EAS Journal of Nutrition and Food Sciences
Abbreviated Key Title: EAS J Nutr Food Sci
ISSN: 2663-1873 (Print) & ISSN: 2663-7308 (Online)
Published By East African Scholars Publisher, Kenya
Volume-7 | Issue-1 | Jan-Feb; 2025 | DOI: https://doi.org/10.36349/easjnfs.2025.v07i01.004

Original Research Article

Cost-Effectiveness of Four Improved and Enriched Local Infant Flours from Chad in the Nutritional Care of Moderately Malnourished Children Aged 6 to 59 Months Admitted to the Nutrition Unit of Notre Dame of Apostles Hospital at N'Djamena

Barnabas Kayalto[1], Moukhtar Roumane[2], Abdelsalam Tidjani[3]*

[1]Ecole Normale Supérieure de Bongor, Bongor/Tchad (ENS-B), Département-SVT, B.P. 234 Tchad
[2]Centre Hospitalier Universitaire d'Abéché (CHUA), Tchad, B.P 87
[3]Food Science and Nutrition Research Laboratory (FSNRL), Faculty of Human Health Sciences (FHHS), University of N'Djamena, Chad

Article History
Received: 22.12.2024
Accepted: 27.01.2025
Published: 30.01.2025

Journal homepage :
https://www.easpublisher.com

Quick Response Code

Abstract: The aim of this study was to assess cost-effectiveness of four improved and enriched infant flours. The study was carried out at the Supplementary Nutrition Unit (UNS) of the Notre Dame of Apostles Hospital (HNDA) at N'Djamena. The results of the study, which included 416 children, showed that moderately malnourished children on experimental flours with dried *Moringa oleifera* leaf powder took a maximum of three weeks to recover from malnutrition. The *Pennisetum typhoïdes* flour with *Moringa* gave the best results, with 96% of children recovering after an average duration of recovery of 17.5 days. Children on red sorghum flour from Bongor without *Moringa* (SRBSM) showed the highest daily weight gain in the study, at 8 g/kg-body weight per day. The same flour, SRB, with *Moringa* showed the highest hemoglobin gain of 13.5 g/dl. Children on maize flour without *Moringa* took the longest to recover in the study, an average of 32.7 days. To conclude, in in accordance with our results, from a cost-effectiveness point of view, flours of *Pennisetum typhoïdes* and red sorghum flours with *Moringa* leaf powder showed the best results of the study. They are likely to help improve health and reduce the prevalence of malnutrition, which is currently recurrent among a large proportion of Chadian children.

Keyword: Infant flours, *Moringa oleifera*, iron, cost-effectiveness, Chad.

INTRODUCTION

Cost-effectiveness is defined as the cost of obtaining a specific result [1]. In the food fortification, the result might be: avoiding a case of vitamin A deficiency, avoiding a case of anemia, or avoiding a case of goiter or iodine deficiency. In many cases, food fortification is the least expensive way of achieving a particular nutritional objective, for example a defined reduction in the prevalence of anemia or vitamin A deficiency. Several studies have shown that food fortification is not only a good cost-effective, i.e. a less costly way of increasing micronutrient intakes than other interventions, such as supplementation, aimed at the same goal, but also cost-benefit, i.e. a good investment [1]. The estimated unit costs of various fortification and supplementation programs compiled by [2] have shown that the unit equipment costs of supplementation are systematically higher than those of fortification.

Two outcome measures, effectiveness, are often used in cost-effectiveness assessment of healthcare interventions, the cost per death averted, and the cost per disability-adjusted life year (DALY) gained, which combines mortality and morbidity outcomes into a single indicator [1]. The CHOICE project, 'CHoosing Interventions that are Cost-Effective', is a tool developed by the WHO to help decision-makers choose interventions and program that provide maximum benefit for the resources available.

Success of a food fortification program are greatly enhanced if it is supported by a range of activities that together help to create a favorable environment for promoting change at all levels, from the individual to

***Corresponding Author:** Abdelsalam Tidjani
Food Science and Nutrition Research Laboratory (FSNRL), Faculty of Human Health Sciences (FHHS), University of N'Djamena, Chad

political authorities, through communities and industrial companies. There are various ways of communicating messages about the beneficial effects of food fortification, such as nutrition education, social marketing and awareness activities [1].

