

***SPIRULINA (ARTHROSPIRA) PLATENSIS* - A REVIEW OF POSSIBLE HYPOTRIGLYCERIDEMIC EFFECTS**

CIPRIAN ANTON¹, DELIA IVAN², CRINA LOGHIN³, NICOLETA FLUTUR⁴,
MARIUS-NICUSOR GRIGORE⁵

^{1,2,3,4,5} Faculty of Medicine and Biological Sciences, “Ștefan cel Mare” University of Suceava, Str.
Universității 13, 720229 Suceava, Romania

*Corresponding author. E-mail: ciprian.anton@student.usv.ro, anton.ciprian568@gmail.com

Abstract: *Spirulina (Arthrospira) sp.* is a blue-green algae that is often used as a dietary supplement in powder or tablet form because of its beneficial nutrients, lack of toxicity and therapeutic effects. This study investigates its effects on subjects supplemented with *Spirulina*, focusing on its effects on triglyceride values. A literature review was conducted on the effects of *Spirulina* on different organisms, with a focus on triglycerides. Most research with *Spirulina sp.* has shown that it has a hypotriglyceridemic effect on patients given *Spirulina*, but also on some animals, with numerous studies also done on rats. Following analysis, it has been found that *Spirulina* supplementation has a favorable effect on triglycerides, lowering their value considerably, leading to a reduced risk of cardiovascular disease and stroke. The microalga *Spirulina sp.* has been the subject of research due to evidence of its therapeutic potential in several areas, including its ability to prevent and reduce damage caused by dyslipidemia and its antioxidant activity. The present study suggests that *Spirulina* supplementation may produce beneficial effects on triglycerides.

Keywords: food supplement, hypotriglyceridemic regime, *Spirulina maxima*, *Spirulina platensis*, triglycerides.

Introduction

Spirulina platensis (Gomont) Geitler 1925 (this name is currently regarded as a synonym of *Arthrospira platensis* Gomont.) is taxonomically classified in the kingdom *Eubacteria*, subkingdom *Negibacteria*, phylum *Cyanobacteria*, class *Cyanophyceae*, subclass *Oscillatoriothycidae*, order *Oscillatoriales*, family *Spirulinaceae* (Guiry and Guiry, 2023); however, the taxonomy of *Spirulina platensis* may be subjected to various interpretations, according to different taxonomical systems.

It is a photosynthetic, undifferentiated filamentous, spiral-shaped, multicellular, blue-green species that grows naturally in warm climates. The most commonly used species are *Spirulina platensis* and *Spirulina maxima*.

It has been eaten in the form of a cake called dihé since the 16th century by the Kanembu tribe, an Aztec tribe until today by the people living along the alkaline lakes of Chad and Niger (Léonard, 1966).

It has been extensively studied since 1960, cyanobacteria being a well-known source of proteins, essential amino acids, vitamins, β -carotene, minerals, polysaccharides, essential fatty acids, sulfolipids and phycocyanin (Shabana *et al.*, 2017; Bortolini *et al.*, 2022).

Currently there are several companies producing *Spirulina* as a dietary supplement, which is sold in many health food stores around the world.

Spirulina exhibits antioxidant, detoxifying, anti-inflammatory and antibacterial properties (Anvar and Nowruzi, 2021; Aladaileh *et al.*, 2020; Han *et al.*, 2021).

Studies have shown promising results in the treatment of various allergies, anemia, liver toxicity as well as in maintaining the immune and anti-tumor systems (Cingi *et al.*, 2008; Selmi *et al.*, 2011; Ge *et al.*, 2019; Karadeniz *et al.*, 2009).

In addition, clinical evidence has shown that *Spirulina* has a blood triglyceride-lowering effect for healthy patients, patients with heart disease and in diabetic patients.

Material and methods

A literature search was conducted on the effects of *Spirulina* with a focus on triglycerides.

The review targeted multicellular organisms subjected under different conditions. The search terms (in titles and abstracts) were: (Triglycerides) and (*Spirulina*).

The following data were extracted from the studies: 1)first author's name; 2)publication year; 3)groups of subjects; 4)the amount of *Spirulina sp.* administered 5)the duration of the study 6)serum/plasma/liver concentrations of lipid parameters including triglycerides.

Results and discussions

Thirty-one studies were listed, which were performed out on humans, rabbits, mice, birds and fish.

In the studies with human subjects, they suffered from one of the following conditions: hyperlipidemic nephrotic syndrome, obesity, dyslipidemia, HIV, diabetes 2 and hypercholesterolemia.

The mice were induced hyperlipidemia, different intoxications or were exposed to different conditions such as: physical exercise, gamma irradiation.

