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Research Article

Effect of Moringa in the Quality of Flours to Fight Protein-Energy Malnutrition in Mali

Daou Cheickna[1], Coulibaly Moussa[1*], Samake Fasse[2], Keita Ibrahima[3]

[1]Department of Food and Nutrition, Food Technology Laboratory of the Institute of Applied Sciences, Bamako, Mali; [2]Department of Food and Nutrition, Microbiology laboratory of the Institute of Applied Sciences, Bamako, Mali; [3]Department of Food and Nutrition, University of Technical Sciences and Technology, Bamako, Mali

ABSTRACT

Infant flours, made from cereals, locally available legumes easily accessible incorporating *Moringa oleifera* powder have been formulated and composed. Their carbohydrate, lipid, protein and mineral contents were determined by the methods of Bertrand, Soxhlet, Kjeldahl and atomic absorption spectrophotometry respectively. Humidity was determined by the moisture meter. The organoleptic quality of the porridges made with these compound flours was determined by the taste test. Three types of infant flours have been formulated: F1 flour (70% millet, 17% corn, 7% soya, 4.5% milk, 0.5% potato and 1% Moringa), flour F2 (40% millet, 40% corn , 8% soy, 7% peanuts, 3% milk, 1% potato and 1% Moringa) and F3 flour (40% corn, 35% millet, 10% soy, 10% peanuts, 3% milk, 1% potato and 1% Moringa). The flours have an average carbohydrate content of 55.57 mg/100 g, protein 14.21 mg/100 g, fat 8.50 mg/100 g, moisture 7.66%, ash 1.66 mg/100 g, energy 365 kcal/100 g. F2 gave the lowest humidity 6.27%. While F3 had the highest ash content 1.76%. F2 and F3 gave substantially the same protein level 15.75% and 15.37%. The organoleptic quality of the porridge made with the F2 flour was deemed acceptable compared to the two other flours.

Keywords: Flour; Infant; Moringa; Porridge; Protein-energy malnutrition; Mali

INTRODUCTION

Breast milk is considered the best food for newborns. Thus, the World Health Organization (WHO) recommends that mothers feed their children exclusively at the breast until 4-6 months and continue breastfeeding as much as possible until two years, while introducing little few other foods including those in the family dish [1]. During this so-called weaning period, the baby needs special food that provides enough energy, protein and other nutrients such as vitamins, minerals and trace elements. However, in developing countries, many mothers give children, from 6 to 60 months, porridge which is most often prepared with local cereal flour (corn, millet, sorghum, etc.). These porridges fill the stomach of the child and temporarily cut off his appetite, but they are not very nutritious because they are poor in protein, vitamins and mineral salts [2]. Their energy density is less than 60 kcal per 100 ml, less than milk [3]. This diet results in malnutrition, especially the so-called protein-energetic one [4].

Protein-energy malnutrition is a major problem, which affects more than 800 million children under the age of 5 worldwide and that more than 54% of deaths of these children are attributable to it. Globally, 1,300,000 children die each of malnutrition [5,6]. An analysis of 28 epidemiological studies conducted by the FAO showed that 56% of child deaths are attributable to malnutrition and that in 83% of cases it is mild to moderate malnutrition [7]. Indeed, the particularly high mortality and morbidity of children aged six months to three years in developing countries owe a lot to undernourishment and malnutrition [5].

In Mali, 30% of children aged 0 to 35 months suffer from chronic malnutrition. In other words, children are stunted, that is, they are too small for their age [8]. The most affected regions are Mopti and Sikasso respectively with 15% and 13% cases of malnutrition [9]. They are followed by the regions of Kayes and Koulikoro (precisely the circles of Nara and Kolokani) respectively with 12.6% and 12.4% [9]. In Segou, child

Correspondence to: Coulibaly Moussa, Food and Nutrition, Food Technology Laboratory of the Institute of Applied Sciences, Bamako, Mali; E-mail: ballack20061985@yahoo.fr

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malnutrition is not directly linked to a lack of food, but rather to the diet of families [10]. The prevalence of global acute malnutrition in the northern regions is 12.4% in Timbuktu and 13.5% for the entire Gao region characterized as a serious nutritional situation according to the WHO classification [11].

