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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

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ABSTRACT

This study aims to develop infant flours fortified with iron and vitamin A, taken from local products such as powder from dried *Moringa oleifera* leaves and pulps of *Parkia biglobosa* to improve the nutritional status of children aged 6 to 24 months. Chemical analyses show that, for 100 g of local flours destined for children, there are adequate protein levels (between 7.00 ± 0.44 and 12.69 ± 0.44 g) and fat content (between 7.52 ± 0.35 and 16.26 ± 0.84 g), but that there are low levels of *β*-carotene and certain micronutrients Zn (0.67 ± 0.01 to 2.51 ± 0.19 mg), Fe (7.11 ± 0.90 to 12.70 ± 0.56 mg), Ca (0.67 ± 0.01 to 2.51 ± 0.19 mg), Mg (6.79 ± 0.19 to 24.99 ± 1.75 mg). Analyses of minerals and vitamins showed that *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). 100 g of *Parkia biglobosa*'s pulps is rich in magnesium (73.00 ± 1.14 mg), iron (14.82 ± 2.49 mg), zinc (7.79 ± 0.44 mg) and vitamin C (75.29 ± 0.00 mg). In conclusion, we believe that these two ingredients can be effectively used to fortify local infant flours in vitamin A and iron and contribute to eradicating malnutrition due to micronutrients deficiencies.

Keywords: Childhood Flours; Nutritional Value; Hygienic Quality; Fortification; Chad

1. Introduction

The United Nations Millennium Summit [1] made hunger eradication its first development goal (MDG), adopting the main objective of the 1996 World Food Summit; to reduce the number of undernourished people to half their present level no later than 2015 [2].

However, the United Nations *Food and Agriculture Organization* (FAO) estimates that 925 million individuals suffer from hunger and that malnutrition mainly affects Asia, South America and Africa, including 239 million people in sub-Saharan Africa [3].

According to the *Chad General Population and Housing Census* of 2009 [4] Chad's population is 11,175,915, of which 993,492 live in the capital, N'Djamena. Chad's population growth is 3.4% per year against an average of 2.4% for the African continent.

In Chad, poverty is widespread and deep-rooted. According to results from the *Survey on Consumption and the Informal Sector* [5], the 2003 poverty level in Chad stands at around 396 CFA francs (less than one US dollar) per day. About 55% of Chadians live below this poverty line, and so are considered as poor.

From several surveys carried out in Chad, the nutritional problems most frequently encountered are protein-energy malnutrition, iron deficiency anemia, vitamin A deficiencies and endemic goiter. More than 80% of malnourished children admitted to *rehabilitation and nutritional education centers* (CREN) in Chad were between 6 months and 2 years of age [6].

The second *Chad Demographic and Health Survey* [5] indicated that 41% of children under 5 suffer from stunted growth, about 37% are underweight and 14% suffer from emaciation. The infant mortality rate in 2004 was 191 per 1000 live births.

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According to [7], two thirds of Chadian children between 6 and 59 months had moderate anemia (hemoglobin rate between 7.0 g/dl and 11.0 g/dl) and 11% showed signs of severe anemia (hemoglobin rate <7.0 g/dl). The prevalence of anemia (a combined 76% with moderate and severe anemia) is well above the 40% threshold, as used by the WHO to define anemia as a severe public health problem [8].

The prevalence of a clinical vitamin A deficiency, xerophthalmia (dry eyes), in Chadian children between 24 and 59 months is 5%, and the coverage level of vitamin A supplements for children was 32% in 2004 [9].

Vitamin A deficiency significantly aggravates the risk of serious illness and death from common childhood infections, particularly diarrhea and measles. According to a UN report, the improvement of vitamin A levels leads to a 23% reduction in child mortality amongst those aged one to five years [10]. An intake of protein and zinc is essential for vitamin A metabolism.

In 1979, a joint WHO/UNICEF consultation on feeding infants and young children recommended the promotion of local products in food supplements [11].

The treatment of malnutrition in children under 5 years, as well as its prevention, requires nutritious food, exclusive breastfeeding up to six months, a healthy environment, access to health care and adequate prenatal care. Poverty and food insecurity seriously reduce access to a balanced diet comprising high-quality proteins, adequate bio-available micronutrient content minerals, essential fatty acids, low anti-nutrient levels, and a high nutritional value [12].

