Nutrition Rehabilitation of Undernourished Children Utilizing Spiruline and Misola[1]

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Abstract

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The objective of the study is to assess the impact of an alimentary integrator composed of spiruline (*Spirulina platensis*) and Misola (millet, soja, peanut) produced at the Centre Medical St Camille (CMSC) of Ouagadougou, Burkina Faso, on the nutritional status of undernourished children. 550 undernourished children of less than 5 years old were enrolled in this study, 455 showed severe marasma, 57 marasma of medium severity and 38 kwashiorkor plus marasma. We divided randomly our children in four groups: 170 were given Misola, 170 were given Spiruline plus tradicional meals, 170 were given Spiruline plus Misola. Forthy children received only traditional meals and functioned as the control group. The duration of this study was eight weeks. Anthropometrics and haematological parameters allowed us to appreciate both the nutritional and biological evolution of these children. The rehabilitation with Misola, Spiruline plus traditional meals and Spiruline plus Misola and only traditional meals show on average a weight gain of 20, 25, 34 and 15 g per day respectively.

Our results indicate that Misola, Spiruline plus tradicional meals or Spiruline plus Misola are all a good food supplement for undernourished children, but the rehabilitation by

Spiruline plus Misola seems to correct more quickly the weights loss.

Key Words

Spiruline, Misola, Malnutrition, Marasma, Kwashiorkor, Burkina Faso

1 - Introduction

Malnutrition constitutes a public health problem in all the world particularly in the developing countries (1). In Africa, more than 30% of the deaths in children of less than five years result directly or indirectly from malnutrition (2). Since 1999, Burkina Faso is confronted by Protein-energetic malnutrition with 13 % of infant population affected by emaciation, 29% by growth retardation and 30% by insufficient weight (3). The consequences of the protein-energetic malnutrition in Burkina Faso are several and manifested severe forms of marasma, kwashiorkor and kwashiorkor plus marasma (3). To day it is recognized that this form of malnutrition is coupled with deficiencies in vitamins and in minerals (4, 5). It creates inexorably an uncorrectable spiral between malnutrition and

infectious pathologies, which often is associated with chronic diarrhoea. and compound the prognosis of these children (6). In the Centre of Education and of the Nutritional Rehabilitation (CREN) of Ouagadougou, Burkina Faso, Misola or Spiruline or both in association were used since 2000 to improve the nutritional status of undernourished children. The choice of these two alimentary integrators was guided by the biochemical composition of both. The Misola, a local flour traditionally produced at the CREN of the Centre Medical St. Camille (CMSC) of Ouagadougou contains millet, soja, peanut according the original formula proposed by the Association Burkinabe des Unites Misola and the powder of Spiruline, a cyanobacterium which grows easily at the temperature of Burkina Faso, also produced at the CMSC, were recently introduced in the treatment of undernourished children for its biological activities (7). Spiruline was utilized for its elevated content of aminoacids, iron and carotenoids. Spiruline used in this study was also analysed for its chemical composition since their lipid composition is influenced by the environmental condition of growth.

2 - Subjects and Methods

This research was conducted at the CMSC of Ouagadougou during 2002-2003. This center was created in 1974 by the religious of St Camille order and comprises a maternity, a health center, an analysis laboratory for biological and biochemical examination, a center for neonatal pathology, a greenhouse for the culture of the Spiruline (Figure 1) and a Center for Education and for Nutritional Rehabilitation (CREN). The CREN follows in average 700 children per year.

Study Protocol

Infants and children aged <5 years were enrolled using the CONSORT criteria (8). Each child was admitted to the protocol study given a progressive number and at the end each was selected with a casual number generator program. Dehydration resulting in shock (exclusion criteria) require rapid transfer to the Hospital for intensive therapy, while the discontinuation of participation criteria were abandonment, death and the interruption of treatment at the Center during the study.

2a Study patients

At the beginning of this study, undernourished children were anhoressic and many of them had diarrhoea, which was treated with nose-gastric rehydratation according the CMSC protocol (6). The nasogastric rehydration was interrupted before being selected for this study. At the end 550 children were enrolled randomly in three rehabilitation rehydration protocols: A) 170 of them received an alimentation only with Misola, B) 170 were treated by supplementing Spiruline to traditional meals (millet, vegetable, fruit), C) 170 received Spiruline plus Misola. A control group of 40 undernourished children of the same age range was organized between children whose mothers did not accept the protocol study, so they were fed only with traditional meals. The vitamin and mineral deficiencies were corrected only at the end of study.