The birds suffered from imidacloprid poisoning, were subjected to heat stress or were fed with different diets.

The fish were fed with different diets and to the rabbit's hypercholesterolemia was induced.

Subjects were administered different amounts of *Spirulina*. The triglyceride values were recorded in Table 1.

The impact of *Spirulina* on triglycerides depended according to the amount (Hanafy *et al.*, 2022; Kata *et al.*, 2018; Dogan *et al.*, 2016) and duration of administration, the patient's condition (Hernández-Lepe *et al.*, 2019; Makhoulf and Makhoulf, 2019; Mani *et al.*, 2015) and diet (Yigit *et al.*, 2016; El-Sheekh *et al.*, 2014).

Following *Spirulina* administration studies have recorded a significant decrease in triglycerides.

Table 1. Various studies and their results focusing on triglyceride levels

Groups	The amount of <i>Spirulina</i> sp. administered	Duration of supplementation	Observations on TG*	References
Control group	-	12 weeks	128.2±18.1 mg/dl	Lee <i>et al.</i> , 2008
Intervention group	8.0 g/day		98.5±11.6 mg/dl	
Negative control group (normal saline)	-	4 weeks	116.56±38.84 mg/dl	Kata <i>et al.</i> , 2018
Positive control group (cholesterol)	-		243.92±66.61 mg/dl	
First treatment group	33 mg/kg		122.53±27.861 mg/dl	
Second treatment group	66 mg/kg		95.994±10.337 mg/dl	
Control group	2 pills a day containing one gram of chlorophyll-free starch with a <i>Spirulina</i> -like placebo	12 weeks	140.88±72.73 mg/dl	Zeinalian <i>et al.</i> , 2017
Intervention group	A dose of 500 mg/2 times a day		136.65±60.80 mg/dl	
Men	1 g/day	12 weeks	I: 163.6±31.3 mg dl ⁻¹ F: 137.7±24.2 mg dl ⁻¹	Mazokopakis <i>et al.</i> , 2013
Women			I: 170.7±25.6 mg dl ⁻¹ F: 141.4±22.3 mg dl ⁻¹	
Total			I: 166.3±29.2 mg dl ⁻¹ F: 139.1±23.4 mg dl ⁻¹	
100-Broiler chickens weighing around 180 grams at 8 days of age				Hanafy, 2022
Control	-	42 days	90.15 mg/dl	
<i>Spirulina</i> 1	0.2 g/kg		88.27 mg/dl	
<i>Spirulina</i> 2	0.3 g/kg		86.33 mg/dl	
<i>Spirulina</i> 3	0.5 g/kg		82.45 mg/dl	
<i>Spirulina</i> 4	0.7 g/kg		78.55 mg/dl	
Group SE (exercises + <i>Spirulina</i> supplementation)	4.5 g/day	6 weeks	I:157±47 mg·dl ⁻¹ F:135±37 mg·dl ⁻¹	Hernández-Lepe <i>et al.</i> , 2019

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Groups	The amount of <i>Spirulina</i> sp. administered	Duration of supplementation	Observations on TG*	References
Group Ex (exercises + placebo supplementation)			I:139±44 mg·dl ⁻¹ F:124±42 mg·dl ⁻¹	
Group Sm (no exercises + <i>Spirulina</i> supplementation)			I:141±37 mg·dl ⁻¹ F:127±34 mg·dl ⁻¹	
Group C (no exercises + placebo supplementation)			I:131±31 mg·dl ⁻¹ F:125±32 mg·dl ⁻¹	
Control group	-	6 months	150.4±97.5 mg/dl	Ngo-Matip <i>et al.</i> , 2014
Intervention group	10 g/day		139.8±64.2 mg/dl	
Control group	-	12 months	167.1±124.8 mg/dl	
Intervention group	10 g/day		123.5±44.6 mg/dl	
Control group	-	-	113.37±17.9 mg/dl	Mazzola <i>et al.</i> , 2015
The group of exercising rats (E)	-	-	57.42±8.9 mg/dl	
The group that received Spirulina (SP)	26 mg/kg	10 weeks/3 times a week	99.26±19.6 mg/dl	
The exercise group + <i>Spirulina</i> administration (ES)	26 mg/kg	10 weeks/3 times a week	77.00±18.3 mg/dl	
Group 1	-	4 days	111.0±28.9 mg/dl	Torres-Duran <i>et al.</i> , 1998
Group 2: rats fed a 5% <i>Spirulina</i> diet	1 mg/kg		144.2±16.8 mg/dl	
Group 0: Control group-a basic diet	3 g/100g	60 days	67.00±9.854	Yigit <i>et al.</i> , 2016
Group 1 (43% vegetable oil)	-		80.50±11.481	
Group 2 (10% cholesterol)	-		69.38± 5.322	
Group 3 (43% HVO cholesterol)	-		43.63 ± 5.910	
Group 4			37.25±3.683	