In general, malnutrition is characterized by a protein and energy deficiency necessary to ensure the child's development. South of the Sahara in general and in Mali in particular, the food traditionally given to children is cereal-based porridge [1]. This diet is deficient in protein because of inappropriate processing techniques such as hulling. On the other hand, there are good quality infant flours on the market such as phosphatine wheat dina, vita-wheat celac, etc. But they are imported industrial products and are expensive. Therefore they are not accessible to most mothers, who have low incomes.

Moreover, weaning can be considered as a nutritional aggression for the infant accustomed to feeding exclusively on breast milk. Therefore, the use of quality infant flours during this period is of great importance. An infant flour is a compound flour that is given in the form of porridge to children from the age of six (6) months in addition to breast milk. It must be specially designed to meet their nutritional needs, taking into account the intake of breast milk and the daily frequency of meals. Infant flours can be obtained from the mixture of cereals, legumes and other inputs after careful preparation, which taken separately are unable to cover all the nutritional needs of the child [12,13].

Thus, several attempts to produce local weaning foods were made in Africa during the 1950's and 1970s and almost all failed. It was not until the 1980's that industrial infant flour production units appeared, such as Misola in Burkina Faso in 1982, Vita fort in Congo at the end of 1990, Viten in Togo in 1990 [14]. Thus, based on work carried out on the nutritional needs of newborns, infants and young children (before 3 years) for more than 30 years and WHO recommendations [15] that various types Infant foods of good nutritional quality have been proposed [16], such as infant flour made from cassava and soy [17], sprouted corn, sprouted sorghum and sprouted soy flour [18]. A view to expanding the range of infant flours, we have initiated this infant flour formulation study based on our local cereals and legumes that are easily accessible and available for all mothers by incorporating *Moringa oleifera*, for the fight against protein-energy malnutrition in children in Mali.

Moringa oleifera, a plant available almost everywhere in Mali, is rich in nutrients (proteins, minerals, vitamins, etc.). *Moringa oleifera* leaf powder has been introduced into infant flours to increase their protein, vitamin and mineral content [19]. Thus, the objective of this study is to formulate three types of infant flours with millet, corn, soybeans, peanuts, potatoes, whole milk powder and moringa leaf powder, while characterizing them on the physicochemical, nutritional and organoleptic.

MATERIALS AND METHODS

The plant material consisted of cereals (millet, maize), legumes (soya and peanuts), vegetables (sweet potato) and moringa (powder).

Flour production

Production of sprouted millet flour: The millet, purchased at the local market in Kalaban-coura, was cleaned, washed and soaked in a basin containing water at ordinary temperature for 7 hours. After soaking, it was first wrung out using a sieve, then wrapped in a cotton cloth and placed in the germinator for germination for 3 days. The sprouted grains were first dried in the shade before being separated from their seedlings to be finely ground using a UMC5 type cereal grinder. Then it was sieved with a 1 mm mesh sieve.

Corn flour production: The shelled maize grains, purchased at the local market of Kalaban-coura, were cleaned, washed and dried at 45°C in an oven. Then, they were finely ground with the UMC5 type cereal grinder and sieved using a 1mm mesh sieve.

Soybean flour production: The soybeans, purchased at the local Bolibana market, were cleaned, sorted and washed. After spinning and drying, they were crushed and sieved with a 1 mm mesh sieve.

Potato flour production: The potato tubers have been carefully cleaned and finely cut (thickness 1mm). The potato slices were then dried in the shade for 48 hours and then finely ground into a powder (1 mm mesh).

Roasted peanut flour (Dough) production: Peanut kernels, purchased at the local market, were sorted and roasted until golden brown. After roasting, they were cleared of their thin skins by winnowing in order to be ground.

Production of Moringa oleifera leaf powder: The Moringa leaves were washed with bleach (10%) and dried in the shade for four days before being finely ground and sieved (1 mm mesh). All these flours produced were kept in the freezer awaiting future analyses.

Formulation of mixed flours

It was made on the basis of the complementarity of compositions of each flour in order to obtain a compound flour with a high energy and protein value.

Thus, 3 types of compound flours have been formulated:

- F1 compound flour: Soy flour, germinated millet flour, corn flour, potato flour, moringa powder and powdered milk.
- Mixed flour F2: Flour flour, sprouted millet flour, corn flour, potato flour, peanut paste, moringa powder and milk powder.
- F3 compound flour: Soy flour, germinated millet flour, corn flour, potato flour, peanut paste, moringa powder and milk powder.

