

Nutritional and Hematological Recovery of Severely Malnourished Children with New Flour Formulas Developed at Ouagadougou (Burkina Faso)

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Abstract: A longitudinal study was carried out, which tested the efficacy of severe malnutrition recovery with Misola and two experimental flours produced with local products (seeds of *Moringa oleifera* and *Cucurbita maxima*, pulps of *Adansonia digitata* and *Parkia biglobosa*), supplemented with *Zea mays* (F1) or *Pennisetum glaucum* (F2). A total of 187 severely malnourished children aged 6 to 36 months were enrolled in the study and randomly assigned to one of three treatment groups, in order to compare the effects of the experimental flours with those from Misola (F3), the existing complementary flour used frequently for children recovery. The groups were comparable by nutritional and socioeconomic parameters. Anthropometric and hematological measurements were taken between inclusion and recovery. At recovery, the weight for height (WHZ) increased to 2 and 1 SD, respectively in the three groups. The average weight gain was 6 g/kg/day in the F2 group, compared to 4.5 g/kg/day for the F1 and Misola group. The paired t-test of Midupper Arm Circumference (MUAC) indicated a significant change for each group ($p < 0.05$). Between inclusion and recovery, hemoglobin rate within each group was 8 ± 1 vs 8 ± 1 ; 9 ± 1 vs 9.5 ± 1 and 10 ± 1 vs 11 ± 1 g/dL, respectively for group F1, F2 and F3. The PPZ was 7.2 ± 6.1 vs 6.2 ± 3.7 $\mu\text{g/g Hb}$ for F1 group, while for group F2 PPZ it was 7.7 ± 4.7 vs 9.2 ± 6.7 $\mu\text{g/g Hb}$. Lastly, F3 group indicated a PPZ value of 7.5 ± 4.3 vs 8.9 ± 5.7 $\mu\text{g/g Hb}$. The formulated flours appear to be efficacious in improving nutritional and hematological recovery of severely malnourished children and F2 performed best.

Key words: Formulated flours, growth and development, infants

INTRODUCTION

The Sahel has some of the highest child mortality rates in the world (Unicef/WCARO, 2008). One in five Sahelian children dies before age five (Manary *et al.*, 2004). The latest available surveys showed that 1.5 million children under five years of age suffer from acute malnutrition, primarily infants and young children, and over 80% of underfives with acute malnutrition are young children under three (Unicef/WCARO, 2008). An estimated 18% of children under three (i.e., 1.1 million children) suffer from acute malnutrition, and malnutrition is an associated cause of 56% of child deaths (FAO, 2010). This means that more than half the child mortality burden in the Sahel is attributable to child malnutrition, which causes over 300,000 child deaths annually (FAO, 2010).

In Burkina Faso, malnutrition and micronutrient deficiencies are two of the biggest constraints to

achieving the millennium development goals. These two problems are widespread and constitute a serious public health problem (Nana *et al.*, 2006). Children remain a vulnerable group where the risk is exacerbated by inappropriate practices of weaning and care (Compaoré, 2004, 2006). The 2010 Social and Health Survey indicated that 31.4% of children were severely stunted, while 28.8% were severely underweight and 10.5% were severely wasted (DN, 2010). In the recovery of moderate or severe states, especially the clinical cases, it is important to improve the nutritional quality (energy density, macronutrient and micronutrient requirements) of complementary food with products locally available at a low cost for households that conforms to cultural food habits and allows for safe and easy handling (Sawadogo and Kinda, 2004; Simporé *et al.*, 2005; Compaoré, 2006, Bruyeron *et al.*, 2010).

The objective of this study is to demonstrate the efficacy of available and unexploited products, such as

seeds of *Moringa oleifera* and *Cucurbita maxima* and pulps of *Adansonia digitata* and *Parkia biglobosa*, supplemented with *Zea mays* (F1) or *Pennisetum glaucum* (F2), to improve the nutritional and hematological status of the children suffering from severe malnutrition compared to Misola (F3), the existing complementary flour, developed in 1997 and used frequently for child recovery (Laurent, 1995).

MATERIALS AND METHODS

The study was designed in three steps: flours formulation, flours analysis and production and the intervention step (the recovery study).

Formulated flours: Formula 1 (F1) consists of the following products: *Zea mays*, seeds of *Cucurbita maxima* and *Moringa oleifera*, pulps of *Parkia biglobosa*, *Adansonia digitata* and sugar: 60:20:10:3:3:4% (w/w); Formula 2 (F2): *Pennisetum glaucum*, seeds of *Cucurbita maxima* and *Moringa oleifera*, pulps of *Parkia biglobosa*, *Adansonia digitata* and sugar: 60:22:10:4:2:2% (w/w); Misola formula (F3), the existing complementary flour: *Pennisetum glaucum*, *Soja hispida*, *Arachis hypogaeae* and sugar 60:20:10:10 (w/w).