From six months of age, the growth of most children in developing countries (DCs) deviates from a satisfac tory growth model as a result of:

- Repeated infections.
- The inadequacy of complementary feeding [13].

During infancy, an adequate nutritional diet is essential to ensure healthy human resources, and a necessary condition for sustainable development.

To achieve the goals of the World Summit for Children in 1990, the fight against micronutrient deficiencies often follows four strategies: food diversification, fortification, supplementation, and public health/hygiene measures [1].

Our study concerns the fortification aspect. It aims to show the value of local products in improving the nutritional micronutrient status of young children from 6 to 24 months, through the promotion of access to complementary foods fortified with iron and vitamin A.

2. Materials and Methods

2.1. Sampling

A 3 kg sample of local infant flours was each collected from women producers in 3 towns in Chad: in *N'Djaména* the capital of Chad and in *Bongor* and *Koumra located* respectively at 235 km and 670 km south of *N'Djamena* (**Figure 1**). These flours were collected and analyzed during the months of July 2011 and April 2012. **Table 1** gives us origin and composition of these local infant flours.

The fresh *Moringa oleifera* leaves were collected in *Gounou Gaya*, 400 km south west of *N'Djaména.*

Pulps of *Parkia biglobosa*, was collected from women vendors at the market in *Kélo*, a town 370 km south of *N'Djaména*.

2.2. The Local Preparation of Different Flours

Different local flours were made following production charts (**Figure 2**) particular to each group or women's association.

Technology of Marie-Claire MBERBE and Ache Lawane, social center No. 1. The following steps are the same amongst all the women: sorting, shelling, dehulling, drying, sieving, roasting, and mixing.

For red sorghum-based flours, from *Koumra* and *Bongor*, the only operation before sorghum-milling is the cleaning. Other differences occur at the milling stage and at the mixing of various ingredients.

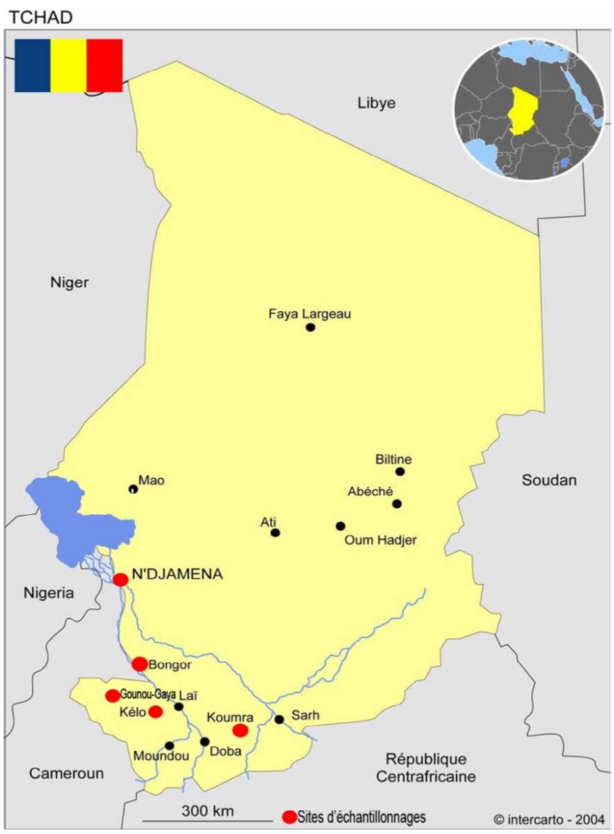

Figure 1. Sampling sites.

