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Research Article

Assessment of Biological Effectiveness of Infant Flours on the Iron Status and Speed of Recovery of MAM Children Admitted to HNDA Hospital at N'Djamena (Chad)

Barnabas Kayalto[1, *], Djimadoum Kimassoum[2], Brahim Boy Otchom[3], Emilienne Soubeiga[4], Alfred Sadjo Traore[5]

[1]Department of Life and Earth Sciences, Bongor Teachers' Training Higher School, Bongor, Chad

[2]Faculty of Human Health Sciences, University of N'Djamena, N'Djamena, Chad

[3]Department of Biology, Faculty of Exact and Applied Sciences, University of N'Djamena, N'Djamena, Chad

[4]Notre Dame of Apostles Hospital in Chagoua, N'Djamena, Chad

[5]Department of Biochemistry and Microbiology, Centre for Research in Biological, Food and Nutritional Sciences, Training and Research Unit of Life and Earth Sciences, University of Ouagadougou I Pr Joseph KI ZERBO, Ouagadougou, Burkina Faso

Abstract

Previous study was designed in two steps: flours formulation, improvement to traditional manufacturing processes and fortify five infant flours produced locally in Chad in vitamin A and zinc, iron and vitamin C. This study aimed to assess biological effectiveness of four improved and enriched experimental flours produced with local products on the iron status and speed of recovery in weight, height and MUAC of MAM children aged 6 to 59 months admitted at the Supplementary Nutrition Unit (UNS) of Notre Dame of Apostles Hospital (HNDA) at N'Djamena. The results of this study, which included 416 children, showed that moderately malnourished children under experimental flours enriched with dried *Moringa* leaf powder took a maximum of three weeks to recover from malnutrition. The *Pennisetum typhoides* flour with *Moringa* gave the best results, with 96% of children recovering after a duration of recovery of 17.5 days. Children under red sorghum flour from Bongor without *Moringa* showed the highest daily weight gain in the study, at 8 g/kg-body weight per day. The same flour with *Moringa* showed the highest hemoglobin gain of 13.5 g/dl. Children under maize flour without *Moringa* took the longest to recover in the study, an average of 32.7 days. In conclusion, *Pennisetum typhoides* and red sorghum flours with *Moringa* can make a valid contribution to reducing the prevalence of malnutrition in children.

Keywords

Chad Infant Formula, Nutritional Assessment, *Moringa oleifera*, Iron, Biological Effectiveness

*Corresponding author: bkayalto68@gmail.com (Barnabas Kayalto)

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1. Introduction

With a large part of the country located in the Sahel band, Chad is faced with recurrent cycles of child malnutrition. According to the Integrate Food Security Phase Classification (IPC) 2021 analysis, these high prevalence of malnutrition correspond to a structural situation generated and maintained by several factors [1].

Chad has 23 provinces. The latest available 2022 Standardized Monitoring and Assessment of Relief and Transitions (SMART) surveys in Chad showed that, rate of Global malnutrition was 8.6%. However, this prevalence masks major disparities at provincial level, where it varied from 2.6% in Logone Oriental to 17.7% in Wadi Fira. In fact, three provinces recorded prevalence above the very high (emergency) of 15%: Wadi Fira (17.7%), Borkou (16.2%) and Ennedi East (15.7%). Eleven (11) provinces recorded prevalence above the high threshold of 10% (alert) [2].

By gender, acute malnutrition affects boys significantly more (9.8% [8.8-10.9]) than girls (7.4% [6.6-8.3]) at national level. It also affects significantly more children aged 6 to 23 months (13.3% [11.9-14.9]) than those aged 24 to 59 months (6.0% [5.4-6.8]), which highlights the need to step up action to prevent malnutrition based on the 1000 first days strategy.

By geographical area, the Saharo-Sahelian zone recorded a prevalence of Global Malnutrition of 12.2% [11.0-13.3] compared with 5.2% [4.5-6.1] for the Sudanian zone [2].

This study, which has been the subject of several publications, was carried out to characterize the unitary production operations, enrich in vitamin A and zinc, iron and vitamin C and propose improvements to the traditional manufacturing processes of five infant flours produced locally in Chad, and evaluate their biological efficacy in order to help reduce the prevalence of malnutrition among Chadian infants.

Our present study aim to assess biological effectiveness of four experimental flours produced with local products, improved and enriched based on *Moringa oleifera* Lam. and nere pulp (*Parkia biglobosa* (Jacq.) Benth on the iron status and speed of recovery in weight, height and midupper arm circumference (MUAC) of moderately malnourished children aged 6 to 59 months admitted to the Supplementary Unit of the Notre Dame of Apostles Hospital in Chagoua at N'Djamena.

2. Materials and Methods

The study was conducted in three steps: Firstly, the study focused on traditional production processes and assessing the nutritional and hygienic quality of five (05) infant flours produced locally in Chad. Secondly, the aim was to improve the unit production operations for these flours and to fortify them with iron and vitamin C, vitamin A and zinc and finally, the recovery study in the present document.

2.1. Site of Study and Period

The study was conducted over six months, from 27 may to December 02, at the Supplementary Nutritional Unit (UNS) of the Notre Dame of Apostles Hospital (HNDA) in Chagoua at N'Djamena.

2.2. Sample Size

The study population consisted of moderately acutely malnourished (MAM) children aged 6 to 59 months, without severe disabilities or medical complications, or severely acutely malnourished (MAS) children discharged from Therapeutic Unit (UNT) and admitted to the UNS at Notre Dame of Apostles Hospital in N'Djamena.

The sample size was determined based on previous similar studies conducted in Burkina Faso [3]. We set ourselves the objective of demonstrating a weight increase of 0.9 kg over 4 months between the group of children consuming experimental flours produced with local products with powdered *Moringa* leaves and the group of children consuming control flours. By setting the alpha and beta risks at 5% (statistical power of 80%), 46 children per flour were enrolled, estimating the standard deviation of the difference in weight between the children consuming experimental flours and the children consuming control flours at 1.2 kg. Taking into account possible wastage, and in order to enable the nurses in charge of monitoring to do a homogeneous study, we set this sample at 52 children per flour. Thus, a total of four hundred and sixteen (416) MAM children (52 x 8) were enrolled in the study.