2b Participation criteria

All studied children were undernourished according to the z-score criteria, recommended by the WHO and the Funds of the United Nations for l' Enfance (UNICEF). and their age was 15.29 months (6-60 months). The ages were confirmed by the birth notebooks. The Ethical Committee of CMSC gave permission for the study and

all parents were informed of the aim of this study. They gave written consent for the participation of their children to the study.

2c Anthropometrics parameters

The weight of the children was taken once a week since the day of their admission to the CREN with a 10 grams sensitivity balance. The height of children under 2 years is measured by resting the child on his back; those children over 2 years is measured in the upright position.

The nutritional status, evaluated by brachial perimeters was compared to the classification of Jelliffe (9), considering that it varies little for the children of less than four years.

HAZ (Height for age z-score), WHZ (Weight for height z-score) and WAZ (Weight for age z-score) parameters were calculated according to the references of the National Center for Health Statistics (NCHS) (10).

2d Evaluation of results

The evaluation of nutritional status of the children has been made according to the nutritional indices. The index weight for age expressed in z-score (WAZ) or weight insufficiency indicates a global

malnutrition affecting at once the linear growth and the weight increment. The index height for age expressed in z-score (HAZ) or growth delay is an index that indicated a chronic malnutrition provoked by an extended reduction of the food consumption and by repeated pathologic episodes. The emaciation or weights loss expressed by the index weights for height (WHZ) indicates a slighter status or weight deficit due to a decrease, slowdown of regular growth. These tests were performed for obtain significant changes within the treatment groups in order to detect whether Spiruline or Misola are a useful supplement of feeding in rehabilitation.

2e Plant material.

Spiruline was cultivated in Burkina Faso, in artificial ponds and dried at room temperature. The material was stored in the dark at 4 °C to prevent photodegradation.

2f Preparation and Administration of the Spiruline and the Misola

The mothers of the undernourished children which received spiruline or Spiruline plus Misola were given weekly rations of 70 grams of

spiruline in a sachet. Every day, they had to mix 10 g of spiruline with a graduated container to the traditional meal of their children composed of millet flour. Other mothers added Spirulina to Misola meal. These integrations were made at least two times a day.. The Misola, a kind of bouillon, is a mixture of millet (60%), soja (20%), arachide (10%), sugar (9%) and salt (1%). The preparation of the Misola or millet was carried out according to traditional habits, namely 60 grams of flour and 200 ml of water were mixed and boiled with a tiny fire, mixing for 2 o 3 minutes. This mixture was administrated to children in a quantity covering their caloric requirements, and outside the suckling moments in children whose mothers continued breast feeding. The compliance of mothers in preparing mixes and feeding them to their children was improved and they continue to administrate the mixture also at home. Each day they accompany children in the CREN for a control of weight and other anthropometric parameters.

2g Chemical studies

The fatty matter content was determined by the method of the extraction to the Soxhlet. The fraction « total protein» or « total

nitrogen» was measured by the method of Kjedahl. The content of glucides was determined by a colorimetric dosage or method of orcinol. The lipid composition was evaluated by the analysis of fatty acid methyl esters (FAME).

2h Fatty acids quantification and identification

The spiruline was ground and extracted three times with hexane. The mixture of fatty acid methyl esters has been extracted with hexane and analyzed by Hewlett Packard gas-chromatograph, Model 5890, equipped with a flame ionization detector (FID) and coupled to an electronic integrator. The components were identified by using standard fatty acid methyl esters and quantified by using methyl nonadecanoate (19:0) as an internal standard.

3 - Statistic analysis

A power analysis was performed prior to the iniation of the study and the number of studied children was homogeneously distributed and reached the minimal number to discuss a statistical difference. The data were treated with Excel (Office, Microsoft) software, Epi-Info software V. 6 for the anthropometrics data and SPSS–10 for

biological data, according to the opportunities of calculations and of analysis. The difference between mean values before and after eight week of treatment were calculated by Student T test. $P < 0.05$ was considered significant.

