COMPARATIVE STUDY OF THE NUTRITIONAL VALUE OF SPIRULINA (*SPIRULINA PLATENSIS NORDTSEDT*) AT THREE FARMS IN BURKINA FASO: CASE OF MICRONUTRIENTS

Mahaman M. M. **Ousseini**[1*], Chaibou **Mahamadou**[1], Saidou O**usseina**[1], Fredric **Zongo**[2], Savadogo **Aly**[3]
[1]Faculty of Agronomy, Abdou Moumouni University of Niamey, Niger P.O BOX: 10960 Niamey
[2]Unit of Formation and Research in Sciences of Life and Earth, University of Ouagadougou, Burkina Faso
[3]Laboratory for Molecular Biology, Epidemiology and Surveillance of Bacteria and Viruses Transmitted by Foods (LaBESTF), Research Center for Biological, Food and Nutritional Sciences (CRBSFN), Doctoral School of Science and Technology, 03 P. O BOX: 7021 Ouagadougou
03, University of Ouagadougou, Burkina Faso.
E-mail*:ousseinimahaman43@yahoo.fr

Abstract
A study on the determination of the micronutrient content of spirulina samples was conducted at three farms in Burkina Faso. Eighteen (18) spirulina samples, six (6) per farm were collected. The minerals were assayed by Atomic Absorption Spectrometry and vitamins by high performance liquid chromatography (HPLC).The highest vitamin levels are from the "Nayalgué" farm with 52.3 ± 9.81 mg / 100 g of β-carotene and 1.67 ± 0.57 mg / 100 g of α-tocopherol. The highest calcium content was obtained at Center for Research in Biological Sciences Food and Nutrition with 4.93 ± 95 mg / 100g. The magnesium content is 2.55 ± 18 mg / g at CRBSFN, 1.72 ± 24 mg / g at the "Nayalgué" farm and 1.30 ± 18 mg / g at the "Ouahigouya" farm. The iron content is 0.61 ± 83 mg / g at CRBSFN, 0.69 ± 91 mg / g at the "Nayalgué" farm and 0.54 ± 75 mg / g at the "Ouahigouya" farm. The zinc content is 0.017 ± 1.01 mg / g at CRBSFN 0.02 ± 3.60 mg / g at the "Nayalgué" farm and 0.01 ± 2.51 mg / g at the "Ouahigouya" farm. Micronutrients are more numerous on the "Nayalgué" farm. With such nutrients, spirulina can therefore be used in the nutrition of vulnerable people.

Keywords: Spirulina farm, value, Ouahigouya, Nayalgué, Burkina-Faso

Received: 15.12.2018 Reviewed: 15.03.2019 Accepted: 18.03.2019

1. INTRODUCTION

Spirulina was presented as one of the best foods for the future at the 1974 United Nations Food Conference. It is put forward by several structures within the UN and the WHO for its use in the fight against acute malnutrition in the world (Fox, 1986). The blue-green color and the phycocyanin content have earned it the name of blue algae (FAO, 2009; Bingula & al., 2016). It has been consumed for centuries by some people in Africa and America and is a food of high nutritional quality thanks to the diversity and the richness of its constituents as testify Vicky Jocelyne & al. (2016) which attribute to it nutritional and biological virtues quite remarkable (Jourdan, 2006). If the cultivation of this seaweed needs to be improved in order to better specify the already well-known production conditions, the fact remains that there are differences in the chemical composition related to certain factors such as origin, nature of the sample, the conduct of the crop, the enrichment of inputs, the method of drying and the method of conservation. In an impetus accompanying the development of a pilot production of active biomolecules as the phycocyanin (Bhavisha & Parula, 2010) of spirulina for the nutrition of vulnerable people, this work proposes to contribute to existing data, information on the chemical compositions of Spirulina produced various way. Hence the comparative study of the nutritional value of spirulina produced at three farms (CRBSFN farm, "Nayalgué" farm of Koudougou and the "Ouahigouya" farm) of

Burkina Faso.

2. MATERIALS AND METHODS

2.1. Biological material

The biological material consists of spirulina from three sites which are: the Center for Research in Biological Sciences Food and Nutrition (CRBSFN) of the training and research unit in science of life and earth (TRU-SLE) of the University of Ouagadougou; the "Nayalgué" farm in Koudougou and the "Ouahigouya" farm.