In the Supplementary Nutrition Unit of our study, every thursday and friday, the days dedicated to nutrition, activities always begin with an awareness-raising session on various topics such as breastfeeding, a balanced diet, hygiene, etc. There are also civil society organizations in Chad that provide nutrition education via community radio stations and social networks, not forgetting nutrition teachers...

Chad is faced with recurrent cycles of child malnutrition among children aged between 6 and 59 months. According to the SMART 2022 survey report, at national level, the prevalence of Global Acute Malnutrition (GAM) was estimated at 8.6%, ranging from 7.9% to 9.4%. However, this prevalence masks major disparities at provincial level, where it varies from 2.6% in Logone Oriental to 17.7% in Wadi Fira. According to 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]), hence the need to step up malnutrition prevention measures based on the strategy for the first 1,000 days [3].

Our current state of knowledge, few studies in Chad have assessed the biological effectiveness of infant flours based on local foods. This is why our study was conducted with the main objective of assessment the biological effectiveness and cost-effectiveness of four improved and fortified infant flours with a view to contributing to reducing, to some extent, malnutrition among children aged 6 to 59 months.

The raw materials in our study were purchased on the N'Djamena markets in December 2014, the post-harvest period, and were revalued in September 2024 in order to assess the high cost of living in Chad. The local measure used in the markets for cereals and legumes, instead of scales, is a cup called "coro" in the local language, which means cup in Chadian Arabic. The weight of the cup depends on the ingredient being measured.

MATERIALS AND METHODS

1. Site of study and period

The study was conducted over six months, from 27 may to 02 December 2015, at the Supplementary Unit (UNS) of the Notre Dame of Apostles Hospital (HNDA) in Chagoua at N'Djamena.

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 leaving the UNT transition phase and admitted to the UNS at Notre Dame of Apostles Hospital at N'Djamena.

To determine the study sample, 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.

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.

4. 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), not have severe disabilities and whose parents were resident in N'Djamena during the study months and consented to the study, after information about purpose of the study. These children were follow up until recovery.

5. Non-inclusion criteria

Severely acutely malnourished children (Z-score P/T < - 3ET) 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 families not living in N'Djamena at the time of the study, were also excluded.

6. Materials and methods

6.1. Material

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. Practically, this means that for each flour and depending on the families' eating habits, the children admitted for consultation were allocated to one flour or another until there were 52 children per 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.

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. Then, we will have flour control flour and four experimental flour.

6.2. Methods

6.2.1. Experimental flours

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.

6.2.2. Recruitment and data collection

The data was collected using a questionnaire containing items on the socio-economic characteristics, anthropometric data, clinical data and results of biological examinations 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 to care giver of the 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.

6.2.3. 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. Midupper arm circumference (MUAC) was measured with ribbon method described by [7].

6.2.4. Collection of blood samples

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

The blood samples 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 WHO [8], because of its simplicity and its correlation with the cyanmethemoglobin method reported in various populations, including African populations [9].

6.2.5. Hematological 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 [10] with Hemocue kit.

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

6.2.6. 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 indices (P/T, P/A, T/A) were determined and monitored.

6.2.7. 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 $p < 0.05$.

RESULTS

Our previous studies has enabled us, firstly, to determine the nutritional and microbiological value of the flours, as well as the powder of dried *Moringa* leaves and pulps of *Parkia biglobosa*; secondly, to master their manufacturing technology through trials at the CREN MORIJA of the SCHIPHRA Protestant Hospital in Ouagadougou. Thirdly, in the present study, the biological effectiveness of these flours in the nutritional recovery of moderately malnourished children was tested and the costs calculated in order to conclude our work.

What did we observe at the end of this present study?

1. Distribution of children by sex and age group

We made a randomized allocation of 52 boys and girls per study flour. According to our results, 59.13% of the children admitted to the Supplementary Unit of HNDA were boys, compared with 40.87% of the girls.

The age distribution of moderately acutely malnourished children admitted to the Unit revealed that 74.52% of MAM children admitted to the Unit are aged between 6 and 18 months; this figure rises to 88.70% for children aged between 6 and 24 months and 97.34% for children aged between 6 and 30 months. Up to 36 months, 99% of MAM children are affected.

2. Duration of recovery

Under different flours feeding at the UNS, the shortest duration of recovery was recorded for children subjected to *Pennisetum typhoïdes* flour from N'Djamena with *Moringa* leaf powder (PNM), which was 17.5 days (Table 1). Children on 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 subjected to flours with *Moringa* took a maximum of 22,3 days to recover.

