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Research for progress

Spirulina

in the fight against malnutrition

Assessment and prospects

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Introduction

Malnutrition is defined as a pathological state arising from the prolonged use of food that does not supply all the elements necessary for health. In developing countries, malnutrition is the cause of many harmful consequences for young children: increased risk of mortality, weakened immune system, delayed motor development, diminished cognitive capacity and school performance.

Several organizations have chosen to take part in the prevention of child malnutrition. This prevention is mainly based on the nutritional education of populations, the development and consumption of locally produced foodstuffs and the provision of supplemental food.

On the basis of its micronutrient composition, its health potential and the fact that it can be grown locally, spirulina offers important advantages to fight against chronic malnutrition. However, in spite of increasing evidence, its use in many nutritional centres and major technological improvements in its production in developing countries, spirulina is still not supported by intergovernmental agencies.

The perception about spirulina is bound to evolve with the increasing number of field initiatives, the accumulation of scientific studies and the hundreds of thousands of people who eat it every day. This document is a review of the arguments, constraints and prospects pertaining to the use of spirulina against malnutrition.

Note: Most of the information presented in this document was taken from the following sources:

- *Falquet J, Hurni JP (2006)* Spiruline, Aspects Nutritionnels. *Antenna Technologies. 41 p.*
- *Charpy L, Langlade MJ, Alliod R (2008)* La Spiruline peut-elle être un atout pour la santé et le développement en Afrique? *Rapport d'expertise pour le Ministère de l'Agriculture et de la Pêche. 49 p.*

Scientific rationale

Review of nutritional and therapeutic arguments

Note: Extensive reviews of the nutritional properties of spirulina can be found in the following publications:

- *Falquet J, Hurni JP (2006)* Spiruline, Aspects Nutritionnels. *Antenna Technologies. 41 p.*
- *Falquet J (1997)* Spirulina, Nutritional Aspects. *Antenna Technologies. 22 p.*
- *Gershwin ME, Belay A (2007)* Spirulina in Human Nutrition and Health. *CRC Press. 312 p.*

The primary characteristic of spirulina that has attracted the attention of both research workers and industrialists is its impressive protein content. As part of more detailed analyses, a number of features of particular interest from the nutritional standpoint have been demonstrated: a balanced protein composition and the presence of rare essential lipids, as well as numerous minerals and vitamins.

In addition to its nutritional interest, spirulina shows some therapeutic properties. It contains different substances that have been studied for their biological activity. The immunostimulatory and antiviral properties of spirulina, for instance, are of great interest in the fight against malnutrition, since malnourished children have weakened immune defenses.

Proteins and amino acids

The protein content of spirulina is especially high, varying between 60% and 70% of its dry weight (Fox, 1999), and comprises almost all amino acids, including the essential ones. It should, however, be noted that a reasonable daily consumption of spirulina cannot provide more than about 15 grams of proteins. This quantity represents approximately a quarter to a third of the daily protein requirements for a 60 kg adult (RDA: 0.7 to 1 g/kg) (Briend, 1998). Nevertheless, in the case of children suffering malnutrition, it would be realistic to incorporate up to 10 g of spirulina in the daily ration. Depending on the weight of the child, this can amount to more than 50% of the recommended protein intake.

Lipids and fatty acids

The total lipid content presents a good balance between saturated and polyunsaturated fatty acids. The composition of the main fatty acids shows a high concentration of essential fatty acids, including *omega-3* and *omega-6* acids, which are reported to prevent cholesterol build-up in the body.

Gamma-linolenic acid (GLA) constitutes up to 40% of spirulina's fatty acids, making it one of the best known sources of GLA (Ciferri, 1983; Cohen, 1993). The presence of this substance is worth stressing in view of its rarity in everyday foods and the fact that it is a precursor of chemical mediators of inflammatory and immune reactions (Falquet, 2006).

Spirulina is also rich in *sulfolipids*, which are of interest to researchers due to their protective activity against viral infections. For example, *in vitro* experiments have shown that the lipid compound sulfoquinovosyl diacylglycerol (SQDG) inhibits the reverse transcriptase of HIV (Kiet, 2006).

Carbohydrates and polysaccharides

Carbohydrates make up 15% to 25% of spirulina's dry weight (Falquet, 2006; Quillet, 1975; Shekharam, 1987). It also contains specific polysaccharides such as *calcium spirulan (Ca-SP)* and *sodium spirulan (Na-SP)* (Lee, 1998), as well as *Immulina* (Lobner, 2008). These polysaccharides have interesting anticoagulant, immunostimulatory and antiviral properties (Lee, 2001).

- Anticoagulant activity: Calcium spirulan activates heparin cofactor II, a molecule that inhibits thrombin and thus coagulation (Hayakawa, 1996, 2000, 2003). Sodium spirulan is also reported to have anticoagulant effects (Yamamoto, 2003).
- Immune system strengthening: Several experiments have shown that spirulina has a favorable regulatory effect on the immune system (Qureshi, 1996; Pascaud, 1993; Borchers, 2007). It stimulates the activation of macrophages, as well as the activity of T cells and NK cells. This process induces the release of interferon-gamma (IFN-γ), which can eventually lead to virus inactivation. These actions are thought to be mediated by polysaccharides.
- Antiviral activity: Spirulina's antiviral effect has been studied on the inhibition of penetration into *HeLa* cells and hamster cells by the *Herpes simplex* virus (Hayashi, 1993). Later, the same authors discovered the role of Ca-SP, which is thought to inhibit the penetration of viruses as well as their replication phase (Hayashi, 1996). As for Immulina, it triggers an activation of monocytes which is 100 to 1000 times higher than with the polysaccharide preparations commonly used in hospitals for cancer treatment. A recent article about the ingestion of Immulina by 11 patients in good health reports an immediate effect on immune defenses (Lobner, 2008).

Vitamins

- Vitamin B12: Among hydrosoluble vitamins, spirulina's content in vitamin B12 is remarkably high. The daily requirement of vitamin B12 for a 6-month to 3-year old child is 0.5 to 0.9 µg. A 10-gram dose of spirulina provides 142% (low content) to 486% (high content) of the child's daily needs.
- Provitamin A (β-carotene): Among liposoluble vitamins, spirulina has a very high content of β-carotene. The human body converts the necessary amount of this pigment into vitamin A to meet its needs (Henrikson, 2009). A recent study on Chinese adults by Wang *et al.* (Wang, 2008) has shown that the ingestion of 4.5 mg of β-carotene from spirulina provides 1 mg of vitamin A. Between 3 and 6 g of spirulina would be necessary to meet the recommended dietary allowance for an adult (900 µg). Concerning 6-month to 3-year old children, given their daily requirement of this vitamin, they would need 1 to 3 grams of spirulina per day.

Minerals and trace elements

Spirulina is naturally rich in some essential minerals that are particularly important in case of malnutrition. It is worth mentioning that the contents of fatty acids and certain minerals can be easily modified by adjusting the cultivation inputs.

- Iron: Natural spirulina has an iron content of up to 500 mg/kg, although values above 1000 mg/kg have been reported (Campanella, 1999). Iron enrichment of spirulina can result in values more than 10 times higher (Végifer®).
- Zinc: Zinc is considered as a major micronutrient in malnutrition (Gibson, 2006). Spirulina usually contains only traces of zinc (21 – 40 µg/g), but it can easily be enriched (Cogne, 2003) (Azina®: 6000 µg Zn/g). Simple protocols exist to obtain zinc-enriched spirulina (Falquet, 2006).
- Magnesium: Magnesium is an important element for health and deficiencies are frequent in malnourished children (Briend, 1998). Spirulina is naturally rich in magnesium and the bioavailability of this element for humans has been demonstrated (Planes, 2002).

Review of clinical studies of malnutrition

Note: The abstracts of some of the studies cited below are given in Appendix 1.