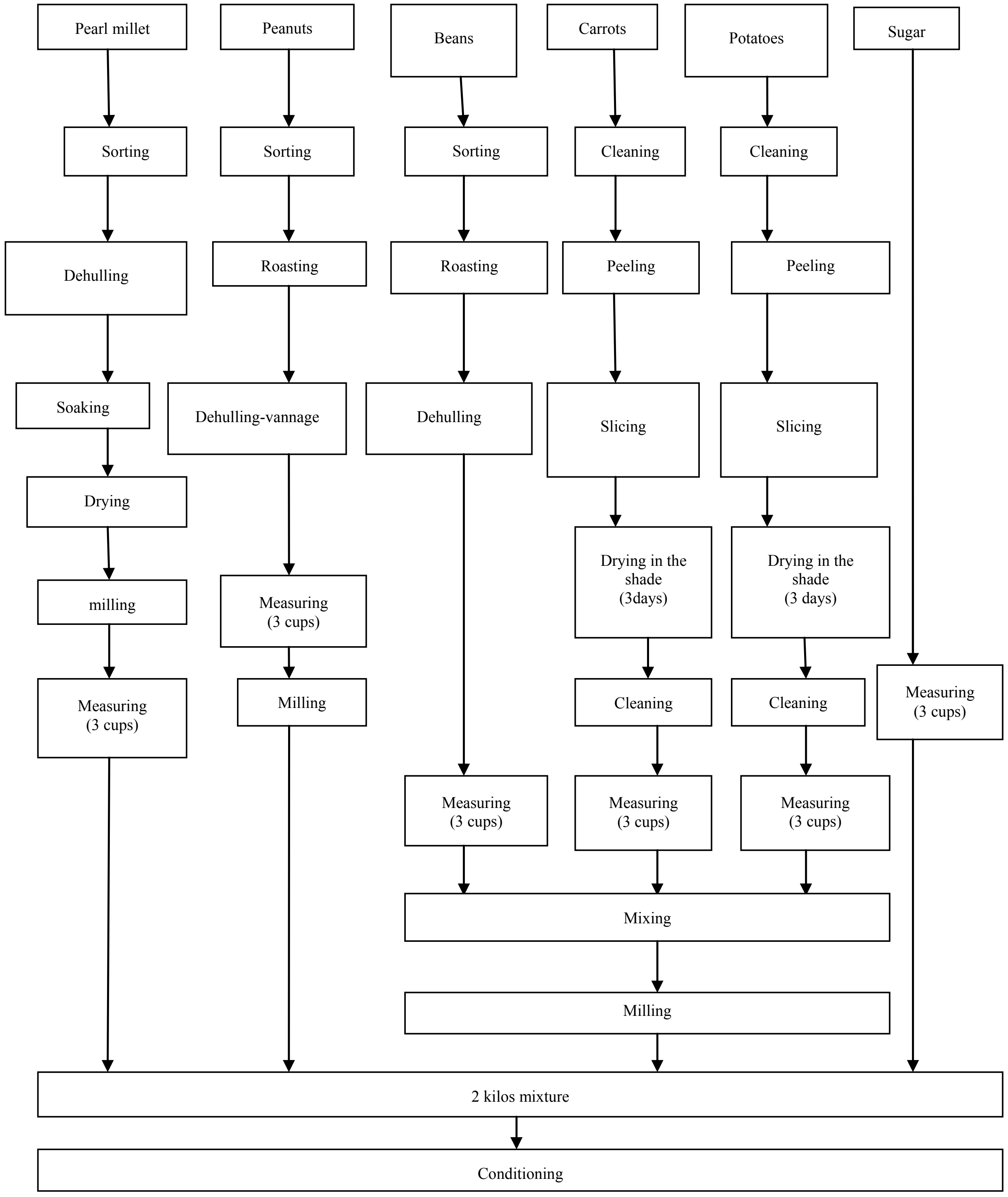

Figure 2. Diagram of the local infant pearl millet (*Pennisetum typhoid*) flour processing.

For rice-based flours, local rice and carrots are treated, ground separately, mixed with powdered sugar and conditioned.

For sorghum-based flours from Bongor, red sorghum, cowpeas, peanuts and potatoes are all processed, mixed together and heated on the stove, then cooled and ground.

Table 1. Origin and composition of local infant flours in Chad.

Nature of meal	Composition	Origin
1. Local child's red sorghum flour, *Sorghum bicolor*.	1) Red sorghum 2) Beans 3) Peanut butter paste 4) Sugar	*Koumra* (SK)
2. Local child's red sorghum flour, *Sorghum bicolor*.	1) Red Sorghum 2) Cowpea 3) Peanut butter paste 4) Sugar 5) Potato 6) Carrot	*Bongor* (SB)
3. Local child's rice flour, *Oryza sativa*.	1) Local husked rice 2) Carrot 3) Sugar	*N'Djaména* (RN)
4. Local child's pearl millet flour, *Pennisetum typhoïdes*.	1) Pearl millet 2) Beans 3) Peanut butter paste 4) Sugar 5) Potato 6) Carrot	*N'Djaména* (PN)
5. Local child's corn flour, *Zea mays*.	1) Corn 2) Bean 3) Peanut butter paste 4) Sugar 5) Potato 6) Carrot	*N'Djaména* (MN)

The carrot is treated separately up to the grinding stage, without cooking, as in the chart above. Finally, the whole lot is mixed with powdered sugar and conditioned.

