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File: ■ Spirulina (*Arthrospira platensis*)
■ Oxidative Stress
■ Free Radicals

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RE: Spirulina Supplementation Significantly Increases Exercise Performance, Fat Oxidation, and Glutathione Concentration

Kalafati M, Jamurtas AZ, Nikolaidis MG, et al. Ergogenic and antioxidant effects of spirulina supplementation in humans. *Med Sci Sports Exerc.* 2010;42(1):142-151.

Spirulina (*Arthrospira platensis*), a photosynthetic cyanobacterium with biological activity, is widely used in nutritional supplements claiming antioxidant and performance-enhancing effects. Spirulina is rich in essential amino acids and fatty acids (palmitic acid, linoleic acid, γ-linolenic acid), vitamin C, vitamin E, and selenium. Furthermore, many of its chemical components, such as phenolic compounds, tocopherols, β-carotenes, and phycocyanins exhibit antioxidant properties. Recently, attention has been placed on the use of spirulina's antioxidant potential to counteract exercise-promoted reactive oxygen and nitrogen species (RONS) that seem to contribute to muscle fatigue.

The aim of this double blind, placebo-controlled, counter-balanced, crossover study was to examine the effect of spirulina supplementation on exercise performance, substrate metabolism, and blood redox status, both at rest and after exercise. Nine healthy, moderately trained male recreational runners [age = 23.3 ± 1.7 yrs; height = 174.3 ± 1.7 cm; weight = 70.7 ± 1.9 kg; body fat = 9.8 ± 1.3%; maximal oxygen consumption (VO_{2max}) = 52.2 ± 1.8 mL x kg x min] took part in this study. To establish that all subjects ran at similar exercise intensity, VO_{2max} was determined using a treadmill test to exhaustion.

Each subject consumed 2 capsules (1 g each) containing either spirulina (Algae AC; Serres, Greece) or placebo (egg protein) 3 times daily for 4 weeks. The basic composition of 100 g of dry spirulina is reported as: 63.3% protein, 7.1% lipid, and 15.2% carbohydrate, 101 mg of vitamin C, 15 mg of vitamin E, 0.13 mg of selenium, 43.6% palmitic acid, 17.2% linoleic acid, and 21.7% γ-linolenic acid of total fatty acids. Subjects ran on a treadmill at an intensity corresponding to 70%-75% of their VO_{2max} for 2 hours, and then at 95% VO_{2max} to exhaustion. Exercise performance and respiratory quotient during exercise were measured after placebo and spirulina supplementation. Blood samples were drawn before, immediately after, and at 1, 24, and 48 hours after exercise. Reduced glutathione (GSH), oxidized glutathione (GSSG), GSH/GSSG,

thiobarbituric acid-reactive substances (TBARS), protein carbonyls, catalase activity, and total antioxidant capacity (TAC) were determined. The second exercise trial was performed 1 day after the end of the supplementation period. A 2-week washout period occurred between the second and the third exercise trials to avoid possible carryover effects. After the washout period, the subjects ran through a third and fourth exercise trial. Fat and carbohydrate oxidation rates were calculated indirectly by monitoring the rate of O_2 consumption and CO_2 production. The distribution of all dependent variables was examined by the Shapiro-Wilk test and was found not significantly different from normal. Data from the first and the third trials were analyzed through two-way (trial x time) ANOVA (ANalysis Of VAriance) with repeated measures on time. Data from the second and the fourth trials were analyzed through two-way (group x time) ANOVA with repeated measures on time. Carbohydrate and lipid oxidation rates during the 2-h run and aerobic performance at the second and fourth exercise trials were examined by paired t-test. Statistical significance was considered $P<0.05$. No adverse effects were reported after spirulina supplementation.

The average exercise intensity during the 2-h sub-maximal run for the placebo and spirulina trials was 70.6 ± 2.4% and 71.0 ± 1.9% of VO_{2max}, respectively ($P>0.05$). Time to fatigue after the 2-h run was significantly higher after spirulina supplementation (2.05 ± 0.68 compared to 2.70 ± 0.79 min for the placebo and spirulina groups, respectively; $P=0.048$). Supplementation of spirulina significantly decreased the carbohydrate oxidation rate by 10.3% ($P=0.008$) and increased the fat oxidation rate ($P=0.003$) by 10.9% during the 2-h run compared with the placebo trial. There was a significant main effect of time ($P<0.001$), with creatine kinase activity increasing 24 and 48-h after exercise in both groups. A significant main effect of group ($P=0.049$) was noted with GSH level being higher after the spirulina supplementation at rest and 24-h after exercise. There was a significant group x time interaction ($P=0.007$), with TBARS levels increasing after exercise after placebo, but not after spirulina supplementation, possibly due to the higher levels of GSH in the spirulina-supplemented individuals. There was a significant main effect of time ($P<0.001$), with protein carbonyls levels, catalase activity, and TAC increasing immediately after and 1-h after exercise in both groups.

The results showed that spirulina supplementation for 4 weeks induced a significant increase in exercise performance, fat oxidation, and glutathione concentration, as well as attenuated exercise-induced increases in lipid peroxidation, indicating that increased levels of fat oxidation and GSH may contribute to enhanced exercise performance. The authors conclude that more research is needed to elucidate the mechanisms behind the apparent ergogenic effect of spirulina, particularly on mitochondrial function and β-oxidation in conjunction with inflammation and oxidative stress. The authors neglect to mention that a main mechanism of action may be the blue polypeptide, phycocyanin.

—Silvia Giovanelli Ris

The American Botanical Council has chosen not to reprint the original article.