



Spirulina – benefits, antioxidant capacity and polyphenols

¹Oana A. Pece, ²Anca Becze, ¹Lucia Simion, ³Adina Sabou, ⁴Aurelia Coroian

¹ Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; ² Research Institute for Analytical Instrumentation, Cluj-Napoca, Romania; ³ Faculty of Forestry and Cadastre, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania; ⁴ Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania. Corresponding author: A. Coroian, aurelia.coroian@usamvcluj.ro

Abstract. The micro-algae spirulina (*Arthrospira platensis*), which has a high concentration of nutrients and biocompounds, has been used to improve people's nutrition and health. Spirulina has a rich chemical composition and it is known for the proteins, polyphenols and iron it contains. Benefits of this algae are significant. We mention here immune system improvement, anticarcinogenic effects and cardiovascular health. In this study we measure the antioxidant capacity and total polyphenols of spirulina for a better understanding of this algae.

Key Words: antioxidant, biocompounds, health, nutrients, polyphenols, proteins.

Introduction. Spirulina (*Arthrospira platensis*) has become known as a superfood due to the high diversity and concentration of nutrients it contains. It is the most nutritious and concentrated food source found in nature. Spirulina is a unicellular microalga that grows in fresh water, salt water and brackish bodies of the water. It grows best in a highly alkaline environment with a pH of 10-12. Spirulina proteins are complete and contain all the essential amino acids. Using the quantitative Kjeldahl method, Babadzhanov et al (2004) found a protein content of 68% in spirulina biomass samples grown during spring and summer. Typical for cyanobacteria, which are generally low in lipids, spirulina contains only 6-13% lipids, half of which are fatty acids. Total lipids decreased with decreasing nitrogen content in a spirulina culture. The antioxidant and anti-inflammatory activity of spirulina is higher by 3 g than in five servings of fruits and vegetables (Piorreck et al 1984; Babadzhanov et al 2004; Capelly & Cysewski 2010; Andrianto et al 2024).

Spirulina is a filamentous cyanobacterium. It has attained considerable popularity in the healthcare sector and also in the food and aquaculture industry. It has been used for the last three decades as a popular food supplement and as a source of bioactive compounds for the food industry, agricultural industry, pharmaceutical industry and cosmetic industry. Recent studies associate the consumption of spirulina supplements with immunomodulatory, proinflammatory, antioxidant and anticancer activities in both animals and humans (Soni et al 2017; Joao et al 2019).

The chemical composition of spirulina. Spirulina is a photosynthetic cyanobacteria, which has biological activity and is cultivated to produce biologically active food additives and treat more diseases. The microalgae cell wall lacks cellulose but includes mycosaccharides. Therefore, spirulina is 85-95% assimilated by an organism (Babadzhanov et al 2004). Spirulina contains much more protein than many other food products; the average protein value in spirulina is 65%, compared to meat and fish which is 15-20%, in soy 35%, in evaporated milk 35%, in peanuts 25%, in eggs 12% and in grains 8-14%. Another thing to note is the fact that the spirulina proteins are complete and contain all the essential aminoacids we need. Due to its high protein content,

spirulina is an essential source of essential and nonessential aminoacids for the vegans and vegetarians (Babadzhanov et al 2004; AlFadhly et al 2022).

Cyanobacteria are generally low in lipids, spirulina containing only 6-13% lipids of which half are fatty acids. If we compare spirulina with eukaryotic algae, we can see that in eukaryotic algae, triglycerides do not accumulate (Piorreck et al 1984).

The blue-green colour is given by the important presence of the pigments (Chirstaki et al 2011). Spirulina has in its chemical structure vitamins B1, B2, B3, B9 and fat soluble vitamins such as vitamin A, vitamin E. The most quantitatively significant mineral in spirulina is iron (Fe). Thus, regular consumption of spirulina can improve the condition of those suffering from Fe deficiency. This cyanobacterium contains a large proportion of essential minerals such as Ca, K, Mg, Na, P, Cu, Fe, Mn, Zn, Cr, Se (Wild et al 2018; Spínola et al 2024).

Secondary metabolites are compounds present in the composition of spirulina. Phenolic acids, polyphenols, sterols may cause biological effects of particular importance. They show anticarcinogenic, anti-inflammatory, antimicrobial, antioxidant, antidiabetic activity (Guldás et al 2021; Spínola et al 2024).

