PharmacologyOnLine

Archives • 2021 • vol.3 • 788-795

DIETARY SUPPLEMENTS BASED ON MICROALGAE FOR DIABETICS WITH COVID-19: CHALLENGES AND FUTURE PERSPECTIVES

Mohamed Abdoul-Latif, Fatouma[1]* ; Ainane, Ayoub[2] ; Houmed Aboubaker, Ibrahim[3] ; Mohamed Ahmed, Nabil[1] ; Ainane, Tarik[2]

[1]Medicinal Research Institute, Center for Research and Study of Djibouti, BP 486, Djibouti.

[2]Superior School of Technology of Khenifra (EST-Khenifra), University of Sultan Moulay Slimane, BP 170, Khenifra 54000 Morocco.

[3]Peltier hospital of Djibouti, BP 2123, Republic of Djibouti.

*fatouma_abdoulatif@yahoo.fr

Abstract

The nutritional value of microalgae considered a challenge for strengthening the immune system and that comes down to the richness of these biomasses by varied compositions and very abundant in proteins, carbohydrates, lipids, vitamins and oligoelements. This article provides a new avenue for using microalgae as a dietary supplement for diabetic patients during the COVID-19 pandemic, in fact, the study features a selection of twenty most requested microalgae globally. After determining the protein, carbohydrate and lipid compositions for each species, a statistical study targeted by the principal component analysis was carried out to classify the microalgae into three groups. According to international health recommendations and nutritional regulations intended for diabetic patients and other parts of the energy supply to strengthen the immune system against COVID-19, a group of three species (*Biddulphia sp.*, *Navicula uncerta* and *Nitzschia sp.*) has been selected, thus they can use as food supplements.

Keywords: *Microalgae, Diabetes, COVID-19, PCA, dietary supplements.*

Introduction

For almost two years, the COVID-19 pandemic has significantly impacted the lives of people around the world **[1]**. Despite the available therapeutic arsenal, no treatment protocol has been unanimously accepted by the medical community **[2]**. The use of several drugs among them hydroxychloroquine is still controversial today. The most common treatment protocol, which is based only on azithromycin and enoxaparin (for the most severe cases), does not prevent the deaths of thousands around the world **[3]**.

As of February 18, 2021, at least seven different vaccines have been made available in countries through three platforms. Vaccination should target vulnerable populations in all countries as a priority. Vaccines save millions of lives every year. Their mode of action is to train and prepare the immune system (the body's natural defenses) to recognize and fight the viruses and bacteria they target. Thus, if the body is subsequently exposed to these same pathogens, it is immediately ready to destroy them, which helps prevent disease **[4-6]**.

Faced with this inability of doctors to find solutions to treat people with COVID-19, the media have been conveying the idea for several months that dietary supplements rich in vitamins and trace elements are effective for the prevention and treatment of COVID-19, among them microalgae **[7-8]**. The use of microalgae as a natural food has been known for centuries. Used by the *Mayans*, *Spirulina*, for example, is still harvested and consumed by the inhabitants of the shores of Lake Chad **[9]**. It was used as food, for its nutritional richness, in Asia, Africa and Mexico. The Chinese used the common *Nostoc* microalgae for food more than 2,000 years ago **[10]**. Also, Epidemiological studies carried out in Asia had shown a lower incidence of breast, colon and prostate cancer linked to their regular consumption **[11]**. The nutritional value of algae can be explained in large part by the joint presence of three main categories of components: fibers, minerals and proteins, but also by the presence of metabolites with antioxidant and anti-radical properties such as carotenoids, polyphenols, vitamins as well as polyunsaturated fatty acids **[12-14]**.

This study deals with the possibility of using microalgae as food supplements according to their composition in proteins, carbohydrates and lipids for diabetics during the COVID-19 pandemic according to the international recommendations in force to balance blood sugar on the part, and on the other hand to strengthen the immune system against viruses.

