Nutrition and Metabolic Insights

ORIGINAL RESEARCH

Potential of *Spirulina Platensis* as a Nutritional Supplement in Malnourished HIV-Infected Adults in Sub-Saharan Africa: A Randomised, Single-Blind Study

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Abstract

Background: Malnutrition is a major global public health issue and its impact on communities and individuals is more dramatic in Sub-Saharan Africa, where it is compounded by widespread poverty and generalized high prevalence of human immunodeficiency virus (HIV). Therefore, malnutrition should be addressed through a multisectorial approach, and malnourished individuals should have access to nutritional rehabilitation molecules that are affordable, accessible, rich in nutrient and efficient. We thus assessed the efficacy of two affordable and accessible nutritional supplements, *spirulina platensis* versus soya beans among malnourished HIV-infected adults.

Methods: Undernourished patients, naïve of, but eligible to antiretroviral treatment (ART), aged 18 to 35 years were enrolled and randomly assigned to two groups. The first group received spirulina (Group A) as food supplement and the second received soya beans (Group B). Patients were initiated ART simultaneously with supplements. Food supplements were auto-administered daily, the quantity being calculated according to weight to provide 1.5 g/kg body weight of proteins with 25% from supplements (spirulina and soya beans). Patients were monitored at baseline and followed-up during twelve weeks for anthropometric parameters, body composition, haemoglobin and serum albumin, CD4 count and viral load.

Results: Fifty-two patients were enrolled (Group A: 26 and Group B: 26). The mean age was 26.4 ± 4.9 years (Group A) and 28.7 ± 4.8 (Group B) with no significant difference between groups ($P = 0.10$). After 12 weeks, weight and BMI significantly improved in both groups ($P < 0.001$ within each group). The mean gain in weight and BMI in Group A and B were 4.8 vs. 6.5 kg, ($P = 0.68$) and 1.3 vs. 1.90 Kg/m^2, ($P = 0.82$) respectively. In terms of body composition, fat free mass (FFM) did not significantly increase within each group (40.5 vs. 42.2 Kg, $P = 0.56$ for Group A; 39.2 vs. 39.0 Kg, $P = 0.22$ for Group B). But when compared between the two groups at the end of the trial, FFM was significantly higher in the spirulina group (42.2 vs. 39.0 Kg, $P = 0.01$). The haemoglobin level rose

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significantly within groups ($P < 0.001$ for each group) with no difference between groups ($P = 0.77$). Serum albumin level did not increase significantly within groups ($P < 0.90$ vs. $P < 0.82$) with no difference between groups ($P = 0.39$). The increase in CD4 cell count within groups was significant ($P < 0.01$ in both groups), with a significantly higher CD4 count in the spirulina group compared to subjects on soya beans at the end of the study ($P = 0.02$). Within each group, HIV viral load significantly reduced at the end of the study ($P < 0.001$ and $P = 0.04$ for spirulina and soya beans groups respectively). Between the groups, the viral load was similar at baseline but significantly reduced in the spirulina group at the end of the study ($P = 0.02$).

Conclusion: We therefore conclude in this preliminary study, firstly, that both spirulina and soja improve on nutritional status of malnourished HIV-infected patients but in terms of quality of nutritional improvement, subjects on spirulina were better off than subjects on soya beans. Secondly, nutritional rehabilitation improves on immune status with a consequent drop in viral load but further investigations on the antiviral effects of this alga and its clinical implications are strongly needed.

Keywords: malnutrition, spirulina, nutritional rehabilitation, HIV infected persons, anthropometric measurements, body composition, CD4 cells count, viral load

Introduction

According to the United Nations program on Acquired Immune Deficiency Syndrome (UNAIDS), about 68% of HIV-infected adults live in Sub-Saharan Africa.[1] Despite the fact that antiretroviral treatment (ART) has spectacularly prolonged the life expectancy among these patients infected with HIV, malnutrition remains a major complication of the disease and a public health problem in low income countries; its influence on the progression of HIV infection is frequently reported.[2–6] In Ghana for example, Tabi et al[7] reported that "*most patients with HIV and AIDS die because of their poor nutritional status than from the disease itself*".