4 – Results

4a Nutritional rehabilitation

Table I shows the anthropometrics parameters of the children at the beginning of our study. The baseline anthropometric status was equivalent among the groups, with exception of HAZ for group C (-2.64). Moreover according to HIV serology, no significant differences are observed in these parameters: HAZ, WHZ, WAZ and the BP.

Only males' weight was greater than females with respective significant differences: $p<0.0001$ (Table II).

The nutritional changes pre/post improved in all children, more significantly in the group who received Misola plus Spirulina. These changes among treatment groups are reported in Table III. This improvement corresponds to an increment of weight which was on the average of 20 g a day in the Misola group, 25 g a day in the

Spirulina plus traditional meals group, 34 g a day in the Misola plus Spirulina group and 15 g a day in the control group. These pre/post differences within groups were statistically significant considering the differences in the nutritional status changes across the groups, but this difference was less significant in the control group.

At the end of the eight weeks of the treatment, nutritional status normalized for the majority of children, WHZ parameter decreasing from -2.26 to -0.93; The index weight for age WAZ at the end of our study allowed to confirm that the severe malnutrition was corrected by this protocol of treatment, more significantly in the Misola plus Spiruline group. The percentage of WHZ and WAZ are reported in table III. The association of Spiruline plus Misola gave a gain of 61 and 38 % respectively. The gain with traditional meals, Misola and Spiruline plus traditional meals was clearly of minor entity.

The compliance to treatment and participation was excellent. They come to weekly appointments, but only the first and the last visit (eight weeks) were considered in the final evaluation.

4b Chemical analysis

The Misola is an infantile flour composed by millet, soja, arachides, sugar and salt produced in the CREN of the CMSC (Ouagadougou). Table III shows the biochemical composition for 100 grams of used Misola at the Medical Center St Camille and the lipid composition of this mixture where the fatty acid content is represented by palmitic, linoleic, oleic, α-linolenic, stearic and palmitoleic acids.

The composition of the cultivated Spiruline of the CMSC is given in Table IV. The values of the composition of the spiruline of the CMSC of Ouagadougou it is in the interval of values of the international Firm green Flamant (11) and his physicochemical elements does not change with the time ($p>0.270$). The composition of our Spiruline proves the good quality of the spiruline of the CMSC. The only difference is situated at the level of the value of the glucides. The lesser content in glucides of the analysed Spiruline in our culture conditions was near the one of Sautier and Tremolieres (12) that in 1975 found a value of 12.4% on the cultivated Spiruline in laboratory. The quality of the Spiruline with the time - in the first three months of storage did not show

significant changes. For longer period of storage some significant changes were detected, such as a decrease of protein content and an increase of pH value.

The lipid composition of the Spiruline growth in Burkina Faso is listed in Table V. The fatty acid content is represented by palmitic, linoleic, oleic, α-linolenic, stearic and palmitoleic acids.

5 - Discussion

After eight weeks of study, children treated with Misola, Spiruline plus traditional meals and Misola plus Spiruline appear improved, their weight grew and many of them appear less anaemic. This improvement was less significant in the control group, who received only traditional meals. The enrolment of this group could appear unethical among these severely malnourished children, but it was organized choosing a control group between children whose mothers did not accept the protocol study, so they were treated only with traditional meals.

The association between Misola plus Spirulina reached the greater gain in term of weight than the Misola or Spirulina alone.

The results of this study prompted us to continue the culture of Spirulina in the CMSC of Ouagadougou in order to utilize the biochemical composition and the beneficial action of this cyanobacterium, which may be considered as an alimentary integrator for undernourished children. In the context of weak intake of proteins, 10 g a day by inhabitant in Africa against 29 g in Latin America and 63 g in the industrialized countries, the integration of traditional meal with Spiruline and Misola plus Spirulina (57 % of protein) improve the nutritional and micronutrient requirement for undernourished children (13).

This may be due to the iron content of Spiruline supplement (14), which correct the anemia due to deficient iron intake.

This mechanism may be due to the high amount in the lipid fraction of ω-6 derivative, namely α-linolenic acid (15). This exclusive presence of ω-6 represents a metabolic gain, since desaturase enzyme could be deficient in the undernourished children (16).

