K. S. E. & Hounmenou 2013. Amélioration de l'état nutritionnel des enfants âgés de 6 à 30 mois à Lissèzoun (Centre-Bénin) par la poudre de feuilles de Moringa oleifera (Lam.). *Int. J. Biol. Chem. Sci.* , 7**,** 225-235.

Jacobs, A. & Greenman, D. A. 1969. Availability of Food Iron. 1**,** 673-676.

Kayalto, B., Zongo, C., Compaore, R., W. , Savadogo, A., Otchom, B. B. & Traore, A. S. 2013. Study of the Nutritional Value and Hygienic Quality of Local Infant Flours from Chad, with the Aim of Their Use for Improved Infant Flours Preparation , *Food and Nutrition Sciences,* 4**,** 59-68.

Kébenzikato, A. B., Wala K., Atakpama W., Dimobé K., Dourma M., Woégan A. Y. , K., B. & K., A. 2015. Connaissances ethnobotaniques du baobab (Adansonia digitata L.) au Togo. 19, 2-13.

Soetan K. O. and Aiyelaagbe O. O. (2016). Proximate analysis, minerals, and anti-nutritional factors of *moringa oleifera* leaves, *Annals. Food Science and Technology*, 17, 253-256.

Kiers, J. L., Nout, R. M. J. & Rombouts, F. M. 2000. In vitro digestibility of processed and fermented soya bean, cowpea and maize. *Journal of the Science of Food and Agriculture,* 80**,** 1325-1331.

Kouevi, K. K. 2013. A study on Moringa oleifera leaves as a supplement to West African weaning foods. 124p.

Lelana, I. Y. B., Purnomosari, L. & Husni, A. 2003. Fortification of plain cracker with fish flour, *Indonesian Food and Nutrition Progress,* 10**,** 26-28.

Lestienne, I. 2004. Contribution à l'étude de la biodisponibilité du fer et du zinc dans le grain de mil et conditions d'amélioration dans les aliments de complément, Thèse de Doctorat, Université de Montpellier II, 245p.

Luqman, S., Srivastava S., Kumar R., Maurya K. A. & D, C. 2012. Experimental Assessment of Moringa oleifera Leaf and Fruit for Its Antistress, Antioxidant, and Scavenging Potential Using In Vitro and In Vivo Assays. *Hindawi Publishing Corporation,* 12

Mama, I. 2003. Evaluation de la consommation alimentaire des enfants en d'âge scolaire dans la période de soudure au nord du Bénin : cas de la commune de Natitingou. *Faculté des Sciences Agronomiques (FSA)***,** Agronomic Engeneer thesis, 124p.

Miller, D. D., Schricker, B. R., Rasmussen, R. R. & Campen, D. V. 1981. An in vitro method for estimation of iron availability from meals. *The American Journal of Clinical Nutrition***,** 2248-2256.

Moringa Association Of Ghana 2010. *Produire et transformer les feuilles de moringa*, 36p

Morou, K. 1996. Modèles alimentaires et niveau de consommation de la vitamine a et de l'iode des populations des départements du zou et du Borgou. *Faculté des Sciences Agronomiques (FSA)***,** Agronomic Engeneer thesis , 109p.

Mumtaz B. & Fatima S. 2017. The story of Amazing Tree life: Moringa Oleifera: A Review. *International Journal of Multidisciplinary Research*, 3, 1-10

Nadeem, M., Javid, A., Abdullah, M., Arif, A. M. & Mahmood, T. 2012. Improving Nutritional Value of Butter Milk by Blending with Dry Leaves of Moringa oleifera. *Pakistan Journal of Nutrition* 11**,** 714-718

Okafor, J. N. C., Okafor, G. I., Ozumba, A. U. & Elemo, G. N. 2012. Quality Characteristics of Bread Made from Wheat and Nigerian Oyster Mushroom (Pleurotus plumonarius) Powder. *Pakistan Journal of Nutrition* 11**,** 5-10.

Oluwamukomi, M. O. & Jolayemi, O. S. 2012. Physico-thermal and pasting properties of soy-melon-enriched "gari" semolina from cassava. *Agric Eng Int: CIGR Journal*, 14**,** 106-114.