Protein-calorie malnutrition impairs the anti-viral function of macrophages and is directly related to the severity of the HIV infection.[8–13] Chronic infections generate a significant energy demand including protein catabolism for energy production via gluconeogenesis. This is worsened by protein intake deficiency.[14] Besides, a range of metabolic abnormalities occur in HIV/AIDS patients on ART treatment, including dyslipidaemia, disorders of glucose metabolism, as well as changes in body composition.[15–18]

All these are indications that the management of HIV-infected individuals should include an assessment of their nutritional status. WHO recommends that the diet of people living with HIV-AIDS should be supplemented with macronutrients and micronutrients.[19] The above recommendation is yet to be fully implemented at national health care levels in Sub-Saharan Africa, in terms of nutritional intervention as complementary to ART, and as added-value in the improvement of the quality of life of these subjects.

Arthrospira platensis, also called *spirulina platensis*, is a blue-green alga with a very high protein content used in nutritional rehabilitation in undernourished/malnourished people with excellent results.[20–24] A more recent study conducted in Central African Republic[25] reported that spirulina could be a strong candidate supplement if it has other potential than just nutritional benefits; they did not test body composition nor viral load, and failed to demonstrate benefits in terms of direct improvement on immune response, due to their limited experimental protocol. Spirulina is generally considered safe for human consumption supported by its long history of use as food source[21] and its favorable safety profile in animal studies.[26–28] Spirulina is locally available in sub-saharan Africa, inexpensive and exhibits some reported therapeutic functions.[24,29] In addition spirulina supplementation does not change usual food intake. We therefore carried out this study to assess the impact of nutritional rehabilitation by *spirulina platensis* on HIV-associated undernutrition/malnutrition.

Methods

Study hypothesis

It was hypothesised that in HIV-infected and malnourished adults, nutritional supplementation with spirulina coupled to ART would be more efficient than ART plus soya beans, on the nutritional status in terms of weight gain and body composition, and in improvement of the immune response due to good nutritional status.

Study objectives

The main objective of this study was to assess the impact of nutritional rehabilitation using *spirulina platensis* versus soya beans on the nutritional status, and the immune response of malnourished HIV-infected adults.

Specifically, the 12-weeks impact of spirulina versus soya beans renutrition therapy was assessed on the clinical nutritional status as measured by anthropometry and body composition analysis and on biological parameters (haemoglobin, serum albumin, CD4 count, viral load).

Study protocol

This was a twelve-week prospective study including two groups of patients. One group of patients was randomized to spirulina as nutritional supplement (treatment group) and the other group received Soya beans. This research was conducted at the AIDS clinic of the Day Care Hospital, a healthcare unit linked to the Internal Medicine Service of the Yaoundé Central Hospital. This unit is located in the central region of Yaoundé town in Cameroon, and has more than 4000 registered HIV-infected patients. It is considered to be a reference centre for multidisciplinary care of individuals living with HIV/AIDS. Data were collected from October 2008 to January 2009.

Participation criteria

In this study patients aged 18–35 years, infected with HIV without distinction of sex, naive to any ART (and about to initiate ART); with body mass index (BMI) <18.5 kg/m^2 and/or a wasting syndrome (loss of $\geq 10\%$ body weight), a state of advanced or severe immune deficiency (CD4 < 349 cells/mm^3), residing in Yaoundé and who gave an informed consent were included in the study.

Bedridden subjects, those having an opportunistic infections or psychiatric illness, including a clinically diagnosed tumour were excluded. All pregnant women, a history of poor compliance to previous treatments, or who refused to participate in the study were also excluded.

Sample size

In addition to weight gain and given the fact that improvement in nutritional status leads to an improvement in immune status we based the calculation of the sample size on the proportion of patient (P) with an increase of 100 CD4 cell count at the end of 3 months of nutritional supplementation. The benchmark of 100 CD4 cells count which was chosen was based on a previous field study in Cameroon.[30] We powered our study to detect a 50% difference in the proportion of patients with a significant increase of CD4 between the treatment (Spirulina) group and the control (Soya) group. We used sample size computational tables to estimate different values of sample size. Our parameters were:

- Ratio Treatment group/Control group = 1; Precision = 0.05; $Z\alpha = 1.645$.
- With a power of 80%, we needed 23 subjects per group.
- The individuals were selected randomly, on the basis of consecutive sampling. The randomisation pattern was stratified according to the time of arrival at the clinic. The subjects were allocated in groups of 5 in each treatment group. Data were analysed as per protocol.