Regarding red sorghum-based flours from *Koumra*, the red sorghum and the beans are processed, ground separately, then mixed with powdered sugar and conditioned.

Finally, for corn flour meals, the corn and peanuts are processed and ground separately, while the beans, potatoes and carrots are processed, mixed and ground together. The whole lot is then mixed and powdered sugar is added.

Sorting, performed manually, eliminates debris such as panicles or spikes. De-husking of millet, corn and rice, is carried out using a husker-sheller.

After washing, the ingredients are dried at room temperature. Drying time depends on the type of grain and sunshine levels.

The grinding is performed using mills and is followed by sieving.

The roasting process significantly reduces moisture, viscosity and anti-nutrients, helps to kill bacteria and insects, but also develops a flavor appreciated those consuming it. Roasting involves grilling in a large aluminum pot [6]. During this operation, the seeds or flour are continuously stirred with a wooden spatula.

2.3. The Physico Chemical Analyzes

The assays were performed according to standard methods. The samples were analyzed in triplicate for calcium, magnesium, iron, zinc, moisture, protein, fat, carbohydrates and ash.

2.3.1. Determining Moisture

The sample (5 g) un-dergoes drying in an oven at 105˚C ± 2˚C for three hours. The weight difference shows the moisture content [14].

2.3.2. Determining the Total Protein Content

It is measured following the Kjeldahl method [14] 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.

2.3.3. Determination of Fats

5 g of each sample was weighed and introduced into an extraction cartridge, covered by cotton. The cartridge was placed in a 150 ml glass Soxhlet [15]. The solvent container was weighed and 400 ml of n-hexane was added. The soxhlet was then introduced into the container placed on the heating mantle, which was then connected to the cryostat cooling thermostat. Four to six siphoning processes were conducted over 5 hours. The heating mantle was disconnected. The solvent was then evaporated in a RE 121 Rotavapor (made in Switzerland). The container with the fat was placed in an oven for 3

hours at 103˚C, and then in a desiccator for 30 min and then weighed. The weight difference gives the fat content of the sample.

2.3.4. Determination of Total Sugars

The determination of the total sugar content of the samples was performed in triplicate by spectrometric assay samples [16]. The reading of optical densities was made at 540 nm using a µquant type plate reader (Bio-tek instrument Serial No. 157904, USA) coupled with a computer running KC integrated Junior (v1.31.5) software.

2.3.5. Determination of Ash Rate

The sample (5 g) 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 weighed. The difference in weight gives the ash content of the sample [14].

2.3.6. Determination of Minerals

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* [17] (with a PELKIN Elmer model 3110 device (Connecticut, USA). A hollow Al-Ca-Cu-Fe-Mg-Si-Zn cathode lamp was used.

2.3.7. Calculation of the Energy Value

The energy value corresponding to the available energy was calculated using [18] coefficients, coefficients adopted by the United Nations Food and Agriculture Organization (FAO) in 1970:

$$X = P \times 4 + G \times 4 + L \times 9$$

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

2.4. Microbiological Analyzes of Locally Made Infant Flours

2.4.1. Preparation of Samples for Analysis

The stock solution for each parameter was prepared with 10 g of each sample (except for the detection of *Salmonella*, where 25 g of flour was used), aseptically removed and diluted in 90 ml of autoclaved Buffered Peptone Water (Liofilchem, Italy). The mixture is placed in a sterile stomacher bag that ensures the grinding for 2 minutes. The mix is put back in the flask, with a 10^{-1} dilution rate. A cascade dilution in autoclaved test tubes was done by taking 1 ml (or 1000 µl by the pipette) of the previous solution and putting it into 9 ml of NaCl. Dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} are then successfully obtained. Each time, the end of the test tube is subjected to flaming as soon as it is opened. After having added the 1000 µl, it is again subjected to flaming before being closed.

