Abstract
Anemia of pregnancy is the worst global health challenge affecting millions of women and girls. It is associated with devastating outcomes like premature births, low birth weight, stunting, intra-uterine growth retardation, maternal morbidity and mortality. Since iron deficiency is the most common cause of anemia, the global public health response has been to provide iron supplements. However, meta-analyses published by Cochrane reviews do not show improvement in the main outcomes, even though there is improvement in anemia. We reviewed here the effects of Spirulina, blue green algae, as an alternative to iron supplements, to not only alleviate the anemia of pregnancy but also have impact on the fetal and maternal outcomes, through its impact on the Gut Microbiome. Widespread cultivation and consumption of Spirulina would provide livelihood for local women, and empower them towards sustainable living. Moreover, Spirulina cultivation is an important carbon sink thus mitigating climate change effects. Thus the simple blue green algae, Spirulina, is a multi-purpose panacea for many ills plaguing our planet, and help towards removing the root causes in inequity in sustainable development and women empowerment.

Keywords: Spirulina; Anemia; Iron-Deficiency; Malnutrition; Pregnancy; Women

Review
Anemia is currently the worst global public health scourge believed to be caused by micro-nutrient deficiency [1]. It has devastating effects in the form of premature births, low birth weight, postpartum hemorrhages, other maternal complications, and stunting and growth-retardation among children below 5 years. All this feeds into a vicious intergenerational cycle and poor health outcomes affecting adolescent girls to mothers, particularly young mothers and their offspring.

The most common cause of anemia is iron deficiency either from blood loss with hookworm infestations or menstrual combined with poor nutrition resulting in failure to compensate for the blood loss [1]. To date the public health response has been to supplement elemental iron along with folic acid to pregnant and lactating women and children. However, data pertaining to India shows that, in spite of such supplementation, 50% women and 70% children under five year of age continue to be anemic. The rates of anemia and its consequences have not changed significantly among women between the NFHS-3 (National Family Health Survey 2005) (Research Collaborators 2006) and the NFHS-4 (2015)(Research Collaborators 2016) even though the provision of iron and folic acid coverage is reportedly more than adequate [2,3].

Arguably, in the context of provision of adequate coverage of iron and folic acid in a large unwieldy public health program, the fault could lie with its governance, implementation, etc. It then becomes necessary to look at clinical trial settings where procedures and protocols have been conducted under systematic conditions. There are more than 44 such randomized clinical trials among > 3000 women, done to date. In addition, two meta analyses through Cochrane Reviews, [4,5] which show the following:

- The iron and folic acid supplementation definitely leads to an increase in the hemoglobin
- However, the quality of the data was poor for the main outcome measures like: pre-eclampsia, low-birth weight, premature birth and postpartum mortality rates were not significantly improved by merely administrating elemental iron. On the other hand, the iron and folic acid tablets caused untoward gastrointestinal side-effects such as constipation, diarrhea, and vomiting which lead to lack of compliance with the regimen. There is minimal average of 30 gram increase in birth weight, and this forms the basis for the current WHO recommendation in public health regulations for iron and folic acid supplementation.

Accordingly, the authors of the two Cochrane reviews strongly recommended the identification of an alternative source of iron as opposed to the currently-recommended elemental iron in view of its adverse effects and lack of efficacy vis-a-vis the main outcome measures. It is in this scenario that supplementation by spirulina as a potent alternative source of iron and folic acid assumes stupendous significance.

Spirulina
An ancient cyanobacterium which from millions of years has populated the earth's atmosphere with oxygen; Spirulina is a superabundant source of protein and almost all other micro-nutrients. The 60-70% protein it contains has the least environmental footprint in terms of land, water, and soil use as compared to other sources of protein such as soya, eggs, or beef.

Also, comparatively, spirulina has astonishing contents of iron and folic acid, which is approximately 100 times the RDA requirement! Moreover, it is readily digestible and bio-available. History also tells us that it was the food of the ancient Aztecs and NASA hails it as the food of the future [6,7].