The nutritional composition of these three formulae was determined in a precedent study (Compaoré *et al.*, 2011).

Site of study: This study was conducted from June to December 2010 at rehabilitation unit of Centre Médical Saint Camille of Ouagadougou for nutritional recovery and at Biological, Food and Nutritional Research Centre (CRSBAN), at University of Ouagadougou (Burkina Faso) for data analysis and interpretation.

The recovery study: The study protocol has been approved by the Ethical committee. The rehabilitation unit of Centre Medical Saint Camille (CMSC) of Ouagadougou (Burkina Faso), a daily outpatient management center where all complicated cases are referred to the hospital. During the presence of children in rehabilitation unit, they received therapeutic food F75 and F100 (skim milk, oil, sugar) containing respectively 75 Kcal/100 mL and 100 Kcal/100 mL (WHO, 1999), and in the afternoon they go back at home. To avoid therapeutic food contamination, none of malnourished children can bring it home (Diop *et al.*, 2003) and the mortality risk due to hypoglycemia conducted the nurses to give blended flour to the children's mothers for preparation at home.

The recovery study was a longitudinal study which consisted of 187 children aged 6 to 36 months. All children discharged from the Nutritional Rehabilitation Unit between 01 June to 30 September 2010 at the Centre Médical Saint Camille of Ouagadougou, and negative to HIV test were eligible for this study and were follow up

until recovery. Children were systematically allocated to one of three dietary regimens: blend maize flour (F1), blend millet flour (F2), and Misola (F3) (the usually complementary flour). Children were followed daily and they completed the study when they reached WHZ>0, relapsed or died. Upon resolution of complications and return of appetite, children were eligible for the home-based therapy study. Children who had not been hospitalized with malnutrition were eligible if they were referred from the outpatient department for treatment of malnutrition with either oedema or a weight-for-height (WHZ) Z score <-3. The mothers of the participants gave their informed consent. Upon patient enrollment, information about the history of illness, family demographics, and socioeconomic status was acquired in an interview with the children's mother, and the inpatient hospital chart in order to determine their nutritional and illness status (presence of oedema, cough, mycosis or diarrhea).

Anthropometric measurements: Weight was measured with an electronic scale (Seca 881, max. 200 kg; CFAO, Sèvres-France) to the nearest 100 g. Infants and children less than two years were weighed using a spring balance to the nearest 10 g. 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. Age was taken using official or health care documents, while midupper arm circumference (MUAC) was measured with ribbon method described by Shakir and Morley (1974).

Determination of HIV status: HIV status was determined using an Enzyme Linked Immunoabsorbent Assay (ELISA) (Vironostika HIV, Organon Teknika, Durham, NC); equivocal and positive tests were confirmed using a second test.

Hematological measurements: Hemoglobin (Hb), Hematocrit (Ht) and red cell protoporphyrin (PPZ) were used to define and treat anemia associated with malnutrition and were taken at inclusion and after recovery. Hematological measurements were taken according to method describe by Dossou *et al.* (2003). The Hb was measured with Hemocue kit (HemoCue® AB, Ängelholm, Sweden), while hematocrit was determined by micro centrifugation (Compurelectronic GMBH, Munich, Germany) and the PPZ by hematofluorimetry using a ProtoFluor-Z kit (Helena-France Labs, Saint-Leu-la-Fôret, France).

Statistical analysis: Epi info 2002 (version 1.1.2, Centers for Disease Control, Atlanta, GA, U.S.A.), which uses the World Health Organization's NCHS reference population, and Stata software were used to establish WHZ score as indices of nutritional status. Data were finally exported

Table 1: Baseline characteristics of children

Children characteristics	Group 1 (F1) N = 52	Group 2 (F2) N = 70	Group 3 (F3) N = 65
Males	25 (48.08%)	29 (41.43%)	25 (38.46%)
Females	27 (51.92%)	41 (58.57%)	40 (61.54%)
Age (months)	6-36	6-36	6-36
Weight-for-height, Zscore	-3±1SD	-3±1 SD	-3±1 SD
MUAC (cm)	10.78±1.12	10.86±0.93	10.74±0.94
Marasmus	33 (63.46%)	68 (97.14%)	51 (78.46)
Kwashiorkor (%)	19 (36.54%)	2 (2.86%)	14 (21.54%)
Cough (%)	18 (34.61%)	24 (34.28%)	13 (20.00%)
Fever (%)	32 (51.54%)	42 (60.00%)	43 (66.15%)
Vomiting (%)	10 (19.23%)	21 (30.00%)	9 (13.84%)
Diarrhoea (%)	22 (42.31%)	37 (52.86%)	50 (76.92%)
Anorexia (%)	23 (44.23%)	47 (67.14%)	34 (52.31%)
Cold	8 (15.38%)	11 (15.71%)	4 (6.15%)
mycosis	7 (13.46%)	19 (27.14%)	27 (41.54%)