Interview

Outpatients infected by HIV, who arrived for routine consultations with a medical doctor, were approached and invited to participate in the study. The purpose, requirements and procedure of the study were explained to them. An interview allowed identifying and partially verifying inclusion criteria. Then, patients who gave their informed consent to participate in the study were submitted to a complete physical examination and blood sample collection for laboratory tests. They received their food supplement, and an appointment was given every two weeks.

Physical examination

Physical examination consisted of anthropometric measurements including body composition analysis and a complete clinical examination.

Anthropometric measures

The height and body weight were measured to a precision of 0.1 cm and 0.01 kg, respectively, utilizing a digital weighing balance (electronic weighing device, LAICA®—Italy) and an anthropometric tape attached to the wall of the evaluation room. Participants wore only under-shorts. The weight measurements were made twice and the height measurements were made two times, adopting the average value. All these measurements were made by a single person who was experienced in the field of measurements and evaluations.

The Body Mass Index was calculated using the formula Weight/height², and interpreted according to the WHO classification of BMI.

Body composition analysis

Participants had a single, tetrapolar BIA measurement of resistance (Res) and reactance at 50 kHz on the right side of the body, using Quantum® Bio-Impedance (BIA) Body Composition Analyzer (RJL systems, USA). The electrodes were placed on the hand, wrist, foot, and ankle of each subject according to the standard placement for adults stated in the manufacturer's guidelines. All metal objects were removed from the subjects before the measurements were made. The subjects were supine for at least 15 min on a non-conductive surface with their arms and thighs apart. All BIA measurements were performed by the same person.

Equations used for determining body composition (from Chumlea et al[31])

The following equations were used to calculate the body composition;

Fat Free Mass (FFM)

$$\text{Men: FFM} = -10.678 + 0.262 \times \text{Weight} + 0.652 \times \text{Height}^2/\text{Res} + 0.015 \times \text{Res}$$

$$\text{Women: FFM} = -9.529 + \text{Weight} + 0.696 \times \text{Height}^2/\text{Res} + 0.016 \times \text{Res}$$

Res = Resistance

Total Body Fat (TBF)

$$\text{TBF} = \text{Weight} - \text{FFM}$$

Biological parameters

The blood samples collected for laboratory tests were divided into three tubes; for haematology, biochemistry and virology. The haemoglobin level was determined by an automat while albumin level was obtained by an indirect assay method. The CD4 cell count was determined by cytometry and the viral load by polymerase chain reaction.

Food supplements distribution

After clinical data and blood sample collection, each patient received either spirulina or soya powder, in a quantity equivalent to the protein supply recommended by according to Coyne-Meyers et al.[32] Based on the information collected by questionnaire, we assumed that patients had a quantitatively adequate protein intake in their diet. We then planned to supplement 25% of protein intake by spirulina, or 0.37 g/kg/day during the first month and 0.20 g/kg/day during the following 2 months. At baseline, all subjects were naive to ART and were initiated simultaneously to ART together with the supplements.

Statistical analysis

Data were analysed with SPSS–version 13.0 and R (version, 2.7.1). Quantitative variables were presented as means ± standard deviation. When distributions were not normal, results were presented as medians including the minimal and maximal values. The Student's T test and the paired T-test were used to compare continuous data with a normal distribution while the Wilcoxon and Mann-Whitney U test were used as appropriate. A difference with $P < 0.05$ was considered significant. A patient who died or disappeared during the study, was also considered as lost and thus excluded from the analysis. It was the same for those who developed opportunistic infections.

Ethical considerations

This study was approved by the National Ethical Committee of Cameroon (Ethical clearance n° 036/CNE/DNM/07). All participants in the study gave an informed consent before inclusion.

Results

Sixty two (62) patients were recruited on the whole. Of this number, 6 died and 4 patients were lost to follow up, giving a follow-up rate of 84%. Our final sample was made up of 52 patients, divided randomly into two groups of 26. The mean age was 26.3 ± 4.9 years in the spirulina group and 28.6 ± 4.7 years in the soya group. Both groups were comparable at baseline for all characteristics (Table 1).

Nutritional rehabilitation

Below, Tables 2, 3 and 4 compare the anthropometric characteristics of the subjects at inclusion (Baseline) and after a follow-up of 12 weeks (Endline).

At the beginning of the study, the median value of the weight was comparable in the two groups. It was

Table 1. General characteristics of our study population at baseline.

