International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

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[Aboubakar *et al.*, 11(6): June, 2022]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

IMPROVEMENT OF THE NUTRITIONAL STATUS OF MALNOURISHED CHILDREN (6-59 MONTHS) TREATED AT THE BÉTHANIE MATERNAL CHILD PROTECTION CENTRE IN N'DJAMENA (CHAD) USING PORRIDGE ENRICHED WITH MORINGA OLEIFERA LEAF POWDER

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DOI: 10.5281/zenodo.6771057

ABSTRACT

Our study focuses on the improvement of the nutritional status of severely malnourished children (6-59 months) treated at the PMI of Béthanie in N'Djaména (Chad) with porridge enriched with Moringa oleifera leaf powder (MOP). The objective of our study is to assess the effect of the recovery regimes of malnourished children by taking daily porridge enriched with PFMo. Two groups were formed from 60 hospitalized infants divided into two batches. In addition to their usual diet served at the PMI, one group received the PFMo-fortified porridge (GpAM) and the other, chosen as a control, received the non-fortified porridge (GpSM). The nutritional status of the children was assessed by anthropometric indicators. At the end of the study, the results show a significant improvement in the children's nutritional status, both for wasting in the GpAM and for underweight, as well as their brachial perimeter (9.85 ± 1.24 to 12.10 ± 0.40). This improvement was also observed in weight gain, at the end of the study, the average daily weight gain observed during recovery was significantly higher in the GpAM (17.19 ± 4.70 g/kg/d) than in the GpSM (9.74 ± 3.60 g/kg/d) ($p < 0.05$). Finally, we analysed the two infant flours (F1 and F2) that were used to prepare the porridges for the two groups (GpAM and GpSM). The study of their nutritional value gives for F1, rates of 17.69% of proteins, 5.80% of lipids and 70% of carbohydrates with an energy value of 403 Kcal. For F2 flour, the levels are 11.02% protein, 5.0% fat and 77.7% carbohydrates with an energy value of 399 Kcal. The comparison with a standard flour shows that the nutrient and energy contents are satisfactory and comply with the standards set by the WHO.

Keywords: *Moringa oleifera leaf powder, severe malnutrition, fortified porridge, infant flour, anthropometry*.

1. INTRODUCTION

The growth of the world's population and the increase in living standards require good nutrition, which is essential for the survival and harmonious development of children (Djénébou, 2006). Malnutrition is a public health problem. For years, undernutrition has been slowly but steadily increasing worldwide. Between 2008 and 2009, the number of undernourished people in the world increased by 10%, with more than a quarter of this increase occurring in sub-Saharan Africa (FAO, 2009). Children are the most vulnerable group.

Malnutrition contributes to 35% of under-five deaths in West and Central Africa. Currently, one million children in this age group die each year in the region from causes associated with malnutrition (UNICEF, 2010). Malnutrition in children under five is a major public health problem in the world in general and in developing

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countries (DCs) in particular. Indeed, between 1995 and 2002, stunting, wasting and underweight affected 32, 10 and 27% of children under five in developing countries respectively (UNICEF, 2004).

Sub-Saharan Africa is second only to South Asia, with 38, 8 and 29 per cent of children under five suffering from stunting, wasting and underweight respectively during the same period (WHO/UNICEF, 2002). Chad, like other Sahelian countries, has been hit by a chronic food and nutrition crisis for several years, especially the Sahelian strip is weakened by a persistent nutrition crisis caused by floods, low rainfall, drought and poor agricultural harvest (WASH, 2015). Malnutrition is the underlying cause of over 50% of child mortality in Chad (UNICEF, 2011). In Chad, 40% of children aged 6-59 months are stunted or chronically malnourished as a result of inadequate feeding over a long period of time; 14% of children aged 6-59 months are wasted (thin), a form of acute malnutrition of recent onset, reflected in a lower-than-average weight/height ratio; 39% of children are underweight at a given age (EDST, 2004).

Malnutrition mainly occurs in children between 0 and 2 years of age. During this period, the child progressively moves from a liquid and milky diet to a diversified semi-liquid then solid diet (Olivier, 2003). Only 35% of infants in developing countries are exclusively breastfed for the first 6 months, complementary feeding often starts too early or too late and the food is often nutritionally and hygienically inadequate (WHO/UNICEF, 2002). Weaning is a nutritional assault on the infant who is used to feeding exclusively on breast milk. It is at this time in the child's life that various signs of malnutrition appear (Gerbouin, 1996; Bouwer *et al.*, 2000; PAHO, 2009).

In Africa, during weaning, mothers generally feed their children traditional porridges prepared from simple or compound flours from cereals, tubers, which are high in carbohydrates and low in protein. These foods are unable to meet all the child's nutritional needs (Briend, 1985).