Methods

Data sources

This study was carried out from December 2020 to July 2021, during the COVID-19 pandemic. Guidelines and official documents from government and non-government sectors, all providing recommendations on food and nutrition during the COVID-19 pandemic, were eligible for inclusion. The literature relating to specific nutritional or pharmacological treatment of already infected patients was excluded.

The descriptors "COVID", "COVID-19", "coronavirus" AND "diet" OR "nutrition" AND "algae" OR "microalga" AND "composition" OR "proteins" OR "carbohydrates" OR "lipids" were used to search for guidelines, position papers and official documents in Google Scholar, PubMed and SciELO databases. The Boolean operators "AND" and "OR" were used to combine terms used in the literature search. Publications in all languages were searched. Three authors (A.M.F, A.A. and A.T.) searched and reviewed all references independently in a 2-step process. All selected documents have been recovered and duplicates have been excluded. The titles and abstracts were then reviewed to identify studies that potentially met the eligibility criteria.

Study design

According to the international recommendations of the health sectors, a description has determined the nutritional intake of proteins, carbohydrates and lipids for the diet intended for diabetics to balance blood sugar and also intended for patients infected with COVID-19 to strengthen the immune system.

The Twenty (20) microalgae were selected according to the first which have a very high number of studies done on a global scale. The selected species are: *Anabaena cylindrica*, *Aphanizomenon*

flos-aquae, *Arthrospira maxima*, *Biddulphia sp.*, *Chaetoceros* sp., Chlamydomonas rheinhardii, Chlorella pyrenoidosa, Chlorella vulgaris, Dunaliella salina, *Euglena gracilis*, *Isochrysis galbana*, *Nannochloropsis sp.*, *Navicula incerta*, *Nitzschia sp.*, *Porphyridium cruentum*, *Scenedesmus obliquus*, *Spirogyra sp.*, *Spirulina platensis*, *Synechococcus sp.* and *Tetraselmis sp.* As a result, the protein, carbohydrate and lipid compositions were determined for each species **[15-18]**.

Statistical methods

The relationship between the twenty selected microalgae and their protein, carbohydrate and lipid compositions has been studied by principal component analysis (PCA) and hierarchical classification **[19]**. These two statistical methods are one of the most important approaches to explore multivariate data. The goal is to know and identify clusters of similar objects in a dataset of variables studied, more precisely, on the dietary vision of diabetic patients during the COVID-19 pandemic.

Results and discussion

Strengthening the immune system is where science meets a healthy lifestyle. Healthy eating habits will help develop balanced immunity and improve health, especially diabetic patients during the COVID-19 pandemic. The nutritional value of microalgae is linked to the simultaneous presence of several components: fibers, minerals, proteins, vitamins and antioxidants. Indeed, it is for this reason that certain species of algae are widely used as food supplements **[20]**.

Table 1 shows the twenty most studied microalgae worldwide with their nutrient compositions of proteins, carbohydrates and lipids. A quick reading of the results shows that all the most studied microalgae have a high protein composition and moderate carbohydrate and lipid compositions.

Figure 1 represents the statistical study made by the PCA of the relationship between microalgae and their nutritional compositions. The axes F1 and F2 were retained, their variabilities being 50.14% and 26.93% respectively, corresponding to a total of 76.83% of the information. Figure 2 shows the dendrogram corresponding to the Ascending Hierarchical Classification (ACH) of microalgae according to the variables of their composition in proteins, carbohydrates and lipids.

Analysis of these results can give a breakdown of microalgae into three groups (Table 2):

- The 1st group assembles 6 species: *Anabaena cylindrica*, *Aphanizomenon flos-aquae*, *Chlorella pyrenoidosa*, *Dunaliella salina*, *Porphyridium cruentum* and *Spirogyra sp.* Microalgae in this group are characterized by high protein and carbohydrate content.
- The 2nd group assembles 3 species: *Biddulphia sp.*, *Navicula uncerta* and *Nitzschia sp.* Microalgae of this group are characterized by moderate protein and lipid contents and low carbohydrate contents.
- The 3rd group assembles 11 species: *Arthrospira maxima*, *Chaetoceros sp.*, *Chlamydomonas rheinhardii*, *Chlorella vulgaris*, *Euglena gracilis*, *Isochrysis galbana*, *Nannochloropsis sp.*, *Scenedesmus obliquus*, *Spirulina platensis*, *Synechococcus sp.* and *Tetraselmis sp.* Microalgae in this group are characterized by a high protein content and moderate carbohydrate and fat content.