Table 1: Average duration of recovery at the Unit 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

The abbreviations MNM, for example, means Maize flour from N'Djamena with *Moringa* leaf powder, while MNSM is control flour without *Moringa*, in French, Sans *Moringa* (SM) leaf powder. PN= *Pennisetum typhoïdes* 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.

Except children fed SRKSM and MNM flours, our results in the present study revealed 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. Evolution of weight and height

The average weight gain per day and per flour, expressed in grams per kilogram of body weight (kg bw) reported in Table 2, 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 2: Average weight gain (g/kgbw/d) by flour

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

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.

As for the rate of weight gain during treatment, the study revealed that this rate was not linear. All the children gained weight at their own rate, but by the fourth week, everything seemed to stabilize. We observed a clear shift above, between the curves representing the evolution of the weight of the children on the experimental flours with *Moringa* and those on control flours, towards the bottom. This is compensatory growth, as they make up for the weight lost through undernourishment.

Figure 1 also clearly showed that the children's height (taille) gain was visible from the 3rd and 4th weeks (semaine).

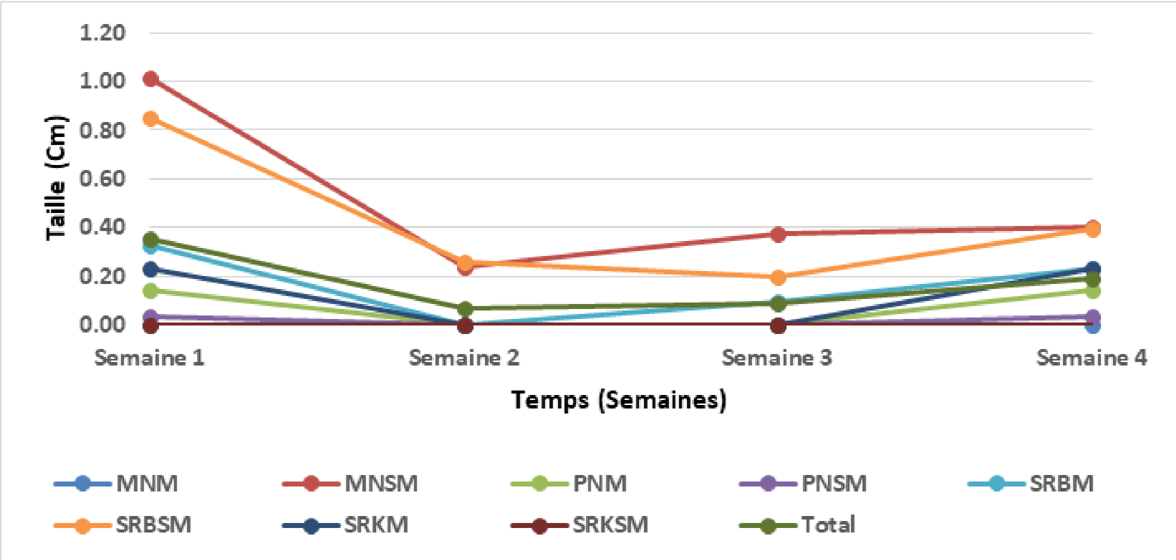

Figure 1: Evolution of height gain during treatment

4. Evolution of MUAC

Between inclusion and discharge, 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) and lastly by children on Bongor red sorghum flour with *Moringa* (SRBM).

5. Evolution in children's hemoglobin status

For hemoglobin (Hb) tests characterizing the prevalence of anemia, the reference thresholds according to [11] are: < 11g/dL = anemia generally; 10-10.9 g/dL = mild anemia; 7-9.9 g/dL = moderate anemia and < 7g/dL = severe anemia. 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), 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.

6. Evolution of cure and drop-out rates

Our results relating to the average cure rate 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 was for PNM flour, at 4%. The highest drop-out rate was for N'Djamena maize flour with *Moringa* (MNM).

When these results are broken down by sex, 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.

7. Degustation parameters of the flours

The assessment of the flours was initially based on an eight (08) point scale. However, in the field, the poor quality of the children's mother tongue led us to simplify the scale to three (03) points: 1 = don't like, 2 = like moderately and 3 = like very much. The color and texture of the flour were appreciated by the mothers. As for the taste and smell of the flour, the mothers reported the children's reactions.