Variables	Overall	Spirulina	Soya bean	*P* value†
	Mean ± SD			
Sex				
Female, n (%)	34 (65.4)	17 (65.4)	17 (65.4)	0.77
Male, n (%)	18 (34.6)	9 (34.6)	9 (34.6)	
Age (years)	27.4 ± 4.8	26.4 ± 4.9	28.7 ± 4.8	0.08
Height (cm)	165 ± 8	165 ± 16	162 ± 15	0.51
Weight (kg)	53.9 ± 15.5	55.7 ± 19.5	52.2 ± 10.3	0.51
BMI (kg/m²)	20.0 ± 4.7	20.1 ± 5.3	20.1 ± 4.2	0.93
Total body fat (kg)	14.0 ± 10.8	15.1 ± 13.1	12.9 ± 8.0	0.50
Fat free mass (kg)	39.9 ± 8.1	40.6 ± 8.9	39.2 ± 7.4	0.68
Haemoglobin (g/dl)	10.4 ± 1.3	10.5 ± 1.6	10.5 ± 1.1	0.74
Albumin (g/l)	30.6 ± 3.5	30.2 ± 4.2	31.0 ± 2.6	0.30
CD4 (cell/mm³)	97 ± 54	96.7 ± 58.6	97.4 ± 49.4	0.89
Viral load (copy Log 10/mm³)	4.8 ± 0.3	4.9 ± 0.4	4.8 ± 0.3	0.90

Note: *P* value† = *P* value for baseline comparison between spirulina and soya beans group only.
Abbreviation: SD, standard deviation.

the same for the mean and median values of the BMI, which were within normal limits. However, when separately analysed, 64% were classified as underweight (BMI less than 18.4 kg/m²) in the spirulina group and 30% in the Soya group. There was no significant difference in the body composition between the two groups.

At the end of the study, there was a significant increase in weight within each treatment group, without a significant difference between the groups. The average weight gain was 4,8 kilograms. 60% of patients had a weight gain greater than 10% of baseline weight, with 58% being in the spirulina group and 62% in the soya group. There was a significant improvement of BMI in the two groups. Concerning the body composition, we observed a significant TBF increase in the two groups. Besides, the FFM increased non significantly within the spirulina group, and was unchanged in the Soya group. When the difference in FFM was compared between the two groups at the end of the study, it was significantly higher in the spirulina than in the soya bean group.

Table 2. Variation of body weight during the course of the study.

Body weight (kg)	Spirulina (*n* = 26)	Soya beans (*n* = 26)	*P*
	Mean		
Baseline	55.6 ± 19.5	52.1 ± 10.3	0.79
Endline	60.4 ± 18.6	58.6 ± 10.6	0.68
Diff.(*)	4.8	6.5	–
P	<0.001	<0.001	–

Note: Diff.(*) = Mean difference in kg.

Biological parameters of our study population

In Table 5, the biological parameters in each treatment group is compared at the beginning and at the end of the study.

The haemoglobin level significantly increased in the two groups at the end of the study, without significant difference between the groups. The mean increase of haemoglobin was 1.6 g/dl in the spirulina group and 1.4 g/dl in the soya group. Sixty two (62)% of patients in the two groups corrected their anaemia at the end of the essay.

There was no significant change in albumin levels within and between treatment groups.

Table 3. Variation of body mass index during the course of the study.

BMI (kg/m²)	Spirulina (*n* = 26)	Soya beans (*n* = 26)	*P*
	Mean ± SD		
Baseline	20.6 ± 5.3	20.1 ± 4.1	0.99
Endline	21.9 ± 5.7	22.0 ± 4.6	0.82
P	0.001	0.001	–

Table 4. Variation of body composition during the course of the study.

Fat free mass (FFM) Total body fat (TBF)		Spirulina ($n = 26$) Mean ± SD	Soya beans ($n = 26$)	Diff.(*) (P)
FFM (kg)	Baseline	40.5 ± 8.9	39.2 ± 7.3	1.3 ($P = 0.80$)
	Endline	42.2 ± 9.5	39.0 ± 6.4	3.2 ($P = 0.01$)
	Diff.(*) (P)	1.7 ($P = 0.56$)	–0.02 ($P = 0.22$)	–
TBF (kg)	Baseline	15.0 ± 8.2	12.9 ± 7.9	2.1 ($P = 0.99$)
	Endline	18.2 ± 9.4	17.6 ± 8.8	0.6 ($P = 0.48$)
	Diff.(*) (P)	3.2 ($P < 0.001$)	4.7 ($P < 0.001$)	–

Note: Diff.(*) = Mean difference in kg.
Abbreviation: SD, standard deviation.