In Africa, good quality infant flours do exist on the market, but they are imported industrial products and are very expensive. Consequently, they are not accessible to generally poor mothers. FAO/WHO (2009) recommend that complementary foods be made from locally available and accessible products of sufficient nutritional quality to cover the child's nutritional needs. However, populations have unsuspected forest food resources, including leafy vegetables. Forest products in general, and leafy vegetables in particular, would contribute to solving such a problem for African populations. Several species of traditional African leafy vegetables are rich in micronutrients (Schippers, 2002; Abukutsa-Onyango, 2007). They are important sources of vitamins (carotene, ascorbic acid, and riboflavin), proteins and minerals such as iron and calcium (Tchiegang and Kitikil, 2004; Akubugwo et al., 2007; Avallone et al., 2007; Ndong et al., 2007; Afoloyan and Jimoh, 2009).

In addition to their food and nutritional qualities, leafy vegetables have healing, regulatory and/or stimulating properties (Dansi et al., 2008). Thus, many leafy vegetables are used in the treatment of numerous ailments. This is the case of *Moringa oleifera* (Lam.), whose leaf extracts have significant antimicrobial activity and are believed to improve the body's immune response (Yang et al., 2006). Leafy vegetables therefore appear today as a means of combating "hidden hunger", i.e. deficiencies in micronutrients such as vitamin A and minerals including iron (Dansi et al., 2008). In Chad, particularly in the southern part of the country, M. *oleifera* is regularly consumed by the local population.

To address this situation, the Ministry of Public Health (MSP), through the National Centre for Nutrition and Food Technology (CNNTA), has put in place strategies to combat malnutrition in Chad. The strategies implemented range from improving supplementary foods to primary health care. The production of infant formula from local raw materials has been encouraged. However, the proposed products have limitations and shortcomings, the most important of which are their still high prices and their low energy density and organoleptic quality after processing into porridges. Moreover, the low purchasing power of the population does not allow them to have access to imported flours. Thus, promoting access for infants and young children to supplementary foods with appropriate nutritional, bacteriological and organoleptic characteristics that are culturally and economically acceptable, and promoting their use according to appropriate methods, are ways of improving the nutritional situation in developing countries (Brown and Lutter, 2000; Huffman, 2000; Dewey, 2000; Trèche, 2002; Daelmans et al., 2003; Lutter, 2003; Dewey and Brown, 2003).

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It is in this context that we have chosen to focus on "improving the nutritional status of severely malnourished children (6-59 months) treated at the Bethany PMI in N'Djamena (Chad) with porridge enriched with M. *oleifera* leaf powder (PFMo)". The main objective of our study is to assess the effect of the recovery regimes of malnourished children, through the daily intake of porridge enriched with M. *oleifera* leaf powder, in order to contribute to the improvement of their nutritional status.

2. MATERIALS

Plant material
The raw materials used for flour production come from the local market. They are imported by the association's suppliers, before undergoing certain operations to obtain a good quality flour. The raw materials that can be used in the formulation of infant flour are chosen according to the following criteria: the nutritional values of the ingredients to meet the needs of the child; the dietary habits of the local population; the availability and cost of the raw materials. It is used in a proportion of 50-60% cereal per 100g in each preparation depending on the formulation.

The plant material used consists of four cereals: maize (*Zea mays*), finger millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) and wheat (*Triticum aestivum*); legumes such as beans (*Phaseolus vulgaris*) and groundnuts (*Arachis hypogeacea* L.) and *Moringa oleifera*.

Non-plant material
Among the materials used for our study we can mention: The children, the ladle used to measure the slurry and the carafe; medical equipment (such as syringes, thermometer etc.); laboratory equipment (oven, Soxhlet apparatus, mineraliser...); paper supports for recordings; software (Word, Excel, WHO Anthro 3.2.2, Sphinx 5)

3. METHODS

Methods of admission to the MCP Bethany
Nutritional status is assessed by means of anthropometric indices calculated from the child's age, height and weight measurements. Weight, age and height are used to calculate weight for height (weight/height) which reflects wasting.

Sampling method
This is a case-control study, with an intervention group and a control group. The intervention group is the group of children receiving a porridge enriched with *Moringa oleifera* leaf powder twice a day. The control group is the group of children who receive the porridge without *Moringa oleifera*.

The sampling for the study was as follows:
- Reference population: children aged 6 to 59 months in Chad;
- Target population: malnourished children aged 6 to 59 months living in N'Djamena;
- Source population: malnourished children hospitalised at the MCP Centre;
- Sample: all children aged 6-59 months who met the inclusion criteria of the study.