There follows a process of autoclaving the test tubes (2 per sample) containing the Rappaport, to search for *Salmonella*. Seeding was done by plating 200 µl of each aliquot taken. Each dilution was inoculated into two Petri dishes and incubated.

2.4.2. Numeration of the Total Aerobic Mesophilic Flora

The total aerobic mesophilic flora (FAMT) was counted in PCA (Plate Count Agar Liofilchem, Italy) conditions, after 24 hours of incubation at 30˚C under aerobic conditions [19].

2.4.3. Searching for Total and Thermotolerant Coliforms

Detection for indicators of fecal contamination in a Eosin Methylen Blue (EMB) medium was carried out, to enumerate total coliforms and thermotolerant, after 48 hours of incubation, at 37˚C and 44˚C (±0.5) respectively, under aerobic conditions [19].

2.4.4. Searching for *Escherichia coli*

E. coli was looked for in eosin methylen blue (EMB) after 24 hours of incubation at 44˚C under aerobic conditions [20].

2.4.5. Searching for Moulds and Yeasts

Yeasts and moulds were counted in a Sabouraud setting, after 3 - 5 days of incubation at 30˚C, under aerobic conditions [19].

2.4.6. Searching for *Salmonella* and *Shigella*

Testing for the presence or absence (PA) of *Salmonella* and *Shigella* was conducted in a SS setting after 3 - 5 days of incubation at 37˚C, under aerobic conditions.

2.4.7. Searching for Suspected Pathogenic *Staphylococci*

Suspected pathogenic *Staphylococci*, especially *Staphylococcus aureus*, were counted in the Chapman, or Mannitol Salt Agar (MSA, Liofilchem, Italy), setting, after 24 hours of incubation at 37˚C, under aerobic conditions [19].

2.4.8. 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.

3. Results

Knowledge of the physico-chemical composition and of the microbiological quality of infant flours is an important aspect when evaluating foodstuffs.

3.1. Physico-Chemical Parameters of Local Infant Flours

The macronutrient, mineral and vitamin contents of the local infant flours are presented in **Tables 2-6**. **Tables 7** and **8** give the same information about the powder from dried *Moringa oleifera* leaves and from pulps of *Parkia biglobosa*.

3.2. Hygienic Quality of Infant Flours Cell Enumeration in Flours Samples

The counting of the different flora in the samples allowed us to achieve results expressed in *Colony Format Units* (CFU) per gram of flours. These are shown in **Table 9**. The Petri dishes with 30 to 300 CFU/g were considered. These values represent averages from two analyzes.