Groups	The amount of <i>Spirulina sp.</i> administered	Duration of supplementation	Observations on TG*		References
Group 5 (43% HVO)	3% from the diet		50.575±6.290		
Group 6 (10% cholesterol)			77.00±9.17		
Group 7 (43% HVO, 10% cholesterol)			38.63±0.581		
Group A: healthy control group	400 mg/kg	6 weeks	151.6± 2.6 mg/dl		Hussaini <i>et al.</i> , 2018
Group B: diabetes + <i>Spirulina</i>			184.4± 3.8 mg/dl		
Control group	-	8 weeks	516.60±37.44 mg/dl		Dogan <i>et al.</i> , 2016
Group 1	0.5% from the diet		505.81±30.15 mg/dl		
Group 2	1% from the diet		427.27±40.22 mg/dl		
Group 3	2.0% from the diet		420.97±13.76 mg/dl		
Control group	-	2 months	155.6±46.6 mg%		Parikh <i>et al.</i> , 2001
The study group	2 g/day		163.9±55.2 mg%		
Control group	-	8 weeks	231.13±86.31 mg/dl		Rostami <i>et al.</i> , 2022
Experimental group	4 g/day		195.33±47.19 mg/dl		
Fed the basic diet and raised under thermoneutral conditions (Control group)	-	From day 21 to 42 of bird age	176 mg/dl		Moustafa <i>et al.</i> , 2021
Exposed to cyclic heat stress	-		184 mg/dl		
3 groups exposed to heat stress	0.5% of diet		176 mg/dl		
	1% of diet		175 mg/dl		
	1.5% of diet	175 mg/dl			
	-	3 weeks	TG in lipid plasma	TG in liver	De Rivera <i>et al.</i> , 1993

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Control- gluc, with a high glucose content (60%).			100.0±19.6 mg/dl	1.27±0.57 mg/dl	
Control- fruc, with a high fructose content (60%).	-		118.8±29.0 mg/dl	6.34±1.60 mg/dl	
Experimental group, high fructose (60%) and <i>Spirulina</i>	5% of diet		137.0±57.6 mg/dl	2.52±1.19 mg/dl	
Control group (basal diet + saline solution)	-	8 weeks	0.88 ± 0.30		Chen <i>et al.</i> , 2019
Model group (high fat diet + saline solution)	-		0.29 ± 0.04		
SPMX group (high fat diet + <i>Spirulina</i> mixed active substance)	150 mg/kg/day SPMX orally 2 ml		0.99 ± 0.37		
Control group	2 g of tablets/day	2 months	2.6 ± 0.23		Mani <i>et al.</i> , 2015
Experimental group (non-transmissible diabetes)			1.67 ± 0.19		
Group 1 (control group)	-	45 days	130.77±3.95 mg/dl		Makhlouf and Makhlouf, 2012
Group 2	300 mg/kg dissolved in water		81.80±4.71 mg/dl		
Irradiated group	2Gy radiation without <i>Spirulina</i>		162.80±2.52 mg/dl		
	4Gy radiation without <i>Spirulina</i>		267.80±5.53 mg/dl		
Irradiated group + <i>Spirulina</i>	300 mg/kg+ radiation 2Gy		145.90±2.10 mg/dl		
	300 mg/kg + radiation 4Gy		188.50±4.52 mg/dl		
Control group	-	7 days	81.10 ± 2.1 mg/dl		

Groups	The amount of <i>Spirulina</i> sp. administered	Duration of supplementation	Observations on TG*	References
Partial hepatectomy group	-		106.28 ± 4.4 mg/dl	Pérez-Juárez <i>et al.</i> , 2022
Group with partial hepatectomy plus intragastric ethanol administration	-		179.90 ± 3.9 mg/dl	
Hepatectomy and <i>Spirulina</i> group	200 mg/kg		105.65 ± 6.2 mg/dl	
Hepatectomy, <i>Spirulina</i> and EtOH administration group	200 mg/kg after 30 minutes from EtOH administration		86.29 ± 2.8 mg/dl	
Control group	0%	3 weeks	98.6±2.3	El-Sheekh <i>et al.</i> , 2014
	2.5%			
	10%			
Group fed a high oil diet	0%		207.7±6.7	
	2.5%		175 ±18.03	
	5%		140±2.8	
	10%		127±4.04	
Group fed with rich butter	0%		212±6.01	
	2.5%		143.3±3.5	
	5%		133.3±3.4	
	10%		107.3±4.2	
Egyptian patient volunteers with a history of hyperlipidemia	4 g/day		Day 0: 155.2±20.7	
		Day 21: 106.1±16.4		
Control group	-	2 months	107.75±64.27 mg/dl	Samuels <i>et al.</i> , 2002
Experimental group	1 g/day		160.26±121.99 mg/dl	
Control group	-	7 days	151±1.4	Sudha <i>et al.</i> , 2011
Group 2 (triton administered at a dose of 100 mg/kg)	-		194.2±2.21	
Group 3 (<i>Spirulina</i> treatment)	0.5 g/day		159.3±1.31	