The sample size was determined according to the Lorentz formula:

$$n = \frac{t2 \times p(1-p)}{e2}$$

Where:
n = sample size;
e = level of precision; e = 0.05;
p = degree of variability (estimated prevalence rate); p = prevalence of severe acute malnutrition in N'Djamena. p = 1.2% according to (SMART, 2013).
t = standard value associated with the required confidence level (95%); i.e., t = 1.96.
The calculations made resulted in a value of n = 18.21≈19. Adding the 10% for those lost to follow-up, we will have 21 children.
Hence n = 21 children

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To be statistically significant, each study group must contain at least 21 children. However, this number may increase as more children come to the PMI. Therefore, 60 children were included in the study, distributed as follows

- 30 children in the group with *Moringa oleifera* (GpAM)
- 30 children in the group without *Moringa oleifera* (GpSM)

Ethical considerations

This study benefited from the ethical approval of the Maternal and Child Protection Centre of Bethany (Appendix 4) and the consents of the mothers of the children meeting the study criteria (Appendix 5).

Flour analysis

The analyses were carried out at the Centre for Research in Biological Food and Nutritional Sciences.
The analyses were carried out on two types of flour (flour without *Moringa* and with *Moringa*) which were used to prepare the porridge given to the children:

- Flour with *Moringa oleifera* (10 bags of 500g)
- Flour without *Moringa oleifera* (10 bags of 500g)

Thus, we named (F1) the flour with *Moringa* and (F2) the flour without *Moringa*.

Flour physicochemical analysis

Analysis of raw taro, pre-boiled and wheat flours for crude lipid, ash and moisture contents was carried out using AOAC (1990) methods, while proteins and available carbohydrates contents were evaluated as previously described (Njintang et al., 2001). Energy content (E) was calculated using the Atwater factor (Omobuwajo 2003) as:

$$\text{Energy} = (\text{Protein}*4) + (\text{Lipids}*9) + (\text{Sugars}*4)$$

Formulation and distribution of porridge to children

The methods of making infant formula vary according to the formulation of the designer or the purpose of achieving a specific objective. It is generally a mixture of a starchy source (cereals or roots) and legumes to which sugar, a mineral and vitamin supplement and a source of amylolytic enzyme are added. The constituents have been processed. The cereals have been cleaned, washed, dried, ground and roasted; except for the sprouted sorghum. The groundnut was roasted, crushed to a paste. The bean was ground and then roasted. In addition to these ingredients, *Moringa* leaf powder was added. The leaves were picked, washed, dried in the shade at room temperature and then ground into flour. The choice of these cereals and legumes is justified by the fact that they are the most widely consumed and accessible locally.

Ten grams of *Moringa* leaf powder were incorporated into the different flours with Moringa. The choice of this dose was based on the relative composition of the powder in proteins, vitamins and minerals, in relation to the recommended daily allowance and its acceptability to children.

Table 1 : Nature of the flours

Ingredients	**Flours with *Moringa* (g)**		**Flours with *Moringa* (g)**
	Ingredients	*Moringa*	
Roasted corn flour	18,75	6,25	33
Roasted millet flour	9,37	6,25	17
Roasted sorghum flour	9,37	6,25	17
Sprouted sorghum flour	9,37	6,25	17
Roasted wheat flour	3,12	6,25	4
Roasted bean flour	437	6,25	8
Peanut paste	1,9	6,25	4

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Composition of the slurry

To prepare the porridge, the flour and ingredients are mixed and cooked for 7-10 minutes. Each of the porridges administered consists of two (2) tablespoons of flour (about 60g), one tablespoon of sugar (15g), 15 ml of groundnut oil and 200 ml of water. Each prepared porridge is distributed and administered twice a day to children (every 7 a.m. and 4 p.m.). Its distribution is according to the child's weight.

Calculation of anthropometric indices

The anthropometric measurements (height and weight) were related to the weight/height indicator. This index was evaluated against the NCHS/WHO-2006 reference standards of ENA for SMART.
Calculation of some indicators

a) Average length of stay

$$\text{Average length of stay} = \frac{\Sigma\ \text{days}}{\Sigma\ \text{Number of patients discharged cured}}$$

b) Weight gain

Weight gain is calculated only for patients discharged cured.

$$\text{Weight gain } (\mathbf{g}/\text{day}) = \frac{\text{Discharge weight (g)} - \text{Initial weight(g)}}{\text{Number of treatment days}}$$

NB: The initial weight is the weight at the beginning of the rehabilitation phase, for children with kwashiorkor, the minimum weight observed after the oedema has melted.
The average daily weight gain is then calculated using the following formula:

$$\text{Average weight gain (g/Kg/day)} = \frac{\Sigma\ \text{of weight gains of warriors}}{\text{Number of patients in group}}$$

Data analysis

All experiments performed during our analyses were repeated at least three times. Means were compared by one-way analysis of variance (ANOVA) with the Duncan test in post hoc. The means were classified into homogeneous subclasses at the threshold of 0.05. Statistical Package for the Social Sciences (SPSS 22.0 for Windows) was used for this purpose.