One has to admit that most of the clinical trials carried out with spirulina are questionable in some respects. Of course, it would be desirable for future studies to provide more conclusive results, but one must keep in mind the difficulty of conducting such studies in developing countries where malnutrition is rife.

Nevertheless, the mass of positive results and testimonies from health professionals gathered over the years should start to provoke a reaction from decision-makers in the fight against malnutrition (Halidou Doudou, 2008). It should also be noted that almost all nutritional supplements recommended by intergovernmental organizations have never been subjected to irrefutable scientific validation, such as required for spirulina.

Below is a survey of some of the most recent clinical studies on malnutrition conducted with spirulina, in particular with children and vulnerable populations (HIV-positive).

Pioneering studies

In Bangui (Central African Republic), the “Nutrition Santé Bangui” association (Nutrition and Health Bangui), which manages a child nutrition centre, has been producing and using spirulina for almost two decades. In 1993, more than 300 children had already benefited from a nutritional treatment based on a sardine-spirulina combination. The centre's manager, Mrs. Picard (Pharm.D.), wrote: “These first results reveal the benefits of spirulina to tackle malnutrition problems, even in severe cases. This product is easy to use and well accepted by mothers when it is properly explained.” (Picard, 1993). This study was later extended and made comparative by observing a group of 592 children aged from 0 to 5 years old fed with the sardine-spirulina combination, in comparison with a group of 182 children receiving only sardine to supplement the staple diet. The treatment duration varied between 94 and 145 days and the dose of spirulina was 5 g/day. Data analysis showed a significantly better improvement for children treated with spirulina, in terms of both average body weight gain and speed of recovery (Dupire, 1998).

In the Democratic Republic of the Congo, a study on 28 children suffering from protein-energy malnutrition was carried out from January to November 1989 (Bucaille, 1990). The parameters measured during this work show the global positive effect of spirulina on the patients' nutritional status, in spite of the inevitable problems inherent in field research.

Recent studies

New studies have been undertaken in recent years. Unfortunately, some of them mainly bring out the difficulty of designing and following a research protocol that is both adequate and rigorous. For instance, a research carried out in Burkina Faso and concluding that spirulina is of no interest in fighting child malnutrition (Branger, 2003) is the perfect example of what should be avoided. The absurdity of the applied protocol, as well as the gravity of the conclusions that the authors still published, have been denounced several times (Darcas, 2004; Falquet, 2004; Fox, 2004). (See *Appendix 1*)

In India, a randomized clinical trial on 60 schoolgirls addressed not only the purely nutritional effects of a small intake of spirulina (1 g/day), but also possible indirect effects on their intellectual performance (Sachdeva, 2004). This study led to positive and statistically significant results on both the haematological status of the pupils and on their intellectual performance. It ends with a recommendation to the Indian government about the supply of free spirulina in schools, particularly in deprived regions.

In Burkina Faso, a comparative study on the nutritional recovery of 170 children (84 HIV-positive and 86 HIV-negative) demonstrates the benefits of spirulina in the treatment of child malnutrition, as well as its particularly positive impact on the nutritional rehabilitation of HIV-infected children (Simpore, 2005). This work was carried out in Ouagadougou, using spirulina that was produced locally and with simple facilities.

Another work by the same authors compared the nutritional benefits of diets composed of spirulina grown in Burkina Faso and/or of Misola[1] (Simpore, 2006). The study was on 550 malnourished children under 5 in Ouagadougou. An improvement in body weight as a function of height and age is observed for all children, especially those whose diet was made of spirulina and Misola. The authors conclude that Misola, spirulina added to traditional food or Misola with spirulina are good diets for severely malnourished children. The diet with spirulina and Misola yields the best results, because it combines Misola's large caloric intake with spirulina's high protein content.

In Central African Republic, a 6-month prospective randomized trial was carried out with people infected and affected by the HIV (Yamani, 2009). 160 patients were divided into two groups. Patients in the first group received 10 grams of spirulina per day, while patients in the second group received a placebo. This study showed a significant improvement in the main follow-up criteria (weight, arm girth, number of infectious episodes, CD4 count, protidemia) that is similar for both groups. However, no clear conclusions could be drawn from a clinical standpoint because of methodological problems reported by the authors.

On the other hand, a similar study on 52 HIV-positive patients compared a group supplemented with spirulina and a group supplemented with soya beans. (Azabji, 2010). This work showed a comparable efficacy for spirulina and soya beans as regards weight gain, but also a significant increase in immunological markers for the group treated with spirulina, and not with the group treated with soya beans.

Finally, a recent article indicates that a 12-week supplementation of spirulina ameliorates anemia and immunosenescence in older subjects (Selmi, 2011).

[1] Misola is a mixture of millet (60%), soy (20%), peanuts (10%), sugar (9%) and salt (1%).

Assessment

A positioning which is complementary to other nutritional strategies

Spirulina is not in competition with other strategies to combat malnutrition such as maternal education, dietary advice, enriched flour or therapeutic milk. On the contrary, it is complementary to such strategies in the long-term prevention of chronic malnutrition, while other solutions specifically address severe acute malnutrition.

For instance, ready-to-use therapeutic foods (RUTF, such as the well-known Plumpy'nut®) are of great interest in the treatment of acute malnutrition (without complications) and in emergency situations. However, besides these critical cases, chronic malnutrition must also be tackled with other, more sustainable methods, in particular to avoid an excessive dependence of the affected populations. In the long term, these populations should be further encouraged to develop their own skills and means of subsistence, using available local resources to manage their nutrition.

Today, spirulina should be considered as a cooking ingredient that can effectively participate in the fight against malnutrition, and therefore complementary to other approaches. To make it a long-term strategy, one must ensure that the populations acquire the necessary skills to locally produce their own spirulina.

A local production which can be integrated into food habits

The nutritional and therapeutic properties of spirulina are not its only advantages. Producing it locally makes it more available and appealing than an imported foodstuff, which should facilitate its acceptance and consumption by the local populations. Countries can thus implement the cultivation of spirulina and gradually integrate it into food habits. Therefore, it emerges not only as a remedy for malnutrition, but also as a tool for development.

Spirulina farms help to counter unemployment and to empower people through the acquisition of expertise. Even though most farms in developing countries are humanitarian in nature and fully aware of spirulina's potential to improve nutrition of the population, they are also motivated to evolve into commercial businesses. This requires the creation of an effective distribution and communication network and the setting up of an appropriate strategy to teach the local population about the nutritional benefits of spirulina.

Several aspects of the production of spirulina are particularly well adapted to the agricultural realities of hot, even desert, countries. The choice of a photosynthetic micro-organism that develops in an aquatic environment avoids the problems of poor soil quality, plant parasites and diseases. Contrary to popular thought, the water consumption of such a crop is far less than that of any other classical agricultural crop. Due to the extremely high productivity and the fact that only small quantities of spirulina are needed per person, the area used for production is consequently very small. Lastly, many climates permit the continuous production of spirulina all year round. If the spirulina is consumed locally, no conservation method is needed. Moreover, fresh spirulina can be consumed immediately, without transformation or cooking, and hence without need for an additional input of energy.

Intergovernmental agencies remain silent

Currently, spirulina is mainly used by NGOs and local health institutions (hospitals; CRENs: Centres for Recovery and Nutritional Education) to fight malnutrition, based on its micronutrient composition, its potential health benefits and the fact that it can be produced locally. These organizations have improved growing methods and their work is supported by studies, observations and testimonies of people using spirulina. In spite of this, spirulina is neither recommended nor promoted by international organizations such as the WHO, the WFP or UNICEF.[2] This silence may partly be explained by the fact that spirulina is neither a drug nor a foodstuff…

For these UN agencies, the potential benefits of spirulina have to be scientifically proven before they take a stance (even though the vast majority of the nutritional supplements that they recommend have never obtained irrefutable scientific validation). The lack of scientific evidence means spirulina is absent from malnutrition protocols, in favour of enriched flours and therapeutic milks. Such imported products are obviously useful in case of food crisis, but unlike spirulina, they don't encourage local initiative and thus the populations remain dependent on northern countries. Revealing examples of this are the Nutriset products, in particular Plumpy'nut®, which are especially successful, thanks to their ease of use. However, since 2010, there has been increasing controversy about Plumpy'nut®, due to the problems caused by its patent and the monopolistic position of Nutriset on such products. (*Appendix 2: Article about the Plumpy'nut® patent controversy, published on the BBC News website in April 2010*)

To date, intergovernmental agencies have taken a non-committal position on the use of spirulina in the fight against malnutrition. Should it be considered as an issue concerning health care (then under the responsibility of the WHO), food security (the FAO) or the improvement of the condition of children (UNICEF)? In the end, none of these institutions actually takes a stand.