Benefits of spirulina. *Spirulina is rich in nutrients and has numerous health benefits reported by consumers.* In 1974, the United Nations named spirulina as one of the best foods for the future. In addition, spirulina provides common nutrients at high levels (Bolanho et al 2014).

Immune system enhancement. Phycocyanin is a powerful antioxidant and has significant immune-enhancing and antiviral properties. For decades, users have reported a decrease in colds and flu following spirulina consumption. Spirulina supplements stimulate the activity of natural killer cells, influencing innate immunity. Spirulina influences innate immunity more than acquired immunity (Henrikson 1989; Finamore et al 2017; Seghiri et al 2019; Rose et al 2023).

High energy level. Constituents such as polysaccharides, rhamnose and glycogen, and essential fat are readily absorbed by human cells and help release energy. Spirulina increases *Lactobacillus* in the gut, allowing the production of vitamin B6, which aids in energy release (Nagaoka et al 2005; Singh et al 2025).

Anticarcinogenic effects. The blue-green pigment phycocyanin has important anti-cancer effects, like: activation of apoptotic enzymes, antiproliferative effects against cancer cells, inhibition of breast cancer cell growth (Anvar & Nowruzi 2021).

Effects against cardiovascular diseases. According to Prete et al (2024) spirulina lowers blood pressure in patients who have consumed spirulina, it exhibits antihypertensive effects. Cyanobacteria can significantly influence lipid profile, with a major impact in the occurrence of cardiovascular diseases.

The objectives of this study were to determine the antioxidant capacity of spirulina through methanol extraction and the determination of total polyphenols in spirulina.

Material and Method

The determination of the antioxidant capacity of Spirulina

Principle of the method. The principle of the method used in the determination of the antioxidant capacity of spirulina involves sample extraction using methanol and subsequent analysis using the Photochem system which allows luminometric detection of free radicals obtained by photochemical excitation. Both pH and temperature will not cause interferences.

Reagents used. We used three reagents: ACW kit (dilution solution for water soluble samples, buffer solution, photosensitizer solution, antioxidant standard solution), ethanol, ultrapure water.

Materials used. We used the following materials: plastic test tubes; 50 mL centrifuge tubes with lid; Photochem Analytik Jena series 3600344 /N.I 20302; single-channel automatic pipettes (500-5000 μL , 100-1000 μL , 10-100 μL); centrifuge D-78532 HETTICH - Germany (Series 0000252-01-00/NI 20258); electronic analytical balance (IU No 88, 32202102/ N.I 20298).

Extraction. We weighed 1 g of sample and used 20 mL of extraction solvent, methanol. Then we centrifuged the sample for 5 minutes at 10 000 rpm. The supernatant was used for analysis.

Expression of results. We followed the manufacturer's instructions to measure the results. The results were expressed in ascorbic acid equivalents, and for solid samples the following calculation method was applied:

$$\text{Concentration} \left[\frac{\mu\text{g}}{\text{mg}} \right] = \frac{Q \times D \times M \times V}{PV \times Mp}$$

where: Q = nmol (ascorbic acid or trolox) read on the apparatus;

D = dilution factor;

M = molecular mass (ascorbic acid = 176.13 ng/nmol and for trolox = 250.3 ng/nmol);

V = extraction volume in mL;

PV = pipetted volume in the test tube;

Mp = sample mass in g.

The determination of total polyphenols in spirulina

Principle of the method. Due to the phenols and the basic medium used, the mixture of phosphotungstic and phosphomolibdic acids will be reduced to blue oxides of tungsten and molybdenum. These oxides have an absorption maximum of 765 nm. Acid pH may cause interferences

Preparation of working solutions. We first prepared the five reagents we needed: ethanol, ultrapure water, sodium carbonate, Folin-Ciocalteu solution, gallic acid. The gallic acid was used to make the calibration curve.

Materials used. We used the following materials: plastic test tubes with 20 mL and 50 mL lids; pipettes with capacities of 500-5000 μL , 100-1000 μL , single channel automatic; 250 mL and 50 mL volumetric flasks; Lambda 25 ultraviolet-visible molecular absorption spectrophotometer, Perking Elmer 101N8031701/N.I 20246; centrifuge D-78532 HETTICH - Germany (Series 0000252-01-00/NI 20258); electronic analytical balance (IU No 88, 32202102/ N.I 20298); quartz cuvettes 1 cm thick.

