

# Production Methods, Economics and Effects of Spirulina Food Supplementation on Malnourished Children

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**Abstract**—The world demand for food and energy is ever exponentially growing. According to the UN we will need 50% more food by the year 2050. Therefore, exploiting new resources is urgent. Experiments on Spirulina as a dietary supplement, economic comparison with Spirulina recording on FM medium about 68% protein in dry weight 15–18g\*m<sup>-2</sup>week<sup>-1</sup> (differs with temperature and sunlight exposure), .The Algae showed environmental and economic viability compared to other comparable products and for unit of value product in since of 1g protein for Spirulina vs. soy bean was 0.7:0.9 cents and land use of 17:1 g\*m<sup>-2</sup> year<sup>-1</sup> (according to National Soybean Research Laboratory. Retrieved 2015-10-14. estimate), also it is hypo-allergic compared to beans and nuts generally . A human supplementation experiment was done on malnutrition effected individuals ageing from 20 month to 5y old to compare the Spirulina protein to a placebo and whey protein showing significant superiority of Spirulina . Dosage of 2.5 g/day Spirulina gave similar effects to 7.5 g of whey, yet higher dosages showed some adverse effects, causing significant muscular growth but over all weight staggering.

**Key words:** Malnutrition, Microalgae-based products, Single cell Protein, Spirulina , Dietary supplements.

## 1 INTRODUCTION

Algae describes as a large and diverse group of simple, plant-like organisms found in salt water and some large fresh water lakes (Tokusoglu and Uunal, 2003). blue-green algae is one of the most nutrient dense foods on the planet. two varieties, *Spirulina* and *Aphanizomenon flos-aquae*, are the most consumed forms of blue green algae; which has superfood status due to high concentrations of proteins, vitamins and nutrients (kay, 1991).

since the early 70s algal products have been realized for their superfood potential by many studies done by a lot of research organizations most notably the FAO, (2011) for its potential to close the food gap and the meal quality/poverty crisis. Spirulina was scale produced and experimented on it as food additive in comparison to market ready whey protein to reduce malnutrition in a group of effected children aging between 20 month to 5 years.

## 2 MATERIALS AND METHODS

Algal Media: Slandered: Zarouk Media (*Spirulina* selective media). , Also a new reduced cost fertilizer based media (FM) was developed in this study for mass production of *Spirulina* which is NaHCO<sub>3</sub> (8g/l), NaNO<sub>3</sub> (2.5g/l), NaCl (0.5g/l), MgSO<sub>4</sub>.7H<sub>2</sub>O (0.15g/l), CaCl<sub>2</sub>.2H<sub>2</sub>O (0.04g/l) Single Super Phosphate “SSP” (1.25g/l), KCl fertilizer “MoP” (0.98g/l) +Pre-Boiled tap water.

### 2.1.Serial dilution:

This method was used to lower cell-count per cm<sup>3</sup> of culture for pure isolation of algal species, it's a general microbiological practice done to lower the cell count in a liquid culture (Ben-Davida & Davidsonb, 2014).

### 2.2.Phototaxis:

This method was used in photo-taxis incubator to isolate single *Spirulina* filament (Baker *et al.*, 2015).

### 2.3. Double-blind placebo/control/substrate clinical trial :

For determination of the effectiveness of *Spirulina* as a food supplement for malnutrition individuals (Astrup *et al.*, 1990).

### 2.4. Amino Acid HPLC analysis :

The determination of amino-acid profile of algae was carried out according to Lookhart and Jones (1985).

### 2.5.Scale-Up culture technique:

Used to scale up cultured algae from 200 ml flasks to 2l bottles to 20l jugs to mini 400l ponds to full mass production 60m<sup>3</sup> ponds to overcome long lag phase of bacterial cultures (Lonsanea *et al.*, 1992).

### 2.6. Clinical trial:

A *Spirulina* based product vs. whey powder based product vs. a placebo, with concentrations of 7.5, 5 and 2.5 grams of *Spirulina* was mixed to an “orange flavor-sugar base” and given codes T@ 7.5, T@ 5 and T@ 2.5 respectively (Gad *et al.*, 2011 ; Mark Wolraich, 2011 and Hassan *et al.*, 2012 ).

The whey based product of 7.5, 5 and 2.5 g was mixed to an "orange flavor-sugar base" and given codes 7.5, 5 and 2.5 B@, respectively.

Finlay, the placebo was made by mixing 7.5 g of wheat flower with the "orange flavor-sugar base" and given code 7.5 K @.

Each of these products was given on a daily basis for 5 malnutrition affected children aging between 2 to 5 years old for a one month period totaling 35 children.

The navel line skin fold measurement, height, body mass biceps and triceps muscle and hand force was taken for every child .

