Research Article

Received: 9 January 2013 Revised: 19 February 2013 Accepted article published: 10 June 2013 Published online in Wiley Online Library: 10 July 2013

(wileyonlinelibrary.com) DOI 10.1002/jsfa.6261

The hypolipidaemic effects of Spirulina (*Arthrospira platensis*) supplementation in a Cretan population: a prospective study

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Abstract

BACKGROUND: Spirulina (*Arthrospira platensis*) is a filamentous cyanobacterium used as a food supplement. The objective of the study was to determine the lipid-lowering effects of Spirulina in Cretan Greek dyslipidaemic patients, and to document its effectiveness as a possible alternative treatment for dyslipidaemia. Fifty-two adultCretan outpatients (32 men, 20 women), median age 47 (range, 37–61) years, with recently diagnosed dyslipidaemia, consumed orally 1 g Spirulina (Greek production) per day for 12 weeks. The full lipid profile was measured in fasting blood samples at the beginning and end of the study period. Anthropometric measurements including systolic and diastolic blood pressure, height, weight and body mass index were also recorded.

RESULTS: At the end of the 3-month intervention period the mean levels of triglycerides, low density lipoprotein-cholesterol, total cholesterol, non-high density lipoprotein-cholesterol levels, and the ratio of total cholesterol to high-density lipoproteincholesterol were significantly decreased: 16.3% ($P < 0.0001$), 10.1% ($P < 0.0001$), 8.9% ($P < 0.0001$), 10.8% ($P < 0.0001$) and 11.5% ($P = 0.0006$) respectively, whereas the mean high-density lipoprotein-cholesterol levels were not significantly increased (3.5%). Blood pressure, weight and body mass index remained almost unchanged.

CONCLUSIONS: Spirulina supplementation at a dose of 1 g daily has powerful hypolipidaemic effects, especially on the triglyceride concentration in dyslipidaemic Cretan outpatients.

Keywords: *Arthrospira platensis*; food supplement; hyperlipidaemia; lipids; Spirulina

INTRODUCTION

Spirulina is a microscopic and filamentous cyanobacterium (blue–green alga) with a long history of use as a food supplement for humans and animals. It is produced primarily from two species of cyanobacteria classified into the genus Arthrospira: *Arthrospira platensis* and *Arthrospira maxima*. Spirulina is a rich source of proteins and vitamins, especially vitamin B_{12} and provitamin A (β-carotene), minerals, carotenoids and phycocyanins.[1] Beyond nutritional value, Spirulina possess specific therapeutic properties. Certain species of Spirulina have shown metabolic (lipid-lowering, hypoglycaemic), anti-viral, liver-protecting and blood-vessel relaxing effects; anti-cancer, anti-inflammatory and antioxidant properties; as well as positive effects on both innate and specific immunity.[1,2]

Cardiovascular disease (CVD), specifically myocardial infarction and stroke, is a leading cause of morbidity and mortality in developed countries.[3,4] Dyslipidaemia is known as a major modifiable risk factor for CVD. Early diagnosis and modification of dyslipidaemia should always be regarded as an essential approach to decrease cardiovascular mortality through preventing the development of atherosclerotic disease.[5] Recently, the European Society of Cardiology and the European Atherosclerosis Society,[5] as well as the Hellenic Society of Atherosclerosis[6] have published guidelines for the management of dyslipidaemia. These guidelines deal with the management of dyslipidaemias as a fundamental and integral part of CVD prevention, and therefore, the recommendations to achieve low density lipoprotein-cholesterol (LDL-C) treatment targets, which is the primary target of therapy, are identified by total cardiovascular risk estimation based on many risk assessment systems.[5–7]

Medicinal plants have been part of the human environment system to prevent and control diseases since the dawn of civilisation. Considering the fact that Spirulina has many beneficial effects on most of the classical risk factors for CVDs, it could be suggested as a food supplement for their prevention.[8] The

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purpose of this study was to determine the lipid-lowering effects of Spirulina (*A. platensis*), administered orally, in Cretan Greek dyslipidaemic patients, and to document the effectiveness of Spirulina as a possible alternative treatment for dyslipidaemia. This is the first human study of this type conducted in Greece.