The sanitary quality of flours must be consistent with

Table 2. The nutritional value of 100 g of a red sorghum-based local infant flours, from *Koumra* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	325.32	682[b]
Moisture (%)	6.67 ± 0.58	
Ash (g)	1.87 ± 0.00	
Proteins (g)	8.31 ± 0.88	10.28[c]
Fats (g)	7.52 ± 0.35	
Total sugars(g)	56.1 ± 0.55	
Vitamins		
Vitamin A (β-carotène)	2.11 ± 0.04 µg ER	400
Vitamin C (mg)	18.82 ± 0.00	30
Minerals		
Iron (mg)	7.11 ± 0.90	11.6
Zinc (mg)	2.17 ± 0.16	8.4
Calcium (mg)	5.65 ± 0.98	400
Magnesium (mg)	24.56 ± 1.02	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF/University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 3. Nutritional value for 100 g of local red sorghum infant flours, from *Bongor* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	299.80	682[b]
Moisture (%)	7.66 ± 0.57	
Ash (g)	2.16 ± 0.01	
Proteins (g)	11.81 ± 4.81	10.28[c]
Fats (g)	10.34 ± 1.91	
Total sugars (g)	39.88 ± 6.42	
Vitamins		
Vitamin A (β-carotène)	30.47 ± 0.15 µg ER	400
Vitamin C (mg)	28.24 ± 0.00	30
Minerals		
Iron (mg)	8.23 ± 1.00	11.6
Zinc (mg)	2.51 ± 0.19	8.4
Calcium (mg)	10.49 ± 1.64	400
Magnesium (mg)	23.30 ± 0.62	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF/University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 4. Nutritional value for 100 g of local infant millet-based flours, from *N'Djamena* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	385.84	682[b]
Humidiy (%)	6.54 ± 0.30	
Ash (g)	1.84 ± 0.00	
Proteins (g)	10.06 ± 0.88	10.28[c]
Fats (g)	10.33 ± 0.57	
Total sugars (g)	63.16 ± 0.49	
Vitamins		
Vitamin A (β-carotène)	3.80 ± 0.04 µg ER	400
Vitamin C (mg)	23.53 ± 4.71	30
Minerals		
Iron (mg)	12.70 ± 0.56	11.6
Zinc (mg)	1.53 ± 0.16	8.4
Calcium (mg)	22.08 ± 2.96	400
Magnesium (mg)	24.99 ± 1.75	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF/University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 5. Nutritional value for 100 g of local rice-based infant flours, from *N'Djamena* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	302.24	682[b]
Humidy (%)	8.95 ± 0.11	
Ash(g)	0.73 ± 0.01	
Proteins (g)	7.00 ± 0.44	10.28[c]
Fats (g)	1.83 ± 0.13	
Total sugars (g)	64.44 ± 4.52	
Vitamins		
Vitamin A (β-carotène)	4.33 ± 0.11 µg ER	400
Vitamin C (mg)	09.41 ± 0.00	30
Minerals		
Iron (mg)	8.94 ± 0.75	11.6
Zinc (mg)	0.67 ± 0.01	8.4
Calcium (mg)	8.40 ± 0.92	400
Magnesium (mg)	6.74 ± 0.19	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF/University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 6. Nutritional value for 100 g of local corn-based infant flours, from *N'Djamena* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	314.07	682[b]
Moisture (%)	7.95 ± 0.35	
Ash (g)	1.75 ± 0.01	
Proteins (g)	12.69 ± 0.44	10.28[c]
Fats (g)	16.26 ± 0.84	
Total sugars (g)	29.24 ± 4.34	
Vitamins		
Vitamin A (β-carotène)	13.79 ± 0.12 µg ER	400
Vitamin C (mg)	14.12 ± 4.71	30
Minerals		
Iron (mg)	8.05 ± 0.61	11.6
Zinc (mg)	1.73 ± 0.14	8.4
Calcium (mg)	09.37 ± 2.22	400
Magnesium (mg)	17.20 ± 0.29	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF/University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 7. Nutritional value for 100 g of powdered *Moringa oleifera* leaves, from *Gounou Gaya* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	253.73	682[b]
Moisture (%)	9.31 ± 0.18	
Ash (g)	10.50 ± 0.07	
Proteins (g)	24.28 ± 0.22	10.28[c]
Fats (g)	7.42 ± 1.56	
Total sugars (g)	22.46 ± 2.02	
Vitamins		
Vitamin A (β-carotène)	624.40 ± 0.41 µg ER	400
Vitamin C (mg)	65.88 ± 0.00	30
Minerals		
Iron (mg)	53.75 ± 5.07	11.6
Zinc (mg)	17.58 ± 0.89	8.4
Calcium (mg)	1443.90 ± 11.03	400
Magnesium (mg)	176.72 ± 0.73	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF /University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 8. Nutritional value for 100 g of *Parkia biglobosa*'s pulps powder, from *Kélo* (average ± standard deviation).

Nutrients	Value	RDA[a]
Energy (Kcal)	304.04	682[b]
Moisture (%)	13.20 ± 0.22	
Ash (g)	5.17 ± 0.29	
Proteins (g)	4.59 ± 0.22	10.28[c]
Fats (g)	2.49 ± 0.65	
Total sugars (g)	65.82 ± 2.51	
Vitamins		
Vitamin A (β-carotène)	33.85 ± 0.25 µg ER	400
Vitamin C (mg)	75.29 ± 0.00	30
Minerals		
Iron (mg)	14.82 ± 2.49	11.6
Zinc (mg)	7.79 ± 0.44	8.4
Calcium (mg)	142.06 ± 4.11	400
Magnesium (mg)	73.00 ± 1.14	54

RDA: Recommended Daily Allowance. [a]Joint FAO/WHO Expert Consultation, 2002. Vitamin and mineral requirements in human nutrition. Geneva: World Health Organization, 2002; [b]WHO (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. UNICEF/University of California-Davis/WHO/ORSTOM. Geneva: WHO/NUT/98.1; [c]FAO/OMS/UNU, 1986. Besoins énergétiques et besoins en protéines. Série Rapports.