Rockwood, J. L., Anderson B. G. & D.A., C. 2013. Potential uses of Moringa oleifera and an examination of antibiotic efficacy conferred by M. oleifera seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. *International journal of phytothearpy research*,3, 61-71.

Salem, A. S., Salama, W. M., Hassanein, A. M. & El Ghandour, H. M. A. 2013. Enhancement of Nutritional and Biological Values of Labneh by Adding Dry Leaves of Moringa oleifera as Innovative Dairy Products. *World Applied Sciences Journal*,22, 1594-1602.

Sankhon, A., Amadou, I. & Yao, W. 2013. Application of resistant starch in bread: processing, proximate composition and sensory quality of functional bread products from wheat flour and African locust bean (Parkia biglobosa) flour. *Agricultural Sciences*, 4, 122-129.

Schönfeldt, H. C., PretoriuS, B. & Hall, N. 2016. Bioavailability of nutrients, 18p.

Ross AC, Taylor CL, Yaktine AL, et al., (2011). Institute of Medicine (US) Committee. Dietary Reference Intakes Summary tables. Washington (DC): National Academies Press (US); 211p.

Solon, F. S., Klemm, R. D., Sanchez, L., Darnton-Hill, I., Craft, N. E., Christian, P. & West JR, K. P. 2000. Efficacy of a vitamin A–fortified wheat-flour bun on the vitamin A status of Filipino schoolchildren. *American journal of clinical nutrition*, 72**,** 738–744.

Zimmermann, M. B., Chaouki, N. & Hurrell, R. F. 2005. Iron deficiency due to consumption of a habitual diet low in bioavailable iron: a longitudinal cohort study in Moroccan children. *American Journal of Clinical Nutrition* 81**,** 7.

Zongo, U., L., Z. S., Savadogo A. & S., T. A. 2013 Nutritional and Clinical Rehabilitation of Severely Malnourished Children with Moringa oleifera Lam. Leaf Powder in Ouagadougou (Burkina Faso), *Food and Nutrition Sciences,* 4**,** 991-997

ANNEXES

Annex 1: Questionnaire for focus group discussion (checklist)

Objectif : collecter des données sur les véhicules alimentaires utilisant la poudre de feuille de moringa et la pulpe du fruit de baobab comme fortifiant chez les enfants de 6-59 mois

GDD (cibles) : Femmes en âge de procréer (15-49 ans) et ayant au moins un enfant de 6-59 mois

Date ……………………………………………………………………………………………………

Zone biogéographique ………………………………………Commune ……………………………..

Arrondissement ……………………………………… Village : ………………………………...

Heure début …………………………… Heure de fin……………….. Durée………………………

Animateur ……………………………………………………………………………………………

Rapporteur …………………………………………………………………………………………...

Liste des participantes

Participantes	Caractéristiques de la mère			Caractéristiques de l'enfant		
	Nom et prénom(s)	Age	Occupation	Nom et prénom(s)	Age	Sexe
P1						
P2						
P3						
P4						
P5						
P6						
P7						
P8						

I- UTILISATIONS

1. Utilisations alimentaires faites de la feuille de moringa et de la pulpe de baobab dans la communauté

Ressources alimentaires	**Utilisations**	**Autres informations**
Pulpe de baobab		
Poudre de feuille de moringa		

1. Aliments fortifiés avec de la poudre de feuille de moringa et de la pulpe de baobab

Ressources alimentaires	**Aliments fortifiés ou ayant subi de la supplémentation**
Poudre de feuille de moringa	
Pulpe de baobab	

2. Technique d'obtention de la poudre de feuille de moringa et de la pulpe de baobab

Ressources alimentaires	Technique d'obtention (grandes étapes)	Mode de stockage (mode et durée)	Mode de conservation (technique et durée)
Poudre de feuille de Moringa			
Pulpe de baobab			

3. Technique de fortification des aliments à partir de la poudre de feuille de moringa et de la pulpe de baobab

Ressources alimentaires	Véhicules alimentaires	Processus de fortification ou de supplémentation	Sujet concerné (Enfants et/ou mère)	Autres informations utiles
Poudre de feuille de moringa				
Pulpe de fruit de baobab				