MATERIAL AND METHODS

Subjects

Adult outpatients of both genders ($n = 52$; 32 men) attending the Outpatient Lipid Clinic of the Naval Hospital of Crete and University Hospital of Heraklion, Crete, with recently diagnosed dyslipidaemia participated in this study. They all met the following inclusion criteria: age >18 years, dyslipidaemia according to Adult Treatment Panel III criteria for the classification of dyslipidaemia [total cholesterol (T-C) >200 mg dL^{-1}, triglycerides (TG) >150 mg dL^{-1}, high density lipoprotein-cholesterol (HDL-C) <40 mg dL^{-1}],[9] commitment to complete the treatment, no history of diabetes mellitus, arterial hypertension (blood pressure > 140/90 mmHg), or CVD, and not consuming vitamin supplements or drugs known to affect lipid metabolism at the time of the study. Individuals with TG levels >400 mg dL^{-1}, renal failure, hypothyroidism [thyroid-stimulating hormone (TSH) >5 IU mL^{-1}] or hepatic disease were excluded. The protocol and aim of the study were fully explained to the subjects, who gave their written consent. Also, all subjects were free to withdraw from the study at any time, without any obligation. The research was carried out in accordance with the Declaration of Helsinki and was approved by the ethics committee of the medical research institution.

Study design

In this open-label, non-randomised study, an intervention period of 3 months was determined sufficient in order to record and research changes, mainly in lipid levels, before and after supplementation of Spirulina (*A. platensis*), a high-quality Greek product (Hellenic Spirulina Net; Production unit: Thermopigi, Sidirokastro, Serres, Greece). During the study period all subjects were asked not to modify dietary habits or lifestyle (in order to minimise the effects on lipids metabolism), as well as to abstain from taking any other supplements or medication without consulting the investigators. At the beginning and end of the 3-month study period, blood samples were collected in the morning after a 12 h fast. Anthropometric parameters were also measured at each visit. Spirulina was orally consumed, 1 g day^{-1} (two tablets of 0.5 g once daily), for 12 weeks.

Baseline characteristics of the subjects

The subjects were individually interviewed for socio-demographic characteristics, habits and lifestyle. Sitting systolic and diastolic blood pressure (average of two measurements), standing body height (measured without shoes to the nearest 0.5 cm) and body weight (measured without shoes and tunic) were also registered using a sphygmomanometer by the uscultatory method, a rigid height meter and a calibrated balance scale, respectively. Body mass index (BMI) was calculated as the weight (kg) divided by the height (m) squared (kg m^{-2}). Based on the classification of the World Health Organization,[10] a subject was defined as normal when the BMI was between 18.5 and 24.9 kg m^{-2}, as overweight when BMI was between 25.0 and 29.9 kg m^{-2}, and as obese when BMI was ≥30.0 kg m^{-2}.

Determination of plasma lipid profiles

Serum concentrations of T-C, HDL-C and TG were measured using an automated chemistry analyser (Olympus AU-600, Abbott Labs, Abbott Park, IL, USA). LDL-C and atherogenic index (AI; T-C/HDL-C ratio) were calculated using the Friedewald[11] and Lauer[12] equations, respectively. Non-HDL-C was calculated as T-C minus HDL-C.[13]

Estimation of total cardiovascular risk

Total cardiovascular risk estimation for each subject was based on HellenicSCORE project.[7] This project is available on the Worldwide Web and estimates the 10 year risk of fatal CVD based on the following risk factors: age, gender, smoking habits, systolic blood pressure, and T-C.[14] Considering the calculated 10 year HellenicSCORE, our subjects were classified according to the following levels of total cardiovascular risk: (1) very high risk (HellenicSCORE ≥ 10%), (2) high risk (HellenicSCORE ≥ 5% and <10%), (3) moderate risk (HellenicSCORE ≥ 1% and <5%), and (4) low risk (HellenicSCORE <1%).[4,6] All subjects with T-C > 305 mg dL^{-1} or very high levels isolated cardiovascular risk factor were classified as high cardiovascular risk.[5,7]