Table 9. CFU/g of different flora in the samples.

	FAMT	Total Coliforms	Therm. Colif	*E. coli*	Moulds	Yeast	Staph.	Salm
SK	5.8×10^4	0	0	0	250	0	0	-
SB	3.4×10^4	250	0	0	375	750	0	-
MN	4.6×10^4	750	0	0	0	750	0	-
RN	1.3×10^4	3.7×10^3	0	0	250	0	0	-
PN	2.3×10^4	10^4	0	0	750	750	0	-
NK	5.2×10^4	250	0	0	0	500	0	-
MG	9.5×10^3	0	0	0	125	250	0	-

-: signifies an absence of salmonella; Therm. Colif = Themotolerant coliforms; Staph. = *Staphylococcus aureus*; Salm = *Salmonella*.

Table 10. Microbiological standards for infant flours.

Microorganisms/g of food	Flours requiring cooking	Instantaneous flours
Aerobic mesophilic bacteria	$<10^5$	$<10^4$
Fecal coliforms	<100	<20
Escherichia coli	<10	<2
Salmonella	0	0
Aflatoxins	0	0
Yeasts and moulds	$<10^3$	Unspecified

international recommendations, and with local legislations in the countries where the flours is manufactured or sold. **Table 10** presents the GRET and ORSTOM microbiological specifications presented by [21].

Considering the microbiological standards above, the analyzed local flours show acceptable hygiene levels. However, work needs to be continued to raise awareness, amongst women producers, of particular issues such as drying conditions (protection against flies) and taking care of their hands when handling the flours.

When searching for suspected pathogenic *Staphylococci*, especially *Staphylococcus aureus*, some suspicious colonies were seen, but the coagulase was negative.

4. Discussion

Analysis of the chemical composition, especially of macronutrients, of local flours produced the results shown in the tables above.

The moisture levels (%) in the flours vary from 6.54 ± 0.30 for PN to 8.95 ± 0.11 for RN, nearly all of which are one unit superior to those obtained by [6] in five infant flours called Vitafort, which were based on the same grains from Chad. The Vitafort meals had three ingredients: cereals, cowpeas and peanut paste. Most homemade flours now also contain potato and carrot.

The standards adopted on complementary feeding of young children [22] say that the water content should be less than 8 g per 100 g of flours. Only the rice-based flours (8.95 ± 0.11) seem to deviate from this. Its process should be reviewed to find the cause of this problem and to solve it.

The study of the chemical composition shown in **Tables 2-6** sets out certain findings. Protein levels (7.00 ± 0.44 for RN to 12.69 ± 0.44 g per 100 g for MN) are lower than the values obtained by [6] (11.5 to 13.7 g per 100 g). However, for fats, with the exception of rice-based flours (1.83 ± 0.13 g per 100 g), our results (7.52 ± 0.35 for SK to 16, 26 ± 0.84 for MN) were superior to their own (5.5 to 8.5). Our results for total sugars ranged from 29.24 ± 4.34 for MN to 64.44 ± 4.52 for RN and energy levels (299.80 Kcal for SB to 385.84 Kcal for PN). The results recorded by [23], who worked on ten cereal-based complementary foods using extruded cereals, roasted cereals and uncooked cereals, are higher than our results for these last two parameters. These were, respectively, sugars (66.2 to 80.17) and energy values (432 to 484 Kcal). The same is true for protein (10.32 to 14.6) and zinc (0.82 to 5.0).

The analysis of micronutrients shows the richness of our flours in iron (7.11 ± 0.90 mg/100g for SK to 12.70 ±

0.56 for PN) and in zinc (0.67 ± 0.01 mg/100g for RN to 2.51 ± 0.19 for SB), compared to Vitafort where the values found were very low, respectively, from 1.94 to 4.77 µg/100g, and 1.98 to 3.23 µg/100g). Given the richness in minerals of the powder from dried *Moringa oleifera* leaves and from pulps of *Parkia biglobosa*, we are optimistic that the enrichment of local flours by these two ingredients will increase their iron and zinc content.