Extraction. In a 50 mL plastic centrifuge flask 1 g of spirulina sample was weighed. As extraction solvent we used methane, 20 mL. Homogenize by shaking the sample. Centrifuge the mixture for 5 minutes at 10 000 rpm. After separation of the phases we took the supernatant for analysis as it contains the phenolic compounds of interest.

Measurement. We pipetted 5 mL distilled water, 1.5 mL 10% sodium carbonate solution, 0.5 mL sample, 0.5 mL Folin Ciocalteu solution into a 15 mL vial. After leaving the formed mixture at room temperature for 45 minutes we measured at a wavelength of 765 nm against a blank solution. Comparison of the measurements was made using a

gallic acid calibration curve (25, 50, 100, 250 ppm) and the results were quantified in gallic acid equivalents.

Results and Discussion. Antioxidant-based studies and its implications in different fields such as food engineering, medicine and pharmacy are of growing interest to the scientific community. The role that antioxidants play is to neutralize free radicals in biological cells, especially those that have a negative impact on living organisms (Munteanu & Apetrei 2021).

Antioxidant capacity of spirulina. The results are depicted in Table 1.

Table 1

Mean value and variability for the antioxidant capacity of spirulina

Type of product	Ascorbic acid equivalent result ($\mu\text{g mg}^{-1}$)	
	$X \pm s_x$	V%
Spirulina	4.6874 \pm 0.08	3.63

The obtained value of 4.6874 \pm 0.08 $\mu\text{g mg}^{-1}$ is a moderate value. In the study carried out by Kumar et al (2022) it was revealed that values of 0.128 \pm 0.005 mg g^{-1} ascorbic acid were present in aqueous extract of spirulina, whereas in ethanolic extract values of 0.111 \pm 0.003 mg g^{-1} ascorbic acid were present. Using Trolox equivalent, Bolanho et al (2014) showed a value of 40.3 mmol kg^{-1} , TE. Spirulina shows an antioxidant capacity of 5.42-9.12 $\mu\text{mol Trolox g}^{-1}$ (Catana et al 2023).

Analyzing four different brands producing spirulina powder, the following results were obtained, depending on the type of extract: 51.70 \pm 0.52, 48.24 \pm 0.52, 36.82 \pm 0.46 and 13.52 \pm 0.61 $\mu\text{mol TE/mL}$ (aqueous extract), 2.50 \pm 0.26, 2.33 \pm 0.26, 1.06 \pm 0.26 and 1.00 \pm 0.17 $\mu\text{mol TE/mL}$ (ethanolic extract). Significantly higher values were observed in aqueous extract (Gonzales-Condori et al 2024).

Polyphenols content of spirulina. The results are depicted in Table 2.

Table 2

Polyphenols content of spirulina

Type of product (mg kg^{-1})	Polyphenols (mg/kg equiv. GAE)	
	$X \pm s_x$	V%
Spirulina	1.08 \pm 0.02	4.29

The spirulina analyzed in this study had slightly low polyphenol values of 1.08 \pm 0.02 mg/kg GAE equivalent. Using methanolic extract and Folin-Ciocalteu method, values of 4.19 \pm 0.21 mg GAE/g dw were recorded for Moroccan spirulina (Seghiri et al 2019).

The total amount of polyphenols was 2.4957 \pm 0.0597 GAE mg/g dw in a study of Andrianto et al (2024). The amount of polyphenols in the study by Kumar et al (2022) was 9.919 mg g^{-1} in aqueous extract and in ethanolic extract it was 3.476 mg g^{-1} . The total level of phenolic compounds was 12.2 g kg^{-1} , in the research of Bolanho et al (2014). The powders with spirulina had values of 154.50-256.26 mg GAE/100g (Catana et al 2023). Kuatrakul et al (2017) obtained a value of 99.76 $\text{mg GAE/100 g dry matter}$ by dehydration of spirulina. The value of 408 mg GAE/100 g was indicated in the research of Rodríguez et al (2014). The amount of polyphenols can vary depending on the drying temperature, according to Larrosa et al (2017). Thus, at a drying temperature of 60°C, 484.2 mg GAE/100 g were recorded, and at 55°C, 607.6 mg GAE/100 g . Rose et al (2023) stated that both the mode and temperature, as well as the grinding method, and the degree of maturity and development of spirulina contribute significantly to the amount of polyphenols present in the sample.