Statistical analysis

Results are expressed as mean ± standard deviation (SD). Statistical analyses were performed using GraphPad Prism 3.0 (GraphPad Software, Inc., San Diego, CA, USA). Comparisons between groups were done using Student's *t*-test. Paired *t*-tests were used to analyse mean differences between primary and after 3-month values for all measured parameters. Significant differences between categorical data were assessed with Fisher's exact test using contingency tables. All *P*-values were two tailed, and values <0.05 were considered statistically significant.

RESULTS

The baseline characteristics of 52 hyperlipidaemic subjects (median age, 47 years; range, 37–61 years) enrolled in the intervention study are presented in Table 1. No statistically noteworthy differences were noted regarding age, glucose and initial plasma lipid concentrations between men ($n = 32$) and women ($n = 20$). In contrast, smoking habits, initial body weight, BMI, and both initial systolic and diastolic blood pressures were substantially different between men and women subjects. The majority of the participants (75%) were found to be moderate level total cardiovascular risk. Also, 67.3% of the subjects were overweight and 30.7% obese (Table 1).

At the end of the intervention period, following 3 months of Spirulina supplementation, there were significant differences in blood lipid levels (Table 2). Particularly, Spirulina supplementation resulted in a significant reduction in T-C levels from 281.6 ± 24.6 to 256.5 ± 21.6 mg dL^{-1} (or −8.9%); $P < 0.0001$, TG levels from 166.3 ± 29.2 to 139.1 ± 23.4 mg dL^{-1} (or −16.3%); $P < 0.0001$, LDL-C levels from 211.8 ± 24.8 to 190.5 ± 20.3 mg dL^{-1} (or −10.1%); $P < 0.0001$, non-HDL-C levels from 244.8 ± 20.8 to 218.3 ± 21.2 mg dL^{-1} (or −10.8%); $P < 0.0001$, and AI from 7.8 ± 1.4 to 6.9 ± 1.2 (or −11.5%); $P = 0.0006$. HDL-C levels were increased by 3.5%, but this change was not significant. No changes were observed in blood pressure, body weight or BMI in our subjects (Table 2). In addition, only the initial prevalence of hypertriglyceridaemia (considered as TG > 150 mg dL^{-1}) in the study population reduced significantly

Table 1. Baseline characteristics of the dyslipidaemic subjects ($n = 52$) enrolled in the intervention study, by gender

Characteristic	Men ($n = 32$)	Women ($n = 20$)	P value
Age (years)	46.6 ± 5.9	46.5 ± 2.8	NS
Smoking			
Yes	24 (75%)	9 (45%)	0.040[a]
No	8 (25%)	11 (55%)	—
Anthropometric values			
Body weight (kg)	86.4 ± 10.2	92.6 ± 10.0	0.036
Body mass index (kg m^{-2})	28.4 ± 2.5	30.3 ± 3.1	0.016
<18.5	0	0	—
18.5–24.9	01	0	—
25.0–29.9	23	12	—
≥30.0	8	8	—
Fasting plasma values			
Glucose (mg dL^{-1})	98.6 ± 6.9	98.1 ± 7	NS
Total cholesterol (mg dL^{-1})	278.9 ± 22.1	285.9 ± 20.3	NS
Triglycerides (mg dL^{-1})	163.6 ± 31.3	170.7 ± 25.6	NS
HDL-C (mg dL^{-1})	37.3 ± 7.9	36.0 ± 6.7	NS
LDL-C (mg dL^{-1})	208.9 ± 27.5	215.7 ± 19.6	NS
Non-HDL-C (mg dL^{-1})	241.7 ± 26.9	249.8 ± 20	NS
Atherogenic index	7.7 ± 1.5	8.0 ± 1.3	NS
Blood pressure			
Systolic (mmHg)	127.5 ± 5.4	123.2 ± 8.4	0.028
Diastolic (mmHg)	76.9 ± 4.8	73.3 ± 7.6	0.041
Cardiovascular risk level			
Very high	0	0	—
High	5 (16%)	3 (15%)	—
Moderate	27 (84%)	12 (60%)	—
Low	0	5 (25%)	—