This situation should soon evolve, since certain countries, like Burkina Faso or Senegal, have implemented governmental plans to develop the cultivation of spirulina. Moreover, in 2005, African countries put forward a draft resolution demanding a clear stance from the UN General Assembly in favour of the production and use of spirulina. (*Appendix 3: Draft resolution at the 2005 UN General Assembly for a stance on the use of spirulina*)

Following this, the FAO was mandated and prepared a review on this subject in 2008. Although this document treats only superficially the issue of malnutrition, it nevertheless recognizes the potential of spirulina in that field. (*Appendix 4: FAO 2008 review on spirulina*) At last, after many years of suspicion, the international organizations finally have a more positive attitude towards spirulina. A slow progression fed by the increasing number of successful field initiatives.

In the fall of 2008, the WHO organized a consultation on programmes for the management of moderate malnutrition and how to improve them. Among the background documents presented on this occasion was an article that confirmed the potential of spirulina in the fight against malnutrition and recommended further investigation on this subject. (*Appendix 5: Excerpt from the background paper presented by Michaelsen* et al. *at the 2008 Consultation on moderate malnutrition organized by the WHO*)

[2] Except for the FAO, which supports a small-scale project of spirulina production in Chad.

An unofficial field recognition

In spite of the lack of support from intergovernmental agencies (WHO, WFP, UNICEF), the efficacy of spirulina is well acknowledged in the field. This explains its acceptance by some local health authorities and its use by CRENs, despite the fact that it is absent from foreign protocols, as illustrated by the following African examples.

Niger: Spirulina is officially considered as an improved traditional drug (ITD) and farms can obtain a marketing authorization. In CRENs, spirulina is distributed during phase 2 of the protocol for the management of acute malnutrition. It is easily adopted by mothers as an outpatient treatment when they see it grown locally.

Burkina Faso: Spirulina is integrated in a diversified programme in the fight against malnutrition. Its local cultivation shows the populations that they can act on their own development. It is distributed in CRENs, preferably during phase 2, and helps children regain appetite. Doctors think that spirulina can act preventively against malnutrition when it can be obtained locally as a supplement to the staple diet. It is also used in the recovery phase, in quantities of 2 to 3 grams a day. Spirulina is prescribed to people with HIV, as a support to antiretroviral therapy. It is reported to bring about 1) a gain in weight, 2) a gain in CD4 lymphocytes and 3) a decrease in opportunistic infections. Several research papers have been published on these subjects by Simpore *et al.* (Simpore 2005, 2006, 2007). Additionally, the Burkinabe Ministry of Health launched a series of epidemiological and clinical studies on the efficacy of spirulina.

Madagascar: Spirulina is distributed in some CRENs since at least 2003 and increasingly in free health centres. Research is conducted, at the Marine Sciences and Halieutic Institute (IHSM) in Toliara, on fungal biodiversity in the spirulina production tanks, and also at the School of Agronomic Sciences (ESSA) in Antananarivo.

Spirulina has also generated great expectations in the Western general public, whose interest for natural dietary supplements is ever growing. As a result, a whole market has evolved around spirulina, which shows a rapid growth since the 2000s. There is also a large increase of production in China, which by itself accounts for 50% of the world market.

Expansion and controlled production in developing countries

The number of spirulina farms in developing countries is estimated at around 50. In Africa, most of them are fairly recent (less than 10 years). They all have a humanitarian purpose of health improvement. Some are included in integrated projects of village associations or communes, whose goal is local development. About a third of the farms are part of nutritional programmes or information campaigns about spirulina's health benefits.

The start-up of farms in developing countries is based on partnerships with structures that are locally well established (NGOs, religious authorities, village associations, municipalities, research and health organizations). The initial project is set up with these partners, who provide the farms with a logistic support (premises, water needs, electricity, fences and computer hardware). Technical support is provided by NGOs and financial support by international or private organizations, NGOs or the government.[3]

[3] In Burkina Faso, the government supports large-scale farm projects. In Chad, the FAO supports a small-scale project of spirulina production.

During the past few years, spirulina farmers have mastered the production methods, from sowing to packaging. In some countries, a Good Manufacturing Practices document (GMPs) is distributed. In Burkina Faso, these practices are controlled through the quality assurance system established by the Ministry of Health. Today, the main technical problems encountered 10 years ago have almost entirely disappeared.

The quality of spirulina in developing countries has greatly improved, so that it can now be exported. African farmers have started to cooperate in order to better their production, support each other and obtain a quality-labelled spirulina. Since 2005, training on growing spirulina is given at the Centre de Formation Professionnelle et de Promotion Agricoles (C.F.P.P.A., an agricultural school) in Hyères, France. Every year, a 3-month course is devoted to humanitarian spirulina in developing countries.

Research aiming at improving the productivity, cost and quality of the production has been carried out. It relates in particular to:

- replacing imported inputs with local products (cost reduction)
- using new materials for the tanks and greenhouses (reduction of water needs)
- improving stirring and working conditions
- improving drying and packaging
- using recycling systems of the growing medium
- specific enrichment with iron (Fe), zinc (Zn) or selenium (Se) (improving the micronutrient content)

Specific enrichment with Fe, Zn or Se is especially important, because deficiencies in these minerals play a major role in malnutrition. The composition of spirulina is dependent on the chemical elements available in the growing medium, which means its nutritional content can readily be modified. Since spirulina easily assimilates the minerals provided by the medium, it can be custom-enriched, and it is perfectly conceivable that spirulina may be produced according to the guidelines and requirements set by the WHO, in particular those regarding zinc and iron.

Prospects

It appears today that spirulina shows a significant potential for fighting chronic malnutrition and for development. In its 2008 report, the FAO made two recommendations in that regard (see *Appendix 4*):

> *"International organization(s) working with spirulina should consider preparing a practical guide to small-scale spirulina production […] This small-scale production should be orientated towards: (i) providing nutritional supplements for widespread use in rural and urban communities where the staple diet is poor or inadequate; (ii) allowing diversification from traditional crops in cases where land or water resources are limited […]"*
>
> *"There is a role for both national governments – as well as intergovernmental organizations – to reevaluate the potential of spirulina to fulfill both their own food security needs as well as a tool for their overseas development […]"*

The first recommendation is widely followed today, since the international organizations working with spirulina continue their efforts for development and humanitarian promotion. In recent years, considerable progress has been achieved in this domain in many countries and on different aspects (technique, organization, education, operation, studies).

Regarding the second FAO recommendation, a lot of work is still to be done. **China has recognized spirulina as a national food** (Henrikson, 2009), but other governments and UN agencies, such as the WHO, UNICEF and the WFP, remain silent.

- Although clinical studies held in developing countries often show some methodological weaknesses, it is no longer justified to reject and obscure them, given their number and positive results.
- Tens of thousands of children worldwide are successfully treated with spirulina. This certainly represents sufficient evidence of its efficacy and innocuousness.

It is now absolutely imperative that these international organizations take a clear stance on the use of spirulina in the fight against malnutrition.