According to international recommendations, the nutrition of patients infected with COVID-19 require very important energy inputs to strengthen their immune systems by consuming proteins, carbohydrates and lipids, but on the other hand, the consideration of diabetic patients of this period infection, which should not be exceeded a well-defined carbohydrate content (50%: recommended minimum is 180 to 200 g per day) or a total absence of carbohydrates in food supplements **[21-22]**. In addition, the specification of this model is directed to the 2nd group which contains the three microalgae: *Biddulphia sp.*, *Navicula uncerta* and *Nitzschia sp.* These species will be considered as food supplements well suited for diabetics to strengthen their immune system against COVID-19. We note that the 1st group of microalgae is not recommended for diabetics according to the highest carbohydrate content.

In general, microalgae are used in food for their richness in carbohydrates, proteins, enzymes and

fibers. In addition, many vitamins and minerals like vitamin A, C, B1, B2, B6, D, niacin, iodine, potassium, iron, magnesium and calcium are found abundantly in all species of microalgae **[23-24]**.

In human nutrition, two valuation approaches exist: the first consists of targeting consumption of the entire microalgae, and the second approach concerns the extraction, transformation and packaging of bioactive molecules **[25]**. Microalgae according to the first approach are sold directly as food supplements, without further processing apart from drying. Over several decades, 75% of the annual biomass production of microalgae has been consumed (or sold on the market) as biomass. The existing commercial forms being biomass in powders, tablets, capsules or lozenges. According to the second approach, a multitude of high added value compounds are produced from microalgae such as polyunsaturated fatty acids (PUFA), carotenoids, proteins and phycobiliproteins. In addition, thanks to their ability to synthesize all amino acids, they represent a potential source for the supply of these molecules to strengthen the immune system **[26]**.

Microalgae are also considered a potential source of polyunsaturated fatty acids, intended for human consumption. They synthesize PUFAs of the ω3 series such as eicosapentaenoic acid "EPA", docosahexaenoic acid "DHA" and α-linoleic acid "LNA", and PUFAs of the ω6 series such as arachidonic acid and linoleic acid **[27]**.

Nutraceuticals have been defined as foods or food products that can simultaneously provide nutritional and pharmaceutical benefits to the body such as prevention and treatment of disease. Nutraceuticals recommend microalgae which can be either a complete food product or dietary supplements.

Conclusion

The work found during this study shows the good nutritional quality of the twenty selected microalgae which are most in demand worldwide. Their compositions and energy contributions offer the advantage of using them as food supplements during infection with COVID-19. In addition, the statistical study carried out by the principal component analysis (PCA) makes it possible to classify the species into three groups, hence the second which contains the three species *Biddulphia sp.*, *Navicula uncerta* and *Nitzschia sp.* can be used as food supplements for diabetic patients at during COVID-19, due to their very low protein and carbohydrate compositions, as well as their richness in well-adequate content in vitamins and trace elements which remain important for treating certain complications of these two diseases.