Before and after the experiment, the bodies mass only were taken on the 15 day's mark.

All the 5 children that were giving the placebo received a 1 month stock of whey powder mix after the end of the experiment working with Belmont Report value of Beneficence.

### 3 RESULTS

Spirulina production proved to be economically viable in the since its startup production is expensive yet it can break even easily within a 2~3 years period with current market prices (roughly 50 used a kilo) according to Alibaba online supplier's market, even thaw it's cheap and convenient to produce individually for personal use, thaw this may appear to be controversial it's due to the fact that large scale production is labor enhancive and use highly specialized equipment and professionals, also 1kg can support a single user for almost 6~12 months (based on this study) which is less than 0.25\$ a day/person if bought from the market and less than 0.07\$ if grown individually

in Table (1) is a detailed total cost and brake even analysis of such a project over time in Egypt.

Table 1: Total cost and brake even analysis of such a project over time in Egypt:

Year	2015		2016	
	January to June	July to December	January to June	July to December
Investment	200,000			
Personnel	18,400	16,650	17,950	16,200
Electricity	18,000	18,000	18,000	18,000
Chemicals	2,000	2,000	2,000	1,000
Other	1,700	1,700	1,700	6000
<b>Total Exp</b>	<b>240,100</b>	<b>38,350</b>	<b>39,650</b>	<b>41,200</b>
Spirulina Sales	120,000	155,000	155,000	155,000
Other Income	----	----	2,000	1,000
<b>Total Rev</b>	<b>120,000</b>	<b>155,000</b>	<b>157,000</b>	<b>156,000</b>
<b>Difference</b>	<b>-120,100</b>	<b>116,650</b>	<b>117,350</b>	<b>114,800</b>
<b>Cash flow</b>	<b>-2,164,400</b>	<b>-1,662,550</b>	<b>-1,055,450</b>	<b>-345,700</b>

It's important to note that the size of this project was on 10 Fadden of land totaling 120 race way pools of dimensions

25\*5+ 2 half circles of radius 2.5m and a depth of 50cm as shown in (Figs.1,2) as mentioned (Belay, 1798) .



Fig. 1. Spirulina pool design.

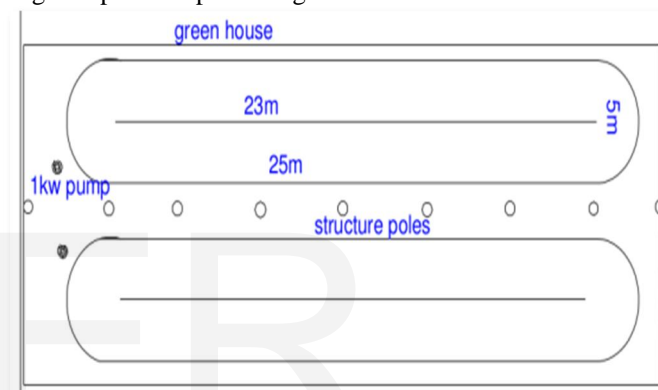


Fig. 2. Spirulina pool design.

Each 2 pools are covered with a plastic greenhouse driven with a 2hp irrigation pump with a modified blade to reduce cell damage, as for the media used for mass production it was "FM" media mentioned in above materials and methods, on the other hand, the harvesting is done with a simple cheese cloth with the same pump of the pool itself( Fig. 3) as mentioned (Cohen, 1798).



Fig. 3. The harvesting.

Then dried on rack ambient air dryer (Fig. 4) to insure nutrients loss is minimal,

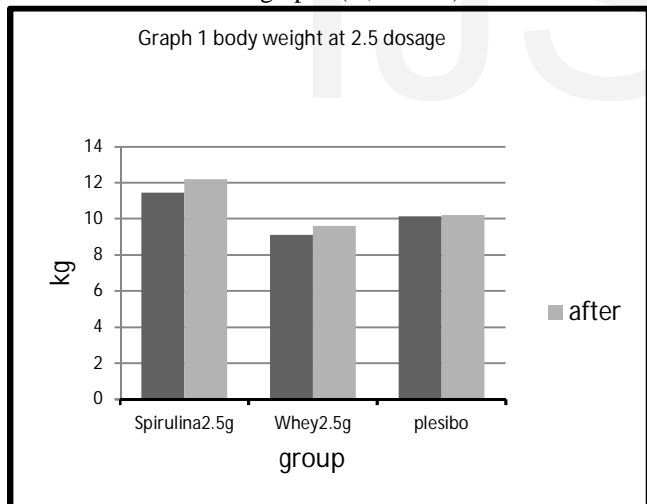


Fig. 4. Spirulina dried on rack ambient air dryer.

