

Full Length Research Paper

## The nutritional quality of *Spirulina platensis* of Tamenrasset, Algeria

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***Spirulina platensis*, a blue green microalga, has been used since ancient times as a source of food because of its high protein content (65%) and nutritional value. Lipids isolated from *S. platensis* have been shown to contain high levels of polyunsaturated fatty acids, including linolenic acid which is a precursor of arachidonic acid; this cyanobacteria contains, also, several kinds of sterols. The aim of this study is to evaluate the nutritional quality of *S. platensis* of Tamenrasset, Algeria. This study shows the analysis of nutritional quality of *S. platensis* of Tamenrasset, Algeria, to know nutritional value of our local strain. Biochemical analysis was performed for moisture, protein, glucose, lipid and minerals content. The chemical composition is based on the identification of fatty acids, using gas chromatography and quantification of the mineral elements by using the atomic absorption spectrometry (AAS). The results showed that *S. platensis* of Algeria has an important nutritional quality.**

**Key words:** *Spirulina platensis*, nutritional, quality, proteins, fatty acids.

### INTRODUCTION

*Spirulina platensis* is a cyanobacterium which acquired the ability for photosynthesis before any other organism and is considered to be the ancestor from which the higher plants evolved. The use of *S. platensis* as food by indigenous populations in different parts of the world is well documented. *S. platensis* was rediscovered in the mid-1960s (Subramanian, 2004).

Nowadays, this organism is used as a food supplement and is marketed in the form of pills, capsules and powder or incorporated into various types of food like cakes, biscuits, noodles, health drinks, etc. Various countries are developing strategic programs for the production and use of *S. platensis* (Subramanian, 2004).

Microalgae have received increased attention due to

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the fact that they represent one of the most promising sources of biological activity compounds that could be used as functional ingredients (Pulz and Gross, 2004). Their balanced chemical composition (good quality proteins, balanced fatty acid profiles, vitamins, antioxidants and minerals) and their interesting attributes can be applied in the formulation of novel food products (Spolaore et al., 2006).

*S. platensis*, a filamentous blue-green (cyanobacteria) alga, attracted the interest of researchers. The biochemical components provide the marketing value to *S. platensis*, it is one of the most promising microalgae for culture due to its high nutritional values (Baylan et al., 2012). It is also well known as a source of protein (60-70 g/100 g) of high biological value, since it is a rich source of vitamins, mainly vitamin B12 and pro-vitamin A, minerals, especially iron and  $\gamma$ -linolenic acid, an essential fatty acid precursor for prostaglandins (Belay et al., 1993; Sempore et al., 2006; Habib et al., 2008).

The concentrated nutritional profile of *S. platensis* occurs naturally, so it is ideal for those preferring a whole food supplement to artificial nutrient sources. *S. platensis*, the blue-green alga, has a unique blend of nutrients that no single source can provide. Moreover, most research has focused on the health effects of *S. platensis* as a dietary supplement for humans and animals. Many studies have shown the effects of these microalgae that may result in significant therapeutic applications: an anti-cancer effect (Hirahashi et al., 2012; Mao et al., 2005; Khan et al., 2005; Basha et al., 2008), a hypolipidemic effect (Narmadha et al. 2012) and a protective effect against diabetes and obesity. These advantages make *S. platensis* a good raw material for the healthy food (Anitha and Chandralekh, 2010).

The production of this small alga is based on environmental conditions (water, climate, salinity, etc.) and its trade and economic interest were highlighted by the Algerian researchers to glimpse the culture of *S. platensis* in southern Algeria. The aim of this study is to analyze *S. platensis* grown in southern Algeria, Tamenrasset and demonstrate its nutritional quality.

## MATERIALS AND METHODS

### Source of *S. platensis*

The strain of *S. platensis* powder used was obtained from Tamanrasset (South of Algeria). The location in the Tamanrasset region is at the Guelta of Palm located at 1824 m altitude.

### Physicochemical analysis of *S. platensis*

A pH meter was used to determine the pH of a solution at 4% *S. platensis* (4 g *S. platensis* powder diluted in 100 mL distilled water). Determination of the humidity content was done according to the official method of American Oil Chemist's Society (AOCS) in 1990. The results were expressed in percentage weight of water relative to the initial weight, by the following equation:

$$H = \frac{m_1 - m_2}{m_1 - m_0} \times 100$$

H is the humidity content expressed as percentage (%) by mass;  $m_0$  is the mass in grams of the empty capsule;  $m_1$  is the mass in grams of the dish and the sample;  $m_2$  is the mass in grams of the dish and the dry residue.