II- PERCEPTIONS

4. Quels sont selon vous les effets de la consommation des aliments fortifiés avec la poudre de feuille de moringa? (sonder sur l'état nutritionnel : traitement de l'anémie, croissance, force ; la réaction des consommateurs)
   a. Sur les enfants 6-59 mois

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5. Quels sont selon vous les effets de la consommation des aliments fortifiés avec la pulpe de baobab ? (sonder sur l'état nutritionnel : traitement de l'anémie, croissance, force; la réaction des consommateurs)
   a. Sur les enfants 6-59 mois

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6. Quels sont les facteurs qui pourraient vous encourager à utiliser comme fortifiant dans l'alimentation de votre enfant de 6-59 mois ? (sonder les facteurs socioculturel, nutritionnel, personnes…)

   a. La poudre de feuille de moringa

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………………………………………………………………………………………………

   b. La pulpe du fruit de baobab

……………………………………………………………………………….................................

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7. Quels sont les facteurs qui pourraient vous décourager à utiliser comme fortifiant dans l'alimentation de votre enfant de 6-59 mois ? (sonder les facteurs socioculturel, nutritionnel, les personnes…)
   a. La poudre de feuille de moringa

…………………………………………………………………………………………………

…………………………………………………………………………………………………

b. La pulpe du fruit de baobab

……………………………………………………………………………..............................

……………………………………………………………………………..............................

8. Quels sont les tabous liés à la consommation de la poudre de feuille de moringa dans votre village/communauté ?

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9. Quels sont les tabous liés à la consommation de la pulpe de baobab dans votre village/communauté ?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

10. Quelles sont les périodes de disponibilité de la poudre de feuilles de moringa dans votre communauté? (sonder les saisons d'abondance et de pénurie)

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…………………………………………………………………………………………………

11. Quelles sont les périodes de disponibilité de la pulpe de baobab dans votre communauté ? (sonder les saisons d'abondance et de pénurie)

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…………………………………………………………………………………………………

12. Quelles sont les sources d'approvisionnement dans votre communauté ? (sonder sur achat, production, dons,…)

    a. De la poudre de feuilles de moringa ?

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…………………………………………………………………………………………………….

    b. De la pulpe de baobab ?

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13. Quelles sont les périodes de disponibilité des véhicules utilisant la pulpe de baobab comme fortifiant dans votre communauté ?

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14. Quelles sont les périodes de disponibilité des véhicules utilisant la poudre de feuille de moringa comme fortifiant dans votre communauté ?

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Annex 2: Questionnaire for key persons

Objectif : Collecter des données sur les véhicules alimentaires utilisant la poudre de feuille de moringa et la pulpe du fruit de baobab comme fortifiant chez les enfants de 6-59 mois

Cible : Agents de CARDER (essentiellement les TSANA : Techniciens spécialisés en Alimentation et en Nutrition Appliquée), Agents des Centres de Promotion Sociale (CPS), Agents des ONG intervenant dans la nutrition, Agents des centres de récupération nutritionnelle.

Date …………………………………………………………………………………………………

Zone biogéographique …………………………………………Commune ……………………………..

Arrondissement ………………………………………………Village ………………………………...

Heure début ……………………………………Heure de fin…… ….   Durée……………………

Animateur …………………………………………………………………………………………….

Rapporteur …………………………………………………………………………………………...

Information sur l'enquêté (e)

Nom et Prénom (s)……………………………………………………………………………………

Age……………………………………….. Sexe…………………………………………...………

Fonction………………………………………………………………………………………………..

Numéro de téléphone…………………………………………………………………………..

1. La poudre de feuille de moringa et/ou la pulpe du fruit de baobab sont-elles utilisées comme fortifiant dans votre village? Si oui passez aux questions suivantes

2. Quels sont selon vous les effets de la consommation des aliments fortifiés avec la poudre de feuille de moringa? (sonder sur l'état nutritionnel : traitement de l'anémie, croissance, force ; la réaction des consommateurs)

   2.1. Sur les enfants 6-59 mois

…………………………………………………………………………………………………
…………………………………………………………………………………………………

3. Quels sont selon vous les effets de la consommation des aliments fortifiés avec la pulpe de baobab ? (sonder sur l'état nutritionnel : traitement de l'anémie, croissance, force ; la réaction des consommateurs)

