# Local and improved infant flours in vitamin A and iron, using powdered *Moringa oleifera* leaves and *Parkia biglobosa's* pulps powder

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***Abstract***- The consequences of malnutrition due to micronutrient deficiency on the health of humans, particularly iron deficiency, vitamin A and iodine, are multiple, particularly mortgaging the socio-economic development of developing countries (DCs). Food diversification, public health actions, food fortification and supplementation are the four (04) main strategies against malnutrition and this can improve the quality of life of a community or a country. The present study aimed to develop Chad infant flours fortified in vitamin A and zinc, iron and vitamin C taken from local products such as powder of dried *Moringa oleifera* leaves and pulps of *Parkia biglobosa* to improve the balance of these micronutrients in flours. The nutritional value of these flours was assessed according to standard analytical methods. The results revealed that, for 100 g of flour, our experimental flour showed 2 times more iron, vitamin C, magnesium, potassium and zinc, 4 times more vitamin A and calcium. The study found a slight increase in protein, total sugars and phosphorus.

Fortification of Chad local infant flours using *Moringa oleifera* leaves powder and pulps of *Parkia biglobosa* increase their micronutrient levels. The leaves of *Moringa oleifera* revealed potentials as a health supplement in the fight against malnutrition due to protein and micronutrient deficiency.

***Index Terms***- Chad, fortification, infant flours, iron, *Moringa oleifera*, vitamin A.

## I. Introduction

In developing countries (DCs), such as Chad, micronutrient deficiencies, especially iron, vitamin A and iodine, are a public health problem with significant physiological and economic consequences. The main weaknesses identified concern iodine deficiency, iron and vitamin A [1]. According to [2], 40% of the world population suffers from micronutrient deficiencies. Iron deficiency affects about 3.5 billion people worldwide mainly women from adolescence, infants and young children. Almost 27% of the world populations have an inadequate intake of zinc [3]. In developing countries, these deficiencies are rarely isolated and often are additional.

In the Sahel, the major determinants of child malnutrition include: inadequate food and feeding practices in the first two years of life (breastfeeding and complementary foods and feeding practices); poor care practices for infants, young children and women particularly during pregnancy and lactation; high morbidity levels and poor access to essential health services, safe drinking water and a healthy environment [4].

In 2005, the anemia affecting more than 47% of children under 5 years worldwide. This rate is about 40% in South America, 17% in Europe and 64.6% in the African continent, representing over 90 million children [5].The prevalence of anemia (hemoglobin, Hb < 11 g/dL) in children 6 months to 5 years, in 11 Francophone African countries amounted to 72.4% (from 60.2 to 87, 8%). Nearly 50% of reproductive age women are anemic. Malnutrition (vitamin and protein-energy) contributes to the development of anemia [6]. Iron deficiency is one of the main causes of anemia in Africa [5]. It is characterized by a low intake of hematopoietic factors (iron, vitamin B12, folates), due to the diets of plant-based that are often the staple food of the poorest populations in developing countries, very rich diets in inhibitory factors (polyphenols, phytates and fibers), and these factors decreasing the bioavailability of iron [7]. The most powerful enhancer of iron is ascorbic acid [8], the dose-dependent effect is a function of other activators or inhibitors (polyphenols, phytates, tannins) and regime [9].

The vitamin A deficiency affects about 127 million pre-school children including 4.4 million with signs of xerophthalmia and nearly 20 million pregnant women, with 25-35% of cases occur in Africa [10].

The vitamin A deficiency is usually due to inadequate intake of preformed vitamin A (retinol) or its precursors. It can also be due to a defect in the intestinal absorption during diarrhea and parasitosis [11].

In Chad, according to the document of the Chadian government, Food and Nutrition National Policy (PNNA) from 2014 to 2025, developed in 2013 with the support of UNICEF [12] for an estimated population of about 12 987 368 inhabitants in 2013; the prevalence of different forms of malnutrition among children under five years are troubling and even see critics across the country, beyond the WHO thresholds. Acute malnutrition (wasting) increased from 14.1% in 1996 [13] to 15.7% in 2010 [14]. Stunting, or chronic malnutrition, decreased from 40.1% in 1996 to 38.7% in 2010. The prevalence of underweight remained too high from 38.8% in 1996 to 30.3 % in 2010. The WHO thresholds being respectively >15%, >40% and >30%, to consider wasting, stunting and underweight as a public health problem. The national rate of exclusive breastfeeding (AME) up to 6 months is 3.4% and the rate of underweight infants at birth is 19.9% according to [14]. Extreme poverty still affects 46.7% of the Chadian population in 2011 and 59% of the poor live in rural areas against 25% in urban areas. According to the study of [15], two thirds of Chadian children 6 to 59 months were with moderate anemia (hemoglobin levels between 7.0 and 11.0 g/dl) and 11% with severe anemia (hemoglobin < 7.0 g/dl). The prevalence of anemia (76% for combined moderate and severe anemia) is well above the 40% threshold set by WHO to define anemia as a public health problem of severe level in the country [16].The prevalence of clinical vitamin A deficiency, xerophthalmia (dry eyes) in Chadian children 24 to 59 months is 5% and the coverage of vitamin A supplementation in children was 32% in 2004 [17]. With the efforts of the Government and partners, vitamin A supplementation was 97% in 2010 [14]. The consumption of iodized salt is low, 53%.

Chad is also facing complex and multifaceted challenges of instability in the sub region, the impact of the environment (drought, land degradation etc.) on food security, and international economic conditions (lower oil prices). Moreover, the country must deal with the consequences of high population growth (3.6% per year). SMART surveys were establishment in 2010, Chad has really engaged in a multi-sectoral approach to nutrition and diet from 2012. Thus, Chad officially joined the movement Scaling Up Nutrition (SUN) and REACH initiatives (Renew Effort Against Child Hunger and Undernutrition) and ACT-Sahel (Global Alliance for Resilience in the Sahel Initiative) in 2012 (REACH) and 2013 (SUN, ACT). Malnutrition is the underlying cause of more than 50% of infant mortality in Chad [18].