It should be noted that this method does not only measure the water content. We recommend using the term "mass loss", as a correct term instead of the one already used "humidity", because the determination of loss is not only water, but any volatile compounds in the operational conditions of drying (Le Meste, 2002).

The protein content was determined using Kjeldahl method, the results were expressed using the following equation:

$$P = \frac{1.4 \times N \times (V_1 - V_0)}{m} \times 6.25$$

P is the protein ratio expressed as a percentage (%) by weight; N is the normal hydrochloric acid;  $V_1$ ,  $V_0$  is the titration volumes of the sample and blank; m is the mass in grams of the initial sample; 6.25 is the conversion factor of *S. platensis* protein.

The anthrone colorimetric method described in research method was applied to measure the total soluble sugar content. One-tenth of a dried gram sample (shattered, fineness: passed through 100-mesh) was weighed in a 10 mL centrifuge tube, and 6-7 mL of 80% ethanol was added to it. The sample was heated in an 80°C water bath for 30 min, then centrifuged (3000 rpm/min) for 5 min. The supernatant was collected, and the extraction was repeated twice (3000 tr/min for 10 min each) (Xinglu and Qiufeng, 2011).

The total supernatant was collected into a flask, and 80% ethanol was added to total volume of 50 mL. Then, 1 mL of solution was taken, and 1.5 mL of water was added, followed by 6.5 mL of anthrone reagent. The sample was mixed and incubated at room temperature (18-30°C) for 15 min to allow color developing. The absorbency at 620 nm wavelength was measured after the sample was cooled down.

$$\text{Content of total soluble sugar \%} = \left\{ \left[ \frac{C \times (V/a)}{W \times 10^6} \right] \times 100 \right\}$$

Where, C is the glucose content obtained by referring to the standard curve ( $\mu\text{g}$ ); V is the total volume of the extracted solution (mL); a is the volume of sample solution for color developing (mL); W is the weight of sample (g).

The fat content is determined by the Soxhlet extraction method by using hexane as solvent (NF V 03-905). 50 g of sample was placed in the Soxhlet and added to 500 ml of hexane in the flask, and the temperature was set to 60°C. Thereafter, most of the solvent were removed using the rotary evaporator. The flask containing the lipid was placed in an oven for 30 min at 103°C, then in a desiccator for 30 min. The lipid weight was obtained by the difference between the final weight and the initial weight of the flask. The results are given by the following formula:

$$\text{Fat content (\% MS)} = (A - B) \times \frac{100}{C} \times \frac{\text{MS}}{100}$$

Where, A is the weight of the ball + extract in grams; B is the weight of the empty flask in grams; C is the weight of the sample in grams; MS is the dry matter percentage.

The ash content (mineral) was estimated to incineration in a muffle furnace to 550°C so as to obtain all of the cations in the form of carbonate and other anhydrous inorganic salts (AOCS, 1990). The results expressed in percentage by weight of ash to the initial weight ratios were obtained from the following expression:

**Table 1.** Results of physicochemical analysis of *S. platensis*

Parameter	<i>S. platensis</i>
Potential of hydrogen (pH)	7.81 ±0.05
Humidity (%)	5.42 ± 0.031
Protein (%)	60.32± 0.15
Lipid (%)	7.28 ±0.021
Rate of total sugars (%)	17.63 ±0.133
Rate ash (%)	6.88 ± 0.05
Caloric intake (kcal)	369.28

$$C = \frac{m_3 - m_0}{m_1 - m_0} \times 100$$

C is the ash, expressed as a percentage (%) by weight;  $m_0$  is the mass in grams of the empty crucible;  $m_1$  is the mass in grams of the crucible and the sample;  $m_2$  is the mass in grams of the crucible and its contents (ash) after incineration.

#### Determination of mineral contents by atomic absorption spectroscopy

Atomic absorption spectrometry is a method of elemental analysis which uses the property of atoms excitation by the addition of an external energy as a defined electromagnetic radiation (photon) frequency,  $\nu$  (Lynch, 2001).

The mineral elements (Mg, Cu, Fe, ZN, K and Na) were determined by atomic absorption spectrometry type (Varian AA 240) related to the flame atomizer (GTA 120). Indeed, the concentration of minerals in ppm was determined using standard prepared curves.