into SPSS 13.0 for further statistical analyses. Descriptive statistics were used to explore the data and describe central tendencies. Pearson correlation was used to explore association between continuous variables, while for categorical variables Student t-test was used. Finally, multiple linear regression analyses were used to describe the nature of associations between dependant variables, and model the rate of weight gain with respect to fever, cough, and diarrhoea. A probability of $p < 0.05$ was considered to be statistically significant. The outcomes for the three dietary groups were compared by a time-event analysis (Kaplan-Meier), which allowed for the inclusion of information from all children while they participated, as well as intention to treat analysis. The differences in weight gain, duration of recovery, hematologic parameters, and the growth in MUAC between the three dietary groups were determined with 95% confidence intervals.

RESULTS AND DISCUSSION

There were no differences in the baseline demographic or nutritional characteristics between the children that received F1, F2 and F3 (Table 1). There were no differences in primary or secondary outcome parameters when boys were compared to girls, so outcomes were not stratified by sex.

Evolution of weight: There was an evolution in weight between the inclusion and recovery (Fig. 1). The weight gain was around 4.5 ± 1.8 g/kg body weight/day for group 1, while for group 2 it was 6 ± 2 g/kg body weight/day. Lastly the weight gain for group 3 was 4 ± 1.2 g/Kg/body weight/day. The comparison of weight gain between these three groups was statistically significant ($p = 0.04$) (Fig. 2). The weight gain is lower than the recommended value which varies from 10 to 20 g/kg of body weight/day (Ashworth and Millward, 1986). The weak weight gain could affect growth parameters (Fjeld *et al.*, 1989), however, studies showed that the home based therapy could be effective if all conditions are

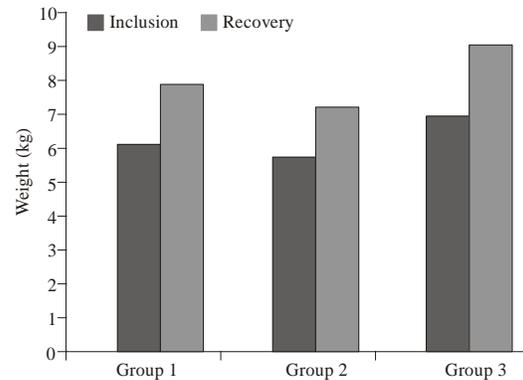


Fig. 1: Evolution of weight of children during the recovery study

necessary to reach a weight gain of 7 to 15 g/kg body weight/day (Spady *et al.*, 1976; Khanum *et al.*, 1994). There are several explanations for this situation: the first is associated with food consumed at home, which could not be measured directly, but was obtained by a questionnaire managed with the mother. So, it was unclear that experimental flour was preferentially given to children at home (Manary *et al.*, 2004). The second reason is associated with energetic value of prepared porridges which could be improved by addition of red sorghum amylase. But in spite of this amylase being added to experimental flours, mothers did not use it. Lastly, difficulties related to wood resources to prepare experimental porridges have been evocated by mothers and constitute a limiting factor.

The recall method to determine morbidity status of children was not validated, and the correlation between growth and morbidity parameters is not statistically significant. The morbidity parameters have an effect on weight evolution (Diop, 2005). So, food and care practices of mother need to be studied in order to help the mother be more effective during malnutrition management (Diop, 2005).