Values are expressed as mean ± standard deviation (SD).
HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol.
NS, not significant; P, significance value, Student's t-test or [a]Fisher's exact test.
To convert mg dL^{-1} to mmol L^{-1}: for total cholesterol, LDL and HDL multiply by 0.026; for triglycerides by 0.0113; and for glucose by 0.0555.

after Spirulina supplementation (from 71.1% to 34.6%; $P = 0.0004$) (data not shown).

In 32 men there was a significant reduction in T-C, TG, LDL-C, non-HDL-C levels and AI (change −8.9%, −15.8%, −13.8%, −10.8%, −10.4%, respectively; HDL-C levels were increased by 2.9% (NS) (Table 2). In 20 women there was a significant reduction in T-C, TG, LDL-C, non-HDL-C levels and AI (change −8.9%, −17.2%, −9.8%, −10.8%, −11.3%, respectively; HDL-C levels were increased by 4.7% (NS) (Table 2). Adjustment of our results against age/sex revealed that Spirulina supplementation among women aged > 47 years resulted to greater change (%) in T-C (−10.4%; $P < 0.0001$), TG (−21.3%; $P < 0.0004$), HDL-C (5%; $P < 0.0038$), LDL-C (−10.9%; $P < 0.0001$) and non-HDL-C (−12.5%; $P < 0.0001$) levels. Moreover, the change (%) in TG levels among women with TG levels > 150 mg dL^{-1} was 18.6% ($P = 0.0004$) compared with the group of women with TG levels <150 mg dL^{-1} (−10.9%; NS).

The prevalence of high cardiovascular (CV) risk level in the participants was reduced from 15.4% (8/52) to 1.9% (1/52); six shifted to moderate CV risk level and one to low CV risk level, but the prevalence of moderate and low CV risk level increased from 75% (39/52) to 82.7% (43/52); two outpatients shifted to low CV risk level, and 9.6% (5/52) to 15.4% (8/52), respectively, after Spirulina supplementation. Moreover, Spirulina supplementation resulted in a significant reduction in blood glucose levels from 97.8 ± 7.0 to 91.7 ± 4.8 mg dL^{-1}; $P < 0.0001$ (data not shown). No side effects, discomfort or any other complaints were reported by any of the subjects.