Determination of the physicochemical properties of mixed flours

All determinations were repeated 3 times.

Determination of moisture and dry matter of mixed flours: Moisture and dry matter were determined with the moisture meter. Thus, 1 g of each type of compound flour was introduced into the device and then switched on. Their values were read on the screen at the end of the dehydration.

Determination of the ash content of flours in mixed flours: The ash content was determined by the incineration method, thus, a test portion of 5 g of each type of flour was incinerated in a muffle furnace at 550°C for 5-6 hours.

The ash content was calculated by the following formula:

%ash=((P3-P1)/(P2-P1)) × 100

Where P1=Empty crucible weight, P2=Crucible weight+sample before incineration and P3=Crucible weight+sample after incineration

Determination of crude proteins by the kjeldahl method: The determination of the protein content of the mixed flours consisted in hot mineralizing 0.5 g of each flour in 10 ml of sulfuric acid and 15 ml of hydrogen peroxide (30%) until the solution becomes clear and limpid. After mineralization, the ammonia was then distilled in 40 ml of 40% NaOH solution then recovered in 50 ml of boric acid. Nitrogen titration was performed with a 0.1 N sulfuric acid solution in the presence of a colored indicator, methyl red.

Thus, the protein content was calculated as follows:

%P=N × 6.25=0.14 × V × 25

Where P: The percentage of protein and N: The rate of crude nitrogen with

%N=(0.0014 × V × 100)/m Where m: The mass of the sample

V: The volume of 0.1N sulfuric acid used in the titration

Determination of total carbohydrates by the Bertrand method: Carbohydrate determination consisted of measuring 4 g of each sample into a flask, to which 40 ml of distilled water, 1 ml of zinc acetate ($Zn(CH_3COO)_2$) and 1 ml of concentrated Hydrochloric acid (HCL) were added. The mixture was boiled for 2 h 30 min. After cooling, 3 drops of phenolphthaleins and 20 ml of 27% NaOH were added. Subsequently, the mixture was transferred to a 1000 ml flask and topped up with lukewarm water to the mark. After filtration, 20 ml of the sample was measured in a test tube to which 20 ml of alkaline solution (double sodium and potassium tartrate, NaOH and distilled water) and 20 ml of copper sulphate were added. This mixture was heated to boiling and held for 3 min.

After cooling, the solution was centrifuged and the residue washed with hot water and then centrifuged. The final residue was dissolved in 5 ml of ferric solution in an Erlenmeyer flask and titrated with the calibrated KMnO4 solution until a pink color was obtained. The total carbohydrate content was calculated by the following formula:

G=S × 100/M × V

Where S East the correspondence of Cu according to the Fehling table, M: The mass of the test sample (g) and V: The descent from oilcan (ml)

On the other hand, Cu=X × V

Where X: Quantity of Cu (mg) corresponding to 1 ml of $KMnO_4$

Cu: Amount of copper (mg) reduced by the sugars in the sample

Dosage of lipids by the Soxhlet method: The dosage of the lipids was carried out by the Soxhlet method, which consisted in measuring 50 ml of hexane, in a flask of 100 ml of weight (P1) defined beforehand. Then 5 g of each sample were weighed into extraction cartridges adapted to the extractor (SOXTEC 10461042) and closed with cotton plugs. The whole was heated at 205°C. for 90 min. After heating, the flask was placed in a 60°C water bath to evaporate the hexane and dried in an oven set at 105°C. After cooling in the desiccator, the flask and its contents were weighed (P2). The lipid level was calculated as follows:

%L=((P2-P1) PE) × 100 with PE=Weight of the test portion

Determination of minerals by atomic absorption spectrophotometry: The determination of minerals was done using atomic absorption spectrophotometry. Thus, 0.5 g of each sample were weighed and placed afterwards in matras. Then 10 ml of 95% concentrated sulfuric acid and 15 ml of oxygenated water were added and the whole was mixed well by vortexing. The solutions were mineralized until a clear and limpid solution was obtained. After cooling, they were transferred to 100 ml flasks and filled with distilled water to the mark. The solutions thus prepared were analyzed by atomic absorption spectrophotometry to determine the different minerals.

