

Nutrition Rehabilitation of Undernourished Children

Utilizing Spiruline and Misola¹

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1 **Abstract**

2 **Background:** Malnutrition constitutes a public health problem throughout the world
3 and particularly in developing countries.

4 **Aims:** The objective of the study is to assess the impact of an elementary integrator
5 composed of spiruline (*Spirulina platensis*) and Misola (millet, soja, peanut) produced
6 at the Centre Medical St Camille (CMSC) of Ouagadougou, Burkina Faso, on the
7 nutritional status of undernourished children.

8 **Material and Methods:** 550 undernourished children of less than 5 years old were
9 enrolled in this study, 455 showed severe marasma, 57 marasma of medium severity
10 and 38 kwashiorkor plus marasma. We divided the children randomly into four groups:
11 170 were given Misola, 170 were given Spiruline plus traditional meals, 170 were given
12 Spiruline plus Misola. Forty children received only traditional meals and functioned as
13 the control group. The duration of this study was eight weeks.

14 **Results and Discussion:** Anthropometrics and haematological parameters allowed us to
15 appreciate both the nutritional and biological evolution of these children. The
16 rehabilitation with Misola, Spiruline plus traditional meals and Spiruline plus
17 Misola and only traditional meals show on average a weight gain of 20, 25, 34 and 15
18 g per day respectively.

19 **Conclusions:** Our results indicate that Misola, Spiruline plus traditional meals or
20 Spiruline plus Misola are all a good food supplement for undernourished children, but
21 the rehabilitation by Spiruline plus Misola seems to correct weight loss more quickly..

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23 **Key Words** Spiruline, Misola, Malnutrition, Marasma, Kwashiorkor, Burkina Faso

24 **Running Title:** Nutrition Rehabilitation Utilizing Spiruline and Misola

1 **1 - Introduction**

2 Malnutrition constitutes a public health problem throughout the world and particularly
3 in developing countries (1). In Africa, more than 30% of the deaths of less than five
4 year old children result directly or indirectly from malnutrition (2). Since 1999, Burkina
5 Faso has been confronted by protein-energy malnutrition with 13 % of the infant
6 population affected by emaciation, 29% by growth retardation and 30% by insufficient
7 weight (3). The consequences of the protein-energy malnutrition in Burkina Faso are
8 several, but especially severe forms of marasma, kwashiorkor and marasmic
9 kwashiorkor are manifested (3). Today it is recognized that this form of malnutrition is
10 coupled with deficiencies in vitamins and minerals (4, 5). It inexorably creates an
11 incorrectable spiral between malnutrition and infectious pathologies, which are? often
12 associated with chronic diarrhoea and compound the prognosis of these children (6). In
13 the Nutrition Education and Rehabilitation Centre (I think this is correct) (CREN) of
14 Ouagadougou, Burkina Faso, Misola or Spiruline or both together have been used since
15 2000 to improve the nutritional status of undernourished children. The choice of these
16 two elementary integrators was prompted by the biochemical composition of both.
17 Misola, a local flour traditionally produced at the CREN of the Centre Medical St.
18 Camille (CMSC) of Ouagadougou contains millet, soja, peanut following the original
19 formula proposed by the Association Burkinabe des Unites Misola and powder of
20 Spiruline, a cyanobacterium which grows easily under the climate of Burkina Faso, also
21 produced at the CMSC, were recently introduced in the treatment of undernourished
22 children for its biological activities (7). Spiruline was utilized for its elevated content of
23 aminoacids, iron and carotenoids. Spiruline used in this study was also analysed for its

1 chemical composition since its lipid composition is influenced by the environmental
2 growing conditions.

3 **2 - Subjects and Methods**

4 This research was conducted at the CMSC of Ouagadougou during 2002-2003. The
5 centre was created in 1974 by the St Camille religious order and comprises a maternity
6 centre, a health centre, an analysis laboratory for biological and biochemical
7 examination, a centre for neonatal pathology, a greenhouse for growing the Spiruline
8 (Figure 1) and a Nutrition Education and Rehabilitation Centre (CREN). The CREN
9 follows? on average 700 children per year.

10 *Study Protocol*

11 Infants and children aged <5 years were enrolled using the CONSORT criteria (8). Each
12 child was given a progressive number and was selected randomly with a casual number
13 generator program, before to be admitted to four protocol study. Dehydration resulting
14 in shock requires rapid transfer to the hospital for intensive therapy (exclusion criteria).
15 Discontinuation criteria were abandonment, death and the interruption of treatment at
16 the Center during the study.