#### The chemical composition of fatty acids

The fatty acid composition of *S. platensis* was determined by gas chromatography (GC). The fat tested was obtained by esterification by soxhlet of *S. platensis*. 0.35 g of *S. platensis* in a flask of 100 mL was added to 6 mL of a methanol solution (2 g NaOH in 100 mL methanol) for 10 min at 70°C; was added after 7 mL of BF<sub>3</sub> (2 min at 70°C), then 5 mL N-heptane (1 min), and adjusted to 100 mL with a saturated NaCl solution. After decanting the solution, the lipid phase was recovered.

The condition for the GPC analysis included: instruments, Chromatography Chrompack with detector CP9002, injector FID SPLIT 1/100, carrier gas: Azote, column DB23 (column length: 30 m; column diameter: 0.32 mm; film thickness: 0.25  $\mu$ m); temperatures: injection, 250°C; detector, 250°C; temperature programming in column, starting temperature was 150°C and final temperature, was 220°C; rate of temperature increase was 4°C/min, amount injected is 0.2  $\mu$ L; paper speed was 0.5 Cm/mN

#### Statistical analysis

The results were analyzed using one-way analysis of variance (STATISTICA), (Version 10). A p value < 0.05 was regarded as statistically significant.

## RESULTS AND DISCUSSION

### Physicochemical analysis of *S. platensis*

The results of physicochemical analysis performed on *S. platensis* are shown in Table 1. The composition variety depends on growing conditions and production techniques of *S. platensis*; some differences were observed. It was noticed that the pH of *S. platensis* was 7.81 ± 0.05, a slightly basic pH. Moisture (water content) is the water content of the *S. platensis* powder, measured as a percentage of water relative to its dry weight. It is 5.42 ±0.031% for our test; this value is similar to that found by previous work: 4-6% by Espiard (2002) and 4-7% by Pierlovisi (2007).

*S. platensis* is rich in protein because they represent 50-70% of its dry matter (Clément, 1975; Fox, 1999). The highest values are obtained when the harvest takes place at the beginning of the light period. On the other hand, in comparison with other vegetable protein sources which are less rich, *S. platensis* is consumable as a whole (Dillon et al., 1995). This value (60.32 ±0.15%) showed great value when compared with the average protein content of some legume seeds: bean (22%), peas (22%) and even soybeans (38%). *S. platensis* appears as one of the greatest protein-rich plant species (Léonard and Compère, 1967).

The incorporation of *S. platensis* powder resulted in considerable improvements of the contents of protein in the product of foods (Rodríguez De Marco et al., 2014). Protein contents of *S. platensis* show very high digestibility (83-90% as compared to 95.1% for pure casein) due to lack of cellulose walls. Hence, cooking is not necessary to increase the proteins availability (Hoseini et al., 2013). The major protein constituents with significant beneficial health effects are the phycobiliproteins, phycocyanin C and allophycocyanin (at approximately 10:1 ratio), which have linear tetrapyrrole prosthetic groups (phycocyanobilin) covalently linked to specific cysteine residues of the proteins. Phycocyanins constitute about 15-25% of the dry weight of the microalgae (Bermejo et al., 1997; Romay et al., 2003). Phycocyanins can be considered as a safe natural food colorant in non-acidic foodstuffs such as chewing gum, confectionaries and dairy products (Downham and Collins, 2000)

The carbohydrate content was 17.63 ± 0.133%, and this value is similar to the values of other researchers which represented 13.6 to 25% carbohydrates of the dry matter of *S. platensis*. The wall of *S. platensis* as Gram-negative bacteria, is composed of glucosamine and muramic acid associated with peptides (Quillet, 1975).

The cell wall of *S. platensis* has an approximate 0.5% of its dry weight glycogen content (Quillet, 1975; Fox, 1999). The major polymeric component of *S. platensis* is a branched polysaccharide, structurally similar to glycogen. High molecular weight anionic polysaccharides with antiviral and immunomodulating activities have been isolated from *S. platensis* (Parages et al., 2012).

**Table 2.** Composition of the inorganic powder of *S. platensis* (mg/g).

Inorganic powder	Fe	Zn	Ca	Na	K
<i>S. platensis</i> (this study)	0.88	0.009	0.22	27	20
<i>S. platensis</i> (Johnson and Shubert, 1986)	0.58-1.8	0.021-0.040	1.3-14	4.5	6.4- 15.4

According to Hayashi (1996) and Lee and Coll (1998), the antiviral and immunomodulating activities of polysaccharides of *S. platensis* are discussed in the related sections. A sulphated polysaccharide fraction with antiviral property (calcium spirulan) has been extensively purified and shown to be composed of rhamnose, 3-O-methylrhamnose (acofriose), 2,3-di-O-methylrhamnose, 3-O-methylxylose, uronic acids and sulfate.