Finally, there are many different ways to incorporate spirulina into food nowadays. In India, for instance, spirulina biscuits and sweets have been locally developed by Antenna Technologies and are particularly enjoyed by thousands of children (Heierli, 2007). The creation of new food products that incorporate spirulina certainly represents the best solution.

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International organizations

United Nations - Draft resolution submitted during the 60th session of the UN General Assembly (2005) about "The use of spirulina to combat hunger and malnutrition and help achieve sustainable development". This document can be downloaded from the following page (under A/C.2/60/L.14/Rev.1 Item 52):
http://www.un.org/ga/60/second/draftproposals.htm

FAO - Review on spirulina (2008)
The abstract of the FAO report on spirulina is given in Appendix 4. The full publication can be downloaded from the following address
ftp://ftp.fao.org/docrep/fao/011/i0424e/i0424e00.pdf

WHO - List of publications / Nutrition guidelines. Links to official recommendations and dietary and nutritional guidelines. To this day, spirulina is still not included in the WHO recommendations.
http://www.who.int/nutrition/publications/en/
http://www.who.int/nutrition/en/

Non-governmental organizations

The Antenna Technologies Foundation is an international organization whose goals are to identify, develop and favour the diffusion of efficient technologies that are suitable for populations with limited resources. In order to fight against malnutrition, Antenna Technologies has developed tools and trainings especially adapted to the local production of spirulina in a sustainable way. Today, Antenna Technologies is involved in spirulina programmes in about twenty African and Asian countries.
http://www.antenna.ch/en
http://www.antenna-france.org
http://www.antennaindia.org

TECHNAP is an organization that brings together several NGOs active in the cultivation of spirulina. TECHNAP currently manages spirulina farms in Africa, particularly in Burkina Faso and Benin.
http://www.technap-spiruline.org

Africa'Spi - Association founded in 2009 and comprising Africans and members of different French NGOs. The goal of this association is to diffuse the methods necessary to ensure a truly sustainable development of African spirulina farms.
http://www.africaspi.org

Spiruline du Burkina - Website of the association bringing together the spirulina producers in Burkina Faso. This association organized the 2010 international symposium on spirulina.
http://www.spirulineburkina.org/en.html

SpirulinaSource.com - Website gathering information on spirulina.
http://www.spirulinasource.com

Appendices

Appendix 1: Abstracts of recent clinical studies on spirulina

Over a thousand studies have been carried out on the properties and use of spirulina. The abstracts of some of them are given below. Other will be necessary, especially studies related to human malnutrition. A more thorough bibliography is available on our website: http://www.antenna.ch/en/research/malnutrition/documents/

Rev Epidemiol Sante Publique. 2008;56(6):425-31.

The effect of spiruline during nutritional rehabilitation: Systematic review
(Article in French)

Halidou Doudou M, Degbey H, Daouda H, Leveque A, Donnen P, Hennart P, Dramaix-Wilmet M.

Background: To evaluate the impact of spiruline on nutritional rehabilitation. **Data sources:** Systematic search in medical and scientific databases (Medline, Cochrane, Embase) and other specific databases (PhD theses, reports…). **Methods:** We selected studies in which spiruline was used as supplementation in malnourished patients, irrespective of the form and dose of spiruline and in controlled trials or not. Two persons made the selection separately. Nutritional status was estimated by anthropometric and biological measures. **Results:** Thirty-one references were identified and seven studies were retained for this review; three randomized controlled and four non-controlled trials. Spiruline had a positive impact on weight in all studies. In non-controlled trials, the other parameters: arm circumference, height, albumin, prealbumin, protein and hemoglobin improved after spiruline supplementation. For these studies, methodology was the main drawback. None of the studies retained for analysis were double-blinded clinical trials and all involved small samples. Four of them did not have a control group for comparison. **Conclusion:** The impact of spiruline was positive for most of the considered variables. However, the studies taken into account in this review are of poor-methodological quality. A randomized, a large-sized double-blind controlled clinical trial with a longer follow-up should be conducted to improve current knowledge on the potential impact of spiruline on nutritional rehabilitation.

Arch Pediatr. 2003;10(5):424-31.

Spiruline as a food supplement in case of infant malnutrition in Burkina-Faso
(Article in French)

Branger B, Cadudal JL, Delobel M, Ouoba H, Yameogo P, Ouedraogo D, Guerin D, Valea A, Zombre C, Ancel P, les personnels des CREN.

Background. – Spiruline, a microscopic algae with nutritious quality was put forward as food supplement to fight malnutrition in infant. **Population and methods. –** To assess its effectiveness, a survey was carried out among children with malnutrition whose Z-score was <2 for their age, in the Koudougou province, Burkina-Faso. Within five centers, three groups were defined at randomization: group 1 with usual nutritional rehabilitation program, group 2 as above + 5g.d^{-1} of spiruline, group 3 as above + spiruline + fish. 182 children, aged three months – three years, were originally involved. Six died (3.3%) and 11 hospitalised were excluded; the study was carried out on 165 children and lasted three months. Judging criteria were: length per aged, weight for length

group evolution and the corresponding Z-score at 60 et 90 days. **Results. –** At the inclusion, children were aged 14.6 months on average and weighed 6.7kg (Z-score of –3.2 weight/age) with a length of 71.4cm (–2.0 Z-score length/age) and weight for length of 0.093 (–2.5 Z-score). 9.4% had oedema. There were no noticeable differences between the three groups as to weight gain, length gain, weight for length gain. **Conclusion. –** A $5g.d^{-1}$ spiruline dose does not bring any benefit over 90 days, compared to traditionnal renutrition. Furthermore, at the moment, it is costly, and the battle against infant malnutrition cannot be based on one single element, such as a wonder drug, but on a national or local policy based on training, education, economical aid, and nutritional rehabilitation centers and infection treatment.

Commentaries: Arch Pediatr. 2004;11(5):465-7.
(In French)

Falquet J, von der Weid D.

L'étude publiée par Branger et al. surprend à plus d'un titre : on y trouve en effet la conclusion suivante : « La spiruline à la dose de 5 g/jour n'apporte aucun bénéfice par rapport à la renutrition traditionnelle sur 90 jours ». Or, on s'aperçoit que dans cette étude tous les groupes-tests ont reçu une renutrition « traditionnelle », ainsi qu'un supplément vitaminique, certains recevant en plus de la spiruline, voire de la spiruline et du poisson. Ainsi, le protocole lui-même exclut la possibilité de détecter un éventuel bénéfice de la spiruline par rapport à une renutrition « traditionnelle ». Au mieux, la conclusion pouvait être « la spiruline, ajoutée à une renutrition classique et à un supplément vitaminique ne produit pas d'effet discernable ». Bien sûr, une telle conclusion est à peu près dénuée d'intérêt, puisqu'on préconise généralement un apport de spiruline en tant que source de micronutriments lorsque précisément une renutrition « classique » et un apport vitaminique ne sont pas disponibles. Soulignons qu'il ne s'agit pas là d'une querelle d'interprétation puisqu'on trouve encore, dans le dernier paragraphe de l'introduction, cette déclaration : « L'objectif de cette étude était de mettre en évidence une action de la spiruline avec ou sans autres apports nutritionnels dans la malnutrition de l'enfant de moins de trois ans ». Objectif qui, comme mentionné plus haut, ne peut être atteint en suivant le protocole de l'étude. Bien d'autres points de ce travail soulignent malheureusement sa faible qualité scientifique, jusqu'à sa bibliographie, très partiale, qui attribue à tort un article sensationnaliste tiré d'un simple quotidien à l'un des signataires de cette lettre (D. von der Weid).

Fox R, Pagnon Y, Weber B.