Conclusions. Spirulina is an important superfood with a higher content of proteins and vitamins. As well, it contains a significant quantity of iron. Its antioxidant capacity and the polyphenols present in this cyanobacteria contribute to cardiovascular health, energy improvement and immune system enhancement. A regular consumption of spirulina is indicated.

Conflict of interest. The author declares that there is no conflict of interest.

References

- AlFadhly N. K. Z., Alhelfi N., Altemimi A. B., Verma D. K., Cacciola F., Narayanankutty A., 2022 Trends and technological advancements in the possible food applications of spirulina and their health benefits: a review. *Molecules* 27(17):5584.
- Andrianto D., Safithri M., Tarman K., 2024 Total phenolic content and proliferation activity of spirulina extract in lymphocyte cell. *BIO Web of Conferences* 92:02009.
- Anvar A. A., Nowruzi B., 2021 Bioactive properties of spirulina: a review. *Microbial Bioactives* 4(1):134-142.
- Babadzhanov A. S., Abdusamatova N., Yusupova F. M., Faizullaeva N., Mezhlumyan L. G., Malikova M. K., 2004 Chemical composition of *Spirulina platensis* cultivated in Uzbekistan. *Chemistry of Natural Compounds* 40(30):276-279.
- Bolanho B. C., Egea M. B., Jacome A. L. M., Campos I., de Carvalho J. C. M., Danesi E. D. G., 2014 Antioxidant and nutritional potential of cookies enriched with *Spirulina platensis* and sources of fibre. *Journal of Food and Nutrition Research* 53(2):171-179.
- Capelly B., Cysewski G. R., 2010 Potential health benefits of spirulina microalgae: a review of the existing literature. *Nutra Foods* 9(2):19-26.
- Catana L., Catana M., Constantinescu F., Burnete A. G., Asanica A. C., 2023 Research on the nutritional value, bioactive compounds content and antioxidant capacity of spirulina. *Scientific Papers. Series B, Horticulture LXVII* (1):735-744.
- Finamore A., Palmery M., Bensehaila S., Peluso I., 2017 Antioxidant, immunomodulating, and microbial-modulating activities of the sustainable and ecofriendly *Spirulina*. *Oxidative Medicine and Cellular Longevity* 2017(1):3247528.
- Gonzales-Condori E. G., Jara-Quille V. R., Gonzales-Condori J., Alvarez-Gonzales R., 2024 Comparative study between different extracts and brands of spirulina regarding antioxidant activity. 22nd LACCEI International Multi-Conference for Engineering, Education, and Technology: Sustainable Engineering for a Diverse, Equitable, and Inclusive Future at the Service of Education, Research, and Industry for a Society 5.0. Hybrid Event, San Jose – COSTA RICA, July 17-19, pp. 1-6.
- Guldaz M., Ziyank-Demirtas S., Sahan Y., Yildiz E., Gurbuz O., 2021 Antioxidant and anti-diabetic properties of *Spirulina platensis* produced in Turkey. *Food Science and Technology* 41(3):615-625.
- Henrikson R., 1989 Earth food spirulina. Ronore Enterprises Inc., Hana, Maui, Hawaii, 201 pp.
- Joao R., Rafaela F., Susete P., Joana S., Celso A., Rui P., Susana B., 2019 Spirulina. In: Nonvitamin and nonmineral nutritional supplements. Nabavi S. M., Silva A. S. (eds), Academic Press, pp. 409-413.
- Kuatrakul I., Kuarthongsri P., Yabuuchi C., Somsai K., Utama-ang N., 2017 Sensory Descriptive analysis and physicochemical properties of *Spirulina platensis* from different drying processes: hot air drying and microwave vacuum drying. *Current Applied Science and Technology* 17(2):191-199.
- Kumar A., Ramamoorthy D., Verma D. K., Kumar A., Kumar N., Kanak K. R., Marwein B. M., Mohan K., 2022 Antioxidant and phytonutrient activities of *Spirulina platensis*. *Energy Nexus* 6:100070.
- Larrosa A. P. Q., Comitre A. A., Vaz L. B., Pinto L. A. A., 2017 Influence of air temperature on physical characteristics and bioactive compounds in vacuum drying of *Arthrospira spirulina*. *Journal of Food Process Engineering* 40(2):e12359.