DISCUSSION

The results of our study showed a beneficial effect of Spirulina supplementation on the lipid profile of 52 dyslipidaemic Cretan Greek outpatients. Although all the undesirable lipid fractions (T-C, TG, LDL-C, non-HDL-C) were considerably reduced at the end of the 3-month Spirulina supplementation, the major reduction was observed in TG levels (−16.3%). In women this reduction reached 17.2%, but in women aged > 47 years was 21.3% and in women with TG levels > 150 mg dL^{-1} was 18.6%. These findings are very interesting considering the importance of elevated TG levels as a risk factor for CVD, mainly in women.[15] The improvement of the CV risk levels in the study population was clearly due to the favourable change of lipid parameters, taking into account that apart from the T-C levels, the remaining risk factors for its calculation (gender, age, systolic blood pressure, smoking habits) did not change in the 3-month duration of our study. Many other animal (preclinical) and human studies have also reported the lipid-lowering effects of Spirulina.[2,16–24] These effects seem to vary depending on the population (race, sex, age, underlying diseases), the source and dose of consumed product. The target populations of human clinical trials included healthy volunteers, patients with ischaemic heart disease, type 2 diabetes and nephrotic syndrome, and elderly participants with or without hypercholesterolemia.[2,16–24] The first human study was carried out in 1988 and included 30 otherwise healthy male volunteers with mild hyperlipidaemia and mild hypertension.[16] The 30 participants were divided into two groups: one group received 4.2 g of Spirulina daily for 8 weeks, whereas the other group was given 4.2 g of Spirulina daily for 4 weeks followed by a regular diet for another 4 weeks. Intake of Spirulina for 4 or 8 weeks significantly decreased serum T-C and LDL-C levels, and this decrease was more marked in mild hyper- than in normo-cholesterolaemic subjects.[16] Discontinuing the Spirulina supplementation for 4 weeks resulted in a return of the T-C and LDL-C levels to the baseline (prior to Spirulina supplementation) and HDL-C levels were slightly increased although not significant.[15] There were no changes in serum TG and body weight, and subjects did not report adverse effects during the study.[16] In a clinical trial with 36 healthy volunteers (16 male and 20 female) aged between 18 and 65 years, ingestion of Spirulina at a dose of 4.5 g daily for 6 weeks decreased plasma T-C and TG levels by 10% and 28%, respectively.[17] Lipoprotein analysis showed that HDL-C increased by 15%, whereas LDL-C significantly decreased.[17] In addition, both systolic and diastolic blood pressures were considerably reduced in both men and women.[17] Spirulina supplements administration at a dose of 2 or 4 g daily for 3 months in ischaemic heart disease patients with serum T-C above 250 mg dL^{-1}, and noted both a significant reduction in plasma T-C, TG and LDL-C, and a significant increase in HDL-C levels (at the end of the supplementation in both treated groups), whereas no noteworthy change was detected in the control group.[18] Marked reduction in serum levels of T-C, TG, LDL-C and free fatty acid levels was recorded after Spirulina supplementation at a dose of 2 g daily for 2 months in 15 patients with type 2 diabetes.[19] Blood sugar and glycated serum

Table 2. Impact of Spirulina supplementation on the studied variables (all patients)

Variable	Total cholesterol (mg dL^{-1})	Triglycerides (mg dL^{-1})	HDL-C (mg dL^{-1})	LDL-C (mg dL^{-1})	Non-HDL-C (mg dL^{-1})	Atherogenic index	Body weight (kg)
Total ($n = 52$)							
Initial	281.6 ± 24.6	166.3 ± 29.2	36.8 ± 7.4	211.8 ± 24.8	244.8 ± 20.8	7.8 ± 1.4	88.8 ± 10.5
Final	256.5 ± 21.6	139.1 ± 23.4	38.1 ± 7.2	190.5 ± 20.3	218.3 ± 21.2	6.9 ± 1.2	88.4 ± 10.5
Change (%)	−8.9	−16.3	+3.5	−10.1	−10.8	−11.5	−0.5
P value	<0.0001	<0.0001	NS	<0.0001	<0.0001	0.0006	NS
Men ($n = 32$)							
Initial	278.9 ± 22.1	163.6 ± 31.3	37.3 ± 7.9	208.9 ± 27.5	241.7 ± 26.9	7.7 ± 1.5	86.4 ± 10.2
Final	253.9 ± 22.3	137.7 ± 24.2	38.4 ± 7.6	180.1 ± 20.2	215.5 ± 21.8	6.9 ± 1.5	86.1 ± 10.4
Change (%)	−8.9	−15.8	+2.9	−13.8	−10.8	−10.4	−0.3
P value	<0.0001	0.0005	NS	<0.0001	<0.0001	0.037	NS
Women ($n = 20$)							
Initial	285.9 ± 20.3	170.7 ± 25.6	36.0 ± 6.7	215.7 ± 19.6	249.8 ± 20	8.0 ± 1.3	92.6 ± 10
Final	260.5 ± 20.5	141.4 ± 22.3	37.7 ± 6.5	194.6 ± 20.1	222.8 ± 20	7.1 ± 0.9	92.05 ± 9.8
Change (%)	−8.9	−17.2	+4.7	−9.8	−10.8	−11.3	−0.6
P value	0.0003	0.0004	NS	0.0018	0.0001	0.015	NS