17 *2a Study patients*

18 At the beginning of this study, undernourished children were anorectic and many of them
19 had diarrhoea, which was treated with nose-gastric (NG) re-hydration according to the
20 CMSC protocol (6). They were taken off NG feeding before being selected for this
21 study, since this condition had sufficiently improved to allow moving on to oral feeding.
22 At the end, 550 children were enrolled randomly in three rehabilitation re-hydration
23 protocols: A) 170 of them received an alimentation with only Misola (≤ 738 Kcal/day),
24 B) 170 were treated by supplementing Spiruline to traditional meals (millet, vegetable,

1 fruit) (≤ 754 Kcal/day), C) 170 received Spiruline plus Misola (≤ 772 Kcal/day). A
2 control group of 40 undernourished children from the same age range was chosen
3 randomly between children whose mothers did not accept the protocol study, so they
4 were fed only with traditional meals (≤ 730 Kcal/day). The vitamin and mineral
5 deficiencies were corrected only at the end of study.

6 ***2b Participation criteria***

7 All studied children were undernourished according to the z-score criteria,
8 recommended by the WHO and the United Nations Children's Fund (UNICEF), and
9 their median age was 15.29 months (6-60 months). The ages were confirmed by their
10 birth notebooks. The Ethical Committee of CMSC gave permission for the study and all
11 parents were informed of its aims. They gave written consent for the participation of
12 their children in the study.

13 ***2c Anthropometric parameters***

14 The weight of the children was taken once a week starting from the day of admission
15 to the CREN with a 10 grams sensitivity balance. The recumbent length is measured by
16 resting the child on his back; children over 2 years are measured in an upright position.

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

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

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1 ***2d Evaluation of results***

2 The evaluation of the nutritional status of the children has been made according to the
3 nutritional indices. The weight for age index expressed in z-score (WAZ) or weight
4 deficit indicate a global malnutrition affecting both the linear growth and the weight
5 increment. The height for age index expressed in z-score (HAZ) or growth delay is an
6 index indicating chronic malnutrition provoked by an extended reduction of food
7 consumption and by repeated pathologic episodes. Emaciation or weight loss expressed
8 by the weight for height index (WHZ) indicates a slightly malnutrition status or weight
9 deficit due to a decrease or slowdown of regular growth. These tests were performed to
10 obtain significant changes within the treatment groups in order to detect whether
11 Spiruline or Misola are a useful supplement for rehabilitation.

12 ***2e Plant material.***

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

15 ***2f Preparation and Administration of Spiruline and Misola***

16 The mothers of the undernourished children to receive spiruline or spiruline plus Misola
17 were given weekly rations of 70 grams of spiruline in a sachet. Every day, they had to
18 mix 10 g of spiruline with the traditional meal of their children composed of millet flour
19 in a graduated container. Other mothers added Spirulina to Misola meal. These
20 integrations were made at least twice a day. The Misola, a kind of bouillon, is a mixture
21 of millet (60%), soya (20%), peanut kernel (10%), sugar (9%) and salt (1%). The
22 preparation of the Misola or millet was carried out according to traditional customs,
23 namely 60 grams of flour and 200 ml of water were mixed and boiled over a low fire,
24 mixing for 2-3 minutes. This mixture was administered to children in a quantity

1 covering their caloric requirements, and apart from the suckling times for children
2 whose mothers continued breast feeding. The mothers rapidly learned to prepare the
3 mixtures and feed their children inside the CREN. After this preliminary phase they
4 continued to administer the mixture at home. Each day they accompanied their children
5 to the CREN to monitor weight and other anthropometric parameters.

6 ***2g Chemical studies***

7 The fatty matter content was determined by the Soxhlet. method. The «total protein» or
8 «total nitrogen» fraction was measured by the Kjeldahl method. The content of glucides
9 was determined by a colorimetric dosage or method of orcinol. The lipid composition
10 was evaluated by the analysis of fatty acid methyl esters (FAME).

11 ***2h Fatty acids quantification and identification***

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

18 ***3 - Statistic analysis***

19 A power analysis was performed prior to the initiation of the study and the number of
20 studied children was homogeneously distributed. The study reached the minimal
21 number to observe?discuss a statistical difference. The data were treated with Excel
22 (Office, Microsoft) software, Epi-Info software V. 6 for the anthropometric data and
23 SPSS–10 for biological data, according to the opportunities of calculations and of

1 analysis. The difference between mean values before and after eight weeks of treatment
2 were calculated by Student T test. $P < 0.05$ was considered significant.