The fat content is 7.28% dry weight; *S. platensis* can be considered to have very high protein content and less fat sources. This feature gives it the advantage of being relatively easy to be kept away from lipid oxidation and rancidity phenomena. Lipids generally represent 6 to 8% of the dry weight of *S. platensis* but this percentage may reach 11%. The total lipid composition is characterized by a balance between saturated fatty acids and polyunsaturated fatty acids (Hudson and Karis, 1974).

Lipids contents of *S. platensis*, are separated into a saponifiable fraction (83%) and a non-saponifiable fraction (17%), containing essential pigments, paraffin, sterols and terpene alcohol. Half of the total lipids are fatty acids and cholesterol (< 0.1 mg/100 g of *S. platensis* dry mass) (Gershwin and Belay, 2008), which is a component of *S. platensis* sterol fraction (Clement, 1975).

*S. platensis* is rich in mineral ( $6.88 \pm 0.05\%$ ) in our study; *S. platensis* contains all essential minerals for the body: iron, magnesium, manganese, potassium, calcium, phosphorus, zinc and selenium (uncommon). Meanwhile, *S. platensis* is one of the best natural sources of iron according to Fox (1999). The calorific value of *S. platensis* is not very high (369.28 kcal/g), it is easily restored by its protein and vitamin value, when compared with other energy foods such as cereals.

#### Determination of mineral contents by atomic absorption spectroscopy (NF V05-113 1972)

Analytical results of the mineral composition of the powder of *S. platensis* are shown in Table 2. *S. platensis* is rich in iron bioavailability which is two to three times higher than that of meat, and proves very useful in improving iron deficiency-anemia associated with protein-energy malnutrition (Pierlovisi, 2007).

*S. platensis* is also a good source of magnesium bioavailable in humans. Potassium is richly represented in *S. platensis*; interesting asset in industrialized countries where the sodium/potassium ratio is often too high.

Finally, it is possible to enrich *S. platensis* strains with some trace elements (zinc, selenium, etc.) (Falquet, 2012).

The high levels of several micronutrients, especially minerals (iron 0.58-1.8, calcium 1.3-14, phosphorus 6.7-9.0 and potassium 6.4-15.4 g/kg) in *S. platensis*, which have made it suitable nutritional supplement for vegetarians, are due to absorption of these elements while growing. Consequently, mineral content of *S. platensis* depends on source and culture conditions. Calcium, phosphorus and magnesium are present in quantities comparable to those found in milk. *S. platensis* is considered to be an iron rich food, with an iron content ten times higher than in common iron rich foods. Absorption of *S. platensis* iron is 60% more than ferrous sulphate (present in iron supplements) (Falquet, 2012).

#### The chemical composition of fatty acids

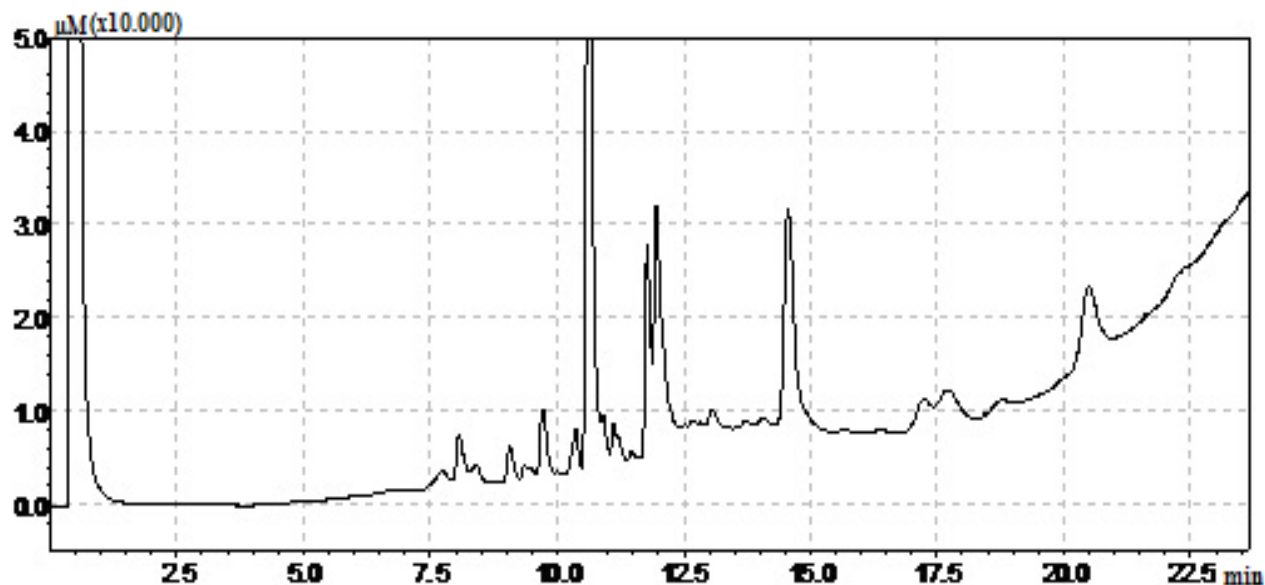
Figure 1 illustrates the profile and the percentages of the components identified by CPG as shown in Table 3.