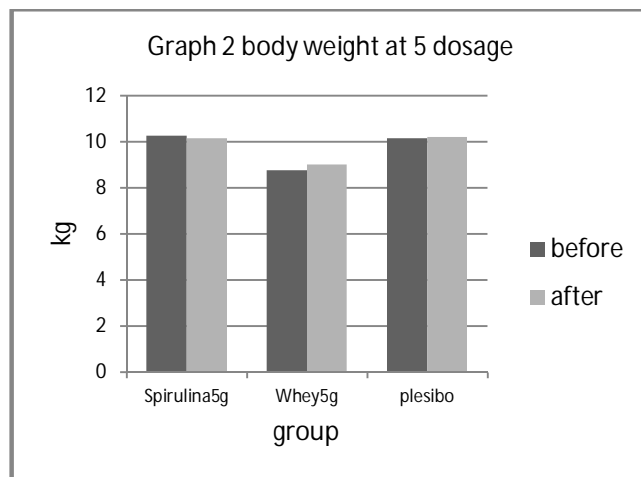
The dry chunks is then milled down to powder and sterilized with an ultraviolet light for 2h.

This production method proved to be cheap, repeatable and not sophisticated to be home made with materials and chemicals available for poor families and farmers compared to the other production modules of algae.

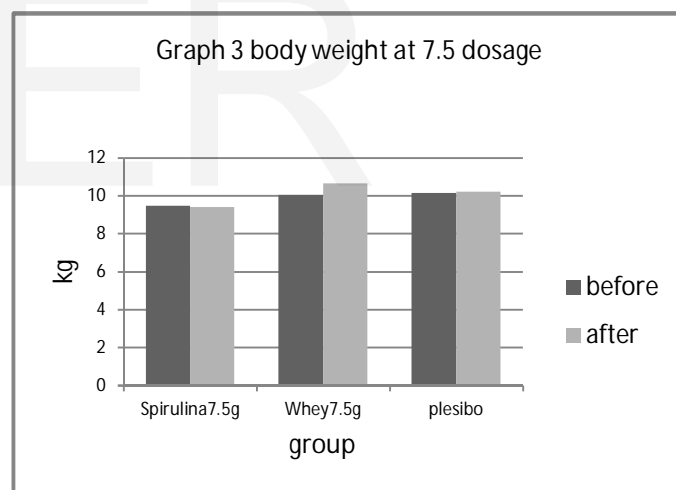
Finally in the clinical trial the sterile Spirulina powder was mixed with an orange flavor and sugar base and distributed on local public health care centers (poskesmas) to be given to malnourished children after local authorities and their parent's consciences, along with whey powder and a placebo and the results are as illustrated in graphs ( 1,2 and 3) .



In the 2.5g dosage Spirulina gave the best body mass increase, also quantitatively somewhat higher lean mass increase than whey protein in the same dosage level, the slight increase in body mass in the placebo group is not statistically significant and is due to the fact that these children are growing.



the 5g dosage Spirulina gave a lowering effect on body mass something very undesirable in underweight individuals, but also quantitatively a significantly higher lean mass increase than whey protein in the same dosage level, Also a very high increase in grip strength >50%in Spirulina group individuals but <25% for whey group individuals, the slight increase in body mass in the placebo group is not significant and is due to the fact that this children are growing.



In the 7.5g dosage Spirulina gave an insignificant lowering effect on body mass still undesirable in underweight individuals, but also quantitatively a significantly higher lean mass increase than whey protein in the same dosage level, Also a very high increase in grip strength >50%in Spirulina group individuals but <25% for whey group individuals, the slight increase in body mass in the placebo group is not statistically significant and is due to the fact that this children are growing.

A. Hypothesis explaining the clinical trial results:

High dosages of Spirulina seem to have a fat burning effect, it's not recommended to use a dosage over 2.5g per day for underweight children.

Thaw (5g,7.5g) dosages showed weight loss, high muscular (biceps and triceps) volume increased and stomach skin-fold decreased, also the grip strength increased by about 55% in all test subject pointing to high muscular anabolism, Thaw more

research in needed the result recommend a dosage of at-least 5g Spirulina for individuals looking to increase lean mass to fat percentage ratio.

Low dosage of Spirulina (2.5g/day) showed similar results to 7.5g/day of whey making it not only a cheaper but a more effective per unit dosage than whey.

It's important to note that a better overall health were reported by caregivers of the children taking Spirulina that may be due to the effect reported in FAO (2011) That that Spirulina help increases the immunity.

#### 4 DISCUSSION

Among 10 countries 9 were found to have a direct link between poverty and malnutrition – Chad was the only country that was poor but had no malnutrition.

Modern day technology allows us to grow Spirulina in man-made machines called Photo Bio-Reactors (PBR) – these machines are ideal to grow the algae in conditions where the natural habitat would otherwise not permit the cell to normally grow.