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Groups	The amount of <i>Spirulina</i> sp. administered	Duration of supplementation	Observations on TG*	References
Group 4 (administered with standard Fenofibrate)	-		154.3±2.12	
Group A (<i>Spirulina</i> treatment)	2 g/day	3 months	171.9±35.94 mg/dl	Ramamoorthy and Premakumari, 1996
Group B (<i>Spirulina</i> treatment)	4 g/day		171.8±33.56 mg/dl	
Group C (control group)	0 g		213.2±33.20 mg/dl	
Control group	-	35 days	78.0 ± 2.31 mg/dl	Alwaleed <i>et al.</i> , 2020
Group 2-3 (basic diet + <i>Spirulina</i>)	Sp-5 g/kg		79.0 ± 4.58 mg/dl	
	Sp-10 g/kg		74.0±2.65 mg/dl	
Group 4-5 (staple diet + <i>Amphora coffeaeformis</i> (Am))	Am-5 g/kg		73.0 ± 3.21 mg/dl	
	Am-10 g/kg		64.0±2.65 mg/dl	
T1	-		16 weeks	
T2	0.05%	341.99±3.39 g/dl		
T3	0.1%	307.81±3.75 g/dl		
T4	-	366.95±10.35 g/dl		
T5	1 ml cytosan + 0.05% SP	377.32±6.33 g/dl		
T6	1 ml cytosan + 0.1% SP	378.21±6.32 g/dl		
Control group	-	60 days	61.66±1.15 mg/100 ml	Bashandy <i>et al.</i> , 2011
Group 2 (<i>Spirulina</i> group)	300 mg/kg dissolved in water		62.83±3.91 mg/100 ml	
Group 3 (HgCl ₂)	-		179.82±10.41 mg/100 ml	
Group 4 (<i>Spirulina</i> +HgCl ₂)	300 mg/kg by gavage		116.56±8.16 mg/100 ml	
Control group	-	60 days	80.96±1.22 mg/dl	Gupta <i>et al.</i> , 2014
Group 2	0.2%		68.35±1.71 mg/dl	
Group 3	-		90.22±2.25 mg/dl	

Groups	The amount of <i>Spirulina sp.</i> administered	Duration of supplementation	Observations on TG*	References
Group 4	0.2%. and imidacloprid 50 ppm		80.80±2.46 mg/dl	
Group 5	-		75.98±2.28 mg/dl	
Group 6	-		84.07±2.98 mg/dl	
Control group	-	30 days	64.42±4.55 mg/dl	Kandula <i>et al.</i> , 2017
Group 2 (toxic control)	-		88.10±1.99 mg/dl	
Group 3 (ASP)	100 mg/kg body weight/day + NaF (100 ppm)		81.00±1.63 mg/dl	
Group 4 (ASP)	200 mg/kg body weight/day + NaF (100 ppm)		69.05±2.35 mg/dl	
Group 5 (ASP)	400 mg/kg body weight/day + NaF (100 ppm)		65.38±2.354 mg/dl	
Group 6 (received ASP hydroalcoholic extract)	400 mg/kg		52.56±1.28 mg/dl	
Control group	-	10 weeks	262.61±48.86 mg/dl	Yeganeh <i>et al.</i> , 2015
Group 2 (SP)	2.5%		246.56±60.76 mg/dl	
Group 3 (SP)	5%		251.14±41.27 mg/dl	
Group 4 (SP)	7.5%		228.39±21.66 mg/dl	
Group 5 (SP)	10%		216.22±28.57 mg/dl	

* triglycerides

Conclusions

Overall *Spirulina* has shown beneficial effects on organisms under different stress conditions by reducing triglyceride levels.

In this way, *Spirulina* becomes a possible treatment but also a preventive method for diseases causing hypertriglyceridemic symptoms such as diabetes, hypothyroidism, insulin resistance, metabolic syndrome, nephrotic syndrome, obesity, etc.

Further studies are needed to confirm the clinical value of *Spirulina* for the treatment of hypertriglyceridemic disorders.

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