The consequences of micronutrient deficiencies on people health are multiple.

Iron deficiency, which in its most severe form results in anemia, affects deeply the cognitive development of young children and therefore impairs their ability to learn and their subsequent social and economic integration [19, 20]. Growth and physical performance are also affected [21] and increasing the immune infectious morbidity [22, 23, 24]. It is for these reasons that eradication of iron deficiency is a public health priority. In pregnant women, severe anemia is responsible for 20% of maternal deaths [25]. They increase the risk of morbidity, fetal and neonatal mortality and the risk of preterm birth and low infant weight at birth [26].

Vitamin A deficiency is the leading cause of blindness and visual disturbances (xerophthalmia) and increases the risks of morbidity and mortality probably while affecting the integrity of epithelial barriers and immunological functions [27]. It increases the risk of iron deficiency and anemia in particular negative effect on the mobilization of iron stores [28]. Zinc deficiency has a negative impact on the immune system and growth, and is associated with a higher risk of morbidity including diarrhea [29].

In developing countries, these deficiencies are rarely isolated and often additional. Yet in deficient populations, improving vitamin A status can reduce by 23% the mortality and morbidity in young children and women of childbearing age [30].

There are four (04) main strategies against malnutrition due to micronutrients deficiencies that are part of larger strategies for improving the quality of life of a community or a country. These four strategies, in decreasing order of sustainability [31] are: food diversification; public health actions; food fortification and supplementation. All international, local or family activities that improve household food security, health and care received by people individualy impact micronutrient deficiencies and should always be considered.

In 1979, a joint expert consultation of the WHO/UNICEF infant feeding and young children, recommended the promotion of local products in complementary foods [32]. In West Africa, from private and public sectors dialogue held in Accra (Ghana) in 2002 as part of food fortification in the sub region, food fortification approach has gained ground [33].

The valorization of local plant resources rich in protein and micronutrients, accessible at low cost is a strategy to effectively fight against nutritional deficiency [7, 34]. Imported or commercially developed foods generally are not used by low-income rural households due to high cost and poor availability. Our study is in this topic, valorization local products and strategy, fortification.

Several studies in many countries have highlighted the exceptional nutritional qualities of *M. oleifera leaves,* plant from India, used as food in Asia and Africa [7, 35, 36, 37, 38, 39, 40, 41]. Indeed, studies have shown the effectiveness of these leaves in the prevention, correction of malnutrition and related diseases although they contain anti-nutrients such as phytates and oxalates [38, 39, 40, 42, 43]. They can therefore be a food supplement for subjects malnourished because of its high protein, vitamins (A, B, C, E) and minerals (Ca, K, Mg, P, iron, Zn, As, Cu, Mn Na, Cl) and position itself as a tonic product, fortifying and stimulating the immune system.

Very few works have been conducted in Chad on the nutritional qualities of *Moringa* and *Parkia biglobosa*'s pulp, yet commonly consumed. Knowing also that the soil and climatic conditions strongly affect the nutrient composition of the plants, we have undertaken in one of our previous studies [44] to know the nutritional value and hygienic quality of the powder of dried leaves of *Moringa* and *Parkia biglobosa*'s pulp. This study revealed that the powder of *Moringa oleifera* leaves, for 100g, have a very high content of (ash, Ca, Fe, β-carotene); high content of (Mg, Zn, Vit.C and total sugars). Néré pulp for 100g, content a very good level of (total sugars, Vit.C, Ca and Zn), a good level of (Mg and Fe). Compared to 100g of *Moringa* from Burkina Faso, *Moringa* from Chad had lower levels in (fat, protein, Mg, Zn) [41].

Analysis of our local infant flours, powder of the *Moringa oleifera* dried leaves and néré pulp showed an acceptable hygienic quality according to the microbiological standards (GRET and ORSTOM) presented by [45]. However work is ongoing education to make to women producers to attach particular attention to drying conditions (protection against flies), and take care of their hands when handling flours.

The purpose of the present study was then to fortify Chad infant flours with vitamin A and zinc, iron and vitamin C taken from local products such as powder of dried *Moringa oleifera* leaves and pulps of *Parkia biglobosa* to improve the balance of these micronutrients and proteins in experimental flours.

## II. MATERIALS AND METHODS

Our study was conducted at the Laboratory of Biotechnology, Food and Nutritional Sciences (LABSAN) of the Research Center in Biological, Food and Nutritional Sciences (CRSBAN), UFR-SVT, University of Ouaga I Pr Joseph KI-ZERBO from 14 April to 15 October 2013. It focused on fortification of Chad infant flours in iron and vitamin C, vitamin A and zinc incorporating three rate of powder from dried leaves of *M. oleifera* and one rate of *Parkia biglobosa's* pulps powder.

### 1. Sample collection

Samples of local infant flours was each collected during April 2013 from women producers in 3 towns in Chad : in *N'Djaména* the capital of Chad and in *Bongor* and *Koumra , cities located* respectively at 235 km and 670 km south of *N'Djamena*. **Table I** displays origin and composition of these local infant flours.

The fresh *Moringa oleifera* leaves were collected in *Gounou Gaya*, town 400 km south west of *N'Djaména*. *Parkia biglobosa's* pulps powder was collected from saleswomen at the market in *Kélo*, a town 370 km south of *N'Djaména*.
Afterwards, enquiries were made with flours providers by oral questioning to access for flours processing in particular diagram of flours preparations.