As for the texture, the mothers were asked to assess how fine the flour was. They had to say whether, after milling and sifting, the flour was very fine or whether there were elements in it that were not finely crushed. A descriptive statistical analysis of the results of the survey forms reveals the following results, summarized in Tables 3 and 4.

Table 3: Mothers' and children's appreciation of the color and taste of flour

Flours	Color			Taste		
	like very much (%)	like moderately (%)	Don't like (%)	like very much (%)	like moderately (%)	Don't like (%)
MNM	100,0	-	-	85,7	14,3	-
MNSM	94,4	5,6	-	94,4	5,6	-
PNM	97,9	2,1	-	97,9	2,1	-
PNSM	96,8	-	3,2	93,5	3,2	3,2
SRBM	100,0	-	-	100,0	-	-
SRBSM	97,4	2,6	-	97,4	2,6	-
SRKM	96,9	3,1	-	96,9	3,1	-
SRKSM	100,0	-	-	100,0	-	-

Children seem to like the taste and smell of maize flour the least (85.7%), compared with other flours.

Table 4: Mothers' assessment of the smell and texture of the flours

Flours	Smell			Texture	
	like very much (%)	like moderately (%)	Don't like (%)	like very much (%)	like moderately (%)
MNM	85,7	14,3	-	92,9	7,1
MNSM	94,4	2,8	2,8	91,7	8,3
PNM	97,9	2,1	-	68,1	31,9
PNSM	96,8	-	3,2	64,5	35,5
SRBM	100,0	-	0,0	100,0	0,0
SRBSM	97,4	-	2,6	94,9	5,1
SRKM	96,9	3,1	-	96,9	3,1
SRKSM	100,0	-	-	63,0	37,0

8. Adverse effects of the flour

Adverse effects such as diarrhea, vomiting and coughing contributed to weight loss in children admitted to the Supplementary Unit. These effects manifested by the children in the study are summarized in Table 5.

Table 5: Adverse effects of flours

Flours	diarrhea (%)			vomiting (%)			cough (%)		
	once	twice	thrice	once	twice	thrice	once	twice	thrice
MNM	-	7,4	7,4	-	-	3,57	-	-	-
MNSM	35	17,5	-	25	44,4	-	50,0	7,5	-
PNM	-	-	2,17	-	-	-	-	-	-
PNSM	-	-	6,9	-	3,45	-	-	-	-
SRBM	-	3,45	-	3,45	-	-	-	-	-
SRBSM	-	6,9	-	-	-	-	-	-	-

SRKM	-	6,9	-	-	-	-	-	-	-
SRKSM	-	-	5,13	-	-	-	-	-	-

- means, unmanifest effect.

Corn flour without *Moringa* (MNSM) showed the highest adverse effects in the study. The nurse responsible for monitoring the children in the study highlights in the files that, particularly for cough; some children came into the study coughing. The cause of the cough seems not to be entirely attributable to the flour.

For the rest, by group, by children on control porridges or children on porridges with *Moringa*, expressing the results as an average, related to the four flours of each group, study revealed that:

- Children on control flours: In this group 8.75% of children had diarrhea once; 6.1% twice and 3.01% three times; 6.25% of children vomited once compared to 11.96% twice. As for cough: 12.5% of children coughed once compared to 1.87% twice. Here, we did not observe abdominal pain or stomach bloating ;
- Children on experimental flours with *Moringa*: For these children, only diarrhea and vomiting were observed at the start of the study. Children had diarrhea twice at 4.44% and three times at 2.39%. For vomiting, it was observed once at 0.86% compared to 0.89% three times.

The raw materials for our study were purchased on the markets of N'Djamena in December 2014. The local measure for cereals and legumes, in place of the scale, is a cup called in the local language "coro" which means cup in local Arabic whose weight depends on the ingredient. In Table 6 are presented the weights and prices of some ingredients.

Table 6: Cost price (FCFA) of one kilogram of infant flour (December 2014)

	***Pennisetum typhoïdes* flour**	**Bongor red sorghum**	**Koumra red sorghum**	**Corn flour**	**Bean**	**Niébé**	**Peanuts**
Gross weight of a cup, kg	2,6	2,6	2,4	2,7	2,13	2,5	2,13
Net weight of one cup with hulled, kg	1,8	2,6	2,4	2,13	1,665	1,75	1,93
Average loss rate, %	30,77	0	0	21,12	21,83	30	9,39
Purchase price of a cup, FCFA	600	400	500	600	1000	1200	1600
Cost price of one kg of flour (FCFA)	**895**	**555,46**	**451,48**	**785,74**			
Selling price of one kg (FCFA).	**1150**	**800**	**700**	**1050**			