4. RESULTS

Analysis of infant formula used: physicochemical characteristics

The physicochemical characteristics (chemical composition and functional properties) of the flours are presented in Table 2 in comparison with a standard flour. The results indicate that the moisture content of the flours ranged from 4.76±0.86 for the flour with *Moringa* (F1) to 4.77±0.64 for the flour without *Moringa* (F2). The carbohydrate content was 70±1.52 for F1 and 77.7±1.22 for F2, the protein content was 17.69±0.96 and 11.02±0.80 for F1 and F2 respectively, and the lipid content ranged from 5.80±0.82 for F1 to 5.0±0.33. The ash levels varied from 1.5±0.02 and 1.37±0.05 for F1 and F2 respectively and the vitamin C content was 17.5±1.02 and 1.25±0.97 in mg per 100 g product. The energy values of the flours ranged from 403 to 399 Kcal per 100 g of flour.

The comparison of the nutritional value of the F1 and F2 infant flours with a standard flour is shown in table 2. The F1 and F2 flours are compared with the standard flour reported by Sanogo et al., 1994.

Table 2: Comparison of the nutritional value of F1 and F2 with a standard flour

Nutrients per 100g of product	**Nutrient content (%)**		
	F1	**F2**	**Standard flour**
Moisture	4,76± 0,86^{a3}	4,77± 0,64^{a3}	5
Carbohydrates	70± 1,52^{b1}	77,7± 1,22^{a1}	68
Proteins	17,69± 0,09^{a2}	11,02± 0,80^{b2}	13

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Fat	5,80± 0,82^{b3}	5,0± 0,33^{a3}	7
Ash	1,5± 0,02^{a4}	1,37± 0,05^{a4}	2
Vitamin C (mg)	19,8± 1,02^{a2}	12,5± 0,97^{b2}	-
Energy (kcal/100g)	403	399	400

Results with the same letters (a, b, c) on the same row are not significantly different (P <0.05).
Results with the same numbers (1, 2, 3) on the same column are not significantly different (P <0.05).

The study involved 60 children divided into two groups. One group of 30 children who received a Moringa-based porridge and another group of the same size who did not receive this porridge.

General characteristics of the studied population

The exact determination of age posed difficulties, given the absence of administrative documents (birth certificate) but also and above all by forgetting or referring to events (ceremonies, festivals or the month of Ramadan). This distorts the date of birth of the children, the dates recorded are approximate dates.

Socio-demographic characteristics

The table below (3) presents the socio-demographic characteristics of the 60 children in the study. The results show the predominance of the female sex with 56.7% against 43.3% of males with a sex ratio of 1.30. The most represented age group was 6-17 months (61.7%), followed by 18-29 months (36.7%) and finally the lowest was 30-41 months (1.6%). The sibling rank is 48.3% with 3-5 children in the household, followed by 30.0% (1-2) and 21.7% for the rank above 5 children.

Table 3 : Socio-demographic characteristics of children

Characteristics		Number	Frequency (%)
Sex	Male	26	43,3
	Female	34	56,7
Age (months)	6-17	37	61,7
	18- 29	22	36,7
	30-41	1	1,6
Rank in siblings	1-2	18	30,0
	3-5	29	48.3
	>5	13	21,7

The reason for consultation

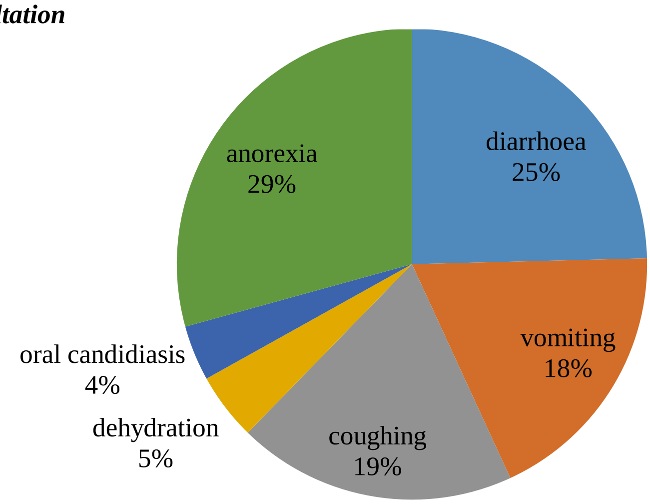

Figure 1: Clinical signs in children

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The most common symptom was anorexia (29%), followed by diarrhoea (25%), coughing (19%), vomiting (18%), dehydration (5%) and oral candidiasis (4%), as reported by the children's mothers.

Evolution of the children's anthropometric indices during recovery
Table 4 presents the Z-scores and the prevalence of wasting in the population of malnourished children aged 6 to 59 months. The results indicate that the consumption of porridge enriched with Moringa resulted in an improvement of anthropometric indices in the children of the intervention group. Indeed, the tests of comparison of means indicated that there was no significant difference between the values of the Z-scores Weight/height (emaciation) of the two groups of children at the beginning of the intervention (P > 0.05). At the end of the study, the Z-scores improved significantly in both the study and control groups.