### 2. Formulation of experimental flour

The SRK0, SRB0, MN0 and PN0 are Chad infant flours.

### 2.1. Processing of raw materials.

Treatment of maize, local rice and millet includes the following steps: manual sorting debris, skinning, winnowing and washing. Duration of drying at sun after washing, depending on the nature of the grain and sunshine. The grinding is performed using public mills followed by sieving. Make sure to ask the owners to clean the mill before grinding.

The millet after winnowing is soaked in water overnight, washed several times in the morning and dried. As for red sorghum, the only operation before the grinding is cleaning.

White beans (*Bongor*'s producer used *Vigna*) and peanuts are sorted, roasted sweet separately under fire, skinned and winnowed. Roasting is intended to significantly reduce humidity and viscosity, destroy bacteria, insects, anti-nutrients factors and allow the development of a particularly popular taste. Groundnut is measured and ground separately.

Fresh carrot and soil apple are washed, peeled, sliced and dried. The carrot is dried in the shade.

### 2.2. Manufacture of Chad infant flours.

Manufacture of red sorghum flour from *Koumra*: Production of the flour, after the common treatments above, is separately grind red sorghum, white beans and groundnuts. It then measures quantities for mixing, according to the manufacturing diagram.

Manufacture of red sorghum flour from *Bongor*: Here, sorghum and *Vigna* are roasted together. Peanuts are roasted on low heat to get white peanut tending towards brown smelling. Sorghum, cowpea, groundnut, potato, carrot; all dried, are ground together. Finally wherever powdered sugar is added with just a little cooking salt and any conditioning.

Manufacture of local rice flour from N'Djaména: Dried rice is toasted, ground and measured. The dried carrot in the shade is cleaned and milled. Both flours are mixed and measurement of powdered sugar was added thereto. According to the producer, this light and digestible rice flour is suitable from 4 months in case of impossibility or breastfeeding or mother's illness.

Manufacture of millet flour from N'Djaména: The dried millet, ground is measured separately. Beans, carrot and potato are measured and ground together. To this is added the millet flour, peanut paste and powdered sugar.

Manufacture of corn flour from N'Djaména: Dried maize, measured is ground separately. Beans, carrot and potato are measured, ground together. All are mixed with peanut paste and powdered sugar.

The percentage compositions of the above ingredients, weight per weight (w/w), in local flours such as developed by the producers are:

Red sorghum flour from *Koumra*: *Sorghum bicolor*: *Phaseolus vulgaris*: *Arachis hypogaea*: sugar (56: 16: 11.5: 16.5).

Red sorghum flour from *Bongor: Sorghum bicolor*: *Vigna unguiculata*: *Arachis hypogaea*: *Daucus carota*: *Solanum tuberosum*: sugar (52: 14: 12: 4: 2: 16).

Local rice flour: *Oryza sativa*: *Daucus carota*: sugar (67: 16.5: 16.5).

Millet flour: *Pennisetum typhoïdes*: *Phaseolus vulgaris* : *Arachis hypogaea*: *Daucus carota*: *Solanum tuberosum*: sugar (38: 9: 18.5: 9: 9: 16.5).

Corn flour: *Zea mays*: *Phaseolus vulgaris* : *Arachis hypogaea*: *Daucus carota*: *Solanum tuberosum*: sugar (38: 13: 19: 4.5: 9: 16.5).

### 2.3. Formulation experimental flours.

Each of this local flour was fortified with three levels of *Moringa* leaves powder and one level of néré pulp:
- *Moringa*: 5, 10 and 15%;
- *Parkia biglobosa's* pulps powder: 5%.

The standard flour (SRK0 for example) is composed of 100% of the local flour. SRK1 contains 90% SRK0, 5% *Moringa* and 5% néré; SRK2 = SRK0: *Moringa* powder: néré pulp: 85: 10: 5; SRK3 = SRK0: *Moringa* powder: néré pulp: 80: 15: 5% w / w.

### 3. Physical and Chemical Analysis

The parameters was determined using standard methods. The samples were analyzed in triplicate for ash, calcium, magnesium, iron, zinc, moisture, protein, fat, carbohydrates, vitamins A and C.

### 3.1. Determining Moisture

The sample (5g) undergoes drying in an oven at 103 ° C ± 2 ° C for three hours. The weight difference shows the moisture content [46].

### 3.2. Determining the Total Protein Content

Total protein content is determined following the Kjeldahl method [46] based on the total mineralization of the biological material in an acid environment, followed by distillation of nitrogen in ammonia form. The total mass of vegetable protein is calculated using a conversion factor of 6.25.

**3.3. Determination of Fats**

The fat content was analyzed according to the Soxhlet method [47]. The weight difference gives the fat content of the sample.

**3.4. Determination of Total Sugars**

The determination of the total sugar content of the samples was performed in triplicate by spectrometric assay samples [48]. The reading of optical densities was made at 540 nm using a µquant type plate reader (Biotek instrument Serial No. 157904, USA) coupled with a computer running KC integrated Junior (v1.31.5) software.

**3.5. Determination of Ash rate**

The sample (5g) introduced in metal crucibles was mineralized in a muffle furnace (type VOLCA V50) at 550°C for five (05) hours, removed using thongs and then cooled in a desiccators for about one (01) hour before being weighted. The difference in weight gives the ash content of the sample [47].

**3.6. Determination of Fe, Zn, Ca and Mg.**

Mineralization was achieved through dry ashing. The ash obtained contains major elements (Na, Ca, Mg, K, etc.) and trace elements (Fe, Zn, etc.). These minerals were determined by *Atomic Absorption Spectrometry* [49] (with a PELKIN Elmer model 3110 device (Connecticut, USA). A hollow Al-Ca-Cu-Fe-Mg-Si-Zn cathod lamp was used.