En publiant l'article concernant l'action de la spiruline comme complément alimentaire dans les malnutritions, votre journal a rendu non intentionnellement un très mauvais service aux enfants malnutris où qu'ils soient. Il n'y a aucun doute : cela dissuadera de nombreux médecins et organisations d'assistance de recommander ou donner de la spiruline à des enfants sévèrement malnutris ou atteints de kwashiorkor.
Conclure que la spiruline est sans efficacité ne peut pas être pris au sérieux car le produit a été donné à des mères pour qu'il soit pris à la maison, entre leurs visites hebdomadaires au centre de renutrition. Sans intention de critiquer ces mères, quiconque a eu à s'occuper de problèmes de ce genre en Afrique (ou autre part) sait qu'il n'y a aucune preuve que la spiruline ait été réellement consommée par les enfants testés. La coutume dans ces cas là est que la nourriture de qualité est donnée à l'homme de la maison ou vendue sur le marché au village pour procurer un peu d'argent tellement nécessaire.
Une enquête récente menée auprès de personnes ayant participé à l'étude menée au Burkina Faso montre que les enfants n'ont été hospitalisés que dans un seul endroit. Dans les autres centres, la plupart des doses de spiruline étaient remises aux mères chaque semaine, mais le nombre de doses que celles-ci ont effectivement données aux enfants n'a pas été noté ni autrement vérifié.
Il faut d'ailleurs signaler que la prise de poids des enfants ayant reçu la renutrition traditionnelle est tout à fait insuffisante, probablement pour les mêmes raisons.

Cette étude a eu au moins le mérite de faire prendre conscience de cette difficulté aux responsables de certains centres : quel que soit le type de renutrition, ils hospitalisent maintenant les enfants pour surveiller leur prise alimentaire. En dernier lieu, la malnutrition protéino-énergétique est mesurée seulement en partie par des critères anthropométriques, spécialement pour les victimes du kwashiorkor (disparition des œdèmes). Les modifications hématologiques, sérologiques et en tout cas celles du comportement ne suivent pas étroitement les mesures anthropométriques.

Darcas C.

Le collectif TECHNAP est atteint par l'étude portant sur l'utilisation de la spiruline, étude concluant à son inefficacité pour remédier aux conséquences de la malnutrition, publiée dans les *Archives de Pédiatrie*. TECHNAP, ONG engagée dans la lutte contre la malnutrition, en particulier par son implication dans la production de spiruline au Bénin, à Pahou, est un collectif rassemblant des ONG ayant les mêmes motivations et méthodes dans le domaine de la nutrition. CODEGAZ, ONG produisant de la spiruline à Koudougou au Burkina Faso, fait partie de ce collectif.
L'équipe scientifique de notre association a, pour sa part, avisé votre rédaction des erreurs majeures relevées au niveau du protocole qui invalident les conclusions de l'étude. Pour mémoire, nous reprenons seulement ici la lacune essentielle, qui était l'absence presque totale du contrôle de l'ingestion de la spiruline par les enfants. En tant que président de TECHNAP, je m'élève contre les autres inexactitudes de cette étude :

- bien que n'étant pas en charge de la ferme de Koudougou, TECHNAP en connaît le fonctionnement, ayant souvent à comparer les performances respectives et similaires des installations de Pahou (Bénin) et de Koudougou (Burkina Faso). Aussi, lisant ce qui a été publié « *sur le coût manifestement élevé de la spiruline pour beaucoup de familles* », TECHNAP se demande d'où viennent les chiffres surprenants cités dans l'article. CODEGAZ ne sera pas en peine pour rétablir la vérité, mais encore une fois citer des prix faux et dissuasifs ne peut que décourager ceux qui ont l'intention de promouvoir la spiruline ;
- en fin d'article, on lit : « *cette conclusion ne remet pas en cause le principe des fermes de spiruline, dont la production peut être exportée en Occident en particulier, permettant le recueil de devises, dans des indications diverses comme la supplémentation à l'effort ou lors des régimes amaigrissants* ». Venant après l'assertion de l'inefficacité de la spiruline en tant que moyen de renutrition, c'est le coup de pied de l'âne : outre le ton condescendant voire méprisant de cette phrase, elle s'avère de plus inexacte, le principe des fermes de spiruline mises en place progressivement par TECHNAP, comme par CODEGAZ, étant la lutte contre la malnutrition, pour une part, et l'utilisation par la population locale du reste de la spiruline ainsi produite. La spiruline produite à Koudougou, ou à Pahou, n'est pas du tout exportée en Occident comme indiqué, mais consommée totalement en Afrique de l'Ouest. À noter que les productions de Koudougou et de Pahou ne suffisent pas à la demande. Une bonne partie de la spiruline est prescrite par les médecins burkinabés, ou béninois, qui ne doutent pas pour leur part de l'efficacité de ce micronutriment. CODEGAZ pourra vous fournir des données exactes, et TECHNAP peut lui aussi témoigner de l'ampleur des besoins béninois ;
- page 430, en bas de page, il est indiqué : « *Au total, dans cette étude, il n'a pas été trouvé d'avantages à proposer la spiruline comme complément alimentaire à la dose de 5 g/jour, contredisant les allégations non fondées de quelques références, souvent électroniques, ou fondées sur des études sans groupe témoin*. » Cette affirmation montre malheureusement bien l'état d'esprit des auteurs, puisque ces derniers considèrent que ce qui a pu être écrit sur les effets de la spiruline dans les cas de malnutrition est erroné, faisant partie d'un « *véritable culte* » voire nimbé de charlatanisme « *électronique* » (traduire : sur support Internet). TECHNAP s'étonne qu'on puisse refuser de voir la réalité : depuis près d'un demi-siècle, les observations montrant l'efficacité de la spiruline pour lutter contre la malnutrition s'accumulent. De nombreuses thèses attestent son rôle positif et de très nombreuses communications scientifiques ont dévoilé son contenu par des analyses chimiques et biologiques poussées, les substances identifiées validant a posteriori les effets observés. Cela relève-t-il de l'imagination ? Doit-on taxer d'illusion les succès obtenus sur le terrain par les personnels soignants en contact avec les enfants souffrant de malnutrition, constatant la réussite de leurs

efforts et redemandant de la spiruline ? Ce n'est pas scientifique mais cela devrait inciter les auteurs de l'article à plus de modestie et de prudence. Toutes les études n'ont certes pas la même importance. Il est pourtant regrettable que les auteurs ne mentionnent pas comme référence des études telles que : « Spirulina, a nutrition booster » des Dr *Thinakar Vel* et Pr Dr *N Edwin*, Department of Pædiatrics, Madurai Medical College, Madurai, Tamil Nadu, India (1999), et dont le sérieux n'est pas à mettre en doute. Les *quelques* références mentionnées par les auteurs concernant la spiruline dépassent aujourd'hui le millier. Il apparaît malheureusement ainsi que, à la fois le travail bibliographique qui aurait dû précéder l'étude, et les contacts avec des organismes médicaux ayant déjà l'expérience de la spiruline dans le Tiers-Monde, n'ont pas été effectués avec le sérieux nécessaire ;

- en fin de compte, TECHNAP, collectif rassemblant des ONG se souciant de promouvoir la spiruline pour combattre la malnutrition, proteste en leur nom contre les aberrations de cet article.

TECHNAP considère que, outre le fond, la forme de l'article est préjudiciable aux démarches humanitaires en cours dans le monde entier, qui s'appuient sur la spiruline dans la lutte contre la faim. Laisser de telles contrevérités se répandre dans l'opinion, c'est commettre une injustice contre ceux qui luttent pour améliorer l'alimentation des malnutris, en insinuant le doute, notamment chez les médecins et les organismes de santé.

Ann Nutr Metab. 2005;49(6):373-80.

Nutrition rehabilitation of HIV-infected and HIV-negative undernourished children utilizing spirulina

Simpore J, Zongo F, Kabore F, Dansou D, Bere A, Nikiema JB, Pignatelli S, Biondi DM, Ruberto G, Musumeci S.