Table 4: Improvement in children's Z-scores during recovery

Paramètres	**GpAM**		**GpSM**	
	On entry	On exit	On entry	On exit
P/T	-5,22±0,69[a]	-1,38±0,68[b]	-5,83±1,31[a]	-1,52±1,07[b]
PB	9,85±1,24[a]	12,10±0,40[b]	9,42±1,45[a]	11,78±0,86[b]

Results with the same letters (a, b, c) on the same row are not significantly different (P <0.05).

Weight gain during recovery of children in both groups
Daily weight gain (g/kg/day) is an indicator of change in the nutritional status of children undergoing nutritional care, and is an integral part of health facility management (Zongo et al., 2013).

Figure 3 shows the average daily weight gain in children in the GpAM and GpSM of the study. The average daily weight gain observed during recovery in this study was significantly high in the GpAM 17.16±5.05 g/kg/d versus 9.74±3.66 g/kg/d in the GpSM (p <0.05). The comparison of gain between the 2 groups of children was significant (p < 0.05).

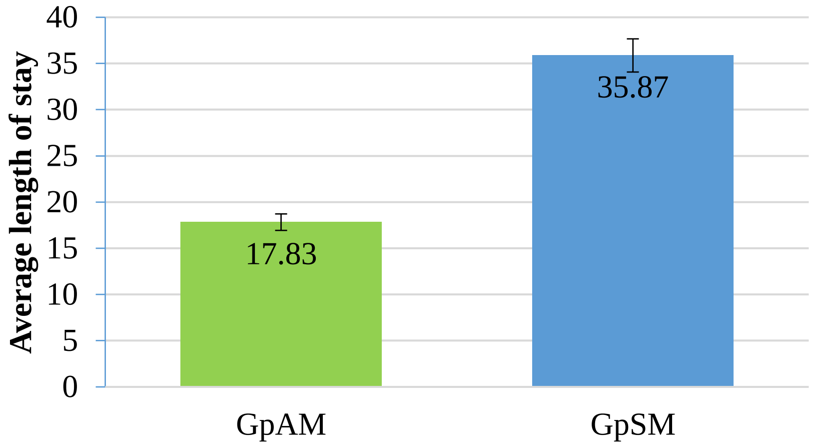

Figure 2: Average length of stay

Average length of stay of children in the two groups during the study
The average length of stay is an indicator to measure the effectiveness of the management of malnourished children (*Zongo et al*., 2013). Figure 4 shows the average length of care during the study in both groups. During this study, the average length of stay was 17.83±2.56 days for children in the group with Moringa and 35.87±9.14 days for the group of children without Moringa.

5. DISCUSSIONS
The various results obtained were compared with the results of other authors who have worked on the same subject.

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General characteristics of the studied population

Socio-demographic characteristics

Our study was characterised by a predominance of women (56.7%) with a sex ratio of 1.30. This predominance was also noted in the case of the women in the study.

This predominance has also been noted by several authors including Julien in Ouagadougou in 2013 with 54.68%, by Arnaud in the Ivory Coast in 2004 with a female predominance (51.36%) and by Randia in Madagascar in 2010 found a predominance similar to that of our study.

On the other hand, it is opposite to that observed by Iknane *et al*. (2011) in Chad, who found a male predominance (69% of boys against 31% of girls). This could be explained by the difference in the size of their sample (400 versus 60 children in this study). Several authors, including Nguelé in Chad in 2001, Djenébou in Mali in 2006 and Olivier in Chad in 2003, found a sex ratio of 1.29, 1.64 and 1.37 respectively in favour of boys. Similarly, in the SMART studies or national nutrition surveys, males have always been predominant. This difference could therefore be explained by the small sample size.

The most represented age group was 6 to 17 months (61.7%), followed by 18 to 29 months (36.7%) and 30 to 41 months (1.6%). The average age of the children was 16 months, with extremes of 6 and 39 months.

Similar results were reported by WFP in the 2009 Food Security Analysis in Chad, by Aïcha in 2009 in Chad and by Ouédraogo et al. According to Nguelé in his study in Chad in 2001, this age group corresponds to the age of predilection for acute malnutrition. The existence of food taboos in this age group is much higher.

Most of the children in this study are between the third and fifth birthdays (48.3%). This age group is the most vulnerable in developing countries, as it is often at this period that weaning occurs, which could have a negative impact on the nutritional status of children (Trèche et al., 1994).

Reason for consultation

The results we obtained on the reason why mothers bring their children to the centre are as follows:

- Anorexia: 29%.
- Diarrhoea: 25
- Coughing: 19
- Vomiting: 18
- Dehydration: 5%.
- Oral thrush: 4%.

These signs are associated with malnutrition and affect children's immune defences, causing their health to deteriorate.

Several studies have indicated that malnutrition is a vicious circle. According to Agbessi and Damon, in 1987, it only takes one measles or diarrhoea to tip the child into more severe malnutrition, often a kwashiorkor in a child at risk and in an unstable state. According to FAO in 1998, more generally, malnutrition is the result of the combination of inadequate food intake and infectious disease, determining a vicious circle of infection and malnutrition.