2.3. Ethical and Administrative Considerations

The study protocol has been approved by the National Bioethics Committee of Chad in its deliberation N° 850/PR/PM/MESRS/SG/CNBT/2015. We also obtained authorization from health administrative authorities, from the HNDA and the mothers of the participants gave their informed consent.

2.4. Inclusion and Non-inclusion Criteria

According to [4] several surveys carried out in Chad have shown that more than 80% of malnourished children admitted to UNS are aged between 6 months and 2 years. As for anemia in Chad, it affects more children aged between 6 and 59 months [5]. For these two reasons, in order to be eligible, we decided to include in the study children aged between 6 and 59 months at the time of recruitment at the UNS. These children had to be breastfed by their mothers (for those aged 6 months to 2 years) in addition to complementary foods, not be severely malnourished (Z-score P/T and Z-score T/A > - 3ET NCHS), not have severe disabilities and whose parents were resident in N'Djamena during the study months and consented to the study, after explanation of the purpose of the study.

These children were follow up until recovery.

Severely acutely malnourished children (Z-score P/T < -3ET NCHS) were excluded from the study. Children with severe physical or mental disabilities, aged less than 6 months or more than 59 months and belonging to a family moving to N'Djamena, were also excluded.

This study was a transversal study in which 08 types of flours were offered to children aged 6 to 59 months, during meals at home, who usually consumed at least 2 meals per day in addition to breast feeding. Each child received the same type of flour, control flour or experimental flour. In order to ensure the quality of the flours, all the flours were made on site at the HNDA's UNS, as and when required, according to the improved diagram. The mothers were trained in culinary techniques in hygienic conditions at the first meeting, so that the knowledge they had acquired could be passed on to their families.

Three meals administered at 10 a.m., 15 and 18 p.m. will be enriched after cooking with 5g of *Moringa oleifera* leaf powder and 5g of *Parkia biglobosa*'s pulp.

The meals were prepared using two level tablespoons of flour to 250 ml of drinking water. Once boiling, the flour was mixed with a small quantity of cold water and added to the pot. The meal was cooked for 10 minutes from the boiling point. The children received 2 to 5 meals a day, depending on their appetite, at 7, 10, 13, 16 and 18 o'clock. Mothers were asked to add 5g of dried *Moringa oleifera* leaf powder to the meal, i.e. one teaspoonful slightly rounded, as well as pulps of *Parkia biglobosa*, for three (03) different meals a day.

The study carried out by [6] showed that the incorporation of *Parkia biglobosa*'s pulp at a level of 5% of the initial flour improved the acceptability of the meal and was the most appreciated by the panelists. In our study, we used 5% of *Parkia biglobosa*'s pulp in our experimental flours. This ingredient is available in Chad.

The Formulated flours including *Moringa* powder established by the moringanews network provide for a minimum dosage of 10 g of Moringa powder per flour, according to [7]. However, as part of the partnership between the Burkinabe Association of Misola (ABUM) and Moringanews, a study into the feasibility of adding *Moringa* powder to the Misola unit recipe launched in April 2009 revealed that this dose seemed too high for children to accept, and suggested 5 g per flour, i.e. a slightly rounded teaspoon [7].

In the light of this scientific literature, we planned to conduct the study with four control flours and four experimental flours with 5% *Moringa* three times a day i.e. 15%. Many previous and recent studies [3, 8, 9] have used up to 10% *M. oleifera* powder. Then, we will have flour control flour and four experimental flour.

2.5. Recruitment and Data Collection

Data were collected using a questionnaire containing items on the socioeconomic parameters, anthropometric and biological measurements of moderately acutely malnourished children aged between 6 and 59 months.

The administration of meals and the purpose of the study were explained to the mothers or Careers of malnourished children at the first distribution session, and their informed consent was obtained. After the first hemoglobin test, children receiving the control flour were systematically given a single dose of 200 mg iron sulphate tablets equivalent to 65 mg Fe^{2+} and 0.4 mg folic acid. Children receiving experimental flours containing *Moringa* leaf powder did not receive this tablet.

2.6. Anthropometric and Non-anthropometric Measurements

On admission, anthropometric measurements (weight, height, MUAC) were taken; age was taken using official health care documents. During recovery time at the UNS, weight and MUAC were determined once a week. Weight, height and MUAC was also measured, at discharge.

Height: Height is a measure of skeletal stature. Height was taken on bare feet; for infants and for children less than two years, recumbent length was measured using a wooden measuring board to the nearest 0.1 cm. Height Children over the age of two years were measured in the standing position. The child must be standing, feet together, looking horizontally. Measurements are taken using a UNICEF wooden measuring. Height was measured every 21 days.

Weight: Weight measurement is the most widely used anthropometric measurement. Weight loss is an important clinical sign of the energy component of acute malnutrition. The weights of all the children enrolled in the study were measured with Seca electronic double-weighting scales. Infants and children less than two years were weighed using balance to the nearest 10 g. Before each weighing, the scale was tared and adjusted to zero with the mother's weight. The child (without clothes) was then returned to its mother. From then on, the value was read directly in digital form.

MUAC measurement: Midupper arm circumference (MUAC) was measured with ribbon method described by [10]. The MUAC can only be used in children aged over six months ($\geq$ 65 mm). The measurement was taken by convention on the child's left arm, hanging alongside the body and halfway between the acromion and the olecranon, avoiding compressing the soft tissues. This gives the child's MUAC.

Age: The date of birth was recorded using official documents (birth certificate, health record, baptismal record) where these were available. Otherwise, local event calendars were used.