   3.1.Sur les enfants de 6-59 mois

…………………………………………………………………………………………………
…………………………………………………………………………………………………

4. Quels sont les facteurs qui pourraient encourager les femmes en âge de procréer à utiliser comme fortifiant dans alimentation de leurs enfants de 6 à 59 mois? (sonder les facteurs socioculturels, nutritionnels, personnes…)

   4.1. La poudre de feuille de moringa

…………………………………………………………………………………………………
…………………………………………………………………………………………………

   4.2. La pulpe du fruit de baobab

…………………………………………………………………………………………………
…………………………………………………………………………………………………

5. Quels sont les facteurs qui pourraient décourager les femmes en âge de procréer à utiliser comme fortifiant dans l'alimentation de leurs enfants de 6 à 59 mois? (sonder les facteurs socioculturels, nutritionnels, personnes…)

5.1. La poudre de feuille de moringa

………………………………………………………………………………………………

………………………………………………………………………………………………

5.2. La pulpe de baobab

………………………………………………………………………………………………

………………………………………………………………………………………………

6. Quels sont les tabous liés à la consommation de la poudre de feuille de moringa dans votre village/communauté ?

………………………………………………………………………………………………

………………………………………………………………………………………………

7. Quels sont les tabous liés à la consommation de la pulpe de baobab dans votre village/communauté ?

………………………………………………………………………………………………

………………………………………………………………………………………………

8. Quelles sont les périodes de disponibilité de la poudre de feuilles de moringa dans votre communauté? (sonder les saisons d'abondance et de pénurie)

………………………………………………………………………………………………

………………………………………………………………………………………………

9. Quelles sont les périodes de disponibilité de la pulpe de baobab dans votre communauté ? (sonder les saisons d'abondance et de pénurie)

………………………………………………………………………………………………

………………………………………………………………………………………………

10. Quelles sont les sources d'approvisionnement ? (sonder sur achat, production, dons,…)

10.1. De la poudre de feuilles de moringa

……………………………..………………………………………………………………………

………………………………………………………………………………………………….

10.2. De la pulpe de baobab

…………………………………………………………………………………………………

…………………………………………………………………………………………………

11. Quelles sont les périodes de disponibilité des véhicules utilisant la pulpe de baobab comme fortifiant dans votre communauté ?

…………………………………………………………………………………………………

……………………………………………………………………………………………..........

12. Quelles sont les périodes de disponibilité des véhicules utilisant la poudre de feuille de moringa comme fortifiant dans votre communauté ?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

13. Pensez-vous que la pulpe de baobab est accessible pour les populations dans votre communauté ? (sonder l'accessibilité physique et financière)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

14. Pensez-vous que la poudre de feuille de moringa est accessible pour les populations dans votre communauté ? (sonder l'accessibilité physique et financière)

…………………………………………………………………………………………………

……………………………………………………………………………………

15. Quel est le niveau de consommation de la poudre de feuille de moringa et de la pulpe de baobab dans votre village? (noter avec une base de 100 ménages, 100 enfants)

   - Pour la pulpe de baobab

………………………………………………………………………………………………….

………………………………………………………………………………………………….

   - Pour la poudre de feuille de moringa

....

…………………………………………………………………………………………………

16. Comment pensez-vous que l'on puisse amener les enfants de cette communauté à consommer ou consommer plus la poudre de feuilles de moringa ?

....

....

17. Comment pensez-vous que l'on puisse amener les enfants de cette communauté à consommer ou consommer plus la pulpe de fruit de baobab ?

....

....

18. Quels sont les reproches que font les mères sur la consommation de la poudre de feuille de moringa par rapport aux enfants? (il s'agit ici des effets indésirables éventuels, diarrhée, etc., les difficultés de préparation, stockage, conservation)

…………………………………………………………………………………………………

…………………………………………………………………………………………………….

19. Quels sont les reproches que font les mères sur la consommation de la pulpe du fruit baobab par rapport aux enfants ? (il s'agit ici des effets indésirables éventuels, diarrhée, etc. les difficultés de préparation, stockage, conservation)

…………………………………………………………………………………………………

……………………………………………………………………………………………………..