According to Iknane (2002) malaria, acute respiratory infections, diarrhoeal diseases, measles and malnutrition constitute 63% of the causes of consultation of children and 46% of the causes of death. And according to the EDST-2004, the main causes of death for children under five are, in order of importance, diarrhoea (17%), measles (13%), fever (11%), respiratory infections (7%), malaria (6%) and cough (6%). For children aged 1-59 months, fever was the most commonly reported symptom (82%) and in many cases the fever was 'high' (65%). Just over one in two children (51%) were extremely thin and signs of oedema (face and swollen feet/legs) were reported in 13% of cases. More than two out of five children (43%) had diarrhoea and 11% had signs of dysentery (bloody diarrhoea in the stool).

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Before death, more than one in four children (26%) had coughing and short, rapid breathing, which is characteristic of acute respiratory infections (ARI). In addition, 42% of children were unconscious before death and 34% had convulsions. Finally, one in five cases (20%) had a rash. This proves that children under five years of age have malnutrition problems that are considered serious according to the results of the EDST-2004. Aisha in 2009 observed that 78.7% of children admitted had good hydration status and 21.3% were dehydrated. Only 18.5% had a depressed fontanel. Olivier in 2003 found 74.6% dehydrated children among the malnourished. This state of dehydration is almost constant because malnourished children generally have diarrhoea. This almost constant presence of diarrhoea observed among the malnourished is explained by the fact that during malnutrition, there is a significant disruption of the intestinal flora associated with atrophy of the villi lining the gastroduodenal mucosa (Aisha, 2009). Djénébou (2006) stated that 56.8% of children had fever and 32.4% had diarrhoea. Diarrhoea was the third most common reason for consultation in her study and ARI the last. This indicator is particularly useful to show the quality of care, including meal monitoring. It indicates the amount of RUTF that the child actually ate.

Prevalence of malnutrition

The management of severe acute malnutrition is crucial to reduce infant and child mortality. Poor countries face a low capacity to hospitalise many cases of severe acute malnutrition. Recent successes in community-based management of uncomplicated cases (reserving hospitalisation for severe cases with complications) have rekindled the debate on the need to change management options (Savadogo *et al*., 2007).

The anthropometric variables of the children at the beginning of our study (Table 4), show that the children are affected by severe acute malnutrition with a significant P/T wasting below the P/T<-3 z-score and a PB<11 cm if the height is greater than 65 cm. We can say that this meets our inclusion criterion, and also for the management criterion of severe malnutrition (children with or without bilateral oedema with a P/T<-3 z-score and a PB<11 cm if height greater than 65 cm). Severe acute malnutrition has even deteriorated according to EDST in 2004 in Chad, as the proportion of children suffering from severe stunting has increased from 20% in 1996-1997 to 23% in 2004 (EDST, 2004). According to several studies or surveys carried out in Chad cited by the CNNTA in 2012, such as the EDST in 1997 (14% of children suffered from wasting, MICS in 2000 (12% of emaciated children against 16% for the MICS 2010. According to the Chad DHS in 2004, the NCHS found that 16% of children aged between 6 and 23 months in the city of N'Djamena were emaciated.

Changes in children's anthropometric indices during the recovery period

Table 4 presents the Z-scores and the prevalence of emaciation in the study population of malnourished children aged 6 to 59 months.

The results indicate that the consumption of Moringa enriched porridge led to an improvement in anthropometric indices in the children in the intervention group. Indeed, tests of comparison of means indicated that there was no significant difference between the weight/height (wasting) Z-scores of the two groups of children at the beginning of the intervention (P > 0.05). At the end of the study, the Z-scores improved significantly in both the study and control groups.

The change in P/T, and PB at the beginning and end of the study showed a faster recovery in the children in the group receiving the PFMo enriched porridge as a food supplement. Children with a P/T index between -1 and -2 z-score are considered well-nourished (WHO, 2006).

This result shows that the daily consumption of 10 g of PFMo, combined with a recovery programme, leads to a better improvement of the nutritional status of children with wasting.

The nutritional benefits of eating leafy vegetables in general by children had already been noted in many studies. They provide children with minerals, vitamins and nutritional factors that are often missing from their diet.

Due to their high nutritional value, leafy vegetables can therefore be used for children during their growth period (Dansi et al., 2008). They could fill the nutrient gap that is often present in regular foods when added to them.

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Guyot et al. (2010) proposed supplementation with plant sources of protein, fat and micronutrients such as leafy vegetables as one approach to reducing malnutrition.

The results obtained from the present study are consistent with those obtained by Tété-Bénissan et al. (2012) using PFMo as a food supplement for malnourished children in Togo, and with those found by Bidossessi et al. (2013) in Benin and by Zongo *et al*. (2013) in Burkina.