2.7. Collection of Blood Samples

Following informed consent from the mothers or careers of malnourished children, blood samples were taken from each child in the study on admission and discharge to determine hemoglobin status.

The blood samples (one drop) were taken at the same time as the anthropometric measurements, from each child aged between 6 and 59 months, by a nurse from the UNS. A drop of capillary blood was taken by a nurse from each child in the study. After carefully disinfecting the fingertip chosen for puncture, a drop of capillary blood was obtained by pricking with a sterile lancet. A micro-cuvette was used to collect the drop of blood and the whole unit was inserted into the HemoCue device for reading. This method is recommended by [11], because of its simplicity and its correlation with the cyanmethaemoglobin method reported in various populations, including African populations [12].

2.8. Hemoglobin Measurement

Participants' iron status (anemia) was assessed on the basis of blood hemoglobin levels measured using a digital reading device called a haemocue, type Hb 201+ (HemoCue 201, Angelholm, Sweden). Hemoglobin (Hb) was used to define and treat anemia associated with malnutrition and were taken at inclusion and discharge. Hematological measurements were taken according to method describe by [13] with Hemocue kit.

Safety measures were taken for blood sampling, including the use of gloves and single-use equipment.

2.9. Clinical Measures

Illnesses associated with malnutrition were diagnosed by the study nurse at the UNS. Diarrheal episodes, acute respiratory infections, fevers and other illnesses were monitored throughout the study. Nutritional index (Weight-for-height index P/T, Weight-for-age index P/A, Height for age index T/A) were determined and monitored.

2.10. Statistical Analysis

The results were analyzed using Microsoft Excel 2010 software for data entry, statistical analysis and the construction of tables and graphs. SPSS Statistics 21 was used for the analysis of variance (ANOVA), to determine whether there were significant differences between the means of the various parameters analyzed.

For all comparisons made on variables from different studies, the threshold of statistical significance was set at $p < 0.05$.

3. Results

In our previous study, the nutritional and hygienic quality of the flours and *Moringa* leaf powder, pulps of *Parkia biglobosa* were determined, manufacturing technology of flours mastered through trials at the CREN MORIJA of the SCHIPHRA Protestant Hospital at Ouagadougou. We still had to verify the biological effectiveness of these flours in the nutritional recovery of moderately malnourished children in order to conclude our work.

What did we observe at the end of this study?

3.1. Distribution of Children by Sex and Age Group

Children were systematically allocated to one of eight dietary regimens. Table 1 shows the random allocation of boys and girls by flour in the study. The table shows that boys accounted for 59.13% of the children admitted to the Supplementary Nutrition Unit (UNS) at the Notre Dame of Apostles Hospital (HNDA), compared with 40.87% of the girls. The abbreviations MNM, for example, means Maize flour from N'Djamena with *Moringa* leaf powder, while MNSM is control flour without *Moringa* leaf powder (SM).

Table 1. *Distribution of children by flour and sex.*

Flours	Girls	Boy	Total
MNM	24	28	52
MNSM	15	37	52
PNM	20	32	52
PNSM	13	39	52
SRBM	25	27	52
SRBSM	20	32	52
SRKM	28	24	52
SRKSM	25	27	52
Total	170	246	416

With, PN = *Pennisetum typhoides* flour from N'Djamena; SRB = Red Sorghum flour from Bongor; SRK = Red Sorghum flour from Koumra; M means, flour with *Moringa* leaf powder and SM = flour without *Moringa* leaf powder.

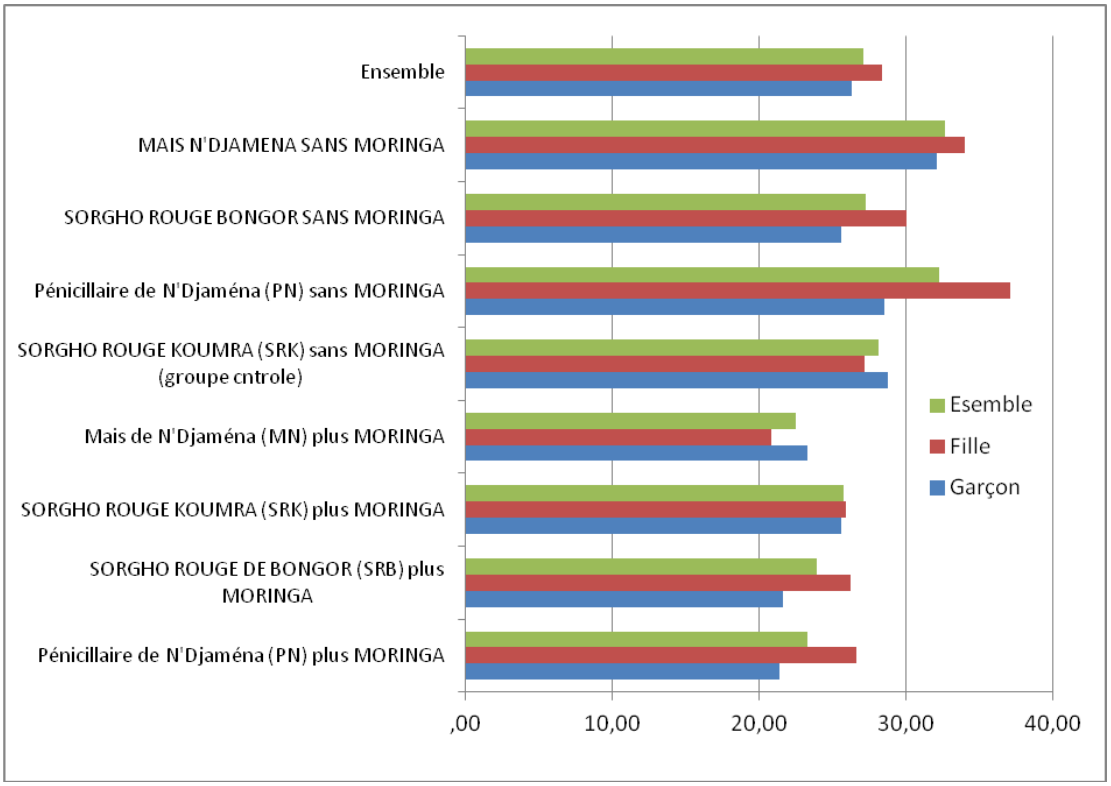
The distribution by age group of moderately acutely malnourished children admitted to UNS is shown in Table 2. From this table, the frequency of age groups shows that 74.4% of MAM children admitted to the UNS are aged between 6 and 18 months. This figure rises to 88.70% between 6 and 24 months. From 6 to 30 months, the rate is 97.34%. Up to 36 months, 99% of MAM children are concerned.