Annex 3: Consumption frequency questionnaire

Objectif :Déterminer la fréquence de consommation des aliments contenant la pulpe de fruit de baobab et/ou de poudre de feuille de moringa chez les enfants de 6-59 mois estimer les portions généralement consommées à chaque prise.

Cible : Femmes mères d'enfant (s) de 6-59 mois dont l'enfant consomme des aliments contenant la pulpe de fruit de baobab et/ou de poudre de feuille de moringa.

Date de l'enquête : ………………....................... Zone biogéographique : …………………..

Département :……………………………... Commune …………………………………

Arrondissement : …………………………Village /quartier…………………………………

Heure début ………………………………. Heure de fin…… …. Durée…………………

Animateur …………………………………………………………………………………….

Rapporteur …………………………………………………………………………………….

Information sur l'enquêté :

Mère

Nom et Prénom (s)…………………………………………………………………………

Age………………………………………………………………………………………

Occupation…………………………………………………………………………………

Numéro de Téléphone: ……………………………………………………………………….

Enfant [1]

Nom et Prénom (s)…………………………………………………………………………

Age………………………………………………………………………………………

Sexe :……………………………………………………………………………………….

[1:] Enfant le plus jeune (6-59 mois) chez la femme enquêtée

1. Technique d'obtention de la poudre de feuille de moringa et de la pulpe de baobab

Ressources alimentaires	Technique d'obtention (grandes étapes)	Mode de stockage (mode et durée)	Mode de conservation (techniques et durée)
Poudre de feuille de Moringa			
Pulpe de baobab			

2. Techniques de fortification des aliments avec la poudre de feuilles de moringa et la pulpe du fruit de baobab (prenez les quantités de véhicule alimentaire et du fortifiant utilisé)

Fortifiants	Véhicules alimentaires	Quantité du fortifiant utilisé	Quantité du véhicule alimentaire (aliment de base)	Processus de fortification ou de supplémentation	Conservation de l'aliment fortifié (technique, durée de conservation)	Stockage de l'aliment fortifié (mode et durée de stockage)
Poudre de feuille de moringa						
Pulpe de baobab						

3. Quels sont les tabous liés à la consommation de la poudre de feuille de moringa dans votre village/communauté ?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

4. Quels sont les tabous liés à la consommation de la pulpe de baobab dans votre village/communauté ?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

5. Comment pensez-vous que l'on puisse amener les mères de cette communauté à en faire consommer davantage à leurs enfants davantage la poudre de feuilles de moringa ?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

6. Comment pensez-vous que l'on puisse amener les enfants de cette communauté à consommer davantage la pulpe de baobab ?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

7. Combien de fois vos enfants ont l'habitude de consommer les aliments contenant le moringa (feuille et /ou poudre de feuille) et/ou de la pulpe du fruit de baobab

Fréquence/Véhicules alimentaires / Fortifiants	Aliments véhicules	Combien de jour par semaine, le véhicule contenant le moringa (feuille et /ou poudre de feuille) et/ou pulpe du fruit de baobab est consommé (a)	Combien de fois par jour, le véhicule contenant le moringa (feuille et /ou poudre de feuille) et/ou pulpe du fruit de baobab est consommé (b)	Nombre d'occasion de consommation hebdomadaire du véhicule alimentaire fortifié (a*b)
Moringa (feuille et /ou poudre de feuille)				
Pulpe du fruit de baobab				

8. Plus précisément, votre enfant a t'il consommé des aliments contenant le moringa (feuille et/ou poudre de feuille) et/ou la pulpe du fruit de baobab la semaine passée ?