3 **4 – Results**

4 *4a Nutritional rehabilitation*

5 All randomly chosen children completed the eight weeks of treatment. Table I shows
6 the anthropometric parameters of the children at the beginning of our study. The
7 baseline anthropometric status was equivalent among the groups, with the exception of
8 HAZ for group C (- 2.64). Moreover, according to HIV serology, no significant
9 differences are observed in these parameters: HAZ, WHZ, WAZ and the BP.

10 Males were heavier than females with respective significant differences:
11 $p < 0.0001$ (Table II).

12 The nutritional pre/post changes improved in all children, but more significantly
13 so in the group that received Misola plus Spiruline. These changes among treatment
14 groups are reported in Table III. This improvement corresponds to an increment of
15 weight which was on average 20 g a day in the Misola group, 25 g a day in the Spiruline
16 plus traditional meals group, 34 g a day in the Misola plus Spiruline group and 15 g a
17 day in the control group. These pre/post differences within groups were statistically
18 significant considering the differences in the nutritional status changes across the
19 groups, but this difference was less significant in the control group.

20 At the end of the eight weeks of the treatment, nutritional status normalized for
21 the majority of children, with the WHZ parameter decreasing from -2.26 to -0.93. The
22 index weight for age WAZ at the end of our study allowed to confirm that severe
23 malnutrition was corrected by this protocol of treatment, more significantly in the
24 Misola plus Spiruline group. The percentages of WHZ and WAZ are reported in table

1 III. The association of Spiruline and Spiruline plus Misola gave a gain of 61% and 38
2 % respectively. The gain with traditional meals, Misola and Spiruline plus traditional
3 meals was clearly of minor entity.

4 The compliance to treatment was excellent and no children dropped out. The
5 mothers reported that the children accepted the mixes and rarely had difficulties in
6 feeding their children. They came to weekly appointments, but only the first and the last
7 visit (eight weeks) were considered in the final evaluation.

8 ***4b Chemical analysis***

9 Misola is a flour for infancy composed of millet, soya, peanut kernel, sugar and
10 salt produced in the CREN of the CMSC (Ouagadougou). Table III shows the
11 biochemical composition for 100 g of Misola used at the St Camille Medical Center
12 and the lipid composition of this mixture where the fatty acid content is represented by
13 palmitic, linoleic, oleic, γ -linolenic, stearic and palmitoleic acids.

14 The composition of the cultivated Spiruline of the CMSC is given in Table IV.
15 The values of the composition of the spiruline from the CMSC of Ouagadougou are
16 within the interval of values of the international firm Green Flamant (11) and its
17 physicochemical elements do not change with time ($p>0.270$). The composition of our
18 Spiruline proves the good quality of the spiruline from the CMSC. The only difference
19 lies at the level of the value of the glucides. The lower glucide content of the analysed
20 Spiruline in our growing conditions was near the one of Sautier and Tremolieres (12)
21 who in 1975 found a value of 12.4% in the laboratory cultivated Spiruline. The quality
22 of the Spiruline in time - in the first three months of storage - did not show significant
23 changes. For longer storage periods some significant changes were detected, such as a
24 decrease in protein content and an increase in pH value.

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

4 **5 - Discussion**

5 After eight weeks of study, children treated with Misola, Spiruline plus traditional
6 meals and Misola plus Spiruline appeared clinically improved; their weight increased
7 and many of them showed an increase of Hb levels. This improvement was less
8 significant in the control group, who received only traditional meals. The enrolment of
9 this group might seem unethical among these severely malnourished children, but it was
10 organized by choosing a control group randomly between children whose mothers did
11 not accept the protocol study, so they were treated only with traditional meals. In this
12 way, the influence of being unwilling to participate in a study on caloric and nutrient
13 intake (supplement of spiruline vs. traditional meals) becomes negligible.

14 The association between Misola plus Spiruline achieved greater gains in terms of
15 weight than the Misola or Spiruline alone. This result is clearly due to higher energy
16 intake (≤ 772 Kcal/day) and to greater protein assumption (≤ 34.5 g/day).

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

1 This may be due to the iron content of Spiruline supplement (14), which corrects
2 anaemia owing to deficient iron intake and to the high amount in the lipid fraction of ω -
3 6 derivative, namely γ -linolenic acid (15). The exclusive presence of ω -6 represents a
4 metabolic gain, since desaturase enzyme could be deficient in undernourished children
5 (16).