Table 2. Distribution of patients by age group.

	[6 - 12[	[12 - 18[	[18 - 24[	[24 - 30[	[30 - 36[	[36 - 42[	[42 - 48[	[48 - 54[	Total
MNM	21	17	8	6	0	0	0	0	52
MNSM	15	26	5	3	3	0	0	0	52
PNM	28	8	11	4	0	0	0	1	52
PNSM	18	21	6	6	1	0	0	0	52
SRBM	25	18	6	2	1	0	0	0	52
SRBSM	16	17	12	6	1	0	0	0	52
SRKM	23	15	9	4	0	1	0	0	52
SRKSM	19	23	2	5	1	2	0	0	52
Total	165	145	59	36	7	3	0	1	416

3.2. Duration of Recovery

The average duration of recovery at the UNS under different flour feeding is shown in Table 3. The shortest duration of recovery at the UNS was 17.5 days for children fed a flour of *Pennisetum* from N'Djamena with *Moringa* leaf powder (PNM). Children under maize flour from N'Djamena without *Moringa* (MNSM) took longer to recover, at 32.7 days. The average for all flours was 23.2 days. All children who received flours with *Moringa* took a maximum of 22,3 days (SRBM) to recover.



With: Fille = Girls (red color); garcon = boys (blue); Ensemble = the whole (green)

Figure 1. Duration of recovery of children, in days, at the UNS by flour and gender.

Table 3. *Duration of recovery at the UNS per flour.*

Flours	PNM	MNM	PNSM	SRBM	SRKM	SRKSM	SRBSM	MNSM
Average duration of recovery (days)	17,5	18,6	20,1	21, 2	22,3	24,6	27,3	32,7

In Figure 1, with the exception of children receiving SRKSM and MNM flours, we can see that, on average, girls take longer to recover than boys: Girls spent between 25.93 and 37.14 days recovering compared with 21.40 to 32.14 days for boys.

3.3. Evolution of Weight

The average weight gain per day and per flour, expressed in grams per kilogram of body weight (kg bw) reported in Table 4, ranged from 4.87 to 8.00 g/kg bw/d. The children under the red sorghum flour from Bongor without *Moringa* (SRBSM) showed the highest weight gain in the study. They were followed by the children on the *Pennisetum* flour with *Moringa* (PNM), followed by PN without *Moringa* (PNSM). Finally, came the children on maize flour from N'Djamena (MNM) and sorghum flour from Koumra with *Moringa* (SRKM).

Table 4. *Weight gain (g/kg body weight/day) by flour.*

Flours	PNM	MNM	PNSM	SRBM	SRKM	SRKSM	SRBSM	MNSM
Average weight gain g/kg/day	6,75	6,29	6,63	5,50	5,93	4,87	8,00	5,81

In Figure 2, with the exception of the Koumra red sorghum flour (with and without *Moringa*), we see that, compared with the control flours (without *Moringa*), all the children subjected to the experimental flours with *Moringa* had a higher average weight at discharge.

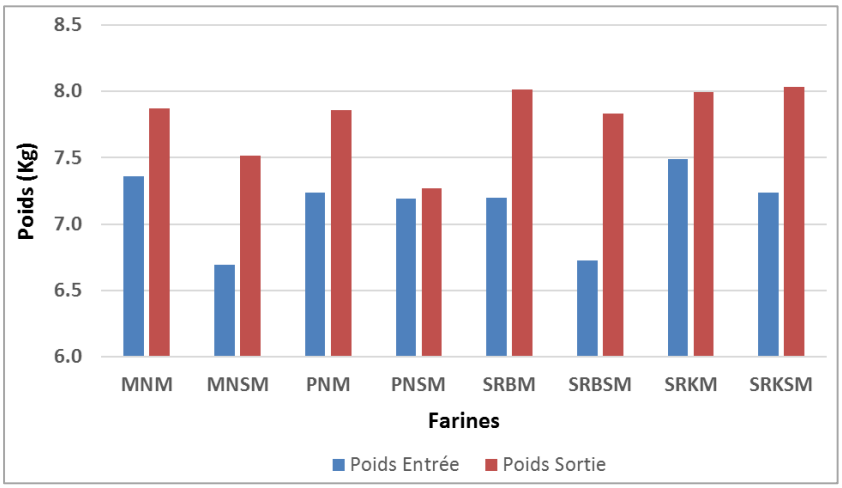


Figure 2. *Weight evolution of children at inclusion and discharge.*

Figure 3, which shows the rate of weight gain (pesée) during treatment, reveals that this rate is not linear. All the children gained weight at their own rate, but by the fourth week everything seemed to stabilize. We observed a clear gap between the curves showing the weight gain of the children on flours with *Moringa* above and those on the control flours below. This is compensatory growth, as they make up for the weight lost through undernourishment.