References

1. Ainane, T. (2020). Moroccan traditional treatment for fever and influenza, similar to symptoms of coronavirus COVID-19 disease: Mini Review. *Journal of Analytical Sciences and Applied Biotechnology*, 2(1), 1-3.
2. Gourch, A., Zejli, H., Lfitat, A., Bousraf, F. Z., Yassine, E. L., Ainane, A., Ainane, T., Taleb, M. (2020). Preventive impact of traditional medicine against covid-19. *Journal of Analytical Sciences and Applied Biotechnology*, 2(2), 78-82.
3. Asdadi, A., Hamdouch, A., Gharby, S., Hassani, L. M. I. (2020). Chemical characterization of essential oil of Artemisia herba-alba asso and his possible potential against covid-19. *Journal of Analytical Sciences and Applied Biotechnology*, 2(2), 67-72.
4. Chen, Y., Cheng, L., Lian, R., Song, Z., Tian, J. (2021). COVID-19 vaccine research focusses on safety, efficacy, immunoinformatics, and vaccine production and delivery: a bibliometric analysis based on VOSviewer. *BioScience Trends*. 1-10.
5. Yazdanpanah, F., Hamblin, M. R., Rezaei, N. (2020). The immune system and COVID-19: Friend or foe?. *Life sciences*, 256, 117900.
6. Tufan, A., Güler, A. A., Matucci-Cerinic, M. (2020). COVID-19, immune system response, hyperinflammation and repurposing antirheumatic drugs. *Turkish journal of medical sciences*, 50(1), 620-632.
7. Hamulka, J., Jeruszka-Bielak, M., Górnicka, M., Drywień, M. E., Zielinska-Pukos, M. A. (2021). Dietary Supplements during COVID-19 outbreak. Results of Google Trends analysis supported by PLifeCOVID-19 online studies. *Nutrients*, 13(1), 54.

8. Carbone, D. A., Pellone, P., Lubritto, C., Ciniglia, C. (2021). Evaluation of Microalgae Antiviral Activity and Their Bioactive Compounds. *Antibiotics*, *10*(6), 746.
9. Pangestuti, R., Noerdjito, D. R., Siahaan, E. A., Sapulete, S., Kim, S. K. (2020). Marine Microalgae in Food and Health Applications. *Encyclopedia of Marine Biotechnology*, *1*, 445-458.
10. Yang, Y., Park, Y., Cassada, D. A., Snow, D. D., Rogers, D. G., Lee, J. (2011). In vitro and in vivo safety assessment of edible blue-green algae, Nostoc commune var. sphaeroides Kützing and Spirulina plantensis. *Food and chemical toxicology*, *49*(7), 1560-1564.
11. Abd El-Hack, M. E., Abdelnour, S., Alagawany, M., Abdo, M., Sakr, M. A., Khafaga, A. F., Gebriel, M. G. (2019). Microalgae in modern cancer therapy: Current knowledge. *Biomedicine & Pharmacotherapy*, *111*, 42-50.
12. Ainane, T., Abourriche, A., Kabbaj, M., Elkouali, M., Bennamara, A., Charrouf, M., Lemrani, M. (2014). Biological activities of extracts from seaweed Cystoseira tamariscifolia: Antibacterial activity, antileishmanial activity and cytotoxicity. *J. Chem. Pharm. Res*, *6*, 607-611.
13. El Yaagoubi, B., Mohamed Abdoul-Latif, F., Oumaskour, K., Boujaber, N., Mohamed, J., Ouassil, M., Ainane, A., Ainane, T. *(2021).* Evaluation of the antibacterial and cytotoxicity activities of Cystoseira gibraltarica by bioguided fractionation. *Pharmacologyonline*, 2, 443-448.
14. Abdoul-Latif, F. M., Oumaskour, K., Boujaber, N., Ainane, A., Mohamed, J., Ainane, T. (2021). Formulations of a cosmetic product for hair care based on extract of the microalga Isochrysis galbana: in vivo and in vitro activities. *Journal of Analytical Sciences and Applied Biotechnology*, *3*(1), 15-19.
15. Gan, Y. Y., Chen, W. H., Ong, H. C., Lin, Y. Y., Sheen, H. K., Chang, J. S., Ling, T. C. (2021). Effect of wet torrefaction on pyrolysis kinetics and conversion of microalgae carbohydrates, proteins, and lipids. *Energy Conversion and Management*, *227*, 113609.
16. Romero, N., Visentini, F. F., Márquez, V. E., Santiago, L. G., Castro, G. R., Gagneten, A. M. (2020). Physiological and morphological responses of green microalgae Chlorella vulgaris to silver nanoparticles. *Environmental Research*, *189*, 109857.
17. Tan, J. S., Lee, S. Y., Chew, K. W., Lam, M. K., Lim, J. W., Ho, S. H., Show, P. L. (2020). A review on microalgae cultivation and harvesting, and their biomass extraction processing using ionic liquids. *Bioengineered*, *11*(1), 116-129.
18. Alavijeh, R. S., Karimi, K., Wijffels, R. H., van den Berg, C., Eppink, M. (2020). Combined bead milling and enzymatic hydrolysis for efficient fractionation of lipids, proteins, and carbohydrates of Chlorella vulgaris microalgae. *Bioresource technology*, *309*, 123321.
19. Ainane, A., Abdoul-Latif, F. M., Mohamed, J., Attahar, W., Ouassil, M., Shybat, Z. L., Ainane, T. (2021). Behaviour desorption study of the essential oil of Cedrus atlantica in a porous clay versus insecticidal activity against Sitophilus granarius: explanation of the phenomenon by statistical studies. *International Journal of Metrology and Quality Engineering*, *12*, 1-10.
20. Maadane, A., Merghoub, N., Mernissi, N. E., Ainane, T., Amzazi, S., Bakri, I. W. (2021). Antimicrobial activity of marine microalgae isolated from Moroccan coastlines. *Journal of Microbiology, Biotechnology and Food Sciences*, *2021*, 1257-1260.
21. Ramos-Romero, S., Torrella, J. R., Viscor, G., Torres, J. L. (2021). Edible microalgae and their bioactive compounds in the prevention and treatment of metabolic alterations. *Nutrients*, *13*(2), 563.
22. Reynolds, A. N., Akerman, A. P., Mann, J. (2020). Dietary fibre and whole grains in diabetes management: Systematic review and meta-analyses. *PLoS medicine*, *17*(3), e1003053.
23. Leandro, A., Pacheco, D., Cotas, J., Marques, J. C., Pereira, L., Gonçalves, A. M. (2020). Seaweed's bioactive candidate compounds