We went to the markets of N'Djamena this Friday, September 27, 2024 to inquire about the prices of ingredients. The situation is as follows:

Table 7: Comparison of the prices of ingredients for a cup of ingredient in 2014 and 2024

	Pennisetum typhoïdes	**Bongor red sorghum**	**Koumra red sorghum**	**Corn**	**Bean**	**Niebe**	**Peanuts**
Purchase price of a cup, FCFA (**2014**)	600	400	500	600	1000	1200	1600

Purchase price of a cup, FCFA (**2024**)	**1000**	**1000**	**1000**	**1500**	**2750**	**3000**	**2000**

The parameters that are used in determining the cost price of one kilogram of each infant flour produced locally in Chad are as follows: The quantity of ready-to-use ingredients used in the composition of the flours has been calculated according to the percentage of ingredients in our flours.

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

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

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

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

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

The quantities obtained of cereals and hulled legumes were compared to the raw quantities per cup and the prices thus calculated. To this, we added:

- The costs of shelling cereals (corn, *Pennisetum*), i.e. 50 Frs CFA per cup (approximately the weight of 2 kg of ingredient);
- Milling into flour (cereals, legumes, carrots and potatoes), 50 Frs per cup; except for corn seeds where we paid 100 francs CFA per cup;
- One (1) kilogram of powdered sugar cost 500 Frs CFA; In September 2024, this price is 2,500 CFA francs;
- Transporting a bag of cereal from the market to home which cost on average 250 Frs CFA;
- Firewood for roasting peanuts, beans and cowpeas, then roasting the cereal flour with bean's flour after grinding in order to reduce anti-nutritional factors, minimize contamination of public mills and give a good taste to the flour. According to our work, we estimated the firewood or gas equivalent at 200 Frs CFA for 10 to 15 kg of flours. Carrot's flour containing β-carotene is not roasted.

We estimated the price of carrots and potatoes as follows:

- **Fresh carrots** were sold in quantities of 5 carrots for 200 Frs. **In September 2024**, this price is 500 CFA francs. Twenty fresh carrots weighed an average of 2.1 kg. These peeled, sliced and shade-dried carrots gave an average dry weight of 340 grams. This constituted our basis for calculation.
- Potatoes were evaluated in the same way. In December 2014, five (05) big potatoes cost 500 Frs. **In September 2024**, this price is 1000 CFA francs. The average weight of twenty (20) fresh apples was 5.8 kg which allowed us to obtain 900 grams of dried apples whose cost price was 2000 Frs CFA.

All these evaluations made, the flours of the different ingredients mixed; we added one (01) kg of powdered sugar to five (05) kg of flour. The cost price was divided by the total quantity obtained, in kg and the cost price of one (01) kg of flour was thus obtained.

We added 250 Frs CFA to this cost price to obtain the selling price in 2014. These 250 Frs cover the salary of the producers-sellers (100 Frs per kg of flour sold) and operating costs which include the supply of water, electricity, the purchase of consumables (soaps, detergents, plastic bags, jute bags, etc.).

DISCUSSION

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

Our recovery rates obtained are higher than those reported by [12] where children on flours with *Moringa* recovered to 92.5% compared to 55.2% of children on control flour. However, it should be noted that Zongo *et al*., worked with severely malnourished children (MAS).

The high dropout rate in our study, on average 30%, is partly explained by the weight of society. In Chad, people greatly appreciate the physical presence of a person when a family member dies. Mothers, for these social reasons, go to cases of death to the detriment of the health of their children and return with children who have relapsed.

The average daily weight gain in our study ranged from 4.87 to 8.00 g/kgbw/day. This remains low compared to the recommended values which range from 10 to 20 g/kg/day [13]. Some authors explain this by the fact that, during outpatient studies, it is difficult to directly measure intake. We rely more on the statements of the mother or the career. This is why [14] state that it is not clear that the experimental flour was preferentially given to the child under study at home. Our results obtained agree with those obtained by [12] which were 5.7 to 8.9 g/kgbw/d but were found to be a little higher than those obtained by [15] who obtained a gain varying between 4.5 to 6 g/kgbw/d.