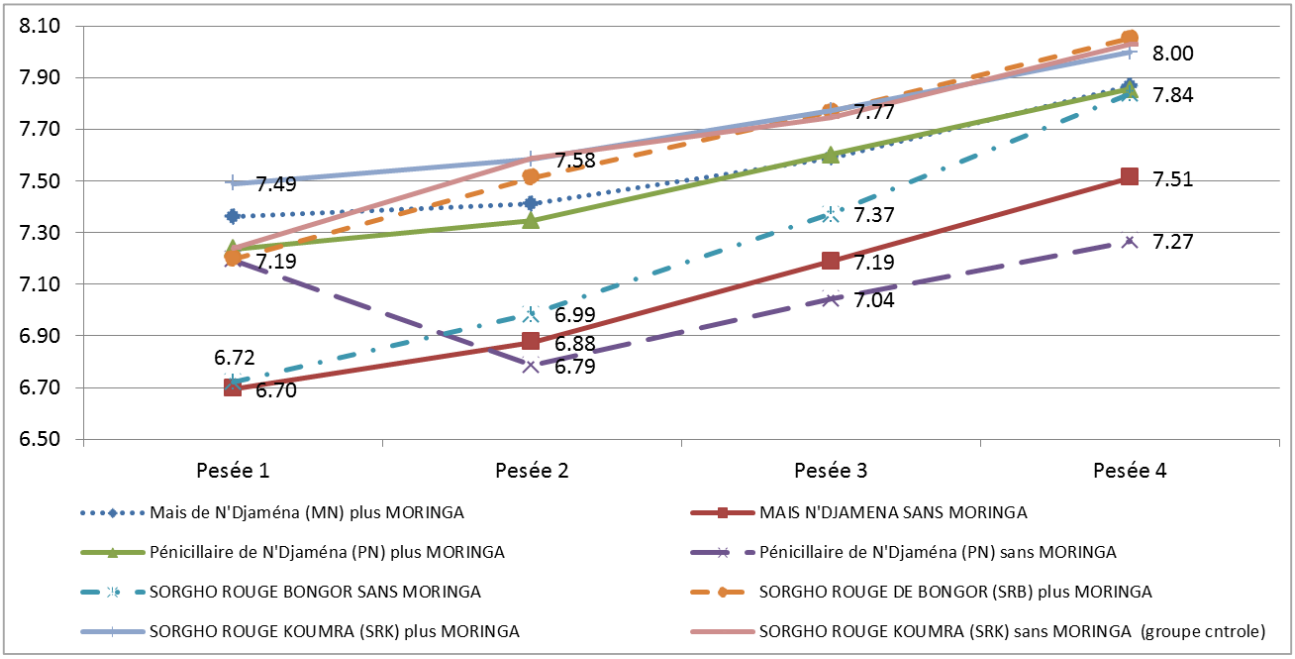


Figure 3. *Evolution of weight (kg) during treatment.*

3.4. Evolution of Height

In Figure 4, the difference in the height of the children between inclusion (taille entrée, blue color) and discharge (taille sortie, red color) is not very noticeable, except for the children allocated to the Bongor red sorghum flour, the control and the experimental flours.

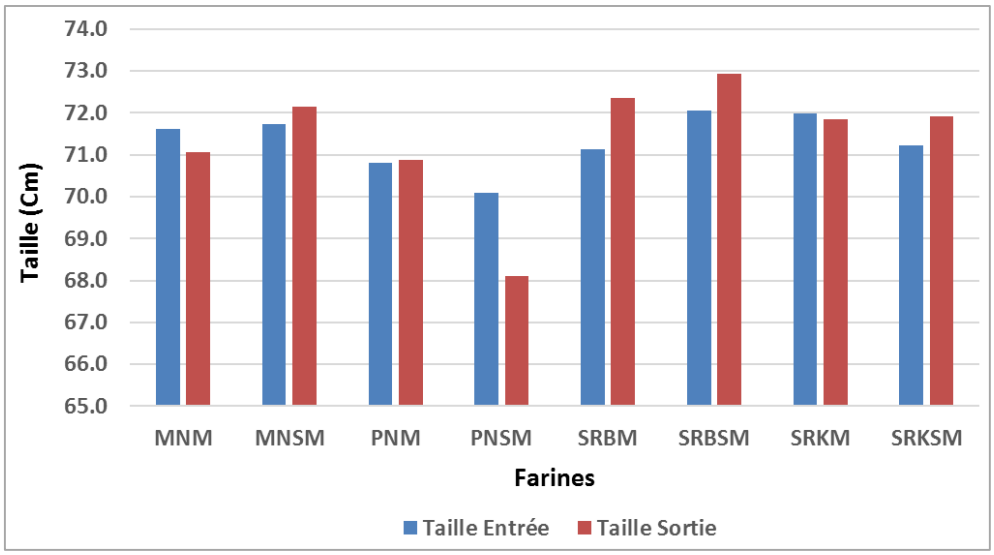


Figure 4. *Evolution of children's height from inclusion to discharge.*

Figure 5 clearly shows that the children's height gain is visible from the 3rd and 4th weeks (semaine) onwards.

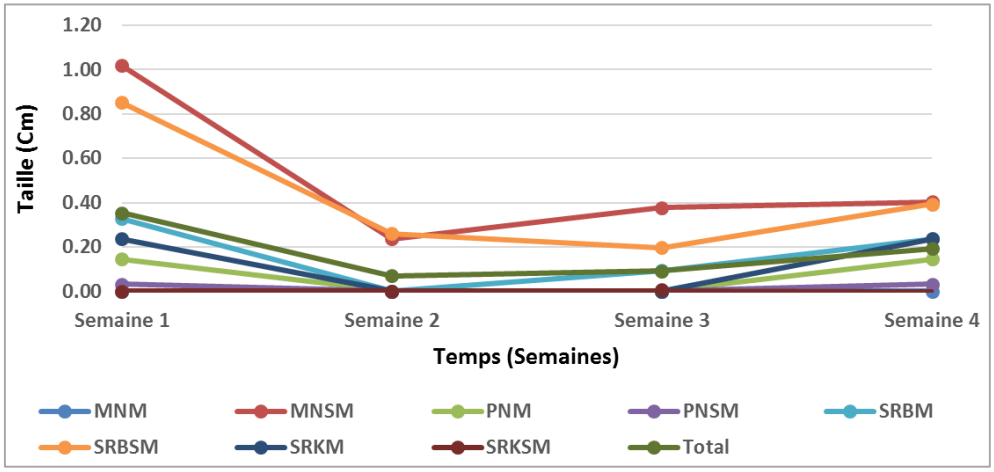


Figure 5. Evolution of height gain during study.