Calculation of the energy value

The energy values (Kcal) of the complementary flours (F1, F2, F3) were calculated using the Atwater and Benedict coefficients according to the following formula:

VE=m carbohydrates (g) × 4 kcal+m proteins (g) × 4 kcal+m fats (g) × 9 kcal

Organoleptic tests of porridge

The organoleptic tests were carried out with porridges prepared by mixing 40 g of each flour with 350 ml of water, to which 0.5 g of NaCl was added. Cooking lasts 10 min. Thus, fifteen (15) participants (6 men and 9 women) were chosen on the basis of their tasting experiences to appreciate the color, flavor, smell and texture of the different porridges by rating them from 1 to 5. Very poor-2, poor-3, fair-4, good-5, excellent-1

Statistical analyzes

The results of the Descriptive analyzes were presented as the mean ± standard deviation of three (3) replicates. The results were processed by Analysis of Variances (ANOVA) at the significance level P<0.0001. These tests were performed using Epi info for Windows version.7.0 software.

RESULTS

Prepared improved blended flours

Table 1 summarizes the qualitative and quantitative composition of the compound flours F1, F2 and F3. In F1 flour, millet represents 70%. In F2 flour, maize and millet are in equal proportion, *i.e.* 40%, while in F3 flour, the proportion of maize is slightly higher than that of millet (40% against 35%). At the end of the 500 g mixture, five hundred grams were conditioned for the preparation of porridges and analyze.

Table 1: Flour formulas composed.

Subjects	Quantities in percentage (%)		
	Flours 1	**Flour 2**	**Flour3**
Sprouted millet flour	70%	40%	35%
Corn flour	17%	40%	40%
Soy flour	7%	8%	10%
Potato flour	0.5%	1%	1%
Peanut paste	0	7%	10%
Milk milk	4.5%	3%	3%
Moringa	1%	1%	1%

Physicochemical and nutritional composition of mixed flours

It emerges from the analysis of Table 2 that the carbohydrate content of flour F1 is 60.64 ± 2.03 mg/100 g, followed by flour F2 with 58.18 ± 1.45 mg/100 g. This carbohydrate content is 52.94 ± 1.05 per mg/100 mg for Misola flour. Overall we can say that the carbohydrate content of F1 and F2 flour is higher than that of Misola.

The protein content of flour 2 is 15.75 ± 0.60 mg/100 g. This value is higher than that of Misola and Monibarikama with respectively 12.18 ± 0.95 and 9.71 ± 1.4 per mg/100 mg. The lipid content of Misola and flour 3 are almost identical with 10.48 ± 0.20 mg/100 g and 10.89 ± 0.10 mg/100 g, the lowest lipid content is observed in flour 1 with 5.87 ± 0.62 mg/100 g. The ash value of flours 1, 2 and 3 is lower than the ash value of Monibarikama and Misola. Flours 1, 2 and 3 have a higher energy value than Monibarikama and Misola flour, this allows us to say that formulated flours better meet food standards.

Table 2: Physico-chemical composition of mixed flour (mg/100 g of flour).

Nutrients	Flour 1	Flour 2	Flour 3	Monibarikama	Misola	P-value
Carbohydrate	60.64 ± 2.03	58.18 ± 1.45	50.51 ± 0.6	61.74 ± 07	52.94 ± 1.05	0.0001
Protein	11.52 ± 0.55	15.75 ± 0.60	15.37 ± 1.30	9.71 ± 1.4	12.18 ± 0.95	0.0001
Lipid	5.87 ± 0.62	8.73 ± 0.22	10.89 ± 0.10	5.60 ± 0.56	10.48 ± 0.20	0.0001
Humidity	8.32 ± 0.31	6.27 ± 0.83	8.39 ± 0.79	9.58 ± 071	7.25 ± 2.09	0.0409
Ash	1.60 ± 0.35	1.63 ± 0.45	1.76 ± 0.27	2.30 ± 0.52	2.8 ± 0.01	0.01
Energy	350 ± 0.00	376 ± 0.00	369 ± 0.00	344 ± 0.00	351 ± 0.23	0.0001