The Cochrane reviews clearly state that it is imperative to administer iron in a form which is both absorbable and bio-available as this would not only correct the anemia but also preempt the negative outcomes associated with anemia such as low birth weight, premature birth, etc. [4,5]

Data to Show Spirulina can Treat Anemia
There are several published and unpublished data, which show that anemia can be ameliorated among women and children.
of various ages. For example, in a randomized controlled study of anemic girls between 7–9 years of age, by Sachdeva, et al. showed a significant increase in hemoglobin and intellectual levels. In the study they ingested Spirulina powder for just five weeks [8]. Similar increase in IQ and hemoglobin levels with Spirulina has been shown in 2001 by Kauser, et al. [9]. More recently, we showed an increase in IQ and hemoglobin levels, in our non-randomized study of 1000 children given two doses (1 and 2 grams) of Spirulina, versus control groups [10].

Improvement of hemoglobin levels with Spirulina for six months along with iron, folic acid and vitamin B12, as compared to control groups has been documented in tribal women in the northeastern states of India in a difficult to reach population [11,12]. In a recent randomized clinical trial in the Gaza Strip, among malnourished children under age five, we received 3 grams of Spirulina had significant improvement in height, weight and hemoglobin levels by the end of 12 weeks therapy, when compared to controls who received vitamin supplements [13].

We also have found an improvement of hemoglobin levels up to 1.5–3 percent on average among 100 children at a Mutt in Tumkur, Karnataka, who were given 1–2 grams of Spirulina (personal communication). Furthermore, our work in Bellary, Karnataka, under the “Mission Against Malnutrition” program, more than 45,000 pregnant women, lactating mothers and children under six years receiving 1–2 grams of Spirulina showed dramatic results by reducing malnutrition and anemia in the cohort measured [14,15]. As part of the mission, in a non-randomized study, out of 1000 children, those given Spirulina were seen to have significantly higher iron and hemoglobin levels as compared to controls [10].

**What does Spirulina actually do for the Human Body?**

*In vitro* data as well as animal data have established that Spirulina enhances the gut micro-biome by rendering it more diversified therefore healthier [16–18]. This is confirmed by preliminary data among humans [19].

Meanwhile, emerging data on gut micro-biome studies show that iron micro nutrient deficiency is perhaps indicative of a poor, unhealthy, less diverse micro-biome [20]. On the other hand, studies on mice show that merely replenishing iron could be counter-productive; for administering iron to an already impoverished gut micro-biome has been known to have deleterious effect on it [21]. This agrees with the finding now commonly accepted that elemental iron supplements should not be given in the initial 4–7 days of acute malnutrition management because of increased risk of mortality. However, the public health policy does not take the gut micro-biome data into account. We need further causality data which are awaited.

Since it is an accepted fact that like intra-uterine growth retardation and stunting commences in the mother’s womb, we recommend based on the above data, dietary supplementation by Spirulina to tackle the antecedent problems of anemia and poor gut micro-biome. Astonishingly, just 1–2 g of Spirulina per day for 3–6 months will suffice to impact the twin problems of anemia and stunting due to intrauterine under-nutrition, thus killing two birds with one stone. Serendipitously with Spirulina we have the solution to the nagging impediment to the human health potential of our country.

Incidentally, the widespread cultivation and consumption of Spirulina would significantly address the Millennium Development Goals (MDG) formulated by the UN. For instance, local women Self Help Groups (SHGs) can cultivate and harvest Spirulina. This would promote sustainable living, women empowerment, reduction in under nutrition and food security globally nationally and locally. What is more, the cultivation of Spirulina will help mitigate the fallout of climate change because it is a powerful carbon sink. Thus the simple blue green algae multi-purpose panacea for many ills plaguing our planet, and help towards removing the root causes in inequity in sustainable development. Integrating economic, social and environmental dimensions.

**Conflict of Interest**

There are no conflicts of interest to declare.

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*Corresponding author: Fehmida Iyer Visnegarwala, Spirulina Foundation, 2nd Main, 4th Cross, Srinagar, Koyath sandra, Tumkur, Bengaluru-72104, Karnataka, India. Tel: 91-974-184-6068, E-mail: fehmidav@gmail.com

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