The growth recovery is more slow than the weight recovery and this could be determined by the diarrhoea, which was present at the beginning of treatment of these children (17). In fact, in our

study regarding a period of eight weeks, the variations of weight were more significant owing to the liquid content dehydratation associated to malnutrition. The percentage of increment in weight with the association of Misola plus Spirulina confirms the opportunity for continuing this kind of association in undernourioshed children. Previous study made by Branger et al. (18) in Burkina Faso did not show a significant improvement adding spirulina to traditional meal and Misola, but, as considered by the same authors, the scarce results which they obtained could be due to the quantity of Spirulina, which was half than that used in our study (5 g *vs*. 10 g). Moreover, the present study is more conclusive than the one realized in Dakar by Alling *et al*. (19), in which the gain of weight was inferior, probably due also in this case, to a reduced supplement in Spiruline.

The anthropometrics characteristics varied little according to the sex (Table II), but were different according to the nutritional and serologic status. This observation is the same as the one of Kelly *et al*. (20) in undernourished HIV-infected children with persistent diarrhoea. The strong prevalence of kwashiorkor and/or marasma is characteristic of sub-Saharan Africa, where maize and

millet are the staple. In fact, high intake of linoleic acid in a diet deficient in other polyunsaturated fatty acids and in riboflavin results in these countries in high tissue production of prostaglandin E2, which in turn causes inhibition of the proliferation and cytokine production of Th1 cells, mediators of cellular immunity (21). Diet-associated inhibition of the Th1 subset is a major contributor to the high prevalence of these diseases in sub-Saharan areas.

The high percentage of undernourished children in Burkina Faso highlights the problem of the charge of medical and nutritional structures, and this study could suggest a preliminary solution with Spiruline plus Misola or Spiruline plus traditional meal for accelerating the nutritional rehabilitation.

6- Conclusion

This study shows that malnutrition remains a public health problem in Burkina Faso. The consequences of malnutrition represent a global problem, which affects morbidity as well as mortality. Awaiting for the enrolment of these undernourished children in riabilitation protocols, the persons in charge at public health service and epidemiologists should work very synergically with nutritionists,

bacteriologists and virologists in order to fight efficiently against malnutrition.

The Misola which has 61 % of glycides with 410 kcal is more energetic than the Spirulina which has only 13.84 % of glycides with 338 kcal. Inversely, the Spirulina has 57.10 % of protein and the Misola has only 16 %. At the end the high amount of ω-6 lipid component support an efficient recovery of the precarious immune system of these children. These characteristics confirm the utility to supplement Misola with Spirulina (this association gave a gain of 34 g a day). According to the instructions which the mothers received, an involvement of the families of the undernourished children and of the whole community is essential to control the great prevalence of the malnutrition in African countries.

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Table I – Anthropometric parameters of the children subjected to the study[a].

	A 170 Children with Misola	**B** 170 Children with Spiruline plus traditional meals	**C** 170 Children with Misola plus Spiruline	**D** 40 children with traditional meals	**Variance Analysis**
Age (months)	15.39±8.3	14.96±5.9	13.86±8.5	15.19±4.35	P = 0.269
Height (cm)	67.00±8.3	69.84±5.8	69.06±8.5	68.24±4.5	P = 0.005
B.P.	11.17±1.2	10.40±1.0	11.20±1.2	10.37±1.0	P = 0.0001
Weight (kg)	6.12±1.4	5.98±1.1	5.99±1.5	6.10±1.2	P = 0.741
HAZ	-3.93±5.3	-2.64±2.1	-3.35±5.3	-3.23±1.5	P = 0.057
WHZ	-1.73±2.5	-2.88±0.9	-3.05±0.75	-2.32±1.02	P = 0.0001
WAZ	-4.01±1.0	-3.88±1.0	-4.38±0.9	-3.99±0.9	P = 0.0001

[a]HAZ = Height for age z-score; WHZ = Weight for height z-score; WAZ = Weight for age z-score,
B.P = Brachial Perimeter.

Table II - Median anthropometrics parameters of the children according to the sex at the beginning of the study.