**3.7. Determination of Vitamin A (β-caroten) using HPLC.**

The analyzes were performed in the laboratory of toxicology and analytical chemistry Research and Training Unit in Health Sciences (UFR/SDS) from the University of Ouaga I Pr Joseph KI-ZERBO by a method adapted from that of [50] and described by [51]. The HPLC system used for analysis of vitamin A consists of a pump model JASCO PU 980, a UV/Visible JASCO 975, a chromatographic column C18 Nucleosyl model SUPELCO LC18 of 25 mm long; 4.6 mm in diameter with particles of size 5 µm. The system is coupled to an integrator type HP3395 and a computer with software (Galaxy Work Station) for registration, integration and data processing.

Analysis of vitamin A by HPLC: In analysis of vitamin A by the HPLC method at a wave length of 325 nanometers, the following steps should be taken: after the preparation of standards and calibration mixtures, the latter are injected into the system. Each mixture was injected three times and from the average of the values of the areas, the correction factors are calculated. The internal standard and the samples were then prepared and injected. Each sample must be injected three times and the content of vitamin A is retained from average of the triple injection.

**3.8. Determination of vitamin C by the method of 2, 6-DIP.**

The dosage of vitamin C was made by the method of [52].
Principle: The method is based on reduction of 2, 6-dichlorophenol-indophenol (2,6-DIP) at pH < 3. The solution of 2, 6-dichlorophenol-indophenol blue from becoming pink in acid. During the titration with a solution of ascorbic acid, it is reduced to a colorless base and at the same time the ascorbic acid is oxidized to dehydroascorbic acid. This method exploits the reducing properties of vitamin C, thus allows the determination of ascorbic acid and dehydroascorbic acid. Indeed, in acid or neutral medium, that is to say under the influence of oxidizing agents, there is opening of the double bond and C = C forming an α-diketone. The reaction is not specific, it is for this reason that acetone is used to trap the $SO_2$ may be present.

**Procedure: Extraction and determination.**

5g of sample are triturated for 5 minutes in a mortar in the presence of Fontainebleau sand of gram and 10 ml of acetic acid 90% (v/v). Add 5 ml of distilled water. Filter and recover the supernatant containing vitamin C in a 50 ml vial. The operation is repeated 3 times with 10 ml of 90% acetic acid. Make the volume of the vial with 90% acetic acid to obtain the extract. If the extract is highly concentrated, it must be diluted in 1% acetic acid (v/v) and refrigerate. 50 ml solution prepared from the powder of *Moringa* leaves was pipetted into a 100 ml flask and made up to 100 ml with oxalic acid to 1%. 10 ml of the solution was pipetted, and 2.5 ml acetone was added to it, then all placed in the dark for 10 minutes. The solution was titrated with 2, 6-dichlorophenol-indophenol until the color turns pink. We then prepared a blank in which the sample was replaced by distilled water. The title of DCPIP solution can be determined by titrating 10 ml of vitamin C solution.

Vitamin C content was calculated by the following relationship:

$$Vitamine\ C\ content = \frac{40\ (V - V')}{A}$$

where:
V = Volume (ml) of DCPIP used for titration of the powder;
V = volume (ml) of DCPIP used for titration of the blank;
A = Volume (ml) of DCPIP used for titration of 10 ml of standard solution of vitamin C.

**3.9. Determination of phosphorus.**

Phosphorus was determined using a Skalar autoanalyzer (Skalar, Breda, The Netherlands) [53].

**3.10. Determination of potassium and sodium.**

Potassium (K) and sodium (Na) were assessed by flame photometer (Corning 400, Essex, England) [53].

**3.11. Calculation of the Energy Value**

The energy value of flours was calculated using Watt and Merill coefficients [54], coefficients adopted by the United Nations Food and Agriculture Organization (FAO) in 1970:
X = P x 4 + G x 4 + L x 9

Where P = protein percentage, G = carbohydrates percentage, L = lipids (fats) percentage and *X* = energy value in Kcal/100g.

**3.12. Statistical Analysis**

All assays were carried out in triplicate, and the averages and Standards Deviations (SD) calculation have been done with the software Excel 2007. SPSS Statistics 21 was used for analysis of variance (ANOVA) between flours.

## III. RESULTS

What have we seen at the end of our work ?

The contents of moisture, energy, macro- and micronutrients of our local flours (SRK0, SRB0, PN0, RN0 and MN0) per 100g, in our previous study were: moisture [6.54 ± 0.30 (PN0 ) to 8.95 ± 0.11 (RN0)], energy [299.80 (SRB0) to 385.84 Kcal (PN0)], protein [7.00 ± 0.44 (RN0) to 12.69 ± 0 44g (MN0)], lipids [1.83 ± 0.13 (RN0) to 16.26 ± 0.84 g (MN0)], total sugars [29.24 ± 4.34 (MN0) to 64, 44 ± 4.52 g (RN0)], vitamin A [2.11 ± 0.04 (SRK0) to 30.47 ± 0.15 µg ER (SRB0)], vitamin C [9.41 ± 0.00 ( RN0) to 28.24 ± 0.00 g (SRB0)], Ca [5.65 ± 0.98 (SRK0) to 22.08 ± 2.96 g (PN0)], Mg [6.74 ± 0, 19 (RN0) to 24.99 ± 1.75 g (PN0)], P [109.00 ± 37.00 (RN0) to 295.00 ± 7.00 g (MN0)], K [115.50 ± 10.5 (RN0) to 722.50 ± 10.5 g (SRB0)], Na [1.50 ± 0.50 (PN0) to 7.00 ± 0.00 g (RN0)], Fe [7 11 ± 0.90 (SRK0) to 12.70 ± 0.56 g (PN0)] and Zn [0.67 ± 0.01 (RN0) to 2.51 ± 0.19 g (SRB0)].