An experiment conducted in Cameroon on young guinea pigs revealed that M. *oleifera* leaves appeared to be a supplement of choice for improving the growth performance of guinea pigs, at a lower cost in a farming environment (Tedonkeng et al., 2005).

Similar results were obtained with the whole leaf of M. *oleifera* on animal subjects. Thus, cattle receiving this plant as a supplement gained significantly more weight than those not receiving it (Nikolaus et al., 2001; Fuglie, 2001). These results can be explained by the fact that PFMo is rich in protein. Indeed, fortification of dishes with this powder improves protein contents (Ndong et al., 2007).

The digestibility of amino acids and proteins is close to 60%, which allows a good absorption of the nutrients provided by the M. *oleifera* leaf powder (Yang et al., 2006).

Weight gain during recovery of children in both groups
Daily weight gain (g/kg/day) is an indicator of variation in the nutritional status of children undergoing nutritional care, and is an integral part of health facility management.

These results are higher than those observed by Zongo *et al* (2013) who found 8.9±4.30 g/kg/d and 5.7±2.72 g/kg/d respectively for the Moringa group and the group without Moringa in Burkina Faso. Only the average weight gain in the Moringa group reached the WHO recommendations of 10 to 20g/kg/d.

The difference in average weight gain in our study could be attributed to the incorporation of PFMo in the children's porridge. PFMo is rich in digestible protein and iron (Ndong, 2007). However, the digestibility of Moringa protein could be reduced by the presence of fibre and anti-nutritional factors such as tannins and phytates in Moringa.

However, authors have reported that drying and cooking of leafy vegetables, particularly Moringa, reduces the anti-nutrient content and improves the in vitro bioavailability of protein and iron (Price, 2007; Yang et al., 2006). Moreover, this supports the conclusions of some authors who stated that regular consumption of Moringa leaves improves the nutritional status of children and probably increases their weight gain (Tété-Bénissan et al., 2012; Houndji et al., 2013; Zongo et al., 2013).

Average length of stay of children in the two groups during the study
The average length of stay is an indicator that measures the effectiveness of the management of malnourished children.

The average length of care during the study in the two groups was illustrated in Figure 4. During this study, the average length of stay was 17.83±2.56 days for children in the GpAM and 35.87±9.14 days for the GpSM.

The average length of stay in a therapeutic feeding unit is considered an output indicator for determining the effectiveness of the management of severe child malnutrition. The average length of stay was significantly different between the two groups of children ($p<0.05$).

We found that children in the GpAM (17.83±2.56 days) stayed less than children in the GpSM (35.87±9.14 days). Their average stay was half that of children who did not take porridge with *Moringa*.

At the end of this study, only the average length of stay in the GpAM is acceptable and is in line with the standard set by WHO/UNICEF (2006) of 28 days (4 weeks).

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This short stay observed could be attributed to the incorporation of PFMo in the porridge of the GpAM children. Moringa leaves are rich in essential amino acids and vitamin A and antioxidants that help increase the response of the children's immune system against intestinal parasites and rapidly improve the nutritional status of the children (Zongo et al., 2013; Yang et al., 2006). Diets rich in amino acids help stimulate the immune system against intestinal parasites (gastro infestations), which is conducive to recovery from weight gain (Kyriazakis et al., 2006).

However, the long recovery period in general can be explained by the low contribution of bioavailable iron during nutritional recovery due to cell and red blood cell synthesis (Diop et al., 2003).
Furthermore, we found that the long stay observed at the GpSM is the main cause of abandonment of care at the PMI in Bethany.

Analysis of infant formula used

Physicochemical characteristics
The nutritional value of supplementary feeds also depends on their nutrient bioavailability, i.e. their ability to be actually released during digestive processes, to be absorbed correctly and then used efficiently at the metabolic level (Besançon, 1999; Trèche, 2002). It depends on the physico-chemical environment of the molecules, the technological processes undergone, the absence of anti-nutritional factors (phytates, polyphenols, alpha-galactosides, etc.) and the balance of the diet (Besançon, 1999).

The comparison of the nutritional value of F1 and F2 infant flours with a standard flour is shown in Table 2. F1 and F2 flours are compared with the standard flour reported by Sanogo et al.

Moisture is a determining factor for the quality and preservation of the finished product. The higher the moisture content, the greater the risk of microbial growth or spoilage. The values found for the two flours (F1 and F2) are around 4%, which is in the range of the standard composition of an infant flour reported by Sanogo et al, 1994 (5%), and in line with that found by ITRA, 2011 (4.03%) for the Moringa-based NUTRIMO flour (10% of the MFP) but lower according to the value reported by Edith, 1995 (10%).

It can be seen that the carbohydrate levels respectively F1 and F2 (70±1.52 and 77.7± 1.22) found are higher than those obtained by Sanogo et al, 1994 (68%), by Zannou-Tchokoi et al, 2011 (63% and 61%), by ITRA, 2011 (58.87%) and Traoré , 2005 (60.7%) but lower than those of Soro et al, 2013 (89.02±0.2).