The objective of this study was to assess the impact of an alimentary integrator composed of spirulina (Spirulina platensis; SP), produced at the Centre Médical St Camille of Ouagadougou, Burkina Faso, on the nutritional status of undernourished HIV-infected and HIV-negative children. We compared two groups of children: 84 were HIV-infected and 86 were HIV-negative. The duration of the study was 8 weeks. Anthropometric and haematological parameters allowed us to appreciate both the nutritional and biological effect of SP supplement to traditional meals. Rehabilitation with SP shows on average a weight gain of 15 and 25 g/day in HIV-infected and HIV-negative children, respectively. The level of anaemia decreased during the study in all children, but recuperation was less efficient among HIV-infected children. In fact 81.8% of HIV-negative undernourished children recuperated as opposed to 63.6% of HIV-infected children (Z: 1.70 (95% CI -0.366, -0.002, p = 0.088)). Our results confirm that SP is a good food supplement for undernourished children. In particular, rehabilitation with SP also seems to correct anaemia and weight loss in HIV-infected children, and even more quickly in HIV-negative undernourished children.

Nutr J. 2006;5:3.

Nutrition rehabilitation of undernourished children utilizing spiruline and Misola

Simpore J, Kabore F, Zongo F, Dansou D, Bere A, Pignatelli S, Biondi DM, Ruberto G, Musumeci S.

Background: Malnutrition constitutes a public health problem throughout the world and particularly in developing countries. **Aims:** The objective of the study is to assess the impact of an elementary integrator composed of spiruline (Spirulina platensis) and Misola (millet, soja, peanut) produced at the Centre Medical St Camille (CMSC) of Ouagadougou, Burkina Faso, on the nutritional status of

undernourished children. **Materials and methods:** 550 undernourished children of less than 5 years old were enrolled in this study, 455 showed severe marasma, 57 marasma of medium severity and 38 kwashiorkor plus marasma. We divided the children randomly into four groups: 170 were given Misola (731 ± 7 kcal/day), 170 were given spiruline plus traditional meals (748 ± 6 kcal/day), 170 were given spiruline plus Misola (767 ± 5 kcal/day). Forty children received only traditional meals (722 ± 8 kcal/day) and functioned as the control group. The duration of this study was eight weeks. **Results and Discussion:** Anthropometrics and haematological parameters allowed us to appreciate both the nutritional and biological evolution of these children. The rehabilitation with spiruline plus Misola (this association gave an energy intake of 767 ± 5 kcal/day with a protein assumption of 33.3 ± 1.2 g a day), both greater than Misola or spiruline alone, seems to correct weight loss more quickly. **Conclusion:** Our results indicate that Misola, spiruline plus traditional meals or spiruline plus Misola are all a good food supplement for undernourished children, but the rehabilitation by spiruline plus Misola seems synergically favour the nutrition rehabilitation better than the simple addition of protein and energy intake.

Med Trop. 2009;69(1):66-70.

Use of spirulina supplement for nutritional management of HIV-infected patients: Study in Bangui, Central African Republic

(Article in French)

Yamani E, Kaba-Mebri J, Mouala C, Gresenguet G, Rey JL.

Treatment of HIV-infected persons including nutritional management is a major concern in Africa and in particular in the Central African Republic (CAR). This six-month randomized prospective longitudinal study was carried out at the Friends of Africa Center that was a facility for comprehensive management of persons infected and affected by HIV in Bangui, CAR. The purpose of the study was to assess the impact of spirulina supplement on clinical and laboratory findings in HIV-infected patients who were not indications for ARV treatment. A total of 160 patients were randomly assigned to two groups. Patients in group 1 (n=79) received 10 grams of spirulina per day on a regular basis while patients in group 2 (n=81) received a placebo. In addition patients in both groups received dietary products supplied by the World Food Program (WFP). Follow-up of the 160 patients at three and six months showed that 16 patients had been lost from follow-up and 16 had died, with no difference in distribution between the two groups. A significant improvement in the main follow-up criteria, i.e., weight, arm girth, number of infectious episodes, CD4 count, and protidemia, was observed in both groups. No difference was found between the two groups except with regard to protidemia and creatinemia that were higher in the group receiving spirulina supplement. From a clinical standpoint results were less clear-cut since the Karnofsky score was better in the group receiving spirulina than in the group receiving the placebo at 3 months but not at 6 months and fewer patients presented pneumonia at six months. Further study over a longer period will be needed to determine if spirulina is useful and to evaluate if higher doses can have beneficial nutritional and immunitary effects without adverse effects, in particular renal problems.

Efficacy of *Spirulina platensis* as a nutritional supplement in malnourished HIV-infected adults: A randomised, single-blind study

(Submitted for publication in June 2010)

Azabji Kenfack M, Edie Dikosso S, Loni G, Onana A, Sobngwi E, Gbaguidi E, Nguefack T, von der Weid D, Njoya O, Ngogang J

Background: Malnutrition is a major global public health issue and its impact on communities and individual is more dramatic in Sub-Saharan Africa, where it is compounded by widespread poverty and generalized high prevalence of human immunodeficiency virus (HIV). Therefore, malnutrition

should be addressed through a multisectorial approach, and malnourished individuals should have access to nutritional rehabilitation molecules that are affordable, accessible, rich in nutrient and efficient. We thus assessed the efficacy of two affordable and accessible nutritional supplements, Spirulina platensis versus soya beans among malnourished HIV-infected adults. **Methods:** Undernourished patients, naïve of antiretroviral treatment (ART), aged 18 to 35 years were enrolled and randomly assigned to two groups. The first group received spirulina (Group A) as food supplement and the second received soya beans (Group B). Food supplements were auto-administered daily, the quantity being calculated according to weight to provide 1.5g/kg body weight of proteins with 25% from supplements (spirulina and soya beans). Patients were monitored at baseline and followed-up during twelve weeks for anthropometric parameters, body composition, haemoglobin and serum albumin, CD4 count and viral load. **Results:** Fifty-two patients were enrolled (Group A: 26 and Group B: 26). The median age was 27.4±4.8 years (Group A) and 28.5±4.7 (Group B) with no significant difference between groups (P=0.10). After 12 weeks, weight and BMI significantly improved in both groups (P<0.001 within each group). The mean gain in weight and BMI in Group A and B were 4.8 vs 6.5 kg, (P=0.68) and 1.3 vs 1.90 Kg/m2, (P=0.82) respectively. In terms of body composition, fat free mass (FFM) did not significantly vary within each group (40.5 vs 42.2Kg, P=0.56 for Group A; 39.2 vs 39.0Kg, P=0.22 for Group B). But when compared between the two groups at the end of the trial, FFM was significantly higher in the spirulina group (42.2 vs 39.0Kg, P=0.01). The haemoglobin level was significantly increased within groups (P<0.001 vs P<0.001) with no difference between groups (P=0.77). Serum albumin level did not significantly increased within groups (P<0.90 vs P<0.82) with no difference between groups (P=0.39). The increase in CD4 cell count value within groups was significant (P<0.001 in both groups), with a significantly higher CD4 count in the spirulina group compared to subjects on soya beans at the end of the study (P=0.02). Within each group, HIV viral load significantly reduced at the end of the study (P<0.001 for each group). Between the groups, the viral load was similar at baseline but significantly reduced in the Spirulina group (P<0.001), compared to Group B (P=0.04). **Conclusion:** We therefore conclude in this preliminary study, firstly,that both spirulina and soja improve on nutritional status of malnourished HIV-infected patients but in terms of quality of nutritional improvement, subjects on spirulina were better off than subjects on soya beans. Secondly, nutritional rehabilitation improves on immune status with a consequent drop in viral load.

Cell Mol Immunol. 2011; Jan 31: advance online publication.