The energy value of these flours is lower. To solve this problem, we increased peanut paste content in our experimental flours at the expense of the bean (w/w).

Then, our results leads us to suggest in the formulation of flours, a minimum of 12% to 20% (w/w) of ready to use peanuts in the total weight of the flour in order to have an energy value that meets the standards of at least 400 Kcal/100 g of flour.

According to the producers of these flours, rice flour, which contains only rice, carrot and a little sugar; is a light, easy to assimilate flour. It is not intended for nutritional recovery. For producers, it can be used from the 4th month in case of illness or death of the mother. It is recommended after these women, add after cooking porridge, an egg cooked separately, cooled and crushed.

Our experimental flours were made to improve their energy content (peanut paste) and balance of micronutrients (*M. oleifera* and pulp of *Parkia*). After fortification of flours, we obtained the following results: humidity [3.50 ± 0.16 (SRB1) to 6.96 ± 0.09 (PN1)], energy [349.10 (SRK1) to 439.36 Kcal (MN2)] protein [7.69 ± 0.32 (SRK1) to 16.10 ± 0.60 g (PN3) ] lipid [9.03 ± 0.10 (SRK1) to 13.64 ± 0.11 g (MN2)], total sugars [58.39 ± 4.46 (SRK1) to 71.25 ± 1.77 g (SRB3)], vitamin A [19.58 ± 0.09 (SRK1) to 115.88 ± 0.08 µg ER (MN3)], vitamin C [16.84 ± 0.00 (SRK1) to 37.89 ± 4.21 mg (SRK3) and (SRB3)], Ca [21.54 ± 3.27 (SRK1) to 86.33 ± 4.64 mg (PN3)], Mg [28.65 ± 1.80 (SRK1) to 53.82 ± 4.73 mg (MN3)], P [112.00 ± 44.00 (SRB2) to 302.00 ± 14.00 g (MN1)], K [513.00 ± 10 (MN1) to 858.50 ± 20.5 g (SRB3)], Na [2.00 ± 0.00 (PN1) to 10.50 ± 0.50 g (MN 2)], Fe [15.26 ± 1.38 (SRK2) to 28.42 ± 2.40 mg (PN3)] and Zn [2.18 ± 0.23 (SRB1) to 5.30 ± 0.46 mg (SRB2)].

All these results in macronutrients, minerals, vitamins A and C contents are displayed in Tables II-VI below. These results are compared to Plumpy'nut [55], Ready-to-Use Therapeutic Food (RUTF).

## IV. DISCUSSION

The fortification of our local flours in vitamin A and zinc, iron and vitamin C taken from local products such as powder dried *Moringa oleifera* leaves and pulps of *Parkia biglobosa* decreased moisture and lipid content in the experimental flours.

The comparison of 100g of local infant flours in macro- and micronutrients to 100 g of experimental flours shows 2 times more iron, vitamin C, magnesium, potassium and zinc; 4 times more vitamin A and calcium in experimental flours. But analysis of variance (ANOVA) showed that no significant difference has been found between flours. The study revealed a slight increase in protein, total sugars and phosphorus.

Compared to the standards of complementary foods listed in tables [56, 57, 58], we can say that all our experimental flours have a good iron content, beyond required standards. It is the same for potassium.

For proteins, PN2 and PN3; MN2 and MN3 meet standards. About lipids content, only corn-based flours meet the standards. All red sorghum flours from *Bongor* (SRB), rice's flour from N'Djamena, SRK3, PN2 and PN3, MN2 are in conformity with the standards that relate to total sugars. The SRK3, SRB3, PN2 and PN3, MN3 flours are in conformity with vitamin C standards for children. Three flours, SRK3, SRB2 and MN3 have contents that meet the standards for the content of zinc in addition to infant flours.

As for the other parameters, although there was an increase compared to local flours, we note that our results fall short of the recommendations concerning the vitamin A, calcium, phosphorus, magnesium and sodium content. All experimental flours have a moisture content in conformity with complementary foods. As to the recommended energy value for these flours, only the red sorghum flours from *Koumra* do not reach the minimum of 400 kcal required for 100 g of flour.

Compared to the Plumpy'nut, our experimental flours have the same levels of protein but their total sugars and iron content are higher. For the rest, our results were lower than average levels of Plumpy'nut.

[59] in their study of feasibility of adding the powder of *Moringa* leaves in the flour MISOLA reported that the addition of 5 to 10 g of the *Moringa* powder to 100 g of flour allowed to obtain the following results: vitamin A (300 to 600 µg ER /day), zinc (0.1 to 0.2 mg/day), iron (1.2 to 2.4 mg/day), vitamin C (2.5-5 mg/day) and calcium (100 to 200 mg/day). These results compared to ours show high levels of vitamin A and calcium in their study while the rest of the parameters analyzed (Zn, Fe and vitamin C), our flours had higher levels.

The contents of our experimental flours in vitamin A, calcium, phosphorus and zinc were lower than those found by [60] who used the mineral and vitamin complex (CMV). Our flours are similar to [60] in energy and iron but have a higher level of fat content.

[40] in their study fortified their cereal flours (corn, rice and millet) using *Cucurbita maxima*, *Moringa oleifera*, pulp of *Parkia biglobosa* and pulp of *Adansonia digitata*. Our experimental flours are in concordance with their moisture and total sugars levels. Their results in protein, potassium and zinc are lower than ours. However, all other parameters analyzed, except for vitamins A and C that are not included in their study, they scored higher than ours. Their results are: energy (424.56 to 458.96), fat (11.82 ± 0.02 to 17.02 ± 0.02), calcium (400 ± 1 to 710 ± 1), phosphorus (251 ± 1 to 430 ± 4), magnesium (115 ± 10

to 190 ± 25) sodium (14 ± 1 to 40 ± 5) and iron (30.23 ± 10 to 37.96 ± 12).