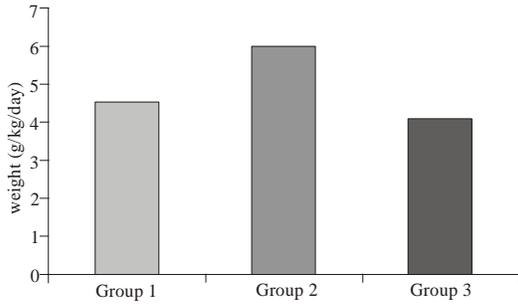


Fig. 2: Weight gain of children during the recovery study

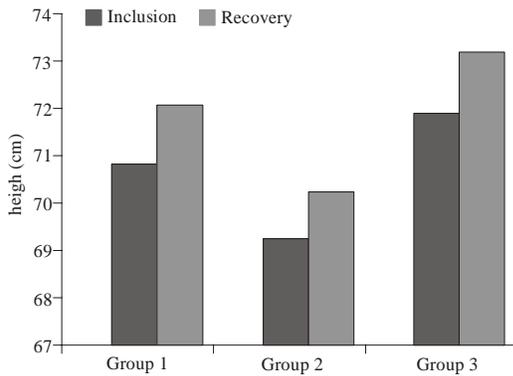


Fig. 3: Evolution of height of children during the recovery study

Evolution of height: Evolution of height was similar between the three groups of nutritional recovery, and so, the difference was not statistically significant (Fig. 3). The notion that diets which are entirely plant based may lack components needed for optimal growth is supported by work done in Kenya (Neumann *et al.*, 2002). The energy density of these experimental flours is higher than to maize/soy food, and many cereal-legume combinations that are often advocated as healthy foods for undernourished children in the developing world (Manary *et al.*, 2004).

Evolution of MUAC and WHZ: The MUAC was the most sensitive parameter and its change is presented in Fig. 4. Comparison of the MUAC value within each group revealed a significant difference for Group 1 ($r = 0.513$; $p = 0.000$), Group 2 ($r = 0.538$; $p = 0.000$) and Misola ($r = 0.202$; $p = 0.107$).

Comparison between three groups by the time-event analysis (Kaplan-Meier) revealed a better efficacy of recovery for Group 2 than Groups 1 and 3 ($p = 0.046$). This situation can be explained by the physico chemical composition and energetic content of F2, which has more Lipids, carbohydrates than F1 and Misola (Compaoré *et al.*, 2011).

Morbidity and growth: Analysis by linear regression showed that many parameters of morbidity had an influence on the statural growth of children. The role of

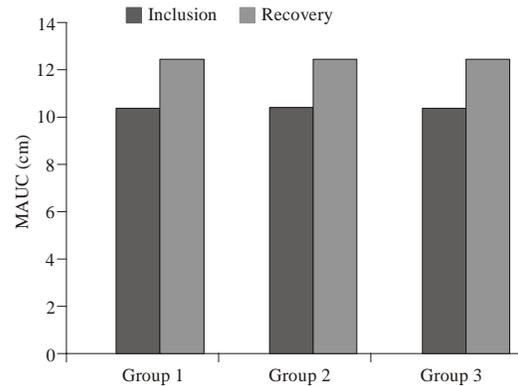


Fig. 4: Evolution of MUAC

infections on child growth has been defined for many years (Scrimshaw *et al.*, 1968; Lopez de Romana *et al.*, 1989; Rowland *et al.*, 1997); and these morbidity parameters are: anorexia ($p = 0.032$), diarrhea ($p = 0.000$), cough ($p = 0.027$), and mycosis ($p = 0.003$). The effect of these morbidity parameters (illness) on weight gain was calculated by regressing weight gain against number of days ill. Anorexia reduces the food intake and diarrhea and cough reduce weight gain (Motarjemi *et al.*, 1993; Manary *et al.*, 2004), but the role of mycosis remains to be determined. Diarrhea produced a deficit in weight gain of 32 g per day ill, and cough/cold a deficit of 16.4 g per day ill. From these data the overall impact of illness on weight gain was calculated and in the average child between 12 and 24 months diarrhea reduced growth by 160 g and cough/cold by 95 g.

Hardly any of the studies examining poor growth as a risk factor for morbidity contained information on social or environmental variables (Tielsch *et al.*, 2008). An increase in duration of illness might be a reflection of the less than satisfactory feeding patterns during illness that sometimes occurs in poorer families (Layte *et al.*, 2005). Similarly, poorer families may have less opportunity to obtain access to health services or purchase medicines, and so illnesses may last longer. Effects of nutritional status on incidence of diarrheal episodes, is more determined by environment and personal hygiene, so it is important to minimize the infant's exposure to diarrheal pathogens, which are common in other foods and in water (Sheth and Dwivedi, 2006). Thus, poor growth may be a proxy indicator for poor social, economic and environmental background. Respiratory infections have also been implicated in growth faltering, and anorexia, fever, pain, vomiting (especially in pertussis) and associated diarrhea, may all be important contributory factors (Tomkins and Watson, 1993).