Immune response

Table 6 shows the evolution of CD4 cells counts and viral load in the two groups of subjects. The CD4 cells count increased in all patients, but significantly more in the group which received spirulina. 73% of patients had an increase of more than 10% of their baseline CD4 cells count, with 77% being in the spirulina group and 69% in the soya group. The difference between the two groups was significant ($P = 0.02$).

The variation of viral load is reported in table 7: in patients receiving spirulina, the viral load significantly decreased at the end of the study as opposed to the subjects on soya ($P = 0.02$).

Discussion

This study comprised 52 patients divided into two groups of 26 each. Our sample size was lower than that of Simpore et al[23] and Diop et al[33] which were 84 and 61 patients respectively. The mean age of our study population was 27.4 ± 4.8 years.

The choice of soya beans as nutritional supplement for the control group was due to the fact that, for ethical reasons, we had to provide a real nutritional supplement to HIV malnourished participants not under spirulina. Soya has known beneficial effects in malnourished subjects.[34–36]

After 12 weeks of study, patients supplemented with spirulina improved as concerns their nutritional status. Weight gain was significant in the two groups, with an average 4,8 kilograms increase. This value is slightly higher than that obtained by Diop et al[33] which was 4 kilograms, for the same period of study. The weight increase was associated to an improvement of the BMI. Diop et al[33] didn't report a significant improvement of BMI in their study. Yamani et al[25] reported less than 1,4 kg weight gain in spirulina and placebo groups after 3 months supplementation, when we recorded at least 4 kg. This could be due to the fact that we included people with evident weight loss whereas Yamani's sample did not take it in consideration, nor indicating the need for nutritional intervention among their patients. Their limited protocol did not provide any information on the analysis of weight gain quality in term of body composition; they used arm girth as measure of muscle mass reconstitution, but this is usually rejected for adults, it is more valid in paediatric nutritional interventions.

Table 5. Variation of biological parameters during the course of the study.

		Spirulina ($n = 26$) Mean ± SD	Soya ($n = 26$)	Diff.(*) (P)
Hemoglobin (g/dl)	Baseline	10.4 ± 1.5	10.4 ± 1.0	0 ($P = 0.96$)
	Endline	12.0 ± 1.7	11.8 ± 1.1	0.2 ($P = 0.77$)
	Diff.(*) (P)	1.6 ($P < 0.01$)	1.4 ($P < 0.01$)	–
Albumin (g/l)	Baseline	30.2 ± 4.2	31.0 ± 2.6	–0.8 ($P = 0.41$)
	Endline	31.2 ± 4.3	31.4 ± 3.1	–0.2 ($P = 0.39$)
	Diff.(*) (P)	1.0 ($P = 0.90$)	0.4 ($P = 0.82$)	–

Note: Diff.(*) = Mean difference in g/dl or g/l respectively.
Abbreviation: SD, standard deviation.

Table 6. Variation of CD4 count during the course of the study.

CD4 count (cells/mm³)	Spirulina ($n = 26$)	Soya beans ($n = 26$)	Diff.(*) (P)
	Mean ± SD		
Baseline	96 ± 58	97 ± 49	–1 ($P = 0.3$)
Endline	195 ± 90	143 ± 69	52 ($P = 0.02$)
Diff.(*) (P)	99 ($P < 0.01$)	46 ($P < 0.01$)	–

Note: Diff.(*) = Mean difference in cells/mm³.
Abbreviation: SD, standard deviation.

In terms of the quality of weight gain, the body composition of our patients showed an increase of FFM within the spirulina group, though not significant. The FFM in the soya group remained unchanged. But when we compared the FFM between the two groups at the end of 12 weeks of nutritional supplementation, the FFM was significantly greater in the spirulina group This result suggests that spirulina intake as opposed to soya intake is more efficient in correcting loss of FFM in persons infected with HIV. Compared to the soya, spirulina is richer in essential amino acids, important for anabolism and muscle mass reconstitution. Although the increase of TBF was higher in the soya beans group, the difference between the two groups at the end of the study was not significant. This result can be explained by the fact that when we balance the two supplements by their protein rates, the caloric supply maximised in the Soya group, favours directly lipogenesis. From another point of view, there is adipose tissue redistribution during the HIV-infection, and this phenomenon is more accentuated with the use of highly active antiretroviral therapy. The values that we obtained are not absolute, but allowed us to appreciate the quality of weight gain.