N°	Forme de consommation (Ex : bouillie, akassa,…)	Ingrédients utilisé (s)	Consommé au cours de la semaine dernière	
			Oui/non	Si oui, combien de jours ?
1	Ex : Bouillie	Ex : farine de mil, poudre de moringa,	Oui	4
2				

9. Pour les aliments contenant de la feuille/poudre de feuille de moringa et/ou de la pulpe de fruit de baobab et consommés au cours de la semaine dernière, préciser le nombre de fois par jour, et les quantités généralement consommées à chaque prise (demander l'instrument de mesure habituel et convertir selon les graduations des bols codés)

Cible	Reporter [1] N°	Si consommé au cours de la semaine dernière, combien de fois par jour de consommation ?							Portion généralement consommée à chaque fois	
		J1	J2	J3	J4	J5	J6	J7	Code bol[a]	Code portion [b]
Enfant (6- 59 mois)										

[a] : bol codé servant d'instrument de mesure
[b] : graduation préalablement faite dans chaque bol codé ,[1] reporter les numéros des formes de consommation des aliments citées plus haut

Annex 4: Sampling questionnaire (spot check)

Objectif : Déterminer la proportion d'enfant de 6-59 mois qui consomment de la pulpe de fruit de baobab et/ou de la poudre de feuille de moringa.

Cible : Femme en âge de procréer ayant au moins un enfant de 6-59 mois.

Date ……………………………………………………………………………………………………

Zone biogéographique ………………………………………Commune ……………………………..

Arrondissement ……………………………………………Village ………………………………...

Nom de l'enquêteur :…………………………………………………………………………...

Je voudrais vous demander si vous et/ou votre enfant de 6 à 59 mois consommez des aliments contenant la feuille de moringa et/ou la pulpe du fruit du baobab.

Faire une croix dans la cellule correspondant à la réponse de l'enquêté. **Un seul choix par enquêté ! Prenez cinquante (50) enquêtés**

N° enquêté	Consommation oui ou non d'aliment contenant le moringa ou la pulpe de baobab			
	OUI			NON
	Feuille de moringa	Pulpe du fruit de baobab	Les deux (feuille de Moringa et Pulpe de baobab)	
1				
2				
3				
4				
5				
6				

Annex 5: Acceptability test questionnaire for porridges

Date (JJ/MM): _____/ 05 /2017 Fiche no. ---------------

EVALUATION SENSORIELLE DES BOUILLIES DE MAÏS ET DE SORGHO FORTIFIEES AVEC LA POUDRE DE FEUILLE DE MORINGA (PFMO) ET/OU AVEC LA PULPE DE FRUIT DE BAOBAB

Nom et Prénoms de l'enfant: -------------------------- ---------------------------

Nom et Prénoms de la mère: -------------------------- ---------------------------

Sexe--------------------------- Age ------------------- Ethnie ---------------------

Consigne :

Consigne :

Donner à l'enfant les bouillies et observer sa réaction après la première cuillerée. Cocher l'expression faciale qui correspond à la réaction de l'enfant pendant la consommation des bouillies. Rincer chaque fois la bouche de l'enfant entre deux bouillies.

<u>Echantillon no. --------</u>

<u>Echantillon no. --------</u>

<u>Echantillon no. --------</u>

Annex 6: Acceptability test questionnaire for koata sauce

Date (JJ/MM): _____/ 05 /2017   Fiche no. ---------------

EVALUATION SENSORIELLE DE LA SAUCE KOATA FORTIFIEE AVEC LA POUDRE DE FEUILLE DE MORINGA (PFMO)

Nom et Prénoms de l'enfant: -------------------------- ---------------------------

Nom et Prénoms de la mère: -------------------------- ---------------------------

Sexe---------------------------   Age ---------------- Ethnie ------------------------

Consigne :

Donner à l'enfant les sauces koata (dans l'ordre indiqué) et observer sa réaction après la première cuillerée. Cocher l'expression faciale qui correspond à la réaction de l'enfant pendant la consommation des sauces. Rincer chaque fois la bouche de l'enfant entre deux sauces.

Echantillon no. --------

Echantillon no. --------

L'échantillon le plus apprécié est : … … …

Annex 7: Facial expressions of children (Acceptability tests)

Annex 8: Authorization for writing MSc thesis report in english

RÉPUBLIQUE DU BÉNIN

UNIVERSITÉ D'ABOMEY-CALAVI

FACULTÉ DES SCIENCES AGRONOMIQUES

Vice-Doyen

COORDONNATEUR DES ETUDES

N°..877/17../FSA/UAC/VD-CE Abomey-Calavi, le..31/05/..2017

Le Vice-Doyen, Coordonnateur des Etudes

A

Monsieur AFFONFERE Marius

(Etudiant en Master IAA/FSA/UAC)

Objet : a/s votre demande d'autorisation de rédaction de mémoire de Master en anglais

Monsieur AFFONFERE,

J'ai pris connaissance du contenu de votre lettre enregistrée sous le numéro 849 du 3 avril 2017 relative à votre demande d'autorisation de rédaction du mémoire de master en anglais.