	286 Female		264 Males		All children (550)	
Parameters	Mean	Variance	Mean	Variance	Mean	Variance
Age (months)	15.64	8.08	15.01	6.87	15.30	7.41
Weight (Kg)	5.82	1.17	6.28*	1.36	6.07	1.29
Height (cm)	68.07	6.73	68.43	7.48	68.27	7.13
P.B.	10.75	1.13	10.99	1.25	10.88	1.20

Student T test * P = 0.0001

Table III - Nutritional status to the beginning (1) and at the end of the study (2)[a].

	A 170Children with Misola	B 170 Children with Spiruline plus traditional meals	C 170 Children with Spiruline plus Misola	D 40 Children with traditional meals
WHZ1 1 →2	-1.73±2.51 P = 0.035*	-2.88±0.95 P = 0.000	-3,05±0.75 P = 0.000*	-2.42±1.02 P = 0.065*
WHZ2	-1.14±2.64	-1.80±1.53	-1,18±1.63	-2.00±0.99
WHZ2/WHZ1+WHZ2	34.14 %	37.50 %	62.90 %	17.35 %
WAZ1 1 →2	-4.01±0.98 P = 0.000**	-3.88±0.90 P = 0.000**	-4,38±0.91 P = 0.000**	-3.99±0.9 P = 0.013**
WAZ2	-2.95±1.12	-3.10±1.14	-2,71±1.17	-3.45±1.0
WAZ2/WAZ1+WAZ2	26 %	20 %	38 %	14 %

[a]WHZ1 = Weight for height z-score at beginning of the study; WHZ2 = Weight for height z-score at the end of the study;
WAZ1 = Weight for age z-score at the beginning of study; WAZ2 = Weight for age z-score at the end of the study.
Student T test *WHZ1→WHZ2; **WAZ1→WAZ2 ;

Table IV - Nutritive composition of 100 grams of Misola used in the CMSC

Biochemical Composition	Mean Concentration
Lipid	12 %
Protein	16 %
Glucide	61 %
Calories (kcal/g)	410

Table V - The Nutrition Composition for 100 grams of cultivated Spiruline to the Center Medical St Camille in comparison of the given values in the literature (Green Flamant,. 1998).

	Our results	Green Flamant values
Water content	4.87%	3-7%
Ash	10.38%	7-13%
Vegetal Fiber	7.81%	8-10%
Lipid	6.00%	6-8%
Protein	57.10%	55-70%
Glucide	13.84%	15-25%

Table VI - Physicochemical composition of the spiruline with the time

Analysed sample	*T0 (1th day)*	*T1 (1th month)*	*T2 (2nd month)*	*T3 (3th month)*	*T4 (10th month)*
Protein (%)	**57,10**	**56,22**	**54,69**	**52,28**	**49,22**
Formic index (ml NaOH)	**4,35**	**4,20**	**4,47**	**5,19**	**4,81**
Total sugars (%)	**12,77**	**16,43**	**19,59**	**18,16**	**16,07**
Reductive sugars (%)	**1,07**	**2,52**	**2,17**	**1,56**	**1,62**
Fat matter (%)	**6,00**	**7,19**	**6,69**	**5,92**	**7,25**
Fatty acids (mg NaOH/g)	**6,6**	**6,0**	**7,5**	**6,9**	**10,2**
pH	**6,53**	**6,56**	**6,36**	**6,78**	**7,33**
Humidity (%)	**4,87**	**4,86**	**5,01**	**4,83**	**4,42**
Ash (%)	**10,76**	**12,12**	**10,19**	**11,46**	**14,44**
Phycocyanin (%)	**9,76**	**7,46**	**6,12**	**7,32**	**4,46**
Energetic value (kcal/100g)	**338**	**360**	**363**	**340**	**331**

Student T test for paired data : T0 → T1 : p = 0.273; T0 → T2 : p = 0.310 ; T0 → T3 : p = 0.763 ; T0 → T4 : p = 0.625

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Table VII - Fatty acid composition of *Spirulina* strain from Burkina Faso

Fatty acid	Wt % of total fatty acid
Palmitic acid, 16:0	28.04
Palmitoleic acid, 16:1 (9)	2.69
Stearic acid, 18:0	13.44
Oleic acid, 18:1 (9)	18.88
Linoleic acid, 18:2 (9, 12)	21.87
□Linolenic acid, 18:3 (6, 9, 12)	15.08

Figure1: Particular of basins for the Spiruline cultivation

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Figure 1