The albumin level remained relatively constant in the two groups at the end of the study. Despite the fact that we observed a slight increase in the majority of patients, some of them remained in hypoalbuminemia. This result is similar to those obtained by Diop et al[33] who didn't observed any improvement of albumin in patients under spirulina. Doudou et al[37] reported that spirulina seemed to have little effect on the albumin level. A low albumin level is one of the biological indicators of disease progression among malnourished people.[38–40] This mild increase in malnourished HIV-infected individuals, who received a food supplement rich in proteins could be due to other factors which have to be investigated.

As concerns the haemoglobin levels, there was a significant increase in the two groups at the end of the study. The average increase was 1.6 g/dl in the spirulina group. This value is similar to those obtained by Simpore et al[23] which was 1.4 g/dl. Diop et al[33] did not observe a significant increase of haemoglobin levels. 62% of the study participants corrected their anaemia against 43% reported by Doudou et al.[37] Spirulina is known to be rich in iron and this result suggests the positive impact that it could have, on the prevention and long-term treatment of anaemia in HIV infected and malnourished patients.

At the beginning of the study, the average CD4 cells counts were low, without differences between the two groups. After 12 weeks of supplementation, we observed a significant increase in the two groups. However this increase was significantly higher in those who received spirulina ($P = 0.02$). Diop et al[33] reported a non significant increase of CD4 cells count in their patients. This indicates that the immune response may be more efficient among HIV-infected patients under ART and supplemented with spirulina, than in those with ART alone. Simpore et al[23] reported that spirulina seemed to have an effect on the CD4 cells preservation. This could be explained by the immunostimulatory effects of any kind of successful nutritional rehabilitation, since it is generally admitted

Table 7. Variation of viral load during the course of the study.

Viral load ($\log_{10}$ copies/mm³)	Spirulina ($n = 26$)	Soya beans ($n = 26$)	Diff.(*) (P)
	Mean ± SD		
Baseline	4.86 ± 0.35	4.81 ± 0.31	0.05 ($P = 0.59$)
Endline	4.45 ± 0.49	4.75 ± 0.36	–0.30 ($P = 0.02$)
Diff.(*) (P)	–0.41 ($P < 0.001$)	–0.06 ($P = 0.04$)	–

Note: Diff.(*) = Mean difference in $\log_{10}$ copies/mm³.
Abbreviation: SD, standard deviation.

that a good nutritional status is a good predictor of better immune response by the so-called *nutrition modulation of immune response* effect.[12]

The viral load was significantly decreased in the spirulina group, without any significant change in the soya group at the end of the study. This result suggests that spirulina, as reported in in-vitro studies, may have an intrinsic antiviral activity, inhibiting the replication of HIV.[41,42] This study however does not allow clinical confirmation of its antiviral activity since it was not possible for ethical reasons to make comparisons against a group not treated by ART. Nevertheless, Diop et al[33] reported an undetectable viral load after 6 months of spirulina supplementation and it can be assumed that the decrease of viral load shown in this study could have reached similar levels with the same study duration.

Conclusion

At the end of this study, it can be concluded that spirulina supplementation over a period of 12 weeks in malnourished adults infected with HIV and/or having a severe case of immune deficiency; promotes weight gain and improvement in body composition in terms of increasing the FFM compared to soya beans; increases the haemoglobin level and by doing so reduces anaemia. It is also suggested that ART coupled to spirulina supplementation may be more beneficial for immune response than ART plus soya beans in terms of CD4 cells count and the viral load kinetics. Spirulina is a strong candidate supplement for HIV infection, when coupled with ART treatment among especially undernourished HIV infected persons. This study demonstrating improvements of anthropometric and immunological parameters among HIV-patients with spirulina supplementation confirms the interest in considering this alga routinely for nutritional rehabilitation among this type of patients. Further investigations on the in-vivo antiviral effects of this algae and its clinical implications are strongly recommended.

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Disclosure

This manuscript has been read and approved by all authors. This paper is unique and is not under consideration by any other publication and has not been published elsewhere. The authors and peer reviewers of this paper report no conflicts of interest. The authors confirm that they have permission to reproduce any copyrighted material.

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