3.5. Evolution of MUAC

The evolution of MUAC, between inclusion (PB entrée, blue) and discharge (PB sortie, red) is shown in Figure 6 for all the children in the study. The best performance was achieved by children on maize flour with *Moringa* (MNM), followed, by children on Koumra red sorghum flour without *Moringa* (SRKSM).

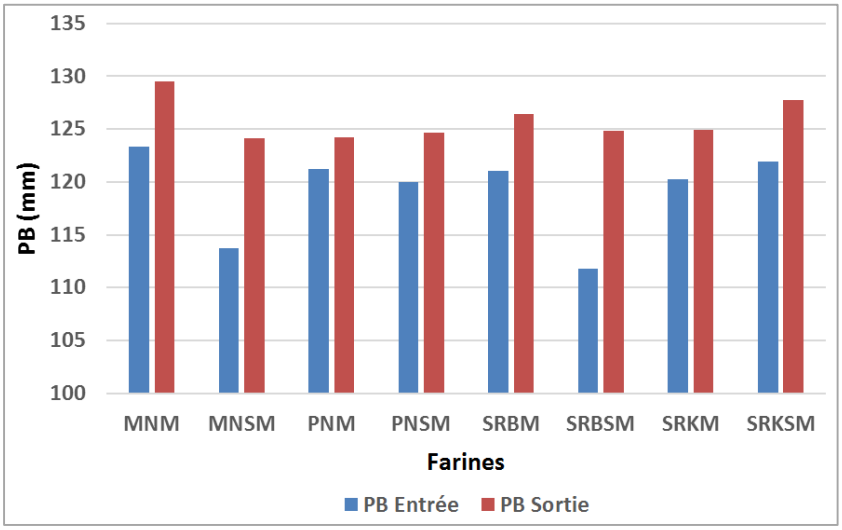


Figure 6. Evolution of MUAC at inclusion and discharge.

3.6. Evolution in Children's Hemoglobin Status

For hemoglobin (Hb) tests characterizing the prevalence of anemia, the reference thresholds according to [14] are: < 11g/dL = anemia generally; 10-10.9 g/dL = mild anemia (anémie légère); 7-9.9 g/dL = moderate anemia (anémie modérée) and < 7g/dL = severe anemia (anémie sévère). Normal value for children = 11.5 to 14.5 g/dL.

At baseline, we had 0.07% severely anemic children out of the total number of children. At discharge, we noted a slight improvement in hemoglobin status for all flours (from 8.11-10.78 g/dL at inclusion to 9.5-10.72 g/dL at discharge), except for Bongor red sorghum flour with *Moringa* (SRBM), red color, where there was a slight drop from 10.78 to 10.72 g/dL between inclusion and discharge. It was the SRBM flour that gave the maximum hemoglobin gain in the study, with some children leaving with 13.5 g/dL. Figure 7 shows the different hemoglobin statuses of the children at the end of the study, grouping together the children receiving flours with *Moringa* and the children receiving the control flours (sans Moringa, blue color):

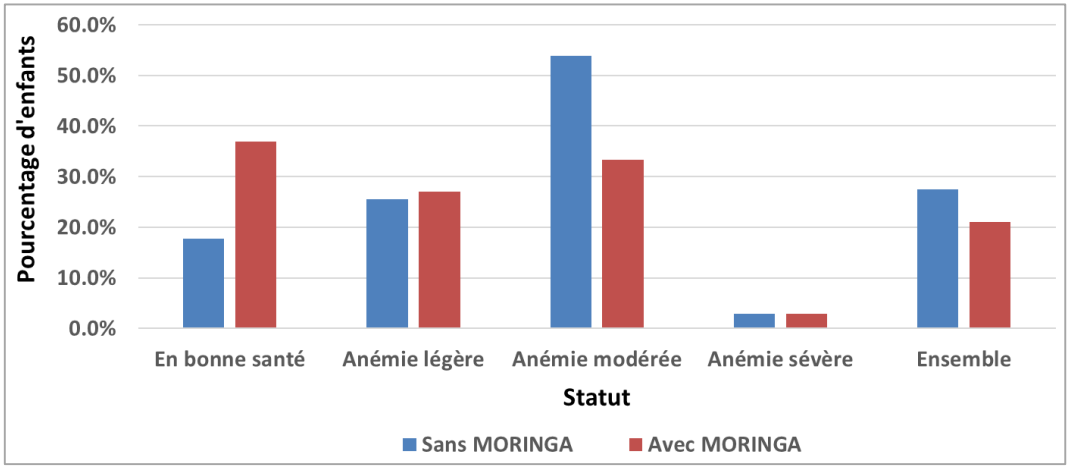


Figure 7. Hemoglobin status of children at discharge.

Our results relating to the average cure rate (guéri, in blue) per flour show that the cure rate varied from 33% for N'Djamena maize flour without *Moringa* (MNSM) to 62% for Bongor red sorghum flour without *Moringa* (SRBSM) for children on control diets. The average for these flours was 51.75%. For the experimental flours, the rate varied from 52% for N'Djamena maize flour with *Moringa* (MNM) to 96% for *Pennisetum* flour with *Moringa* (PNM), with an average of 66.5%. The lowest drop-out rate (abandon, in green color) was for PNM flour, at 4%. The highest drop-out rate was for N'Djamena maize flour with *Moringa* (MNM).

3.7. Cure and Drop-out Rates by Sex of Child

When these results are broken down by sex (fille = girl; garcon = boys), as shown in Figure 8, it can be seen that boys respond better to the treatment, with a cure rate of 63% compared with 52.9% for girls, for all the flours combined. Girls also had the highest drop-out rate, at 34.7% compared with 26.8% for boys.