Mineral determination

Table 3 presents the mineral contents of the flours. The Zinc value in F2 flour is (6.14 ± 1.06 mg) while it is (6.85 ± 1.96 mg) in Misola flour. The zinc values (3.44 ± 0.41, 2.88 ± 0.52 and 1.4 ± 0.5) of the F1, F3 and MB flours respectively are the lowest. As for the copper values of our flours 0.77±0.46, 0.80 ± 0.07, 0.87 ± 0.80 they are significantly lower than those of the control flours (0.97 ± 0.13) flour MB. Magnesium values vary depending on the types of flour. That is (97.88 ± 0.434), (77.38 ± 1.65), (65.04 ± 12.81), (80.63 ± 8.03) and (55.55 ± 3.92) respectively F1, F2, F3 MB and Misola. The potassium values are 373.95 ± 96.75 mg for F3 flour, 355.75 ± 115 for F2 flour, 349.75 ± 104 for F1 flour, 364.22 ± 0.14 are significantly lower 391.82 ± 83.8 to those of the Misola control flour. The sodium contents are 36.43 ± 15.70 for F3 flour, (42.37 ± 4.90 mg) for F2 flour, (45.54 ± 10.8) for F1 flour. The value for the Codex Alimentarius is 24 mg. These values are much lower than that of the control flour MB (245 ± 41.40 mg) and Misola (92.34 ± 14.3).

The iron content for MB flour is (22.64 ± 4.37 mg) this value is significantly higher than those of compound flours F3: (3.61 ± 0.62), F2: (3.88 ± 0.85), F1: (5.24 ± 095) and also superior to Misola flour (6.38 ± 1.05). The manganese contents are respectively for flours F3 (0.55 ± 0.1), F2 (0.60 ± 0.08), F1 (0.65 ± 0.10) and (0.54 ± 0.12) for MB. This value is markedly high (2.48 ± 1.26) in flour made from Misola. Indeed, the calcium in F2 compound flours is (10.33 ± 081), (14.04 ± 2.00) for F1 and (15.02 ± 2.42) for F3. These values comply with the standards of the Codex Alimentarius which is 20 mg. But these values are five times higher than in the control flours respectively (3.54 ± 0.72) for MB and (4.33 ± 1.86) for Misola.

Table 3: Mineral content of mixed flours (mg/100 g of flour).

Minerals	Flour 1	Flour 2	Flour 3	Moni barikama	Misola	P-value
Zinc	3.44 ± 0.41	6.14 ± 1.03	2.88 ± 052	1.4 ± 050	6.85 ± 1.96	0.0004
Copper	0.87 ± 0.80	0.77 ± 0.46	0.80 ± 0.07	0.97 ± 0.13	0.97 ± 0.13	0.5315
Magnesium	97.88 ± 0.434	77.38 ± 1.65	65.04 ± 12.81	80.63 ± 8.03	55.55 ± 3.92	0.0003
Potassium	349.75 ± 104	355.75 ± 115	373.95 ± 96.75	364.22 ± 0.14	391.82 ± 83.8	0.084
Sodium	45.54 ± 10.8	42.37 ± 4.90	36.43 ± 15.70	245 ± 41.40	92.34 ± 14.3	0.0001
Manganese	0.65 ± 0.10	0.60 ± 0.08	0.55 ± 0.11	0.54 ± 0.12	2.48 ± 1.26	0.0071
Iron	5.24 ± 095	3.88 ± 0.85	3.61 ± 0.62	22.64 ± 4.37	6.38 ± 1.05	0.0001
Calcium	14.04 ± 2.00	10.33 ± 0.81	15.02 ± 2.42	3.54 ± 0.72	4.33 ± 1.86	0.0001

Organoleptic tests

Table 4 gives us the results of the organoleptic test. Tables 4 shows that the color score of porridge F2 is lower than the other two porridges F1 and F3. The flavor scores of porridges F2 and F3 are higher than porridge F1. The odor ratings of porridge F2 are also superior to porridges F1 and F3. The texture scores and the acceptability of the F2 porridge are clearly superior to the two other flours. The flavor and acceptability of porridge F2 are superior to the other two porridges F1 and F3, because millet and but are in equal quantity.

Table 4: Organoleptic characteristics of porridge.