Après examen de votre demande, la Coordination des Etudes vous autorise à le faire, à condition que la soutenance dudit mémoire se déroule aussi bien en français qu'en anglais, devant un jury mixte composé de francophones et d'anglophones, pour une meilleure analyse du document.

Tout en espérant que cette explication qui vous est fournie vous servira pour que la soutenance se passe dans les meilleures conditions possibles, je vous prie de recevoir, Monsieur AFFONFERE, mes salutations cordiales.

Le Vice-Doyen, Coordonnateur des Etudes

Le Vice Doyen

Professeur Bonaventure Cohovi AHOHUENDO

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Annex9: Deliverables (posters)

Mapping food traditionally fortified with moringa leaf powder and baobab fruit pulp for infant food in Benin

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Picture 1: baobab fruit

BACKGROUND

Reduction of the nutritional deficiencies can be achieved efficiently through food fortification (Bhagwat et al., 2014). Food-to-food fortification is more and more practiced; baobab fruit pulp (picture1) and moringa leaf powder (picture 2) are used as fortificants.

Picture 2: Moringa leaf powder

OBJECTIVES

(i) identify the local food candidate for food formulation, **(ii)** assess the consumption frequencies of the food traditionally fortified with moringa leaf powder and baobab fruit pulp.

METHODOLOGY

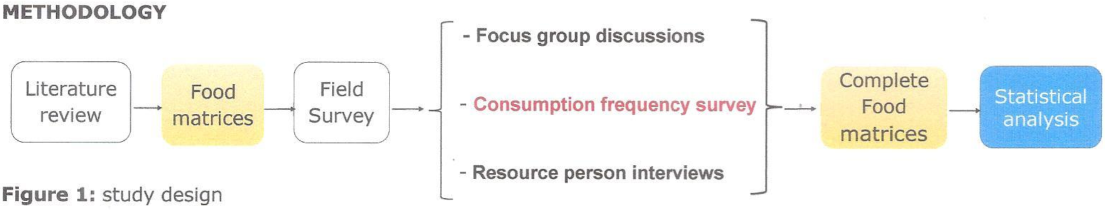


Figure 1: study design

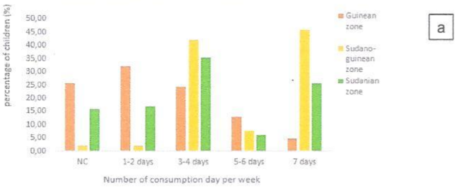
RESULT

Moringa leaf powder and baobab fruit pulp are traditionally used in infant diet in the three biogeographical zones of Benin; the Chi square test showed that their consumption frequency vary significantly from one zone to another (P<0.05), figure 2. Pictures 3, 4 and 5 show some foods identified.

Picture 3: Maize +sorghum porridge

Picture 4: Koata sauce

Picture 5 : Fresh tomato sauce



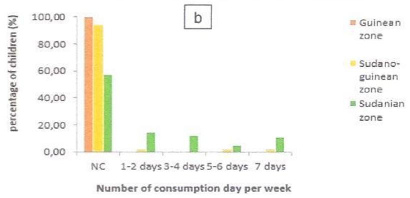


Figure 2: Frequency of consumption of the traditional foods fortified with moringa leaf powder (a) and baobab fruit pulp (b) , NC: Not consumed

CONCLUSION

The food using moringa leaf powder and baobab fruit pulp as fortificants are identified in the 3 biogeographical zones of Benin. Consumption of baobab fruit pulp as fortificant in infant food is absent in the guinean zone while moringa leaf powder is widely consumed throughout the country.

REFERENCE

Bhagwat, S., Deepti Gulati, D., Sachdeva, R. and Sankar, R. 2014. Food fortification as a complementary strategy for the elimination of micronutrient deficiencies: case studies of large scale food fortification in two Indian States. *Asia Pac J Clin Nutr*, 23: 4-11.