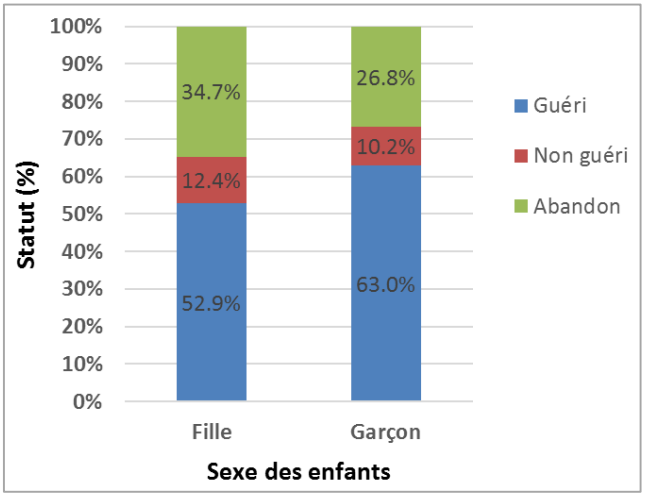


Figure 8. Cure and drop-out rates by sex of child.

4. Discussion

The results of our study showed that of the 416 children enrolled in the study, 59.13% were boys and 40.87% girls. These results are almost similar to those obtained by [15] in 2021 in another town in Chad, Mongo, where malnutrition affected 56% of boys compared with 44% of girls. However, it should be noted that their study involved 112 severely acutely malnourished children aged between 6 and 59 months. Does this mean that, from a societal point of view in Chad, we take better care of girls than boys? One might be tempted to say yes, because in many communities, the dowry provided for a girl's marriage is a source of wealth for her family. For example, in the Massa community in Mayo Kebbi East Province, to marry off a girl, ten oxen have to be brought in. On the other hand, the study by [16] (2017), which involved 322 moderately malnourished children in the Kouroussa prefecture in Guinea, showed a predominance of females (54%) compared with males (46%).

The group of children on experimental flours recovered, depending on the flour, from 52% to 96% for an average of 66.5% compared with 33% to 62% for an average of 51.75% for children on control flours.

For our experimental flours with *Moringa*, the average cure rate was 66.5%. *Thierno et al*. (2017) obtained a cure rate of 90% [16]. Their study lasted four months, from 1 August to 30 November 2017 and, they used seven recipes for enriched flours, prepared in the Foyers d'Apprentissage et de Réhabilitation Nutritionnelle (FARN), using local foods (maize, rice, fonio, groundnuts, eggs, banana, lemon) and advice on good feeding and hygiene practices.

Amadou *et al*. (2021) enriched a weaning meal with spirulina, soya and vegetable oil [17]. This flour is called CSS+ (Cereal+ Soya+ Spirulina flour). They assessed the therapeutic efficacy of two cohorts of 15 moderately acutely malnourished children aged between 6 and 24 months over a two-week period, using outpatient nutritional rehabilitation. The children in the first cohort were given a flour-based

ration; those in the second cohort, representing the controls, were given a plumpy-nut-based ration. The CSS+ flour had an energy value of 437.98 Kcal. The recovery rate was 80% with flour and 87% with plumpy-nut. This study showed that the cereal-legumin-spirulin complex is also highly nutritious.

The study by Bidossesi *et al*. (2013) in Benin focused on children aged between 6 and 30 months [18]. The aim of their study was to assess the effect of a daily intake of 10 g of *Moringa oleifera* leaf powder (PFMo) on the nutritional status of children suffering from moderate acute malnutrition after 6 months of supplementation. At the end of the 6 months, the results showed that daily supplementation with PFMo significantly improved the nutritional status of the children, both in terms of wasting (Z-score Weight/Height from -1.0 ± 0, 9 at the start of the intervention to 0.7 ± 1.0 at the end of 6 months), stunting (Z-score Height/Age from -2.6 ± 0.7 to 0.4 ± 0.7) and underweight (Z-score Weight/Age from -2.2 ± 0.6 to 0.7 ± 0.7). The improvement in Z-scores was greater in the intervention group than in the control group and resulted in zero prevalence for the three types of malnutrition at the end of the experimental period.

Our recovery rates are lower than those reported by Zongo *et al*. in 2012, where children on flours with *Moringa* recovered 92.5% compared with 55.2% of children on control flours. However, it should be noted that Zongo *et al*. worked with severely malnourished children (MAS) and that they had two groups of children, each group of fifty children received a same flour, whereas we have eight groups of children.

The high drop-out rate in our study, averaging 30%, is partly explained by the weight of society. In Chad, the physical presence of someone when a family member dies is valued more highly than telephone calls or donations of any kind. An obvious example is the case of a mother who was very happy to see her child recovering. But one day she came to tell us that her mother had just died in Sudan and that she had to leave while the child was one step away from the target weight. She left and came back with a child who relapsed.

The average daily weight gain in our study ranged from 4.87 to 8.00 g/kg-bw per day. This is still low compared with the recommended values of 10 to 20 g/kg/day [19]. Some authors explain this by the fact that, in outpatient studies, it is difficult to measure ingestion directly. Instead, they rely on statements made by the mother or carer. For this reason, [20] state that it is not evident that the experimental flour was given preferentially to the child under study at home. Our results are consistent with those obtained by [7] which were 5.7 to 8.9 g/kg bw/d, but were slightly higher than those obtained by [3] who obtained a gain of 4.5 to 6 g/kg bw/d.

As for [16] (2019), the average daily weight gain was good at 8g/kg/d. Weight gain was noted in 79% of children, with weight gain ≥ 400g and adequate growth in 11%, with weight gain ≥ 200g but < 400g.

Amadou *et al*. (2021) obtained an average weight gain of 8.24g/d for their CSS+ flour and 8.02g/d for plumpy-nut [17].