2.2. Methodology

2.2.1. Farms producing spirulina

➢ **CRBSFN culture basin**

The production of spirulina at the Center for Research in Biological Sciences Food and Nutrition (CRBSFN) was carried out under shelter. Two reinforced concrete basins of rectangular shape and rounded corners were built. These basins are in an enclosure covered with a roof made of translucent sheets and the sides surrounded by fine wire. Each basin has 12.5 m^2 surface, 50 cm deep, and a volume of 2750 L. Each basin was equipped with a paddle wheel, motorized and provided with a timer to ensure discontinuous agitation of the culture medium. The agitation worked for 30 minutes and 15 minutes of rest with a stop at night. The cultivation method is semi-artisanal in view of the small size of the pond seeding.

This operation consisted of starting a new culture basin. The input quantities were weighed according to the Jourdan (2006) formula using a scale whose characteristic is PR503 Delta Range for low quantities (<1000g) and another balance of capacity 20 kg for measurements greater than 1000 g. These inputs (sodium bicarbonate, sodium chloride, potassium nitrate, dipotassium sulphate, monoammonium phosphate, iron sulphate, mabnesium sulphaten urea and lime) were then dissolved in water giving the culture medium nine. The seed used to grow the first pond came from the Loumbila production site. The choice of this site is explained by its proximity to Ouagadougou. To ensure the purity of spirulina and check for the presence or absence of foreign algae, the seed was first observed under a microscope.

2.2.1.1 Sowing basin

The new culture medium (sodium bicarbonate, sodium chloride, potassium nitrate, dipotassium sulphate, monoammonium phosphate, iron sulphate, mabnesium sulphaten urea and lime) used is that proposed by Jourdan (2006) with however some modifications in relation to the water used for the culture. Control of the parameters of the culture medium such as pH, spirulina concentration of the culture medium (by a Secchi disk), the water level and the temperature took place every morning from 8 hours.

2.2.1.2. Feeding ponds

After each harvest, inputs were brought to the basins in which the harvest was made and the amount of each input is a function of the amount of dry Spirulina harvested.

➢ **Nayalgué Farm in Koudougou**

The production management of the "Nayalgué" farm differs from that of CRBSFN in the drying mode and the stirring frequency. The latter operates for 15 minutes and rested for 15 minutes from 6 am to 12 pm and from 3 pm to 6 pm and then from 12 pm to 3 pm and finally a stop at sunset. The only basin at which samples are harvested is out of shelters and 200 m^2. As for drying, the mixed solar / gas dryer is used. Usable in the rainy season, this dryer is equipped with a gas bruner whose heat is distributed thanks to the low that enters through an opening made of mosquito net.

➢ **Ouahigouya Farm**

At the level of the "Ouahigouya" farm, the culture medium was that of Jourdan (1999). Three basins are functional and each basin contains 22 m^3 of culture. The basin in which our samples were taken is out of shelter. The spirulina species (*Spirulina platensis Nordstedt*) grown is the same as CRBSFN and "Nayalgué". The stirring frequency is a quarter of an hour with 15 minutes of rest and a stop at night. In a harvesting workshop, the culture medium is sucked by a pumping system. The drying mode used is mixed solar / gas. The average drying time is 6 hours.

Table 1: Similarities and differences between CRBSFN Laboratory, Nayalgué farm and Ouahigouya farm

Parameter	CRBSFN Laboratory	Nayalgué Farm	Ouahigouya Farm
Spirulina strains	*Spirulina platensis Nordstedt*	*Spirulina platensis Nordstedt*	*Spirulina platensis Nordstedt*
Type of culture medium	Culture medium of Jourdan (1999)	Culture medium of Jourdan (1999)	Culture medium of Jourdan (1999)
Water used in the culture medium	Tap water	Drilling water	Drilling water
Volume of culture medium per basin (m^3)	2,75	44	22
Stirring material	Paddle wheel at muniterie	Paddle wheel at muniterie	Paddle wheel at muniterie
Frequency of agitation	-30 minutes of operation and 15 minutes of rest from 6 am to 6 pm -Stop at night	-15 minutes of operation and 15 minutes of rest from 6 am to 12 pm and from 3 pm to 6 pm -Permanent from 12 pm to 15 pm -Stop at night	-15 minutes of operation and 15 minutes of rest from 6 am to 6 pm -Stop at night
Harvesting equipment	-30µ mesh filtering mesh - shovel and small plastic buckets	Pumping system	Pumping system
Dryer display equipment	SIKA silicone extruder	SIKA silicone extruder	SIKA silicone extruder
Type of dryer	Shell	Mixed solar / gas	Mixed solar / gas
Average drying time	5 hours 30 minutes	5 hours	6 hours
Number of samples taken	6	6	6
Quantity taken per sample (g)	150	150	150
Grinding equipment	Mortar pestle	Mortar pestle	Mortar pestle
Size of the crushed	0.5 mm	0.5 mm	0.5 mm
How to store samples	Plastic bags closed in boxes	Aluminized bags	Aluminized bags