## V. CONCLUSION

Fortification of our local infant flours using powder of dried *Moringa oleifera* leaves and pulps of *Parkia biglobosa* increased all levels of minerals, vitamins, proteins and carbohydrates. The strongest increase was in vitamin A and calcium. This contribution decreased moisture and lipid content in the experimental flours. *Moringa oleifera* is able to fortify complementary foods and can be used in the fighting against malnutrition. Bioavailability in non-heme iron still remains to be explored. The use of roasted peanuts and winnowed in formulas between 12 and 20% of the total weight of the infant flour improves the energy value of flours even if the manual mixing of paste with flour remains a difficult task. Product promotions of *Moringa oleifera* necessarily involve good sensitization of the population on the importance of the plant. We must also train people for good processing and better storage of products of *Moringa oleifera*.

This study showed that fortification of complementary foods using local plant resources rich in protein and micronutrients such as *Moringa oleifera*, accessible at low cost is a strategy to effectively fight against malnutrition due to micronutrient deficiency.

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**Table I. Origin and composition of local infant flours in Chad.**

| Nature of flour | Composition | Origin |
|---|---|---|
| **1. Local child's red sorghum flour, *Sorghum bicolor*.** | 1) Red sorghum<br>2) Beans<br>3) Peanut butter paste<br>4) Sugar | *Koumra* (SRK0) |
| **2. Local child's red sorghum flour, *Sorghum bicolor*.** | 1) Red Sorghum<br>2) Cowpea<br>3) Peanut butter paste<br>4) Sugar<br>5) Potato<br>6) Carrot | *Bongor* (SRB0) |
| **3. Local child's rice flour, *Oryza sativa*.** | 1) Local husked rice<br>2) Carrot<br>3) Sugar | *N'Djaména* (RN0) |
| **4. Local child's pearl millet flour, *Pennisetum typhoides*.** | 1) Pearl millet<br>2) Beans<br>3) Peanut butter paste<br>4) Sugar<br>5) Potato<br>6) Carrot | *N'Djaména* (PN0) |
| **5. Local child's corn flour, *Zea mays*.** | 1) Corn<br>2) Bean<br>3) Peanut butter paste<br>4) Sugar<br>5) Potato<br>6) Carrot | *N'Djaména* (MN0) |

**Table II : Nutrient content of 100 grams, experimental *infant* flours *of a red sorghum-based, from Koumra (average ± standard deviation)***

| **Nutrients** | **SRK0** | **SRK1** | **SRK2** | **SRK3** | **Plumpy'nut[a] (per 100 g)** | **RNI** |
|---|---|---|---|---|---|---|
| Energy (Kcal) | 353,30 | 349,10 | 381,34 | 400,03 | 520 | 400-425[e] |
| Moisture (%) | 3,19 ± 0,64 | 3,67 ± 0,19 | 3,97 ± 0,08 | 4,11 ± 0,34 | 2,5 | ≤ 5[e] |
| Ash (g) | 1,87 ± 0,00 | 2,37 ± 0,02 | 2,80 ± 0,00 | 3,15 ± 0,02 | | ≤ 3[e] |
| Proteins (g) | 10,31 ± 0,48 | 7,69 ± 0,32 | 10,97 ± 0,55 | 14,25 ± 0,22 | 13 | 15[d] |
| Fats (g) | 9,74 ± 0,11 | 9,42 ± 0,14 | 9,10 ± 0,28 | 9,03 ± 0,10 | 26 | 10-25[e] |
| Total sugars(g) | 63,16±0,58 | 58,39 ± 4,46 | 63,89 ± 4,01 | 65,44 ±0,57 | 41 | 64 ± 4[e] |
| **Vitamins** | | | | | | |
| Vitamin A[b] (µg RAE) | 2,11 ± 0,04 | 19,58 ± 0,09 | 38,70 ± 0,06 | 60,70 ± 0,12 | 800 | 200[d] |
| Vitamin C (mg) | 18,82 ± 0,00 | 16,84 ± 0,00 | 16,84 ± 0,00 | 37,89 ± 4,21 | 50 | 30[c] |
| **Minerals** | | | | | | |
| Calcium (mg) | 5,65 ± 0,98 | 21,54 ± 3,27 | 32,10 ± 3,22 | 45,98 ± 1,95 | 300 | 400[c] |
| Phosphorus (mg) | 140,50±60,50 | 136,00±56,00 | 150,00±70,00 | 149,00±61,00 | 361 | 456[e] |
| Potassium (mg) | 502,50 ± 20,5 | 649,00 ± 21 | 754,00 ± 21 | 827,50 ± 10,5 | 1100 | 516[e] |
| Magnesium (mg) | 24,56 ± 1,02 | 28,65 ± 1,80 | 37,96 ± 1,42 | 51,99 ± 0,86 | 80 | 60[c] |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sodium (mg) | 2,00 ± 0,00 | 2,50 ± 0,50 | 2,00 ± 1,00 | 3,00 ± 1,00 | 290 | 296[e] |
| Iron (mg) | 7,11 ± 0,90 | 16,30 ± 1,40 | 15,26 ± 1,38 | 26,76 ± 1,19 | 10 | 11,6[c] |
| Zinc (mg) | 2,17 ± 0,16 | 3,17 ± 0,22 | 3,75 ± 0,24 | 4,74 ± 0,24 | 11 | 4,8[c] |

[a] LECOSSAIS, 2014.
[b] Estimated from µg beta-carotene using 06 µg beta-carotene = 1 µg RAE
RNI: Recommended Nutrient Intake.
[c] FAO/WHO, 2002.
[d]CODEX CAC. 1989.
[e] CODEX CAC/GL 08. 1991.