- Munteanu I. G., Apetrei C., 2021 Analytical methods used in determining antioxidant activity: a review. *International Journal of Molecular Sciences* 22(7):3380.
- Nagaoka S., Shimizu K., Kaneko H., Shibayama F., Morikawa K., Kanamaru Y., Otsuka A., Hirahashi T., Kato T., 2005 A novel protein C-phycocyanin plays a crucial role in the hypocholesterolemic action of *Spirulina platensis* concentrate in rats. *The Journal of Nutrition* 135(10):2425-2430.
- Piorreck M., Baasch K. H., Pohl P., 1984 Biomass production, total protein, chlorophylls, lipids and fatty acids of freshwater green and blue-green algae under different nitrogen regimes. *Phytochemistry* 23(2):207-216.
- Prete V., Abate A. C., Di Pietro P., De Lucia M., Vecchione C., Carrizzo A., 2024 Beneficial effects of *Spirulina* supplementation in the management of cardiovascular diseases. *Nutrients* 16(5):642.
- Rodríguez De Marco E., Steffolani M. E., Martínez C. S., León A. E., 2014 Effects of spirulina biomass on the technological and nutritional quality of bread wheat pasta. *LWT - Food Science and Technology* 58(1):102-108.
- Rose H., Bakshi S., Kanetkar P., Lukose S. J., Felix J., Yadav S. P., Gupta P. K., Paswan V. K., 2023 Development and characterization of cultured buttermilk fortified with *Spirulina plantensis* and its physico-chemical and functional characteristics. *Dairy* 4(2):271-284.
- Seghiri R., Kharbach M., Essamri A., 2019 Functional composition, nutritional properties, and biological activities of Moroccan *Spirulina* microalga. *Journal of Food Quality* 2019:3707219.
- Singh K., Kumar R., Kumari R., Subudhi R. N., Dalabehera M., Chaudhari S., Kumar R., Mishra P., 2025 *Spirulina*: a superfood with multifaceted health benefits and commercial applications. *International Journal of Pharmaceutical and Healthcare Innovation* 2(2):533-546.
- Soni R. A., Sudhakar K., Rana R. S., 2017 *Spirulina* - from growth to nutritional product: a review. *Trends in Food Science and Technology* 69:157-171.
- Spínola M. P., Mendes A. R., Prates J. A. M., 2024 Chemical composition, bioactivities, and applications of *Spirulina (Limnospira platensis)* in food, feed, and medicine. *Foods* 13(22):3656.
- Wild K. J., Steingäß H., Rodehutschord M., 2018 Variability in nutrient composition and *in vitro* crude protein digestibility of 16 microalgae products. *Journal of Animal Physiology and Animal Nutrition* 102(5):1306-1319.

Received: 20 September 2025. Accepted: 31 October 2025. Published online: 20 December 2025.

Authors:

Oana Andreea Pece, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine, Calea Mănăştur 3-5, 400372 Cluj-Napoca, Romania, e-mail: oanamastan@yahoo.com

Anca Becze, Research Institute for Analytical Instrumentation, ICIA Cluj-Napoca Subsidiary, 400293 Cluj-Napoca, Romania, e-mail: anca.naghiu@icia.ro

Lucia Simion, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine, Calea Mănăştur 3-5, 400372 Cluj-Napoca, Romania, e-mail: simion_lucia@yahoo.com

Adina Sabou, Faculty of Forestry and Cadastre, University of Agricultural Sciences and Veterinary Medicine, Calea Mănăştur 3-5, 400372 Cluj-Napoca, Romania, e-mail: lia-adina.longodor@usamvcluj.ro

Aurelia Coroian, Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine, Calea Mănăştur 3-5, 400372 Cluj-Napoca, Romania, e-mail: aurelia.coroian@usamvcluj.ro

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Pece O. A., Becze A., Simion L., Sabou A., Coroian A., 2025 *Spirulina* - benefits, antioxidant capacity and polyphenols. *AAB Bioflux* 17(1):55-60.