Data are expressed as mean ± SD.
HDL-C: high density lipoprotein-cholesterol; LDL-C: low density lipoprotein-cholesterol.
NS, not significant; *P*, significance value, Student's *t*-test.
To convert mg dL^{-1} to mmol L^{-1}: for total cholesterol, LDL and HDL multiply by 0.026; for triglycerides by 0.0113.

protein levels were also significantly decreased.[19] In a randomised controlled study, 25 patients with type 2 diabetes mellitus were randomly assigned to a study or control group.[20] Subjects in the study group received 2 g of Spirulina per day for 2 months. At the end of the study, serum T-C and LDL-C were reduced, whereas HDL-C was slightly increased in the study group. As a result, a marked decrease in atherogenic indices and ratios of T-C/HDL-C and LDL-C/HDL-C were achieved.[20] TG and fasting and postprandial blood glucose levels were significantly reduced.[20] Finally, the level of apolipoprotein B showed a significant decrease with a concurrent significant increase in the level of apolipoprotein A_1.[20] In a randomised controlled study among 37 patients with type 2 diabetes, intake of Spirulina at a dose of 8 g daily for 12 weeks significantly reduced serum T-C, LDL-C and TG levels.[21] Subjects with higher initial T-C, LDL-C and TG levels showed greater reduction.[21] In addition, blood pressures were decreased.[21] Samuels *et al.* also observed a hypolipidaemic benefit (substantial reduction in serum T-C, LDL-C and TG, ratios of LDL-C/HDL-C and T-C/HDL-C) of Spirulina supplementation at a dose of 1 g daily for 2 months in patients with nephrotic syndrome and hyperlipidaemia.[22] In a randomised, double-blinded, and placebo-controlled study in 78 healthy elderly Koreans aged 60–87 years, after consumption of 8 g Spirulina per day for 16 weeks, plasma T-C and LDL-C levels were significantly reduced in female subjects whereas the lowering effect on plasma T-C and LDL-C was not statistically significant in male subjects.[23] The levels of HDL-C and TG did not change after the intervention in either men or women.[23] In another study conducted in a thesis, Spirulina supplementation at a dose of 1.6 g day^{-1} in capsule form for a period of 60 days showed a positive impact on the lipid profile of hyperlipidaemics: the mean TG, T-C, very low density lipoprotein-cholesterol (VLDL-C) levels of experimental hyperlipidaemics reduced significantly (26.16, 8.65 and 25.38%, respectively) at the end of the intervention with Spirulina when compared to initial values; the HDL-C and T-C/HDL-C risk ratio also decreased in the experimental group, but was found to be insignificant.[24] It also improved the blood haemoglobin status of the subjects.[24] Although the majority of these human clinical trials have the disadvantage of a limited sample size and poor experimental design, their results clearly demonstrate the hypolipidaemic effect of Spirulina in humans. However, additional clinical trials with larger sample sizes and higher quality experimental design are warranted to confirm the hypolipidaemic benefits of Spirulina in various target populations.

The active ingredients in Spirulina responsible for its hypolipidaemic activity remain to be identified. In some studies in rats it was found that a constituent of Spirulina (*A. platensis*) inhibited jejunal cholesterol absorption and ileal bile acid reabsorption, and it was proposed that C-phycocyanin was responsible for these effects.[25] In another study in rats, a glycolipid, designated as glycolipid H-b2 isolated from Spirulina was shown to inhibit pancreatic lipase activity in a dose-dependent manner and to reduce postprandial TG levels.[26] In the same study it was found that phycocyanin also inhibits pancreatic lipase.[26] Another hypothesis is that the hypolipidaemic effect of Spirulina can be attributed to its 5–6% content of essential fatty acids of which γ-linolenic acid (GLA) and linolenic acid (LA) account for approximately 30%, which can prevent the accumulation of fat and cholesterol.[24,27] GLA is an omega-6 fatty acid made in the body from the conversion of LA in the presence of the enzyme δ-6-desaturase. While young, healthy individuals can synthesise GLA from LA, a large percentage of the population is unable to produce GLA effectively due to dietary deficiencies, alcohol abuse, smoking, viral infection, medical conditions or ageing.[24,28,29] Considering that a deficiency of GLA in the system results in the thickening of arteries and an increase in blood pressure and cholesterol levels,[28] such as that senescence is associated with decreased activity of enzyme δ-6-desaturase,[28,29] it is obvious that a dietary supplementation with Spirulina ensures a direct availability of GLA in the body resulting in cholesterol reduction, especially in older people.[27–30] This assumption could explain the finding of greater change in lipid parameters (T-C, TG, HDL-C, LDL-C, non-HDL-C) among older people of our