6 Growth recovery was slower than weight recovery and this may have been
7 compounded by the diarrhoea, which was present at the beginning of treatment of these
8 children (17). In fact, in our eight week study, the variations of weight were more
9 significant owing to the liquid content dehydration associated with malnutrition. The
10 percentage of increment in weight with the association of Misola plus Spiruline
11 confirms the suitability for continuing this kind of combination in undernourished
12 children. A previous study made by Branger et al. (18) in Burkina Faso did not show a
13 significant improvement by adding spiruline to traditional meals and Misola, but, as
14 considered by the same authors, the results they obtained could be due to the quantity of
15 Spiruline, which was half that used in our study (5 g vs. 10 g). Moreover, the present
16 study is more conclusive than the one realized in Dakar by Alling *et al.* (19), where
17 weight gain was less, probably also due in this case, to a reduced supplement in
18 Spiruline.

19 The anthropometric characteristics varied little according to sex (Table II), but
20 were different according to the nutritional and serologic status. This observation is the
21 same as the one by Kelly *et al.* (20) in undernourished HIV-infected children with
22 persistent diarrhoea. The strong prevalence of kwashiorkor and/or marasma is
23 characteristic of sub-Saharan Africa, where maize and millet are the staple diet. In fact,
24 high intake of linoleic acid in a diet deficient in other polyunsaturated fatty acids and in

1 riboflavin results in high tissue production of prostaglandin E2 in these countries, which
2 in turn causes inhibition of the proliferation and cytokine production of Th1 cells,
3 mediators of cellular immunity (21). Diet-associated inhibition of the Th1 subset is a
4 major contributor to the high prevalence of these diseases in sub-Saharan areas.

5 The high percentage of undernourished children in Burkina Faso puts a
6 considerable strain on medical and nutritional resources and organizations, and this
7 study could suggest a preliminary solution with Spiruline plus Misola or Spiruline plus
8 traditional meal to accelerate nutritional rehabilitation.

9 **6- Conclusion**

10 This study shows that malnutrition remains a public health problem in Burkina Faso.
11 The consequences of malnutrition represent a global problem, which affects morbidity
12 as well as mortality. Awaiting the enrolment of these undernourished children in
13 rehabilitation protocols, those in charge of public health services and epidemiologists
14 should work in synergy with nutritionists, bacteriologists and virologists in order to
15 combat malnutrition efficiently.

16 Misola, which has 61 % of glycidic with 410 kcal/100g, has a higher energy
17 content than the Spirulina which has only 13.84 % of glycidic with 338 kcal/100g.
18 Inversely, Spirulina has 57.10 % of protein and the Misola has only 16 %. At the end
19 the high amount of ω -6 lipid component helped an efficient recovery of the precarious
20 immune system of these children. These characteristics confirm the suitability of
21 supplementing Misola with Spirulina (this association gave an energy intake of ≤ 772
22 Kcal/day with a protein assumption of ≤ 34.5 g a day), both greater than Misola or
23 Spiruline alone. According to the instructions which the mothers received, involvement

1 of the families of the undernourished children and of the whole community is essential
2 to control the great prevalence of malnutrition in African countries.

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8 **8- References**

- 9 1 - ONUSIDA/OMS (2000) Le point de l'épidémie de sida, Décembre 2000
- 10 2 - WHO, 2000. Projected budget for 1^{er} exercice 2000-2003
- 11 3 – Some JF. Itinéraire des enfants admis pour malnutrition dans les centres de
12 réhabilitation et d'éducation nutritionnelle de Ouagadougou. Thèse de doctorat,
13 Université de Ouagadougou, 1999.
- 14 4 - Boulet M. Micronutrient deficiencies. Reports from the field -- Africa. Glob
15 Impacts. 1997, 13.
- 16 5 - Ashworth A, Chopra M, McCoy D, Sanders D, Jackson D, Karaolis N, Sogaula N,
17 Schofield C. WHO guidelines for management of severe malnutrition in rural South
18 African hospitals: effect on case fatality and the influence of operational factors.
19 Lancet. 2004, 363: 1110-5.
- 20 6 – Pignatelli S, Simporé J, Musumeci S. Effectiveness of forced rehydration and
21 early re-feeding in the treatment of acute diarrhoea in a tropical area. Minerva Pediatr.
22 2000, 52: 714-7.
- 23 7 - Blinkova LP, Gorobets OB, Baturo AP. Biological activity of Spirulina Zh
24 Mikrobiol Epidemiol Immunobiol. 2001, 2: 114-8
- 25 8 - Altman DG, Schulz KF, Moher D. The revised CONSORT statement for reporting
26 randomized trials: Explanation and elaboration. *Ann Intern Med.* 2001, 134: 663–694.

- 1 9 - Shiveley LR, Thuluvath PJ. Assessment of nutritional status via anthropometry.
2 Nutrition 1997, 13: 714-7
- 3 10 - Stevenson RD. Feeding and nutrition in children with developmental disabilities.
4 *Pediatr Ann.* 1995, 24: 255-60
- 5 11 – Flamant Vert (1988) Produire de la spiruline en systèmes autonomes. La spiruline
6 une algue pour l’Homme et la Planète. Georg Editeur SA, Geneve
- 7 12 - Sautier C, Tremolieres J. Food value of the spiruline algae to man. *Ann Nutr*
8 *Aliment.* 1975, 29: 517-34.
- 9 13 - Effectiveness of spirulina algae as food for children with protein-energy
10 malnutrition in a tropical environment. Editor P. Bucaille, University Paul Sabatier,
11 Toulouse, France, 1990.
- 12 14 - Kapoor R, Mehta U. Iron bioavailability from *Spirulina platensis*, whole egg and
13 whole wheat. *Indian J Exp Biol.* 1992, 30: 904-7.
- 14 15 - Decsi T, Koletzko B. Effects of protein-energy malnutrition and human
15 immunodeficiency virus-1 infection on essential fatty acid metabolism in children.
16 *Nutrition* 2000, 16: 447-53.
- 17 16 – Koletzko B, Abiodun PO, Laryea, MD, Bremer HJ. Fatty acid composition of
18 plasma lipids in Nigerian children with protein-energy malnutrition. *Eur. J. Pediatr.*
19 1986, 145: 109-15.
- 20 17 - Leandro-Merhi VA, Vilela MM, Silva MN, Lopez FA, Barros Filho A. Evolution
21 of nutritional status of infants infected with the human immunodeficiency virus. *San*
22 *Paulo Med J.* 2000, 118: 148-53.
- 23 18 - Branger B, Cadudal JL, Delobel M, Ouoba H, Yameogo P, Ouedraogo D, Guerin
24 D, Valea A, les personnels des CREN, Zombre C, Ancel P. La spiruline comme

1 complément alimentaire dans la malnutrition du nourrisson au Burkina Faso. Archives
2 de Pédiatrie 2003, 10: 424-431

3 19 – Sall MG, Dankako B, Badiane M, Ehua E, Kuakuwi N. Resultats d'un essai de
4 rehabilitation nutritionelle avec la Spiruline a Dakar (A propos de 59 cas) Medécine
5 d'Afrique noire. 1996, 46 : 143-146.

6 20 - Kelly P, Musuku J, Kafwembe E, Libby G, Zulu I, Murphy J, Farthing MJ.
7 Impaired bioavailability of vitamin A in adults and children with persistent diarrhoea in
8 Zambia. Aliment Pharmacol Ther. 2001, 15: 973-9.

9 21 - Sammon AM. Dietary linoleic acid, immune inhibition and disease. Postgrad Med
10 J. 1999, 75: 129-32.

1 **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 = NS
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 = NS
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
Energy intake (Kcal/day)	≤738	≤754	≤772	≤730	P = NS
Protein (g/day)	≤28.8	≤29.4	≤34.5	≤23.4	P = 0.0001

2 ^aHAZ = Height for age z-score; WHZ = Weight for height z-score; WAZ = Weight for age z-score,
3 B.P = Brachial Perimeter. NS = not significant

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1 **Table II** - Median anthropometric parameters of the children according to 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

2 Student T test * P = 0.0001

1 **Table III** - Nutritional status at the beginning (1) and end of the study (2)^a.

	A 170 Children 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/W HZ1+WH Z2	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/W AZ1+WA Z2	26 %	20 %	38 %	14 %

2 ^aWHZ1 = Weight for height z-score at beginning of the study; WHZ2 = Weight for height z-score at the end of the study;

3 WAZ1 = Weight for age z-score at the beginning of study; WAZ2 = Weight for age z-score at the end of the study.

4 Student T test *WHZ1→WHZ2; **WAZ1→WAZ2 ;

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1 **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/100g)	410

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5 **Table V** - The Nutrition Composition for 100 grams of cultivated Spiruline from the
6 Center Medical St Camille in comparison to the given values in literature (Green
7 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%

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2 **Table VI - Physicochemical composition of the spiruline with time**

<i>Analysed sample</i>	<i>T0</i> (1 th day)	<i>T1</i> (1 th month)	<i>T2</i> (2 nd month)	<i>T3</i> (3 th month)	<i>T4</i> (10 th 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
Energy value (kcal/100g)	338	360	363	340	331

3 **Student T test for paired data : T0 → T1 : p = 0.273; T0 → T2 : p = 0.310 ; T0**
4 **→ 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
γ -Linolenic acid, 18:3 (6, 9, 12)	15.08

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Figure 1