Regarding the hemoglobin status of the children, at study entry, we had 0.07% of children entering severely anemic out of the total number of children. By flour, the majority of children entered the study with a moderately anemic status, except the children under N'Djamena corn flour (MNM) and under red sorghum from Bongor (SRBM) with *Moringa* where the children were came in slightly anemic. At the discharge, we note a slight improvement in the hemoglobin status for all the flours (from 8.11-10.78 at the inclusion to 9.5-10.72 g/dL at the discharge), except the flour of red sorghum from Bongor with *Moringa* (SRBM) where between inclusion and discharge, we have a slight drop from 10.78 to 10.72 g/dL. The SRBM gave the maximum gain in hemoglobin in the study where some children left with 13.5 g/dL (normal status).

In their study on the bioavailability of iron from *Moringa* concluded that *Moringa oleifera* powder is rich in proteins with a digestibility of 56% and despite its high iron rate, the bioavailability of iron is low, often less than 1% [16]. Notes that the rate of iron absorption depends on the iron status of the individual and in particular on the state of their iron reserves. Absorption increases when reserves decrease and, conversely, decreases during iron overload. Therefore, knowledge of the iron status of children at the inclusion in the study is necessary [17].

In her medical thesis and as part of the project "Valorization and processing natural resources in a process of combating poverty in Chad and Cameroon" (VALRENA), studied variations in anthropometric parameters, hemogram and concentrations of albumin and ferritin in healthy children aged 5 to 8 years after introduction of 3 grams and 5 grams of *M. oleifera* leaf powder respectively in flour and bread chocolate for 18 weeks [18]. Although these quantities of *Moringa* seem lower than the quantities recommended and accepted by children, which are 10 g of *Moringa* per day, but its study is more complete on hematological parameters; she came to the conclusion that the anemia found in children is non-iron deficient. It would be of inflammatory origin due to parasitic and other infections (intestinal parasites, blood parasites). Consumption of *Moringa* did not remedy the situation. But, it is interesting to note that the anemia rate decreased from 92.3% to 87.87% in boys consuming *Moringa*, while in the control groups, the anemia rate increased by 69.05 % to 87.71%.

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

CONCLUSION

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

Quickly recover and at the best rate seems undoubtedly to be attributable to *Moringa oleifera*. Children on *Moringa* take a maximum of three weeks to recover. All children subjected to experimental flours with *Moringa* had a higher average weight at discharge than the children receiving control flours. *Pennisetum typhoides* flour with *Moringa*, regarding the healing rate showed the best result. Children fed red sorghum flour from Bongor (SRB) without *Moringa* showed the highest daily weight gain in the study. The same flour with *Moringa* showed the maximum rate of hemoglobin gain. Children subjected to corn flour with *Moringa* (MNM) showed the best average gain in upper arm circumference (MUAC). They follow those under SRB. The children given corn flour without *Moringa* in the study 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. In view of the results of our work, the flours of *Pennisetum typhoides* and red sorghum flours obtained from improved diagrams, associated with the powder of *Moringa* leaves, from the cost/effectiveness point of view, gave the best results of the study. They are likely to contribute to improving health and reducing the prevalence of malnutrition currently recurrent among a large proportion of Chadian children. These flours produced are socially acceptable because they have not changed either eating habits or the foods consumed. All of these results constitute a scientific basis for the use of these flours. @

ACKNOWLEDGEMENT

The authors acknowledge head managers of the University Ouaga I Pr Joseph KI-ZERBO, Professors Alfred S. TRAORE, Aly SAVADOGO (CRSBAN/UO1 PJKZ) and Brahim Boy OTCHOM (FSEA/N'Djamena); all workers of the Supplementary Unit of HNDA of N'Djamena (Chad) for providing facilities for this work. Particular thanks to Sisters Emilienne SOUBEIGA and Léa, Doctor Mianbé, nursery Mariam ADAH. The financial support from French Cooperation through Campus France, CONFOFOR grant awarded by Government of the Republic of Chad, Ecole Normale Supérieure de Bongor (ENSB) and the West African Biotechnology Network (RA-BIOTECH) were also appreciated.

Conflict of Interest: None declared

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Cite This Article: Barnabas Kayalto, Moukhtar Roumane, Abdelsalam Tidjani (2025). Cost-Effectiveness of Four Improved and Enriched Local Infant Flours from Chad in the Nutritional Care of Moderately Malnourished Children Aged 6 to 59 Months Admitted to the Nutrition Unit of Notre Dame of Apostles Hospital at N'Djamena. *EAS J Nutr Food Sci, 7*(1), 29-38.