Proteins play a role as building material. They are essential for growth and the need for them is greatest during the first months of life. They serve to continuously renew all tissues.

The protein content found for F1 (17.69± 0.09) is higher than that of standard flour (13%), that found by Lalaina , 2000 (13%), and slightly higher than that obtained by Traoré, 2005 (16.9%), by Edith , 1995 (16.5). This content is in line with that of Nutrimix 2nd age flour (17.6%) produced in Togo and reported by Trèche , 1995, but it is below that obtained by ITRA, 2011 (21%).

As for the protein content of F2 (11.02±0.80), it is within the range of values found by Oscar, 1995 (11-13%), Tchibindat and Trèche , 1995 (>10.5 and < 16%) but lower than that of standard flour (13%).

Lipids are important for the young child as sources of essential fatty acids with important metabolic functions. Fat is a concentrated source of energy, providing high energy intake in a small volume of food and promoting the absorption of fat-soluble vitamins. Daily fat requirements have been estimated at 30-45% of total energy (WHO, 1998; Dewey and Brown, 2003).

The determination of fat (lipids) gave us a value of 5.80±0.82 for F1 and 5.0±0.33 for F2. These values are in line with those given by Tchibindat and Trèche, 1995 for Vitafort flour in Congo (>4%) and in the range of Vitafort in Chad reported by Oscar O., 1995 (5.5-8.5). They are lower than those of Traoré, 2005 (10.5%), ITRA, 2011 (13.54%) for NUTRIMO flour produced in Togo, those of Edith, (1995) for SOSOMA flour (7%) in Rwanda and lower than standard flour (7%).

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Impact Factor: 5.164
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The ash levels of F1 and F2 (1.5±0.02 and 1.37±0.05 respectively) are close to the recommended value for infant supplement foods (2%).

The F1 and F2 infant flours produced have an ascorbic acid (vitamin C) content comparable to the daily vitamin recommendation for a complementary food.

The energy contents (403 Kcal for F1 and 399 Kcal for F2) obtained are in line with the WHO recommended standards for weaning foods.

The study of the chemical composition shows satisfactory results in table 2: The protein (17.69% F1 and 11% F2), lipid (5.80% for F1 and 5.0 F2), carbohydrate (70% F1 and 77.7% F2) and energy contents (403 Kcal for F1 and 399 Kcal for F2) that were determined are in accordance with the standards recommended by the WHO for weaning foods. These levels are between 11 and 21% for proteins and above 8% for lipids, and between 60 and 70% for carbohydrates with an energy value of 400 Kcal according to Mouquet (2006) and Mouquet et al. (1998). However, the nutritional quality of a processed product depends on the nature of the raw materials used (cereals, vegetables or legumes, leaves and/or vitamin supplements), the production technology (modern or traditional), and the packaging of the product obtained.

6. CONCLUSION

At the end of our study, the main factors of child malnutrition that exist in many developing countries are: poverty, ignorance and disease. Malnutrition is a scourge in Chad given the percentages of malnourished children (acute, severe and moderate). It mainly affects rural but also urban areas. The poorest households are unable to provide for their children. Breastfeeding is therefore a fundamental concern in the food security strategy. It is in this sense that breastfeeding is strongly recommended in developing countries and is the only source of food during the first months of life. However, breast milk is not sufficient to cover the nutritional needs of infants after the first six months of life. Thus, supplementing the child's diet with nutrient-rich products is essential. The management of severe acute malnutrition has evolved in recent years with the development of ready-to-use therapeutic foods. This new generation of easy-to-use, high nutritional value products covers all the nutritional needs of severely malnourished young children. They allow treatment at home and thus avoid hospitalisation in cases without medical complications. However, this curative approach faces problems of cost and design of sustainable and effective delivery systems. In the CRENs, acute malnutrition is treated for a period of three months with the participation of the mother so that she can continue at home and prevent a possible relapse of the child; the mother's daily trip to the PMI is a significant constraint for a mother obliged to provide for her family. Given the results we obtained for the different parameters (anthropometric parameters, nutritional and microbiological quality of the flours), we can affirm that the use of local cereals and the valorisation of vegetables in the diet of young children can contribute to the improvement of their nutritional status. All these results underline the interest of formulating infant foods based on Moringa leaves for the management of severely malnourished children. In view of the results obtained, it would be interesting to carry out organoleptic analyses of the flour and porridge in order to characterise the flour for use in nutrition centres as a nutritional rehabilitation food. To conduct similar studies on a large sample size to assess and confirm the impact of Moringa leaves on the nutritional status of children during recovery. To popularise the use of Moringa leaves in households and its daily consumption by children. And to incorporate other sources (cereals, legumes and leaves e.g. spirulina) for diversification.

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