Flours	Color	Flavor	Smell	Texture	Acceptability
Flour F1	3.4	2.9	3	3	2.7
Flour F2	3.3	2.9	3.1	3.3	2.8
Flour F3	3.6	2.8	2.9	3.1	2.7

DISCUSSION

Three compound flours have been formulated. Their qualitative and quantitative compositions were determined. The moisture contents of the flours analyzed vary from 6.27 ± 0.83 (flour 2) to 8.39 ± 0.79 (flour 3). Normal moisture values for flours 6 and 8. These flours have higher moisture contents than cassava flour +soy (5 g/100 g) and atcheke flour+soy (5 g/100 g) 100 g) obtained by [17], but lower than those of maize flour (12.38 g/100 g) and millet (19.71 g/100 g) found by Sall [15]. A large amount of water in these flours would compromise their keeping quality; in fact, the water promotes the proliferation of micro-organisms capable, using their amylases, of hydrolyzing the starch contained in the flours and thus facilitating the acidification of the latter.

Flour 3 has a low ash content (1.60 ± 0.35) while flour F3 has a higher content (1.76 ± 0.27). These levels are higher than those found by Ponka et al. [20] (0.19 ± 0.01 g/100 g) and also higher than the Codex Alimentarius standard (1 g/100 g) for cereal flours. This could be explained by the fact that our flours have a lot of minerals.

The highest lipid content (10.89 ± 0.10 g) is found in F3 flour while the lowest content (5.87 ± 0.62) is found in F1 flour. The value of the Codex Alimentarius standard is 5.5. This high content could be explained by the addition in the groundnut F3 flour which is an oilseed. These results are comparable to those found by Amoin et al., 7.5±0.5 in prepared corn flours [21]. These different flours have lipid contents lower than that proposed by Sanogo et al. (7g/100g) [14]. The protein contents of the flours analyzed vary from 11.52 ± 0.55 g (flour 1) to 15.75 ± 0.60 g (flour 2). These values are higher than the control flours, namely approximately 9.71 ± 1.4 to 12.18 ± 0.95. This results in F2 and F3 flours having a high proportion of soy. This value is consistent with that found by Amoin et al. [21], who found (15.80 ± 1.4 g), these levels are also higher than that found by Zannou et al. [17] in Attieke cassava flour (13 g/100 g). The Codex standard is between 12 and 14 g/100 g, this high protein value helps to better compensate for protein-energy malnutrition, hence the objective of this study.

The carbohydrate content of F1 flour is higher (60.64 ± 2.03) compared to F3 flour and F2 flour (50.51 ± 0.6), (58.18 ± 1.45) respectively. The value of the Codex Alimentarius standard is between 62 g to 70 g/100 g. This high carbohydrate content in F1 flours is justified by the presence of millet in a high proportion. Because cereals like millet, corn which are foods very rich in carbohydrates can contain 60-70% carbohydrate. These levels are lower than the level (82.10-86.85 g/100 g) found in porridge flour consumed in the Far North of Cameroon, more specifically in the city of Maroua [20] and that of 73.52 g/100 g found in Akamu porridge flour consumed in Nsukka located in northern Nigeria [20]. Carbohydrates have an essentially energetic role, they constitute the source of energy quickly usable by the body and are involved in the anabolism of proteins. Some carbohydrates have a so-called constitutional role, they are part of the composition of fundamental body tissues: cartilage, nucleic acids, mucus, antigenic substances [22].

The energy values of the flours analyzed vary from 350 ± 0.00 kcal/100 g for flour 1 to 376 ± 0.00 kcal/100 g for flour 2. These results are comparable to the energy values (361.39 ± 1.52 kcal/100 g) of porridges based on fermented mixed flour FB [21]. Energy comes from the food and drink we consume. The FAO recommends that weaning foods be high in energy [23]. This FAO recommendation is important, because the low energy density of certain porridges tends to limit the total quantity of energy consumed necessary for the proper functioning of the body of the young child as well as the use of other essential nutrients. Given the small size of their stomach (30 to 40 g/kg) of body weight (150 ml to 200 ml), children need high energy foods to meet their energy needs [24]. Hence the importance of fortification of weaning foods.