The effects of Spirulina on anemia and immune function in senior citizens

Selmi C, Leung PS, Fischer L, German B, Yang CY, Kenny TP, Cysewski GR, Gershwin ME

Anemia and immunological dysfunction (i.e. immunosenescence) are commonly found in older subjects and nutritional approaches are sought to counteract these phenomena. Spirulina is a filamentous and multicellular bule-green alga capable of reducing inflammation and also manifesting antioxidant effects. We hypothesized that Spirulina may ameliorate anemia and immunosenescence in senior citizens with a history of anemia. We enrolled 40 volunteers of both sexes with an age of 50 years or older who had no history of major chronic diseases. Participants took a Spirulina supplementation for 12 weeks and were administered comprehensive dietary questionnaires to determine their nutritional regimen during the study. Complete cell count (CCC) and indoleamine 2,3-dioxygenase (IDO) enzyme activity, as a sign of immune function, were determined at baseline and weeks 6 and 12 of supplementation. Thirty study participants completed the entire study and the data obtained were analyzed. Over the 12-week study period, there was a steady increase in average values of mean corpuscular hemoglobin in subjects of both sexes. In addition, mean corpuscular volume and mean corpuscular hemoglobin concentration also increased in male participants. Older women appeared to benefit more rapidly from Spirulina supplements. Similarly, the majority of subjects manifested increased IDO activity and white blood cell count at 6 and 12 weeks of Spirulina supplementation. Spirulina may ameliorate anemia and immunosenescence in older subjects. We encourage large human studies to determine whether this safe supplement could prove beneficial in randomized clinical trials.

Appendix 2: Article published on the BBC News website about Plumpy'nut®

Legal fight over hunger wonder-product

BBC NEWS – Hugh Schofield – 8 April 2010

Should a revolutionary humanitarian food product be protected by commercial patent, when lifting restrictions might save millions of starving children?

That is the moral conundrum at the heart of a bitter transatlantic legal dispute.

On one side are the French inventors of Plumpy'nut, a peanut paste which in the last five years has transformed treatment of acute malnutrition in Africa. Nutriset, the Normandy-based company, says the patent is needed to safeguard production of Plumpy'nut in the developing world, and to stop the market being swamped by cheap US surpluses.

And on the other side are two American not-for-profit organisations that have filed a suit at a Washington DC federal court to have the patent overturned. They say they are being stopped by Nutriset from manufacturing similar – and cheaper – peanut-based food products, despite the proven demand from aid agencies.

"By their actions, Nutriset are preventing malnourished children from getting what they need to survive. It is as simple as that," said Mike Mellace, of the San Diego-based Mama Cares Foundation.

Wonder-product

For Nutriset's general manager, Adeline Lescanne, such accusations are unfair and distressing. "No child in the world has even been denied access to the product as a result of the patent issue, she said. If they had – how would any of us be able to go to work in the morning?"

The one point of agreement between the two parties is that Plumpy'nut is that rare thing: a wonder-product. A blend of peanut-butter, powdered milk, sugar and vegetable oil fortified with vitamins and minerals, the paste won its glowing reputation during a 2005 food crisis in Niger.

"Before, we had to hospitalise malnourished children – which is a huge drain on resources. With Plumpy'nut, largely because it does not have to be mixed with clean water, the children can stay at home, said Stephane Doyon, nutrition team leader at Medecins Sans Frontieres (Doctors without Borders). In 2002 it took 2,000 staff to treat 10,000 children during a famine in Angola. In Niger we needed just 150 staff for the same number of patients. Thanks to Plumpy'nut, mass treatment is suddenly possible."

Such has been its success that in the aid world Plumpy'nut is today the standard "ready-to-use therapeutic food" (RUTF), with Nutriset and its partners providing some 90% of global supply. But it is this near-monopoly which is now being challenged. For Mike Mellace – whose proposed alternative is called Re:vive – it is absurd to be barred from making something which is in essence very simple.

"Plumpy'nut is not some secret formula. Basically it's fortified Nutella. Anyone with a basic knowledge of peanuts could have developed it! he said. But at Nutriset they do all they can to stop people competing. We have had cease-and-desist letters from them, and lots of other companies around the world have too."

African production

According to Mellace, worldwide demand for RUTFs can only be met if supply is opened up – especially in the US, with its large peanut industry. He cites UN figures showing that while 26 million children currently suffer from malnutrition, only between one and two million are receiving Plumpy'nut or equivalents.

At Nutriset, they do not dispute the figures – but they do offer a very different interpretation.

First, the patent is not universal. In a dozen countries such as Niger, Malawi and Kenya, Nutriset has set up a network of partnerships and franchises so that Plumpy'nut can be made locally and with locally-grown produce.

"Our motto is nutritional autonomy, said Nutriset's communications manager, Remi Vallet. We want poor countries to be able to produce the nutrients they need in a sustainable way. If the US companies were able to beat the patent, the global volume of RUTFs would of course go up. But it would also mean the end for our local partners in Africa, who wouldn't be able to compete. That is not what we want."

As for the question of demand, Nutriset says it and its partners have plenty of spare capacity. "It is true that something like only 5% of malnourished children are getting RUTFs. But the problem there is not lack of production. It's because at the moment there is neither the international funding nor the systems in place to provide RUTFs," Mr Vallet said.

'Aggressive'

Underlying the Nutriset position is concern over the United States' historic policy on food aid, which remains heavily influenced by domestic agricultural lobbies. The US is the world's biggest food donor, but laws there require that 99% of aid money be spent on American-grown surpluses. Nutriset believes its would-be competitors in the US are trying to cash in on this opportunity – to the huge detriment of local producers in Africa.

That argument holds little water for Mellace, who notes that Nutriset has itself just opened a joint venture in Rhode Island. The not-for-profit company called Edesia will be America's first ever RUTF producer. "They come here and get a $2m USAID grant to set up a factory, and then they stop us producing basically the same thing. They are talking out of both sides of their mouth!" he said.

Mellace's case against Nutriset was given added force after Medecins Sans Frontieres also criticised the French company for a "policy of aggressive protection of… patents". In a letter sent in November, the charity accused Nutriset of invoking patent rights to block a Norwegian competitor from transporting a Plumpy'nut equivalent via Kenya. The dispute was subsequently resolved amicably.

"We are not against patents per se, said Stephane Doyon of Medecins Sans Frontieres. But we do believe that in a domain as sensitive as humanitarian aid they need to handled with extreme flexibility."

At Nutriset they say they agree. "We know a patent for a life-saving food product is not the same as a patent for a toaster, said Remi Vallet. It needs special management, and we give it."

"We are confident that we are acting for the best, said Adeline Lescanne. Our goal is long-term – so that governments in the developing world can eventually take charge of nutrition by themselves."

This article is available on the BBC News website: http://news.bbc.co.uk/2/hi/europe/8610427.stm

Appendix 3: Draft resolution at the 2005 UN General Assembly for a stance on the use of spirulina

United Nations A/C.2/60/L.14/Rev.1

General Assembly

Distr.: Limited
8 November 2005

Original: English

Sixtieth session
Second Committee
Agenda item 52
Sustainable development

Burundi, Cameroon, Dominican Republic, Nicaragua and Paraguay: revised draft resolution

The use of spirulina to combat hunger and malnutrition and help achieve sustainable development

The General Assembly,

Noting with concern that hunger and malnutrition are a major impediment to sustainable development, and reaffirming that reducing hunger is a primary target of the Millennium Development Goals,

Recognizing the value of new technologies to enhance food security in environmentally compatible ways, including through public-private alliances for rural development,

Noting that the nutritional benefits of spirulina (food micro-algae) have been reported in academic research and in the work of agencies of the United Nations system, including the Food and Agriculture Organization of the United Nations and the World Health Organization,

Noting in particular that the merits of spirulina have been recognized through the adoption of international agreements, namely the Free Agreement for Cooperation in Scientific Research and Humanitarian Use of Micro-alga Spirulina as Food[1] and the Convention for the Use of Food Micro-algae and the Intergovernmental Institution for the Use of Spirulina against Malnutrition,

Taking into account that an intergovernmental organization known as "Convention for the Use of Food Micro-algae and the Intergovernmental Institution for the Use of Spirulina against Malnutrition" has been established in keeping with the above agreements and has been granted observer status in the work of the Economic and Social Council, in accordance with Council decision 2003/212 of 5 March 2003,

[1] United Nations, *Treaty Series*, vol. 2151, No. 37542.