However, our flours have very low levels of calcium (5.65 ± 0.98 mg per 100 g for SK to 22.08 ± 2.96 for PN) and of magnesium (6.74 ± 0.19 for RN to 24.99 ± 1.75 for PN, mg per 100 g) compared to the flours used by [6], which respectively recorded (32 - 60) and (59 - 138) the differences between the results may be explained by the transformation process (drying and roasting), by the soil type and also by possible interactions between nutrients. We hypothesize that these low levels of Ca and Mg in our flours will be improved by the addition of *Moringa* and *pulps of Parkia biglobosa*; both of which were found to be rich in these minerals.

The protein, fat, iron, zinc and vitamin A levels were found to be higher than those of [13] in seven types of traditional porridge, which were respectively 6.6 ± 2.1 g; 3.0 ± 0.8 g; 7.2 ± 2.1 mg; 1.8 ± 1.1 mg and 1.4 ± 0.9 µg ER. Regarding the fats, our results are similar to those of [23], but concerning calcium and iron levels, we obtained figures higher than [23]'s, which were respectively 2.73 to 10.7 mg and 2.64 to 9.0 mg.

The powder of the dried *Moringa oleifera* leaves was alone more concentrated for the majority of the nutrients in our study, except for fats (7.42 ± 1.56 g) and total sugars (22.46 ± 2.02 g), than the local infant flours: proteins (24.28 ± 0.22 g), minerals (Ca 1443.90 ± 11.03 mg; Mg 176.72 ± 0.73 mg; Fe 53.75 ± 5.07 mg; Zn 17.58 ± 0.89 mg) and vitamins (β-carotene 624.40 ± 0.41 µg ER, vitamin C 65.88 ± 0.00 mg). The high mineral content of the *Moringa oleifera* powder is easily explained by its high ash content (10.50 g per 100 g).

In their study [24] of the powder from dried *Moringa oleifera* leaves, obtained results superior to our own, regarding the protein, carbohydrate, calcium, magnesium, ash and energy values. These values were respectively: 39.69 ± 0.01g; 35.33 g; 1526.74 ± 50.03 mg; 428.87 ± 85.96 mg; 11.39 ± 0.66 g and 358.73 Kcal. In terms of iron and zinc levels, we obtained results superior to those of their study, which were respectively 18.86 ± 1.20 mg and 2.13 ± 0.07 mg per 100 g. Our results are similar with regard to fats. They found 7.85 ± 0.28 g per 100 g.

Analysis of pulps of *Parkia biglobosa* showed higher levels in our study, total sugars being 65.82 ± 2.51 g and vitamin C levels at 75.29 ± 0.00 mg.

This pulp is richer in iron (14.82 ± 2.49 mg), zinc (7.79 ± 0.44 mg), calcium (142.06 ± 4.11 mg), magnesium (73.00 ± 1.14 mg), and β-carotene (33.85 ± 0.25 µg ER) than our local infant flours, and so is similar to *Moringa* in terms of richness, in our study. It also has the highest water content (13.20 ± 0.22%) but remains low in protein (4.59 ± 0.22 g).

5. Conclusions

In conclusion, this study identified the physico-chemical parameters (moisture, ash, protein, fat, carbohydrates, minerals, vitamins A and C), and the microbiological quality of five local infant flours, of the powder of dried *Moringa oleifera* leaves and of *Parkia biglobosa*'s pulps, all of which came from Chad.

This study shows that local infant flours have adequate protein and fat levels, but the levels of certain micronutrients (Zn, Ca, Mg) are below recommended levels for this type of flours. Their β-carotene content is very low. *Moringa oleifera* powder is rich in protein, while pulps of Parkia biglobosa are richer in total sugars.

Mineral analyses showed that *Moringa oleifera* powder is very rich in calcium and magnesium for macronutrients, rich in iron and zinc for trace elements, and rich in β-carotene. Pulps of *Parkia biglobosa* are rich in magnesium for macronutrients, rich in iron, zinc for trace elements, and rich in vitamin C.

The transformation of *Moringa* leaf into powder remains good practice, for better preservation of the product but also for a high concentration of nutrients.

Analysis of the chemical composition of dried *Moringa oleifera* leaves and of *Parkia biglobosa*'s pulps reveals qualities of nutritional great interest.

We hypothesize that the addition of *Moringa oleifera* and pulps of *Parkia biglobosa* into local meals will lead to an increase in levels of protein, iron, zinc, and vitamins A and C.

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