Although briefly mentioned in this study PBRs are not ideal to grow and harvest Spirulina in the ESA-IO region for primarily two reasons.

Firstly the initial start-up costs are too high – and although most PBRs promise high yields in micro-algae production in reality only some are able to achieve those promises. Secondly most of the region is favorable to Spirulina growth without the use of expensive machines and it can be cultured and harvested fairly easily in man-made basins and ponds.

Spirulina is a highly nutritious natural substance, which has in recent years gained, once again, interest in both developing and developed countries. It is very in high protein content; yields 20 times more protein per acre than soybeans, 40 times more than corn, and over 200 times more than beef make it an ideal food supplement for everyone (Kaldy, 1972).

More awareness needs to be raised so that people understand what Spirulina can do, its high protein, vitamin, mineral and micro-nutrient properties are good for both the ill (HIV/AIDS), malnourished children and infants and for the public health

Conscious: In some cases Spirulina has been incorrectly marketed as a medicine giving people, particularly the ill, false hope – in fact Spirulina is a food supplement whose main benefit is the boosting of the immune system (FAO, 2011).

This study found very similar results to that stated in this report thaw the production was slightly less than that stated by the F.A.O. but was well above average and can create investment attractive revenue, we strongly recommend Spirulina as a food additive/ supplement for the poor in Indonesia, Egypt and other countries across the world.

“Substantial amounts of vitamin B12 were found in some edible algae (green and purple layers) and algal health food (chlorella and Spirulina tablets) using the *Lactobacillus delbrueckii* subsp. *lactis* ATCC7830 microbiological assay method. Corrinoid compounds were purified and characterized from these algae to clarify the chemical properties and bioavailability of the algal vitamin B12. True vitamin B12 is the predominate cobamide of green and purple layers and

chlorella tablets. Feeding the purple layer to vitamin B12-deficient rats significantly improved the vitamin B12 status. The results suggest that algal vitamin B12 is a bioavailable source for mammals (Watanabe *et al.*, 2002).

In this study we found no evidence that the dry Spirulina had any active B12 and that the cobamide is ineffective and biologically invaluable for humans (Pseudo-vitamin B12) We strongly Advice against the use of dry Spirulina as a source of B12, low B12 levels have been linked to severe and irreversible damage, especially to the brain and nervous system in humans, Spirulina need to be fortified otherwise it's a Nell source of the vitamin.

Spirulina is highly nutritious but it's not risk free, a high dosage can cause liver damage (vitamin A toxicity), high load on kidneys (salts and urea) and hypertension (it's significantly high in sodium).

Spirulina is cheap to produce and very profitable to sell but the infrastructure of the production facilities is budget braking and a very big investment.

Whey in not cheap and contain lactose, making it not palatable by most adults (65% of the world population according to the FAO are sensitive or intolerant to lactose), also doesn't seem to effect lean mass and grip strength like Spirulina making it an inferior product.

Thaw a 2.5g dosage may seem insignificant, this experiment was done on children weighing around 10kg each, and for similar effects on heavier individuals we recommend adjusting the dosage to their body mass.

#### 5 RECOMMENDATIONS

“Spirulina proved to be a cheap alternative protein, thaw dosage have to be closely monitored, unlike conventional whey supplements also lower in palatability yet a good source that could be given to malnutrition effected children in low dosages to elevate the effects of malnutrition leading to a better overall health, immunity, body weight and strength, very scalable and versatile to fit individual and community needs even in poverty affected households”

**So we recommend that :**

- 1.Spirulina to be given to malnutrition and underweight Individuals.
- 2.Education and tanning about spirulina home and community culture to be applied in Indonesia were individuals learn how to grow and use spirulina for their personal use and for economic profit .
- 3.National Production of Spirulina and distribution on “Puskemas” (local health care posts) as a food supplement for malnutrition effected children , Moms and elderly.
- 4.Development of a system for Local in puskesmas production to cover the needs of community.
- 5.More research is needed in the way of consumption and added taste because Spirulina is not something that a child would be willing to eat.
- 6.Spirulina showed that it have a lean mass increasing effect while lowering body fat% ,it may have the potential to be a very good food supplement for the old, cancer patients and people seeking weight loss and lean mass increase, more

research is needed to clarify this point and to determine suitable dosages for this applications.

vitamin B12-Compounds from Edible Algae, *J. Nutr. Sci. Vitaminol.*, 48 (5) : 325-331.

7. Spirulina is a food supplement not a wonder-drug as some marketers claim, An individual with a balanced diet and no weight issues, A stable immunity and vitamin intake should not take Spirulina supplements, Spirulina suppliants can cause over-nutrition, and in extreme cases toxicity by vitamins and minerals.

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