Potassium is the most abundant mineral in flours. Potassium contents vary from 349.75 ± 104 for F1 flour to 373.95 ± 96.75 mg/100 g for F3 flour, (364.22 ± 0.14) for MB flour and 391.82 ± 83.8 mg/100 g for Misola flour. The value of the Codex Alimentarius standard is 180 to 230 mg/100 g [25]. The potassium contents (373.95 ± 96.75 mg/100 g) are higher than those of potassium (318.81 ± 6.72 mg/100 g) of maize porridges prepared in Maroua, Cameroon [26]. Potassium is necessary for the regulation of the water balance of cells, the use of carbohydrates and the construction of proteins. It acts against the disturbances of the cardiac rhythm and intervenes in the regulation of the osmotic pressure of the cell. Potassium participates in membrane transport and enzyme activation and plays a role in muscle contraction (increased neuromuscular excitability). Calcium content 10.33 ± 081 flour 2 to 15.02 ± 2.42 mg/100 g flour 3. Magnesium content, 65.04 ± 12.81 (flour 3) to 97.88 ± 0.434 mg/100 g (flour 1) that of sodium, 36.43 ± 15.70 (flour 3) to 42.37 ± 4.90 mg/100 g (flour 2). Zinc content, 2.88 ± 0.52 (flour 3) to 6.14 ± 1.03 mg/100 g (flour 2); that of iron, 3.61 ± 0.62 (flour 3) to 5.24 ± 095 mg/100 g (flour 5). That of the Codex Alimentarius standard is 0.5 mg/100 g. Copper and manganese are the least abundant minerals in flours with contents varying from 0.77 ± 0.46 to 0.87 ± 0.80 and 0.55 ± 0.11 (flour 3) 0.65 ± 0.10 mg/100 g (flour 1).

In humans, calcium has a major role in the constitution of the skeleton, but also in various metabolic functions such as muscle activity, nervous stimuli, enzymatic and hormonal activities and oxygen transport [27]. The magnesium contents of the flours analyzed (65.04 ± 12.81 mg/100 g) are comparable to the contents of (49.35-80.56 mg/100 g) found in the porridge consumed in Maroua in the far North from Cameroon [28]. Magnesium is found primarily in the bones, but also in most body tissues. Most diets contain enough magnesium, but in case of diarrhea for example, the losses are significant and can induce weakness, behavioral problems and sometimes convulsions. The sodium contents of the flours analyzed (36.43 ± 15.70 mg/100 g) are lower than those (45.54 ± 10.8 mg/100 g) found in F1 flour. Sodium is involved in the acid-base balance and the water balance of the body. It promotes nerve function and muscle contraction. Sodium salts are very common in foods and are easily absorbed by the digestive tract and by major cations in body fluids. The zinc contents of the F2 and F3 flours analyzed (2.88 ± 0.52 mg/100 g to 6.14 ± 1.03 mg/100 g) are lower than those (6.85 ± 1.96 mg/100 g) found in Misola flour these values are lower than those of germinated compound flour [21].

The manganese contents of the F3 flours analyzed ((0.55 ± 0.11 mg/100 g) are lower than that of F1 M flour (0.65 ± 0.10 mg/100 g) the latter is consistent with that found in flour of maize (0.64 ± 0.01) [29]. Manganese is involved in the growth of bones and tendons, it also plays an important role in the synthesis of complex carbohydrates and proteins [16]. The overall acceptability of the porridges shows that the porridges were variously appreciated, however the formulated flour porridge F2 was deemed acceptable, followed by the porridge F3 and the porridge F1. F2 flour porridge was better accepted than other F1 and F3 porridges because the average rating for smell, color and other is higher than other flours. This better score is explained by the fact that the porridge is made from millet and maize flour in equal proportions.

CONCLUSION

The studies carried out with a view to making our contribution to the formulation of complementary food for young children during the weaning period have made it possible to formulate three types of infant flour: compound flour F1, F2 and compound flour F3. It is the F1 composite flour which contains good levels of proteins, lipids, carbohydrates and minerals, according to the recommendations of the FAO/WHO.

However, the germination process would therefore better improve the quality of the flours. Moreover, the compound flour F1, thanks to its composition, made it possible to improve the consistency of the boils and the energy density. The F1 compound flour increases the potential to overcome protein-energy malnutrition in infants and young children. In perspective, we plan to carry out microbiological tests in order to assess the quality of the mixed flours as well as their side effects. The porridge from the F2 flour was deemed acceptable compared to the two other F3 and F1 according to the organoleptic tests.

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