3. RESULTS AND DISCUSSION

3.1. Micronutrient composition

3.1.1. β-carotene (provitamin A) and α-tocopherol (vitamin E)

β-carotene is in terms of carotenoid the most remarkable element in Spirulina. α-Tocopherol has a significant content in spirulina as shown in Table 2.

Table 2: Content of β-carotenes (provitamin A) and α-tocopherol (vitamin E) in mg per 100 g of CRBSFN spirulina, "Nayalgué" and "Ouahigouya".

	CRBSFN Laboratory	Nayalgué Farm	Ouahigouya Farm
β-carotenes (mg / 100 g)	46,3±4,72	52,3±9,81	35 ±3,60
α-tocopherol (mg /100g)	1±0,00	1,67±0,57	0,67±0,57

Table 2 shows that samples from the "Nayalgué" farm had the highest β-carotene content with an average of 52.3 ± 9.81 mg / 100 g.

The β-carotene content of "Nayalgué" samples (52.3 ± 9.81 mg / 100 g) is less than 64 mg / 100g, 70 mg / kg and 3.80 g/100g obtained respectively by Babadzhanov & al. (2004); Careri & al. (2001) and Vicky Jocelyne & al. (2016). The variations of the β-carotene contents of our samples could be related to the drying mode. In the CRBSFN laboratory, the shell dryer has been used, the biomass spread on grids is exposed to the sun. The solar dryer / gas was used for the farms of "Nayalgué" and "Ouahigouya", the biomass is sometimes dried in the open air sometimes dried with the solar gas dryer.

The temperature (variant 27 to 41°C) and air (Accompanied often by a weak, medium or strong wind) used during drying, which important parameters for spirulina are drying, are not stable. Exposure of spirulina containing β-carotenes to high temperature, humidity and light conditions may cause variations in β-carotene content, which may also justify this difference in β-carotene levels. In addition, the particle size of the final product obtained by pounding spirulina in a mortar could be a source of variations in the β-carotene content. Whatever the spirulina content of β-carotene, this content is considerably higher than the β-carotene content of a supplement feed composed of Germinated maize-Germinated millet-Fermented soybean obtained by Akinsola & al. (2017). A good drying and a lower water content would allow a better immediate preservation as well as a long-term preservation of β-carotenes.

Carotenoids being very sensitive to oxidation and heat, it is necessary to take into account the drying processes used to have good compositions of spirulina. As in spirulina, Glover-Amengor & al. (2012) reported that light and residual oxygen retained in packaging material prior to packaging can catalyze the oxidation of lipid in stored dehydrated vegetable resulting loses of fat soluble vitamins.

The α-tocopherol content (1.67 ± 0.57 mg / 100 g) of "Nayalgué" farm spirulina is the most important followed by 1.00 ± 0.00 mg / 100 g for the CRBSFN farm and 0.67 ± 0.57 mg / 100 g of the "Ouahigouya" farm. The α-tocopherol content of the "Nayalgué" farm is less than 2.06 ± 0.37 mg / 100 g found by Kambou (2006), 50-190 mg / kg by Challem & al. (1981) and 120 µg / g by Vincenzini & al (1979) for spirulina content and 11.08 mg / g (Adejumo & Dan Emmanuel, 2018) for vitamin E content of de *Moringa oleifeira* but greater than 13 mg / kg found by Gomez-Coronado & al. (2004). The heterogeneity of the α-tocopherol content for our samples could be related to the drying mode as well as to the levels of β-carotenes. Wilhelm & al. (2004) reported that moisture content of hygroscopic materials such as dried food is in direct relation to the humidity of the surrounding air. In addition, the disparities observed in our results compared to those of the authors could be explained by the growing conditions. The composition of Spirulina is dependent on the chemical elements of the culture medium. These include inputs, but also drying mode and storage conditions.