The fatty acid profile of *S. platensis* varies depending on the strain studied. *S. platensis* contains mainly polyunsaturated fatty acids essential for 18 carbon atoms, in particular the omega-6 ( $\omega_6$ ). It is indeed one of the best sources of gamma linolenic acid (18: 3 $\omega_6$ ) after human milk and some expensive vegetable oils according to Pierlovisi (2007).

The presence of gamma-linolenic acid, C18: 3 omega - 6 was noted because of its scarcity in common foods and its presumed high food value (Kay, 1991; Cohen and Voushak, 1991; Otles and Pire, 2001).

The omega-3 and omega-6 fatty acids in *S. platensis* would prevent the accumulation of cholesterol in the body. This may partly explain the decrease in cholesterol and triglycerides observed in experiments for Ramamoorthy and Premakumari (1996) and Samuels et al. (2002).

*S. maxima* and *S. platensis* contain  $\gamma$  linolenic acid (GLA), which comprises 10-20 and 49% of their fatty acids, respectively. *S. platensis* can be considered as a good source of GLA. *S. maxima* also contains unsaturated oleic and linoleic acids as well as saturated palmitic acid, which constitute more than 60% of its lipids. Monogalactosyl- and sulfoquinovosyl-diacylglycerol as well as phosphatidylglycerol are the major *S.* lipids (20-25% each) (Petkov, 1988; Toyub et al., 2011).



**Figure 1.** Fatty acid profile of *S. platensis*. Retention time (min) = 8.066: lauric acid; 9.718: myristic acid; 10.615: palmitic acid; 10.909: palmitoleic acid (omega 6); 11.111: stearic acid; 11.473: oleic acid (omega 6); 11.781: linoleic acid (omega 6); 11.961: gamma linolenic acid (omega 6); 14.567: behenic acid.

**Table 3.** Fatty acid composition of *S. platensis*.

Fatty acids	Nomenclature	Contents (%)	Contents (%) (Pascaud, 1993)
Lauric acid	C 12:0	3.10	-
Myristic acid	C 14:0	3.60	0.2-0.5
Palmitic acid	C 16:0	42.79	25
Palmitoleic acid (Omega 6)	C 16:1	0.52	3.8
Stearic acid	C 18:0	1.81	1.7
Oleic acid (Omega 6)	C 18:1	0.33	16.6
Linoleic acid (Omega 6)	C 18:2	9.43	12
Gamma linolenic acid (Omega 6)	C 18:3	18.41	40.1
Behenic acid	C 22:0	20.01	traces

## Conclusion

*S. platensis* represents a source of important natural compounds for human nutrition; its nutritional quality fits the standard measurements, when compared with other searches. We can conclude that *S. platensis* cultivated is characterized by a high nutritional quality. This *S. platensis* is characterized by a high protein content of up to  $60.32 \pm 0.15\%$  of the dry weight. This is the richest food known today because the protein content is twice that of soybeans and more than three of meat or fish. Carbohydrate represents  $17.63 \pm 0.133\%$  of the dry weight. It is a low calorie food. Total lipid varies between  $7.28 \pm 0.021\%$  of dry weight. It provides minerals and trace elements such as iron, magnesium, manganese, phosphorus, selenium and zinc. *S. platensis* contains essential polyunsaturated fatty acids with 18 carbon

atoms, in particular, the omega-6 ( $\omega_6$ ).

## Conflict of Interest

The author(s) did not declare any conflict of interest.

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