**Table III : Nutrient content of 100 grams, experimental *infant* flours *of a red sorghum, from Bongor (average ± standard deviation)***

| **Nutrients** | **SRB0** | **SRB1** | **SRB2** | **SRB3** | **Plumpy'nut (per 100 g)** |
|---|---|---|---|---|---|
| Energy (Kcal) | 403,33 | 399,49 | 409,30 | 420,46 | 545 |
| Moisture (%) | 3,22 ± 0,03 | 3,50 ± 0,16 | 4,05 ± 0,15 | 4,05 ± 0,29 | |
| Ash (g) | 2,16 ± 0,01 | 2,62 ± 0,01 | 3,01 ± 0,03 | 3,44 ± 0,01 | |
| Proteins (g) | 13,81 ± 2,41 | 11,95 ± 1,30 | 12,94 ± 1,22 | 12,94 ± 0,32 | 13,6 |
| Fats (g) | 8,77 ± 0,98 | 9,69 ± 0,21 | 9,38 ± 0,06 | 9,30 ± 0,06 | 35,7 |
| Total sugars(g) | 67,29 ± 4,05 | 66,12 ± 1,54 | 68,28 ± 0,01 | 71,25 ± 1,77 | 33,5 |
| **Vitamins** | | | | | |
| Vitamin A (µg RAE) | 30,47 ± 0,15 | 46,92 ± 0,09 | 86,86 ± 0,12 | 103,54 ± 0,08 | 910 |
| Vitamin C (mg) | 21,05 ± 0,00 | 27,37 ± 2,11 | 29,47 ± 0,00 | 37,89 ± 4,21 | 53 |
| **Minerals** | | | | | |
| Calcium (mg) | 10,49 ± 1,64 | 35,63 ± 5,63 | 53,58 ± 7,80 | 53,78± 37,80 | 320 |
| Phosphorus (mg) | 140,00±52,00 | 127,00±47,00 | 112,00±44,00 | 120,50±44,50 | 394 |
| Potassium (mg) | 722,50±10,5 | 848,00±10 | 712,00±21 | 858,50±20,5 | 1111 |
| Magnesium (mg) | 23,30 ± 0,62 | 37,24 ± 1,29 | 45,07 ± 0,47 | 52,94 ± 0,59 | 92 |
| Sodium (mg) | 2,50±0,50 | 3,00±0,00 | 3,00±0,00 | 4,00±0,00 | 189 |
| Iron (mg) | 08,23 ± 1,00 | 17,25 ± 0,79 | 18,83 ± 0,80 | 21,51 ± 2,14 | 11,5 |
| Zinc (mg) | 2,51 ± 0,19 | 2,18 ± 0,23 | 5,30 ± 0,46 | 4,02 ± 0,28 | 14,00 |

**«** Same abbreviations as in table II »

**Table IV : Nutrient content of 100 grams, experimental *infant* flours *of millet-based, from N'Djamena (average ± standard deviation)***

| Nutrients | PN0 | PN1 | PN2 | PN3 | Plumpy'nut (per 100 g) |
|---|---|---|---|---|---|
| Energy (Kcal) | 390,06 | 384,35 | 403,47 | 422,97 | 545 |
| Moisture (%) | 7,47 ± 0,12 | 6,96 ± 0,09 | 6,90 ± 0,12 | 6,73 ± 0,14 | |
| Ash (g) | 1,84 ± 0,00 | 2,39 ± 0,00 | 2,69 ± 0,01 | 3,06 ± 0,01 | |
| Proteins (g) | 12,06 ± 0,52 | 12,19 ± 0,25 | 15,6 ± 0,29 | 16,1 ± 0,60 | 13,6 |
| Fats (g) | 9,91 ± 0,24 | 9,35 ± 0,18 | 9,47 ± 0,30 | 9,21 ± 0,41 | 35,7 |
| Total sugars(g) | 63,16 ± 0,50 | 62,86 ± 1,28 | 63,96 ± 2,30 | 68,92 ± 1,32 | 33,5 |
| **Vitamins** | | | | | |
| Vitamin A (µg RAE) | 3,80 ± 0,04 | 36,26 ± 0,16 | 51,92 ± 0,16 | 98,85 ± 0,09 | 910 |
| Vitamin C (mg) | 21,05 ± 4,21 | 25,26 ± 0,00 | 33,68 ± 0,00 | 25,26 ± 0,00 | 53 |
| **Minerals** | | | | | |
| Calcium (mg) | 22,08 ± 2,96 | 51,91 ± 0,59 | 66,22 ± 3,09 | 86,33 ± 4,64 | 320 |
| Phosphorus (mg) | 120,50±44,50 | 116,50±48,50 | 121,00±53,00 | 116,50±48,50 | 394 |
| Potassium (mg) | 429,50±10,5 | 659,50±31,5 | 525,50±81,5 | 722,50±31,5 | 1111 |
| Magnesium (mg) | 24,99 ± 1,75 | 32,88 ± 3,00 | 35,19 ± 2,89 | 46,54 ± 3,26 | 92 |
| Sodium (mg) | 1,50±0,50 | 2,00±0,00 | 2,50±0,50 | 3,50±0,50 | 189 |
| Iron (mg) | 12,70 ± 0,56 | 16,49 ± 1,55 | 23,77 ± 2,69 | 28,42 ± 2,40 | 11,5 |
| Zinc (mg) | 1,53 ± 0,16 | 2,59 ± 0,41 | 3,37 ± 0,01 | 4,34 ± 0,01 | 14,00 |