Duration of recovery: The duration of study is showed at Fig. 5. This long period of recovery can be explained

Table 2: Evolution of hematologic parameters

Parameters	N	Inclusion	Recovery	p-value
Hb (g/dl)	1 (n = 52)	8±1	8±1	0.535
	2 (n = 70)	9±1	9±1	0.402
	3 (n = 65)	10±1	11±1	0.011*
Ht rates (%)	1 (n = 52)	24±3	26±3	0.345
	2 (n = 70)	26±3	26±3	0.202
	3 (n = 65)	25±2	27±2	0.023*
PPZ (µg/g Hb)	1 (n = 52)	7.2±6.1	6.2±3.7	0.206
	2 (n = 70)	7.7±4.7	9.2±6.7	0.042*
	3 (n = 65)	7.5±4.3	8.9±5.7	0.044*

Values are means ± SD (n = 3); *: p<0.05

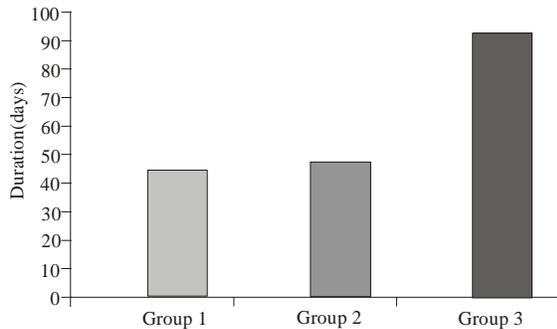


Fig. 5: Duration of total recovery

by high dilution of prepared flours at home, which contain low energy (Traoré, 2005). It also suggests that there is sharing of the experimental flours at home with other family members. Even though ample experimental flour of each sample was provided to mothers, it may have not been prepared due to the additional time and resources needed to prepare 6 feedings per day in a African setting where cooking is done outside over a wood fire.

Evolution of hematologic parameters and growth: At inclusion the Hb and Ht rates of children were low, but, PPZ value was high, probably due to ferriprive anemia (Table 2). The PPZ is a good indicator of iron deficiency in children (Mei *et al.*, 2003), but the interpretation of these results must be completed by analysis of other parameters of martial deficiency, like serum ferritin, transferrine and protein of the inflammatory phase. The Iron supplementation during nutritional recovery improves the Hb rate significantly but this variation was determined by weight gain, because high weight gain is not favorable to significant Hb evolution (Macdougall *et al.*, 1982; Michaelsen *et al.*, 1995; Wharf *et al.*, 1997; Georgieff *et al.*, 2002; Thorsdottir *et al.*, 2003). So, the weak evolution of Hb and Ht in Groups 1 and 2 can be explained by this situation, because F1 and F2 have the better weight gain compared to F3, which has the lower weight gain. This lower weight gain can explained by the better evolution of Hb and Ht in Group 3 which is significant (10±1 vs 11±1 g/dL; p = 0.011 and 25±2 vs 27±2%, p = 0.023

respectively for Hb and Ht) between inclusion and recovery (Table 2). A negative correlation between weight gain and Hb variation was found (r = -0.371; p = 0.016) and could be explained by low contribution of bioavailable iron during nutritional recovery due to synthesis of cells and red cells (Diop *et al.*, 2003).

CONCLUSION

The formulated flours appear to be efficient in improving nutritional and haematological recovery of children suffering from severe malnutrition, and F2, a mixture of *Pennisetum glaucum*, seeds of *Cucurbita maxima* and *Moringa oleifera*, pulps of *Parkia biglobosa* and *Adansonia digitata*, performed best. Nutritional supplementation studies have generally shown that improved growth is very difficult to achieve. Where supplementation has been followed by reduction in morbidity it is difficult to know if it was the result of nutritional change or attention to improved environment, education and health care. It seems clear that the only effective way to improve growth is to reduce the burden of infection at the same time as improving dietary intake. This study showed that home based therapy for uncomplicated severely malnourished children has been successful in West Africa and could offer a better alternative in Burkina Faso, and contribute to food diversification and valorization of locals products.

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AUTHOR'S CONTRIBUTION

Nutritional recovery was taken at Centre Médical Saint Camille where Father Doctor Pignatelli is the director and medical treatment was rigorously followed by him. Father Professor Simporé is the director of CERBA and Centre Médical Saint Camille Laboratory where hematological analyses were taken and the ethical protocol was corrected and defined by him. Professor Mouecoucou reviewed this article and gave final interpretation for statistical analyses and results. Professor Traoré, the director of CRSBAN at University of Ouagadougou had original idea for this study and financial support for this study is passed by him. Doctor Nikiéma corrected the final protocol for study and Doctors Savadogo and Bassole reviewed this article and help to correction. The daily management of children, study implementation, data collection and final interpretation and discussion were given by Doctor Compaoré.