to food industry and global food security. *Life*, *10*(8), 140.
24. Galasso, C., Gentile, A., Orefice, I., Ianora, A., Bruno, A., Noonan, D. M., Brunet, C. (2019). Microalgal derivatives as potential nutraceutical and food supplements for human health: A focus on cancer prevention and interception. *Nutrients*, *11*(6), 1226.
25. Ainane, T., Mohamed Abdoul-Latif, F., Ainane, A., Rais, A., Bennamara, A., Abourriche, A. *(2021).* Methoxycystoketal quinone: Natural compound from bioactive diethyl ether extract of brown seaweed Cystoseira tamariscifolia. *Pharmacologyonline*, 2, 583-589.
26. Schade, S., Stangl, G. I., Meier, T. (2020). Distinct microalgae species for food—Part 2: Comparative life cycle assessment of microalgae and fish for eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and protein. *Journal of Applied Phycology*, *32*(5), 2997-3013.

Table 1. General composition of different microalgae (% of dry matter).

Alga	Proteins	Carbohydrates	Lipids
Anabaena cylindrica	56	30	7
Aphanizomenon flos-aquae	62	23	3
Arthrospira maxima	60	13	6
Biddulphia sp.	20	9	15
Chaetoceros sp.	47	11	12
Chlamydomonas rheinhardii	48	17	21
Chlorella pyrenoidosa	57	26	2
Chlorella vulgaris	58	17	22
Dunaliella salina	57	32	6
Euglena gracilis	61	18	20
Isochrysis galbana	45	22	15
Nannochloropsis sp.	58	16	16
Navicula incerta	11	7	24
Nitzschia sp.	14	6	12
Porphyridium cruentum	39	57	14
Scenedesmus obliquus	56	10	12
Spirogyra sp.	6	33	11
Spirulina platensis	46	8	9
Synechococcus sp.	63	15	11
Tetraselmis sp.	42	15	15

Table 2. Classification of selected microalgae according to the PCA.

Group 1	**Group 2**	**Group 3**
Anabaena cylindrica *Aphanizomenon flos-aquae* *Chlorella pyrenoidosa* *Dunaliella salina* *Porphyridium cruentum* *Spirogyra sp.*	*Biddulphia sp.* *Navicula uncerta* *Nitzschia sp.*	*Arthrospira maxima* *Chaetoceros sp.* *Chlamydomonas rheinhardii* *Chlorella vulgaris* *Euglena gracilis* *Isochrysis galbana* *Nannochloropsis sp.* *Scenedesmus obliquus* *Spirulina platensis* *Synechococcus sp* *Tetraselmis sp.*

Figure 1. Statistical study by PCA of the relationship between microalgae and their nutrient composition.

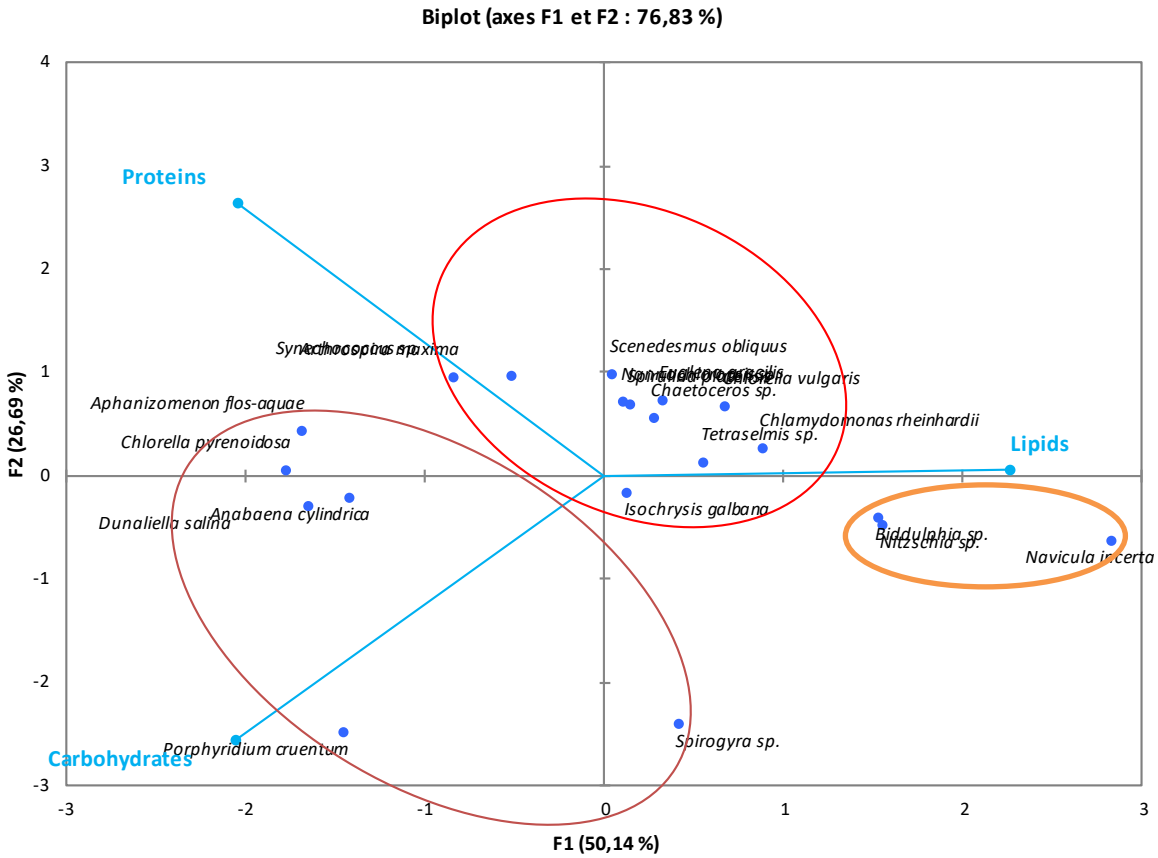

Figure 2. Dendrogram corresponding to the hierarchical classification of microalgae according to their nutritional compositions.