The comparative test results of the β-carotene and α-tocopherol content between samples from one farm to another are shown in Table 3.

Table 3: Test t for paired samples of vitamins

Paired	Parameter	*P*
2	β-carotènes OHG - β-carotènes NYG	0,141
3	β-carotènes CRBSFN - β-carotènes OHG	0,117
4	α-tocophérol CRBSFN - α-tocophérol NYG	0,184
5	α-tocophérol CRBSFN - α-tocophérol OHG	0,423

NYG : "*Nayalgué*", OHG : "*Ouahigouya*" ; p: Threshold of service

After the observation of Table 3, there is no significant difference between the samples from three farms, although there were variations in the levels of the two vitamins from one farm to another.

3.1.2. The minerals

The levels in mg / g of spirulina minerals differ from one farm to another as shown in Table 4.

Table 4: Mineral content in mg / g of CRBSFN Spirulina, "Nayalgué" and "Ouahigouya"

Element (mg/g)	CRBSFN Laboratory	Nayalgué Farm	Ouahigouya Farm
Calcium	4,93 ± 95	3,04 ± 82	2,75 ± 44
Magnesium	2,55 ± 18	1,72 ± 24	1,30 ± 18
Iron	0,61± 83	0,69 ± 91	0,54 ± 75
Zinc	0,01 ± 1,01	0,02 ± 3,60	0,01 ± 2,51

The calcium levels of the CRBSFN samples are highest (4.93 ± 95 mg / g) compared to that of "Nayalgué" (3.04 ± 82 mg / g) and "Ouahigouya" (2.75 ± 44 mg / g). These three levels are in the range of 1.3 to 1.4 mg / g for result of Falquet (1996). The calcium content of CRBSFN samples is greater than 3.4 mg / g than Razafindrajaona & al. (2006) they found. However, that of "Ouahigouya" samples is lower 8.76 ± 96.7 g / kg (M'Baye & al. (2011)). The inputs in the culture medium provide nutrients necessary for the proper growth of spirulina. Indeed the composition of the culture medium of spirulina consists of various inputs could change the content of minerals including the calcium content in spirulina. One of the sources of calcium used in the culture medium is lime, the use of it in the culture medium could explain the variation of the calcium content of our samples. It is the same as the water used in the culture medium can also influence the mineral content in general and the calcium content in particular. ONEA drinking water (hydrogen potential or pH between 6.5 and 8.5, turbidity or clarity of water ≤ 5 NTU or Nephelometric turbidity unit and residual chlorine between 0.5 and 5.0 mg /l) has been used in CRBSFN's production culture and can be a source of high calcium for this site. On the farm of "Nayalgué", the drilling water was used. On the "Ouahigouya" farm, the water used to supplement the culture medium is well water, this water exposed to pollution can influence the mineral content of samples of "Ouahigouya" including calcium content. The heterogeneity of the mineral content of our samples compared to the results of M'Baye & al. (2011) could be explained by the method of mineralization of the samples. Indeed, to obtain the ash that determines the mineral content of a sample, we used the Official method (AOAC, 1984) of incineration mineralization while M'Baye & al. (2011) used the dry mineralization method and removing the silica with hydrofluoric acid. The magnesium content obtained at CRBSFN (2.55 ± 18 mg / g) is highest, followed by that of "Nayalgué" (1.72 ± 24 mg / g) and "Ouahigouya" (1.30 ± 18 mg / g).This content of CRBSFN samples is in the range of 2 to 2.9 g / kg found Falquet (1996) and that of "Nayalgué" and "Ouahigouya" are close to 2.0 g / kg (Razafindrajaona & al., 2006). But the averages of each farm are less than 10.8 ± 17 g / kg (M'Baye & al. (2011)).