study (>47 years of age) after Spirulina supplementation. Finally, Spirulina contains a small content of niacin (vitamin B_3), the oldest known hypolipidaemic agent in use since 1955,[31] and this might contribute to its hypolipidaemic activity as a supplement.

Our study also revealed a significant hypoglycaemic effect from Spirulina supplementation among the 52 non-diabetic outpatients. This effect is also known from previous clinical trials conducted mainly on diabetic patients.[19,20,32–37] This effect may be due to the down-regulation of nicotinamide adenine dinucleotide phosphate (NADPH) and nicotinamide adenine dinucleotide (NADH), a co-factor in the fat metabolism,[38] and could represent a protective mechanism against the development of atherosclerosis, and help maintain euglycaemia. The current scientific evidence supporting the use of Spirulina for weight loss is weak. In a small double-blind cross-over study versus placebo, Becker *et al.* found that a supplementary diet of 2.8 g of Spirulina three times a day over a period of 4 weeks resulted in a small but statistically significant reduction in body weight in obese outpatients.[39] Also, in the above-mentioned study by Ramamoorthy *et al.*, in patients with ischaemic heart disease, a significant loss in body weight was observed in both groups treated, whereas no change was detected in the control group.[18] On the contrary, our study did not reveal a significant loss in body weight among the 52 participants following Spirulina supplementation. The discrepancy of our results may be due to the small dose of Spirulina administered to our outpatients, as well as the requirement that there is no modification to their dietary habits or lifestyle during the study. It is essential to note that the fat content of Spirulina is only 5–7%, far lower than almost all other protein sources, and moreover, 1 g Spirulina has only 3.6 calories and virtually no cholesterol (0.13 mg).[40] This means that Spirulina is a low-calorie, low-fat, cholesterol-free source of protein, in other words, not loaded with the calories, fat and cholesterol of meat and dairy protein.[40,41] The absence of side effects and discomfort, and the lack of complaints during the study confirm the safety profile of Spirulina, supported by its long history of use as food source and its favourable safety profile in animal studies.[2]

The present study, despite its limitations (small sample size, lack of control group, no blind protocol), revealed a remarkable hypolipidaemic effect of a small dose of a high quality Spirulina (Greek product) in dyslipidaemic outpatients. We used a small dose (1 g day^{-1}) because this dose achieves better patient compliance, mimicking conditions of everyday clinical practice, and ensures potentially fewer undesirable side effects. However, the observed changes (improvements) to the lipid profile in our outpatients were weak compared with the proven more powerful action of statins on lipids, which remain the first-line therapy for lowering cholesterol.[5,6] Considering that agents with the ability to decrease T-C, LDL-C or non-HDL-C levels, increase HDL-C or lower TG, have beneficial effects on preventing CVDs,[5,42] the role of Spirulina as a natural food supplement in combating hyperlipidaemia, in higher dose and/or in combination with other therapeutic options, should not be overlooked.

CONCLUSIONS

The results of this study demonstrate that Spirulina (*A. platensis*) supplementation at a dose of 1 g daily has strong hypolipidaemic effects, especially on the TG concentration, in dyslipidaemic Cretan outpatients. We propose that Spirulina could be used as a dietary supplement for dyslipidaemic patients. Further studies are needed to ascertain the mechanism of Spirulina's action on lipid profiles.

ACKNOWLEDGEMENTS

The authors would like to thank all the subjects who participated in this study.

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