Acknowledgments

What is the bioaccessibility of micronutrients in the fermented sorghum ogi porridge dual fortified with moringa leaf powder and baobab fruit pulp ?

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Picture 1: Baobab fruit pulp (BFP)

1. BACKGROUND: Worldwide, more than 2 billion people are deficient in key minerals especially iron and zinc (Das et al., 2013)). Food-to-food fortification based BFP (picture 1) and PFMo (picture 2) can be promoted. Nevertheless, high nutrient content does not mean much if bioavailability is low (Hambidge; 2010, Schonfeldt et al; 2016).

Picture 2: Moringa leaf powder (PFMo)

2. OBJECTIVES : (i) formulate sorghum ogi porridge fortified with PFMo and BFP and **(ii)** assess micronutrients (Ca, Fe and Zn) content and their bioaccessibility

3. METHODS : Fortification rate was defined according with the local population practices and those identified in the literature. The digestibility study was performed using (Kiers et al., 2000) method.

4. RESULTS: 10g and 5g respectively of PFMo and BFP were blended with 100 g sorghum ogi porridge. The flow diagram for processing fermented sorghum ogi porridge is presented in figure 1.

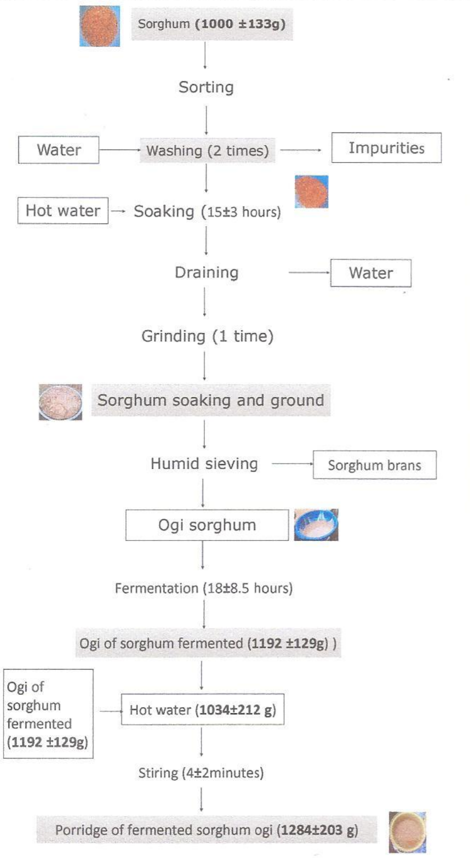

Figure 1 : Flow diagram for the processing of fermented sorghum ogi porridge

Tables 1 and 2 show respectively the micronutrients content and the bioaccessibility of micronutrients in the fortified and unfortified fermented sorghum ogi porridge.

Table 1: Micronutrients content of the fortified and unfortified fermented sorghum ogi porridge.

Foods	Ca (mg/100 g dw)	Fe (mg/100 g dw)	Zn (mg/100g dw)
Unfortified sorghum porridge	43.6±1.9[a]	7.3±0.2 [a]	**88.2±3.8 [a]**
Fortified sorghum porridge with PFMo and BFP	3454.5±86.4[b]	88.4±1.2 [b]	**202.4±3.1[b]**

Table 2: In Vitro Solubility (IVS) of the fortified and unfortified fermented sorghum ogi porridge.

Foods	IVS Ca (%)	IVS Fe (%)	IVS Zn (%)
Unfortified sorghum porridge	24.2±1.1[a]	3.8±0.4 [a]	0.5±0.1 [a]
Fortified sorghum porridge with PFMo and BFP	4.7±0.2 [b]	2±0.2 [b]	2.1±0.1 [b]

For tables 1 and 2 means (±standard deviation) with the same letter are not significantly different ($p>0.05$).

Fortification increases significantely the micronutients (Ca, Fe and Zn) content of the fermented sorghum ogi porridge ($p<0.05$), (Table 1). For IVS, a significant increasing ($p<0.05$) was observed only for zinc (Table 2).

5. CONCLUSION: Blending fermented sorghum ogi porridge with moringa leaf powder and baobab fruit pulp appears interesting for micronutrients content increasing especially zinc content improvement and its bioaccessibility.

Acknowledgments: