

Nutrition Rehabilitation of Undernourished Children

Utilizing Spiruline and Misola¹

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¹ Supported by the Medical Center St Camille and the Foundation of Pope Jean-Paul II for Sahel.

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1 **Abstract**

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

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

9 **Material and Methods:** 550 undernourished children of less than 5
10 years old were enrolled in this study, 455 showed severe marasma,
11 57 marasma of medium severity and 38 kwashiorkor plus
12 marasma. We divided the children randomly into four groups: 170
13 were given Misola (731±7 Kcal/day), 170 were given Spiruline plus
14 traditional meals (748±6 Kcal/day), 170 were given Spiruline plus
15 Misola (767±5 Kcal/day). Forty children received only traditional
16 meals (722±8 Kcal/day) and functioned as the control group. The
17 duration of this study was eight weeks.

18 **Results and Discussion:** Anthropometrics and haematological
19 parameters allowed us to appreciate both the nutritional and
20 biological evolution of these children. The rehabilitation with
21 Spiruline plus Misola (this association gave an energy intake of 767
22 ± 5 Kcal/day with a protein assumption of 33.3 ± 1.2 g a day), both

1 greater than Misola or Spiruline alone, seems to correct weight loss
2 more quickly.

3 **Conclusions:** Our results indicate that Misola, Spiruline plus
4 traditional meals or Spiruline plus Misola are all a good food
5 supplement for undernourished children, but the rehabilitation by
6 Spiruline plus Misola seems synergically favour the nutrition
7 rehabilitation better than the simple addition of protein and energy
8 intake.

9

10 **Key Words**

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

12

13 **1 - Introduction**

14 Malnutrition constitutes a public health problem throughout the world
15 and particularly in developing countries (1). In Africa, more than 30%
16 of the deaths of less than five year old children result directly or
17 indirectly from malnutrition (2). Since 1999, Burkina Faso has been
18 confronted by protein-energy malnutrition with 13 % of the infant
19 population affected by emaciation, 29% by growth retardation and
20 30% by insufficient weight (3). The consequences of the protein-
21 energy malnutrition in Burkina Faso are several, but especially severe
22 forms of marasma, kwashiorkor and marasmic kwashiorkor are
23 manifested (3). Today it is recognized that this form of malnutrition is

1 coupled with deficiencies in vitamins and minerals (4, 5). It
2 inexorably creates an spiral between malnutrition and infectious
3 pathologies, which are often associated with chronic diarrhoea and
4 compound the prognosis of these children (6). In the Nutrition
5 Education and Rehabilitation Centre (CREN) of Ouagadougou, Burkina
6 Faso, Misola or Spiruline or both together have been used since 2000
7 to improve the nutritional status of undernourished children. The
8 choice of these two elementary integrators was prompted by the
9 biochemical composition of both. Misola, a local flour traditionally
10 produced at the CREN of the Centre Medical St. Camille (CMSC) of
11 Ouagadougou which contains millet, soja, peanut following the
12 original formula proposed by the Association Burkinabe des Unites
13 Misola and powder of Spiruline, a cyanobacterium which grows
14 easily under the climate of Burkina Faso, also produced at the CMSC,
15 were recently introduced in the treatment of undernourished children
16 for its biological activities (7). Spiruline was utilized for its elevated
17 content of aminoacids, iron and carotenoids. Spiruline used in this
18 study was also analysed for its chemical composition since its lipid
19 composition is influenced by the environmental growing conditions.

20 **2 - Subjects and Methods**

21 This research was conducted at the CMSC of Ouagadougou during
22 2002-2003. The centre was created in 1974 by the St Camille
23 religious order and comprises a maternity centre, a health centre, an

1 analysis laboratory for biological and biochemical examination, a
2 centre for neonatal pathology, a greenhouse for growing the Spiruline
3 (Figure 1) and a Nutrition Education and Rehabilitation Centre
4 (CREN). The CREN follows on average 700 children per year.

5 *Study Protocol*

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

13 **2a Study patients**

14 At the beginning of this study, undernourished children were anorectic
15 and many of them had diarrhoea, which was treated with nose-
16 gastric (NG) re-hydration according to the CMSC protocol (6). They
17 were taken off NG feeding before being selected for this study, since
18 this condition had sufficiently improved to allow moving on to oral
19 feeding. At the end, 550 children were enrolled randomly in three
20 rehabilitation re-hydration protocols: A) 170 of them received an
21 alimentation with only Misola, B) 170 were treated by supplementing
22 Spiruline to traditional meals (millet, vegetable, fruit), C) 170
23 received Spiruline plus Misola. A control group of 40 undernourished

1 children from the same age range was chosen randomly between
2 children whose mothers did not accept the protocol study, so they
3 were fed only with traditional meals. The vitamin and mineral
4 deficiencies were corrected only at the end of study.

5 ***2b Participation criteria***

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

13 ***2c Anthropometric parameters***

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

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

21 HAZ (Height for age z-score), WHZ (Weight for height z-score)
22 and WAZ (Weight for age z-score) parameters were calculated

1 according to the references of the National Centre for Health
2 Statistics (NCHS) (10).

3

4 ***2d Evaluation of results***

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

18 ***2e Plant material.***

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

1 ***2f Preparation and Administration of Spiruline and Misola***

2 The mothers of the undernourished children to receive Spiruline or
3 Spiruline plus Misola were given weekly rations of Spiruline in a
4 sachet. Every day, they had to mix 5 g of Spiruline with the
5 traditional meal of their children composed of 50 grams of millet flour
6 in a graduated container. Other mothers added 5 g of Spiruline to 50
7 grams of Misola flour. These integrations were made at least twice a
8 day. The Misola, a kind of bouillon, is a mixture of millet (60%), soya
9 (20%), peanut kernel (10%), sugar (9%) and salt (1%). The
10 preparation of the Misola or millet was carried out according to
11 traditional customs, namely 50 grams of Misola or millet and 200 ml
12 of water were mixed and boiled over a low fire, mixing for 2-3
13 minutes. Each mother have to cook it 4 times a days (6:30; 10:30;
14 14:30 and 18:30) in order to feed her child. The mothers rapidly
15 learned to prepare the mixtures and feed their children inside the
16 CREN. A simple twenty-four hour diet recall was used in a printed
17 double A4 sheet of paper, with the aim to obtain reliable data for
18 energy and protein intake. It asked for a record of all foods, taken
19 over the day. A written example was included. Every morning the
20 sheet was collected, the children were weighed and the exact
21 quantity of food ingested clearly annotated in a register. After this
22 preliminary phase they continued to administer the mixture at home.
23 Each day they accompanied their children to the CREN to monitor

1 weight and other anthropometric parameters and deliver the 24
2 hours diet recall sheet to CREN.□At the end of the sheet, a number
3 of additional questions were asked, such as the appetite, liveliness,
4 humour.

5

6 ***2g Chemical studies***

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

13 ***2h Fatty acids quantification and identification***

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

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1 **3 - Statistic analysis**

2 A power analysis was performed prior to the initiation of the study
3 and the number of studied children was homogeneously distributed.
4 The study reached the minimal number of observations to discuss a
5 statistical difference. The data were treated with Excel (Office,
6 Microsoft) software, Epi-Info software V. 6 for the anthropometric
7 data and SPSS-10 for biological data, according to the opportunities
8 of calculations and of analysis. The difference between mean values
9 before and after eight weeks of treatment were calculated by Student
10 T test. $P < 0.05$ was considered significant.

11

12 **4 – Results**

13 ***4a Nutritional rehabilitation***

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

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

1 The nutritional pre/post changes improved in all children, but
2 more significantly so in the group that received Misola plus Spiruline.
3 These changes among treatment groups are reported in Table III.
4 This improvement corresponds to an increment of weight which was
5 on average 20 g a day in the Misola group, 25 g a day in the
6 Spiruline plus traditional meals group, 34 g a day in the Misola plus
7 Spiruline group and 15 g a day in the control group. These pre/post
8 differences within groups were statistically significant considering the
9 differences in the nutritional status changes across the groups, but
10 this difference was less significant in the control group.

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

21 The compliance to treatment was excellent and no children
22 dropped out. The mothers reported that the children accepted the
23 mixes and rarely had difficulties in feeding their children. They came

1 to weekly appointments, but only the first and the last visit (eight
2 weeks) were considered in the final evaluation.

3

4 ***4b Chemical analysis***

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

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

1 changes were detected, such as a decrease in protein content and an
2 increase in pH value.

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

6

7 **5 - Discussion**

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

20 The association between Misola plus Spiruline achieved greater
21 gains in terms of weight than the Misola or Spiruline alone. This result
22 is clearly due to higher energy intake (767 ± 5 Kcal/day) and to

1 greater protein assumption (33.3 ± 1.2 g/day), which synergically
2 favour the nutrition rehabilitation.

3 The results of this study prompted us to continue the culture of
4 Spiruline in the CMSC of Ouagadougou in order to utilize the
5 biochemical composition and the beneficial action of this
6 cyanobacterium, which may be considered an alimentary integrator
7 for undernourished children. In the context of low intake of proteins,
8 10 g a day per inhabitant in Africa against 29 g in Latin America and
9 63 g in the industrialized countries, and the integration of traditional
10 meals with Spiruline and Misola plus Spiruline (57 % of protein),
11 improve the nutritional and micronutrient requirement for
12 undernourished children (13).

13 This may be due to the iron content of Spiruline supplement
14 (14), which corrects anaemia owing to deficient iron intake.

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

19 Growth recovery was slower than weight recovery and this may
20 have been compounded by the diarrhoea, which was present at the
21 beginning of treatment of these children (17). In fact, in our eight
22 week study, the variations of weight were more significant owing to
23 the liquid content dehydration associated with malnutrition. The

1 percentage of increment in weight with the association of Misola plus
2 Spiruline confirms the suitability for continuing this kind of
3 combination in undernourished children. A previous study made by
4 Branger et al. (18) in Burkina Faso did not show a significant
5 improvement by adding Spiruline to traditional meals and Misola, but,
6 as considered by the same authors, the results they obtained could
7 be due to the quantity of Spiruline, which was half that used in our
8 study (5 g vs. 10 g). Moreover, the present study is more conclusive
9 than the one realized in Dakar by Alling *et al.* (19), where weight gain
10 was less, probably also due in this case, to a reduced supplement in
11 Spiruline.

12 The anthropometric characteristics varied little according to sex
13 (Table II), but were different according to the nutritional and
14 serologic status. This observation is the same as the one by Kelly *et al.*
15 (20) in undernourished HIV-infected children with persistent
16 diarrhoea. The strong prevalence of kwashiorkor and/or marasma is
17 characteristic of sub-Saharan Africa, where maize and millet are the
18 staple diet. In fact, high intake of linoleic acid in a diet deficient in
19 other polyunsaturated fatty acids and in riboflavin results in high
20 tissue production of prostaglandin E2 in these countries, which in turn
21 causes inhibition of the proliferation and cytokine production of Th1
22 cells, mediators of cellular immunity (21). Diet-associated inhibition

1 of the Th1 subset is a major contributor to the high prevalence of
2 these diseases in sub-Saharan areas.

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

8

9 **6- Conclusion**

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

18 Misola, which has 61 % of glycidic with 410 kcal/100g, has a
19 higher energy content than the Spirulina which has only 13.84 % of
20 glycidic with 338 kcal/100g. Inversely, Spirulina has 57.10 % of
21 protein and the Misola has only 16 %. At the end the high amount of
22 ω -6 lipid component helped an efficient recovery of the precarious
23 immune system of these children. These characteristics confirm the

1 suitability of supplementing Misola with Spirulina (this association
2 gave an energy intake of 767 ± 5 Kcal/day with a protein assumption
3 of 33.3 ± 1.2 g a day), both greater than Misola or Spiruline alone.
4 According to the instructions which the mothers received,
5 involvement of the families of the undernourished children and of the
6 whole community is essential to control the great prevalence of
7 malnutrition in African countries.

8

9 **7- Acknowledgement**

10 We are deeply grateful to the personnel of the Centre Médical de
11 Saint Camille and particularly to Sister Perpétue Tiemtore, Sister
12 Noële Zoungrana, Mrs. Justine Yara, Mrs. Jaqueline Kando and Ms.
13 Robert Makamba for their skilful technical assistance.

14

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1 **Table I** – Anthropometric parameters of the children subjected to the study^a

	A 170 Children with Misola 200g/day	B 170 Children with Spiruline 10g/day plus traditional meals 200g/day	C 170 Children with Spiruline 10g/day plus Misola 200g/day	D 40 children with traditional meals 200g/day	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 < 0.01
B.P.	11.17±1.2	10.40±1.0	11.20±1.2	10.37±1.0	P < 0.001
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 < 0.001
WAZ	-4.01±1.0	-3.88±1.0	-4.38±0.9	-3.99±0.9	P < 0.001
Energy intake (Kcal/day)	731±7	748±6	767±5	722±8	P < 0.001
Protein (g/day)	27.1 ±1.7	27.8±1.6	33.3±1.2	22.1±1.3	P < 0.001

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

1

2 **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

3 Student T test * P = 0.0001

4

5

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

	A 170 Children with Misola 200g/day	B 170 Children with Spiruline 10g/day plus traditional meals 200g/day	C 170 Children with Spiruline 10g/day plus Misola 200g/day	D 40 Children with traditional meals 200g/day
WHZ1 1 →2	-1.73±2.51 P = 0.035*	-2.88±0.95 P < 0.001	-3,05±0.75 P < 0.001*	-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/WH Z1+WHZ2	34.14 %	37.50 %	62.90 %	17.35 %
WAZ1 1 →2	-4.01±0.98 P < 0.001**	-3.88±0.90 P < 0.001**	-4,38±0.91 P < 0.001**	-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/WAZ 1+WAZ2	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
3 of the study;
4 WAZ1 = Weight for age z-score at the beginning of study; WAZ2 = Weight for age z-score at the end of
5 the study. Student T test *WHZ1→WHZ2; **WAZ1→WAZ2 ;

1 **Table IV** - Nutritive composition of 100 grams of Misola used in the
2 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
6 Spiruline from the Center Medical St Camille in comparison to the
7 given values in 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%

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3 **Table VI** - Physicochemical composition of the Spiruline with time

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<i>Analysed sample</i>	<i>T0 (1th day)</i>	<i>T1 (1th month)</i>	<i>T2 (2nd month)</i>	<i>T3 (3th month)</i>	<i>T4 (10th month)</i>
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

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6 Student T test for paired data : T0 → T1 : p = 0.273; T0 → T2 : p =

7 0.310 ; T0 → T3 : p = 0.763 ; T0 → T4 : p = 0.625

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

4



Figure 1