« Same abbreviations as in table II »

**Table V : Nutrient content of 100 grams, experimental *infant* flours *of rice-based, from N'Djamena (average ± standard deviation)***

| Nutrients | RN0 | RN1 | RN2 | RN3 | Plumpy'nut (per 100 g) |
|---|---|---|---|---|---|
| Energy (Kcal) | 327,88 | 346,91 | 356,41 | 366,07 | 545 |
| Moisture (%) | 6,20 ± 0,04 | 6,27 ± 0,07 | 6,33 ± 0,10 | 6,08 ± 0,05 | |
| Ash (g) | 0,73 ± 0,01 | 1,35 ± 0,00 | 1,94 ± 0,01 | 2,39 ± 0,01 | |
| Proteins (g) | 9,00 ± 0,22 | 10,67 ± 0,12 | 11,56 ± 0,57 | 11,75 ± 0,64 | 13,6 |
| Fats (g) | 3,79 ± 0,01 | 3,23 ± 0,16 | 3,33 ± 0,07 | 4,11 ± 0,04 | 35,7 |
| Total sugars (g) | 64,44 ± 0,25 | 68,79 ± 1,60 | 70,05 ± 1,67 | 70,52 ± 0,76 | 33,5 |
| **Vitamins** | | | | | |
| Vitamin A (µg RAE) | 4,33 ± 0,11 | 32,02 ± 0,11 | 54,91 ± 0,09 | 87,40 ± 0,20 | 910 |
| Vitamin C (mg) | 16,84 ± 0,00 | 21,05 ± 0,00 | 25,26 ± 4,21 | 31,58 ± 2,11 | 53 |
| **Minerals** | | | | | |
| Calcium (mg) | 08,40 ± 0,92 | 30,31 ± 2,07 | 84,23 ± 7,29 | 77,19 ± 9,73 | 320 |
| Phosphorus (mg) | 109,00±37,00 | 41,50±13,50 | 39,50±15,50 | 54,50±18,50 | 394 |
| Potassium (mg) | 115,50±10,5 | 230,00±21 | 324,50±31,5 | 429,50±10,5 | 1111 |
| Magnesium (mg) | 06,74 ± 0,19 | 15,24 ± 0,79 | 26,15 ± 0,70 | 33,38 ± 0,23 | 92 |
| Sodium (mg) | 7,00±0,00 | 3,00±1,00 | 1,00±0,00 | 1,00±0,00 | 189 |
| Iron (mg) | 08,94 ± 0,75 | 14,50 ± 0,84 | 14,37 ± 1,68 | 25,39 ±2 ,02 | 11,5 |
| Zinc (mg) | 0,67 ± 0,01 | 1,57 ± 0,11 | 2,93 ± 0,14 | 1,99 ± 0,21 | 14,00 |

« Same abbreviations as in table II»

**Table VI : Nutrient content of 100 grams, experimental *infant* flours *of corn-based, from N'Djamena (average ± standard deviation)***

| Nutrients | MN0 | MN1 | MN2 | MN3 | Plumpy'nut (per 100 g) |
|---|---|---|---|---|---|
| Energy (Kcal) | 439,18 | 410,66 | 439,36 | 419,76 | 545 |
| Moisture (%) | 4,02 ± 0,08 | 4,35 ± 0,09 | 4,18 ± 0,05 | 3,93 ± 0,05 | |
| Ash (g) | 1,75 ± 0,01 | 2,50 ± 0,22 | 3,07 ± 0,01 | 3,41 ± 0,00 | |
| Proteins (g) | 14,69 ± 0,34 | 12,72 ± 1,12 | 15,13 ± 1,36 | 13,59 ± 1,25 | 13,6 |
| Fats (g) | 14,74 ± 0,68 | 13,46 ± 0,48 | 13,64 ± 0,11 | 13,16 ± 0,48 | 35,7 |
| Total sugars (g) | 61,94 ± 1,12 | 59,66 ± 2,16 | 64,02 ± 1,92 | 61,74 ± 1,32 | 33,5 |
| **Vitamins** | | | | | |
| Vitamin A (µg RAE) | 13,79 ± 0,12 | 41,27 ± 0,09 | 76,50 ± 0,04 | 115,88 ± 0,08 | 910 |
| Vitamin C (mg) | 16,84 ± 0,00 | 29,47 ± 4,21 | 25,26 ± 0,00 | 35,79 ± 2,11 | 53 |
| **Minerals** | | | | | |
| Calcium (mg) | 09,37 ± 2,22 | 32,82 ± 7,45 | 41,39 ± 6,32 | 71,79 ± 16,82 | 320 |
| Phosphorus (mg) | 295,00±7,00 | 302,00±14,00 | 280,50±21,50 | 209,50±78,50 | 394 |
| Potassium (mg) | 366,50±10,5 | 513,00 ± 10 | 565,00±21 | 586,00±0,00 | 1111 |
| Magnesium (mg) | 17,20 ± 0,29 | 30,68 ± 4,84 | 39,84 ± 1,45 | 53,82 ± 4,73 | 92 |
| Sodium (mg) | 2,00±0,00 | 3,00±0,00 | 10,50±0,50 | 7,00±0,00 | 189 |
| Iron (mg) | 8,07 ± 0,61 | 15,49 ± 0,59 | 21,53 ± 2,41 | 26,65 ± 1,05 | 11,5 |
| Zinc (mg) | 1,73 ± 0,14 | 2,89 ± 0,05 | 3,82 ± 0,01 | 5,11 ± 0,28 | 14,00 |

« Same abbreviations as in table II»