Finally, Adam *et al*. (2023) conducted their study from October 1st 2021 to 31 January 2022 on children aged 6 to 59 months suffering from moderate acute malnutrition in the town of Abéché in Chad [21]. Two complementary foods were used: local flour (sorghum, groundnuts, soya, sugar and salt) with an energy value of 400 kcal/100 g and ready-to-use therapeutic food (RUTF). The study showed that group 1, which consumed the locally produced flour, gained an average of 1,100g and that group 2, which consumed the Plumpy sup, gained an average of 400g.

With regard to the hemoglobin status of the children, at the inclusion of the study we had 0.07% severely anemic children out of the total number of children. By flour, the majority of children entered the study moderately anemic, with the exception of children on the N'Djamena maize flour (MNM) and the Bongor red sorghum flour (SRBM) with *Moringa*, who entered slightly anemic. At discharge, we noted a slight improvement in hemoglobin status for all the flours (from 8.11-10.78 at inclusion to 9.5-10.72 g/dL at discharge), except for Bongor red sorghum flour with *Moringa* (SRBM), where there was a slight drop from 10.78 to 10.72 g/dL between inclusion and discharge. It was this same SRBM flour that gave the maximum hemoglobin gain in the study, with some children leaving with 13.5 g/dL (normal status).

Nassaradine *et al*. in 2021, in their study noted that, the hemoglobin level of the anemic children at entry was normalized to 64% at discharge and the leukocyte level was normalized to 74% [15]. The children's staturo-weight parameters normalized with a weight gain that varied between 0.1 and 1.6 kg, i.e. 63% and 104% of the target weights respectively.

Gning *et al*., in their study of the bioavailability of iron from *Moringa* concluded that *Moringa oleifera* powder is rich in protein with a digestibility of 56% and despite its fairly high iron content, iron bioavailability is low, often less than 1% [8]. Cook notes that the rate of iron absorption depends on the iron status of the individual and in particular the state of their iron reserves [22]. Absorption increases when reserves are depleted and, conversely, decreases when iron is overloaded. It is therefore necessary to know the iron status of children at the start of the study.

Raouda in her medical thesis and as part of the 'Valorisation et transformation des resources naturelles" (VALRENA), in the fight against poverty in Chad and Cameroon project, studied variations in anthropometric parameters, hemograms and albumin and ferritin concentrations in healthy children aged 5 to 8 years after the introduction of 3 grams and 5 grams of *M. oleifera* leaf powder in flour and chocolate bread respectively for 18 weeks [23]. Although these quantities of *Moringa* appear to be lower than the quantities recommended and accepted by children, which are 10 g of *Moringa* per day, her study is more comprehensive in terms of hematological parameters; she concluded that the anemia found in the chil-

dren was non-ferrous. It is thought to be inflammatory in origin, due to parasitic and other infections (intestinal parasites, blood parasites). *Moringa* consumption did not remedy the situation. However, it is interesting to note that the anemia rate fell from 92.3% to 87.87% in the boys consuming *Moringa*, while in the control groups, the anemia rate rose from 69.05% to 87.71%.

We can therefore conclude with many other authors that *Moringa* leaf powder can be considered a food supplement, but the consumption of *M. oleifera* leaves alone, despite their exceptional nutritional qualities, is not a medicine.

5. Conclusion

At the end of this study, we can conclude that:

Rapid recovery at the best rate seems unquestionably to be attributable to *Moringa oleifera*. Children on *Moringa* take a maximum of three weeks to recover. All the children subjected to the experimental flours with *Moringa* had a higher average weight at discharge than the children on the control flours. In terms of recovery rate, the penicillin flour with *Moringa* showed the best results. Children on red sorghum flour from Bongor (SRB) without *Moringa* showed the highest daily weight gain in the study. The same flour with *Moringa* showed the highest rate of hemoglobin gain. Children given maize flour with *Moringa* (MNM) showed the best average gain in MUAC. They followed those on SRB. The children on maize flour without *Moringa* were those in the study who took the longest to recover. At the start of the study, there were more boys than girls, but the boys recovered more quickly than the girls. The porridges in our study are socially acceptable because they did not change either eating habits or the foods consumed.

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Abbreviations

BMI	Body Mass Index
IPC	Integrate Food Security Phase Classification
MAM	Moderately Acutely Malnourished
MAS	Severely Acutely Malnourished
MUAC	Mid-upper Arm Circumference
HNDA	Notre Dame of Apostles Hospital
SMART	Standardized Monitoring and Assessment of Relief and Transitions
UNS	Supplementary Nutritional Unit
UNT	Therapeuutic Nutritionnal Unit
NCHS	National Center for Health Statistics of United States of America
ABUM	Burkinabe Association of Misola
UNICEF	United Nations Children's Fund
P/T	Weight-for-height Index
P/A	Weight-for-age Index
T/A	Height for Age Index
ANOVA	Analysis of Variance
SPSS	Statistical Package for Social Sciences
CREN	Recovery and Nutritional Education Center of MORIJA at Ouagadougou
MORIJA	
CRSBAN	Centre for Research in Biological, Food and Nutritional Sciences

Author Contributions

Barnabas Kayalto: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing

Djimadoum Kimassoum: Project administration, Validation, Writing – review & editing

Brahim Boy Otchom: Formal Analysis, Funding acquisition, Methodology, Supervision, Writing – review & editing

Emilienne Soubeiga: Resources

Alfred Sadjo Traore: Methodology, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Fields

Barnabas Kayalto: Human nutrition, Infant flours, food microbiology, food quality, Water pollution by heavy metals, Pesticide residues in food

Djimadoum Kimassoum: Food safety, Nutrition, Food microbiology, Food quality, Dietetics, Food technology

Brahim Boy Otchom: Biochemistry

Alfred Sadjo Traore: Human nutrition, applied microbiology, Microbial biotechnology, PCR, Biochemistry