As for the calcium content, the variation of the magnesium content of our samples could be explained by the composition of the inputs contained in the culture medium. Indeed each input brings elements necessary for the growth of Spirulina, magnesium is provided by magnesium sulfate and its consumption

depends on the good conduct of production. It is also possible to blame the quality of ONEA drinking water, which could have significant magnesium levels to influence the high magnesium content of CRBSFN.
The iron contents of the CRBSFN (0.61 ± 83 mg / g) and "Nayalgué" (0.69 ± 91 mg / g) samples were in the range of 0.58 to 1.8 g / kg for Razafindrajaona & al. (2006). The iron content of spirulina obtained in our study than those found by Montasell (2009) (0.7 to 1.2 mg / 100 g) and slightly higher than 25.6 mg / 100 g obtained by Vicky Jocelyne et al. (2016)
The ferrous sulphate input into the Spirulina culture medium as a source of iron could explain the presence of the iron content of our samples. On the farm of "Nayalgué" the drilling water was used to complete the culture medium. This water coming from the subsoil could have acceptable quality in mineral elements that will be used in the culture medium of Spirulina, this could also explain the variability of the iron content for the samples of the farm of "Nayalgué". Spirulina can be a good source of iron for iron deficiency anemia.
For zinc, the results of the analyzes of the different samples of three farms are 0.02 ± 3.60 mg / g for the samples of "Nayalgué", 0.01 ± 1.01 mg / g for those of CRBSFN and 0, 01 ± 2.5 mg / g for those of "Ouahigouya". These three levels are greater than 0.01 g / kg (Razafindrajaona & al., 2006) but lower than 25.01± 0.01 mg / kg obtained by Vicky Jocelyne et al. (2016) and that of "Nayalgué" is in the range of 0.02 to 0.04 g / kg (Falquet, 1996). It should be noted that our results are far inferior to the zinc content (9.41 mg/g) of *Moringa oleifera* obtained by Adejumo & Dan Emmanuel (2018).
The differences in the zinc content of our samples could be explained by the water used in the culture medium. Table 5 presents the t-test for paired samples of minerals.

Table 5: Test t for paired samples of minerals

Paired	Parameter	*P*
1	Calcium CRBSFN - Calcium NYG	0,001[b]
2	Calcium OHG - Calcium NYG	0,553[a]
3	Calcium CRBSFN - Calcium OHG	0,045[b]
4	Magnésium CRBSFN - Magnésium NYG	0,469[a]
5	Magnésium OHG- Magnésium NYG	0,448[a]
6	Magnésium CRBSFN - Magnésium OHG	0,143[a]
7	Iron CRBSFN - Iron NYG	0,423[a]
8	Iron OHG - Iron NYG	0,230[a]
9	Iron CRBSFN - Iron OHG	0,085[a]
10	Zinc CRBSFN - Zinc NYG	0,122[a]
11	Zinc OHG - Zinc NYG	0,041[b]
12	Zinc CRBSFN - Zinc OHG	0,212[a]

NYG : "Nayalgué", OHG : "Ouahigouya"
- The values with the letter a in exponent correspond to values of which p> 0.05;
- The values carrying the letter b in exponent correspond to values of which p <0.05.
P: Threshold of service.

Significant differences were observed between the calcium content of the CRBSFN samples and those of "Nayalgué" (p = 0.001) on the one hand and between those of CRBSFN and Ouahigouya (p = 0.045) on the other hand. There was also a significant difference in zinc content between the "Ouahigouya" and "Nayalgué" samples (p = 0.041).

4. CONCLUSION

This work shows that Spirulina is rich in nutritional value. The important levels of micronutrients, in particular vitamins (β-carotene and α-tocopherol) and iron and zinc, were determined on the "Nayalgué" farm. For magnesium and calcium levels, CRBSFN has the highest levels observed. Production can thus be easily popularized because most equipment as well as inputs are available. Spirulina can therefore continue to be considered a quality dietary supplement. It can thus be considered as a dietary supplement for vulnerable people.

5. REFERENCES

[1]. Fox, R. D. Algoculture : Spirulina, a hope for the world of hunger. Edisud, Aix-en-Provence, ISBN 2-85744-262-9, 319 p.1986.

[2]. FAO, Basic Glossary on the Right to Food. Electronic document "www.fao.org/righttofood/kc/glossary_en.htm;" accessed 04-11-2012, 2009.