05-59373 (E) 101105
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Aiming to encourage greater attention to the production and use of spirulina for the reduction of hunger and poverty and to combat the food crises,

1. *Takes note* of the potential of spirulina to reduce hunger and malnutrition and to improve the prospects for sustainable development;

2. *Calls upon* Member States, United Nations agencies and other intergovernmental organizations, as well as non-governmental organizations and the private sector, to encourage the production and use of spirulina;

3. *Emphasizes* the importance of assisting national activities for the production and use of spirulina, especially in member countries of the Convention for the Use of Food Micro-algae and the Intergovernmental Institution for the Use of Spirulina against Malnutrition;

4. *Decides* to review, at its sixty-second session, the progress made in these areas, and requests the Secretary-General to submit a report, through the Economic and Social Council, on the relevant efforts.

Appendix 4: FAO 2008 review on spirulina

FAO Fisheries and Aquaculture Circular No. 1034 FIMA/C1034 (En)

ISSN 2070-6065

A REVIEW ON CULTURE, PRODUCTION AND USE OF SPIRULINA AS FOOD FOR HUMANS AND FEEDS FOR DOMESTIC ANIMALS AND FISH

ABSTRACT

Spirulina are multicellular and filamentous blue-green microalgae belonging to two separate genera *Spirulina* and *Arthrospira* and consists of about 15 species. Of these, *Arthrospira platensis* is the most common and widely available spirulina and most of the published research and public health decision refers to this specific species. It grows in water, can be harvested and processed easily and has significantly high macro- and micronutrient contents. In many countries of Africa, it is used as human food as an important source of protein and is collected from natural water, dried and eaten. It has gained considerable popularity in the human health food industry and in many countries of Asia it is used as protein supplement and as human health food. Spirulina has been used as a complementary dietary ingredient of feed for poultry and increasingly as a protein and vitamin supplement to aquafeeds.

Spirulina appears to have considerable potential for development, especially as a small-scale crop for nutritional enhancement, livelihood development and environmental mitigation. FAO fisheries statistics (FishStat) hint at the growing importance of this product. Production in China was first recorded at 19 080 tonnes in 2003 and rose sharply to 41 570 tonnes in 2004, worth around US$7.6 millions and US$16.6 millions, respectively. However, there are no apparent figures for production in the rest of the world. This suggests that despite the widespread publicity about spirulina and its benefits, it has not yet received the serious consideration it deserves as a potentially key crop in coastal and alkaline areas where traditional agriculture struggles, especially under the increasing influence of salination and water shortages.

There is therefore a role for both national governments – as well as intergovernmental organizations – to re-evaluate the potential of spirulina to fulfill both their own food security needs as well as a tool for their overseas development and emergency response efforts. International organization(s) working with spirulina should consider preparing a practical guide to small-scale spirulina production that could be used as a basis for extension and development methodologies. This small-scale production should be orientated towards: (i) providing nutritional supplements for widespread use in rural and urban communities where the staple diet is poor or inadequate; (ii) allowing diversification from traditional crops in cases where land or water resources are limited; (iii) an integrated solution for waste water treatment, small-scale aquaculture production and other livestock feed supplement; and (iv) as a short- and medium-term solution to emergency situations where a sustainable supply of high protein/high vitamin foodstuffs is required.

A second need is a better monitoring of global spirulina production and product flows. The current FishStat entry which only includes China is obviously inadequate and the reason why other countries are not included investigated. Furthermore, it would be beneficial if production was disaggregated into different scales of development, e.g. intensive, semi-intensive and extensive. This would allow a better understanding of the different participants involved and assist efforts to combine experience and knowledge for both the further development of spirulina production technologies and their replication in the field. A third need is to develop clear guidelines on food safety aspects of spirulina so that human health risks can be managed during production and processing. Finally, it would be useful to have some form of web-based resource that allows the compilation of scientifically robust information and statistics for public access. There are already a number of spirulina-related websites (e.g. www.spirulina.com, www.spirulinasource.com) – whilst useful resources, they lack the independent scientific credibility that is required.

Habib, M.A.B.; Parvin, M.; Huntington, T.C.; Hasan, M.R.
A review on culture, production and use of spirulina as food for humans and feeds for domestic animals and fish.
FAO Fisheries and Aquaculture Circular. No. 1034. Rome, FAO. 2008. 33p.

The full publication is available at this address: ftp://ftp.fao.org/docrep/fao/011/i0424e/i0424e00.pdf

Appendix 5: Excerpt from the background paper presented by Michaelsen *et al.* at the 2008 Consultation on moderate malnutrition organized by the WHO

Food Nutr Bull. 2009 Sep;30(3 Suppl):S343-404.

Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age

Michaelsen KF, Hoppe C, Roos N, Kaestel P, Stougaard M, Lauritzen L, Molgaard C, Girma T, Friis H.

Spirulina

Spirulina belongs to the cyanobacteria. Unlike the true microalgae, *Spirulina* does not have cellulose walls, and therefore protein and other nutrients from *Spirulina* are more bioavailable than those from yeasts and unicellular algae [253]. Although the nutritional interest of other microorganisms has faded due to problems of digestibility, the cyanobacterium *Spirulina* may offer simple production of a high-quality nutritional supplement.

The protein quality of *Spirulina* is high, and it is reported to be rich in highly available iron, calcium, potassium, and phosphorus [254]. *Spirulina platensis* has a high content of essential n-6 PUFAs, linoleic acid (C18:2 n-6), and γ-linolenic acid (C 18:3 n-6). The total lipid content is around 6%, of which around 40% is PUFA [255, 256]. With a total energy content of around 340 kcal/100 g, the fat contributes 16 E%.

Spirulina grows naturally in some alkali lakes of Africa and can be produced in tanks appropriate for small-scale industry. However, when produced in ponds or basins it tends to accumulate heavy metals, so that water quality is very important. Alkaline production reduces the risk of contamination or overgrowth of most other microorganisms, as they cannot survive the high pH caused by *Spirulina*.

Spirulina (10 g daily) was used in an 8-week nutritional rehabilitation study of undernourished children in Burkina Faso [257]. Improved weight gain was reported with *Spirulina* as compared with traditional millet meals, particularly for HIV-negative children. Hemoglobin also improved with *Spirulina* supplementation. However, the randomization procedure was poorly described in this study. In another, larger study by the same group, *Spirulina* and misola (millet, soy, peanuts, and sugar) were compared with a two-by-two factorial design for nutritional rehabilitation of severely and moderately underweight children aged 6 to 60 months [256]. Unfortunately, the children receiving the control diet were chosen from those families who refused to be part of the trial. However, it appeared that a combination of *Spirulina* and misola was superior to *Spirulina* or misola alone, and that *Spirulina* or misola alone was superior to the control diet (of unknown composition). In conclusion, although the evidence is sparse, it seems that *Spirulina* deserves attention as a potential natural dietary supplement for use in the nutritional rehabilitation of moderately malnourished children.

Conclusions and recommendations on algae

» Seaweeds are rich in iron, calcium, iodine, and a variety of antioxidants and contain several essential amino acids.
» Seaweeds are traditionally used in East Asian food culture, but due to their sensory characteristics seaweeds may be difficult to introduce into other food cultures.
» In East Asia and in coastal regions where seaweeds are accepted, they could be promoted as a nutritious component of diets for children with moderate malnutrition.
» Microalgae may be good sources of micronutrients and high-quality protein, but availability might be low due to the cellulose content.
» *Spirulina*, a cyanobacterium, seems to have protein and micronutrients with a better bioavailability and has a high content of n-6 PUFAs.

Research recommendations

» Some studies suggest that *Spirulina* could have a role in treating children with moderate malnutrition, but this should be investigated further.