Letter to the Editor: On the increased haemoglobin concentration and improved oxygen uptake after Spirulina supplementation

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LETTER TO THE EDITOR

Letter to the Editor: On the increased haemoglobin concentration and improved oxygen uptake after Spirulina supplementation

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Dear Editor,

A comment to the study: Gurney T and Spendiff O. Spirulina supplementation improves oxygen uptake in arm cycling exercise. *Eur J Appl Physiol* 2020; 120: 2657-2664. 2020/09/07. https://doi.org/10.1007/s00421-020-04487-2.

We enjoyed reading the interesting and well-written study by Gurney and Spendiff demonstrating an enhancement in oxygen (O_2) uptake during arm cycling following 7 days of Spirulina Platensis (SP) supplementation. In this letter, we would like to suggest a complimentary mechanism which may shed light on the increased haemoglobin concentration (Hb) and improved O_2 consumption reported in the study. Notably, the increase in Hb following supplementation could result from splenic contraction—a physiological mechanism which has not been mentioned by the authors.

During exercise, many mammals can mobilize large numbers of erythrocytes from the spleen to improve oxygenation of metabolically active tissue (Stewart and McKenzie 2002). Such "autotransfusion" of erythrocytes improves O_2 carrying capacity and increases both the aerobic performance in highly aerobic terrestrial mammals like the horse and the dog and the apneic diving capacity of, e.g., seals (Stewart and McKenzie 2002). In healthy adult humans, the spleen contains in average 200–250 ml of blood, with a Hb twice that of arterial blood (Stewart and McKenzie 2002) and it shares with most investigated animals the ability to contract and elevate Hb (Stewart and McKenzie 2002).

The extent of splenic contraction after breath holding or exercise in humans has been reported to be 18–56%, resulting in a concomitant increase in Hb by 3–6% (Stewart and McKenzie 2002). Hypoxia is a key stimulus initiating spleen contraction, but in a recent study, we reported that spleen contraction also results upon dietary nitrate ($NO3^-$) supplementation (Engan et al. 2020). We suggest that supplementation with SP may, related to its NO_3^- content, similarly stimulate spleen contraction and elevate Hb, resulting in an ergogenic effect.

Gurney and Spendiff discuss that the increased Hb could be explained by increased Hb synthesis following iron-rich SP supplementation, and that the improved O_2 consumption could partly be explained by increased bioavailibility of nitric oxide (NO) and increased expression of eNOS resulting from arginine and phycocyanin in SP. We suggest that not only the ergogenic effects but also the haematological effects observed in the study could be explained by increased bioavailability of NO, and that NO could be derived from other sources than those mentioned by Gurney and Spendiff.

In the growth of the cyanobacterium SP, several supporting factors are required, one of which is NO_3^-. Nitrate is an important factor in the formation of proteins and amino acids in cells, and helps in increasing biomass in SP. In fact, it has been shown that NO_3^- salts (sodium and potassium nitrates) and ammonium salts are the main nitrogen sources assimilated by SP (Esen and Ozturk Urek 2015). Acknowledging the fact that the concentration of intracellular pools of NO_3^- in cyanobacteria are influenced by ecological factors and assimilation of nitrogen (Esen and Ozturk Urek 2015), SP represents an available source of dietary NO_3^- for humans.

Ingestion of dietary NO_3^- is associated with improved exercise tolerance and reduced oxygen cost of exercise by increasing NO bioavailability through the nitrate–nitrite–nitric oxide pathway (Jones 2014). The

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recent finding that dietary NO_3^- reduced spleen volume at rest resulting in a 3% increase in Hb suggests that substances that improve NO bioavailability have the potential to improve performance both by increasing O_2 carrying capacity through spleen-induced haemoglobin elevation and through metabolic effects on mitochondrial respiration and muscle contractile function (Engan et al., 2020; Jones 2014).

We agree with the authors that an increase in Hb from SP could represent an ergogenic aid for athletes. However, we suggest that the increase in Hb could very likely derive from expulsion of erythrocytes from the spleen rather than an iron-mediated increase in Hb synthesis, especially in studies with short supplementation period and in subjects with adequate iron status.

We fail to understand how elevated circulating iron levels would facilitate the necessary erythropoietin release resulting in erythrocyte production in healthy subjects. Patients with iron deficient anemia could manifest a response to iron with reticulocytosis in three to seven days, followed by an increase in Hb in 2–4 weeks (Alleyne et al. 2008). We call for a more detailed description, or a reference that could demonstrate that iron supplementation could enhance erythropoiesis in the short term in non-deficit individuals. Aside of possibly high NO_3^- concentration in the SP, other influences that may limit their study conclusions are that they did not control for potential iron or NO_3^- containing food during the supplementation period and that they did not measure serum iron and serum ferritin levels.

In summary, we agree with the authors that phycocyanin and arginine from SP could potentially present mechanism of action for improved O_2 uptake. However, the interacting or independent metabolic and circulatory effects of dietary $NO3^-$ clearly deserve attention to determine active agents and safe levels of use of SP as a sports supplement as well as a functional food.

Author contribution statement On the increased haemoglobin concentration and improved oxygen uptake after Spirulina supplementation. HE, AP and ES designed and prepared the Letter to the Editor. All authors wrote, read and approved the letter.

Compliance with ethical standard

Conflict of interest The authors declare that they have no conflicts of interest to report.

References

Alleyne M, Horne MK, Miller JL (2008) Individualized treatment for iron-deficiency anemia in adults. Am J Med 121(11):943–948. https://doi.org/10.1016/j.amjmed.2008.07.012

Engan HK, Patrician A, Lodin-Sundström A, Johansson H, Melin M, Schagatay EK (2020) Spleen contraction and Hb elevation after dietary nitrate intake. J Appl Physiol. https://doi.org/10.1152/japplphysiol.00236.2020

Esen M, Ozturk Urek R (2015) Ammonium nitrate and iron nutrition effects on some nitrogen assimilation enzymes and metabolites in Spirulina platensis. Biotechnol Appl Biochem 62(2):275–286. https://doi.org/10.1002/bab.1268

Jones AM (2014) Dietary nitrate supplementation and exercise performance. Sports Med (Auckland, NZ) 44(Suppl 1):S35–S45. https://doi.org/10.1007/s40279-014-0149-y

Stewart IB, McKenzie DC (2002) The human spleen during physiological stress. Sports Med 32(6):361–369. https://doi.org/10.2165/00007256-200232060-00002