[3]. Bingula R., Dupuis C., Pichon C., Berthon J.Y., Filaire M., Pigeon L., Filaire E. Study of the effects of betaine and/or C-phycocyanin on the growth of lung cancer A549 cells in vitro and in vivo. J. Oncol. 2016. [CrossRef] [PubMed]

[4]. Vicky Jocelyne A. M., Constant Anatole P., Prosper Cabral N. B., Marthe Elise N. M., Bruno M. M., Francine T. N., Pauline N., Jeanne N. Chemical composition of spirulina platensis of nomayos-yaounde (Cameroon). Annals. Food Science and Technology, 17, 2, 2016, 524-528.

[5]. Jourdan J. P.Grow your spirulina. In: Jourdan, J.P. (Ed). Antenna Technology. 2006, 146p.

[6]. Bhavisha R., Parula P. Spirulina: Potential clinical therapeutic application. Journal of Pharmacy Research, 3, 8, 2010, 1726-1732.

[7]. Pinta, Reference Methods for the Determination of Mineral Elements in Plant Oleaginous by Atomic Absorption, 28, 1973, 87-92.

[8]. Babadzhanov A. S., Abdusamatova N., Yusupova F. M., Faizullaeva N., Mezhlumyan L. G. and Malikova M. Kh. Chemical composition of Spirulina platensis cultivated in Uzbekistan. Chemistry of Natural Compounds. 40, 3, 2004, 276-279.

[9]. Careri M., Furlattini L., Mangia A., Musci M., Anklam E., Theobald A. and Von holst C. Supercritical fluid extraction for liquid chromatographic determination of carotenoids in Spirulina Pacifica algae: a chemometric approach J Chromatography A 912, 2001, 61-71.

[10]. Akinsola A. O., Idowu M. A., Oke E. K., Idowu O. A., Laniran A. M. Nutritional evaluation of maize-millet based complementary foods fortified with soybean.Annals. Food Science and Technology, 18, 2, 2017, 173-182.

[11]. Glover-Amengor M., Diako C. and Kyei-Baffour V. Investigation of appropriate packaging material and shelf life stability of Moringa oleifera leaf powder, Journal of research in biology, 2, 8, 2012, 691-695.

[12]. Kambou S. Contribution to the determination of the content of fat-soluble vitamins (Alpha Tocopherol and Beta carotene) and total proteins of spirulina grown on the Koudougou farm (Burkina Faso), Th. Doc. Pharm. University of Ouagadougou,2006, p 88.

[13]. Challem J. J., Passwater R. A. and Mindell E. M. Spirulina. Keats Publishing, IncNew Canaan, Connecticut, 1981.

[14]. Vincenzini M., Ferrari F., Margheri M. O. and Florenzano G. Quinonoid and tocopherol levels in Spirulina platensis. Microbiologica 3, 1979, 131-136.

[15]. Adejumo B. A. and Dan E. J. Nutritional composition of packaged Moringa oleifera leaves powder in storage. Annals. Food Science and Technology, 19, 2, 2018, 226-231.

[16]. Gomez-Coronado D. J. M., Ibanez E., Ruperez F. J. and Barbas C. Tocopherol measurement in edible products of vegetable origin, J. Chromatogr. A 1054, 2004, 227-233.

[17]. Wilhelm L. R., Suter D. A. and Bruzwitz G. H. Physical Properties of Food Materials. In: Food and Process Engineering Technology, 23-62, St Joseph, Michigan: ASAE. American Society of Agriculture Engineers. 2004, 29-34.

[18]. Falquet J. "Spirulina, Nutritional Aspects", Antenna Technologie, Geneva, 1996.

[19]. Razafindrajaona J. M., Rakotozandriny J. N., Rakotozandrindrainy R., José N. R. and Ramampiherika K. D. Study of the nutritional value of spirulina of Madagascar (Spirulina platensis Toliara variety), Malagasy Land 26, 2006, 162-188.

[20]. M'Baye B. K., Lo B. B. and Bassene E. Study of Carotenoids, Phycocyanines and Proteins of Spirulina in Mauritania, ScienceLib Editions Mersenne, 3, 110906, ISSN 2111-4706, 2011, 8.

[21]. AOAC. Official methods of analysis association of official analytical chemists. Centennial edition 1884-1984 (14 th ed), Virginia 22209 USA. 1984.

[22]. Montasell.Montasell. Import SARL, Spirulina, Pressbook, 2009, 12-13.